UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
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Ride the Ducks International, LLC	)
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CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's violations of the National Traffic and Motor Vehicle Safety Act ("Safety Act") and NHTSA's regulations as detailed herein under the following terms and conditions.

I. NATURE OF THE ACTION

1. The Safety Act provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins "whether it

actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. § 577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

10. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make, model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are required to submit to the Agency an index for each communications to dealers, owners, or

purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

11. In general, motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery. 49 U.S.C. §§ 30112(a), 30115. This certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

12. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e); 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

13. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers ("VINs") in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e); 49 C.F.R. Part 565.

14. A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). A separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A person who violates 49 U.S.C. § 30166, 49 C.F.R. Part 565, 49 C.F.R. Part 566, and 49 C.F.R. Part 579

is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

15. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

16. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

17. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading

and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

18. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

19. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

20. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

21. After learning of the Aurora Bridge crash, NHTSA issued an Information Request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its

licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015.

22. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it manufactured motor vehicles under the Safety Act.

23. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the October 1, 2013 Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

24. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. TERMS AND CONDITIONS OF CONSENT ORDER

A. Admission of Safety Act Violations

25. RTDI did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules were applicable to the

amphibious vehicles it manufactured. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. RTDI admits that it manufactured vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 30112. RTDI also failed to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and did not report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. RTDI also did not notify NHTSA of the safety defect in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, did not provide a remedy for axle defect without charge as directed by 49 U.S.C. § 30120 and admits that its communication to owners regarding a safety related defect in the 57 Stretch Duck axles did not fully comply with 49 C.F.R. § 577.5 (describing potential safety consequences of a defect).

B. Civil Penalty

26. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

27. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand dollars ($480,000.00) in accordance with the instructions provided in Paragraph 28 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 49 through 52 (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order during the term of this Consent Order,

RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand dollars ($500,000), in accordance with the terms and conditions set forth below (the "Deferred Amount").

28. RTDI shall make a payment of two hundred forty thousand dollars ($240,000) no later than May 14, 2017. The remaining two hundred forty thousand dollars ($240,000) shall be due in three equal annual increments due not later than May 14, 2018, May 14, 2019, and May 14, 2020 respectively. At its option, RTDI may pay any remaining amounts prior to their respective due dates. RTDI expressly agrees that the obligation to pay the foregoing sums as specified above shall survive the termination of this Consent Order.

29. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 30 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (30) calendar days following a determination that they are due and owing.

30. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA.

Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining three hundred thousand dollars ($300,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

31. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. Performance Obligations

32. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 34 through 54 below.

33. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

1. Remedying Past Noncompliance with the Safety Act

34. No later than 5 working days after the execution of this Consent Order, RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and a report of a claim alleging that a death resulted from a safety defect related to the September 2015 crash involving deaths as referenced in Paragraph 20 above.

35. No later than 30 calendar days after the execution of the Consent Order, RTDI will send owners of the 57 Stretch Ducks formal customer notification as directed by 49 C.F.R. Part 577 and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge.

36. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a FMVSS compliance plan to NHTSA. The plan will identify those FMVSS for which RTDI has made a good faith determination are applicable to the vehicles it has manufactured. For each such FMVSS, RTDI shall state when and how RTDI intends to bring the vehicles into compliance with a particular standard by following the statutory recall process or filing a petition for inconsequential noncompliance under 49 C.F.R. Part 556 or a petition for exemption under 49 C.F.R. Part 555. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by

contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan or are subject to ongoing design and/or engineering efforts which, subject to NHTSA's consent, require further extension of the 120 day deadline) and have been certified as such by the application of certification labels. If NHTSA should not grant any part of RTDI's inconsequentiality petition or exemption petition, the parties agree to consult in good faith with regard to determining next steps to address the issue.

37. RTDI shall submit all manufacturer identification information required by 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

38. RTDI shall submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order. If vehicles have been assigned VINs that are not in compliance with the requirements of 49 C.F.R. Part 565, RTDI will provide a detailed report to NHTSA no later than 90 days after the execution of this Consent Order, with each vehicle's assigned VIN and a description of why the VIN does not conform to the requirements of Part 565.

39. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with 49 U.S.C. §30166(f) and 49 C.F.R. § 579.5 any notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to 49 C.F.R. § 579.5, regardless of whether RTDI has already provided those service bulletins in response to NHTSA's Information Request. RTDI shall also include indexes for each document that was issued since October 1, 2012.

40. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA. No later than 180 calendar days after execution of this Consent Order, RTDI shall submit any and all reports required by 49 C.F.R. § 579.27 for the five years preceding the aforementioned date of execution.

2. Retention of Outside Consultant

41. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 46 and 47. The Consultant shall review for sufficiency technical service bulletins ("TSBs"), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

42. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 41, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

43. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

45. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 1, 2013 Service Bulletin is effective and report the results to NHTSA.

46. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle owners, licensees, and purchasers of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring vehicles manufactured by RTDI in the future comply with applicable FMVSS and other statutory and regulatory requirements administered by NHTSA (collectively, "Compliance Plan"). If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in the Paragraph shall be publicly available.

47. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to

be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

48. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 46 and the Training Plan specified in Paragraph 47.

4. The Industry Outreach Performance Obligations

49. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The industry outreach performance obligations will be satisfied through the activities as set forth in Paragraph 50 through 52 below.

50. The parties agree that RTDI will expend not less than $20,000 in execution of the industry outreach. Not less than 120 days after execution of this Consent Order, RTDI shall provide NHTSA with a plan for industry and consumer outreach, which NHTSA, at its option, may accept, reject, or revise and submit it back to RTDI for further revision, if necessary. The proposed plan shall include the following and which are to be completed over the next year:

a. Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and

other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

b. Develop Safety Act educational materials for distribution to manufacturers.

c. Offer to assist other manufacturers and, if requested, help these manufacturers in developing their own safety outreach programs.

d. Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

e. Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

The outreach plan shall include metrics of success for the foregoing targeted performance obligations. The targeted performance obligations may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

51. RTDI shall expend its best efforts to complete the targeted performance obligations not less than one year after NHTSA gives its approval of the industry outreach plan. No later than 360 calendar days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations. In the event of a dispute as to whether RTDI has expended any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have 15 working days to respond.

52. RTDI is responsible for the satisfactory completion of the targeted performance obligations described above. Subject to the provisions for extending the term of this Consent

Order in Paragraph 57, if RTDI has reasonably achieved all of the targeted performance obligations on or before 365 calendar days after the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 57, RTDI's responsibility for the satisfactory completion of the targeted performance obligations shall also be extended for the term of one year.

5. Completion of Performance

53. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

54. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

D. Compliance

55. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to

thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

56. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

III. TERM OF CONSENT ORDER

57. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraph 28 and Paragraphs 34 through 54 shall survive the term of this Consent Order until the Non-Deferred Amount is paid in full and the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

IV. AMENDMENT

58. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

V. MISCELLANEOUS

59. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

60. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 27 and 28, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 34 through 54, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraph 39, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraph 39, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

61. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

62. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

63. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 31 above.

64. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

65. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

66. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

67. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 27 and 28, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

68. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

69. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

70. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

71. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

72. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY
ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: November 15, 2016

By: **// ORIGINAL SIGNED BY //**

Mark R. Rosekind, Ph.D.
Administrator

Dated: November 15, 2016

By: (b)(6)

Paul A. Hemmersbaugh
Chief Counsel

Dated: November 15, 2016

By: (b)(6)

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: November 15, 2016

By: (b)(6)

Otto G. Matheke, III
Senior Trial Attorney

Dated: November 15, 2016

By: (b)(6)

Sarah E. Sorg
Senior Trial Attorney

Dated: November 15, 2016

By: (b)(6)

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE T[redacted]L, LLC

Dated: __, 2016 11 / 15 / 2016

By: [redacted]

Chris Herschend
President

Dated: __, 2016 11/15/2016

By: [redacted]

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

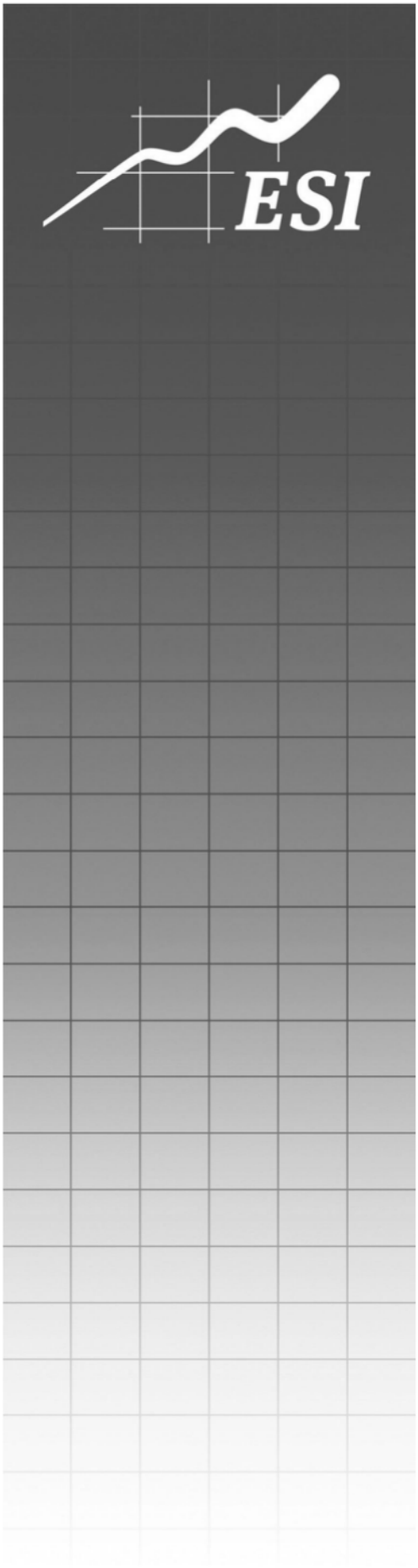
By: _____

Robby Hultz
Managing Partner

Dated: 11/5, 2016

By: (b)(6)

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC



Engineering Investigation

R&C VEHICLE DESIGN FOR RIDE THE DUCKS
ESI Project: 55440G

4215 Campus Drive
Aurora, IL 60504

Engineering Investigation

R&C VEHICLE DESIGN FOR RIDE THE DUCKS
ESI Project: 55440G

Report Prepared for:

Mr. Brian Deckard
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Submitted by:

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Stanley Sangdahl, P.E.
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12/15/16
Date

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Introduction

This report presents the findings of the engineering analysis performed on the front axles used in the Stretch Duck (Duck) manufactured by Ride the Ducks International (RTDI). Specifically, Engineering Systems Inc (ESI) was requested by RTDI to perform a mechanical and metallurgical analysis of the front axle in the area of the knuckle ball housing where isolated failures have occurred. Additionally, ESI was to evaluate the reinforcement of the knuckle ball housing designed by RTDI and described in their service bulletin SB-00-14-13. This engineering analysis is based upon the information reviewed, work performed and the education, training and experience of the authors. The resulting conclusions are stated to a reasonable degree of engineering certainty.

Background

Ride the Ducks International is one of the largest operators of amphibious tours in the nation. As part of its operation the company refurbishes and modifies existing WWII DUKW vehicles for their use. Over the past 13 years there have been three failures of the front axle housing in the area where it transitions into the steering knuckle ball housing. Additionally, there have been three instances where a fracture in the same area was discovered prior to any actual failure. In response to this, RTDI devised a reinforcement intended to increase the section properties in the area of the failures, thereby reducing the stresses. This modification is detailed in RTDI service bulletin SB-00-14-13 which was sent out to all of the operators of their vehicles who were instructed to perform the modification prior to the start of operations of the 2014 season. This same modification is applied to replacement axles produced at the RTDI facility in Branson, Missouri. Since the service bulletin was issued, there have been no reported failures of any axle which has been reinforced.

Material Reviewed

The following material was reviewed and relied upon as part of the engineering analysis.

- NTSB Docket material for accident ID: HWY15MH011
- RTDI Service Bulletin SB-00-14-13
- RTDI Service Bulletin SB-00-01-16
- RTDI Stretch Duck Front Axle Weight Survey
- RTDI MT103 Magnetic Particle Examination Procedure
- Department of the Army Technical Manual TM 9-8024
- Data plate for a M-135 Cargo Truck
- The First Century of GMC Truck History, Donald E. Meyer
- Notes on the GMC M-Series, http://www3.bc.sympatico.ca/deuce/NOTES.HTML

Additionally, two axles from RTDI were supplied for examination.

DISCUSSION AND ANALYSIS

Part of the RTDI fleet of amphibious vehicles consists of modified World War II vehicles commonly known as "Ducks". These vehicles were originally based on the 2½ ton cargo and troop carrier used during WWII, designated as the CCKW and manufactured by GMC. A specifically designed boat hull was installed resulting in the vehicle designated as the DUKW. Many thousands of these specialized vehicles were manufactured with a large number continuing to be used today by tour operators and enthusiasts.

One of the modifications performed by RTDI is the replacement of the front axle with one from the M-135 or its sister vehicle, the M-211, both of which are GMC 2½ ton trucks manufactured in the early 1950's and designated with the internal model number of G-749. Structurally, this axle is generally similar to the original front axle of the CCKW/DUKW. Aside from the removal of some of the suspension components, the addition of disc brakes and water proofing measures, these axles are little changed from their original design when RTDI uses them on their stretch Ducks.

Besides operating in the Korean conflict, the G-749 family of trucks saw continued use with the Canadian armed forces as well as multiple civilian applications with no apparent issues involving systemic failures of the front axle. During the time that RTDI has used the stretch Duck there have been very few failures of the front axle. Some of these failures are known to be from damage incurred during an accident or similar incident. The majority of Ducks have operated for over a decade under conditions less severe than the original application using the front axle from the G-749 series truck with no known failures.

An important aspect of the engineering analysis was determining the stresses in the area of the fractures under the maximum allowable load. Ordinarily, the manufacturer specifies a Gross Axle Weight Rating (GAWR) for this parameter. Research for data regarding the front axle design of G-749 based trucks found no information regarding the GAWR for the front axle. However, data plates for the M-135 provide some insight as to the load carrying capacity of the front axle (Appendix A). At the fully loaded highway capacity for the M-135 truck with a winch, the total vehicle weight is 23,090 lbs of which 6,420 lbs are carried by the front axle. This compares to the 7,280 lbs at the front axle measured by RTDI with an empty stretch duck (report attached). In the fully loaded condition the RTDI duck has a total weight of 26,480 lbs with the front axle load measured at 6,800 lbs. Even during the infrequent times that the RTDI duck is operated empty, the front axle load is only 13% greater than the maximum load stated by the US Army. This minor increase of the loading on the front axle more than likely would be within the factor of safety for the axle design.

The rim used for the RTDI Duck is made of steel with dimensions of 7.50" wide and 20" diameter. Further the rim has a negative offset of 5¾". This places the location of the reaction force to the axle loads inboard from the hub mounting surface for the wheel. Use of rim sizes different from the RTDI supplied rim might change the location of this reaction force and thus change the stresses on the front axle.

As part of the engineering analysis two complete axle housings were provided to ESI by RTDI. One of these was an axle that had not been modified with the collar reinforcement. Another was an axle from a Duck that was being repaired for a small leak in the area of the spring saddle. This axle, RTDI No. SD-170, had the collar reinforcement installed prior to the 2014 operating season and had been in use since then. The right side end of

SD-170 was cut off and sectioned for dimensional and metallurgical analysis. It is important to note that no cracking was observed in any of the cross sections from this axle.

Hand calculations using the section properties of the reduced area on the knuckle ball housing were performed to estimate the stresses from bending in the area where previous failures had occurred. These calculations also considered the stress concentration factor created by the radius of the fillet at the transition from the reduced section to the ball of the housing. These calculations estimated that at the maximum axle load the stresses in the fillet would be approximately 24,550 psi. These same hand calculations were performed using the increased section properties provided by the addition of the reinforcing collar. These calculations found that the stresses in the critical area of the fillet are approximately 56% of the stresses determined for the unreinforced section.

Finite Element Analysis

To investigate stresses at the fracture location when the axle housing assembly is subjected to a maximum axle weight load, and to determine the efficacy of the reinforcing collar, a small Finite Element Analysis (FEA) was performed using Abaqus, a world-class commercial finite element program. Using the Method of Sections from Statics and relying on St. Venant's Principle, only the outboard section of one side of the axle housing assembly needed to be modeled (approximately 11.7 inches long from the centerline of the kingpin to the "stub" end of the model). This approach minimized the size of the FEA models while providing a conservative stress solution.

The solid geometries of the axle housing and the reinforcing collar were meshed using Abaqus C3D10HS solid elements, which are 10-node general purpose tetrahedrons that use a hybrid formulation with improved surface stress visualization. Linear elastic material properties were assumed for the steel axle housing and steel knuckle ball housing. In addition, the knuckle ball housing and the axle housing were assumed to be perfectly fused at their interfacing surfaces by modeling the two components as one solid part.

Two models of the axle housing assembly were created: one without the reinforcing collar and one with the collar. When the reinforcing collar was added to model, the contacting faces between the collar and the outer surfaces of the knuckle ball housing and axle housing were also assumed to be perfectly fused, but in this case the bond was created between two separate parts using the Tie Constraint feature in Abaqus. No representation of the weld bead was included in the collar geometry.

With respect to loads and boundary conditions, the stub end of the axle housing was assumed to be fully fixed and a vertical force of 3,640 pounds (1/2 of the assumed 7,280 maximum axle load) was applied at a reference point located on the centerline of the axle housing assembly 2.75" outboard of the vertical centerline (axis) of the kingpin. This location accounted for the inboard offset of the centerline of the wheel and tire assembly from the mounting face of the hub. The Kinematic Constraint feature of Abaqus was used to properly transmit the resulting force and moment to the surfaces of the knuckle ball adapter which mate with the outer races of the kingpin bearings.

In terms of results, the finite element solution for the model without the collar indicated that the Maximum Principal Stress at the fracture location (located where the radius on the outer surface of the knuckle ball housing meets the necked-down section adjacent to the end of the axle housing) was 28,486 psi. When the reinforcing collar was added to the second model, the Maximum Principal Stress at the fracture location was reduced to 15,420 psi, a 46% reduction in stress.

Details of the finite element models and the stress results can be found in Appendix B to this report.

Metallurgical Evaluation

Cross sectional samples were made of axle SD-170 in the area of the collar reinforcement in order to evaluate the construction and metallurgy of the knuckle ball housing and the collar reinforcement. The housing is a forging using a medium carbon steel with a microstructure consisting of ferrite in a pearlitic matrix. After forging, the part is machined into its final shape including the reduced section at the base of the knuckle ball. Hardness testing of this material found that it averaged 84 Rockwell B. This would equate to an ultimate tensile strength of approximately 81 ksi (per ATM A370, table 3).

The design of the collar reinforcement uses a short section of low carbon steel pipe cut in half in order to fit around the reduced section of the knuckle ball housing. Additionally, a bevel is ground around the inside diameter of the collar to aid in fitting to the knuckle ball housing. This is then welded around the entire circumference. This joint configuration of the weld prevents the full thickness of the collar from being properly fused to the knuckle ball housing. It also creates a sharp transition at the root of the weld between the collar and the housing leading to elevated stresses. The geometry at the weld root acts as a stress concentrator.

The welding of the collar to the knuckle ball housing is done with no pre or post weld heat treatment. This results in rapid cooling of the weld and heat affected zone which produces a martensitic microstructure in the medium carbon steel of the knuckle ball housing. This type of microstructure can be susceptible to fatigue cracking and growth in the presence of elevated stress concentration factors as are present given the joint geometry of the welded collar reinforcement.

Details of the metallurgical evaluation are presented in Appendix C.

CONCLUSIONS

The engineering investigation outlined above has resulted in the following conclusions:

1. The infrequent occurrence of failures in the front axle of the RTDI Stretch Duck indicates that the underlying cause of these failures is not systemic but related to individual circumstances such as a pre-existing crack caused by a loading event beyond the normal intended use.

2. The collar reinforcement provided for in RTDI service bulletin SB-00-14-13 significantly reduces the stresses in the critical area of the fillet section in the knuckle ball housing. To date there have been no failures of an axle that has received the collar reinforcement.

3. The design and installation of the collar may eventually be subject to failure over a long period of time due to the improper weld joint geometry and the creation of an unfavorable microstructure within the heat affected zone of the weld. If the structural integrity of the collar is lost, the axle would revert back to its original strength prior to the application of the collar.

4. The collar reinforcement prevents the inspection of the underlying section of the knuckle ball housing for the presence of any fatigue cracking that may have been present prior to the installation of the collar. While the collar would significantly inhibit the progression of any pre-existing crack it may not be adequate to entirely arrest the growth.

5. The front axle from the G-749 series GMC 2½ ton trucks as originally designed and manufactured provide adequate strength for the RTDI application in their Stretch Ducks. This is supported by the history of the front axle design prior to the RTDI application and its performance in the Stretch Duck. Furthermore, the hand calculations and Finite Element Analyses described above provide additional support for this.

RECOMMENDATIONS

Based upon the foregoing analysis, the following recommendations are made:

1. All of the axles that have received the collar modification of SB-00-14-13 should be removed from service and replaced with unmodified axles that have undergone the inspection outlined below. Removed axles should be inspected and reworked back to the original condition. Since the collar significantly increases the strength of the reduced section in the knuckle ball housing and there have been no reported failures, the timing of this replacement is not of immediate urgency.

2. Inspection of new axle housings:

   Upon receipt of any salvaged axle housing the part should be thoroughly cleaned and the reduced area at the base of the knuckle ball housing smoothed to a surface finish of 20 to 25 µin RMS using 180 grit sandpaper. After this surface preparation, the entire reduced area should be inspected using magnetic particle according to RTDI MT103.

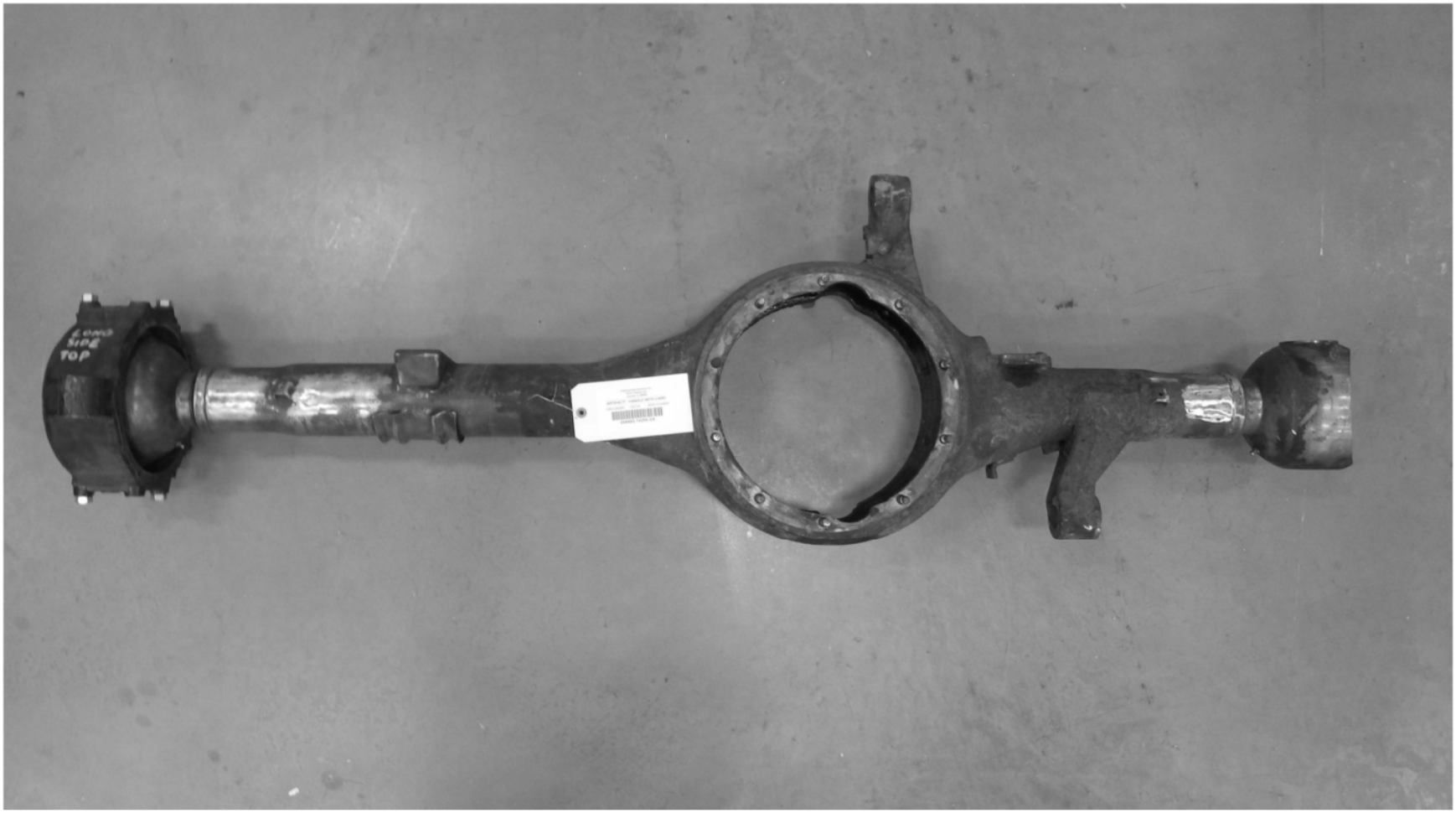
3. Annual inspection of the knuckle ball housing using the magnetic particle inspection procedure described in RTDI MT103 should be performed. If a vehicle is involved in an accident or other incident that could potentially impact the front axle, the inspection should be performed prior to returning the vehicle to service.

End of Report Text

APPENDIX A

General Discussion – Axle Housing Assembly

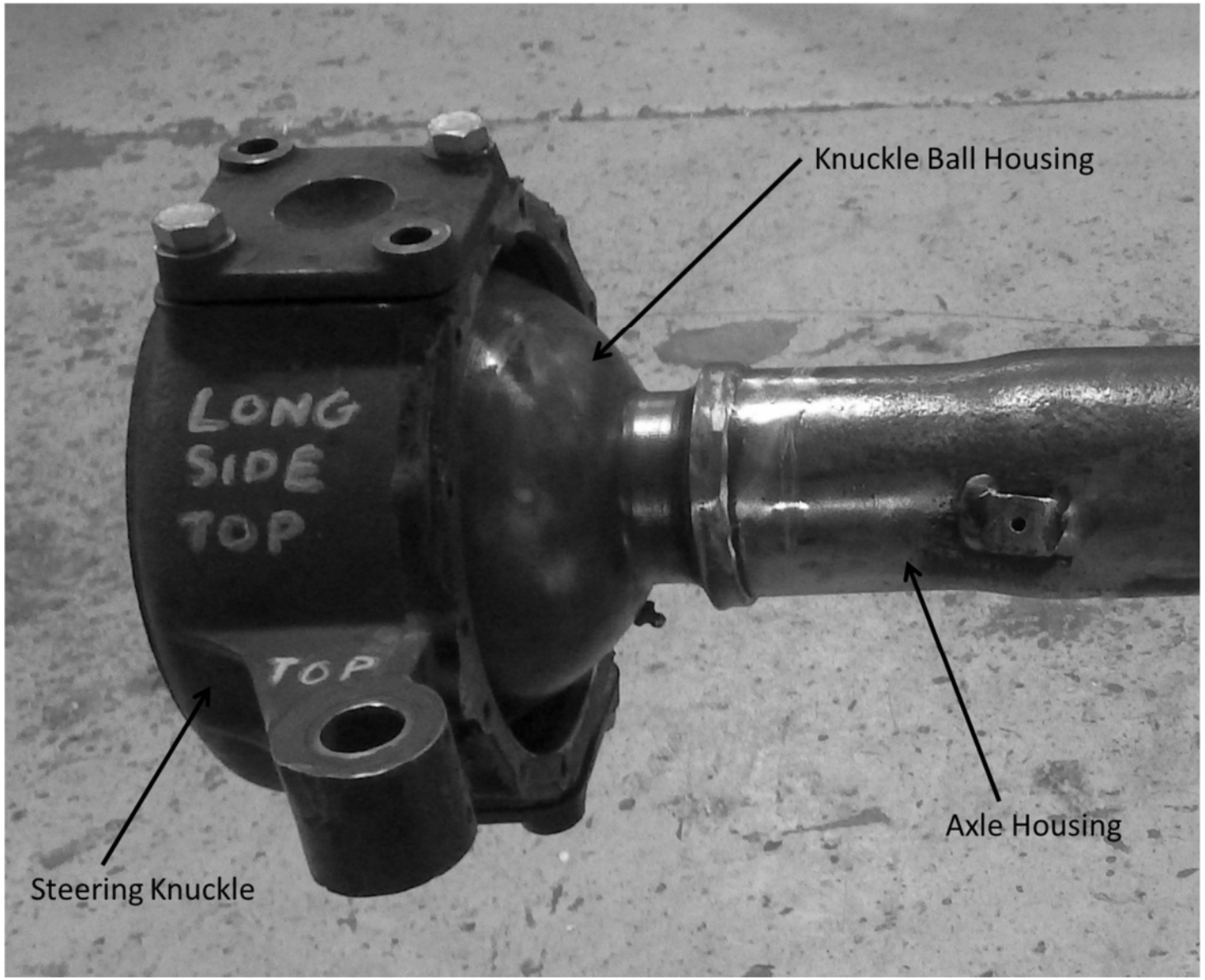
ESI No. 55440G



Axle Housing Assembly

General Discussion – Axle Housing Assembly

ESI No. 55440G



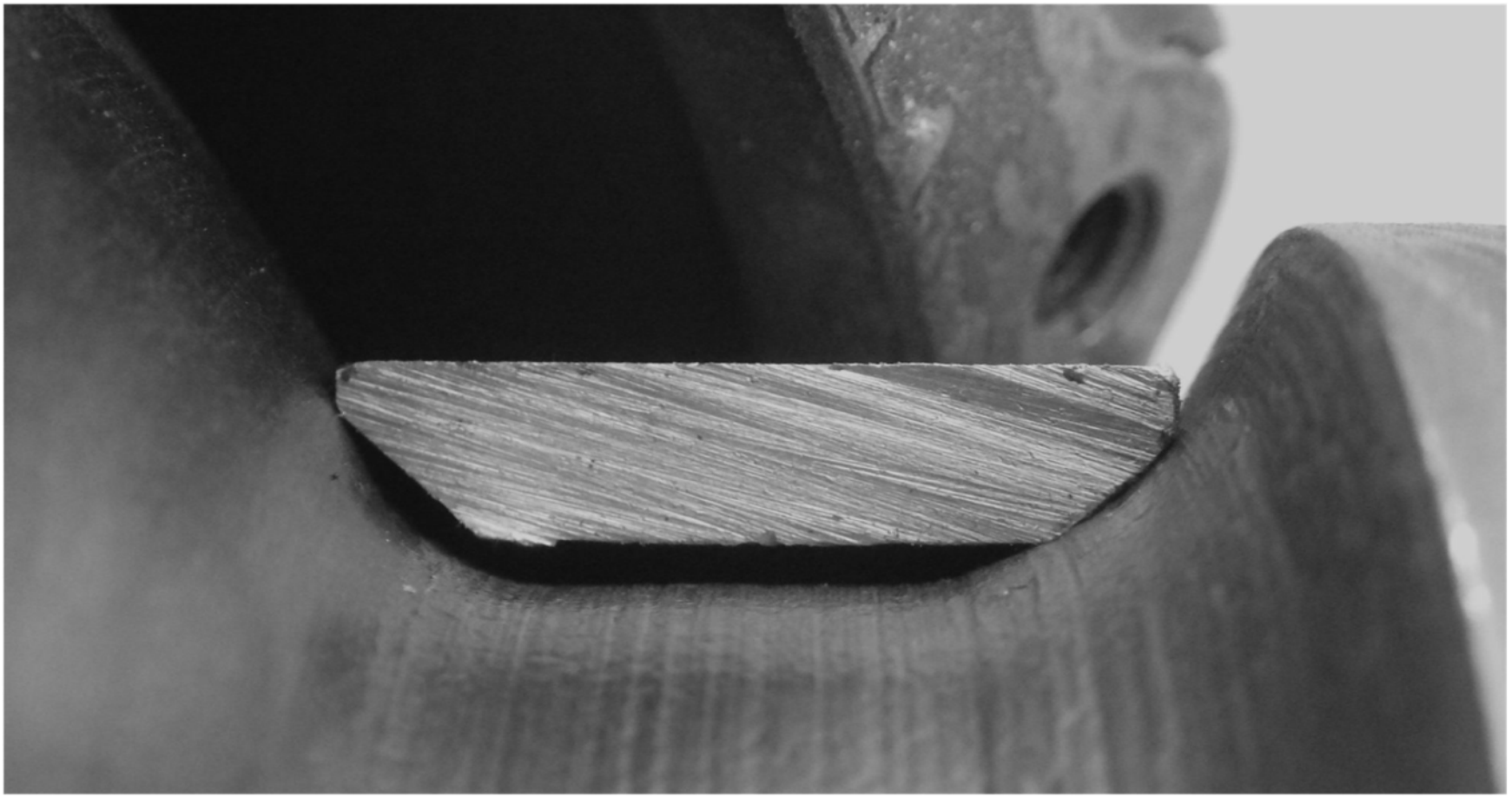
General Discussion – Axle Housing Assembly

ESI No. 55440G

Reduced area at transition to knuckle ball. Arrow indicates area where fractures occur.

General Discussion – Axle Housing Assembly

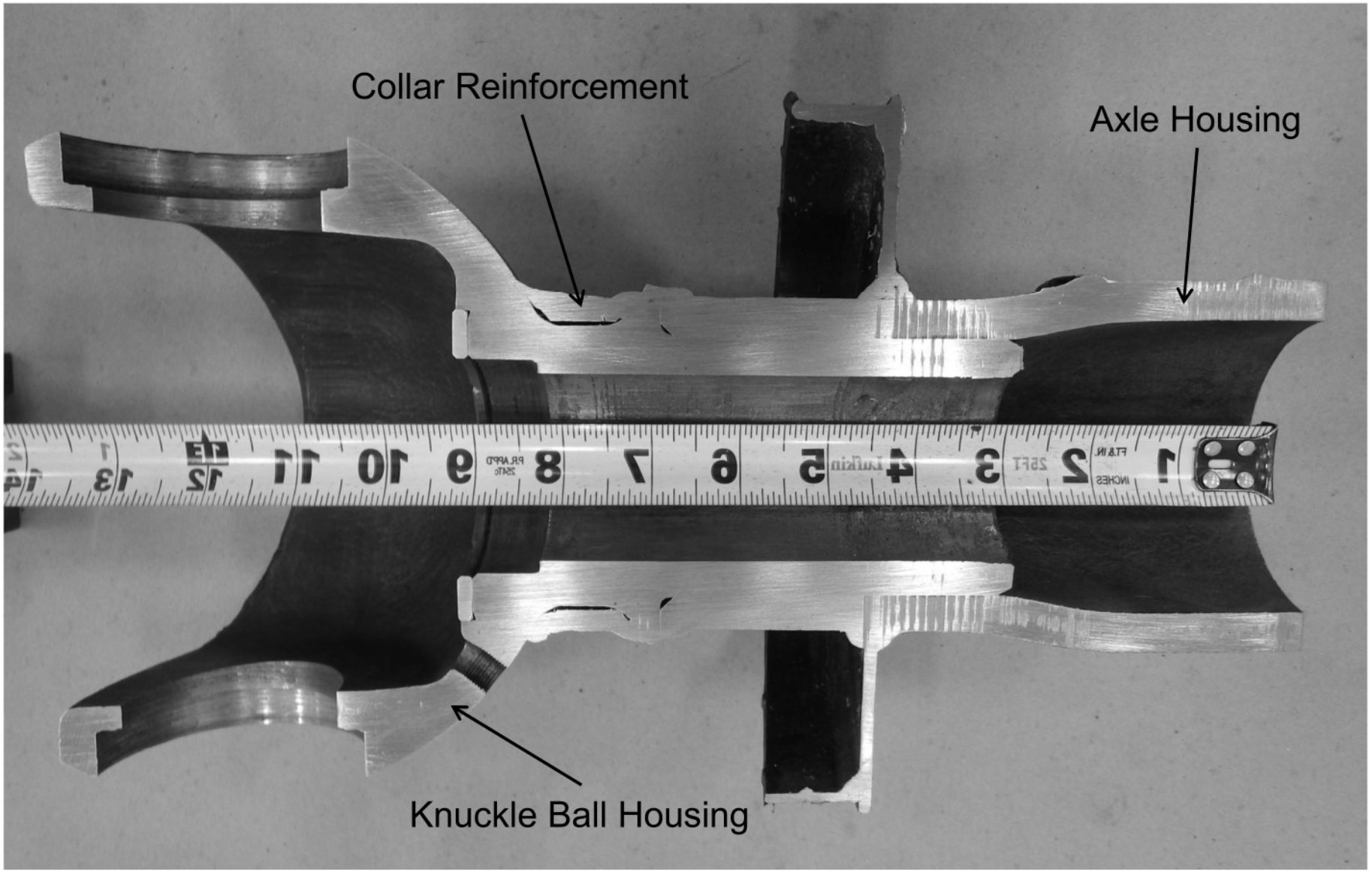
ESI No. 55440G



Reduced area at transition to knuckle ball with collar reinforcement placed in position.

General Discussion – Axle Housing Assembly

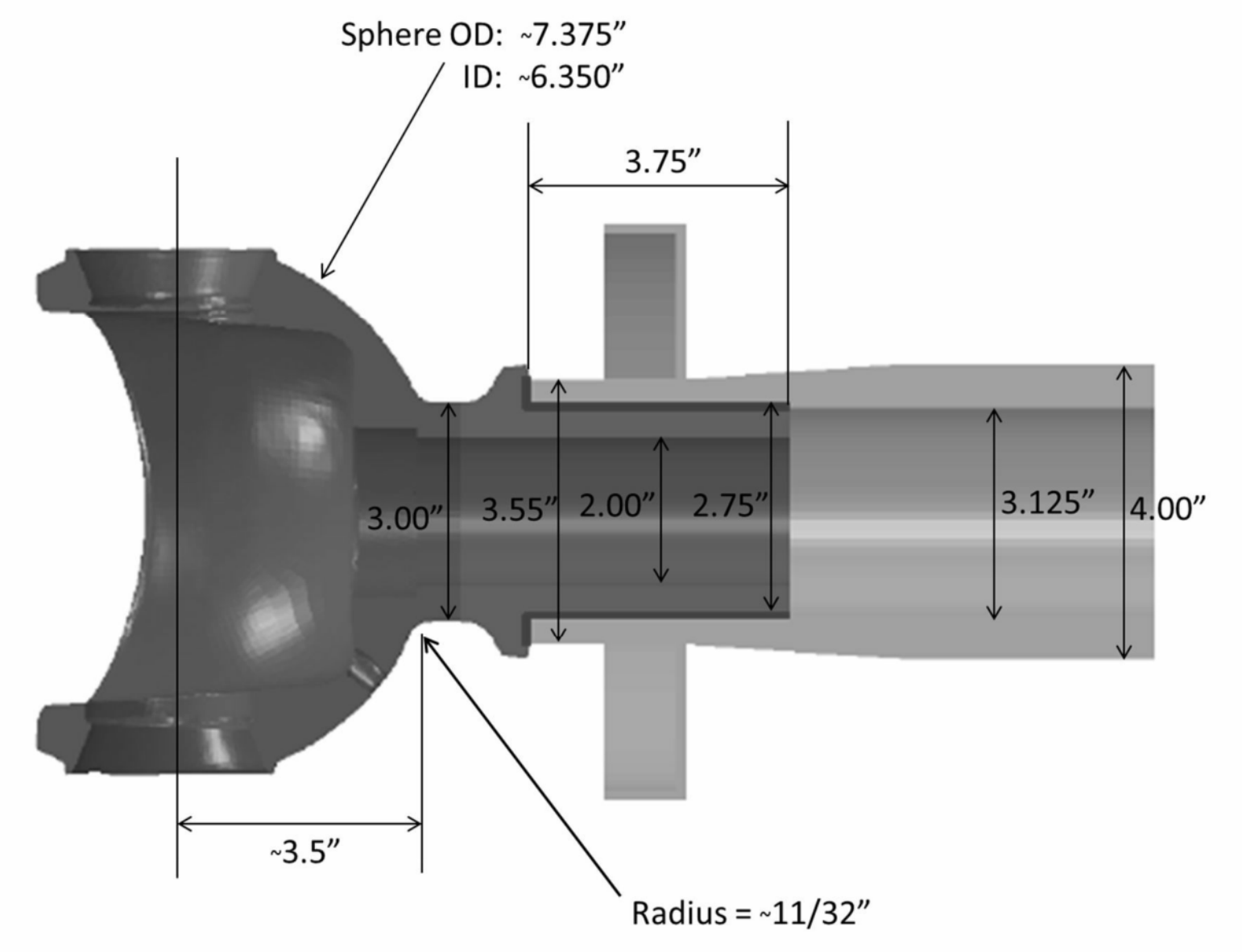
ESI No. 55440G



Cross sectional view of axle housing with collar reinforcement.

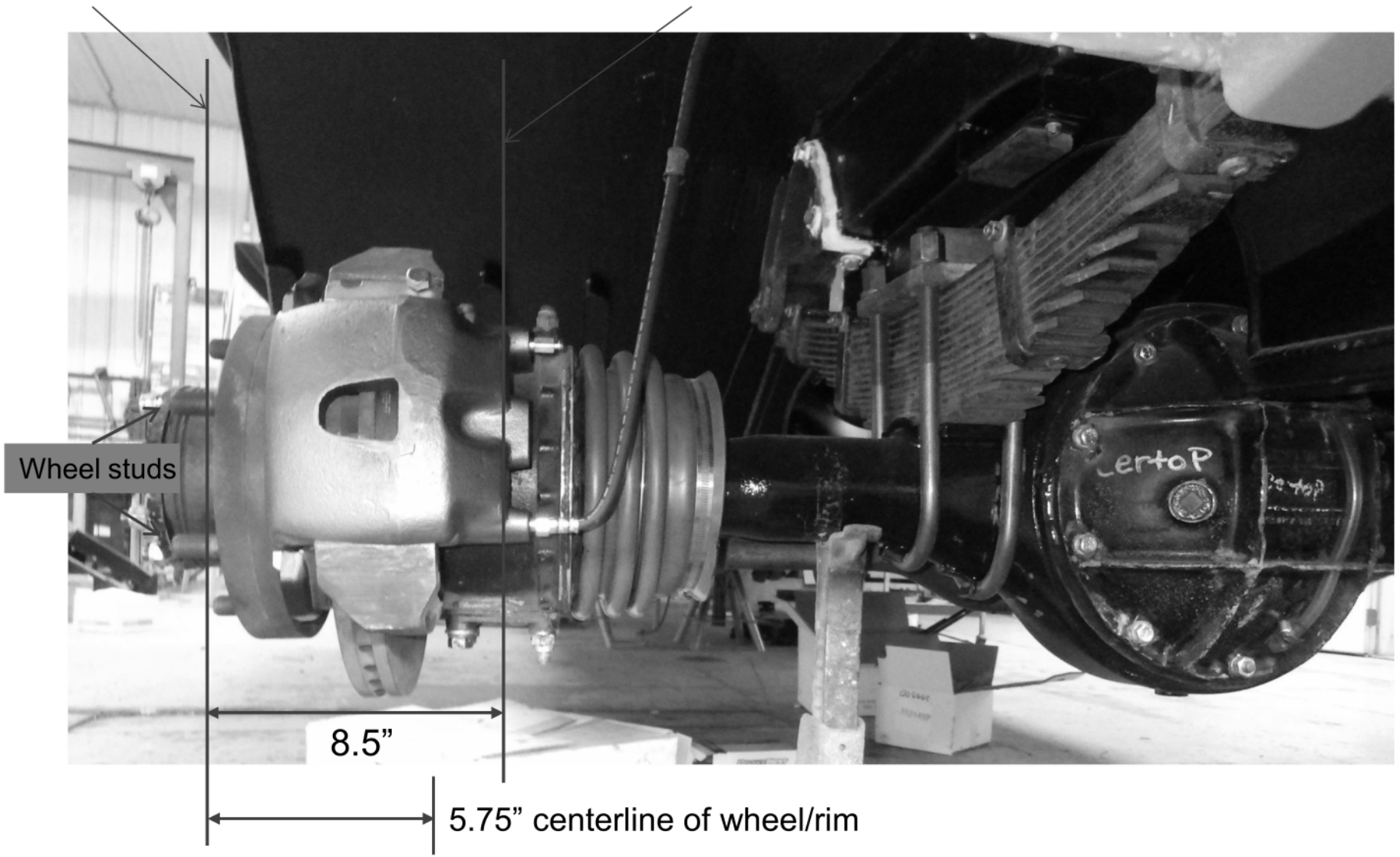
General Discussion – Axle Housing Assembly

ESI No. 55440G



General Discussion – Axle Housing Assembly

ESI No. 55440G



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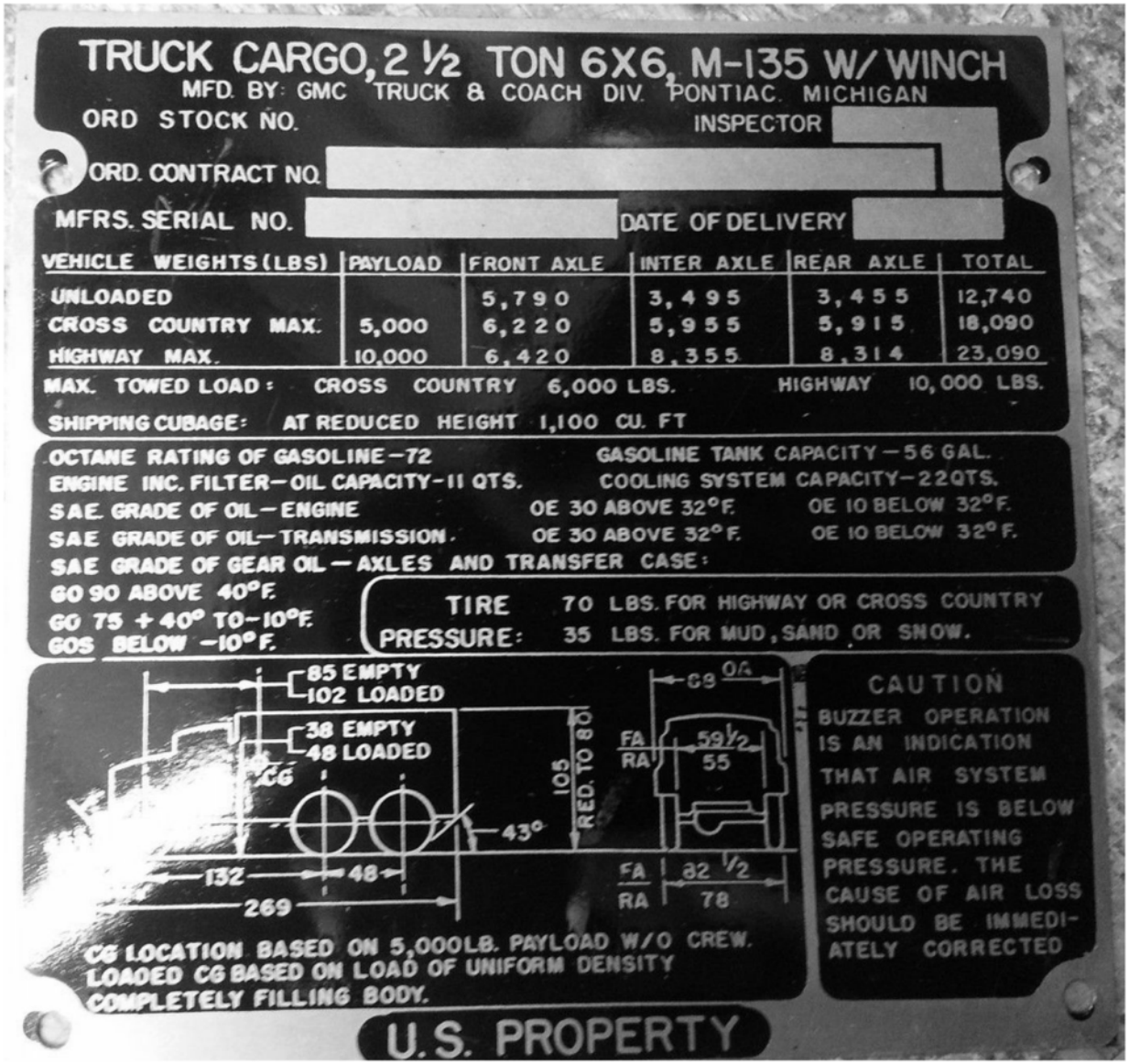
General Discussion – Axle Housing Assembly

ESI No. 55440G



Data plate from a M-135 truck listing the axle loads at various weight configurations

Reduced Area (Dimensions from NTSB photos of fracture)

OD = 3.00" ID = 2.22" t = 0.39"

$I = \frac{\pi}{64}(d_o^4 - d_i^4) = \frac{\pi}{64}(3.0^4 - 2.22^4) = 2.78\ in^4$

$c = \frac{3.00}{2} = 1.5"$

Collar

OD = 3.5" ID = 3.08" t = 0.21"

$I = \frac{\pi}{64}(3.5^4 - 3.08^4) = 2.95\ in^4$

$c = \frac{3.5}{2} = 1.75"$

$I_{combined} = 2.78 + 2.95 = 5.73\ in^4$

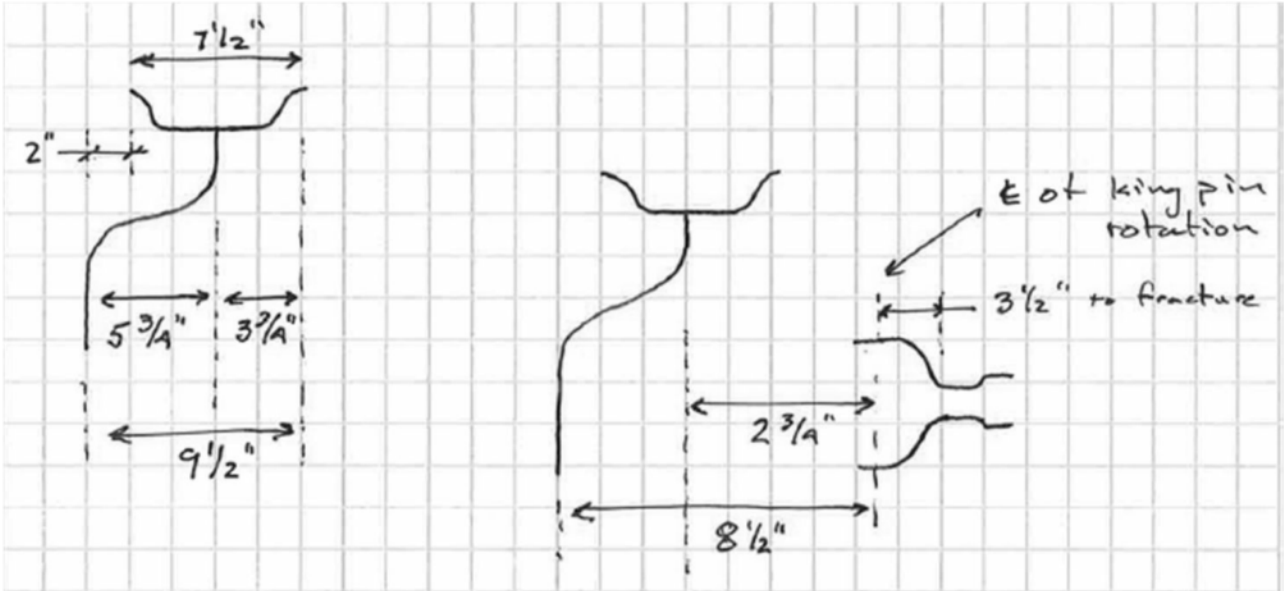
$c = 1.75"$

Stress Calculations

ESI

General Discussion – Axle Housing Assembly

ESI No. 55440G



℄ of tire to fracture: $2\frac{3}{4}" + 3\frac{1}{2}" = 6\frac{1}{4}"$

$$\text{Moment} = \left[\frac{7280}{2}\right](6.25) = 22{,}750 \text{ in·lbs}$$

No Collar $\sigma = \frac{Mc}{I} = \frac{(22{,}750)(1.5)}{2.78} = 12{,}275$ psi

Use $K_t = \sim 2.0$

$(2)(12{,}275) = 24{,}550$ psi

Stress Calculations

With Collar

$$\sigma = \frac{(22750)(1.75)}{5.73} = 6,948 \text{ psi}$$

$K_t = 2$

$(2)(6948) = 13,896$ psi

$$\frac{13,896}{24,550} = 56.6\%$$

Stress Calculations

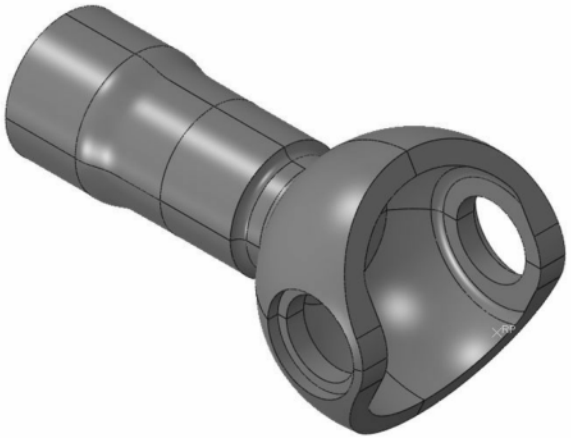
APPENDIX B

Finite Element Analysis (FEA) – Axle Housing Assembly

ESI No. 55440G

CAE FILES

Axle_Housing_Models.cae – Models of axle housing assemblies. Solid geometries created by ESI based measurements obtained by sectioning exemplar axle housings.



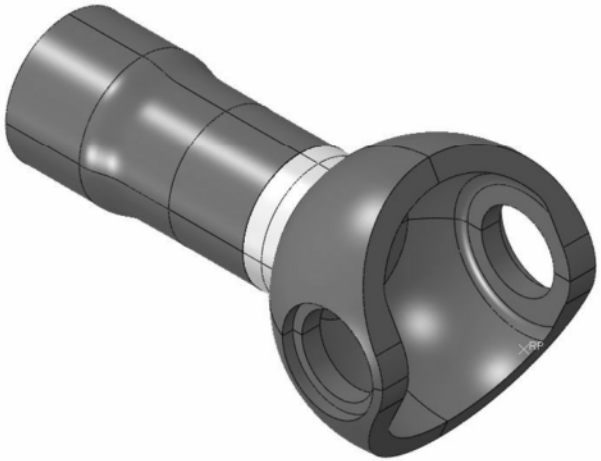
INPUT FILES

AH_Tets.inp – Model of axle housing assembly without a reinforcing collar. Abaqus C3D10HS tetrahedral mesh.

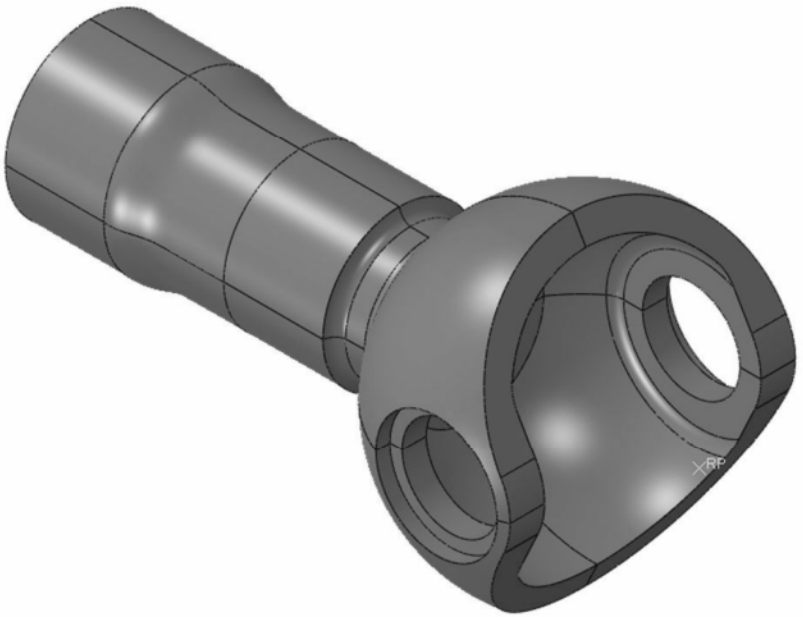
AH+Collar_Tets.inp – Model of axle housing assembly with a reinforcing collar. Abaqus C3D10HS tetrahedral mesh.

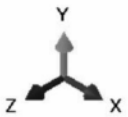
SOFTWARE

ABAQUS 3DEXPERIENCE R2016x



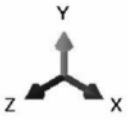
Axle Housing Geometry Without Reinforcing Collar





Axle Housing Mesh

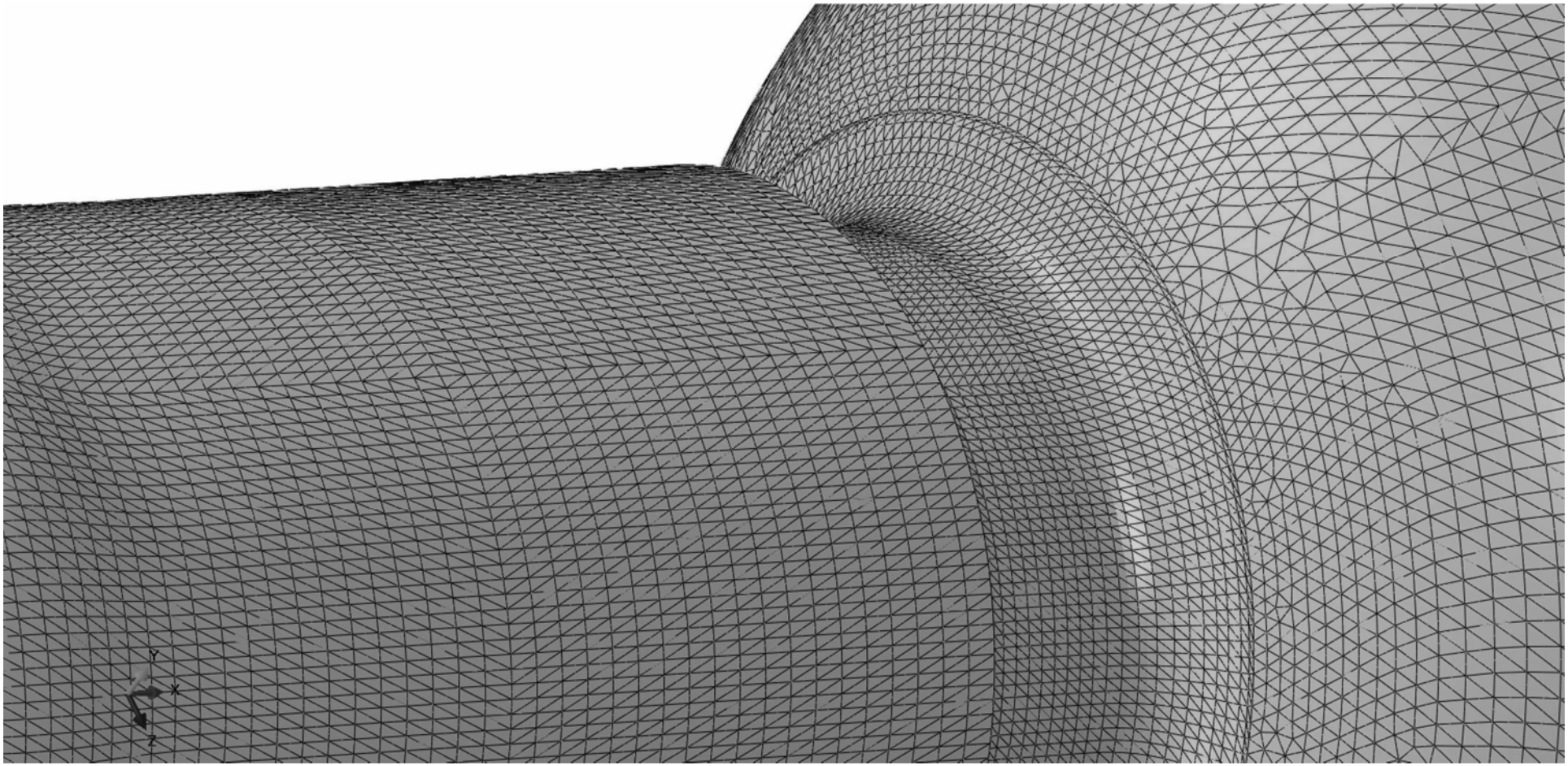
Material: Steel
E = 29e6 psi
v = 0.3



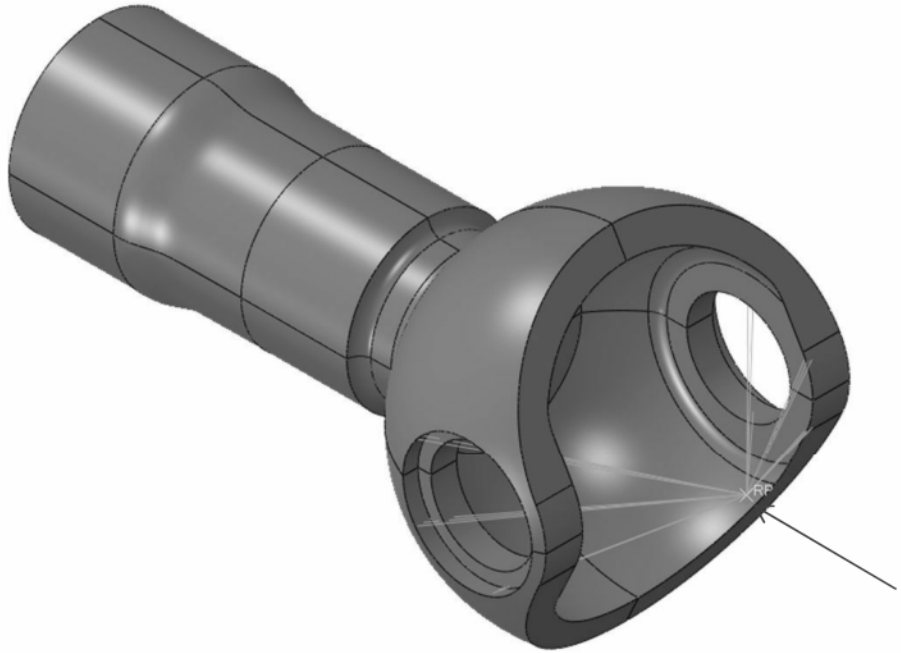
Finite Element Analysis (FEA) – Axle Housing Assembly

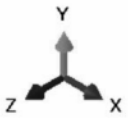
ESI No. 55440G

Axle Housing Mesh

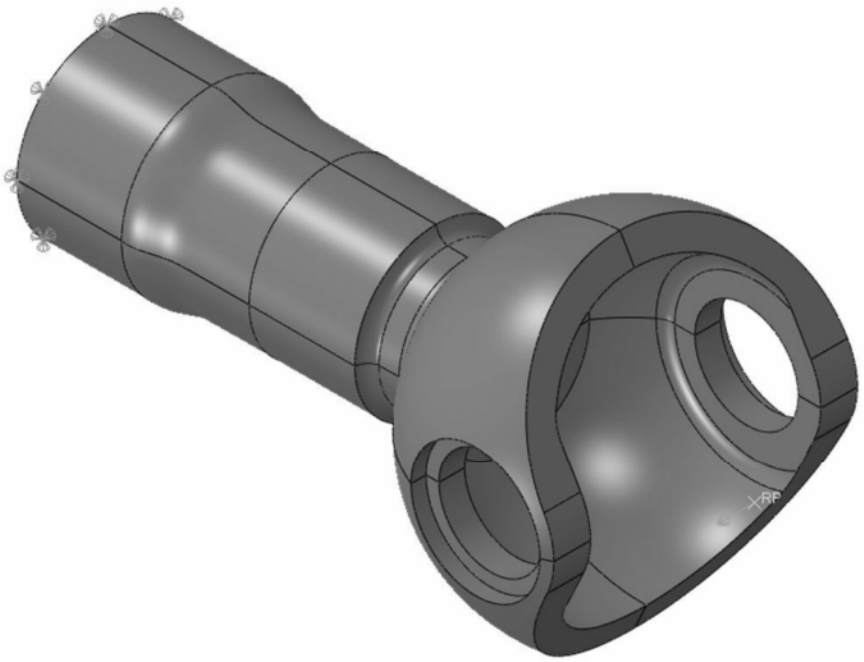


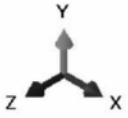
Axle Housing – Kinematic Coupling to Transfer Loads from Reference Point to Bearing Outer Race Locations



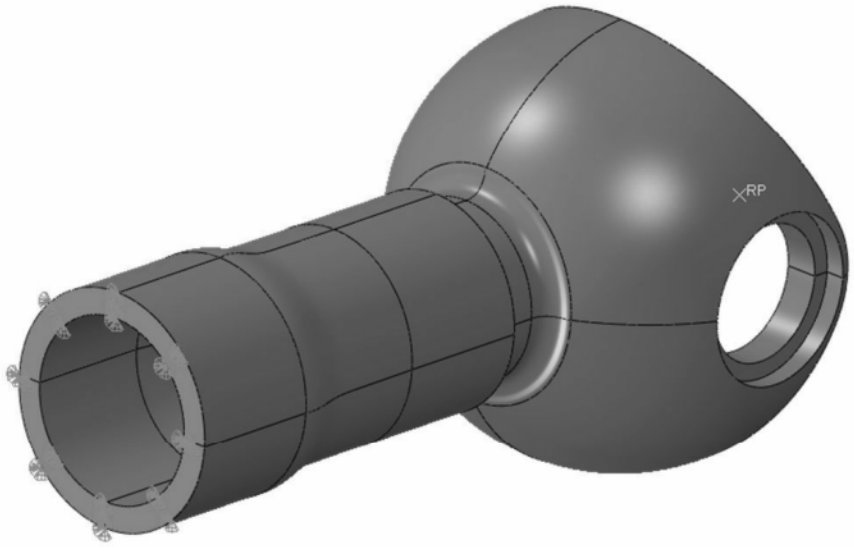


Axle Housing – Loads and Boundary Conditions



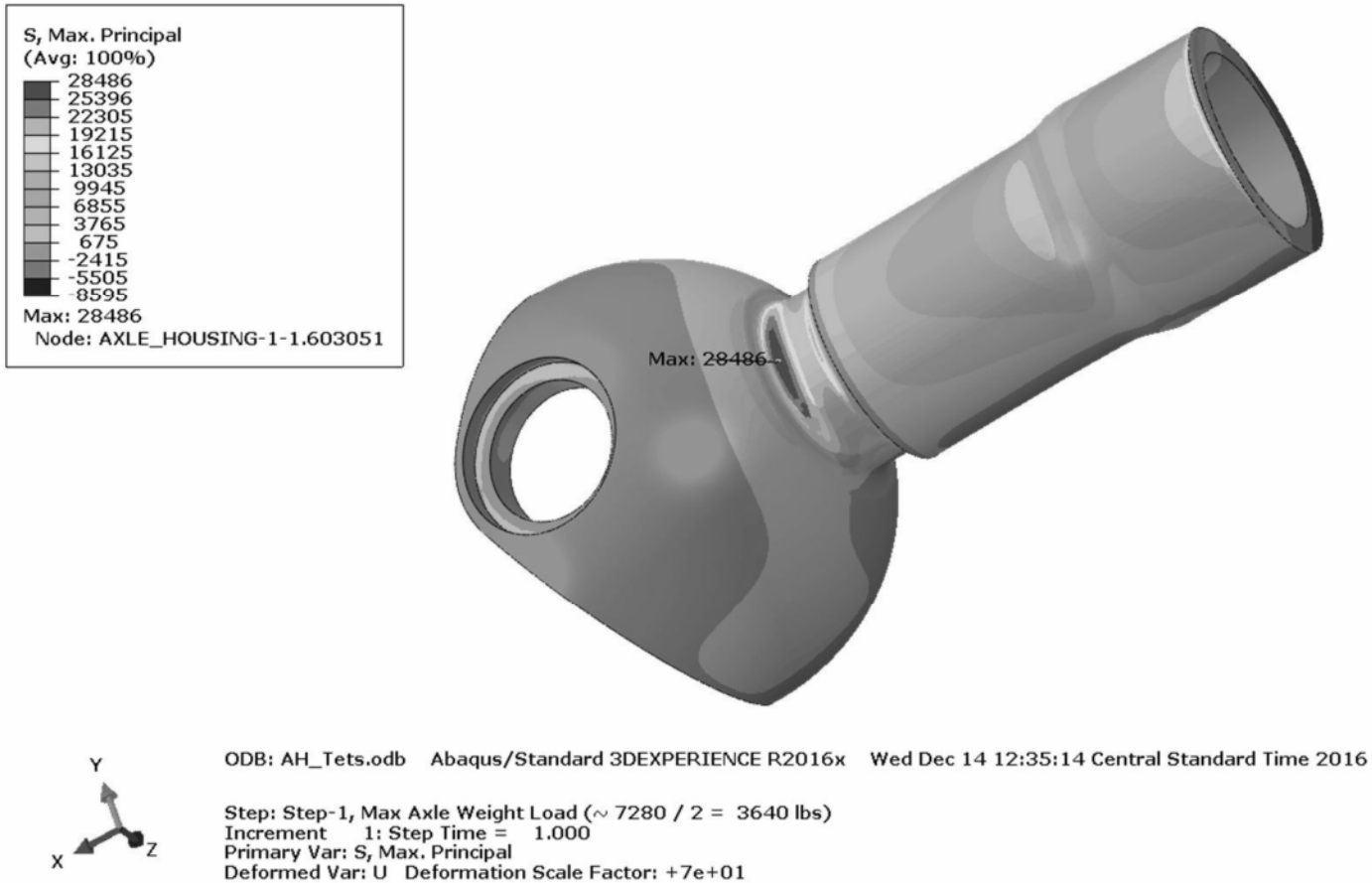


Axle Housing – Loads and Boundary Conditions (continued)

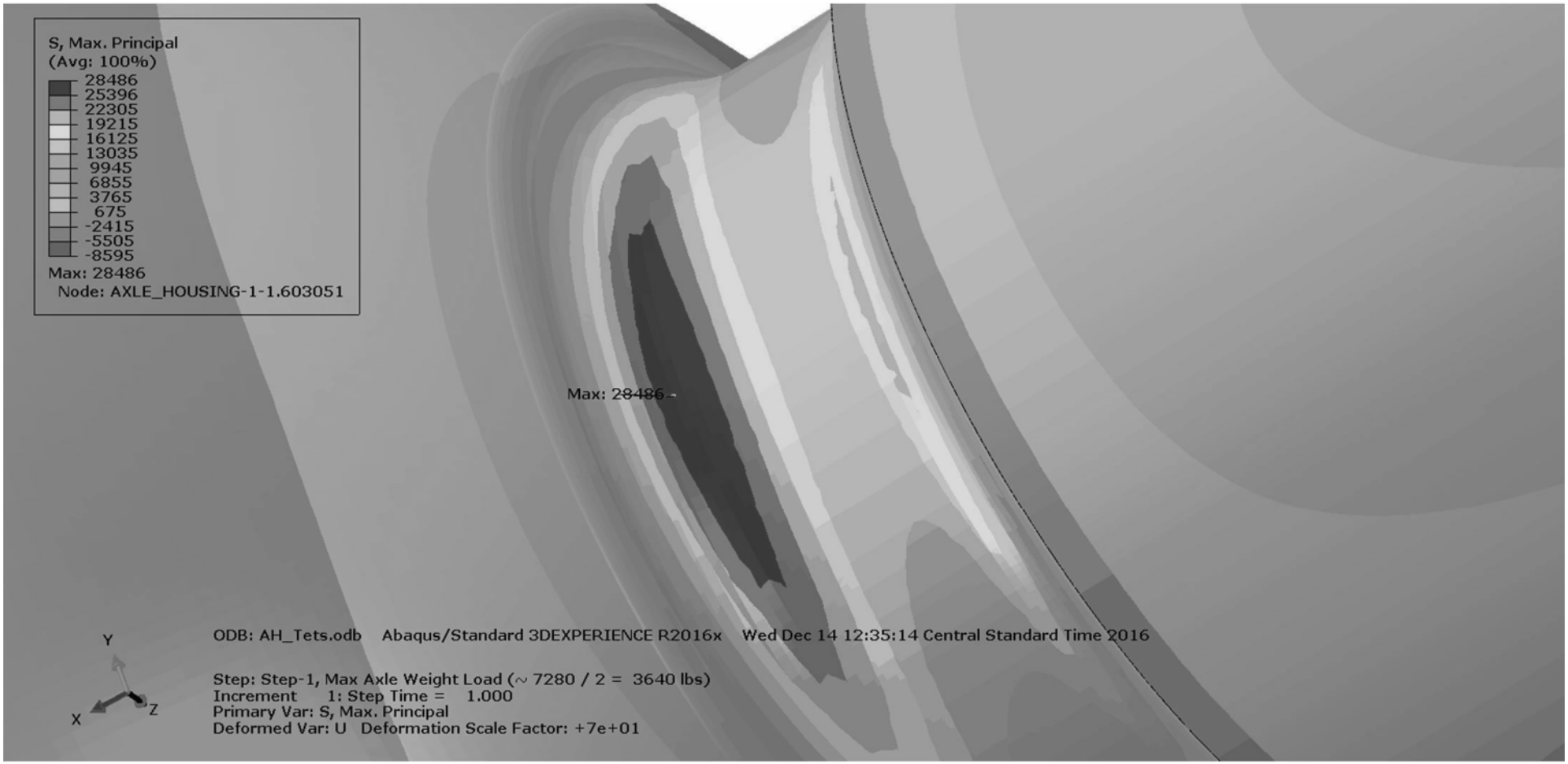


ESI No. 55440G

Axle Housing – Maximum Principal Stresses

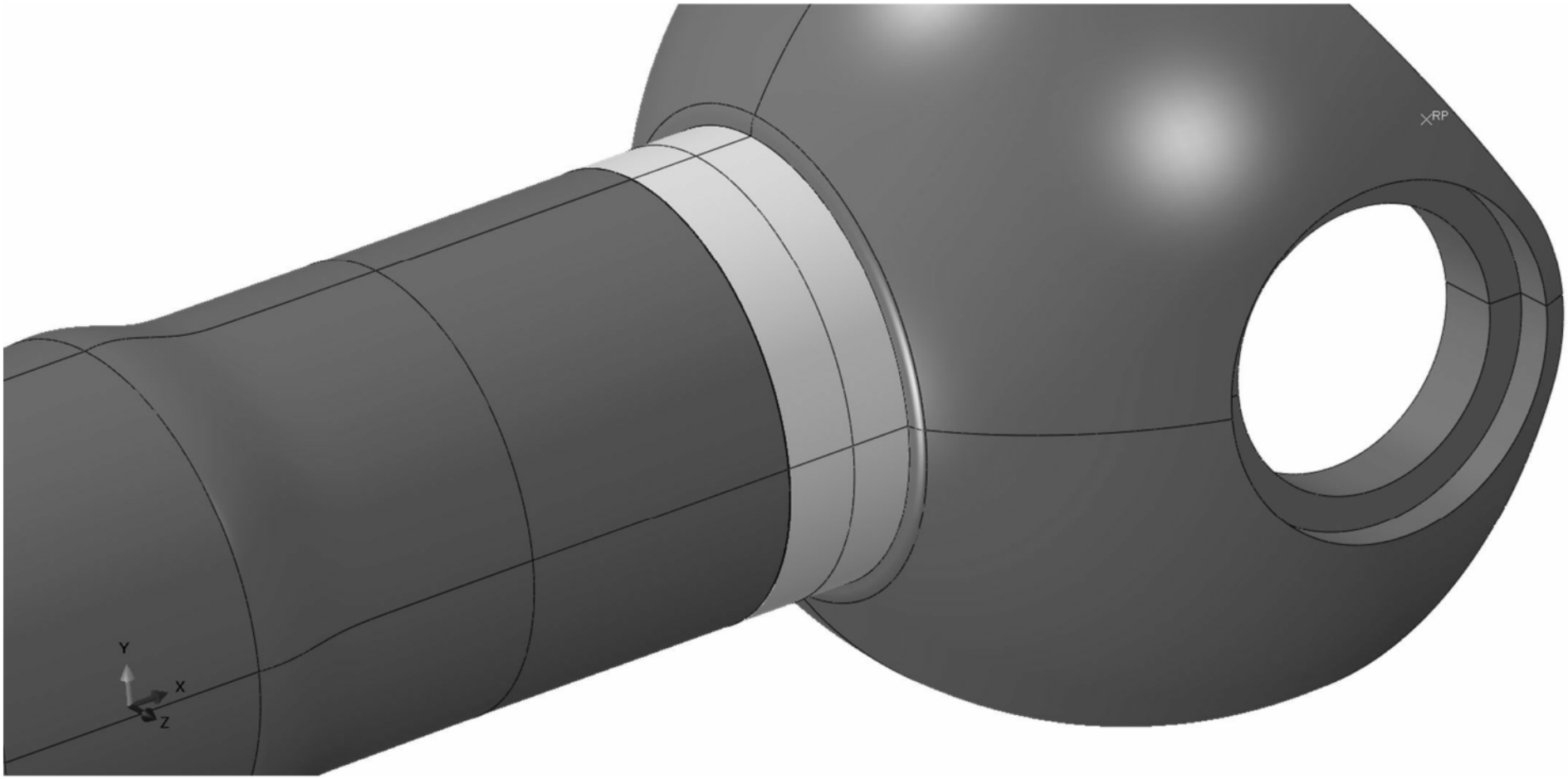


Axle Housing – Maximum Principal Stresses (continued)

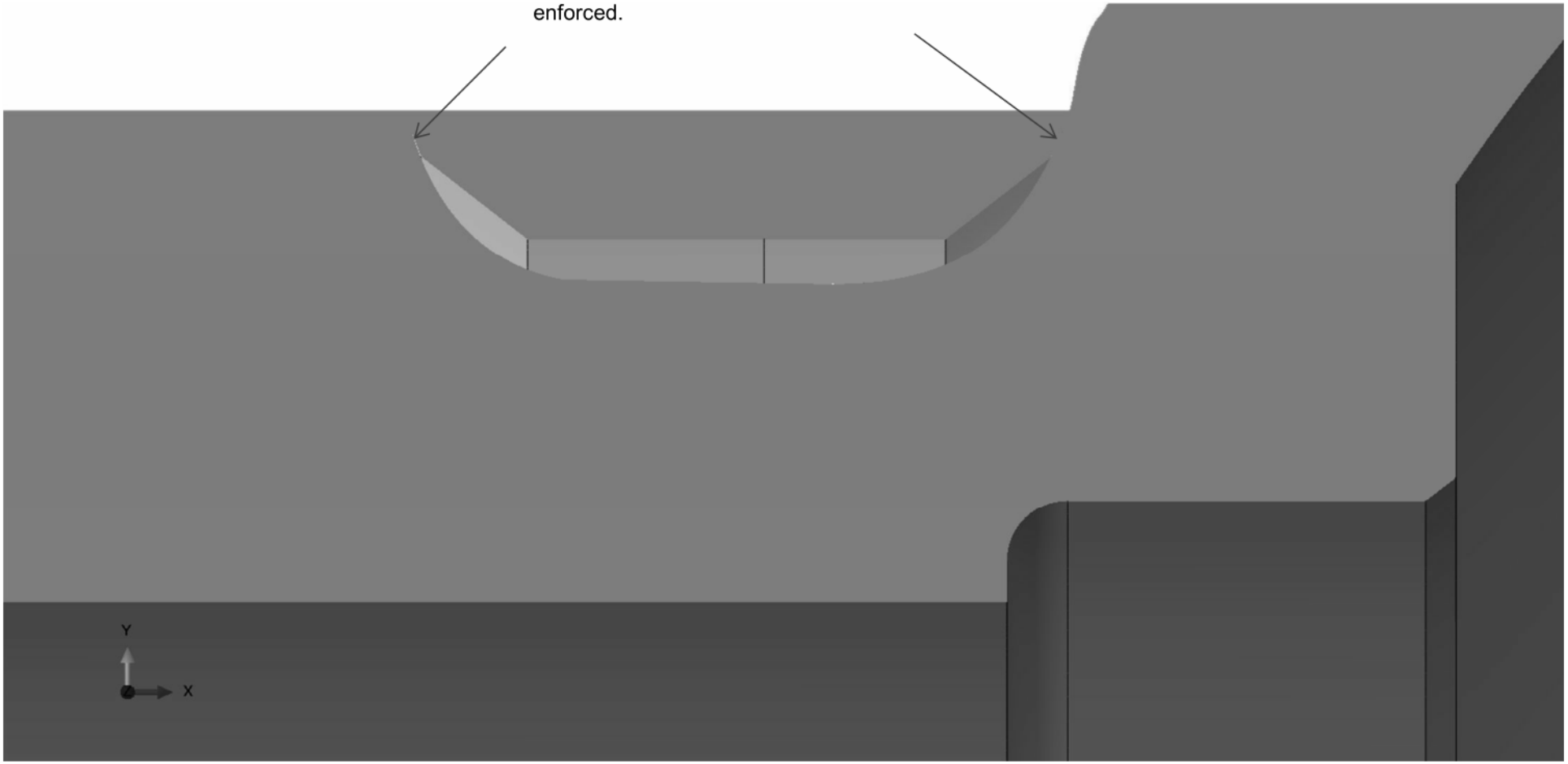


Axle Housing With Reinforcing Collar - Geometry

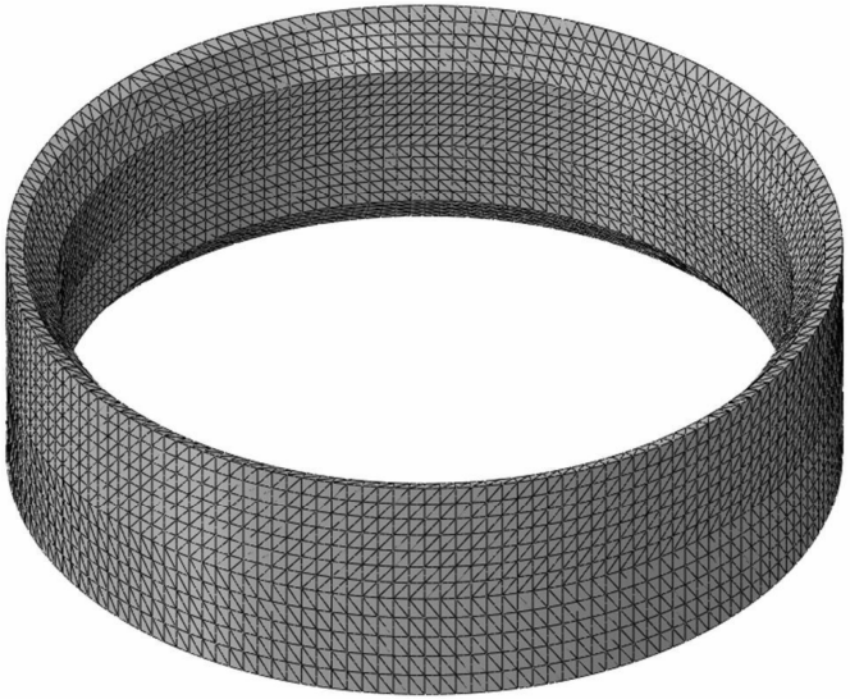
Axle Housing With Reinforcing Collar – Geometry (continued)



Axle Housing With Reinforcing Collar – Geometry (continued)

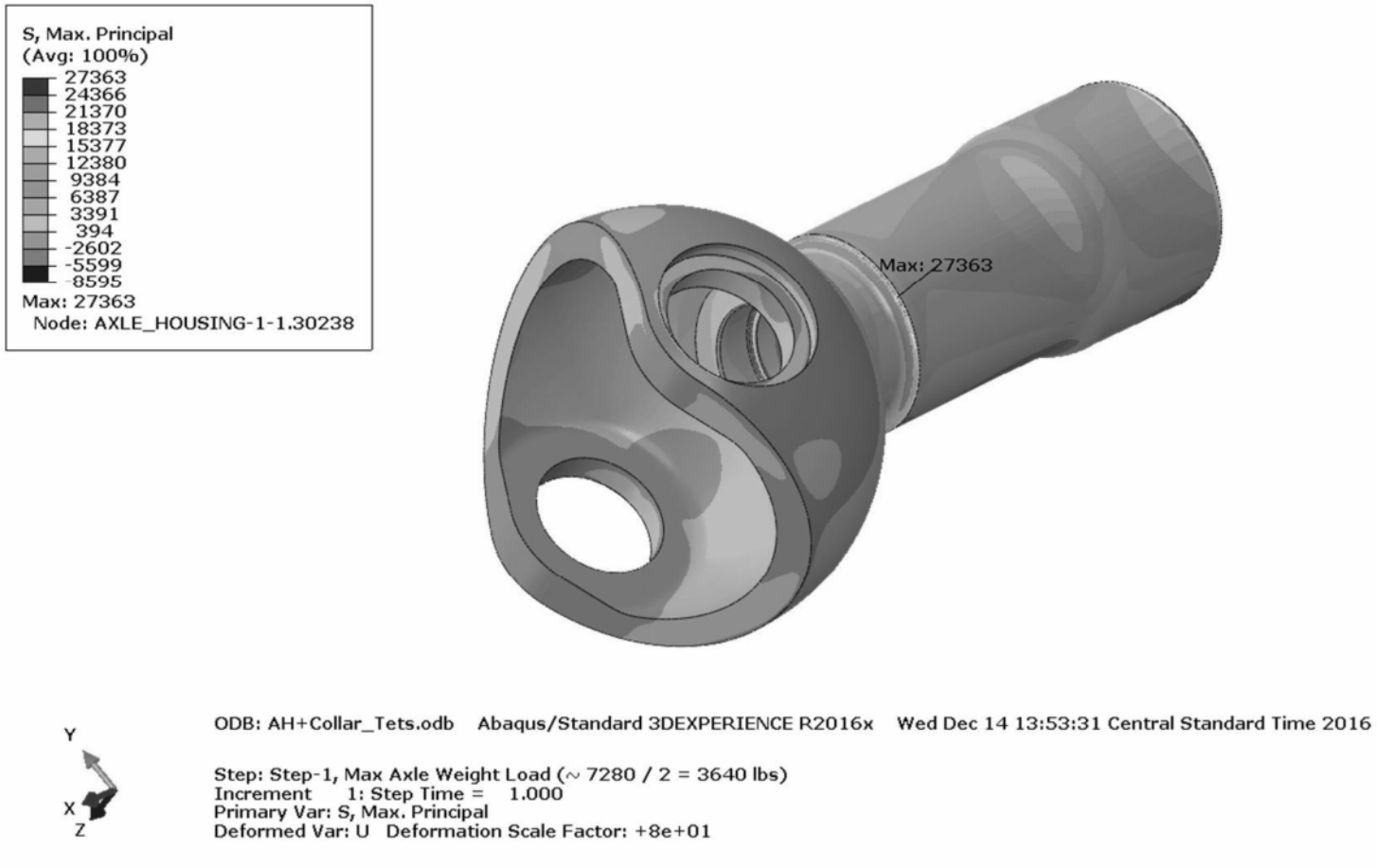


Axle Housing With Reinforcing Collar – Collar Geometry/Mesh

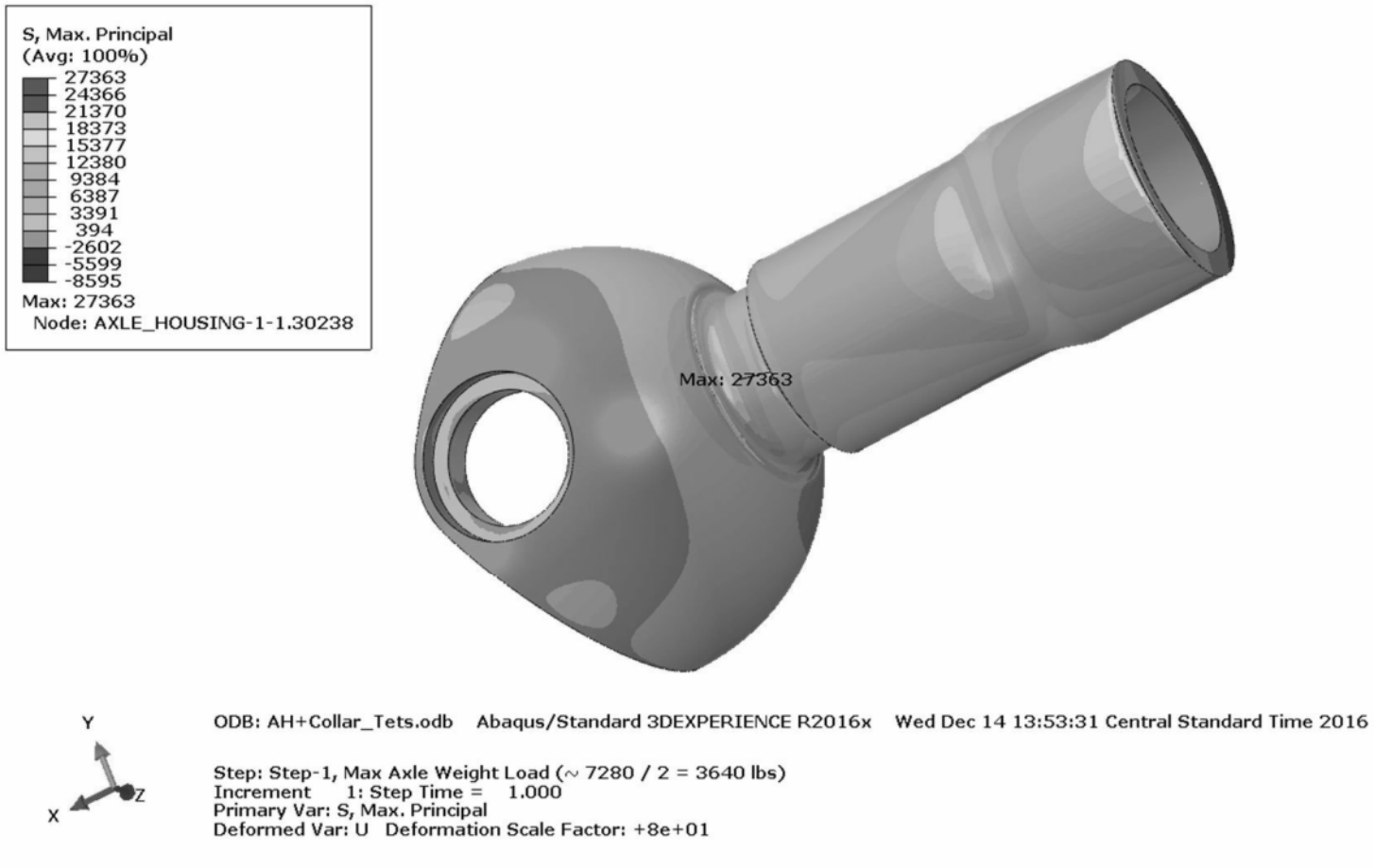


ESI No. 55440G

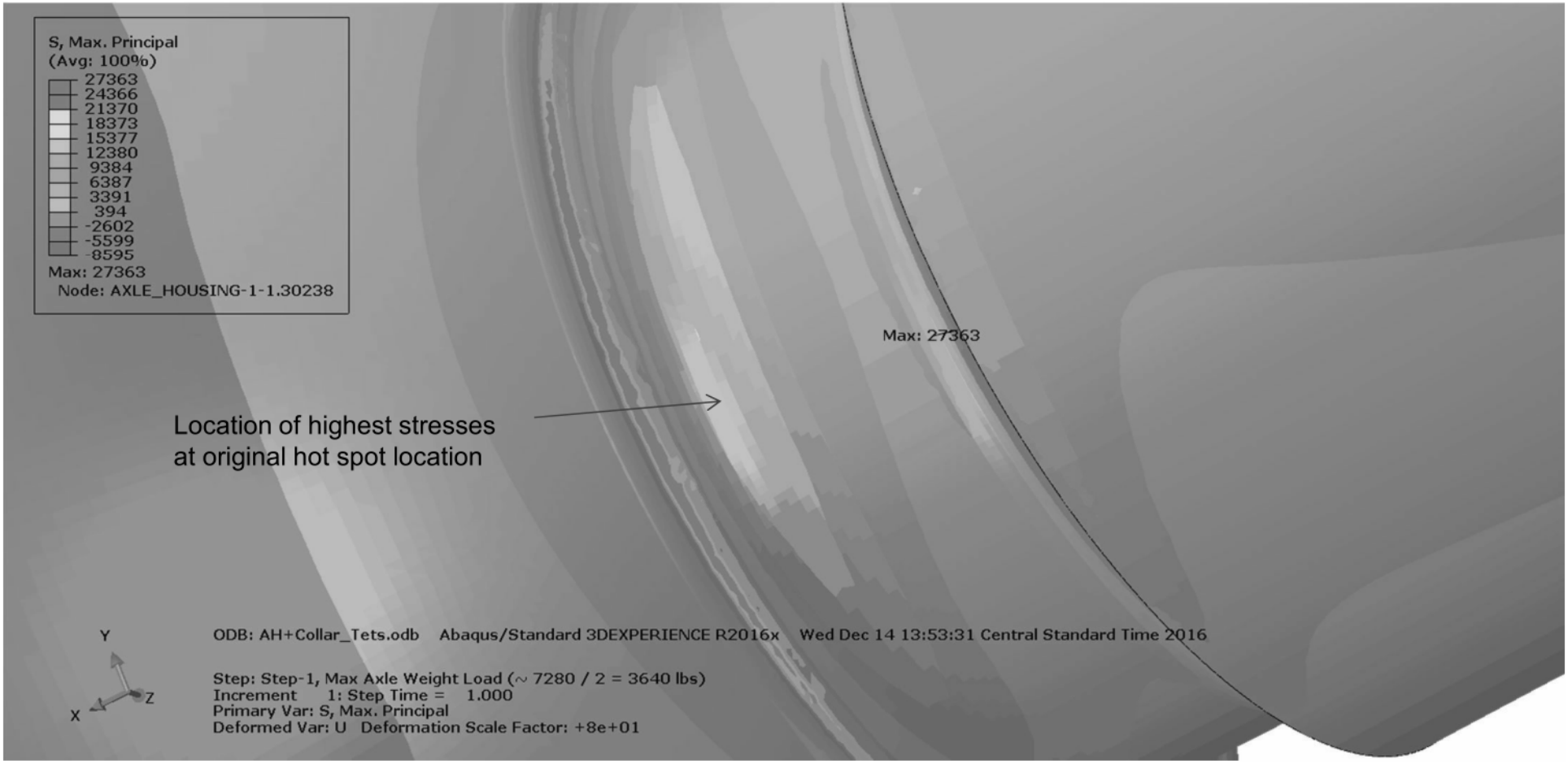
Axle Housing With Reinforcing Collar – Maximum Principal Stresses



Axle Housing With Reinforcing Collar – Maximum Principal Stresses (continued)



Axle Housing With Reinforcing Collar – Maximum Principal Stresses (continued)



Axle Housing With Reinforcing Collar – Maximum Principal Stresses
Interrogation of Highest Nodal Stresses at Location of Original Hot Spot

****

Probe Values Report, written on Wed Dec 14 15:33:50 2016

Source

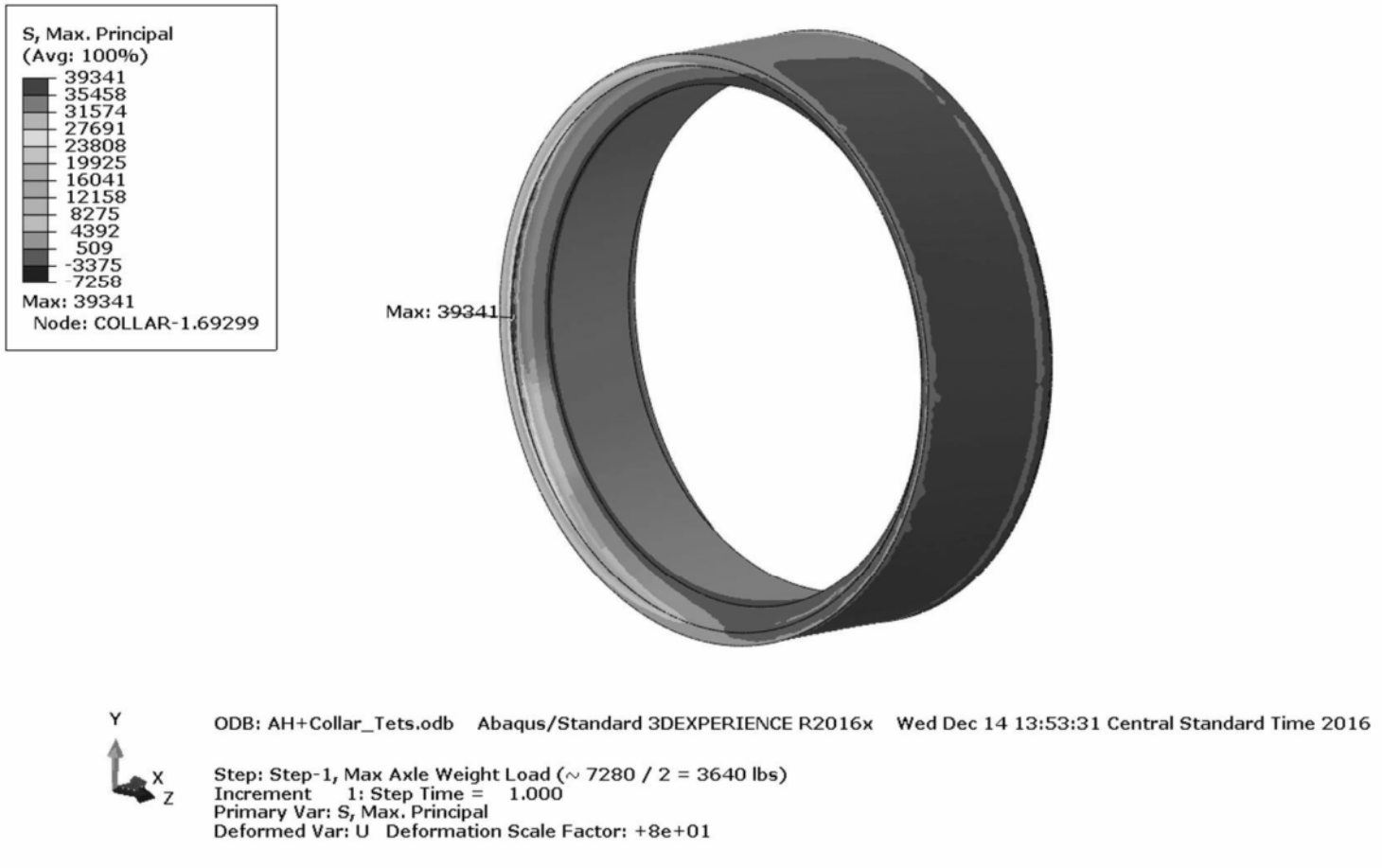
ODB: C:/Scratch/55440/AH+Collar_Tets.odb
Step: Step-1
Frame: Increment 1: Step Time = 1.000
Variable: S, Max. Principal (Avg: 100)

Probe values reported at nodes

Part Instance	Node ID	Orig. Coords			Def. Coords		
		X	Y	Z	X	Y	Z
AXLE_HOUSING-1-1	603051	8.51074	0.	-3.95284	8.51302	95.2471E-09	-3.94572
AXLE_HOUSING-1-1	806494	8.51073	-25.9349E-03	-3.95262	8.51301	-25.9368E-03	-3.9455

Part Instance	Node ID	Attached elements	S, Max. Principal
AXLE_HOUSING-1-1	603051	279396	15.422E+03
AXLE_HOUSING-1-1	603051	454403	15.422E+03
AXLE_HOUSING-1-1	806494	454403	15.4182E+03
AXLE_HOUSING-1-1	806494	461542	15.4182E+03
AXLE_HOUSING-1-1	806494	521514	15.4182E+03

Axle Housing With Reinforcing Collar – Maximum Principal Stresses (continued)

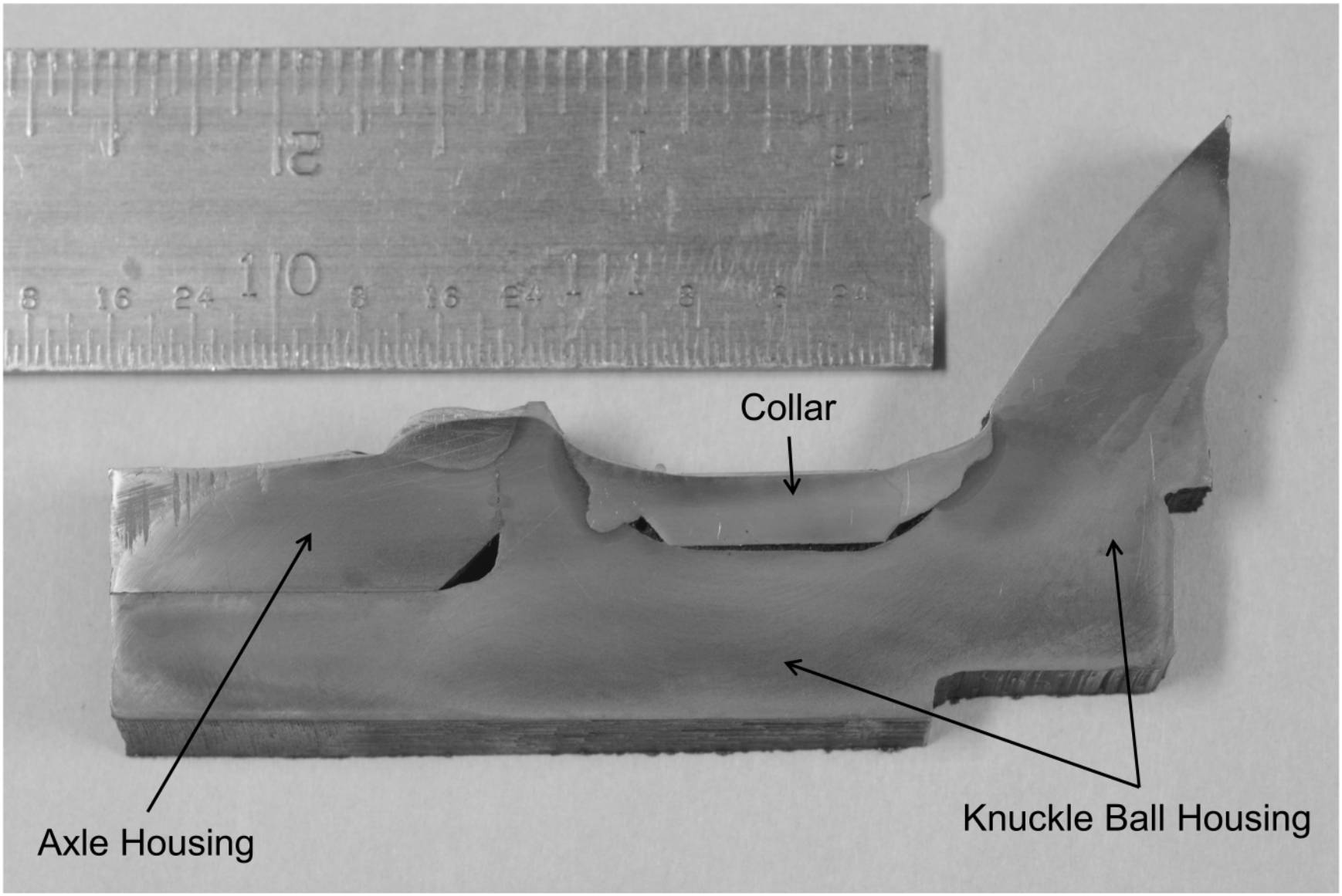


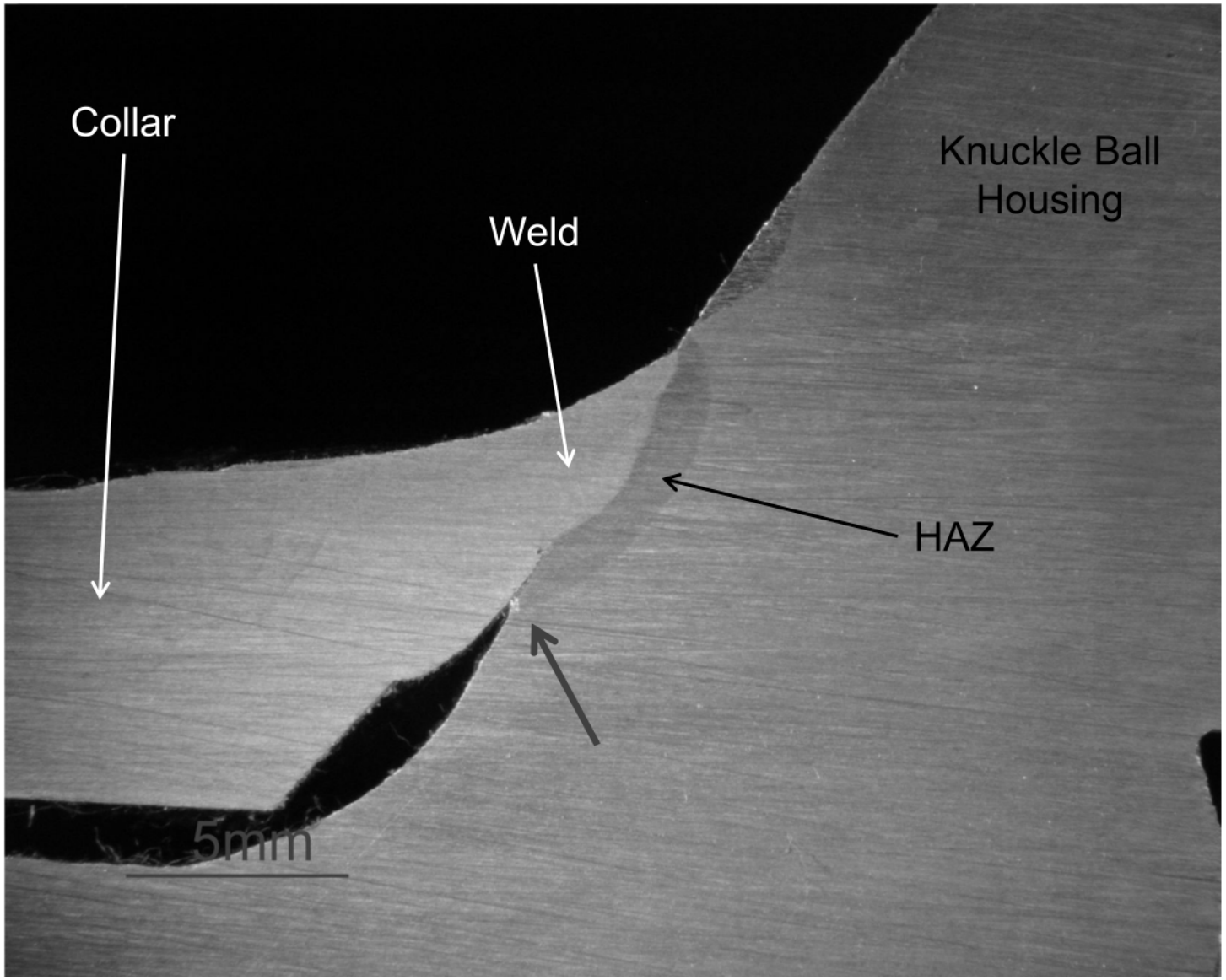
APPENDIX C

ESI

Metallurgical Evaluation – Axle Housing Assembly

ESI No. 55440G

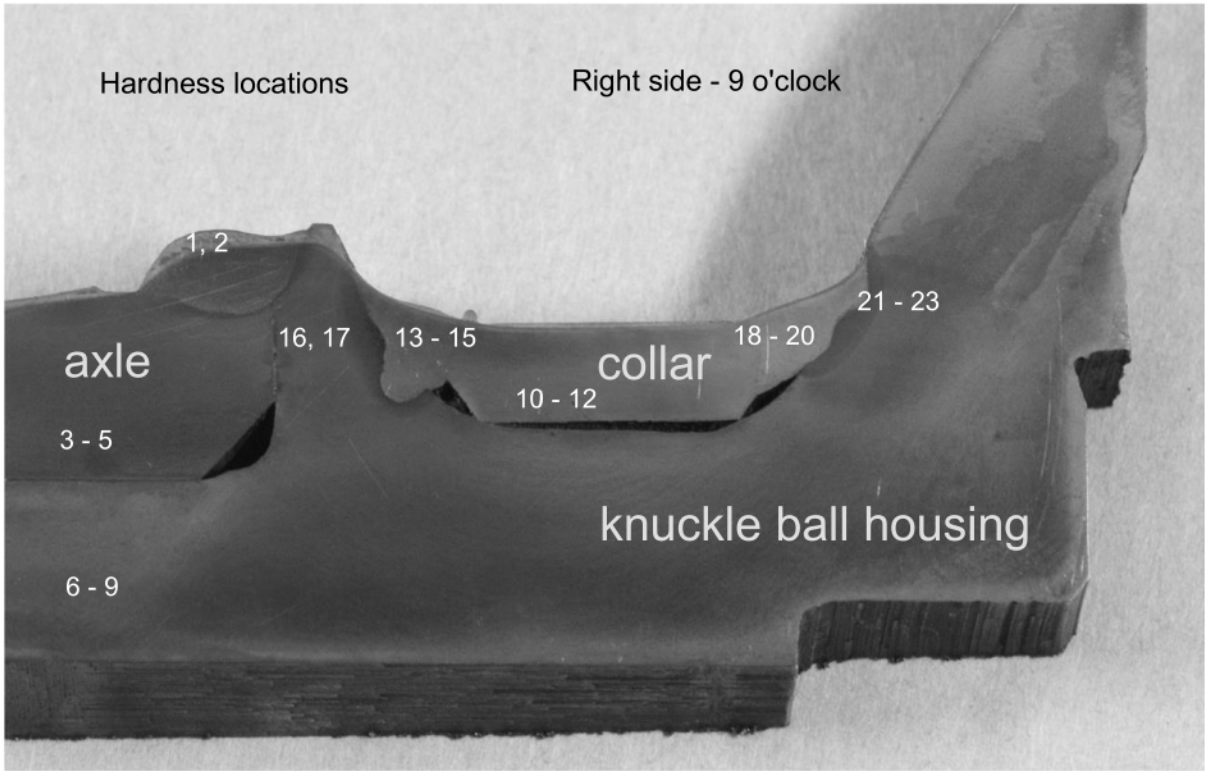




Collar weld with sharp transition at weld root (red arrow)

Metallurgical Evaluation – Axle Housing Assembly

ESI No. 55440G



Hardness test results

Location	Zone	Hard, HRB
1	weld	96
2	weld	91
3	axle housing	80
4	axle housing	78
5	axle housing	79
6	Knuckle ball housing	84
7	Knuckle ball housing	84
8	Knuckle ball housing	--
9	Knuckle ball housing	84
10	collar	59
11	collar	66
12	collar	60
13	weld	86
14	weld	87
15	weld	89
16	HAZ	25 HRC
17	HAZ	95
18	weld	85
19	weld	86
20	weld	81
21	HAZ	88
22	HAZ	94
23	HAZ	89

RTDI Stretch Duck Front Axle Weight Survey

APV: Stretch Duck 56

Full Load Condition - 25,390 LBS
Empty Condition - 19,840 LBS

Enclosed References:

1. Weight simulation chart
2. Weight location drawing
3. Scaled weight ticket (front/rear and overall weight) - (Full Load Condition)
4. Scaled weight ticket (front/rear and overall weight) - (Empty Condition)
5. Photos of testing

Survey Summary,

The APV utilized for this survey was Stretch Duck 56, the latest version Stretch Duck refurbished by RTDI, a sistered vessel/vehicle to RTDS Duck 6 / RTDI production # 47. To establish passenger weight seats were removed and 55 gallon drums were set in place of seats. Each barrel was filled with water to simulate passenger and seat weight. The driver seat, crew seat and the very rear seats were not removed. The drum for the driver and crew was located centered between seats and only filled to simulate personnel weight. The bottom portion of the rear sets were flipped upward and the drums located inline where seats would normally rest when flipped down. The barrel weight for the rear seats were filled to simulate passenger weight only.

To simulate a heavy scenario, the weight ratio for passenger/crew weight for this survey was increased to 185 lbs per person. When the required weight assumptions are utilized, the full load condition is under 26000 lbs or equal to 25,390 lbs.

Prior to weighing the APV, all fluids, including fuel tank were pressed full. All appliances that are normally onboard during tours were located as normal.

The scale utilized to conduct this survey was located at TRAC Materials in Branson MO. The TRAC scale is a certified scale which is generally used to weigh gravel trucks. This same scale is utilized regularly by RTDI for the purposes of verifying vessel weight for USCG stability testing. The Duck was also subject to a wheel pad scale, where each wheel was weighed individually. The results of the wheel pad scale matched the results of the TRAC scale.

After weighing the Duck in full load condition the water barrels were then removed, seats re-installed then re-weighed to establish empty weight. The variance in weight between full load and empty weight was 6640 LBS. A difference of 205 lbs that can not be accounted for.

Weight Simulation Chart

Water Barrel Quantity	Per Water Barrel Weight	Overall Water Barrel Weight	Simulation
15	399 LBS	5985 LBS	2 Passengers 1 seat (General Seating)
1	370 LBS	370 LBS	2 Crew (Driver / Narrator)
2	462.5 LBS	925 LBS	5 Passengers (Rear Seats)

Passengers	Crew	Total Persons Onboard	Total Weight
35	2	37	6845 lbs

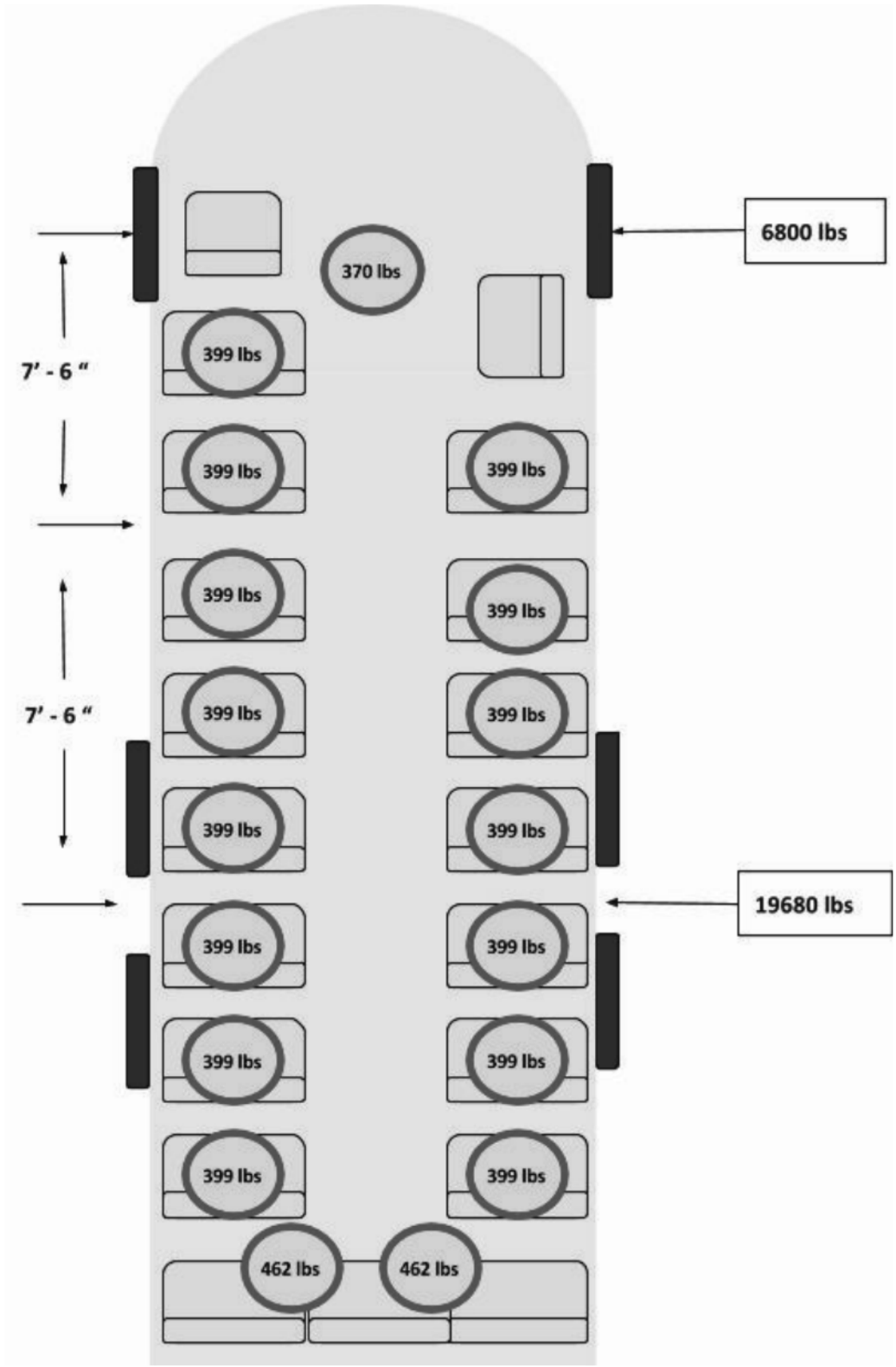
Quantity of Seats	Weight per seat	Seat weight total
15	29 LBS	435 LBS

Overall Seat Weight	Overall Passenger and Crew Weight	Combined Weight
435 LBS	6845	7280 LBS

TRAC Certified Scale (Full load condition)	
Overall Weight	26,480 LBS
Front Axle Weight	6,800 LBS
Rear Axle Weight	19,680 LBS

TRAC Certified Scale (Empty)	
Overall Weight	19,840 LBS
Front Axle Weight	7,340 LBS
Rear Axle Weight	12,660 LBS

Weight Location Drawing



READY MIX CONCRETE

ASPHALT PAVING

LIMESTONE PRODUCTS

WASHED RIVER GRAVEL

TRAC INC. MATERIALS

P.O. Box 1165
Branson, Missouri 65616

No. 545757

Phone: Branson 417-334-2127
Kimberling City 417-739-2684

SOLD TO	DIRECTIONS
RIDE THE DUCKS PO BOX 1837 BRANSON MO 65615	DUCK #56 Total Weight**26480 Ft Axle Weight--6800 Drive Axles Weight--19680

DATE	TIME	ZONE #	DRIVER	TRUCK #		TONS ORDERED	TONS DELIVERED		TICKET #
11/29/16	11:47			PU		0.00	1.00		545757

QUANTITY		DESCRIPTION		PRICE
1.00	EA	WEIGH FEE		

Fred Estes

NOTICE TO OWNER

FAILURE OF THIS CONTRACTOR TO PAY THOSE PERSONS SUPPLYING MATERIAL OR SERVICES TO COMPLETE THIS CONTRACT CAN RESULT IN THE FILING OF A MECHANIC'S LIEN ON THE PROPERTY WHICH IS THE SUBJECT OF THIS CONTRACT PURSUANT TO CHAPTER 429.RSMO. TO AVOID THIS RESULT YOU MAY ASK THIS CONTRACTOR FOR "LIEN WAIVERS" FROM ALL PERSONS SUPPLYING MATERIAL OR SERVICES FOR THE WORK DESCRIBED IN THIS CONTRACT. FAILURE TO SECURE LIEN

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ES18-002672 0071

READY MIX CONCRETE

ASPHALT PAVING

LIMESTONE PRODUCTS

WASHED RIVER GRAVEL

TRAC INC. MATERIALS

P.O. Box 1165
Branson, Missouri 65616

No. 545818

01

Phone: Branson 417-334-2127
Kimberling City 417-739-2684

SOLD TO
RIDE THE DUCKS
PO BOX 1837
BRANSON MO 65615

DIRECTIONS STREACHED DUCK #56

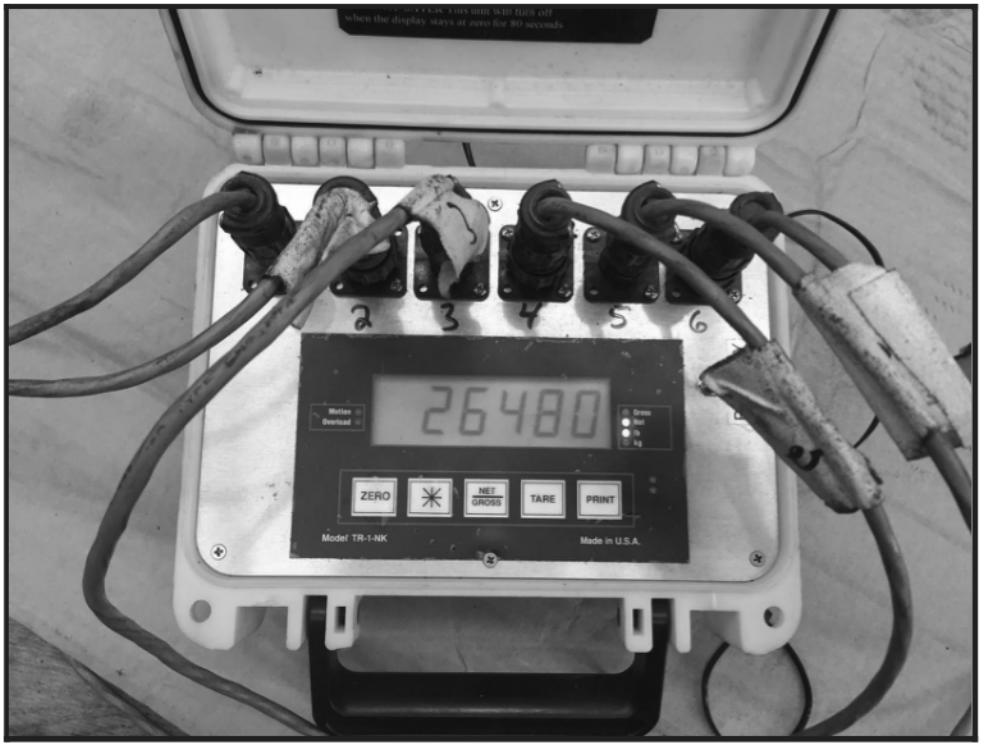
Total Weight**19840
Ft Axle Weight--7340
Drive Axles Weight--12660

DATE	TIME	ZONE #	DRIVER	TRUCK #		TONS ORDERED	TONS DELIVERED		TICKET #
11/30/16	9:07			PU		0.00	2.00		545818

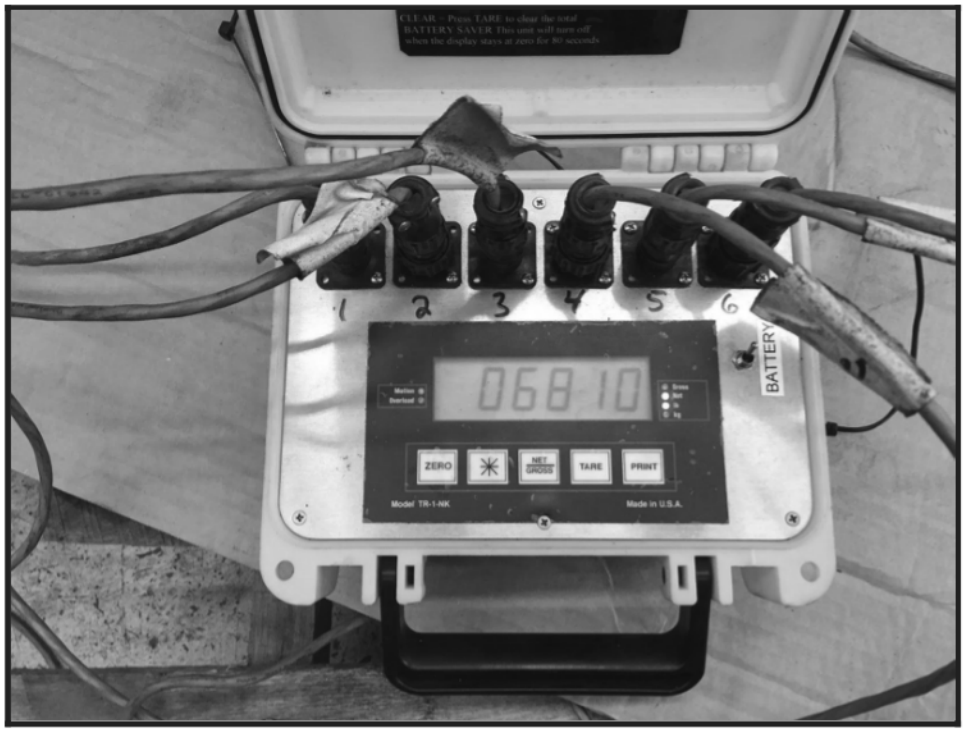
QUANTITY		DESCRIPTION		PRICE
1.00	EA	WEIGH FEE		

ES18-002672 0072

MERGENCY
SPIL KIT
SORBENT
WASTE
ONLY
#3



Wheel Pad Scale - All Wheels - GVRW



Wheel Pad Scale - Front Axle - GVRW

ES18-002672 0076

TM 9-801

T. O. 19–75AAA–4

WAR DEPARTMENT TECHNICAL MANUAL

TRUCK
2½-TON, 6x6
GMC CCKW-352 & 353

WAR DEPARTMENT APRIL 1944

ES18-002672 0077

TECHNICAL MANUAL

TRUCK, 2½-TON, 6 x 6 (GMC CCKW-352 AND 353) AND TRUCK, 2½-TON, 6 x 4 (GMC CCW-353)

CHANGES No. 1

DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *12 September 1950*

TM 9-801, 24 April 1944, is changed as follows:

The title is changed to read as follows: **TRUCK, 2½-TON, 6 x 6 (GMC CCKW-352 AND 353) AND TRUCK. 2½-TON, 6 x 4 (GMC CCW-353).**

1. Scope

a. These instructions are * * * equipment is assigned. They contain information on the operation and maintenance of the Truck, 2½-Ton, 6 x 6, GMC CCKW-352 and 353, **and Truck, 2½-Ton, 6 x 4, GMC CCW-353,** as well as descriptions of the major units and their functions in relation to the other components of this vehicle.

b. This manual has the following arrangement:

* * * * * * *

(3) Part Three, Maintenance * * * and second echelons).

(4) (Superseded.) Part Four, Shipment and Limited Storage and Destruction To Prevent Enemy Use, contains instructions for shipment and limited storage and for destruction of matériel to prevent enemy use.

(5) (Added.) The appendix contains a list of current references, including supply catalogs, technical manuals, and other available publications applicable to this matériel.

2. Forms, Records, and Reports

(Superseded.)

a. GENERAL. Forms, records, and reports are designed to serve necessary and useful purposes. Responsibility for the proper execution of these forms rests upon commanding officers of all units operating and maintaining vehicles. It is emphasized, however, that forms, records, and reports are merely aids. They are not a substitute

*These changes supersede TB 9-706-2, 4 June 1945; TB ORD 85, 5 May 1943; TB ORD 281, 5 April 1945; and those portions of the following technical bulletins and technical manuals pertaining to the equipment herein: TB ORD 54, 3 March 1944; TB ORD 59, 14 July 1943; TB ORD 127, 21 July 1944; TB ORD 185, 12 September 1944; TB ORD 205, 29 September 1944; TB ORD 262, 12 March 1945; TB ORD 376, 27 February 1950; TM 10-1423, 20 July 1942; TM 10-1449, 23 March 1942.

for thorough practical work, physical inspection, and active supervision.

b. AUTHORIZED FORMS. The forms, records, and reports generally applicable to units operating and maintaining these vehicles are listed below. No forms other than approved Department of the Army forms will be used. For a current and complete listing of all forms, see current SR 310–20–6.

Department of the Army Lubrication Orders, LO 9–801 and LO 9–U315.
Standard Form 91, Operator's Report of Motor Vehicle Accident.
Standard Form 91A, Transcript of Operator's Report of Vehicle Accident.
Standard Form 93, Report of Investigating Officer.
Standard Form 94, Statement of Witness.
DA Form 30b, Report of Claims Officer.
DD Form 6, Report of Damaged or Improper Shipment.
DD Form 110, Vehicle and Equipment Operational Record.
DA AGO Form 9–68, Spot Check Inspection Report for Wheeled and Half-Track Vehicles.
WD AGO Form 9–73, Data for Registration—Motor Vehicle.
DA AGO Form 9–74, Motor Vehicle Operator's Permit.
DA AGO Form 9–75, Daily Dispatching Record of Motor Vehicle.
DA AGO Form 348, Driver's Qualification Record.
WD AGO Form 460, Preventive Maintenance Roster.
WD AGO Form 461, Work Sheet for Wheeled and Half-Track Vehicles.
DA AGO Form 461–5, Limited Technical Inspection.
DA AGO Form 468, Unsatisfactory Equipment Report.
WD AGO Form 478, Modification Work Order and Major Unit Assembly Replacement Record and Organization Equipment File.
WD AGO Form 614, Accident-Identification Card.
WD AGO Form 811, Work Request and Job Order.
WD AGO Form 811–1, Work Request and Hand Receipt.

c. FIELD REPORT OF ACCIDENTS. The reports necessary to comply with the requirements of the Army safety program are prescribed in detail in the 385–10–40 series of Special Regulations. These reports are required whenever accidents involving injury to personnel or damage to matériel occur.

d. REPORT OF UNSATISFACTORY EQUIPMENT OR MATERIALS. Any suggestions for improvement in design, maintenance, safety, and efficiency of operation prompted by chronic failure or malfunction of the matériel, spare parts, or equipment or as to defects in the application or effect of prescribed petroleum fuels, lubricants, and/or preserving materials will be reported through technical channels as

prescribed in SR 700–45–5, to the Chief of Ordnance, Washington 25, D. C., ATTN: ORDFM, using DA AGO Form 468. Such suggestions are encouraged in order that other organizations may benefit.

3. Description

a. GENERAL. Vehicles described in this manual are designated as TRUCK, 2½-ton, 6 x 6, GMC CCKW–352 and 353, **and TRUCK, 2½-ton, 6 x 4, GMC CCW–353.** In addition to * * * other wheeled equipment.

b. GENERAL CHARACTERISTICS.

* * * * * * *

(2) *Axles, suspension, and steering.* Driving axles are full floating and may be either split or banjo type. Suspension of axles * * * of rear axles.

(*a*) (Added) *GMC CCKW–352 and 353.* The GMC CCKW–352 and 353 have three driving axles. The front axle incorporates special universal joints at the steering knuckles which permit steering of vehicle in conventional automotive manner.

(*b*) (Added) *GMC CCW–353.* The GMC CCW–353 has an "I beam" type of front axle without any provision for receiving or transmitting power (dead axle).

* * * * * * *

(4) *Power drive units.* Axles are driven * * * type drive shafts.

(*a*) (Added) On the GMC CCKW–352 and 353, a two speed transfer case permits drive by rear axles, or front and rear axles, depending upon position of the manual shift levers.

(*b*) (Added) On the GMC CCW–353, the low speed range is blocked out; hence, there are no manual shift levers.

* * * * * * *

Section III. PARTS, SPECIAL TOOLS, AND EQUIPMENT FOR ORGANIZATIONAL MAINTENANCE

6. General

(Superseded.)

Tools and equipment are issued to the using organization for maintaining the matériel. Tools and equipment should not be used for purposes other than prescribed and, when not in use, should be properly stored in the chest and/or roll provided for them. Spare parts are supplied to the using organization for replacement of those parts likely to become worn, broken, or otherwise unserviceable when

such operations are within the scope of organizational maintenance functions. Spare parts, tools, and equipment supplied for the 2½-ton 6 x 6 truck (GMC CCKW–352 and 353) and 2½-ton 6 x 4 truck (GMC CCW–353) are listed in Department of the Army Supply Catalog ORD 7 SNL G–508, which is the authority for requisitioning replacements.

7. Common Tools and Equipment

(Superseded.)

Standard and commonly used tools and equipment having general application to this matériel are listed in the ORD 7 catalog but are not specifically identified in this manual.

8. Special Tools and Equipment

(Superseded.)

Certain tools and equipment specially designed for organizational maintenance, repair, and general use with the matériel are listed in table I for information only. This list is not to be used for requisitioning replacements.

Table I. Special Tools and Equipment for Organizational Maintenance

Item	Identifying No.	References		Use
		Fig.	Par.	
ADAPTER, puller, steering wheel.	41–A–18–251	211	206	Remove steering wheel.
REMOVER, bearing cone (front), main shaft.	41–R–2368–200	----	----	
WRENCH, wheel bearing nut, dble-end tubular, pronged, OD 3 and 3⅜ in, No of prongs 6 each end, length 3½ in*	41–W–3748–100	----	199c	Used on vehicles with banjo type GMC axle.
WRENCH, wheel bearing nut, sgle-end tubular, hex, size of opng 3¼ in*	41–W–3825–100	----	199c	Used on vehicles with split type Timken axle.

*On vehicle tools

Figure 11—Pioneer tools, spare parts kit, and oil can spout—is rescinded.

Figure 12—Tools and spare parts—is rescinded.

Figure 13—Tank body compartments—is rescinded.

9. On Vehicle Spare Parts

Rescinded. See paragraph 6.

10. Special Tools

Rescinded. See paragraph 8 and table I.

13. Lever Controls

a. Hand-operated lever * * * located in cab (fig. 14).

* * * * * * *

(2) *Transfer case* (superseded).

(*a*) *GMC CCKW–352 and 353.* The transfer case shift lever is used to shift transfer case into high or low range to engage driving axles, and into neutral to disengage axles. Arrangement of this lever is such that low range cannot be used until front axle lever is placed into IN position. Shifting instructions are outlined in paragraph 16.

(*b*) *GMC CCW–353.* The transfer case has the low speed range blocked out, hence, there are no manual shift levers.

(3) *Front axle* (superseded).

(*a*) *GMC CCKW–352 and 353.* The front axle declutching lever is used to engage and disengage the front driving axle. The lever has only two shifting positions IN and OUT. The lever must be placed into IN position (axle engaged) before transfer case shift lever can be placed into low range position. Shifting instructions are outlined in paragraph 16.

(*b*) *GMC CCW–353.* The front axle is of the "I-beam" type and is not capable of transmitting power (dead axle). It does not have a declutching lever.

* * * * * * *

15. Miscellaneous Controls

* * * * * * *

g. (Added) Load Control Dial (Some Vehicles) (fig. 17.1). The load control dial of the trailer brake controller (par. 178.1) is numbered from one to four and is used to vary the severity of brake application on a trailer in accordance with the load carried on the trailer. Number one position on the dial is for a very light load and number four is for a maximum load.

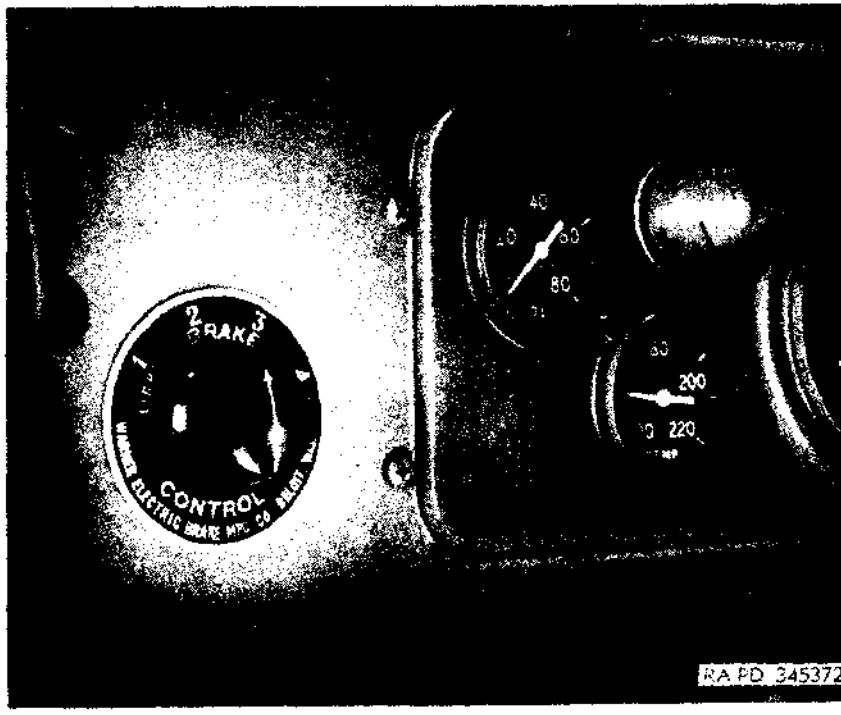


Figure 17.1 (added). *Load control dial.*

16. Transmission, Transfer Case, and Front Axle Shifting

a. GENERAL. **The CCW–353 model does not have a transfer shift lever and has a dead front axle. In all other respects it is similar to the CCKW–352 and 353 models.** The purpose and * * * the transfer case.

* * * * * * *

17. Engine Fuel, Oil, and Water

* * * * * * *

b. CRANKCASE OIL (fig. 21). Crankcase oil filler * * * for lubrication instructions. **If vehicle is to be left standing with oil or coolant drained, attach suitable tag in conspicuous place at driver's position to insure that engine will not be started.**

* * * * * * *

18. Operating the Engine

a. STARTING ENGINE. If vehicle has * * * outlined in paragraph 29. **Inspect vehicle to be sure no warning tags are present to indicate that water or oil has been drained or to warn against opera-**

tion of the vehicle. Perform before-operation services outlined in table II.

* * * * * * *

19. Driving the Vehicle

* * * * * * *

b. UNUSUAL CONDITIONS AND AUXILIARY EQUIPMENT. A thorough study * * * auxiliary equipment (pars. 24 through 28).

* * * * * * *

25. Cargo Dump Body Operation

* * * * * * *

b. HOIST OPERATION.

(1) *General.* Hoist should only * * * for dumping purposes.

Caution: Do not operate hoist pump when vehicle is in motion. **The pump may overheat and the components expand and seize, causing damage to the pump shaft, gears, or case.** Controls for the * * * lower the body.

* * * * * * *

29. Cold Weather Operation

a. GENERAL. The operation and * * * demand special precautions. **In all cases where the normal lubricants cannot be effectively removed while warm nor forced out with the lighter grades required for subzero operation, it is absolutely essential that the affected parts be disassembled, washed in volatile mineral spirits paint thinner or dry-cleaning solvent, and dried before lubricating with the prescribed Arctic grade lubricants.**

b. GASOLINE. **For tactical operations in temperatures consistently below 0° F., Arctic grade motor fuel, designed for tactical operations will be used. When these vehicles are to be used for administrative purposes only Arctic grade motor fuel designed for administrative use may be used.**

(1) *Storage.* Due to condensation * * * precautions are taken.

* * * * * * *

(*c*) Add 1 quart of denatured alcohol, grade **III,** to the fuel tank at start of **subzero weather,** and **one-half pint at each refilling** thereafter. This will reduce * * * in the fuel.

* * * * * * *

e. (Added) OVERNIGHT OR LONG STANDING. At temperatures below 0° F., batteries should be removed from vehicles which are in

the open and inactive for more than 1 or 2 hours, depending upon the temperature. These batteries should be kept in any available shelter in which the temperature is maintained above freezing. When a vehicle is to be used after standing in the open at temperatures below −20° F. for over 1 or 2 hours, its engine should be heated externally before operation. This may be performed with an auxiliary cold starting aid kit (slave kit) when available. Otherwise, cover the engine with a tarpaulin and place any available stoves or heaters under the tarpaulin until the engine has heated sufficiently for operation.

Caution: Extreme care should be exercised to avoid applying a direct flame to the oil pan due to fire hazard.

30. Cold Weather Lubrication

(Superseded.)

a. General. Lubricants will be as specified in lubrication order (figs. 46, 47, 47.1, and 47.2) as modified below.

b. Engine. Sub-zero engine oil (OES) will be used in place of the regularly prescribed lubricant when subzero operation is required. This oil is suitable for use at temperatures as low as −65° F. and therefore no dilution is required.

c. Transmission, Transfer Case, and Differentials. For operation at temperatures consistently below 0° F., drain gear cases while warm and refill with subzero universal gear lubricant (GOS).

d. Steering Gear. Drain, flush, and refill with subzero universal gear lubricant (GOS). Disassemble steering gear joints and, after cleaning thoroughly, lubricate with Ordnance Department lubricating grease No. 00 (OGOO).

e. Hydrovac Cylinders. Lubricate with petroleum base hydraulic oil (OHA) (AN–O–366).

f. Grease Points. All points for which any type of grease is normally prescribed will be lubricated with Ordnance Department lubricating grease No. 00 (OGOO).

g. Oil Can Points. Where engine oil normally is prescribed, use preservative lubricating oil (special) (PS) when subzero temperatures are encountered.

31. Protection of Cooling System and Preparation of Vehicle for Cold Weather Operation

a. Protection of Cooling System (superseded).

(1) *General.*

(*a*) Before adding antifreeze compound, it is necessary that the cooling system be clean and completely free from rust. If the cooling system has been cleaned recently, it may be necessary only to drain, refill with clean water, and again

drain. Otherwise, the system will be cleaned with cleaning compound. For use of reclaimed antifreeze solutions, refer to TM 9–850.

(*b*) Heaters, water-cooled compressors, and other units in the cooling system must be cleaned in addition to the radiator and engine water jacket.

(*c*) All hoses must be inspected and replaced if deteriorated. Hose clamps, plugs, and petcocks must be inspected and tightened if necessary. Radiator leaks must be repaired before adding antifreeze compound. Exhaust gas or air leakage into the cooling system must be corrected.

(2) *Extreme cold weather operation.* Where temperatures consistently below −20° F. are encountered, arctic winter antifreeze compound will be used. This compound is premixed and no water nor any other substance will be added to it at any time. Since this compound is inflammable, it must be kept away from open flames.

(3) *Moderate cold weather operation.*

(*a*) At temperatures between +32° and −20° F., the cooling system will be protected by ethylene glycol antifreeze compound, mixed with water in the following proportions for the temperature 10° F. below the lowest experienced during the winter season:

Atmospheric temperature °F.	*Quantity of ethylene glycol (qt)*	*Quantity of water (qt)*
+20	3¼	15¾
+10	4¾	14¼
0	6½	12½
−5	7	12
−10	7½	11½
−15	8	11
−20	8½	10½
−30	9¼	9¾
−40	10	9

(*b*) After adding this antifreeze compound, fill with water to slightly below the filler neck. Then start and warm the engine to normal operating temperature. Stop the engine and check the solution with a hydrometer, adding antifreeze compound if required. Thereafter, the coolant will be inspected weekly while in service for strength and color. A rusty solution should be drained and the cooling system thoroughly cleaned before the addition of new solution of required strength. Keep antifreeze solutions clean and avoid spilling on painted surfaces. The accuracy of the hydrometer is important and may be checked by mixing one part antifreeze compound to two

parts of water which should produce a reading indicating protection to 0° F.

* * * * * * *

c. ENGINES.

* * * * * * *

(4) *Air cleaners* (superseded). At subzero temperatures, remove air cleaner, disassemble, wash all parts in volatile mineral spirits paint thinner or dry-cleaning solvent, dry thoroughly, and reassemble. Refill to correct level with subzero engine oil (OES). Check reservoir daily and fill to correct level if necessary. Every 1,000 miles, disassemble, wash, dry, reassemble, and refill

* * * * * * *

e. CHASSIS.

* * * * * * *

(2) Inspect the vehicle * * * nuts jarring loose. Cables should operate satisfactorily at all temperatures providing they are coated with **Ordnance Department lubricating grease No. 00 (OGOO)** and there is no excess grease in the housing.

Section VIII. LUBRICATION AND PAINTING

(Superseded.)

36. Lubrication Order

Lubrication Orders LO 9–801 and LO 9–U315 (figs. 46, 47, 47.1, and 47.2) prescribe cleaning and lubricating procedures as to locations, intervals, and proper materials for the vehicles. An order is issued with the vehicle and is to be carried with it at all times. In the event the vehicle is received without a copy, the using organization will immediately requisition one. (See SR 310–20–4 for LO of current date.) Lubrication which is to be performed by ordnance maintenance personnel is listed on the lubrication order in the NOTES.

37. General Lubrication Instructions

a. USUAL CONDITIONS. Service intervals specified on the lubrication order are for normal operation where moderate temperature, humidity, and atmospheric conditions prevail.

b. LUBRICATION EQUIPMENT. Each vehicle is supplied with lubrication equipment adequate for its maintenance. This equipment will be cleaned both before and after use. Lubricating guns will be operated carefully, and in such a manner as to insure a proper distribution of the lubricant.

c. Points of Application.

(1) Lubricating fittings, grease cups, oilers, and oil holes are shown in figures *48* through *56* and are referenced to the lubrication order. Wipe these devices and the surrounding surfaces clean, before lubricant is applied.

(2) A ¾-inch red circle should be painted around all lubricating fittings and oil holes.

d. Reports and Records.

(1) Report unsatisfactory performance or defects in the application or effect of prescribed petroleum fuels, lubricants, and preserving materials in accordance with paragraph 2.

(2) Maintain a record of lubrication of the vehicle on WD AGO Form 460.

37.1 Lubrication Under Unusual Conditions

a. Unusual Conditions. Reduce service intervals specified on the lubrication order to compensate for abnormal operation and extreme conditions, such as high or low temperatures, prolonged periods of high speed operation, continued operation in sand or dust, immersion in water, or exposure to moisture, any one of which may quickly destroy the protective qualities of the lubricant. Intervals may be extended during inactive periods.

b. Changing Grade of Lubricants. Lubricants are prescribed in the "Key" in accordance with four temperature ranges—above 32° F., from 32° to 0° F., from 0° down to —40° F., and below —40° F. When to change grade of lubricants is determined by maintaining a close check on operation of the vehicle during the approach to change-over periods in accordance with weather forecast data. Sluggish starting is an indication of lubricants thickening, and is the signal to change to grade prescribed for the next lower temperature range. Ordinarily, it will be necessary to change grade of lubricants only when air temperatures are consistently in the next higher or lower range.

37.2 Painting

Instructions for the preparation of the matériel for painting, methods of painting, and materials to be used are contained in TM 9–2851.

LUBRICATION ORDER LO 9-801

4 October 1948 (Supersedes WDLO 9-801, 5 FEBRUARY 1945)

TRUCK, 2½-TON, 6x6
(GMC MODELS CCKW-352 AND CCKW-353)

References: ORD 7 SNL G-508; TM 9-801

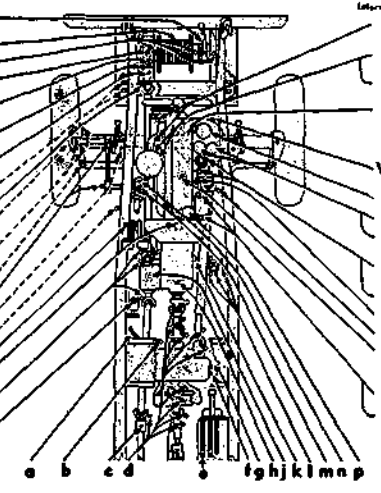
Intervals are based on normal operation. Reduce to components for abnormal operation or severe conditions. During inactive periods intervals may be extended correspondingly with adequate preservation.

Lubricate after washing and fording.

Clean fittings before lubricating.

Clean parts with SOLVENT, dry cleaning. Dry before lubricating.

Lubricate dotted arrow points on both sides.



		Lubricant	Interval
AM, Fig 56	Winch Jaw Clutch — Clean and oil sparingly	OE	W
AL, Fig 56	Winch Cable (See Note 15)	OE	
AJ, AK, Fig 56	Winch Drum and Shaft Brgs.	CG	1
AH, Fig 56	*Winch Worm Housing Drain* (See Note 4) Cap. 1½ qt. Drain and refill		6
AF, Fig 56	Winch Worm Housing Fill — Fill to plug level	GO	
AG, Fig 56	*Winch Worm Housing Level* — Check level		W
AN, Fig 56	Winch Propeller Shaft Shear Pin (See Note 14)	OE	1
AD, Fig 55	Spring Shackle	CG	1
MM, Fig 53	Universal Joint	CG	1
AB, AC, Fig 55	Front Wheel Bearings — Remove, clean and repack	WB	6
CC, DD, EE, Fig 52	Universal Joint and Steering Knuckle Bearings (See Note 13)	CG	1
GG, Fig 52	Tie Rod	CG	1
WW, Fig 54	Drag Link	CG	1
HH, Fig 52	Shock Absorber	LO	6
AE, Fig 55	Spring Bolt	CG	1
UU, Fig 54	Pedal Shaft (Some models)	CG	1
BB, Fig 51	Clutch Pilot Bearing (See Note 7)	SR	
MM, NN, Fig 53	Universal and Slip Joints (See Note 12)	CG	1
FF, Fig 52	Brake Master Cylinder — Fill to ½ in. from top	HB	1

FOLD

Serviced from Under Hood

Interval	Lubricant		
1	OE	Generator 6 to 8 drops (Some models, oiler at rear only)	J, Fig 48
	OE	Carburetor Air Cleaner — Check level (See Note 1)	K, L, Fig 49
6	OE	Governor Air Cleaner — Clean screen and felt, oil felt	
6		*Front Axle Differential Drain* (Underneath truck) Cap. 6½ qt. banjo type; 3 qt. split type Drain and refill (See Note 4)	V, X, Fig 50
W	GO	Front Axle Diff. Fill and Level (Underneath truck) Check level	U, W, Fig 50
1		*Oil Filter* Drain sediment (See Note 6)	D, Fig 48
	OE	Crankcase Fill	A, Fig 48
	OE	Crankcase Ventilator Air Cleaner — Check level (See Note 1)	M, Fig 48 M, Fig 49
1	WB	Distributor Shaft — Turn cup down 1 full turn, refill as required	E, Fig 48
6		Distributor (See Note 6)	F Fig 48
D		*Crankcase Level* Check level	B, Fig 48
1	CG	Universal Joint (Underneath truck)	LL, Fig 53
2		*Crankcase Drain* Drain and refill — Cap. including filter 9 qt. 2-pc. oil pan; 11½ qt. 1-pc. oil pan (See Notes 2 & 3)	C, Fig 48
1	OE	Starter 6 to 8 drops	G, Fig 48
	OE	Starter Outboard Bearing — Lubricate when starter is removed	H, Fig 48

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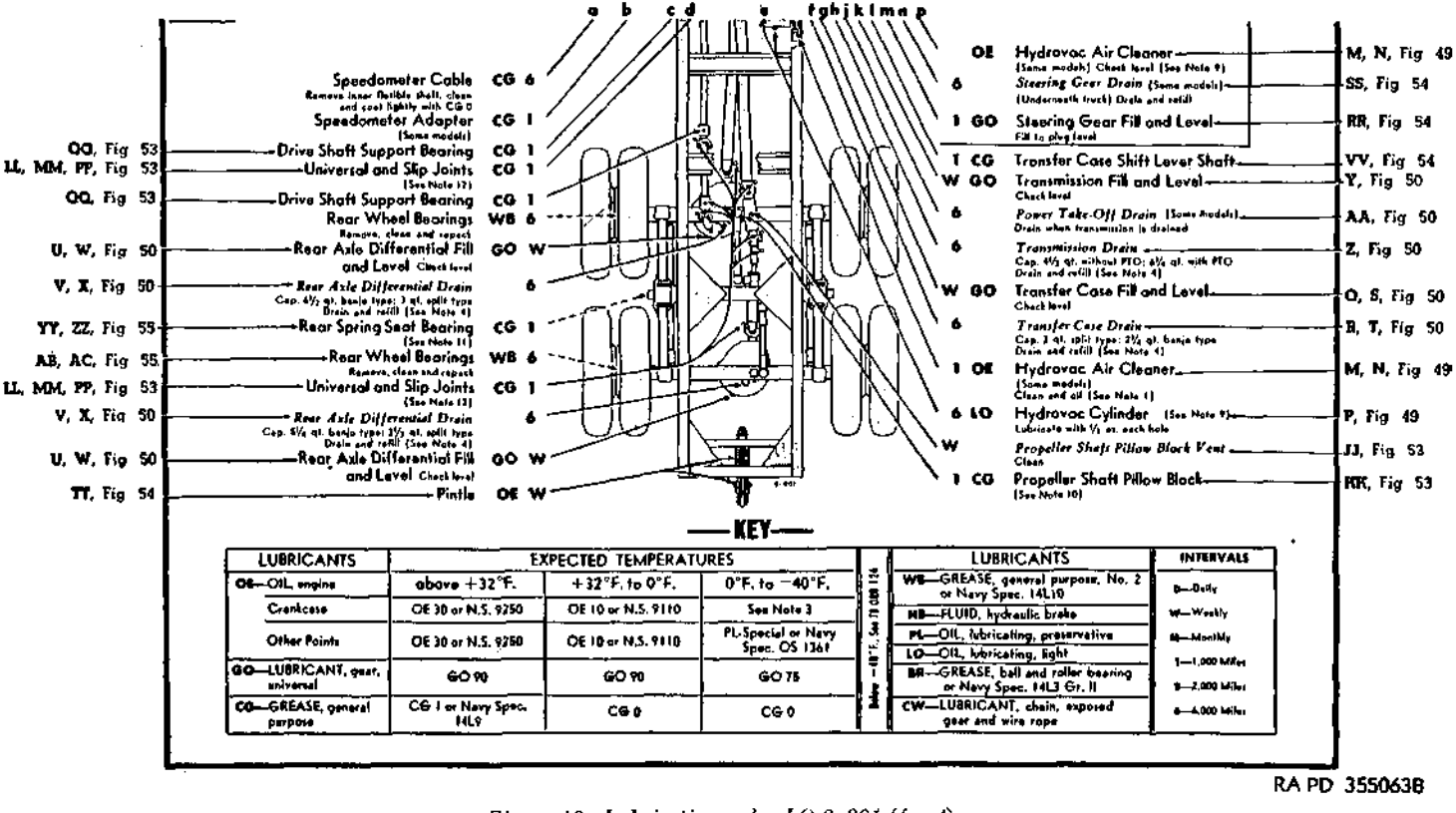


RA PD 355063B

Figure 46. Lubrication order LO 9–801 (front).

CAUTION
Always place a prop or block under body before performing any service work.

NOTES

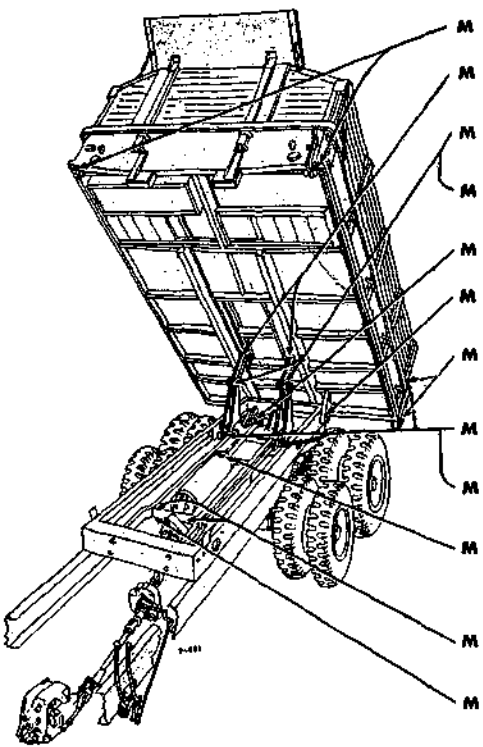
1. AIR CLEANERS AND BREATHERS—(Oil Bath Type) After every 8 hours of operation replenish to bead level with OE. (For temperatures above 0°F., use crankcase grade; from 0°F. to —40°F., use 4 parts of OE 10 with 1 part diluent. Diesel fuel, if available, is preferred as diluent but gasoline may be used.) Every 1,000 miles, disassemble, wash all parts and refill with OE as above. For desert or similar sandy soil operation, disassemble, wash all parts, and refill with OE as above every 4 hours or more frequently if required. (Mesh Type) For normal operation, wash and recoil at indicated intervals with OE as above. For desert or similar sandy soil operation, disassemble, wash all parts, and recoil every 100 miles.

2. CRANKCASE—Drain only when engine is hot. To aid in complete draining, the front end of the truck should be slightly higher than the rear. Refill to FULL mark. Run engine a few minutes, recheck level.

3. ENGINE OIL BELOW 0°F.—If equipment such as winterization kit, slave kit or heated storage is available, use OE 10 undiluted. If dilution is required, gasoline or Diesel fuel may be used but gasoline, if available, must be used. Therefore, fill oil reservoir with OE 10 to normal FULL mark on dipstick. Add diluent to oil reservoir in ratio of 1½ qt. to each 5 qt. of reservoir capacity—approximately 2¾ qt. of diluent (2-pc. pan); 3½ qt. (3-pc. pan). Run engine 5 to 10 minutes to mix lubricant and diluent thoroughly. Stop engine and note level of the diluted lubricant above the normal FULL mark on the gage or dipstick for future reference. Under operation check oil level frequently. During operation add OE 10 if level drops below normal FULL mark. Upon shutdown of engine add OE 10 to normal FULL mark and diluent to diluent FULL mark if anticipated shutdown time will be sufficient to cool engine.

FOLD

DUMP BODIES



Internal • Lubricant

- M OE — Control Rod Linkage Joints
- M CG — Link Pins (Some Heil Models)
- M CG — Link Pins (Some Heil Models)
- M CG — Trunnion Shaft Bearings (Gar Wood Models)
- M CG — Hoist Wrist Pin
- M CG — Body Hinge Pin (Also lubricate points on opposite side)
- M OE — Body Side and End Gate Cross Shafts and Rods (Also lubricate point on opposite side)
- M CG — Lifting Lever (Heil Models)
- M CG — Hoist Arm Links (Gar Wood Models)
- M OE — Hydraulic Cylinder Fill and Level Cap. 14 qt. Heil, 12 qt. Gar Wood. Use OH below 0°F. (See Note 8)
- M CG — Hoist Trunnion Pin (Some Heil Models)
- M CG — Cylinder Hinge (Gar Wood Models)

FOLD

4. GEAR CASES—Drain only after operation. Fill to plug levels before operation and after draining. Fill front and rear banjo type axle differentials to level of lower plug hole. (*Transfer Case Declutching Units, Split Type Axle:*) If disassembled, refill on reassembly through fill plug hole with GO.

5. DISTRIBUTOR—Every 6,000 miles, wipe breaker arm lightly with CG and lubricate breaker arm pivot and wick under rotor with 1 or 2 drops of OE.

6. OIL FILTER—Every 6,000 miles, while crankcase is being drained, remove element, clean inside of case and install new element.

7. CLUTCH PILOT BEARING—*Whenever clutch or engine is removed*, clean and repack clutch pilot bearing with BR. After cleaning parts, fill cavity in crankshaft behind clutch pilot bearing. Also fill clutch release bearing inside recess and coat fork groove; coat shaft spline, release fork socket end stud. CAUTION: Do not wash clutch release bearing.

8. HYDRAULIC CYLINDER—(Hoist) To fill hydraulic cylinder, raise body to only 1/2 its maximum height. While in this position remove filler and vent plug and fill with OE to overflowing. When the cylinder is full, raise the body to maximum elevation, then add approximately 1/2 pt. of OE. Do not replace vent plug. Raise and lower body slowly several times to expel excess oil through the vent plug. Replace vent plug with body at maximum height. Semiannually, drain through plug under pump and refill. (Gar Wood) To fill hydraulic cylinder, raise body to maximum height. Remove filler plug and fill with OE to overflowing. Install plug. Slowly raise and lower body several times. Recheck oil level and fill to plug hole. Replace plug. Semiannually, drain by removing plate under pump and refill.

9. HYDROVAC CYLINDER—Some models are equipped with brake vacuum cylinder located on left side of frame to rear of transfer case. Every 6,000 miles, remove plug in rear of cylinder and lubricate with about 1 oz. of LO. Replace plug. Every 1,000 miles, also lubricate vacuum cylinder, lever bearing located on frame ahead of cylinder, through fitting, with CG.

10. PROPELLER SHAFT PILLOW BLOCK—Remove level plug on side of housing and install fitting. Apply CG through fitting until lubricant appears at vent on top of housing. Do not replace level plug.

11. REAR SPRING SEAT BEARINGS—Lubricate through fitting until grease shows at inner seals.

12. UNIVERSAL AND SLIP JOINTS (Winch and Hoist)—Vents are not provided. Apply lubricant until it appears at journal and splines. Lubricate hoist support bearings until lubricant appears between bearing and shaft.

13. UNIVERSAL JOINTS AND STEERING KNUCKLE BEARINGS—Lubricate with vehicle on level ground. If split type axle is equipped with plug in hub driving flange, remove and insert fitting. Remove plug at steering knuckle housing. Lubricate first through fitting in upper steering knuckle bearing, and then through fitting inserted in hub, driving flange until lubricant is visible at plug hole. Replace plugs. To lubricate split type axles without plug in hub driving flange, remove plug in steering knuckle housing and lubricate through fitting on upper steering knuckle until lubricant is visible at plug opening. On banjo type axles, where two plugs are provided, one on top of joint, the other at front of steering knuckle support, remove plug in steering knuckle support and lubricate through fitting underneath joint until lubricant is visible at plug opening. Every 6,000 miles, remove universal joints, wash and repack with CG.

14. WINCH PROPELLER SHAFT SHEAR PIN—Every 6,000 miles, disconnect front universal joint, remove shear pin and universal joint from shaft, clean, dry and coat end of shaft and inside of universal joint collar with CG to prevent rusting.

15. WINCH CABLE—After each use, clean and oil with OE. Semiannually, if cable is not generally used, unwind entire cable and soak, by means of a brush, with PL-Special. Wipe off excess and coat cable with CW. Coat winch drum also with CW before rewinding cable on drum.

16. OIL CAN POINTS—Every 1,000 miles, lubricate Hand Brake Linkage, Brake Pedal Pull Rod Clevis Pins, Clutch Pedal Linkage; Transfer Case Control Lever Bushings and Clutch and Brake Pedal Shaft if not equipped with fittings, with OE. (Water Tank) Every 1,000 miles, lubricate Control Linkage on Emergency Valve and Clevises, etc. with OE. (Gas Tank) Every 1,000 miles, lubricate Selector Operating Valve Handles and Linkage, Manhole Cover Hinges, etc., with OE.

17. DO NOT LUBRICATE—Fan, Water Pump, Clutch Release Bearing, Generator (some models), Springs.

18. DISASSEMBLED FOR LUBRICATION BY ORDNANCE PERSONNEL—Steering Column Upper Bearing (Annually—BR), Steering Column Horn Contacts (Annually—PL).

Copy of this Lubrication Order will remain with the equipment at all times; instructions contained herein are mandatory and supersede all conflicting lubrication instructions dated prior to the date of this Lubrication Order.

BY ORDER OF THE SECRETARY OF THE ARMY:
OMAR N. BRADLEY,
Chief of Staff.

OFFICIAL:
EDWARD F. WITSELL,
Major General,
The Adjutant General.

LO 9-801

DISTRIBUTION: *Army Tech Sv* (2); *Arm & Sv Bd* (1); *AFF* (2); *OS Maj Comd* (10); *Base Comd* (2); *MDW* (5); *A* (Zi) (18), (Overseas) (3), *CHQ* (2), *D* (2); *B* 3 (1); R 2, 5, 7, 9 (1); *Bn* 2, 3, 5, 6, 8–11, 17, 19, 44, 55 (1); *C* 3, 5–11, 44, 55 (1); *FC* (1); *Class II* (with 9 (3); *USMA* (2); *Sch* (5), *Gen Dep* (2); *Tng Ce* (2); *PE* (Ord O) (5); One (1) copy to each of the following T/O & E's: 2-13; 2-28; 4-37; 4-155; 4-157; 7-25; 7-95; 8-571; 17-17; 17-27; 17-29; 17-117; 17-127; 19-7; 19-37; 19-47; 19-57; 19-87; 19-217; 19-237; SPECIAL DISTRIBUTION. Air Force USAF (5); USAF Maj Comd (2); USAF Sub Comd (3); BU (1); T/O & E 1-407 (1); 1-687 (1); 1-769 (1). For explanation of distribution formula see TM 38-405.

RA PD 355064

Figure 47. Lubrication order LO 9–801 (rear).

LUBRICATION ORDER

LO 9-U315

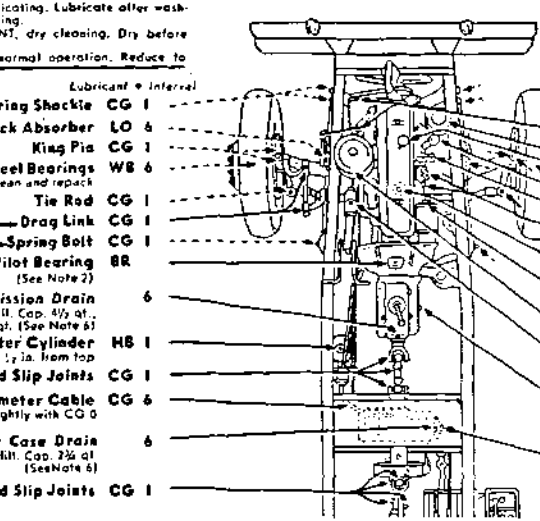
11 June 1948 (Supersedes WDLO 9-U315, 5 March 1945)

TRUCK, 2½ TON, 6x4

(GMC MODEL CCW-353)

Reference: ORD 7 SNL G-508

Clean fittings before lubricating. Lubricate after washing and deep water fording.
Clean parts with SOLVENT, dry cleaning. Dry before lubricating.
Intervals are based on normal operation. Reduce to compensate for abnormal operation or severe conditions. During inactive periods, intervals may be extended commensurate with adequate preservation.
Lubricate dotted arrow points on both sides. Opposite points are shown by short arrows.



		Lubricant	Interval
AD, Fig 55	Spring Shackle	CG	1
HH, Fig 52	Shock Absorber	LO	6
	King Pin	CG	1
AB, AC, Fig 55	Front Wheel Bearings Remove, clean and repack	WB	6
	Tie Rod	CG	1
WW, Fig 54	Drag Link	CG	1
AE, Fig 55	Spring Bolt	CG	1
BB, Fig 51	Clutch Pilot Bearing (See Note 2)	BR	
Z, Fig 50	Transmission Drain Drain and refill. Cap. 4½ qt., Some models 8½ qt. (See Note 6)		6
FF, Fig 52	Brake Master Cylinder Fill to ½ in. from top	HB	1
	Universal and Slip Joints	CG	1
	Speedometer Cable Remove core and coat lightly with CG 0	CG	6
R, T, Fig 50	Transfer Case Drain Drain and refill. Cap. 2¾ qt (SeeNote 6)		6
MM,NN, Fig 53	Universal and Slip Joints	CG	1

Serviced From Under Hood

Interval	Lubricant			
1	OE	Generator 6 to 8 drops (Some models)		J, Fig 48
1		Oil Filter Drain sediment (See Note 7)		D,Fig 48
1	OE	Engine Breather Clean and oil (Some models)(See Note 1)		
	OE	Crankcase Fill		A, Fig 48
D		Crankcase Level Check level		B, Fig 48
6		Distributor (See Note 5)		F, Fig 48
1	WB	Distributor Shaft Turn down cup 1 full turn, refill as required		E, Fig 48
2		Crankcase Drain Drain and refill. Cap. 9 qt., 3-pc. oil pan 11½ qt. 1 pc. oil pan (See Notes 3 & 4)		C, Fig 48
1	OE	Starter 6 to 8 drops When starter is removed lubricate outboard bearing		G, Fig 48
D	OE	Carburetor Air Cleaner Check level (See Note 1)		K, L, Fig 49
1	GO	Steering Gear Fill to plug level		RR, Fig 54
W	GO	Transmission Fill and Level Check level		Y, Fig 50
W	GO	Transfer Case Fill and Level Check level		Q,S, Fig 50

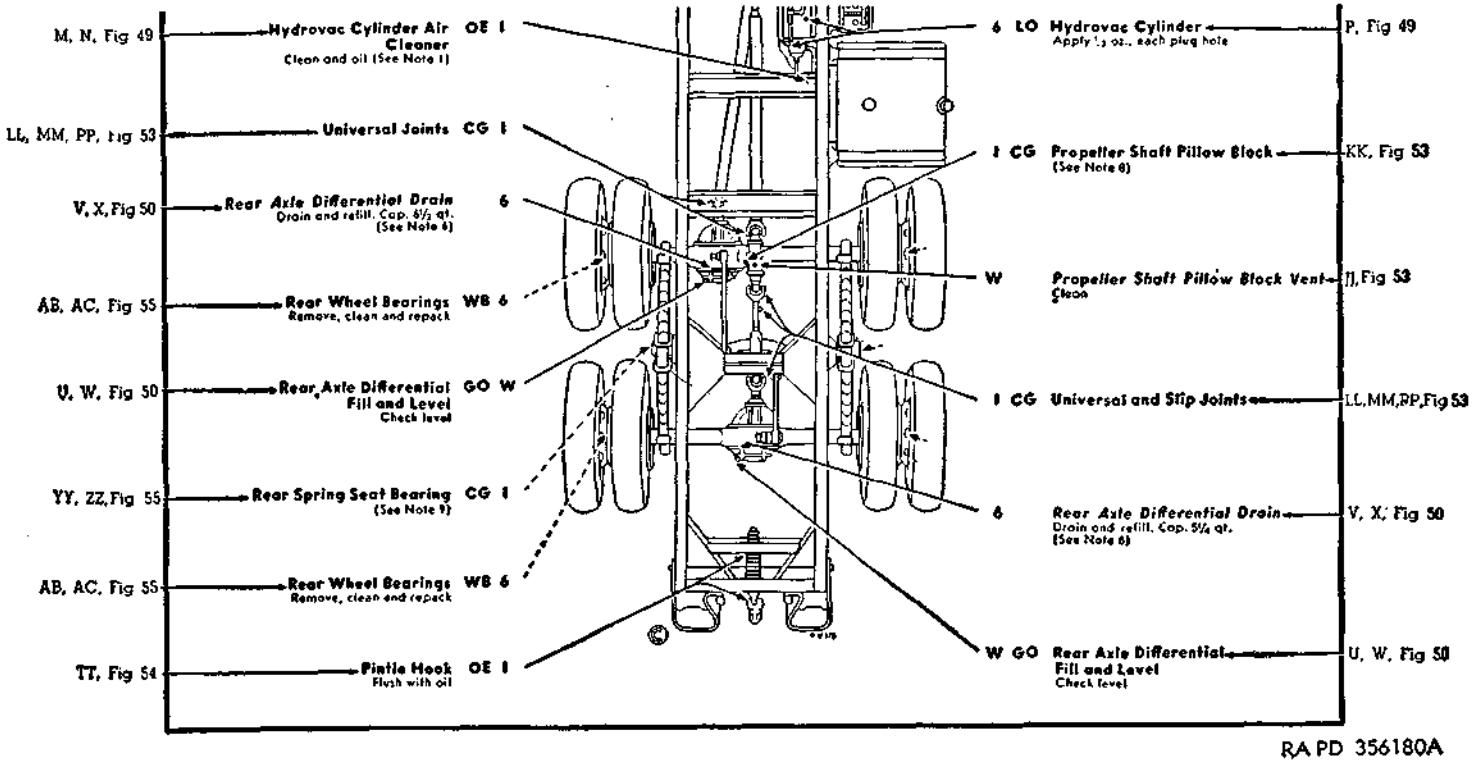


Figure 47.1 Lubrication order LO 9–U315 (front).

KEY

LUBRICANTS	EXPECTED TEMPERATURES			
OE—OIL, engine	above +32°F.	+32°F. to 0°F.	0°F. to −40°F.	Below −40°F. See TB ORD 126
Crankcase	OE 30 or N.S. 9250	OE 10 or N.S. 9110	See Note 4	
Other Points	OE 30 or N.S. 9250	OE 10 or N.S. 9110	PL—Special	
GO—LUBRICANT, gear, universal	Grade 90	Grade 90	Grade 75	
CG—GREASE, general purpose	CG 1 or N.S. 14L9	CG 0	CG 0	
WB—GREASE, general purpose, No. 2 or N.S. 14L10			INTERVALS	
HB—FLUID, hydraulic brake			D—Daily W—Weekly 1—1,000 Miles 2—2,000 Miles 6—6,000 Miles	
LO—OIL, lubricating, light				
BR—GREASE, ball & roller bearing				
PL—OIL, lubricating, preservative				

FOLD

FOLD

NOTES

1. AIR CLEANERS AND BREATHERS—(Oil Bath Type) After every 8 hours of operation replenish to bead level with OE. (For temperatures above 0°F. use crankcase grade; from 0°F., to −40°F., use 4 parts OE 10 with 1 part diluent. Diesel fuel, if available, is preferred as diluent but gasoline may be used.) Every 1,000 miles, disassemble, wash all parts and refill with OE as above. For desert or similar sandy soil operation, disassemble, wash all parts, and refill with OE as above every 4 hours or more frequently if required. (Mesh Type) For normal operation, wash and recoil at indicated intervals with OE as above. For desert or similar sandy soil operation disassemble, wash all parts and recoil every 100 miles.
2. CLUTCH PILOT BEARING—Remove, clean and lubricate every 6,000 miles and whenever clutch or engine is removed, clean and repack pilot bearing and fill cavity in flywheel behind bearing with WB. Also pack ball seat in release fork and coat groove in release bearing for release fork and clutch splines with BR. CAUTION: Do not wash clutch release bearing.
3. CRANKCASE—Drain only after operation. Clean screen attached to drain plug on some models. After refilling, run engine a few minutes, recheck level.
4. ENGINE OIL BELOW 0°F.—If equipment such as winterization kit, slave kit or heated storage is available, use OE 10 undiluted. If dilution is required, gasoline or Diesel fuel may be used but gasoline, if available must be used. Therefore, fill oil reservoir with OE 10 to normal FULL mark on dipstick. Add diluent to oil reservoir in ratio of 1½ qt. to each 5 qt. of reservoir capacity—2¾ qt. for 9 qt. 2-piece oil pan and 3½ qt. for 11½ qt. 1-piece oil pan. Run engine 5 to 10 minutes to mix lubricant and diluent thoroughly. Stop engine and note level of the diluted lubricant above the normal FULL mark on the gage or dipstick for future reference. Under operation check oil level frequently. During operation add OE 10 if level drops below normal FULL mark. Upon shutdown of engine add OE 10 to normal FULL mark and diluent to diluent FULL mark if anticipated shutdown time will be sufficient to cool engine.
5. DISTRIBUTOR—Every 6,000 miles, wipe breaker arm lightly with CG and lubricate breaker arm pivot and wick under rotor with 1 to 2 drops of OE.
6. GEAR CASES—Fill to plug levels before operation and after draining. Drain only after operation.
7. OIL FILTER—Every 6,000 miles, while crankcase is being drained, remove element, clean inside of case, install new element.
8. PROPELLER SHAFT PILLOW BLOCK—Remove level plug inside of housing and install fitting. Apply CG through fitting until grease appears at vent on top of housing. Do not replace plug.
9. REAR SPRING SEAT BEARINGS—Lubricate through fitting until grease shows at inner seals.
10. OIL CAN POINTS—Every 1,000 miles, lubricate Transfer Case Control Lever Bushings and Rods, Hinges, Locks, Hand Brake Linkage, Brake Pedal Pull Rod Clevis Pins, Clutch Pedal Linkage, Clutch and Brake Pedal Shaft, etc., with OE.
11. DO NOT LUBRICATE—Clutch Release Bearing, Generator Bearings (some models), Fan, Water Pump, Springs.
12. DISASSEMBLED PERIODICALLY BY ORDNANCE PERSONNEL—Steering Column Upper Bearing, Steering Column Horn Contacts.

Copy of this Lubrication Order will remain with the equipment at all times; instructions contained herein are mandatory and supersede all conflicting lubrication instructions dated prior to the date of this Lubrication Order.

BY ORDER OF THE SECRETARY OF THE ARMY:

OMAR N. BRADLEY

Chief of Staff, United States Army

OFFICIAL:

EDWARD F. WITSELL,
Major General,
The Adjutant General.

LO 9-U315

DISTRIBUTION: ARMY—Tech Sv (2); Arm & Sv Bd (1); AFF (2); OS Maj Comd (10); Base Comd (2); MDW (3); A (Zl) (18); (Overseas) (8); CHQ (2); D (2); R 9 (1); Bn 9 (1); C 9 (1); FC (1); Class II Instls 9 (3); USMA (2); Sch (5); Gen Dep 9 (2); Tng Ctr (2); PE (Ord O) (5); SPECIAL DISTRIBUTION. AIR FORCE—USAF (5); USAF Maj Comd (2); USAF Sub Comd (3); BU (1). For explanation of distribution formula, see TM 38-405.

Requisition additional Lubrication Orders in conformance with instructions in TM 38-405. **RA PD 356181**

Figure 47.2 Lubrication order LO 9–U315 (rear).

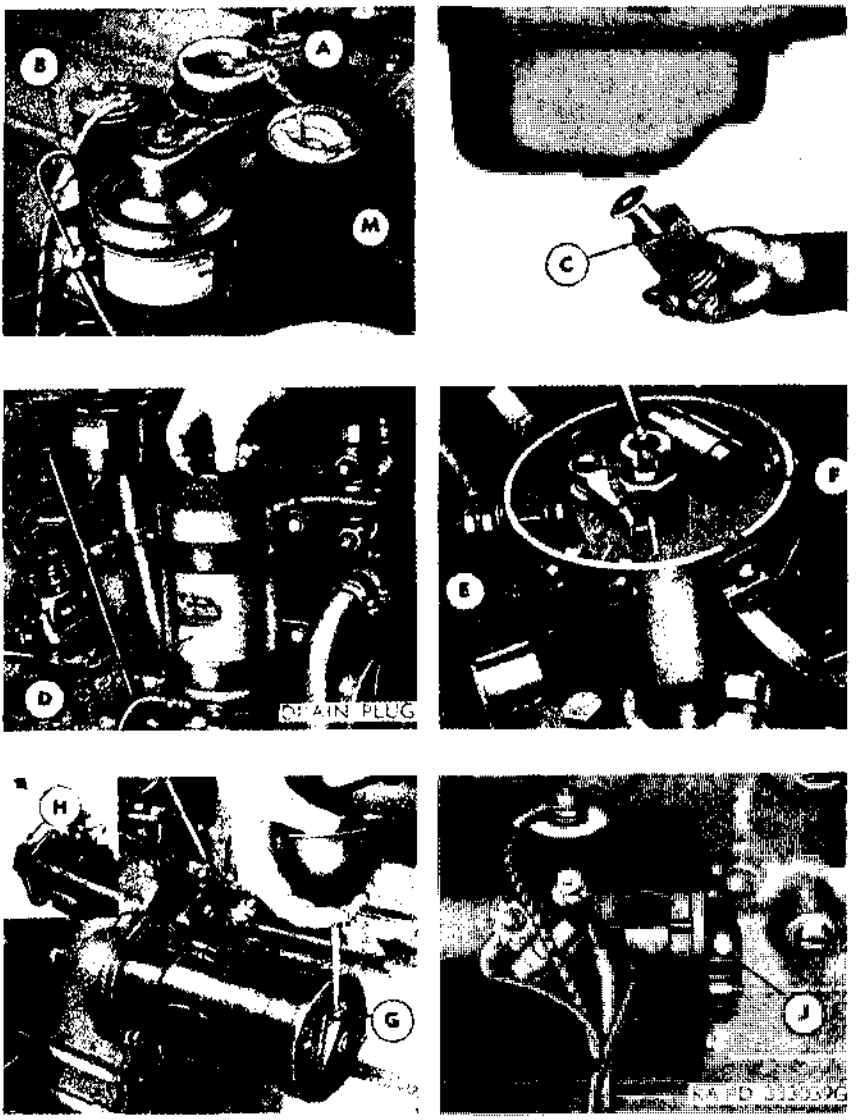


Figure 48. Lubrication localized views.

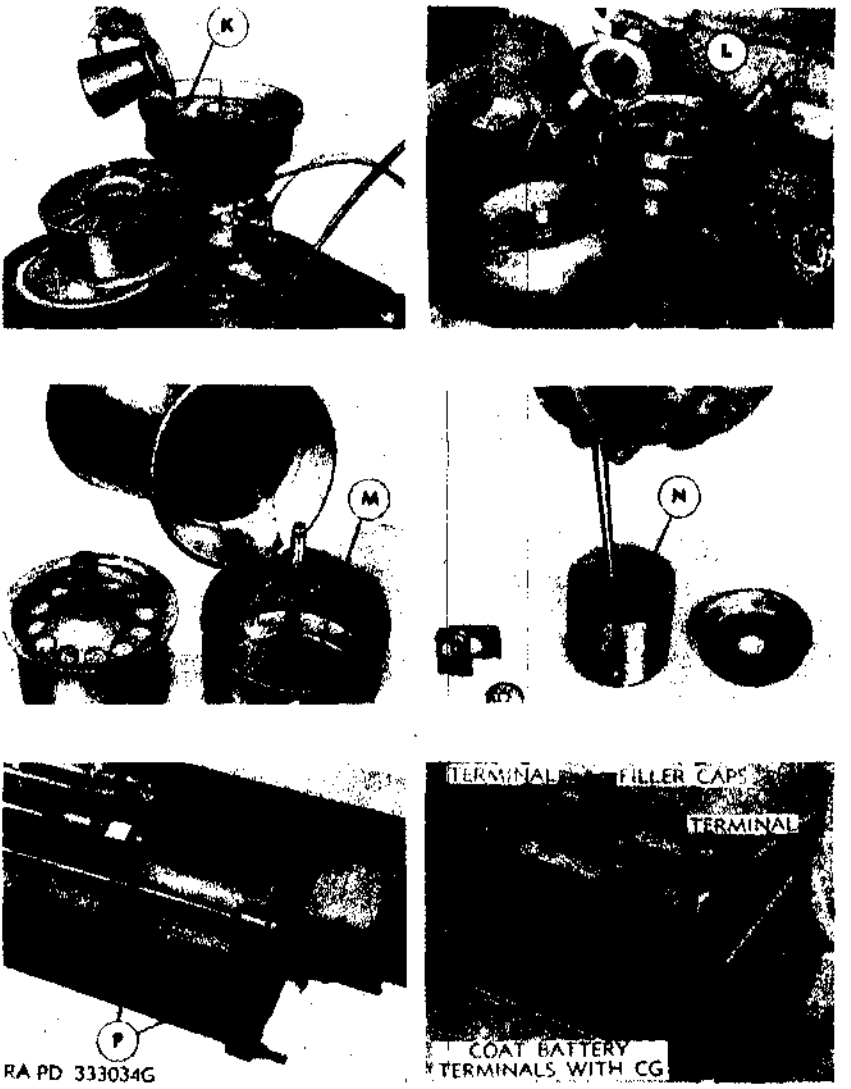


Figure 49. Lubrication localized views.

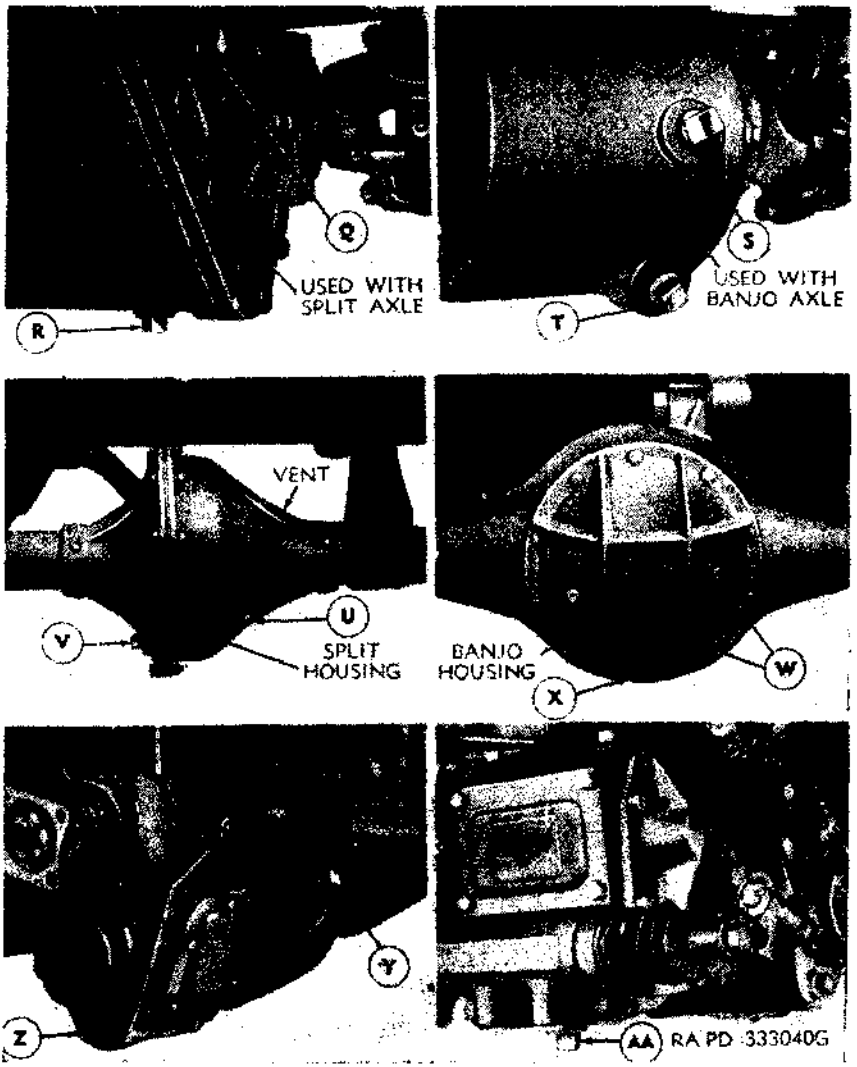
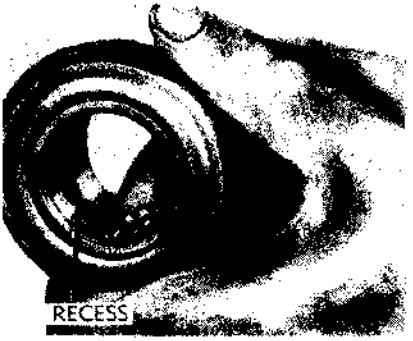
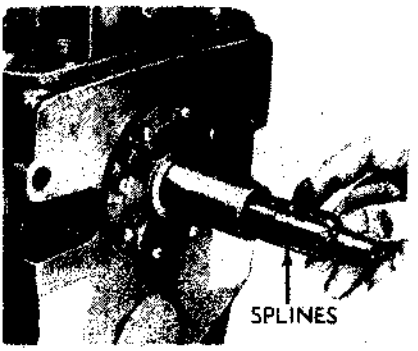


Figure 50. Lubrication localized views.

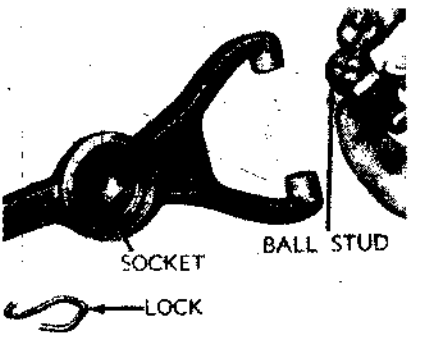


FILL CLUTCH RELEASE BEARING SUPPORT RECESS WITH BR*

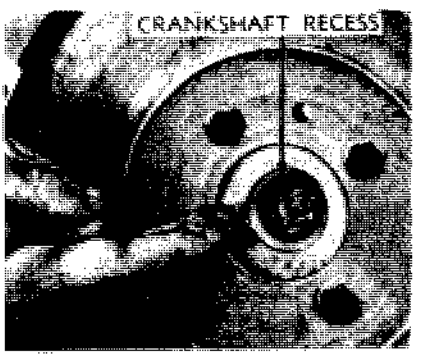
COAT CLUTCH RELEASE BEARING FORK GROOVE WITH BR*



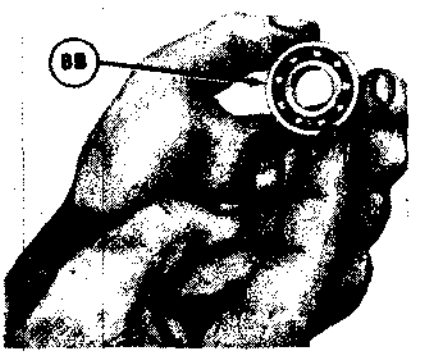
COAT CLUTCH SHAFT SPLINE WITH BR*



COAT CLUTCH RELEASE FORK SOCKET AND STUD WITH BR*



FILL CAVITY WITH BR*



RA PD 333033G

Note. See note 7, LO 9–801 (fig. 47) and note 2, LO 9–U315 (fig. 47.2).

Figure 51. Lubrication localized views.

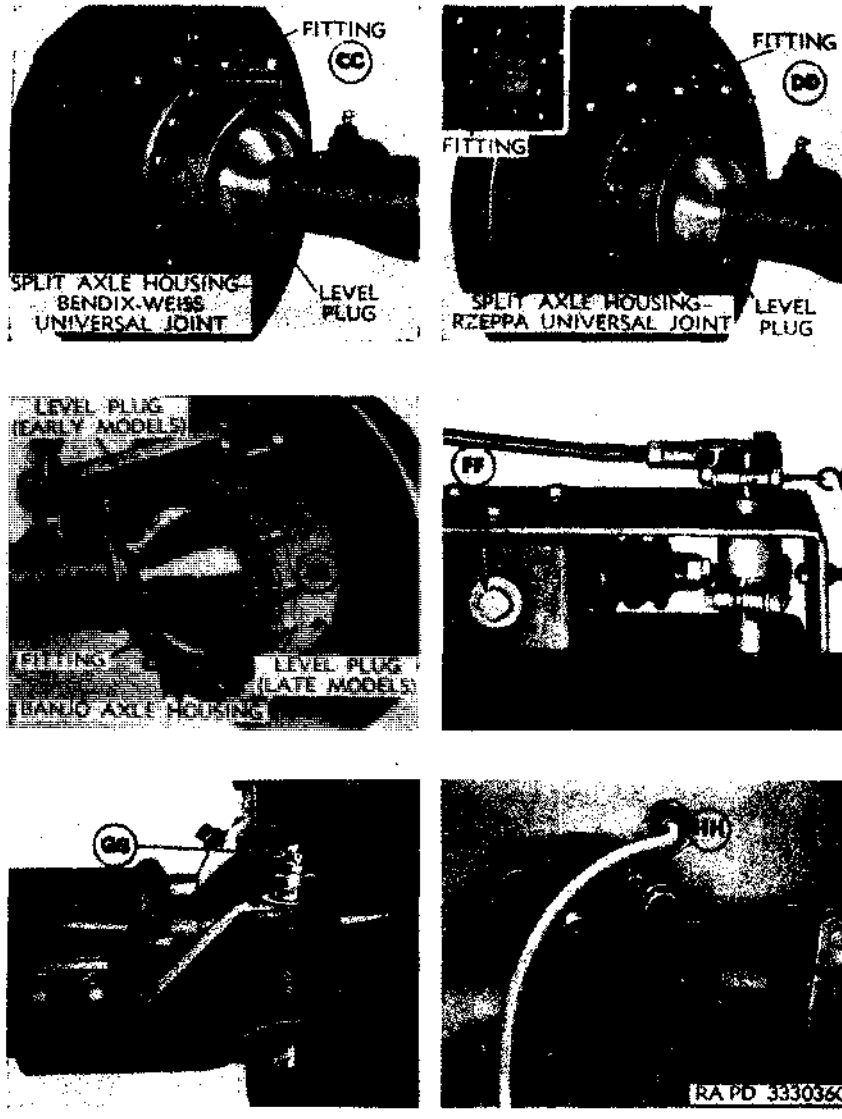


Figure 52. Lubrication localized views.

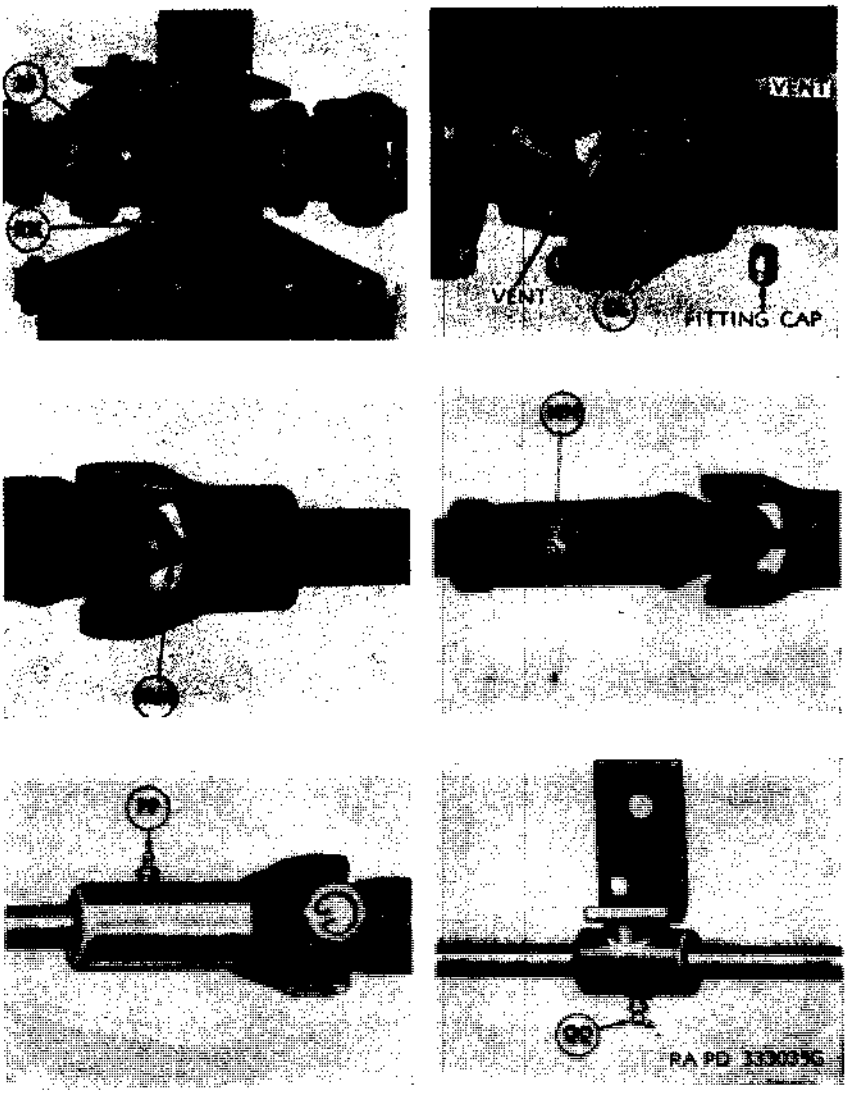
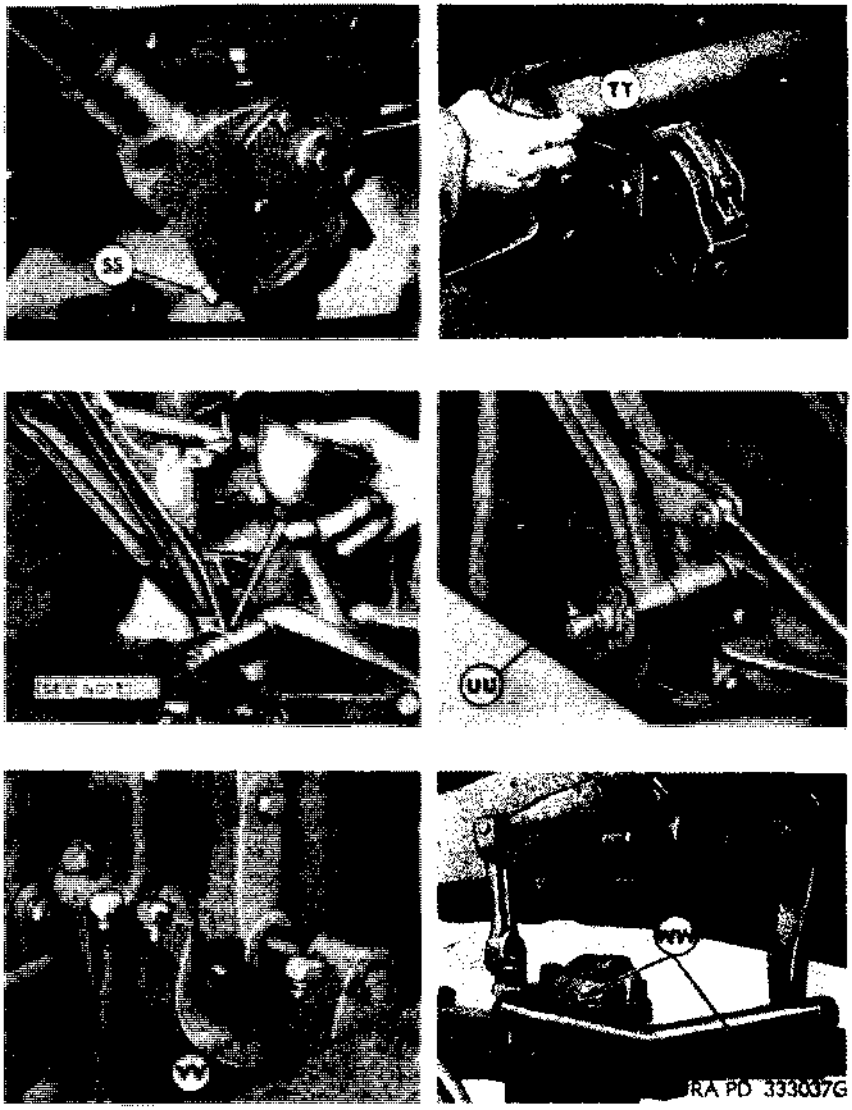


Figure 53. Lubrication localized views.



Note. See note 16, LO 9-801 (fig. 47), and note 10, LO 9-U315 (fig. 47.2).

Figure 54. Lubrication localized views.

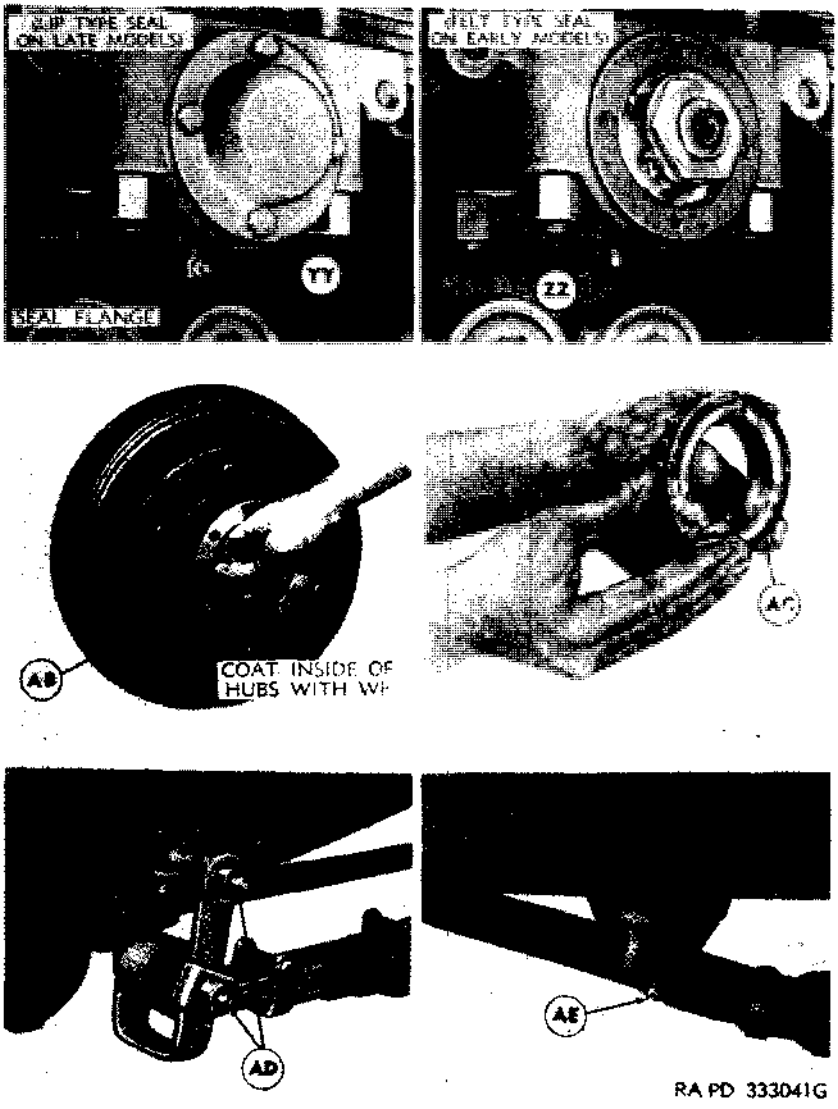


Figure 55. Lubrication localized views.

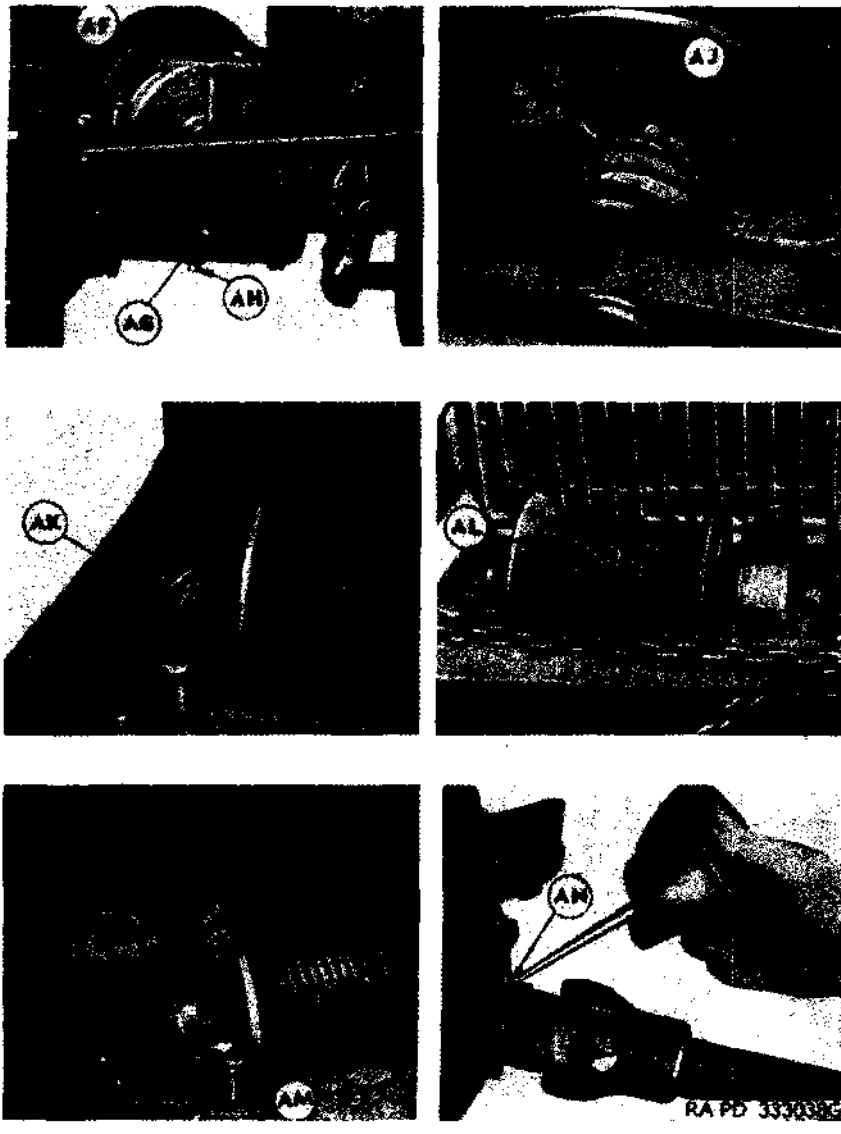


Figure 56. Lubrication localized views

38. Purpose

a. When a new * * * and correctly adjusted. In addition, they will perform a run-in test of at least 50 miles according to procedures in paragraph 40.

40. Run-In Test Procedures

a. PRELIMINARY SERVICE.

* * * * * * *

(26) *Tools and equipment.*

(*a*) (Superseded.) *Tools and equipment.* Check tools and on-vehicle stowage against latest edition of Department of the Army Supply Catalog ORD 7 SNL G–508 to be sure all required items are present. See that they are serviceable and properly mounted or stowed.

(*b*) *Equipment. Rescinded.*

* * * * * * *

c. VEHICLE PUBLICATIONS AND REPORTS.

(1) *Publications* (superseded). See that the vehicle operator's manual, lubrication order, Standard Form 91 (Operator's Report of Motor Vehicle Accident), WD AGO Form 478 (MWO and Major Unit Assembly Replacement Record and Organization Equipment File), are in the vehicle, legible, and properly stowed.

Note. Department of the Army registration number and vehicle nomenclature must be filled in on Form 478 for new vehicles.

* * * * * * *

Section X. PREVENTIVE MAINTENANCE SERVICES

41. General

(Superseded.)

a. RESPONSIBILITY AND INTERVALS. Preventive maintenance services are the responsibility of the using organization. These services consist generally of before-operation, during-operation, at-the-halt, after-operation, and weekly services performed by the driver or operator and the scheduled services to be performed at designated intervals by organization mechanic or maintenance crews. Intervals are based on normal operations. Reduce intervals for abnormal operations or severe conditions. Intervals during inactive periods may be extended accordingly.

b. DEFINITION OF TERMS. The general inspection of each item applies also to any supporting member or connection, and generally is

a check to see whether the item is in good condition, correctly assembled, secure, and not excessively worn.

(1) The inspection for "good condition" usually is an external visual inspection to determine whether the unit is damaged beyond safe or serviceable limits. The term "good condition" is explained further by the following: not bent or twisted, not chafed or burned, not broken or cracked, not bare or frayed, not dented or collapsed, not torn or cut, not deteriorated.

(2) The inspection of a unit to see that it is "correctly assembled" usually is an external visual inspection to see whether or not it is in its normal assembled position in the vehicle.

(3) Inspection of a unit to determine if it is "secure" usually is an external visual examination or a wrench, hand-feel, or a pry-bar check for looseness. Such an inspection must include any brackets, lock washers, lock nuts, locking wires, or cotter pins used.

(4) By "excessively worn" is meant worn beyond serviceable limits, or to a point likely to result in failure if the unit is not replaced before the next scheduled inspection.

42. Cleaning

(Superseded.)

a. General. Any special cleaning instructions required for specific mechanisms or parts are contained in the pertinent section. General cleaning instructions are as follows:

(1) Use dry-cleaning solvent or volatile mineral spirits paint thinner to clean or wash grease or oil from all parts of the vehicle.

(2) A solution of one part grease-cleaning compound to four parts of dry-cleaning solvent or volatile mineral spirits paint thinner may be used for dissolving grease and oil from engine blocks, chassis, and other parts. After cleaning, use cold water to rinse off any solution which remains.

(3) Use clean water or a soap solution of ¼ pound of soap chips to a gallon of hot water for all rubber parts and over-all general cleaning of painted surfaces.

(4) After the parts are cleaned, rinse and dry them thoroughly. Take care to keep the parts clean.

(5) Remove the protective grease coating from new parts, since this grease is usually not a good lubricant.

b. General Precautions in Cleaning.

(1) Dry-cleaning solvent (Stoddard type) and volatile mineral spirits paint thinner are inflammable and should not be used near an open flame. Fire extinguishers should be provided when these materials are used. In addition, they evaporate quickly and have a drying effect on the skin. If used without gloves, they may cause cracks in the skin and, in the case of some individuals, a mild irritation or inflammation. Use only in well ventilated places.

(2) Avoid getting petroleum products such as dry-cleaning solvent, mineral spirits paint thinner, engine fuels, or lubricants on rubber parts as they will deteriorate the rubber.

(3) The use of gasoline or benzene for cleaning is prohibited.

43. Preventive Maintenance by Driver or Operator

(Superseded.)

a. Purpose. To insure mechanical efficiency, it is necessary that the vehicle be systematically inspected at intervals each day it is operated and weekly, so defects may be discovered and corrected before they result in serious damage or failure. Certain scheduled maintenance services will be performed at these designated intervals. Any defects or unsatisfactory operating characteristics beyond the scope of the driver or operator to correct, must be reported at the earliest opportunity to the designated individual in authority. The services set forth in table II are those performed by the driver or operator before-operation, during-operation, at-the-halt, after-operation, and weekly.

b. Use of DD Form 110. Driver or operator preventive maintenance services are listed on the back of DD Form 110 (Vehicle and Equipment Operational Record) (par. 2). Items listed on the form that do not pertain to this vehicle are eliminated from the procedures as written in this manual. Every organization must thoroughly school its personnel in performing the maintenance procedures set forth in this manual, whether they are listed specifically on DD Form 110 or not.

c. Services. Table II lists the services to be performed by the driver or operator at the designated intervals.

Table II. Driver's or Operator's Preventive Maintenance Services

Intervals					Procedure
Before-operation	During-operation	At-the-halt	After-operation	Weekly	
X	------	X	X	X	(1) *Fuel, oil, and water.* Check the amount of fuel in the tanks and note any indications of leaks. Add fuel if necessary and check the spare fuel containers. Check the oil level and add oil if necessary. Check water level in the cooling system and note any leaks. When water is added during period that antifreeze is in use, a hydrometer test must be made and antifreeze added, if necessary, to provide safe operation to meet lowest anticipated temperature. ***Caution:*** Place all tags describing condition of vehicle in the driver's compartment in a conspicuous location so that they will not be overlooked.
X	------	X	X	X	(2) *Tires.* (*a*) All tires should be properly inflated and spares properly secured in their carriers (par. 218).
------	------	------	X	X	(*b*) Remove all foreign matter such as nails, glass, or stones from tires and from between duals. Examine tires for signs of low pressure, abnormal tread wear, cuts, and presence of valve caps. All tires with cuts extending to or into the cord body or worn smooth in center of tread or which show abnormal tread wear must be reported to proper authority for corrective action.
------	------	------	------	X	(*c*) Check tires for proper matching and irregular wear and change position as required. Check wheel nuts and ring bolts for proper tightness.
X	------	X	------	X	(3) *Leaks, general.* Check under the vehicle and in engine compartment for any indication of fuel, oil, or brake fluid leaks.
X	------	X	X	X	(4) *Visual inspection of equipment.* Determine if lamps and reflector, horn, fire extinguishers, mirrors, paulins, tools, etc., are in the proper place and in good operating order. Check for any tampering or damage that might have occurred prior to inspection.
X	X	------	------	------	(5) *Instruments.* With the engine running, check all instruments for normal readings.

Table II. Driver's or Operator's Preventive Maintenance Services—Continued

Intervals					Procedure
Before-operation	During-operation	At-the-halt	After-operation	Weekly	
	X				(6) *Operating observations.* While the vehicle is in operation, the driver or operator should be alert for any sounds that may be a sign of trouble, such as rattles, knocks, squeaks, or hums. The instruments should be checked and any unusual reading noted which would indicate any part of the vehicle or powered ground equipment functioning improperly. Every time the brakes are used, gears shifted, or the vehicle turned, the drive or operator should instinctively consider it a test and note any unusual or unsatisfactory performance.
			X		(7) *Clean equipment.* (*a*) Clean dirt and trash from inside cab and body. Clean glass and, when practicable, wipe off exterior of equipment.
				X	(*b*) Wash the vehicle when possible. If not possible, wipe off thoroughly. Thoroughly clean engine and engine compartment of all excess dirt, trash, fuel, and oil drippings.
				X	(8) *Battery.* Clean and add necessary water. Check terminal connections to see that they are securely fastened and properly coated with grease.
				X	(9) *Assemblies and belts.* Check all assemblies such as carburetor, generator, regulator, starter, and water pump for loose connections or mountings. Check adjustment of fan and drive belts (par. 108). If found to be improperly adjusted, report to the proper authority.
				X	(10) *Electrical wiring.* Check all accessible wiring and ascertain that it is securely connected and supported, that insulation is not cracked or chafed, and that conduits and shielding are in good condition and secure. Report any unserviceable wiring.
			X	X	(11) *Tools and equipment* Check to see that all tools and equipment are serviceable and in their proper place. Clean tools and equipment weekly.
				X	(12) *Fuel filters.* Remove the drain plug or sediment bowl and remove all water and sediment from the filter (par. 98).

Table II. Driver's or Operator's Preventive Maintenance Services—Continued

Intervals					Procedure
Before-operation	During-operation	At-the-halt	After-operation	Weekly	
			X	X	(13) *Lights.* Observe whether the lights operate properly. Inspect all lenses and warning reflectors for dirt or damage; clean if necessary.
			X	X	(14) *Horn and windshield wipers.* Test horn for proper operation. Test windshield wipers to insure proper functioning and cleaning action.
				X	(15) *Towing connections.* Weekly inspect towing hooks, pintle hook, and safety chains for looseness or damage. Clean and lubricate as required and inspect for abnormal wear. Test to be sure that latching mechanism closes completely and latches securely.
				X	(16) *Springs and suspensions.* Check springs for abnormal sag, broken or shifted leaves, loose or missing rebound clips, eyebolts, "U" bolts, or shackles. Also check shock absorbers, radius rods, and any torque rods to see that they are not damaged.
				X	(17) *Axle and transfer vents.* Check and clean all axle housings and transfer vents to see that they are in good condition and secure. Free all breather vents of obstructions.
				X	(18) *Publications.* Check to see that all appropriate publications concerning the operation and maintenance of the equipment are on hand and in good order.
			X	X	(19) *Lubrication as needed.* Lubricate equipment in accordance with instructions contained in Lubrication Orders, LO 9–801 and 9–U315.

44. At-Halt Service

Rescinded. See paragraph 43 and table II.

45. After-Operation and Weekly Services

Rescinded. See paragraph 43 and table II.

46. Second Echelon Preventive Maintenance

a. Regular scheduled maintenance * * * of operating organizations.

* * * * * * *

(5) *Specific procedures.* The procedures for * * * indicated opposite number.

6,000 mile maint (six-month)	1,000 mile maint (monthly)	
		ROAD TEST
		* * * * * * *
----------	19	*Valve mechanism* (*clearance, lubrication, cover gaskets*). Adjust valve clearance * * * indicates a necessity. Correct clearances are: intake 0.012, and exhaust 0.016 inch (**or 0.020 inch on engines with late type camshafts (par. 77c)**), at operating temperature. Be sure bond * * * and tightly connected.
19	----------	*Adjust.* Adjust clearances. Intake 0.012 inch, exhaust 0.016 inch (**or 0.020 inch on engines with late type camshafts (par. 77c)**), at operating temperature. **Check for minimum clearance of 0.040 inch between intake valve spring upper retainer (cap) and oil shield (par. 77c).** Examine valve push * * * unserviceable cover gasket.
		* * * * * * *
		TOOLS AND EQUIPMENT
131	131	*Tools* (*vehicle and pioneer*). Inspect all the standard vehicle and pioneer tools to see that they are all present (**Department of the Army Supply Catalog ORD 7 SNL G–508**), in good condition, clean, and properly stowed or securely mounted. Also examine the * * * glare, or reflection.
		* * * * * * *
135	135	*Publications and Form* **91.** The vehicle and equipment manuals, lubrication order, Standard Form **91** (Accident-Report Form), WD AGO Form 478 (MWO and Major Unit Assembly Replacement Record) must be present, legible, and properly stowed.
		* * * * * * *

51. Engine Miscellaneous Operating Faults

* * * * * * *

b. Excessive Oil Consumption.

* * * * * * *

(7) (Added.) Excessive oil consumption may result from loss of oil through ventilator air cleaner. If top of cleaner element (fig. 68) is dry, the oil is being lost from the cleaner reservoir as a result of splashing caused by operation over extremely rough terrain. Maintain the cleaner reservoir oil level at the full mark (sec. VIII). If the top of cleaner element is wet with oil, the loss is from the engine crankcase, internal pressure forcing the oil out. To correct loss of oil due to internal pressures, perform the following inspections and corrections and *note all cautions:*

(*a*) Adjust governor (par. 96*e*).

(*b*) Do not exceed permissible road speeds in any gear (fig. 19). Do not overspeed while going downhill.

(*c*) Inspect crankcase oil level after engine has been stopped for a few minutes while vehicle is in level position. If oil level is above full mark, drain excess (par. 17*b*).

(*d*) Disassemble and clean ventilator valve (par. 82). If valve spring is distorted or damaged, replace valve assembly.

(*e*) Be sure ventilator air cleaner oil level is correct (sec. VIII). The relation of the cleaner element to the oil level in the reservoir is correct when the bottom of the element reaches, but is not below, the top of the oil level.

(*f*) Inspect for and correct any oil leaks at the rocker arm cover, push rod cover, and ventilator tube fittings (fig. 69). If the rocker arm cover is of the louver type, be sure that the closures are in place and that they do not leak.

(*g*) Engine blow-by past pistons into crankcase may exceed flow of air through ventilator valve, allowing pressure to be built up in the crankcase. If the capacity of the ventilator valve is too low to handle this increased pressure, the engine will have to be overhauled. Notify ordnance maintenance personnel.

* * * * * * *

65. Transfer Case

a. Hard Shifting (GMC CCKW-352 and 353 Only).

* * * * * * *

b. Slips Out of Gear (GMC CCKW–352 and 353 Only).

* * * * * * *

75. Description and Tabulated Data

* * * * * * *

b. Tabulated Data.

* * * * * * *

(2) *Adjustment data.*

Valve clearance (hot)

Intake	0.012 in.
Exhaust (with early type camshaft GM–2136000)	0.016 in.
Exhaust (with late type camshaft GM–2191529)	**0.020 in.**

* * * * * * *

77. Valve Clearance and Adjustment

* * * * * * *

c. Adjust Valve Clearance (superseded).

(1) *Valve stem.* With engine hot and idling, insert feeler gage (0.012 inch for intake and 0.016 or 0.020 inch for exhaust) between rocker arm and valve stem at each valve. (Adjust exhaust valve clearance to 0.016 inch on engines having the early type camshaft installed. Adjust exhaust valve clearance to 0.020 inch on engines having the late type camshaft installed. The late type camshaft can be identified by the GM. part number 2191529 stamped on the shaft between number 1 intake and number 2 exhaust cams and by the dark colored cams in contrast to the highly polished cams of the early type shaft.

Note. If there is any doubt as to whether the camshaft in an engine is of the late type, adjust exhaust valve clearance to 0.020 inch.

Using tool similar to that illustrated in figure 58, or a wrench and screwdriver, loosen rocker arm ball stud nut, and tighten or loosen stud until proper clearance is obtained. Tighten nut and recheck clearance.

(2) *Spring upper retainer (cap) and oil shield.* Check clearance between the intake valve spring upper retainer (cap) and the oil shield (fig. 58.1) with a spark-plug gap gage, bending the 0.040-inch wire to fit. If clearance is less than 0.040 inch, refer to ordnance maintenance for correction. A minimum clearance of 0.040 inch must be maintained between the retainer and shield to insure proper action of the valve locks. Clearance less than 0.040 inch will, when the valve is opened, cause the oil shield to press on the upper retainer. This will

loosen the locks in the retainer, causing the locks to batter against the tapered hole during valve action. The locks may fall out or cause enough wear to pull through the retainer and, in either case, drop the valve into the combustion chamber. The retainer currently in use is thicker and heavier than the original and is rounded to provide more clearance between retainer and oil shield.

Note. Insufficient clearance may be corrected by selective replacement of spring upper retainer and locks.

* * * * * * *

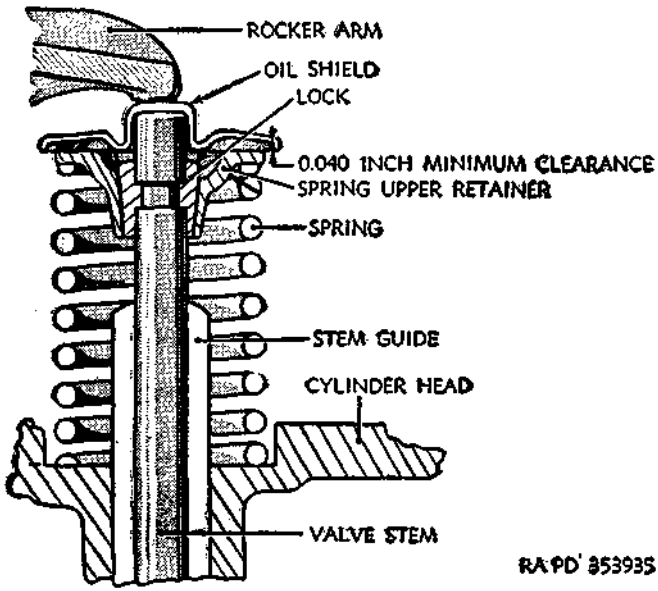


Figure 58.1 (added). *Intake valve assembly.*

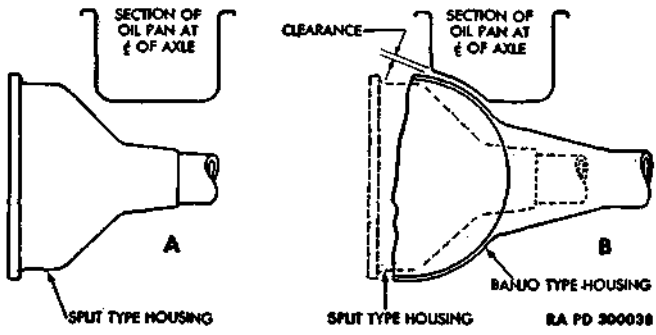


Figure 64.1 (added). *Clearance at oil pan for banjo-type axle.*

80. Oil Pan

a. DESCRIPTION. The deep sump * * * will damage cleaner. **Two types of oil pans are used because of the split-type and banjo-type axle housings that have been installed (par. 163). The first type (GM–2135413) has a plain bottom (A, fig. 64.1) and can be used only with the split-type axle housing. The second type oil pan (GM–2136263) has a depression on the front, right side to provide clearance for the banjo-type axle housing (B, fig. 64.1). This second type oil pan can be used with either of the two types of axle housings.**

* * * * * * *

99. Air Cleaner

* * * * * * *

f. INSTALLATION (FLANGE MOUNTED AIR CLEANER). If unit to * * * at proper level.

(1) *Install cleaner.* Place cleaner tube * * * and tighten snugly. **Check for 1-inch minimum clearance between air cleaner and radiator tie rod. Bend tie rod to obtain proper clearance. After bending adjust tie rod at dash so that there is ¾-inch clearance between fan blades and radiator (fig. 100).**

109. Radiator Assembly

* * * * * * *

e. (Added.) U-BOLT TYPE RADIATOR MOUNTING. To overcome the difficulty caused by the inaccessible location of the carriage type radiator lower support bolt (fig. 100), which made tightening of the nuts and adjustment at the springs very difficult, a U-bolt type mounting was used in later production vehicles and is provided for service purposes. Installation of the U-bolt type mounting is shown in figure 100.1. Adjustment of the nuts and springs is accomplished in a similar manner as for the carriage bolt type installation (*d* above).

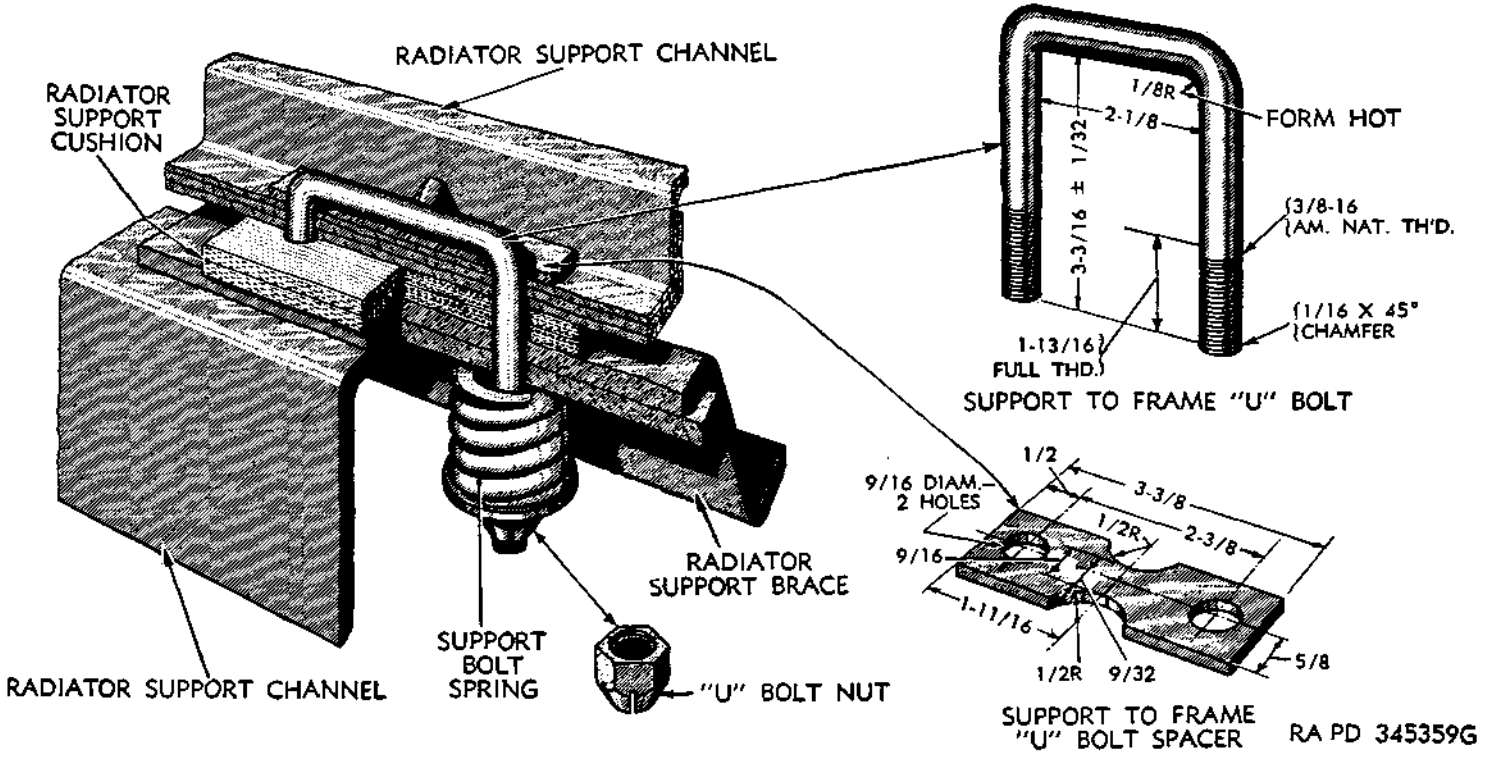


Figure 100.1 (added). *Installation of "U"-bolt type radiator mounting.*

116. Description

* * * * * * *

b. (Added.) Various combinations of generators, generator regulators, pulleys, and fan belts have been installed in these vehicles or are available for service. The major difference between the various combinations is in the current capacity; 25-ampere, 30-ampere, or 40-ampere output combinations being used. The current capacities of the generator and regulator on a vehicle must be matched.

118. Regulator

* * * * * * *

c. REGULATOR INSTALLATION (fig. 106).

* * * * * * *

(2) *Connect wires.* Install wires on * * * "GROUND" terminal—No 14—black. **A change was made in the location of the three terminals on the latest type sealed regulator.**

Caution: **When installing the latest type sealed regulators, the changed terminal locations must be kept in mind to avoid the possibility of improper connection of cables.**

* * * * * * *

159. Description

(Superseded.)

The transfer case is essentially an auxiliary unit consisting of a case, gears, and output shafts for transferring power to each of the driving axles. The transfer case is located between the frame side rails just behind the transmission and is driven by the transmission through a propeller shaft. It is attached to brackets under the transfer case cross member by cap screws.

a. GMC CCKW–352 AND 353. The transfer case has two speed ranges and output shafts to the two rear axles and the front axle. Shifting of transfer case gears is accomplished manually through levers in the cab (par. 16).

b. GMC CCW–353. The transfer case has only one speed range and output shafts to the rear axles, hence, there are no transfer case controls or linkages.

160. Controls and Linkage (CCKW–352 and 353 only)

* * * * * * *

161. Transfer Case Removal

* * * * * * *

b. Disconnect Control Rods (CCKW-352 and 353 only) (fig. 144 or 145).

* * * * * * *

162. Transfer Case Installation

* * * * * * *

e. Connect Control Rods (CCKW-352 and 353 only) (fig. 144 or 145).

* * * * * * *

168. Front Axle Removal (GMC CCKW-352 and 353 only)

* * * * * * *

168.1 Front Axle Removal (GMC CCW-353 only)

(Added.)

a. Position Vehicle. Place vehicle on a level surface and apply hand brake to prevent vehicle from rolling. Jack up front end of vehicle until tires are 3 inches from ground. Place a suitable jack stand on each side of frame just behind front spring rear hanger bracket. Lower front end until weight rests on jack stands. Leave jack raised high enough to support axle assembly.

b. Remove Wheels. Remove wheel stud nuts and remove wheel and tire assembly from each side.

c. Disconnect Shock Absorber Links. Disconnect both front shock absorber links at upper spring clip plates.

d. Disconnect Drag Link. Disconnect drag link at axle steering arm (par. 207).

e. Disconnect Flexible Brake Hose. Turn off the front wheel (brake) shut-off cock inside of right-hand frame rail (fig. 185). Loosen connections at frame side rails; then remove hoses from wheel cylinders.

f. Disassemble Spring-To-Axle Mounting. Remove nuts from spring "U" bolts and remove "U" bolts.

g. Remove Axle Assembly. Lower jack until axle assembly clears underside of chassis and withdraw from under vehicle.

169. Front Axle Installation (GMC CCKW-352 and 353 only)

* * * * * * *

169.1 Front Axle Installation (GMC CCW-353)
(Added.)

a. POSITION AXLE ASSEMBLY. Place axle assembly on jack and move it into approximate position under vehicle. Raise axle assembly into position against springs, being certain spring center bolt heads enter alinement holes in axle spring seats.

b. ASSEMBLE SPRING-TO-AXLE MOUNTING. Place spring "U" bolts in position and tighten nuts evenly.

c. CONNECT FLEXIBLE BRAKE HOSE. Install flexible hoses in wheel cylinders and tighten connections at frame side rails. Turn front wheel (brake) shut-off cock, on.

d. CONNECT DRAG LINK. Refer to paragraph 207 for instructions on installing and adjusting drag link on steering arm ball.

e. CONNECT SHOCK ABSORBER LINK. Connect shock absorber links to upper spring plates.

f. INSTALL WHEELS. Install wheel and tire assemblies on hubs, install wheel stud nuts, and tighten firmly.

g. REMOVE JACK STANDS AND JACK. Raise front of vehicle with jack and remove stands from under frame side rails. Lower jack and withdraw from under vehicle. Check all nuts on spring mounting bolts for tightness with full weight of vehicle resting on springs.

h. BLEED BRAKES. Bleed front wheel brakes (par. 180).

i. LUBRICATE. Check lubrication of complete axle assembly as instructed in section VIII.

178.1 Trailer Brake Controller
(Added.)

a. DESCRIPTION. Some 2½-ton 6 x 6 trucks are equipped with a hydraulically operated controller for electric trailer brakes. The controller consists of the following two units:

(1) *Load control.* The load control which is mounted on the dash (fig. 17.1) is a manually operated variable resistance wired in series with the hydraulically operated brake controller. It is equipped with a dial to vary the severity of brake application on the trailer (par. 15*g*).

(2) *Brake controller.* The brake controller is connected to the hydraulic brake system of the truck to permit uniform application of truck and trailer brakes by the use of the load control variable resistance and the brake pedal. The brake controller (fig. 162.1) is mounted on the rear of the first cross member to the rear of cab on left side and is connected into the hydraulic brakes on the truck.

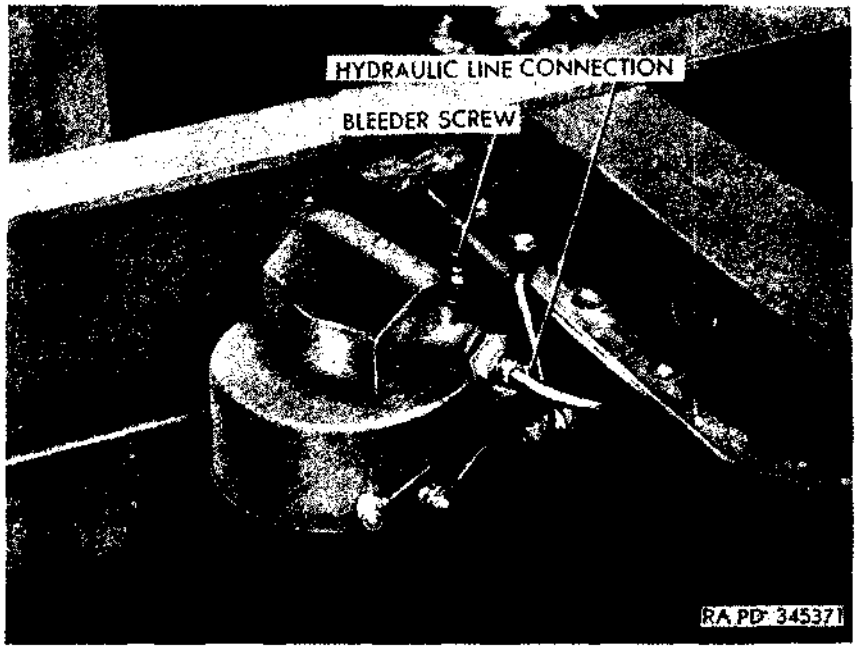


Figure 162.1. Brake controller mounted on cross member.

b. Operation of Brake Controller.

(1) The line pressure enters the actuating assembly at (T) (fig. 162.2) and is carried into the cylinder which has a rubber piston cup (K). As the line pressure is increased by brake pedal pressure, piston (P) pushes against spring (G). Attached to the piston is yoke (N) which actuates the contact lever. The assembly is also equipped with a bleeder screw (A).

(2) The piston travels about one-eighth inch before the spring (G) starts to compress. The spring is compressed still further before the hydraulic brakes on the tractor take effect. This amount of travel of the piston operates the controller sufficiently to start application of the trailer brakes before the tractor brakes are applied.

c. Adjustment.

(1) If it should be desirable to apply the trailer brakes further in advance of the tractor brakes, adjustment nut (B) can be unscrewed one to two turns.

Caution: Two turns is the most that the nut should be unscrewed.

(2) When bleeding operations are necessary, bleed all wheel cylinders first, then bleed the hydraulic electric trailer brake control cylinder at bleeder screw (A, fig. 162.2).

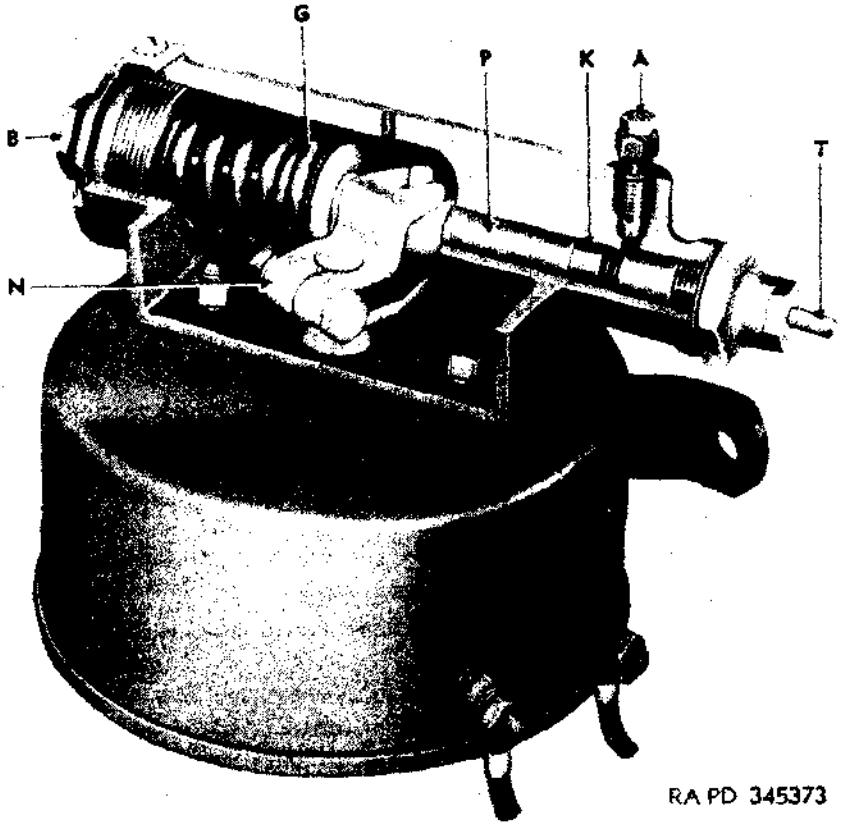


Figure 162.2. Cut-away section showing hydraulic actuating assembly of brake controller.

199. Wheel Bearing Adjustment

* * * * * * *

c. Front Hub Bearing Adjustment.

(1) *Banjo-type axles* (fig. 196).

(*a*) Remove drive flange * * * from outer nut. With wrench (**41–W–3748–100**), furnished with vehicle (use notched end), remove outer nut. Remove nut lock.

* * * * * * *

(2) *Split-type axles* (fig. 197).

(*a*) Remove drive flange * * * from outer nut. With hex end of adjusting wrench (**41–W–3825–100**), remove outer nut. Remove nut lock.

* * * * * * *

Page 463—The material contained in the appendix (pars. 250–255) is superseded by part four and the appendix following:

PART FOUR

SHIPMENT AND LIMITED STORAGE AND DESTRUCTION TO PREVENT ENEMY USE

Section XLV. SHIPMENT AND LIMITED STORAGE

250. Domestic Shipping Instructions

a. PREPARATION. When shipping the 2½-ton 6 x 6 and 6 x 4 trucks interstate or within the zone of interior, the officer in charge of preparing the shipment *will be responsible* for furnishing vehicles to the carriers for transport in a serviceable condition, properly cleaned, preserved, painted, lubricated, etc., as prescribed in SB 9–4.

Note. For loading and blocking instructions of vehicles on freight cars, refer to paragraphs 252 and 253.

b. REMOVAL OF PRESERVATIVES FOR SHIPMENT. Personnel withdrawing vehicles from a limited storage status for domestic shipment *must not remove preservatives* other than to insure that they are complete and serviceable. The removal of preservatives is the responsibility of depots, ports, or field installations (posts, camps, and stations) receiving the shipments.

c. ARMY SHIPPING DOCUMENTS. Prepare all Army shipping documents accompanying freight in accordance with TM 38–705.

251. Limited Storage Instructions

a. GENERAL.

(1) Vehicles received already processed for domestic shipment as indicated on the Vehicle Processing Record Tag (WD AGO Form 9–3), need not be reprocessed unless the inspection performed on receipt of vehicles reveals corrosion, deterioration, etc.

(2) Completely process vehicles if the processing data recorded on the tag indicates that vehicle has been rendered ineffective by operation, freight shipping damage, or upon receipt of vehicles directly from manufacturing facilities.

(3) Vehicles to be prepared for limited storage must be given a limited technical inspection and the results and classification of vehicle will be entered on the Limited Technical Inspection sheet (DA AGO Form 461–5) as prescribed in SB 9–63.

b. Receiving Inspections.

(1) Report of vehicles received in a damaged condition or improperly prepared for shipment will be made on the Report of Damaged or Improper Shipment sheet (DD Form 6) in accordance with SR 745–45–5.

(2) When vehicles are inactivated, they are to be placed in a limited storage status for periods not to exceed 90 days. Stand-by storage for periods in excess of 90 days normally will be handled by ordnance maintenance personnel only.

(3) Immediately upon receipt of vehicles, they must be inspected and serviced as prescribed in section XI. Perform a systematic inspection and replace or repair all missing or broken parts. If repairs are beyond the scope of the unit and the vehicle will be out-of-service for an appreciable length of time, place vehicle in a limited storage status and attach a tag to the vehicle specifying the repairs needed. The report of these conditions will be submitted by the unit commander for action by an ordnance maintenance unit.

c. Inspections During Storage. Perform a visual inspection periodically to determine general condition. If corrosion is found on any part, remove the rust spots, clean, paint, and treat with the prescribed preservatives.

Note. Touch-up painting will be in accordance with TM 9–2851.

d. Removal From Limited Storage.

(1) If the vehicles are not shipped or issued upon expiration of the limited storage period, they must be further treated for stand-by storage (for periods in excess of 90 days up to 3 years) by ordnance maintenance personnel.

(2) If vehicles to be shipped will reach their destination within the scope of the limited storage period, they need not be reprocessed upon removal from storage unless inspection reveals it to be necessary.

(3) Deprocess vehicles when it has been ascertained that they are to be placed into immediate service. Remove all rust preventive compounds and thoroughly lubricate as prescribed in section VIII. Inspect and service vehicles as prescribed in section XI.

(4) Repair and/or replace all items tagged in accordance with *b*(3) above.

e. Storage Site. The preferred type of storage for vehicles is under cover in open sheds or warehouses whenever possible. Where it is found necessary to store vehicles outdoors, they must be protected against the elements as prescribed in SB 9–47.

252. Loading the 2½-Ton 6 x 6 and 6 x 4 Trucks for Rail Shipment

a. PREPARATION.

(1) When vehicles are shipped by rail, every precaution must be taken to see that they are properly loaded and securely fastened and blocked to the floor of car. All "on-vehicle matériel" (OVM) will be thoroughly cleaned, preserved, packed, and securely stowed in or on the vehicle during transit.

(2) Prepare all vehicles for rail shipment in accordance with paragraph 250*a*. In addition take the following precautions:

(*a*) Disconnect the truck battery to prevent its discharge by vandalism or accident. This is accomplished by disconnecting the positive lead, taping the end, and tying it back away from the battery.

(*b*) Apply the truck hand brake and place the transmission in neutral position after the vehicle has been finally spotted on the freight car. The vehicles must be loaded on the car in such a manner as to prevent the car from carrying an unbalanced load.

(*c*) Increase tire pressure slightly higher than normal except in cases where shipment is to be exposed to extremely hot weather conditions.

b. TYPE OF CARS. Instructions contained herein pertain to the loading of vehicles in gondola cars (an open top car having fixed sides, fixed or drop ends, and solid bottom) and flatcars (cars with wooden floors laid over sills and without sides or ends but equipped with stake pockets).

c. METHOD OF LOADING VEHICLES ON FREIGHT CARS.

(1) *Flatcar loading.*

(*a*) When suitable hoisting equipment is not available for loading vehicles on or subsequent unloading from a flatcar, an end ramp must be used in cases where the vehicle is not on a level with the flatcar deck. Vehicles on a warehouse platform or loading dock can be pivoted over spanning platforms aboard a flatcar spotted adjacent to the platform, then again pivoted into lateral position on the flatcar.

(*b*) When unboxed vehicles must be loaded from ground level, a ramp may be improvised ((3) below) by borrowing railroad ties normally found stacked in railroad yards and by procuring necessary planking. An ideal end loading ramp is shown in place in figure 258.

Note. Railroad ties alone, stacked without deck planking and not securely anchored, provide a very unstable ramp and must be rearranged upon each successive use. The torque action of the wheels of self-propelled vehicles will tend to collect and collapse a simple

stack of railroad ties and should, therefore, not be attempted except under conditions of extreme emergency.

(*c*) To load vehicles, the vehicles are towed onto the improvised apron at base of ramp and unhitched. Using a cable laid along the center line of the flatcar, attached to vehicle, the vehicle is pivoted to point toward the ramp.

Caution: Follow up forward movement of the vehicle by chocking behind one wheel on the ramp.

(*d*) After the first vehicle is loaded on the flatcar, additional vehicles may be similarly hauled aboard by passing the towing cable beneath the loaded vehicle. When a train of flatcars is being loaded, steel or wooden spanning platforms or bridges are used to cover the gap between cars. Flatcar brake wheels must first be lowered to floor level to permit passage. A pair of improvised spanning platforms are shown in place in figure 259. These spanning platforms are moved along the train by hand as the vehicle advances.

(*e*) The above method of train loading requires careful advance planning as to the order of loading, so that vehicles are arranged on each flatcar under prescribed methods and combinations.

(*f*) For powering the towing cable, a vehicle with winch is spotted at *right angles* to the train, located at about the third or fourth flatcar to facilitate signaling and because of cable length limits. A single-sheave snatch block located between cars on the train center line will provide the necessary *lateral* pull. Vehicles passing this point can be towed by a vehicle on the ground with personnel guiding its passage. A long tow cable from the towing vehicle will lessen the trend of the vehicle to stray from the center line of the train.

Note. The snatch block fastening chain must be lashed to an adjacent object or stake to offset the cross pull of the powered winch (fig 260). Block movement is allowed for low front winches and high rear (wrecker) winches.

(2) *Gondola car loading.*

(*a*) Fixed-end type gondola cars may be loaded only when hoisting facilities are available for initial loading and for unloading at destination. Hopper- or drop-bottom gondolas are not to be used for shipments of unboxed vehicles without false flooring.

(*b*) Drop-end gondola cars may be loaded exactly as described for flatcars ((1) above). Height of fixed sides is immaterial. Vehicles may progress through a gondola car by passing over the two inwardly dropped ends and over spanning

Figure 258. Construction of improvised loading ramp.

platforms. Vehicles selected to remain in a gondola car are first moved to the *closed* end of the car, then spread out for blocking after the remaining end is closed and latched.

Note. Do not block vehicle flush against ends of gondola car. When ordering gondola cars, specify inside width required as some may be received with gussets along the inner sides which affect clearance.

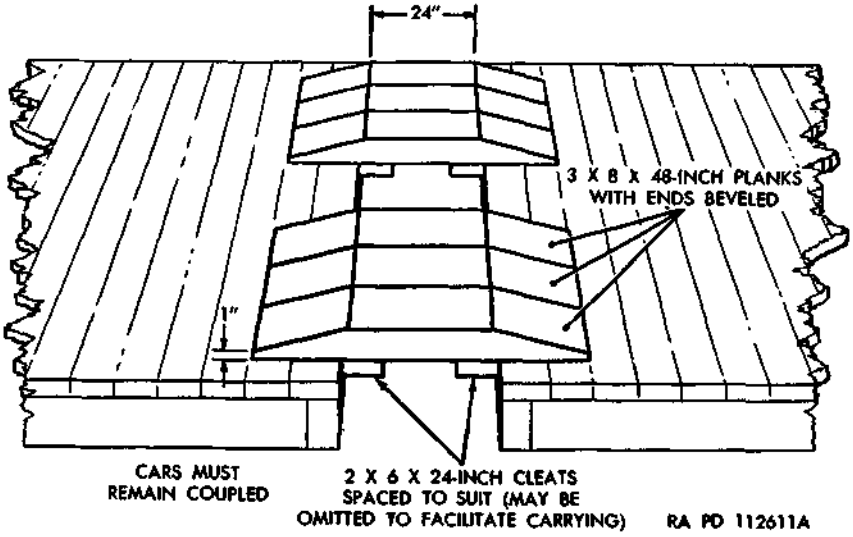


Figure 259. Construction of improvised spanning platforms.

(3) *Loading ramp.*

(*a*) A ramp for end-loading of vehicles on open-top freight cars may be improvised when no permanent ramps or hoisting facilities are available. An ideal ramp suitable for the loading of most ordnance items is shown in figure 258. For loading the 2½-ton 6 x 6 and 6 x 4 trucks, the width of the ramp may be reduced to two double-plank runways, each cleated together. Length of planking must be determined with consideration to under-chassis clearance, in order to clear the hump at upper end of ramp.

Caution: Personnel guiding the vehicle up the ramp must exercise care when working close to the edges of the ramp planking.

(*b*) The flatcar bearing the ramp must be securely blocked against rolling, particularly when the car brakes are not applied as in train loading. Successive cars must remain coupled and be additionally chocked at several points along the train when ground towing of vehicles aboard the train is being effected.

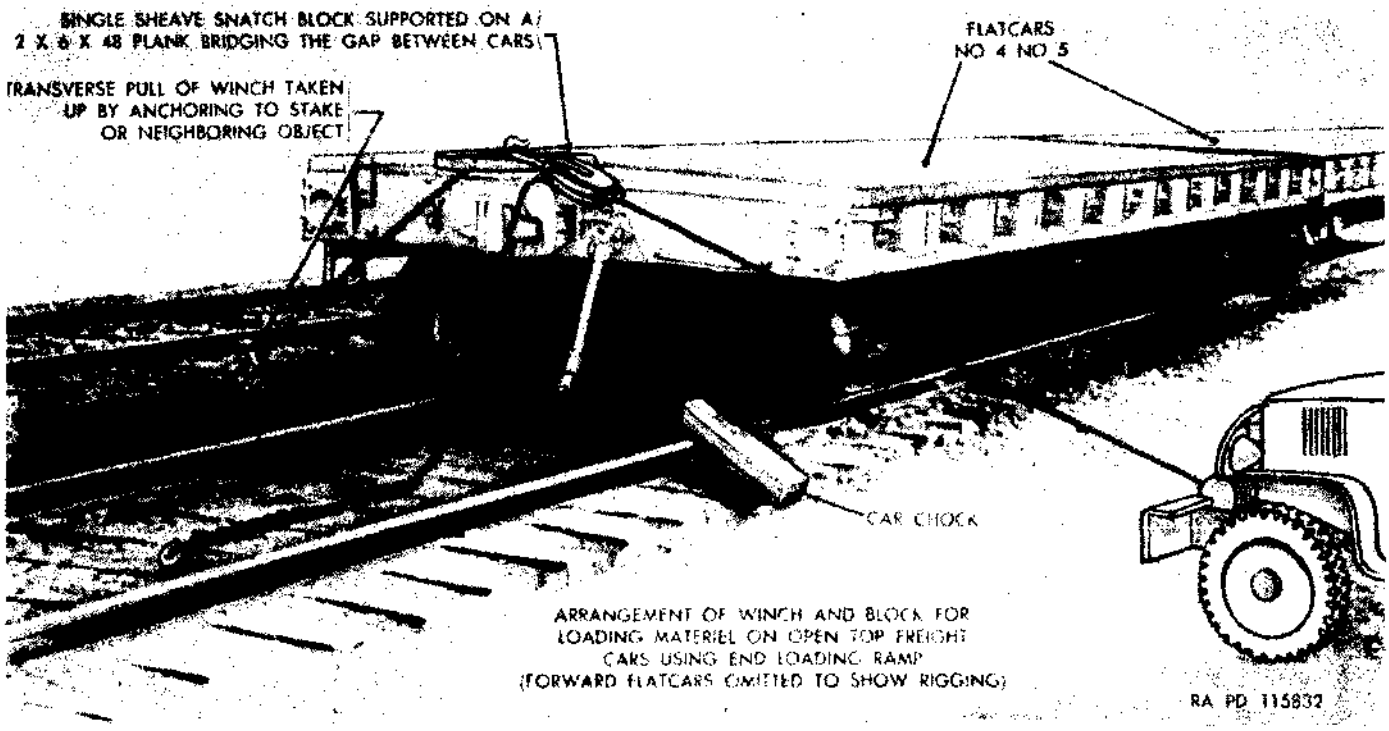


Figure 260. Method of powering the towing cable.

(*c*) Whenever the freight cars are not on an isolated track or blocked siding, each end approach to the train must be placarded (blue flag or light) to advise that men are at work and that the siding may not be entered beyond those points.

(*d*) Upon completion of the loading operation, the ramp planks and bridging devices should be loaded on the train for use in unloading operations. Random sizes of timbers used in building the approach apron up to rail level should be included. All materials should be securely fastened to the car floors after vehicles are blocked in place and entered upon the bill of lading. Railroad ties borrowed for the operation need not be forwarded to the unloading point unless specifically required and only with the consent of the owner.

d. LOADING RULES. For general loading rules pertaining to rail shipment of ordnance vehicles, refer to TB 9–OSSC–G.

253. Blocking the 2½-Ton 6 x 6 and 6 x 4 Trucks for Rail Shipment

a. GENERAL. All blocking instructions specified herein are minimum and are in accordance with the Association of American Railroads "Rules Governing the Loading of Commodities on Open Top Cars." Additional blocking may be added as required at the discretion of the officer-in-charge. Double-headed nails may be used if available, except in the lower piece of two-piece blocking. All item reference letters given below refer to the details and locations as shown in figure 261. The truck shown is not the GMC truck but method of blocking is applicable.

Note. Any loading methods or instructions developed by any source which appear in conflict with this publication or existing loading rules of the carriers, must be submitted to the Chief of Ordnance, Washington 25, D. C., for approval.

b. BRAKE WHEEL CLEARANCE "A." Load trucks on cars with a minimum clearance of at least 4 inches below and 6 inches above, behind, and to each side of the brake wheel (fig. 261). Increase clearance as much as is consistent with proper location of load.

Note. Vehicle should be spotted on flatcar so that wheels are centered between stake pockets in order that wheel strapping "G" (*h* below) provides uniform cross wiring.

c. CHOCK BLOCKS "B" (6 X 8 X 24-IN; 12 REQUIRED PER TRUCK). Locate the 45° face of blocks against the front and rear of front wheels, in front of intermediate wheels, and in back of rear wheels. Blocks are to be positioned in such a manner as to allow flush application of wheel side cleats "D" (*e* below) when nailed to chock blocks. Nail heel of blocks to car floor with three fortypenny nails and toenail sides of blocks to car floor with two fortypenny nails each.

Note. Chock blocks may be cut from timber (or railroad ties when available) as shown in figure 262.

d. Cushioning Material "C" (fig. 261). Locate suitable cushioning material such as waterproof paper, burlap, etc., between tires and cleats "D." The cushioning material must protrude beyond cleats "E" at floor and above cleats "D."

e. Wheel Side Cleats "D" (Front Wheels 1 x 8 x 59-in; Rear Wheels 1 x 8 x 103-in; Two of Each Required). Locate cushioning material (*d* above) against tires and locate and nail cleats to chock blocks "B" with four tenpenny nails at each end.

f. Floor Side Cleats "E" (Front Wheels 2 x 4 x 35-in; Rear Wheels 2 x 4 x 79-in; Four of Each Required).

Note. Four shorter double cleats may be used in lieu of the long ones specified for rear wheels. Locate one pair on vertical center line of each rear and intermediate wheel.

Locate two floor side cleats against each wheel side cleats "D" with cushioning material protruding underneath. Nail lower cleats to car floor with four thirtypenny nails at front wheels and ten thirtypenny nails at rear wheels. Nail upper cleats to lower cleats and car floor with four fortypenny nails at front wheels and ten fortypenny nails at rear wheels.

g. Cross Cleats "F" (2 x 4-in; Length to Suit, Four Required Per Truck). Locate two cleats across the top of the front chock blocks (front of wheels) and two cleats across the rear chock blocks (rear of wheels). Nail lower cleats to the top of chock blocks with two thirtypenny nails at each end. Nail upper cleats to the lower cleats and top of chock blocks with two fortypenny nails, staggered at each end.

h. Wheel Strapping "G" (No. 8 Gage Black Annealed Wire, Length to Suit).

Note. For gondola car loading wheel strapping will not be required.

(1) *Front wheels.* Pass one wire (consisting of four strands, twist-tied together) through ventilating hole at upper part of front wheel slightly *forward* of center and out through adjacent ventilating hole. Attach to stake pocket *rearward* of front wheel, bringing both ends of wire together. Twist-tie and tighten with rod or bolt just taut enough to remove all slack. Pass one wire (consisting of four strands twist-tied together) through ventilating hole at upper part of front wheel slightly *rearward* of center and out through adjacent ventilating hole crossing initial wires. Attach to stake pocket *forward* of front wheel bringing both ends of wire together. Twist-tie and tighten with rod or bolt just taut enough to remove all slack. Repeat above operations for the other front wheel.

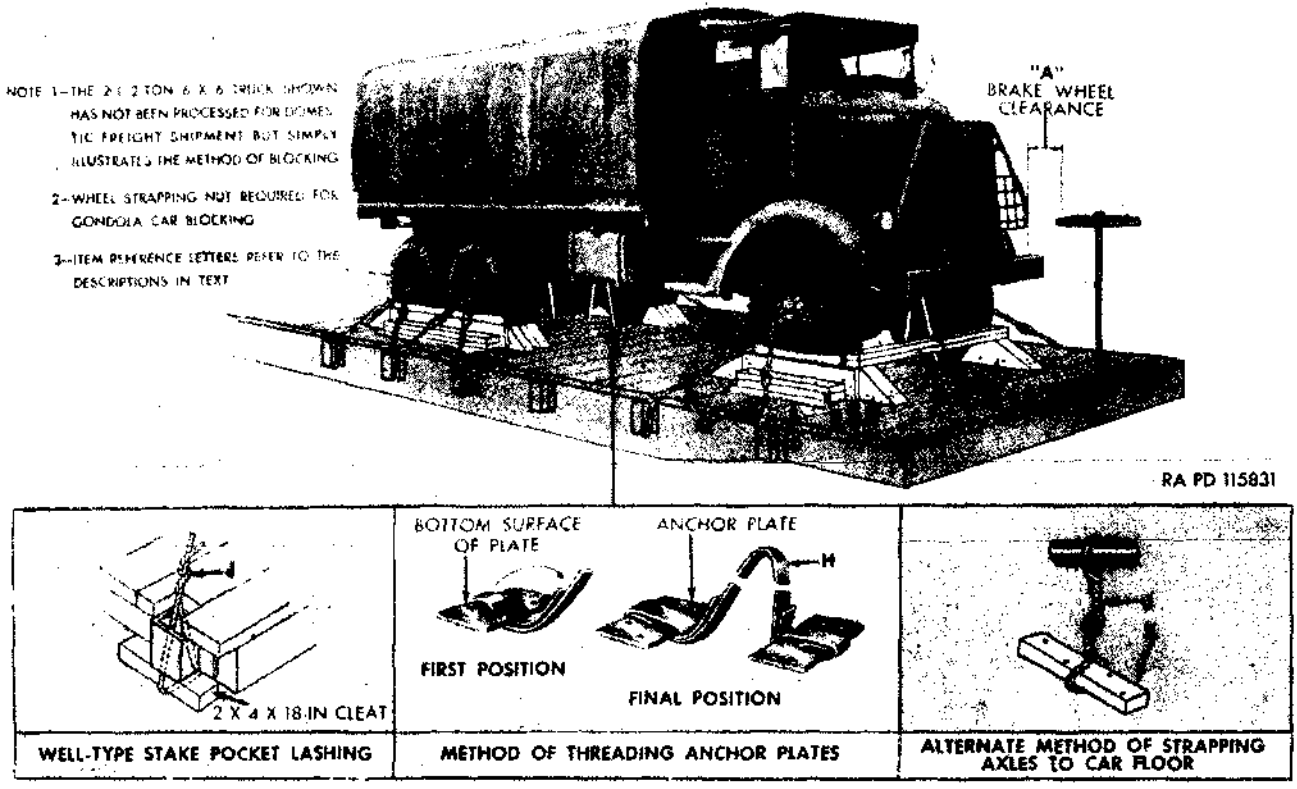


Figure 261. Method of blocking 2½-ton 6 x 6 and 6 x 4 trucks for rail shipment.

(2) *Rear wheels.* Each outside intermediate and rear wheel will be crosswired to stake pocket as prescribed for the front wheels ((1) above) (fig. 261).

Note. Wires are passed through stake pockets in a manner that the wire loop lays against the car frame. A short stake driven into the stake pocket will protect the wire loop from chafing and loosening. (This stake is omitted in fig. 261.) When flatcars are received which are provided with well-type stake pockets, a loop of strapping wire is passed through the stake pocket and a short piece of wood about 2 x 4 x 18 inches is inserted in the loop, below the stake pocket. Subsequent tightening of the strapping will cause the wire to draw the wooden block securely against the bottom of stake pocket.

i. AXLE STRAPPING "H." Locate two pieces of 1-inch No. 14 BW gage hot-rolled steel strapping over each axle (close to brakes) and coil around steel anchor plates as shown in figure 261. Secure by nailing anchor plates to car floor with not less than six twentypenny nails (double-headed nails preferred). As an alternate method of securing axles, substitute a wire "J" (consisting of four strands of No. 8 gage black annealed wire or wires of equivalent strength) at each location for steel strapping "H." Pass wires over axle and around wooden cleats "K" (2 x 4 x 18-in). Locate cleats lengthwise of car and nail to car floor with four thirtypenny nails in each cleat. Bring both ends of wires together and twist taut with rod or bolt just enough to take up slack (fig. 261).

254. Oversea Shipment

a. INSPECTION STANDARDS. All used vehicles destined for oversea use will be inspected prior to shipment to determine their serviceability in accordance with standards given in SB 9–2.

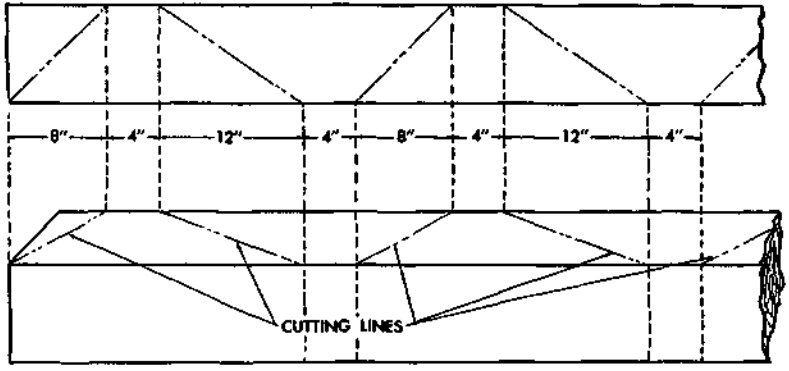
b. PREPARATION FOR SHIPMENT TO PORTS. All vehicles destined to ports of embarkation for oversea shipment that have already been processed for domestic shipment (par. 250) will be further processed in accordance with SB 9–4.

Note. Ports of embarkation will supplement any necessary additional or previously omitted processing upon receipt of vehicle for oversea shipment.

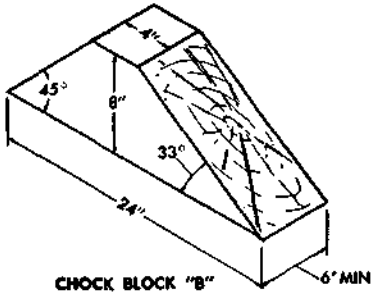
Section XLVI. DESTRUCTION OF MATÉRIEL TO PREVENT ENEMY USE

255. General

a. Destruction of the vehicle, when subject to capture or abandonment in the combat zone, will be undertaken by the using arm only when, in the judgment of the unit commander, such action is necessary in accordance with orders of, or policy established by, the army commander.

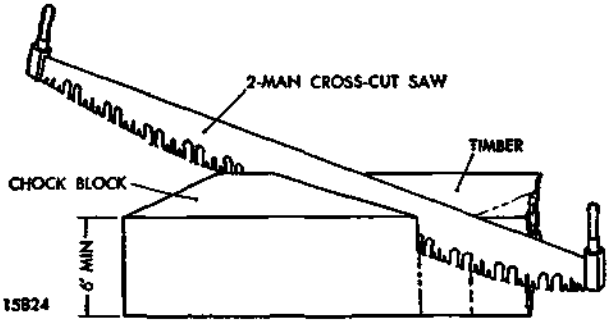


METHOD OF MARKING TIMBER
FOR CUTTING CHOCK BLOCKS



CHOCK BLOCK "B"

NOTE: RAILROAD TIES MAY BE SUBSTITUTED FOR TIMBERS WHEN AVAILABLE



RA PD 115824

Figure 262. Cutting chock blocks from timbers.

b. The information which follows is for guidance only. Certain of the procedures outlined require the use of explosives and incendiary grenades which normally may not be authorized items for the vehicle. The issue of these and related materials, and the conditions under which destruction will be effected, are command decisions in each case, according to the tactical situation. Of the several means of destruction, those most generally applicable are—

Mechanical—Requires ax, pick mattock, sledge, crowbar, or similar implement.

Burning —Requires gasoline, oil, incendiary grenades, or other inflammables.

Demolition —Requires suitable explosives or ammunition.

Gunfire —Includes artillery, machine guns, rifles using rifle grenades, and launchers using antitank rockets. Under some circumstances hand grenades may be used.

In general, destruction of essential parts, followed by burning, usually will be sufficient to render the matériel useless. However, selection of the particular method of destruction requires imagination and resourcefulness in the utilization of the facilities at hand under the existing conditions. Time usually is critical.

c. If destruction to prevent enemy use is resorted to, the matériel must be so badly damaged that it cannot be restored to a usable condition in the combat zone either by repair or cannibalization. Adequate destruction requires that all parts essential to the operation of the matériel, including essential spare parts, be destroyed or damaged beyond repair. However, when lack of time and personnel prevents destruction of all parts, priority is given to the destruction of those parts most difficult to replace. Equally important, the same essential parts must be destroyed on all like matériel so that the enemy cannot construct one complete unit from several damaged ones.

d. If destruction is directed, due consideration should be given to—

(1) Selection of a point of destruction that will cause greatest obstruction to enemy movement and also prevent hazard to friendly troops from fragments or ricocheting projectiles which may occur incidental to the destruction.

(2) Observance of appropriate safety precautions.

256. Detailed Instructions

a. Method No. 1—By Burning.

(1) Remove and empty portable fire extinguishers.

(2) Puncture fuel tanks as near the bottom as possible, collecting gasoline for use as outlined in (6) below.

(3) Using an ax, pick, sledge, or other heavy implement, smash all vital elements such as distributor, carburetor, generator, ignition coil, fuel pump, spark plugs, air cleaner, lights, instruments, and controls. If time permits, and a sufficiently heavy implement is available, smash the engine cylinder block and head, crankcase, and transmission.

(4) Slash tires. If tires are inflated, exercise care to prevent injury should the tire blow out while being slashed. Whenever practicable, it is usually preferable to deflate tires before slashing.

(5) Remove ammunition from packing or other protective material. Place ammunition in and about the vehicle so that it will be fully exposed to the fire and in such locations that the greatest damage will result from its detonation. Remove any safety devices from ammunition.

(6) Pour gasoline and oil in and over the entire vehicle—ignite and take cover. Elapsed time: About 6 minutes.

b. METHOD NO. 2—WITH DEMOLITION MATERIALS.

(1) Remove and empty portable fire extinguishers.

(2) Puncture fuel tank.

(3) Prepare two 2-pound charges of EXPLOSIVE, TNT (two 1-lb blocks or equivalent per charge). Set the charges as follows:

(*a*) One on top of the clutch housing.

(*b*) The second, as low on the left side of the engine as possible. Connect the two charges for simultaneous detonation with detonating cord. Provide for dual priming to minimize the possibility of a misfire. For priming, either a nonelectric blasting cap crimped to at least 5 feet of safety fuse (safety fuse burns at the rate of 1 foot in 30 to 45 seconds) or an electric blasting cap and firing wire may be used. Safety fuse, which contains black powder, and blasting caps must be protected from moisture at all times. The safety fuse may be ignited by a fuse lighter or a match; the electric blasting cap requires a blasting machine or equivalent source of electricity.

Caution: Keep the blasting caps, detonating cord, and safety fuse separated from the charges until required for use.

Note. For the successful execution of methods of destruction involving the use of demolition materials, all personnel concerned will be thoroughly familiar with the provisions of FM 5-25. Training and careful planning are essential.

(4) Destroy the tires by placing an incendiary grenade under each tire. The detonation of the explosive charges should be delayed until the incendiary fires are well started. This

will prevent the fires from being extinguished by the blast when the charges are detonated.

(5) Detonate the charges. If primed with nonelectric blasting cap and safety fuse, ignite and take cover. If primed with electric blasting cap, take cover before firing. Elapsed time: About 6 minutes.

c. METHOD NO. 3—BY GUNFIRE.

(1) Remove and empty portable fire extinguishers.

(2) Puncture fuel tanks.

(3) Destroy the tires as in method No. 1 (*a* above)

(4) Destroy the vehicle by gunfire using artillery, machine guns, rifles using rifle grenades, or launchers using antitank rockets. Fire on the vehicle aiming at the engine, axles, and wheels. Although one well-placed direct hit may destroy the vehicle, several hits are usually required for complete destruction unless an intense fire is started, in which case the vehicle may be considered destroyed. Elapsed time: About 6 minutes.

Caution: Firing at ranges of 500 yards or less should be from cover.

d. METHOD NO. 4—MECHANICAL. Using an ax, pick, sledge, or any other heavy object, smash all vital elements, such as distributor, carburetor, air cleaner, generator, ignition coil, fuel pump, spark plugs, lights, instruments, and controls. If time permits, and a sufficiently heavy object is available, smash the engine cylinder block and head, crankcase, transmission, and axles. Slash and destroy tires

APPENDIX

REFERENCES

1. Publication Indexes

The following publication indexes and lists of current issue should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to matériel covered in this manual:

a. Index of Administrative Publications	SR 310–20–5
b. Index of Army Motion Pictures and Film Strips.	SR 110–1–1
c. Index of Army Training Publications	SR 310–20–3
d. Index of Blank Forms and Army Personnel Classification Tests.	SR 310–20–6
e. Index of Technical Manuals, Technical Regulations, Technical Bulletins, Supply Bulletins, Lubrication Orders, Modification Work Orders, Tables of Organization and Equipment, Reduction Tables, Tables of Allowances, Tables of Organization, Tables of Equipment, and Tables of Basic Allowances.	SR 310–20–4
f. Introduction and Index (supply catalogs)	ORD 1
g. Military Training Aids	FM 21–8

2. Supply Catalogs

The following catalogs of the Department of the Army Supply Catalog pertain to this matériel:

a. AMMUNITION.	
Ammunition, Rifle, Carbine, and Automatic Gun.	ORD 11 SNL T–1
b. ARMAMENT.	
Gun, Machine, Cal. .30, Browning, M1919A4, Fixed and Flexible; M1919A5, Fixed; and M1919A6; and Ground Mounts.	ORD (*) SNL A–6
Gun, Machine, Cal. .50, Browning, M2, Heavy Barrel, Fixed and Flexible; and Ground Mounts.	ORD (*) SNL A–39
c. MAINTENANCE AND REPAIR.	
Antifriction Bearings and Related Items	ORD 5 SNL H–12
Cleaners, Preservatives, Lubricants, Recoil Fluids, Special Oils, and Related Maintenance Materials.	ORD 3 SNL K–1

(*) See ORD 1, Introduction and Index, for published catalogs of the ordnance section of the Department of the Army Supply Catalog.

Items of Soldering, Metallizing, Brazing, and Welding Materials; Gases and Related Items.	ORD 3 SNL K–2
Lubricating Equipment, Accessories, and Related Dispensers.	ORD (*) SNL K–3
Major Items of Automotive and Semiautomotive Vehicles.	ORD 3 SNL G–1
Miscellaneous Hardware	ORD 5 SNL H–2
Oil Seals	ORD 5 SNL H–13
Ordnance Maintenance Sets	ORD 6 SNL N–21
Standard Hardware	ORD 5 SNL H–1
Tool-sets (Common), Specialists' and Organizational.	ORD 6 SNL G–27, Section 2
Tool-sets for Maintenance of Small Caliber Automatic and Semiautomatic Ground and Aircraft Weapons.	ORD 6 SNL A–35, Section 1
Tool-sets (Special), Motor Vehicles	ORD 6 SNL G–27, Section 1
d. VEHICLE.	
Truck, 2½-ton, 6 x 6 (GMC Models CCKWX–353, CCKW–352, 353, and AFKWX–353); Truck, 2½-ton, 6 x 4 (GMC Model CCW–353); and Truck, Bomb Service, M27.	ORD (*) SNL G–508

3. Explanatory Publications

The following explanatory publications contain information pertinent to this matériel and associated equipment.

a. AMMUNITION.	
Allocation and Distribution of Training Ammunition and Explosives within the Zone of Interior.	SR 710–60–50
Ammunition: General	SB 9–AMM–1
Ammunition: General	TM 9–1900
Explosives and Demolition	FM 5–25
Regulations for Firing Ammunition for Training, Target Practice, and Combat.	SR 385–310–1
Reports of Accident Experience	SR 385–10–40
Small Arms Ammunition	SB 9–AMM–4
Small Arms Ammunition	TM 9–1990
b. ARMAMENT.	
Browning Machine Gun, Cal. .50, HB, M2	FM 23–65
Browning Machine Guns, Cal. .30, M1917A1, M1919A4, and M1919A6.	FM 23–55
US Rifle, cal. .30, M1	FM 23–5

(*) See ORD 1, Introduction and Index, for published catalogs of the ordnance section of the Department of the Army Supply Catalog.

c. CAMOUFLAGE.

Camouflage	TM 5–267
Camouflage, Basic Principles	FM 5–20
Camouflage of Vehicles	FM 5–20B

d. DECONTAMINATION.

Decontamination	TM 3–220
Decontamination of Armored Force Vehicles	FM 17–59
Defense Against Chemical Attack	FM 21–40

e. GENERAL.

Automotive Brakes	TM 10–565
Automotive Power Transmission Units	TM 10–585
Chassis, Body, and Trailer Units	TM 10–560
Cooling Systems: Vehicles and Powered Ground Equipment.	TM 9–2858
Dictionary of United States Army Terms	TM 20–205
Driver Selection, Training, and Supervision, Wheeled Vehicles.	TM 21–300
Driver's Manual	TM 21–305
Fuels and Garburetion	TM 10–550
General Safety Manual	TM 20–350
General Supply: Winterization Equipment for Automotive Matériel.	SB 9–16
Hand, Measuring, and Power Tools	TM 10–590
Lubrication	TM 9–2835
Military Vehicles	TM 9–2800
Modification of Ordnance Matériel	SB 9–38
Motor Transport	FM 25–10
Motor Vehicles	AR 700–105
Mountain Operations	FM 70–10
Operation in Snow and Extreme Cold	FM 70–15
Precautions in Handling Gasoline	AR 850–20
Principles of Automotive Vehicles	TM 9–2700
Registration of Motor Vehicles	AR 850–10
Storage Batteries Lead-Acid Type	TM 9–2857

f. MAINTENANCE AND REPAIR.

Basic Maintenance Manual	TM 38–650
Cleaning, Preserving, Sealing, and Related Materials Issued for Ordnance Matériel.	TM 9–850
Inspection of Ordnance Matériel	TM 9–1100
Instruction Guide: Care and Maintenance of Ball and Roller Bearings.	TM 37–265
Lubrication Order: Truck, 2½-ton, 6 x 6 (GMC Models CCKW–352 and CCKW–353).	LO 9–801
Lubrication Order: Truck, 2½-ton, 6 x 4 (GMC Model CCW–353).	LO 9–U315
Maintenance and Care of Hand Tools	TM 9–867

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Maintenance and Care of Pneumatic Tires and Rubber Treads.	TM 31–200
Motor Vehicle Inspection and Preventive Maintenance Services.	TM 37–2810
Painting Instructions for Field Use	TM 9–2851
Preparation of Ordnance Matériel for Deep Water Fording.	TM 9–2853
g. SHIPMENT AND LIMITED STORAGE.	
Army Marking Directive	TM 38–414
Army Shipping Document	TM 38–705
Instruction Guide: Ordnance Packaging and Shipping (Posts, Camps, and Stations).	TM 9–2854
Ordnance Storage and Shipment Chart—Group G.	SB 9–OSSC–G
Preparation for Shipment of Unserviceable Transport and Combat Vehicle Major Assemblies.	SB 9–26
Preparation of Unboxed Ordnance Matériel for Shipment.	SB 9–4
Protection of Ordnance Matériel in Open Storage.	SB 9–47
Report of Damaged or Improper Shipment	SR 745–45–5
Standards for Oversea Shipment and Domestic Issue of Ordnance Matériel Other Than Ammunition and Army Aircraft.	TB ORD 385
Storage, Inspection, and Issue of Unboxed Serviceable Motor Vehicles; Preparation of Unserviceable Vehicles for Storage; and Deprocessing of Matériel Prior to Operation.	SB 9–63

[AG 300.7 (9 Mar 50)]

BY ORDER OF THE SECRETARY OF THE ARMY:

OFFICIAL:
EDWARD F. WITSELL
Major General, USA
The Adjutant General

J. LAWTON COLLINS
Chief of Staff, United States Army

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For explanation of distribution formula, see SR 310–90–1.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1951 O—939051

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WAR DEPARTMENT TECHNICAL MANUAL
TM 9-801

This manual, together with TM 9-1801, 10 Mar 1944 and TM 9-1802A, 15 Jul 1944, supersedes TM 10-1105, 18 Jul 1941; TM 10-1147, 26 Aug 1941; TM 10-1253, 8 Oct 1941; TM 10-1269, 19 Jan 1942; TM 10-1501, 12 Jul 1941; and TM 10-1563, 1 Jul 1944. In addition, this manual supersedes TM 9-801, 12 Apr 1943; OFSTB 801-1, 6 Apr 1943; OFSTB 801-4, 24 Jan 1944; OFSTB 10-1147-1, 6 Apr 1943; OFSTB 10-1501, 6 Apr 1943. Also, this manual supersedes the following publications insofar as they apply to this manual. These publications remain in force until such time as they are incorporated in other affected manuals or are specifically rescinded: OFSTB 800-15, 14 Jul 1943; WDTB ORD 13, 12 Jan 1944; WDTB ORD 20, 24 Jan 1944; WDTB ORD 26, 9 Feb 1944; and WDTB ORD 32, 18 Feb 1944.

TRUCK

2½-TON, 6 x 6

GMC CCKW-352 & 353

WAR DEPARTMENT *APRIL 1944*

WAR DEPARTMENT
Washington 25, D.C., 24 April 1944

TM 9-801, 2½-ton 6x6 Truck (GMC CCKW-352 and 353) is published for the information and guidance of all concerned.

[A.G. 300.7 (20 Nov 43)]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION: D 7 (5); B 18 (2); R 9 (4); Bn 2,4,5,6,7,8,9,17, 18, 44 (2); C 9 (8); IC 2,4,6,7,8,10,17,18,44 (2).

(For explanation of symbols, see FM 21-6.)

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TRUCK, 2½-TON, 6 x 6
(GMC CCKW-352 & 353)

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PART ONE—GENERAL

Section I

INTRODUCTION

1. SCOPE.

a. These instructions are published for the information and guidance of the personnel to whom this equipment is assigned. They contain information on the operation and maintenance of the Truck, 2½-Ton, 6x6, GMC CCKW-352 and 353, as well as descriptions of the major units and their functions in relation to the other components of this vehicle.

b. This manual has the following arrangement:

(1) Part One, General, contains description and data. It lists the tools, spare parts, and equipment carried on the vehicle. It also lists organizational special tools for this vehicle.

(2) Part Two, Operating Instructions, contains instructions for the operation of the vehicle with description and location of the controls and instruments.

(3) Part Three, Maintenance Instructions, contains information needed for the performance of the scheduled lubrication and preventive maintenance services, and instructions for maintenance operations which are the responsibility of the using organizations (first and second echelons). Stock numbers in this part were obtained from the Organizational Spare Parts and Equipment List of SNL G-508, 29 December 1943.

(4) The Appendix contains instructions for shipment and temporary storage, and a list of references including standard nomenclature lists, technical manuals, and other publications applicable to the vehicle.

2. RECORDS.

a. Forms and records applicable for use in performing prescribed operations are listed below with brief explanations of each.

(1) STANDARD FORM NO. 26, DRIVER'S REPORT—ACCIDENT, MOTOR TRANSPORTATION. One copy of this form will be kept with the vehicle at all times. In case of an accident resulting in injury or property damage, it will be filled out by the driver on the spot or as promptly as practical thereafter.

(2) WAR DEPARTMENT FORM NO. 48, DRIVER'S TRIP TICKET AND PREVENTIVE MAINTENANCE SERVICE RECORD. This form, properly executed, will be furnished to the driver when his vehicle is dispatched on non-tactical missions. The driver and the official user of the vehicle will complete in detail appropriate parts of this form. These forms need not be issued for vehicles in convoy or on tactical missions. The reverse side of this form contains the driver's daily and weekly preventive maintenance service reminder schedule.

(3) W.D., A.G.O. FORM NO. 478, MWO AND MAJOR UNIT ASSEMBLY REPLACEMENT RECORD. This form will be used by all personnel completing a modification or major unit assembly (engine,

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transmission, transfer case, and tracks) replacement to record clearly the description of work completed, date, vehicle hours, and/or mileage, and MWO number or nomenclature of unit assembly. Personnel performing the operation will initial in the column provided. Minor repairs, parts, and accessory replacements will not be recorded.

(4) W.D., A.G.O. FORM NO. 6, DUTY ROSTER. This form, slightly modified, will be used for scheduling and maintaining a record of vehicle maintenance operations. It may be used for lubrication records.

(5) W.D., A.G.O. FORM NO. 461, PREVENTIVE MAINTENANCE SERVICE AND TECHNICAL INSPECTION WORK SHEET FOR WHEELED AND HALF-TRACK VEHICLES. This form will be used for all 1,000-mile (monthly) and 6,000-mile (semi-annual) maintenance services and all technical inspections performed on wheeled or half-track vehicles.

(6) W.D., O.O. FORM NO. 7353, SPOT-CHECK INSPECTION REPORT FOR ALL MOTOR VEHICLES. This form may be used by all commanding officers or their staff representatives in making spot-check inspection on all vehicles.

(7) W.D., A.G.O. FORM NO. 468, UNSATISFACTORY EQUIPMENT RECORD. This form will be used for reporting manufacturing, design, or operational defects in material with a view to improving and correcting such defects, and for use in recommending modifications of material. This form will not be used for reporting failures, isolated material defects, or malfunctions of material resulting from fair wear and tear or accidental damage, nor for the replacement, repair, or the issue of parts and equipment. It does not replace currently authorized operational or performance records.

(8) W.D., O.O. FORM NO. 7370, EXCHANGE PART OR UNIT IDENTIFICATION TAG. This tag, properly executed, may be used when exchanging unserviceable items for like serviceable assemblies, parts, vehicles, and tools.

Section II

DESCRIPTION AND TABULATED DATA

3. DESCRIPTION.

a. General. Vehicles described in this manual are designated as *TRUCK, 2½-ton, 6 x 6, GMC CCKW-352 and 353.* The vehicles are equipped with one driving front axle and two driving rear axles, and six driving wheels. Conventionally mounted open type cab is used on all vehicles with either cargo, cargo-dump, gasoline tank, or water tank body. In addition to special purpose use, depending upon type of body, vehicles may also be used for towing tractors, guns, and other wheeled equipment.

b. General Characteristics.

(1) POWER PLANT. Six-cylinder, in-line, valve-in-head engine

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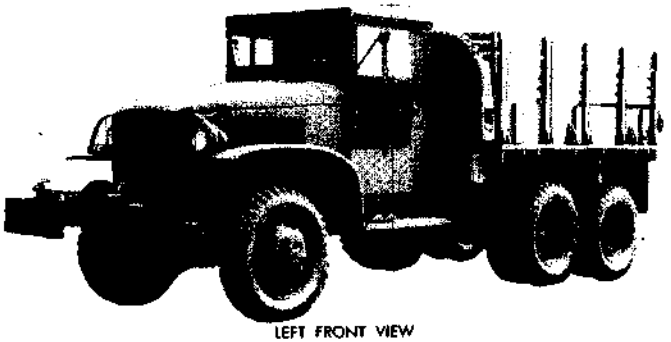
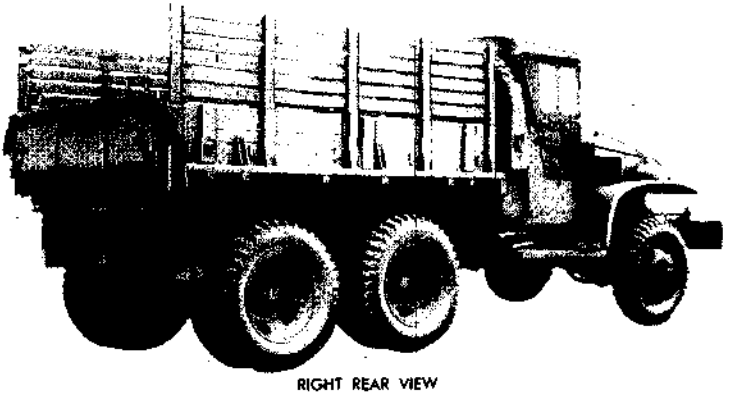
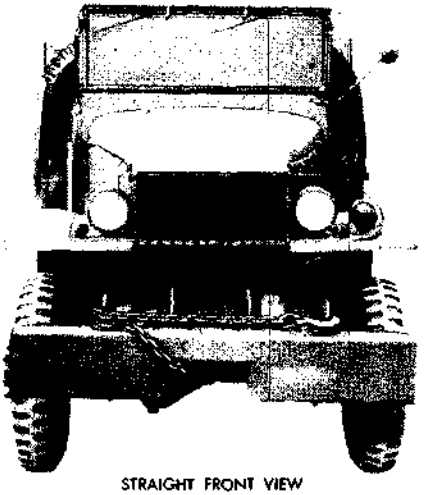
DESCRIPTION AND TABULATED DATA



LEFT FRONT VIEW



RIGHT REAR VIEW

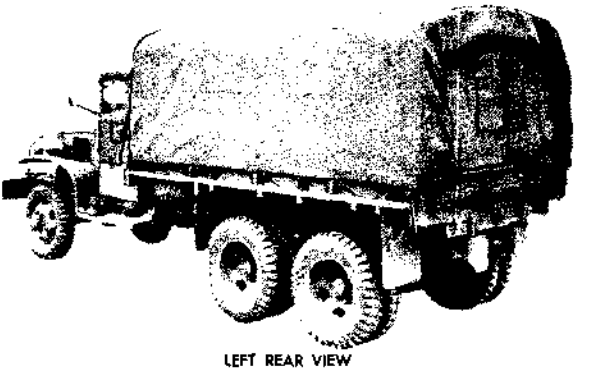


STRAIGHT FRONT VIEW

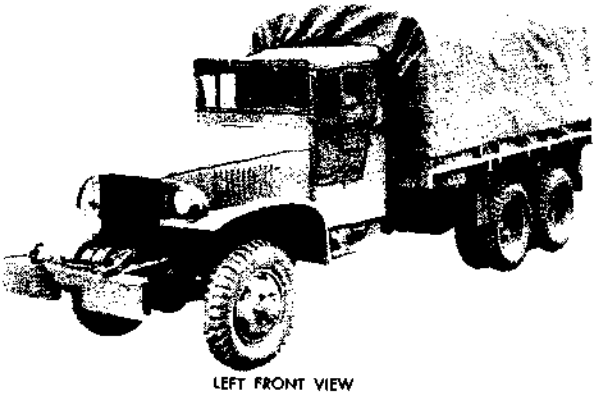
RA PD 332854

Figure 1—CCKW-352 (Short Wheelbase) with Cargo Body and Winch—Less Tarpaulin

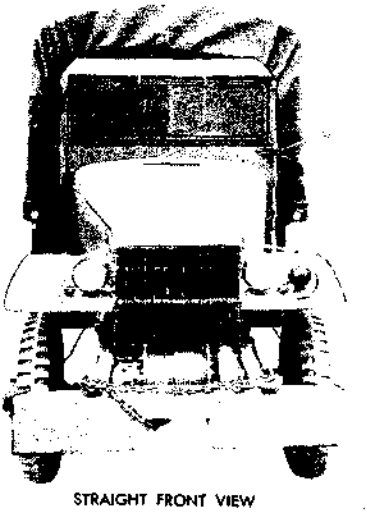
TRUCK, 2½-TON, 6 x 6



LEFT REAR VIEW



LEFT FRONT VIEW



STRAIGHT FRONT VIEW

RA PD 332691

Figure 2—CCKW-353 (Long Wheelbase) with Cargo Body and Winch—Tarpaulin Installed

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is three-point mounted at front end of chassis frame. Conventional accessories such as generator, cranking motor, distributor, oil filter, carbureter, air cleaner, clutch, etc., are attached to engine proper. Transmission, mounted to rear end of engine, has five speeds forward and one reverse, with direct drive in fourth speed and over-drive in fifth. Clutch is single dry-plate type attached directly to flywheel.

(2) AXLES, SUSPENSION, AND STEERING. Three driving axles are full-floating and may be either split or banjo type. Front axle incorporates special universal joints at the steering knuckles which permit steering of vehicle in conventional automotive manner. Suspension of axles from chassis frame is with semi-elliptic springs, with torque rod connections used at rear axles. Each front spring is attached to conventional two-channel type frame by a shackle at front end, and a bracket at rear end. Each rear spring is supported at the center on cross shaft bearings. Ends of rear springs are fitted into guides at wheel ends of rear axles.

(3) BRAKES. Service brakes are vacuum operated hydraulic type, operating two mechanical brake shoes at each wheel. Hydraulic master cylinder, operated by foot brake pedal, actuates Hydrovac power cylinder, which in turn transmits hydraulic pressure to wheel cylinders to apply brakes. Band type hand brake assembly is mounted on output shaft at rear of transfer case. Conventional latch type hand brake lever operates brake through rods and linkage for emergency stops, or to hold vehicle while parking.

(4) POWER DRIVE UNITS. Two-speed transfer case permits drive by rear axles, or front and rear axles, depending upon position of manual shift levers. Axles are driven through conventional type propeller shafts from transfer case. Power take-off for winch and hoist operation (when used) is mounted on left side of transmission, and drives these auxiliary units through universal joint type drive shafts.

(5) WINCH. The winch, when supplied, is mounted at front end of vehicle, and is driven through drive shaft by transmission power take-off.

(6) CAB. The two-man cab consists of a metal open top enclosure around driver's compartment. Cab is equipped with windshield, tarpaulin and hinged side curtains, and provision for gun mount ring.

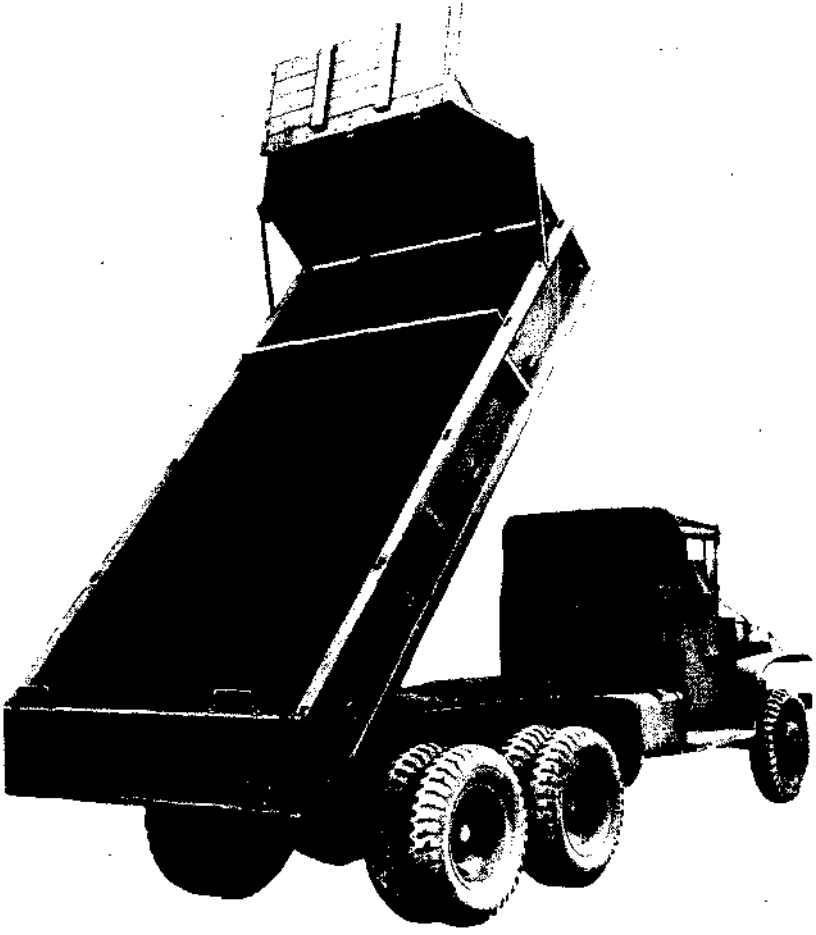
(7) BODY TYPES.

(a) Cargo (figs. 1 and 2). Wood type cargo body, equipped with troop seats, cargo racks, bows, and top tarpaulin, may be mounted on either long wheelbase (CCKW-353) or short wheelbase (CCKW-352) chassis.

(b) Cargo Dump (fig. 3). Metal type cargo dump body, equipped with troop seats, cargo racks, bows, and top tarpaulin, is mounted only on long wheelbase (CCKW-353) chassis with winch. Hydraulic hoist, mounted on subframe, raises body to dumping position.

(c) Gasoline Tank Body (fig. 4). Metal gasoline tank body, consisting of two 375 gallon tanks, is mounted only on long wheelbase (CCKW-353) chassis. Tank is equipped with dump valves and

TRUCK, 2½-TON, 6 x 6



RA PD 64759

Figure 3—CCKW-353 (Long Wheelbase) with Cargo Dump Body—Less Tarpaulin

similar equipment. Chassis upon which gasoline tanks are mounted are not equipped with winches or pintle hooks.

(d) Water Tank Body (fig. 5). Metal water tank body of 700 gallon capacity is mounted only on long wheelbase (CCKW-353) chassis. Tank body is equipped with auxiliary gasoline engine and pump unit, control valves, portable heating unit, and heating connections to chassis exhaust pipe system. Chassis upon which water tank bodies are mounted are not equipped with winches or pintle hooks.

(e) Special Purpose Bodies. Either long wheelbase or short wheelbase chassis (CCKW-353 or 352) with or without winch, may be used with special purpose bodies such as van, water purification,

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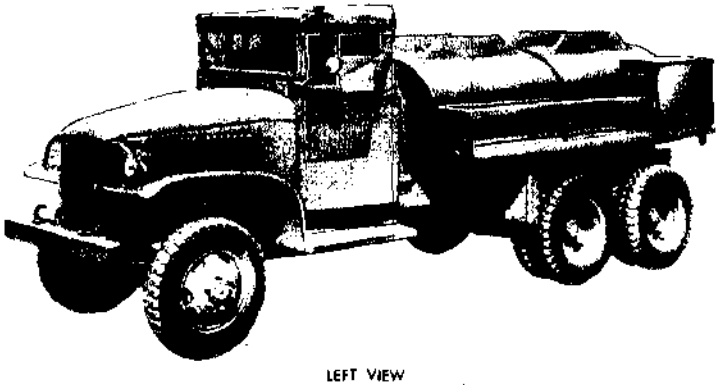
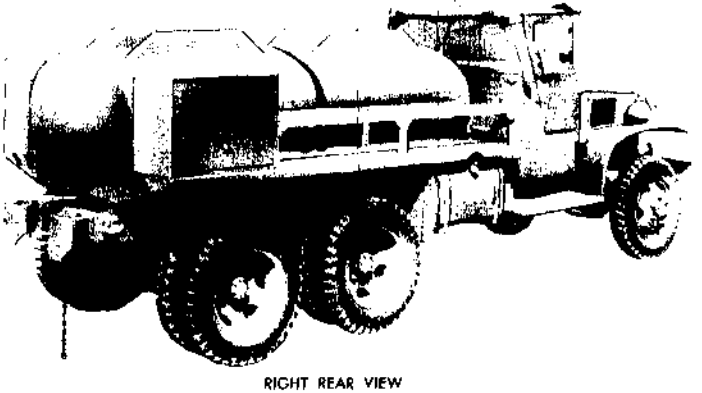
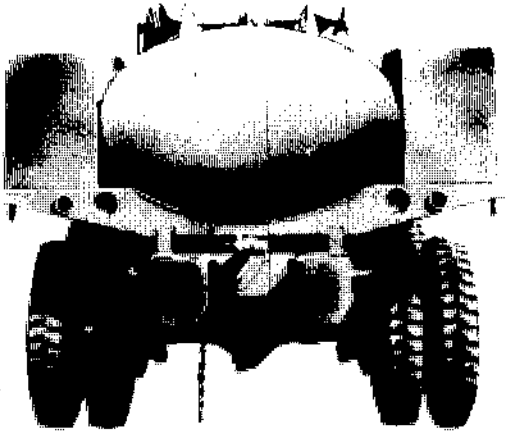
DESCRIPTION AND TABULATED DATA



LEFT VIEW



RIGHT REAR VIEW



STRAIGHT REAR VIEW

RA PD 332688

Figure 4—CCKW-353 (Long Wheelbase) with Gasoline Tank Body—Less Camouflage Equipment

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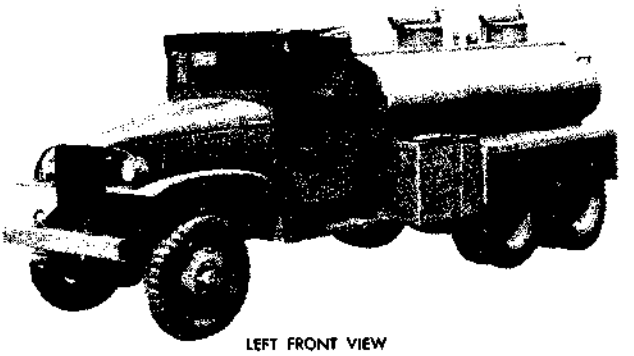
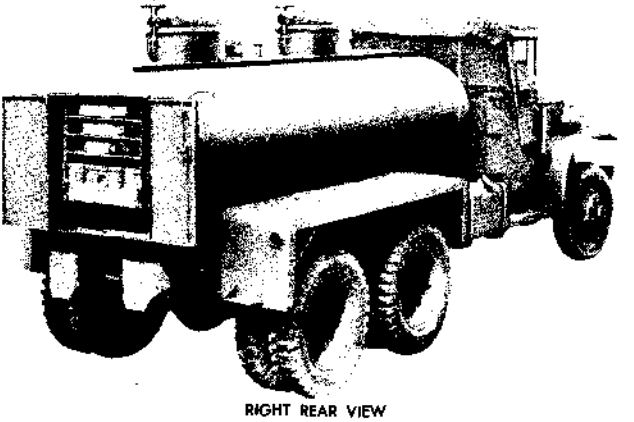
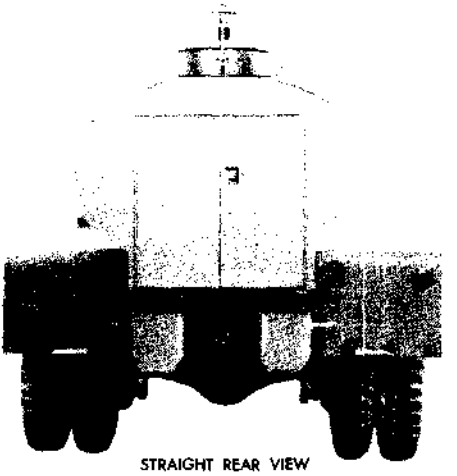
TRUCK, 2½-TON, 6 x 6



LEFT FRONT VIEW



RIGHT REAR VIEW



STRAIGHT REAR VIEW

RA PD 332868

Figure 5—CCKW-353 (Long Wheelbase) with Water Tank Body—Less Camouflage Equipment

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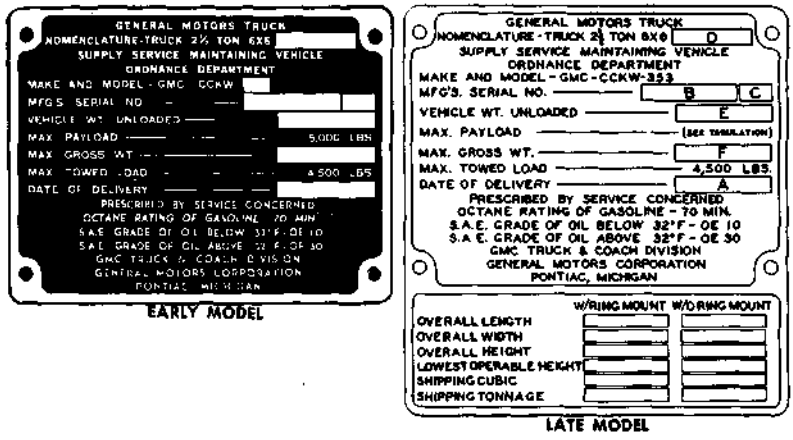
DESCRIPTION AND TABULATED DATA



RA PD 332860

Figure 6—Vehicle Nomenclature Plates

oil service, shop, topophoto, and air compressor. These bodies are not described in this manual.

4. DIFFERENCES AMONG MODELS.

a. Model Designation. Model designation symbols, together with suffix letters and numbers, are stamped on nomenclature plate (fig. 6). These identification letters and numbers are all that are necessary to identify the vehicle as to wheelbase, type of axle, body type, and whether or not it is equipped with a winch. The numerals appearing after the model designation and the equipment suffix represent the chassis serial number. The nomenclature plate used on late vehicles contains information pertinent to shipping (fig. 6). The following table itemizes and explains the vehicle identification symbols.

VEHICLE IDENTIFICATION

Symbols			Explanation of Symbols		
GMC Model	*Equipment Suffix*	*Chassis Wheelbase*	*Axle Type*	*Body Type*	*Winch*
CCKW-352	A1	145-inch	split	cargo	none
CCKW-352	B1	145-inch	split	cargo	yes
CCKW-352	A2	145-inch	banjo	cargo	none
CCKW-352	B2	145-inch	banjo	cargo	yes
CCKW-353	1	164-inch	split	none	with or without
CCKW-353	2	164-inch	banjo	none	with or without
CCKW-353	A1	164-inch	split	cargo	none

TRUCK, 2½-TON, 6 x 6

VEHICLE IDENTIFICATION (Cont.)

Symbols — **Explanation of Symbols**

GMC Model	Equipment Suffix	Chassis Wheelbase	Axle Type	Body Type	Winch
CCKW-353	A2	164-inch	banjo	cargo	none
CCKW-353	B1	164-inch	split	cargo	yes
CCKW-353	B2	164-inch	banjo	cargo	yes
CCKW-353	D1	164-inch	split	gas tank	none
CCKW-353	D2	164-inch	banjo	gas tank	none
CCKW-353	A1	164-inch	split	water tank	none
CCKW-353	G2	164-inch	banjo	water tank	none
CCKW-353	H1	164-inch	split	dump	yes
CCKW-353	H2	164-inch	banjo	dump	yes

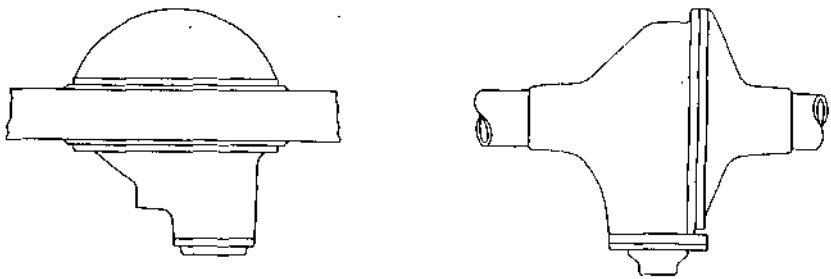


Figure 7—Axle Housing Identification

b. Axle Housing Types. Vehicles may be equipped with either split type (indicated by suffix numeral *1*) or banjo type (indicated by suffix numeral *2*). These axle housing types can be identified as illustrated in figure 7.

c. Spare Tire and Vehicle Gas Tank Location.

(1) SHORT WHEELBASE (CCKW-352). Spare tire and wheel carrier, and gasoline tank on short wheelbase chassis (CCKW-352) are mounted across chassis frame at rear of cab.

(2) LONG WHEELBASE (CCKW-353). On long wheelbase chassis with cargo or cargo dump body only, spare wheel and tire are mounted under body on frame left side rail. The gasoline tank is mounted on frame right side rail immediately forward of forward rear wheel. On long wheelbase chassis with gas or water tank body, the spare wheel and tire are mounted on frame back of cab, while vehicle fuel tank location remains the same as on conventional long wheelbase chassis.

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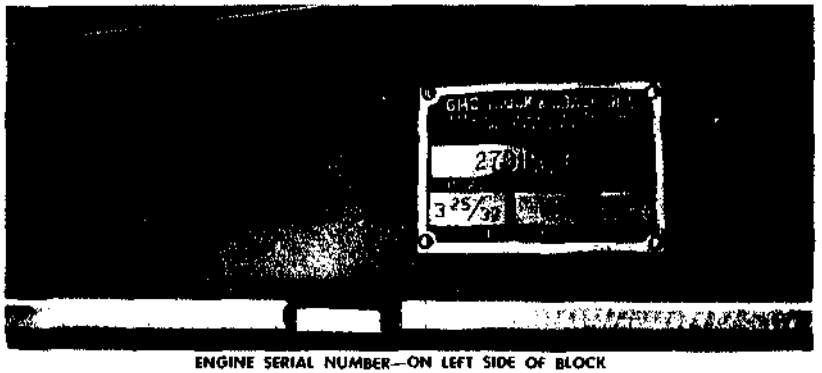
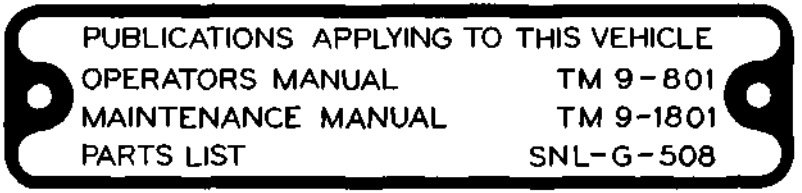
DESCRIPTION AND TABULATED DATA

ENGINE SERIAL NUMBER—ON RIGHT SIDE OF BLOCK



ENGINE SERIAL NUMBER—ON LEFT SIDE OF BLOCK



PUBLICATIONS PLATE

RA PD 332890

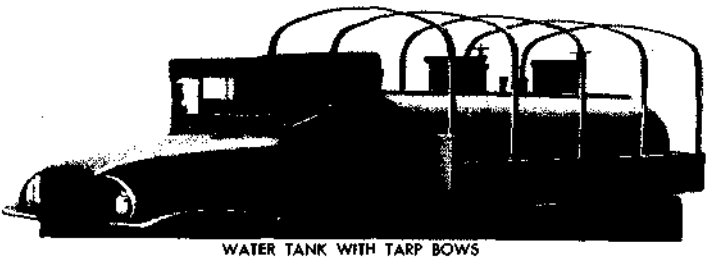
Figure 8—Engine Serial Number and Publication Plates

d. Engine Serial Number and Plate (fig. 8). This plate includes engine serial number, cylinder bore, piston stroke, and number of cylinders. Plate is attached to left side of engine crankcase. Engine serial number is also stamped on right side of engine crankcase near distributor.

e. Publication Plate (fig. 8). This plate includes TM numbers of technical manuals and parts list to use with vehicle. Plate is located on dash panel above package compartment.

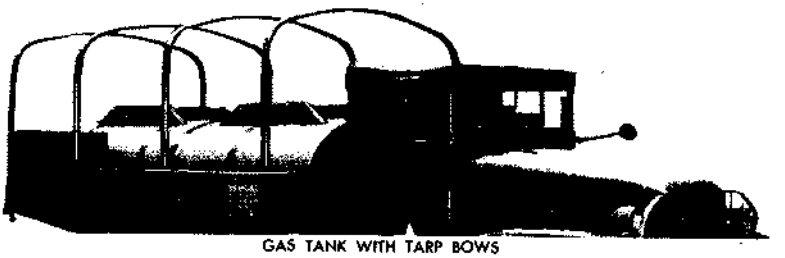
f. Water Tank and Gasoline Tank Body Camouflage (fig. 9). Some vehicles, equipped with water tank or gasoline tank bodies, are provided with bows and tarpaulins to serve as camouflage. With tarpaulin installed, vehicles have the appearance of cargo bodies.

TRUCK, 2½-TON, 6 x 6



WATER TANK WITH TARP BOWS

WATER TANK WITH TARP INSTALLED



GAS TANK WITH TARP BOWS

RA PD 332944

Figure 9—Tarpaulin Camouflage Equipment for Water or Gasoline Tank Body

5. TABULATED DATA.

a. Engine Specifications (All Vehicles).

Type	Valve-in-head
Number of cylinders	6 in-line
Horsepower (S.A.E.)	34.35
Displacement (Cu in.)	269.5
Bore (in.)	$3^{25}/_{32}$
Stroke (in.)	4
Engine governed speed (rpm)	2,750

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b. **Chassis and Body Specifications and Dimensional Data.**

(1) VEHICLE WEIGHTS (Approx.).

	MODELS				
	CCKW-352 A1-A2-B1-B2	CCKW-353 A1-A2-B1-B2	CCKW-353 H1 or H2	CCKW-353 D1 or D2	CCKW-353 G1 or G2
Chassis and cab only—with fuel, oil, and water (lb)					
With winch	9,167	8,800	8,696		
Without winch	8,462	8,100	.....		
Chassis, cab, and body—with fuel, oil, and water (lb)					
With winch	11,050	11,050	11,950	.....	.....
Without winch	10,350	10,350	.....	10,750	12,025
Maximum permissible payload (lb)	5,000	5,000	5,000	750 (gal)	700 (gal)
Maximum permissible towed load (lb)	4,500	4,500	4,500	4,500	4,500
Gross weight (lb)					
With winch	16,400	16,400	17,300	.....	.....
Without winch	15,700	15,700	.....	15,750	18,200

(2) DIMENSIONAL DATA (fig. 10).

Shipping cubic					
With winch—with ring mount	1,246	1,375	1,378	.....	.....
With winch—without ring mount	975	1,043	1,058	.....	.....
Without winch—with ring mount	1,180	1,305	.....	1,334	1,316
Without winch—without ring mount	897	991	.....	1,086	1,252
Shipping Tonnage					
With winch—with ring mount	31.4	34.5	34.8	.....	.....
With winch—without ring mount	24.5	26.0	26.5	.....	.....
Without winch—with ring mount	29.5	32.5	.....	33.4	33.0
Without winch—without ring mount	22.4	24.8	.....	27.2	31.4

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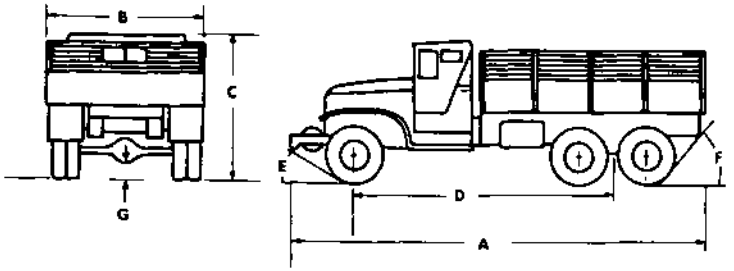

A OVER-ALL LENGTH
B OVER-ALL WIDTH
C OVER-ALL HEIGHT
D WHEELBASE

E ANGLE OF APPROACH
F ANGLE OF DEPARTURE
G GROUND CLEARANCE TO AXLE

NOTE—REFER TO TABULATED DATA

RA PD 332849

Figure 10—Vehicle Dimensional Drawing (CCKW-353 With Cargo Body and Winch Shown)

	MODELS				
Maximum overall length (in.)	CCKW-352 A1-A2-B1-B2	CCKW-353 A1-A2-B1-B2	CCKW-353 H1 or H2	CCKW-353 D1 or D2	CCKW-353 G1 or G2
With winch	244⅞	270⅛	272¾	.....	.....
Without winch	231	256¼	.....	253½	253½
Maximum overall width (in.)	88	88	88	91	90
Maximum overall height (in.)					
Cab—loaded	91	91	91	91	91
Cab—unloaded	93	93	93	93	93
Tarpaulin installed—loaded (without ring mount)	107⅛	107⅛	108	106⅛	106⅛
Tarpaulin installed—unloaded (without ring mount)	109⅛	109⅛	110	108⅛	108⅛
With ring mount—loaded	117	117	117	117	117
With ring mount—unloaded	119	119	119	119	119
Protection plate—loaded	.....	.....	111¾	.....	.....
Protection plate—unloaded	.....	.....	113¾	.....	.....

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Tank—loaded	.....	.....	.....	79½	93
Tank—unloaded	.....	.....	.....	81½	95
Lowest operable height (in.)					
With ring mount—loaded	98	98	98	98	98
With ring mount—unloaded	100	100	100	100	100
Without ring mount—loaded	74	74	74	79½	93
Without ring mount—unloaded	76	76	76	81½	95
Nominal wheelbase (in.)	145	164	164	164	164
Tread (in.)					
Front—banjo	60	60	60	60	60
Front—split	62¼	62¼	62¼	62¼	62¼
Rear—banjo	67½	67½	67½	67½	67½
Rear—split	67¾	67¾	67¾	67¾	67¾
Tire size	7.50 x 20	7.50 x 20	7.50 x 20	7.50 x 20	7.50 x 20

(3) OPERATIONAL DATA (fig. 10).

Angle of approach (deg)					
With winch	31	31	31	.....	.....
Without winch	54	54	.....	54	54
Angle of departure (deg)	44	36	36	36	36
Ground clearance at axles (in.)	9⅞	9⅞	9⅞	9⅞	9⅞
Minimum outside wheel track turning circle diameter—front axle disengaged—left or right turn (ft)	68	70	70	70	70
Maximum gradeability (percent)					
Direct	3½*	3½*	3½	3½	3½
Low	65*	65*	65	65	65
Maximum allowable speed (mph)	45	45	45	45	45

*With 19,500 lb G.T.W.

TRUCK, 2½-TON, 6 x 6

Section III

TOOLS, PARTS, AND ACCESSORIES

6. PURPOSE

a. The lists in this section are for information only and must not be used as a basis for requisition.

7. ON VEHICLE TOOLS.

a. **Pioneer Tools** (fig. 11).

Quantity Per Vehicle	Stockage Number	Name	Stowage Location
1	41-A-1277	Axe, chopping, single bit, 5 lb.	R. H. running board
1	41-M-720*	Mattock, pick M1, with handle	R. H. running board
1	41-S-3170	Shovel, D handle, round point	L. H. running board

b. **Vehicle Tools** (fig. 12).

(1) Following tools are supplied with all vehicles:

1	41-H-523	Hammer, machinists, 16-oz.	Tool compartment
1	GM-2146130	Handle, wrench (used with wheel nut wrench)	Tool compartment
1	41-J-72	Jack, hydraulic, 3-ton, with handle	Tool compartment
1	41-P-1650	Pliers, combination—6-in.	Tool compartment
1	41-S-1076	Screw driver, common, heavy duty, 6-in.	Tool compartment
1	41-S-1636	Screw driver, No. 1, cross recess—3-in.	Tool compartment
1	41-S-1638	Screw driver, No. 2, cross recess—4-in.	Tool compartment
1	41-S-1640	Screw driver, No. 3, cross recess—6-in.	Tool compartment
1	41-S-1642	Screw driver, No. 4, cross recess—8-in.	Tool compartment
1	41-W-991	Wrench, engineers, open end, 3/8-in. and 7/16-in.	Tool compartment
1	41-W-1003	Wrench, engineers, open end, 1/2-in. and 19/32-in.	Tool compartment
1	41-W-1005-5	Wrench, engineers, open end, 9/16-in. and 11/16-in.	Tool compartment
1	41-W-1008-10	Wrench, engineers, open end, 5/8-in. and 25/32-in.	Tool compartment

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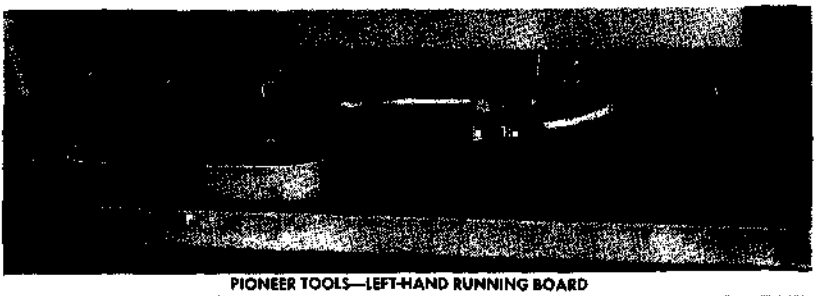
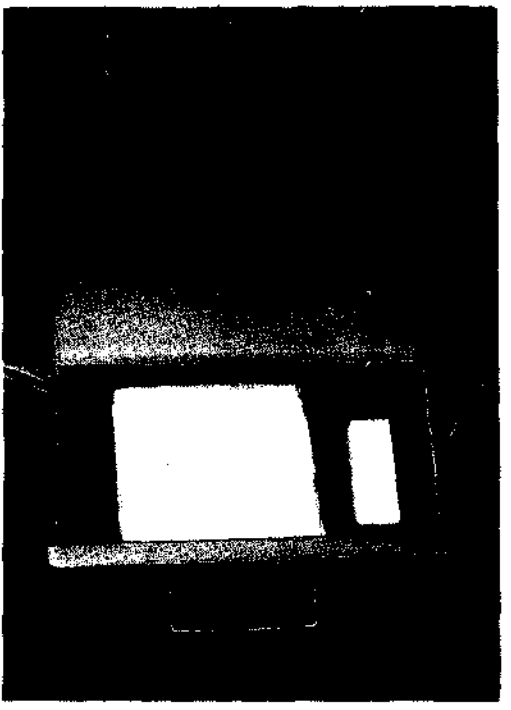
TOOLS, PARTS, AND ACCESSORIES

PIONEER TOOLS—RIGHT-HAND RUNNING BOARD



PIONEER TOOLS—LEFT-HAND RUNNING BOARD



SPARE PARTS KIT CONTAINER

GASOLINE CAN SPOUT

RA PD 332993

Figure 11—Pioneer Tools, Spare Parts Kit, and Oil Can Spout

TRUCK, 2½-TON, 6 x 6

Quantity Per Vehicle	Stockage Number	Name	Stowage Location
1	41-W-1012-5	Wrench, engineers, open end, ¾-in. and ⅞-in.	Tool compartment
1	41-W-450	Wrench, adj. auto type—15-in.	Tool compartment
1	41-W-3335-50	Wrench, spark plug, with handle	Tool compartment
1	41-W-3838-30	Wrench, wheel nut	Tool compartment

(2) The following tool is included in vehicles equipped with banjo type axles:

1	41-W-1493-30	Wrench, wheel bearing nut	Tool compartment

(3) The following tools are included in vehicles equipped with split type axles:

1	41-W-1991-10	Wrench, front wheel bearing nut	Tool compartment
1	41-W-3825-100	Wrench, rear wheel bearing nut	Tool compartment

(4) The following additional tools are supplied with vehicles equipped with water tank bodies:

1	41-P-1650	Pliers, combination—6-in.	Equipment chest
1		Screw driver—3-in.	Equipment chest
1		Wrench, adj. hydrant	Equipment chest
1		Wrench, box end—½ x 9/16-in.	Equipment chest
2		Wrench, adj. pipe—18-in.	Equipment chest
1		Wrench, adj. (monkey)—8-in.	Equipment chest
2		Wrench, spanner—1½-in.	Equipment chest

(5) The following additional tool is supplied with vehicles equipped with gasoline tank bodies:

1	GM-2165960	Wrench, discharge faucet	Cabinet

8. ON VEHICLE EQUIPMENT.

a. The following equipment is supplied with all vehicles:

1		Catalog, Ord. std. nomenclature list G-508	Instrument panel compartment
1		Book, technical manual, TM 9-801	Instrument panel compartment
1	41-B-15	Bag, tool	Tool compartment
2		Container, liquid	Running boards
4	8-C-1575	Chain, dual tire	Under driver's seat
2	8-C-2380	Chain, single tire	Under driver's seat
1	58-E-202	Extinguisher, fire—1 qt.	In bracket in right side of cab

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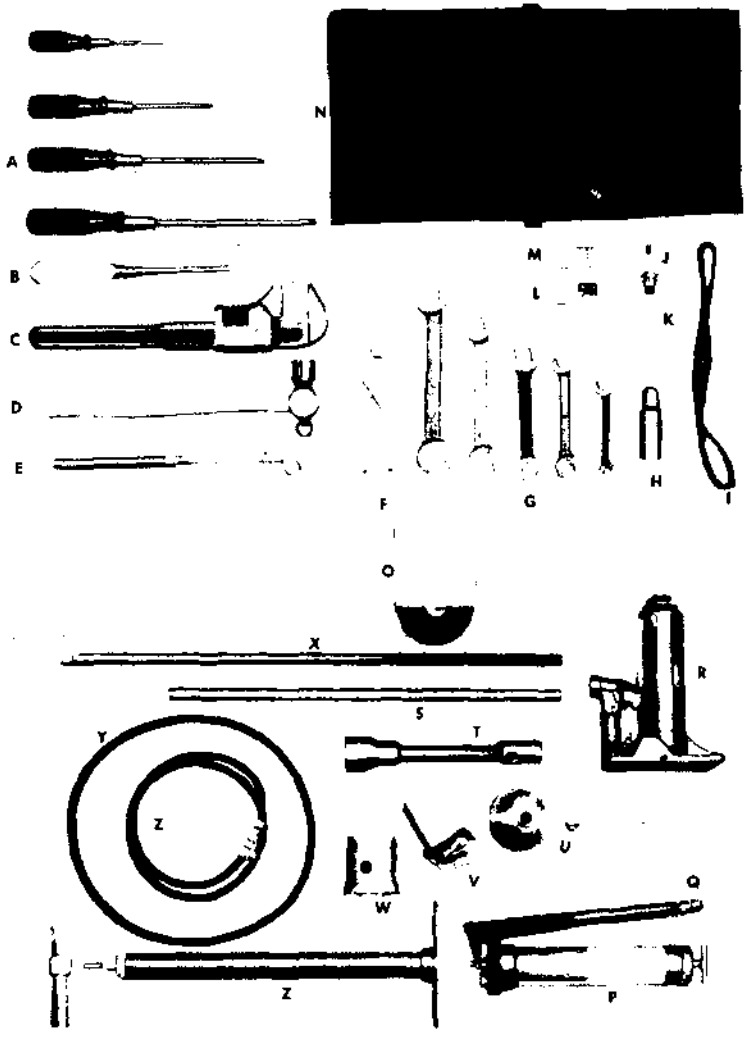
TOOLS, PARTS, AND ACCESSORIES



A CROSS RECESS TYPE SCREWDRIVERS
B STANDARD SCREWDRIVER
C ADJUSTABLE WRENCH
D BALL PEEN HAMMER
E TIRE PRESSURE GAGE
F PLIERS
G END WRENCHES
H SPARK PLUG WRENCH
I IRON WIRE
J SPARK PLUG
K SPARK PLUG GASKET
L TIRE VALVE CAPS
M TIRE VALVE CORES
N TOOL BAG
O FRICTION TAPE
P LUBRICATION GUN
Q LUBRICATION GUN NOZZLE
R JACK
S JACK HANDLE
T WHEEL NUT WRENCH
U OILER AND SPOUT
V COTTER PINS
W WHEEL BEARING NUT WRENCH
X HANDLE FOR BEARING AND WHEEL NUT WRENCH
Y DRIVE BELT
Z TIRE PUMP AND HOSE

RA PD 332972

Figure 12—Tools and Spare Parts

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TRUCK, 2½-TON, 6 x 6

Quantity Per Vehicle	Stockage Number	Name	Stowage Location
1	41-G-615	Gage, tire pressure	Tool compartment
1	41-G-1344-40	Gun, lubricating, hand type	Tool compartment
1	13-O-1530	Oiler, straight spout, spring bottom	Front of dash
1		Order, Lubrication, War Department No. 504	In holder on cab
1	8-P-5000	Pump, tire	Tool compartment
1		Spout, gasoline can	Right side of instrument panel

b. The following additional equipment is included in vehicles not equipped with winch.

1	GM-2146902	Bracket, starting crank	Tool compartment
1	GM-2147197	Crank, starting	Tool compartment

c. The following additional equipment is supplied with vehicles equipped with winch.

1	GM-111301	Adapter, lubrication gun	Tool compartment
1	19-B-30990	Block, snatch	Under driver's seat
1	GM-2146903	Bracket, starting crank	Tool compartment
1	GM-2147196	Crank, starting	Tool compartment

d. The following additional equipment (fig. 13) is supplied with vehicles equipped with gasoline tank bodies:

2	GM-2144329	Can, gasoline—5 gal	On body run boards
1	GM-2165986	Coupling, hose—2 x 1½-in. dia	Cabinet
1	GM-2165987	Coupling, hose—2 x 1½-in. dia	Cabinet
1	GM-2165985	Coupling, twin—2 x 1-in. dia	Cabinet
1	GM-2144530	Funnel	Cabinet
1	GM-2165980	Gage, measuring	Cabinet
1	GM-2182360	Hose, gasoline—10 ft long	Cabinet
2	GM-2154988	Hose, gasoline—8 ft long	Cabinet
2	GM-2165984	Nozzle, valve	Cabinet

e. The following additional equipment (fig. 13) is supplied with vehicles equipped with water tank bodies:

1	WV-U-196	Crank, starting	Pump cabinet
1		Gage, measuring	Equipment compartment
3		Hose, discharge—25 ft. long	Equipment compartment
6		Hose, suction—10 ft. long	Equipment compartment
1		Nipple, pipe—1½ x 6 in.	Equipment chest
1		Nipple, pipe—1½ x 1¾ in.	Equipment chest

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TOOLS, PARTS, AND ACCESSORIES

Quantity Per Vehicle	Stockage Number	Name	Stowage Location
3		Pipe, immersion heater stove	On body running boards
1		Reducer, fire hydrant 2½ x 1½ in.	Equipment chest
1		Strainer, suction hose	Equipment chest
3		Strap, stove pipe	On body running boards
1		Nozzle, valve	Equipment chest

9. ON VEHICLE SPARE PARTS.

a. Following parts are supplied with all vehicles (fig. 12).

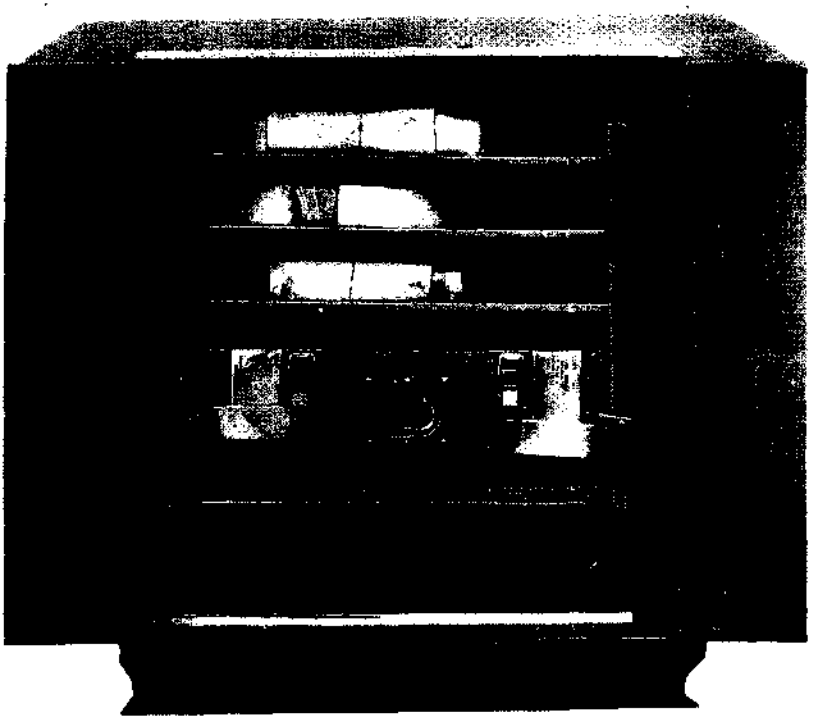
1	8-C-5498-50	Container, metal, spare parts containing	Under co-driver's seat
1	GM-2190551	Belt, drive	Spare parts container
1	8-C-650	Kit, tire valve cap	Spare parts container
1	8-C-6750	Kit, tire valve core	Spare parts container
1	17-L-5215	Lamp, electric, incandescent	Spare parts container
1	8-L-421	Lamp unit, blackout stop	Spare parts container
1	8-L-415	Lamp unit, blackout tail	Spare parts container
1	8-L-419	Lamp unit, service tail and stop	Spare parts container
1	42-P-5347	Pin, assorted cotter	Spare parts container
1	GM-1558516	Plug, spark, with gasket	Spare parts container
1	17-T-805	Tape, friction	Spare parts container
1	41-W-1067	Wire, iron	Spare parts container

b. Following *additional* parts are supplied with vehicles equipped with winch:

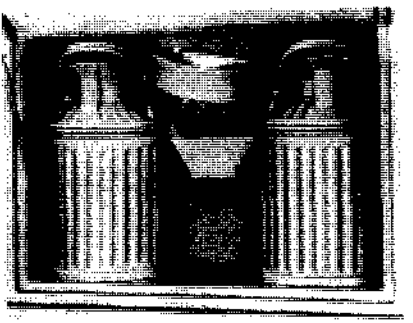
1	GM-2186735	Kit, shear pin	Spare parts container

c. Following *additional* parts are supplied with vehicles equipped with gasoline tank bodies:

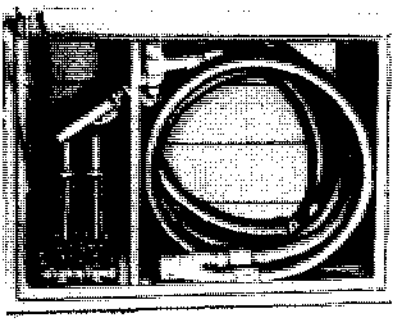
2	GM-2182361	Clamp, hose	Spare parts container



WATER TANK BODY EQUIPMENT COMPARTMENT



GASOLINE TANK BODY LEFT SIDE CABINET



GASOLINE TANK BODY RIGHT SIDE CABINET

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Figure 13—Tank Body Compartments

Quantity Per Vehicle	*Stockage Number*	*Name*	*Stowage Location*

d. Following *additional* parts are supplied with vehicles equipped with water tank bodies:

1	TL-OW-363	Bowl, strainer	Equipment chest
1		Gasket, set (3 pc)	Equipment chest

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TOOLS, PARTS, AND ACCESSORIES

Quantity Per Vehicle	Stockage Number	Name	Stowage Location
1		Gasket, set (10 pc)	Equipment chest
1		Piston and connecting rod	Equipment chest
6	WV-YD-24	Plug, spark	Equipment chest
2	WV-AE-73-C	Valve, exhaust	Equipment chest

10. SPECIAL TOOLS.

a. This special tool list is for information only, and must not be used as a basis for requisition.

Federal Stock No.	Vendor No.	Name of Tool
41-A-18-251	TEC-50-35	Adapter, steering wheel puller (use with 41-P-2954)
41-A-335	KM-K-411	Arbor, clutch alining
41-H-1074	KM-J-1660-1	Handle, driver
41-H-1511	KM-J-872-5	Handle, driver (use with 41-R-2396-20)
41-H-1780	KM-J-1660-3	Head, driver, remover and replacer, bearing cup (front wheel inner and outer)
41-P-2906-15	KM-J-164	Puller, clutch pilot bearing
41-P-2898	KM-J-918-G	Puller, front and rear wheel inner bearing and oil seal (banjo)
41-R-2397-425	SH&G-I-440112	Replacer, rear spring seat seal, inner
41-R-2391-30	KM-J-1733	Replacer, rear spring seat inner bearing
41-R-2391-83	KM-J-1712	Replacer, front and rear wheel inner bearing (split)
41-R-2396-12	KM-J-1709	Replacer, rear wheel bearing inner and outer cup (split)
41-R-2385-275	KM-J-4221	Replacer, rear spring seat inner bearing cup
41-R-2385-276	KM-J-4222	Replacer, rear spring seat outer bearing cup
41-R-2396-22	KM-J-872-4	Replacer, rear wheel inner bearing cup (banjo)
41-R-2396-20	KM-J-872-1	Replacer, rear wheel outer bearing cup (banjo)
41-S-503	KM-J-544-A	Scale, steering gear checking
41-S-3832-7	TEC-20789 YT-20-E-190	Sling, engine lifting
41-W-2964-700	KM-J-187-1A	Wrench, socket (special cylinder head bolt) (close sweep) ¾-in. hex. ½-in. sq drive

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TRUCK, 2½-TON, 6 x 6

PART TWO
OPERATING INSTRUCTIONS

Section IV

CONTROLS AND INSTRUMENTS

11. GENERAL.

a. The gages, switches, pedal and lever controls, and miscellaneous operating controls are grouped in the driver's compartment or cab (fig. 14).

b. **General Data.**

Vehicle weights and dimensions	Refer to paragraph 5
Fuel tank capacity	40 gal
Cooling system capacity	19 qt
Crankcase capacity (refill)	Refer to section VIII
Tire pressure	Refer to paragraph 198
Type of service brakes	Hydraulic-vacuum
Electric system	6 volt
Spark plug size	14 MM
Transmission	Five forward—one reverse
Direct drive in	Fourth
Overdrive in	Fifth
Shifting arrangements	See figure 18
Maximum driving speeds in various gears	See figure 19
Governed speed	2,750 engine rpm (45 mph)

12. GAGES AND SWITCHES.

a. **Instrument and Dash Panel** (fig. 15). All gages, speedometer, and panel lights are mounted in instrument panel on dash panel. Light and ignition switches, and throttle and choke control buttons, are mounted on dash board adjacent to instrument panel.

b. **Ignition Switch** (fig. 15). Switch is lever type. Handle must be turned to "ON" position before engine can be started.

c. **Temperature Gage** (fig. 15). Gage, operated through a capillary tube connected to engine thermal unit, indicates temperature of water in cooling system—not *quantity* of water in system. Face of gage unit is graduated from 100°F to 220°F. Operating temperatures between 160°F and 220°F (205°F at high altitudes) are satisfactory for efficient engine operation. Temperatures above 220°F (205°F at high altitudes) or below 160°F (after several miles of operation), indicate improper cooling system operation (par. 56).

d. **Fuel Gage** (fig. 15). Gage, electrically operated and interconnected with tank unit, indicates level of gasoline in fuel tank and registers only after ignition switch is turned on.

e. **Speedometer** (fig. 15). Speedometer, which indicates road

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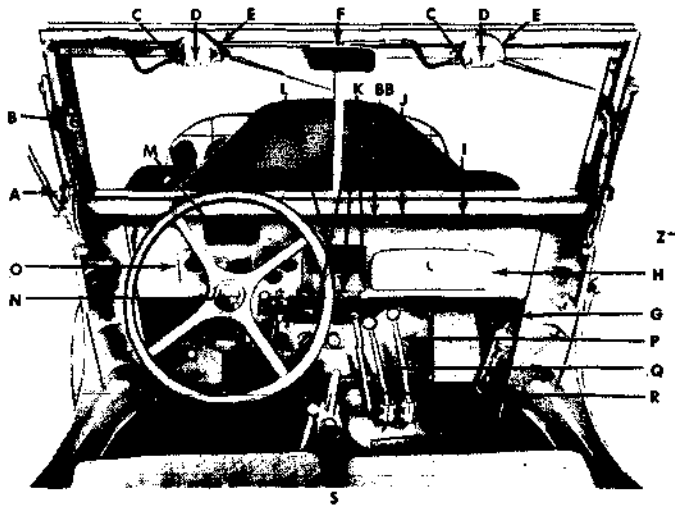
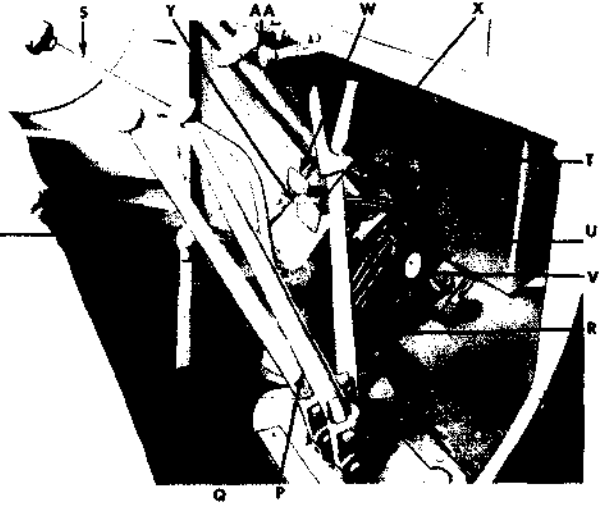


FROM REAR



FROM SIDE

A WINDSHIELD ADJUSTING SCREW (LOWER)
B WINDSHIELD ADJUSTING SCREW (TILT)
C WIPER CONTROL
D WIPER MANUAL HANDLE
E WIPER BODY
F REAR VIEW MIRROR
G FIRE EXTINGUISHER
H MAP COMPARTMENT
I PUBLICATION PLATE
J COOLING SYSTEM DRAIN PLATE
K DASH CONTROLS
L SHIFTING ARRANGEMENT PLATE
M MAX. ROAD SPEED PLATE
N HORN BUTTON

O INSTRUMENT PANEL
P FRONT AXLE DECLUTCHING LEVER
Q TRANSFER CASE SHIFT LEVER
R HAND BRAKE LEVER
S TRANSMISSION GEAR SHIFT LEVER
T NOMENCLATURE PLATE
U ACCELERATOR PEDAL
V STARTER PEDAL
W CLUTCH PEDAL
X BRAKE PEDAL
Y DIMMER SWITCH
Z WINCH P.T.O. CONTROL LEVER
AA COWL VENT OPERATING LEVER
BB WIRE CAUTION PLATE

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Figure 14—Driver's Compartment Views

TRUCK, 2½-TON, 6 x 6

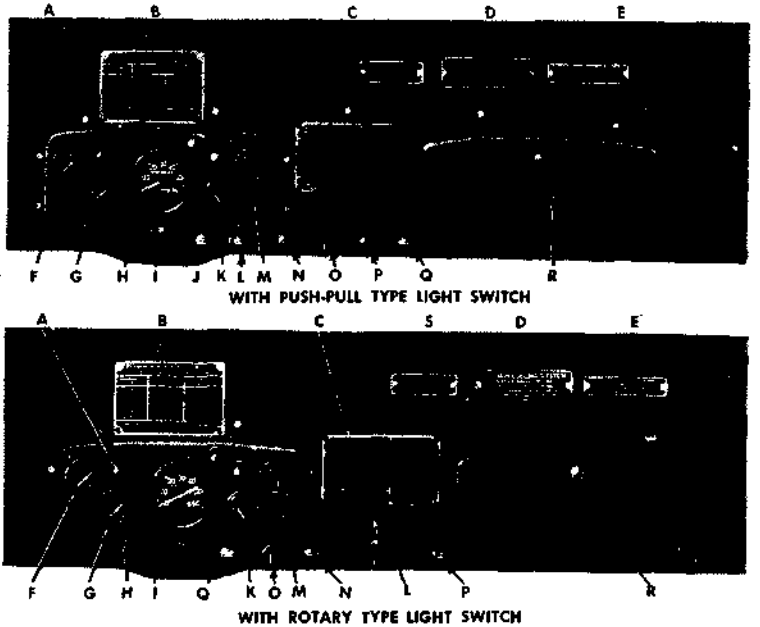

Figure 15—Dash Panel and Instrument Cluster

speed of vehicle in miles per hour and records total mileage and *trip* miles, is operated through a flexible shaft by transfer case gears. Trip indicator can be cleared by turning button located on under side of speedometer head.

f. Oil Pressure Gage (fig. 15). Oil presssure gage, located on instrument panel, indicates pressure of lubricant in engine crankcase; however, it does not indicate *quantity* of oil in crankcase. When engine first starts, oil consistency may cause a sharp rise in pressure reading. As oil warms up, pressure should recede slowly to normal (5 pounds with engine at slow idle). Pressure readings may fluctuate as engine speed increases or decreases. A sudden drop or an erratic fluctuation of pressure indicates trouble.

g. Ammeter (fig. 15). Ammeter indicates charging activity of generating circuit. Ammeter generally shows charge or plus (+) reading when engine is first started. Ammeter will generally show additional charge reading as engine speed is increased, depending upon amount cranking motor has drained the battery.

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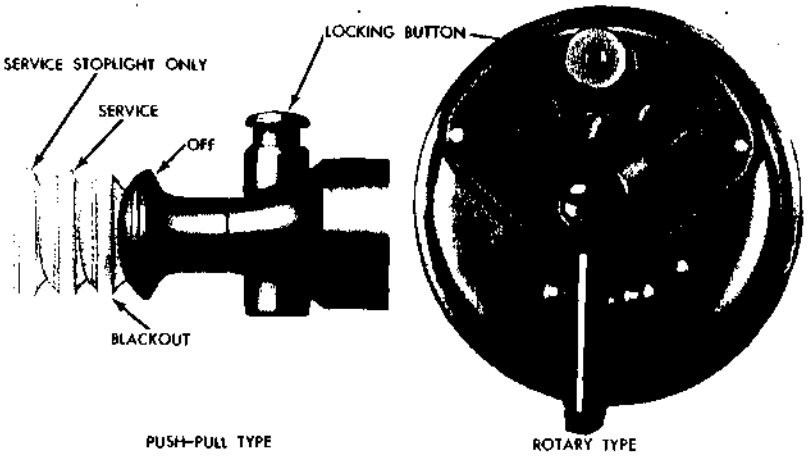

Figure 16—Main Light Switch Operating Positions

h. Main Light Switch. Two types of main light switches have been used (fig. 16).

(1) PUSH-PULL TYPE. Switch, located on instrument panel, is a four-position push-pull type switch which controls both service and blackout headlights and service and blackout stop and taillights. Switch is equipped with a circuit breaker which automatically opens circuit when a short circuit occurs, and closes circuit when thermostatic element in circuit breaker cools off.

(a) Off Position. When switch control button is pushed completely in, all lights, both service and blackout, are turned off. Blackout service stop lights cannot be operated with switch in this position.

(b) Blackout Position. When switch button is pulled to first stage, blackout headlights and blackout stop and taillights are energized. Button is locked in place with automatic plunger type lock when pulled to this position.

(c) Service Position. Switch locking button at left of switch body must be depressed before switch button can be pulled to second stage or service position. When switch is in service position, service headlights, service stop lights and taillights, and instrument panel lights are energized.

(d) Service Stop Light Position. When switch button is pulled completely out, service stop lights may be operated for daylight service.

(2) ROTARY TYPE. Switch is a five-position lever type. This switch is also equipped with a circuit breaker.

(a) Off Position. When lever is placed in "OFF" position, all lights, both service and blackout, are turned off.

(b) Blackout Position. When lever handle is turned to right to "BO MK" position, blackout front marker lights, and blackout stop and taillights are energized.

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(c) Blackout Driving Light. Before lever can be turned to "BO DR" position, left blackout driving light, as well as blackout marker, taillight, and stop light are energized.

(d) Service Stop Light Position. Before lever can be placed in "STOP LT" position from "OFF" position, lock plunger must be held in depressed position. When switch is in "STOP LT" position, service stop lights can be operated for daylight conditions.

(e) Service Position. Before switch can be placed in "HD LTS" position from "OFF," lock plunger must be depressed. With switch in this position, service headlights, taillights, and stop light are energized. Plunger need not be depressed when turning switch from "STOP LT" to "HD LTS" position.

i. Blackout Driving Light Switch (fig. 15). Switch (marked "BO DRIVE"), used only when push-pull main light switch (subpar. **h** above) is used, is located on instrument panel and energizes blackout driving light which is installed adjacent to left-hand service headlight. The shielded driving light is used in addition to the standard blackout headlights when additional illumination is necessary during blackout conditions. Blackout driving light cannot be operated until main light switch (subpar. **h** above) is in blackout position.

j. Blackout Driving Light Switch (with Rotary Type Main Light Switch). No individual switch is provided for the blackout driving light on vehicles equipped with rotary type main light switch. Refer to subparagraph **h** (2) *(c)* above for operation of blackout driving light when rotary type switch is used.

k. Panel Light Switch (fig. 15). Switch, located on instrument panel (marked "PANEL"), is a push-pull type and energizes instrument panel lights after main light switch is placed in second or service position.

l. Dimmer Switch (fig. 14). This is a foot operated switch, accessible to driver's left foot, and is used to control the upper and lower headlight beams. Switch is not operative unless the main light switch is in service position. Use of this switch permits driver to dim lights when passing other vehicles, or to turn on bright lights when needed.

m. Stop Light Switch. Stop light switch, which is connected to hydraulic master cylinder, is not directly actuated by driver. When brake pedal is depressed, hydraulic fluid pressure actuates the switch to light the stop lights when main light switch is in proper position.

n. Cranking Motor Switch Control (fig. 14). Cranking motor switch, mounted on body of cranking motor, is actuated by a foot operated pedal located to right of accelerator pedal. Initial movement of pedal engages cranking motor pinion with flywheel ring gear. Further movement completes electrical circuit between battery and cranking motor, causing armature to rotate, thus cranking engine.

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13. LEVER CONTROLS.

a. Hand operated lever controls for transmission, transfer case, front axle, and auxiliary equipment (winch and hoist) are located in cab (fig. 14).

(1) TRANSMISSION. Transmission gearshift lever, accessible to driver's right hand, is used to select the various gear ratios or speeds provided in transmission. All transmission gear ratios are used in connection with the transfer case. The transmission provides five speeds forward and one reverse. Powr is transmitted directly through transmission in fourth speed, providing a 1 to 1 gear ratio. In fifth speed (overdrive) and all other speeds including reverse, the power is transmitted through gears of various sizes to provide the desired gear ratios. Use of transmission gearshift lever is explained in paragraph 16.

(2) TRANSFER CASE. Transfer case shift lever is used to shift transfer case into *high* or *low* range to engage driving axles, and into *neutral* to disengage axles. Arrangement of this lever is such that low range cannot be used until front axle lever is placed into "IN" position. Shifting instructions are outlined in paragraph 16.

(3) FRONT AXLE. Front axle declutching lever is used to engage and disengage the front driving axle. Lever has only two shifting positions—"IN" and "OUT." Lever must be placed into "IN" position (axle engaged) before transfer case shift lever can be placed into low range position. Shifting instructions are outlined in paragraph 16.

(4) HAND BRAKE. Hand brake lever, located to right of driver (fig. 14), is used to control application of a brake band assembly mounted on transfer case. This band operates directly on transfer case output shaft, transmitting braking effort to wheels through propeller shafts. Primary purpose of this brake is to hold vehicle in stationary position or to assist in bringing it to an emergency stop—not to brake vehicle during normal road operation. Lever is pulled back to apply brakes. A pawl in lower end of lever engages notches in sector at base of lever to hold it in various applied positions. Spring loaded release lever at the handle releases pawl from sector notches to permit release of brake.

(5) AUXILIARY DRIVE. Power take-off control levers for the engagement of winch and hoist, when used, are located in cab (fig. 14). Instructions for the use of these auxiliary control levers are outlined in paragraphs 24 and 25.

14. PEDAL CONTROLS.

a. **Clutch.** Clutch pedal, accessible to driver's left foot, engages and disengages clutch from flywheel. When pedal is depressed, clutch is disengaged, permitting shifting of transmission gears. When pedal is released, clutch is engaged.

b. **Service Brakes.** Service brake pedal, accessible to driver's right foot, controls application and release of vacuum-hydraulic operated brake shoes at each wheel. Pressure applied to pedal in various degrees applies brakes correspondingly. Release of brakes is correspondingly as rapid as pressure on foot pedal is released.

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c. Accelerator Pedal. This pedal, linked to carbureter, is accessible to driver's right foot. Pedal is used to accelerate or decelerate engine as desired. When pedal is completely released, engine will operate at set idling speed. Acceleration from idling to any desired speed up to governed speed is obtained by depressing the pedal in various degrees.

15. MISCELLANEOUS CONTROLS.

a. Throttle Control Button (fig. 15). Throttle control button (marked "THROTTLE") is located on dash panel. Button is interconnected to carbureter and may be used instead of accelerator pedal to accelerate engine. The button is pulled out in varying degrees to accelerate engine and must be pushed back to decelerate. This control is generally used to set throttle to desired starting and warming-up speed, and to obtain sustained speeds when operating auxiliary units.

b. Choke Control Button (fig. 15). Choke control button (marked "CHOKE") is located on dash panel. Button is interconnected to carbureter choke valve. When button is pulled out, carbureter choke valve closes. Return spring on choke linkage returns choke valve to open position when button is released. This button is used to operate choke when starting and operating a cold engine.

c. Windshield Wipers (fig. 14). Dual windshield wipers, mounted on windshield frame, are vacuum operated. Control button, located on each motor, permits independent operation of each wiper. Control button on each wiper must be pulled out to operate wiper and pushed in to turn wiper off. Each wiper is provided with a manually operated lever to use in the event vacuum line or wiper motor is broken.

d. Fuel Pump Hand Primer (fig. 17). Hand primer lever, located at fuel pump, is used to prime carbureter in case vehicle has been standing for long periods, or fuel has been drained from

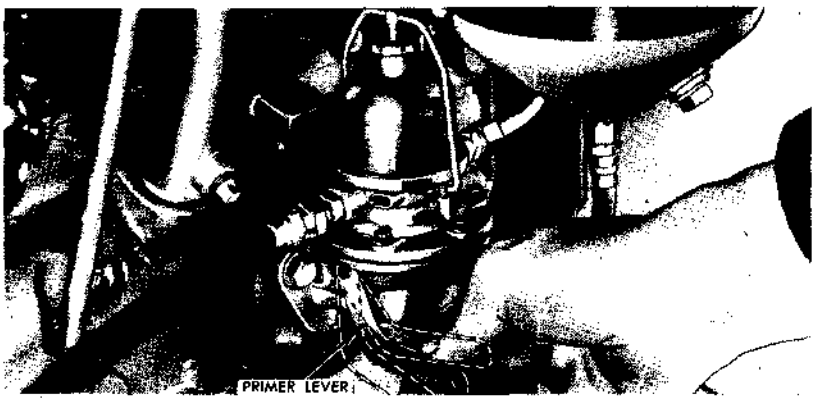

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Figure 17—Fuel Pump Hand Primer

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system, then refilled. As a general rule, several up and down movements of the lever will pump sufficient gas to carbureter for starting.

e. Cowl Ventilator. Cowl ventilator lever, located inside cab directly under center of dash panel, is used to open and close cowl ventilator. Push down and forward on lever to open ventilator—pull in handle to close.

f. Horn Button. Horn button, located in center of steering wheel, must be depressed to sound electric horn.

Section V

OPERATION UNDER USUAL CONDITIONS

16. TRANSMISSION, TRANSFER CASE, AND FRONT AXLE SHIFTING.

a. General. The purpose and use of the transmission and transfer case must be understood by the driver before any attempt is made to drive the vehicle. It must be understood that vehicle cannot be moved until transfer case shift lever is in operating position (high or low range). The transmission gearshift positions do not in any way affect the selection of or shifting into the high and low ranges in the transfer case. The transfer case is the medium by which the power is transferred from the transmission to the driving axles. The ratios provided by the transmission in various speed positions are further increased by gear ratios in the transfer case.

b. Shifting Arrangements (fig. 18). Shifting instruction plates showing shifting arrangements for transmission, transfer case, and auxiliary equipment (when used), are located on dash panel.

c. Maximum Permissible Road Speeds. Maximum permissible road speeds in various transmission gear positions and transfer case gear ranges are listed on a plate (fig. 19) attached to dash panel. These speeds must not be exceeded.

d. Driving Axle Combinations. Vehicles may be driven by rear axles *only*, or by front *and* rear axles. Front axle cannot be driven independently.

(1) DRIVING REAR AXLES ONLY. Transfer case must be operated in *high* range only. Front axle declutching lever must be in "OUT" position. Transfer case cannot be operated in low range when *only rear* axles are driving.

(2) DRIVING FRONT AND REAR AXLES. Front axle declutching lever must be placed into "IN" position before transfer case shift lever is placed into low range. After front axle has been engaged, transfer case can be operated in either low or high range.

e. Transfer Case Low and High Ranges. Various operating

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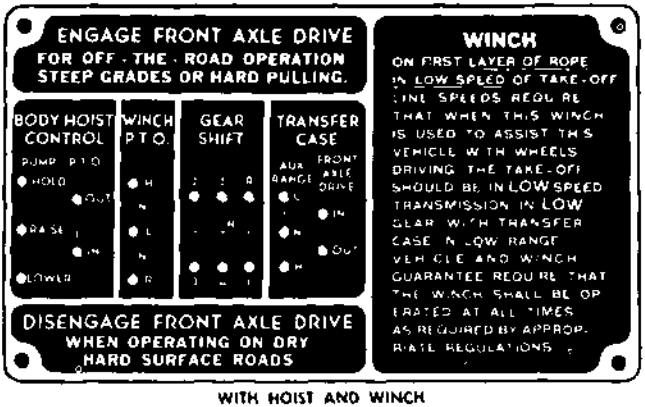
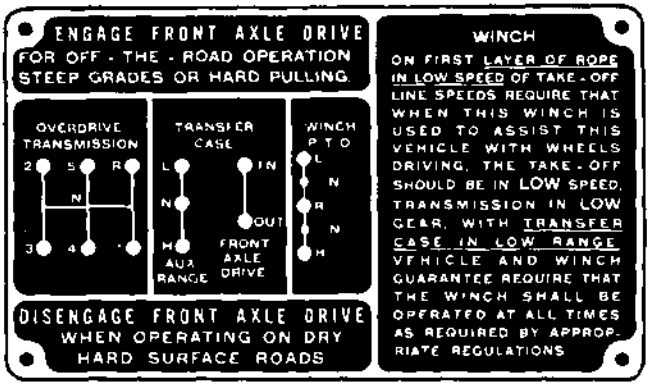
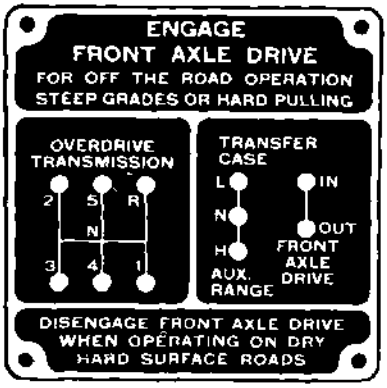


WITH HOIST AND WINCH



WITH WINCH ONLY



WITHOUT HOIST AND WINCH

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Figure 18—Shifting Arrangement Plates

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OPERATION UNDER USUAL CONDITIONS

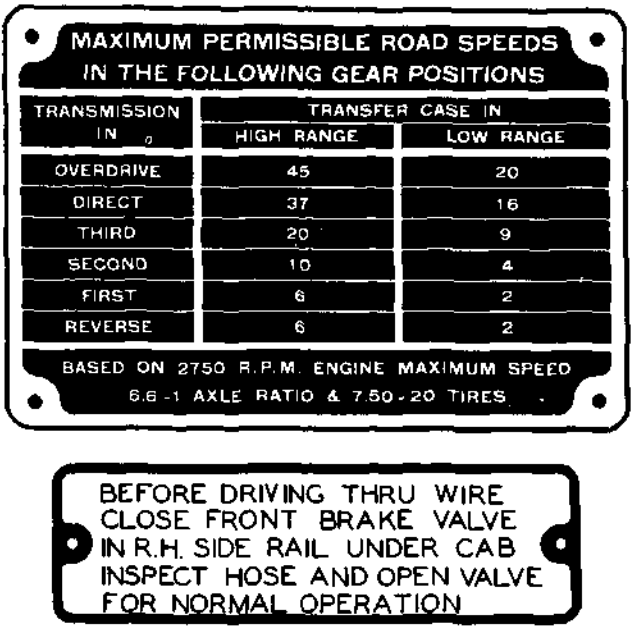

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Figure 19—Maximum Permissible Road Speed Plate and Wire Cutting Caution Plate

conditions must be considered before choice of transfer case high or low range can be determined. The terrain, grade, and load must be taken into consideration. The driver, after some experience, will automatically select the correct transmission speed and transfer case range.

(1) HIGH RANGE. As a general rule, transfer case *high* range is employed when operating on the road where traction is not difficult and the load is light. This range may be used with front and rear axles driving, but generally with only rear axles driving.

(2) LOW RANGE. Transfer case cannot be operated in low range until front axle is engaged. With transfer case in low range, the greatest reduction is provided throughout all transmission speeds. Low range is generally used during off-the-road operations where maximum traction and power are required.

f. **Transfer Case Shifting** (fig. 18).

(1) HIGH TO LOW RANGE. This shift should be made while vehicle is on hard ground before difficult terrain is encountered. Speed of vehicle should be reduced below the maximum speed of gear into which shift should be made (fig. 19). Front axle must be engaged (subpar. g below) before transfer case can be operated in low range.

(a) Place front axle declutching lever into "IN" position (subpar. g below).

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(b) Depress clutch pedal and move transfer case shift lever into neutral ("N") position. Release clutch pedal and accelerate engine (to approximately double that of vehicle speed).

(c) Depress clutch pedal again and move transfer case shift lever forward into low range position. Do not use excessive pressure. Release clutch and accelerate engine to desired speed (refer to maximum permissible road speed plate, fig. 19).

(2) LOW TO HIGH RANGE. This shift may be accomplished regardless of vehicle speed.

(a) Depress clutch pedal, then move transfer case shift lever into neutral ("N") position. Release clutch pedal and synchronize engine with vehicle speed.

(b) Depress clutch pedal, then move transfer case shift lever into high range position. Release clutch and accelerate engine. Front axle declutching lever may, if desired, be placed into "OUT" position without using clutch (subpar. g below).

g. Front Axle Declutching Lever Shifting. Front axle should be engaged only in off-the-road operations, slippery roads, on steep grades, or during hard pulling.

(1) ON-THE-ROAD OPERATION. The shifting arrangement plate (fig. 18), states "*Disengage front axle drive when operating on dry, hard-surfaced roads.*" This rule generally holds true because in most cases the pulling ability of the two rear axles is sufficient. However, if steep grades are encountered, or if vehicle is called upon to help move an additional load, the front axle should be engaged in order to utilize the pulling ability of all three axles. If heavy loads are to be pulled, the front axle should also be used in getting vehicle under way, after which it may be disengaged, provided the two rear axles can pull the load without stalling the engine.

(2) OFF-THE-ROAD OPERATION. The shifting arrangement plate states "ENGAGE FRONT AXLE DRIVE for off-the-road operation, steep grades, or herd pulling." The rule holds true whenever the pulling ability of all three axles is required. The driver must use good judgement according to load as well as road conditions.

(3) ENGAGING FRONT AXLE. Front axle may be engaged at any vehicle speed without declutching. However, if transfer case is in high range and front axle is to be engaged, and it is desired to operate in low range, shift front axle declutching lever into "IN" position, then place transfer case into low range. Push declutching lever forward quickly and all the way. If difficulty is encountered after exerting a normal pressure on lever, "zig-zag" the front wheels while in motion until engagement is completed.

(4) DISENGAGING FRONT AXLE. Front axle may be disengaged at any vehicle speed. If transfer case is in high range, pull declutching lever into "OUT" position without use of clutch; however, if transfer case is in low range, place transfer case shift lever into high range, then place axle declutching lever into "OUT" position. IMPORTANT: *If difficulty is encountered in disengaging front axle while exerting a normal pressure on lever, push accelerator to floor rapidly, then release instantly. If difficulty is still encountered, "zig-zag" the*

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front wheels, run over bumps in road, or run right front wheel over soft shoulder of road. If axle cannot be disengaged readily after foregoing instructions—stop, reverse a short distance, then repeat above procedure. Do not use excessive force on lever to disengage front axle. Difficulty experienced when shifting front axle is not an indication of faulty shifting mechanism.

h. Transmission Shift from Low to High Speeds. With transfer case shift lever in operating position (low or high), transmission shift from low to higher forward speeds can be accomplished in following manner: Refer to shifting arrangement plate (fig. 18) mounted on dash.

(1) Depress clutch pedal and release accelerator pedal. Place transmission shift lever from neutral into first speed position.

(2) Slowly release pressure on clutch pedal, at the same time slowly depressing accelerator pedal. After engagement is made, accelerate engine until road speed is increased to approximately that indicated on maximum permissible road speed plate (fig. 19).

(3) After necessary road speed has been obtained in first speed, release accelerator pedal, depress clutch pedal, and place transmission into second speed position. Release clutch pedal and accelerate to proper road speed and repeat operations for third, fourth, and fifth speeds—in successive stages.

(4) Fourth speed ratio is direct and is generally used for normal operations on average roads. Fifth speed is over-drive and is generally used to attain maximum no-load speed on good roads.

i. Transmission Shift from High to Low Speeds. Transmission should always be shifted into next lower speed before engine starts to labor or before vehicle speed is appreciably decreased. The need for down-shifting is generally apparent when ascending a steep grade or when more power is needed to pull on rough terrain or in muck or sand. As a precautionary measure, the same ratio used to ascend a grade should be used when descending. When shifting to a lower gear at any rate of vehicle speed, make sure that engine speed is "synchronized" with vehicle speed before clutch is engaged. When engine is operating at lower than relative vehicle speed, the drive line may be damaged.

(1) Depress clutch pedal and release accelerator pedal the same instant. Move transmission shift lever into neutral ("N").

(2) Release clutch pedal and accelerate engine momentarily to synchronize transmission gears. Depress clutch pedal again and move transmission shift lever into next lower speed. Do not force lever, but rather "feel" it into position.

(3) Release clutch pedal and accelerate engine to desired speed. Do not exceed speeds shown on maximum permissible road speed plate (fig. 19). Transmission may be shifted successively into all next lower speeds in same manner.

j. Transmission Shift into Reverse. Vehicle must be brought to a dead stop before transmission gearshift lever can be placed into reverse position. With transfer case in either high or low range, shift transmission into reverse as follows:

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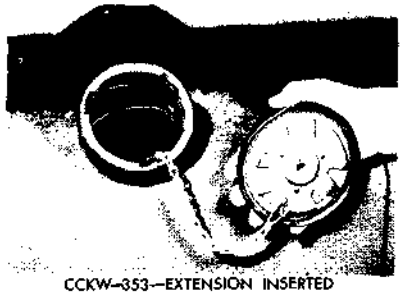
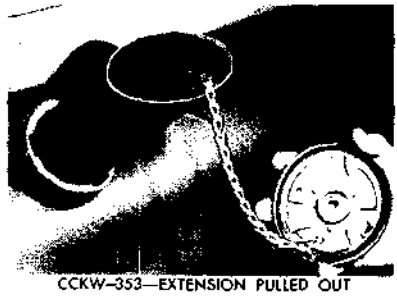


CCKW-353—EXTENSION INSERTED



CCKW-353—EXTENSION PULLED OUT

CCKW-352—ONE SIDE OF TANK SHOWN

RA PD 332872

Figure 20—Fuel Tank Filler Neck Locations

(1) Push clutch pedal down to disengage clutch. Press down on foot brake pedal to stop vehicle.

(2) From neutral position, move shift lever as far as possible to the right, then toward front to reverse ("R") position.

(3) Release clutch pedal and accelerate engine to desired speed; however, do not exceed those speeds shown on maximum permissible road speed plate.

17. ENGINE FUEL, OIL, AND WATER.

a. **Fuel Supply** (fig. 20). One fuel tank filler neck, with extension, located directly at tank on side of vehicle, is furnished on long wheelbase chassis (CCKW-353), while the fuel tank on short wheelbase chassis (CCKW-352) is equipped with a filler neck at each side of tank.

(1) FUEL OCTANE. Octane rating of gasoline recommended is specified on the vehicle nomenclature plate, and on the decalcomania on engine valve cover. Initial timing of engine is made with this fuel. If fuel of lower or higher octane rating is used, readjustment of ignition timing is necessary (par. 87).

(2) FILLING TANK. When filling fuel tank, the supply hose must be properly grounded to prevent static sparks. Pressure type filler cap must be in good condition, and care must be used to prevent entry of dirt, snow, and water into tank.

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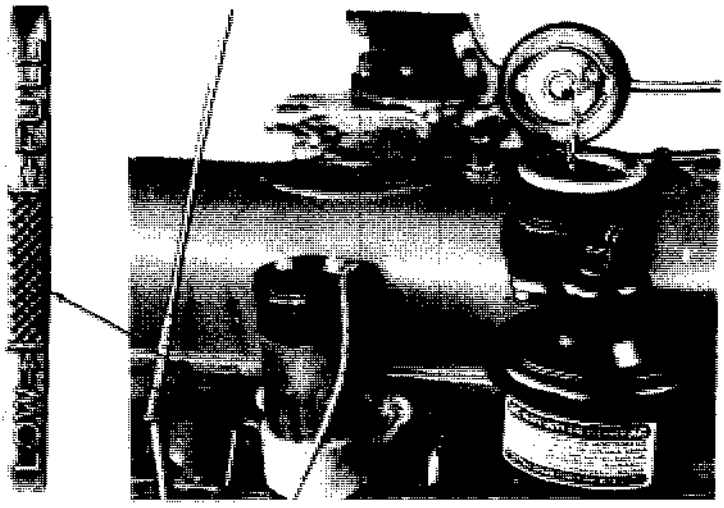


RA PD 332871

Figure 21—Crankcase Oil Filler and Dip Stick

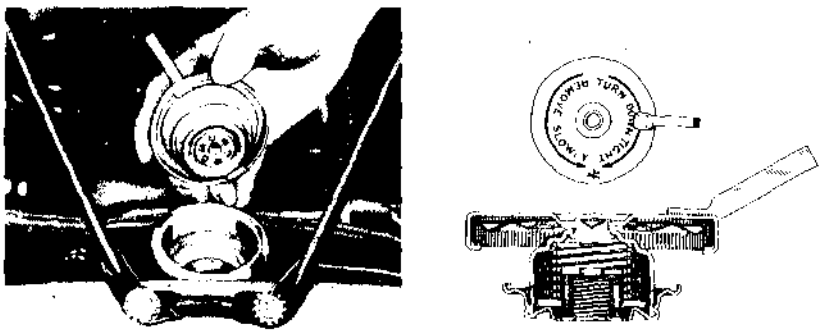
b. Crankcase Oil (fig. 21). Crankcase oil filler neck, mounted on right-hand side of engine, is accessible after engine hood is raised. Oil dip stick is also mounted on right-hand side of engine. Lower portion of dip stick is graduated and shows level of oil in crankcase. When checking oil level, dip stick should be withdrawn, lower portion wiped dry, then reinserted and withdrawn again. Crankcase oil level should be kept to "FULL" mark. Remove filler cap [(GM-2162117) G501-01-31557] to replenish oil. Refer to section VIII for lubrication instructions.

c. Cooling System. The basis of cooling system coolant is *fresh, clean* water to which must be added a rust preventive compound (par. 107) and antifreeze solution when necessary (par. 31).

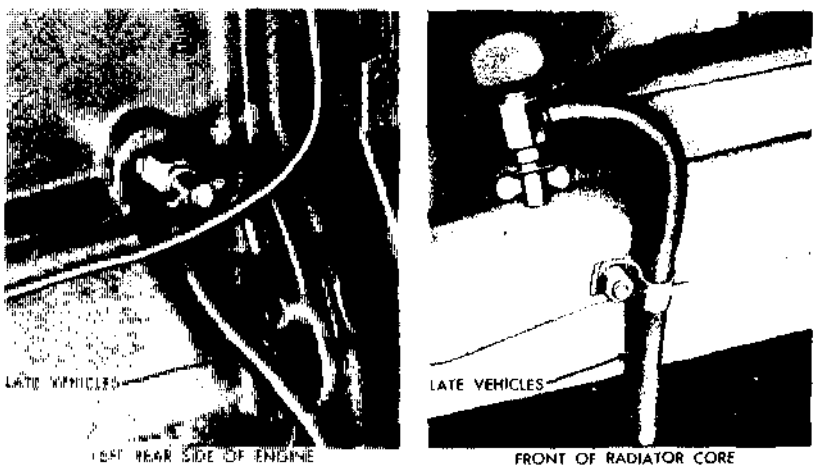
(1) FILLING SYSTEM (fig. 22). Pressure type radiator filler cap is accessible after engine hood has been raised. This type cap is installed on overflow tank, when used, with a plain notched type cap installed on radiator.

(a) Removing Radiator Cap. Loosen cap slowly, particularly when engine is hot. Turn cap in direction of arrow (counterclockwise). Turn cap until it reaches first stage or the safety stop. In this position, cap should be loose so that it can be pressed down against gasket, approximately ⅛ inch. If escaping air or steam is heard, remove hand from filler cap until it stops. After steam and pressure have been released, press the cap downward, turn to the extreme left, then lift it off.

(b) Filling Radiator. Vehicle should be standing on fairly level ground before starting to fill radiator. If system is empty, fill radiator until liquid can be seen through filler neck. If the system is filled with cold liquid, the thermostat will close even though the engine is



RADIATOR FILLER NECK AND CAP



LEFT REAR SIDE OF ENGINE

FRONT OF RADIATOR CORE

RA PD 332873

Figure 22—Radiator Filling and Cooling System Drainage Points

warm. This action may trap air in cylinder block and head. The trapped air will leak through thermostat vent hole, thereby lowering liquid level in radiator. Additional coolant should then be slowly added until no further air bubbles are noticed. This method should be used if more than two quarts are necessary to refill radiator. Always fill radiator until liquid is visible through neck. If engine is cold, a loss of approximately one quart will result. If engine is warm, no appreciable loss will be noticed.

(c) *Use of Antifreeze Solution.* Do not overfill radiator when antifreeze solutions are used. Normal expansion of heated water causes level to rise. When engine is stopped and water cools, contraction of liquid lowers level. It is this apparent low level which might indicate the need of additional fluid. Water in system should be hot before any check of level is made.

(2) DRAINING SYSTEM (fig 22). One drain cock is provided for bottom of radiator and is accessible from lower side of brush guard.

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The second drain cock is located at left rear of engine cylinder block. It is necessary to remove radiator filler cap when draining system.

18. OPERATING THE ENGINE.

a. Starting Engine. If vehicle has been parked in extreme cold weather, follow instructions for cold starting outlined in paragraph 29.

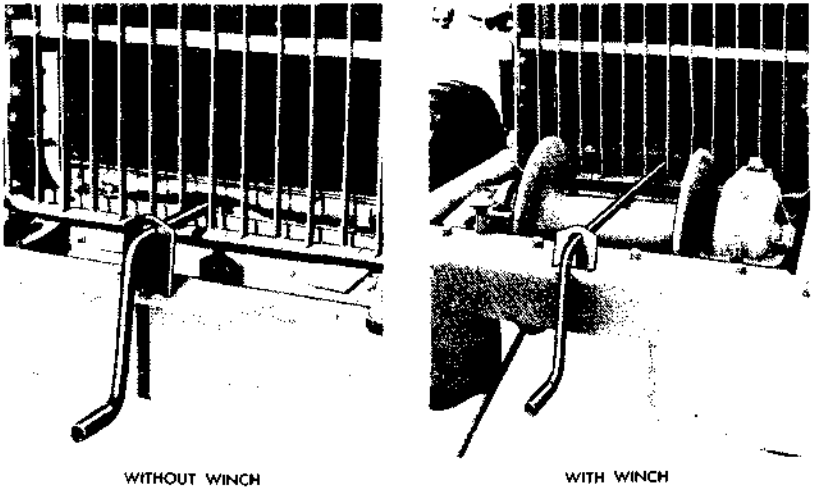
(1) SET CONTROLS. All lever controls (transmission, transfer case, winch, etc.) must be in neutral, out, or off position. If vehicle fuel tank has been drained, refill, then work fuel pump hand primer several times. Pull out throttle control button about ½ inch. Hold out choke button about halfway if engine is cold.

(2) START. Turn ignition switch to "ON" position, depress clutch pedal, then step on cranking motor lever pedal. Release pedal the instant engine fires.

(3) SET CONTROLS. Release clutch pedal. Push throttle button in. Release choke button after engine fires evenly.

b. Use of Cranking Motor. Cranking motor should not be engaged for longer periods than 30 seconds. After cranking motor has been engaged without results, a period of 10 to 15 seconds should elapse before using it again. If engine will not start after reasonable time, do not continue to use cranking motor until reason for failure is determined and corrected (par. 49). If cranking motor fails to crank or cranks slowly and battery is known to be in good condition, report failure to proper authority; then use hand cranking (subpar. c. below) or towing method (par. 23).

c. Hand Cranking (fig. 23). Starting crank with bracket attached is furnished with each vehicle, and is used when hand cranking or "turning over" engine. On vehicles equipped with winch, un-



WITHOUT WINCH WITH WINCH

RA PD 332853

Figure 23—Use of Starting Crank

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wind cable by hand (par. 24) before the starting crank is installed. After cable has been unwound, the two points or dogs of the starting crank bracket must be inserted in the holes in front bumper to position starting crank. Turn engine over several times with crank before the ignition switch is turned on. Crank engine with sharp, quick, upward pulls. Do not attempt to "wind" the engine when using the hand crank. Hand throttle should be pulled out about ½ inch, then adjusted to desired idling speed after engine has been started.

d. Engine Warm-up. Engine should be permitted to operate through a short warm-up period whenever conditions permit. This warm-up period permits the driver to observe and check performance of engine before the vehicle is placed under way.

(1) OPERATING TEMPERATURE. The standard thermostat starts to open at 160° F and is fully open at 185° F. Engine temperature at gage may be slightly higher than at thermostat until thermostat is fully open. Gage may register 190°F to 195°F during warm-up, then drop back to 180° F to 185° F after thermostat is completely open. The following precautions should be observed when checking temperatures during warm-up or during operation.

(a) Operating temperature should not be below 160° F in any climate. This temperature should be attained as soon as possible during warm-up. As a general rule, engine operation equivalent to 5 miles driving should bring temperature to above 160° F.

(b) Operating temperatures between 160° F and 220° F (205° F at high altitude) are satisfactory for engine operation. Temperatures above 220° F (205° F at high altitude) and below 160° F indicate improper cooling system operation.

(c) If temperature rises sharply and quickly above 220° F during warm-up or operation, stop engine and determine cause of overheating.

(d) Select correct gear range when operating to prevent engine from overspeeding (see Maximum Permissible Speed Plate, fig. 19).

(2) OIL PRESSURE. As engine warms up, oil pressure should recede slowly to normal, approximately 5 pounds, with engine slow idling.

e. Stopping Engine. Engine is stopped by turning ignition switch to "OFF" position.

19. DRIVING THE VEHICLE.

a. Preventive Maintenance Services. One of the most essential duties of a driver is the accomplishment of the preventive maintenance services outlined in paragraphs 41 through 45. These services, together with those recommended in section IX, New Vehicle Run-in Tests, are as important as using good driving methods.

b. Equipment Stowage. Correct stowage of equipment and tools before operating the vehicle is outlined in paragraphs 6 through 10. A thorough study should be made of methods for operation under unusual conditions as outlined in paragraphs 29 through 35, as well as instructions on the operation of auxiliary equipment (pars. 24 through 28).

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OPERATION UNDER USUAL CONDITIONS

c. Steering. Vehicle is steered in conventional automotive manner. Steering gear, operated by steering wheel, is connected to front axle steering knuckles and tie rod through a steering arm and drag link.

d. Use of Driving Axles and Maximum Permissible Road Speeds. Use of driving axles and method of shifting transmission and transfer case are outlined in paragraph 16. The maximum permissible road speeds are outlined on instruction plate (fig. 19) mounted on dash. *These speeds must not be exceeded.*

e. Braking Vehicle. Application and release of service brakes (foot brakes) are accomplished in the conventional automotive manner. The driver applies pressure to foot pedal in varying degrees to brake vehicle as desired. Service brakes apply to all six wheels; therefore, only a normal amount of pedal pressure is required to actuate brakes, providing power system is functioning properly.

(1) CHECKING VEHICLE SPEED. Release accelerator pedal. Depress brake pedal slowly and evenly until vehicle is checked to desired speed. Do not "fan" pedal, but apply even pressure. This will permit the engine to assist in checking speed.

(2) NORMAL VEHICLE STOP. At the approach of a normal stop, release accelerator pedal, then check vehicle speed by even pressure on brake pedal. After vehicle speed is checked, depress clutch pedal, and increase pressure on brake pedal until vehicle is stopped.

(3) EMERGENCY STOP. Release accelerator, step sharply and hard on brake pedal, and at same time pull up on hand brake lever. Depress clutch pedal. This action should be used only in emergencies.

(4) HAND BRAKE LEVER. This lever should not be used to brake vehicle during normal driving. Primary purpose of hand brake is to hold vehicle in stationary position.

f. Use of Lights. Refer to paragraph 12 for operation of light switches.

(1) SERVICE HEADLIGHTS. The driver must depend upon the service headlights for night time visibility. These headlights, when aimed correctly and kept in good order, will provide adequate lighting for all conditions.

(a) High Beam. The high and low beams are controlled by foot-operated dimmer switch after main light switch is in service position. The high beam is generally used when there are no approaching vehicles or when operating on unlighted roadways.

(b) Low Beam. The low or depressed beam should be used when approaching and passing another vehicle. The low beam may not throw light far enough ahead for clear road driving; however, when another vehicle is approaching, objects between the two vehicles show up in silhouette against the road. The visibility under this condition is sometimes greater than the clear road visibility with the high beam.

(2) BLACKOUT DRIVING LIGHT. This light is used only under blackout conditions and is controlled by either a separate switch on instrument panel when push-pull type main light switch is used, or by a position on main light switch when rotary type is used.

(3) BLACKOUT TAILLIGHTS. The lens on each blackout light is designed to produce two beams which merge into a single beam at a specified distance. This design is such that when one truck is following another at a safe distance, these two beams appear as a single beam.

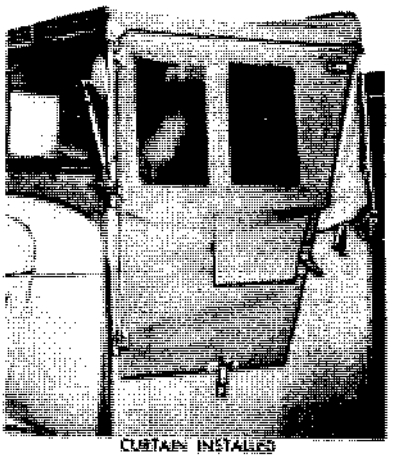
20. CAB SEATS, TOP, AND CURTAINS.

a. Cab Seats. Cab is equipped with individual seats for driver and co-driver.

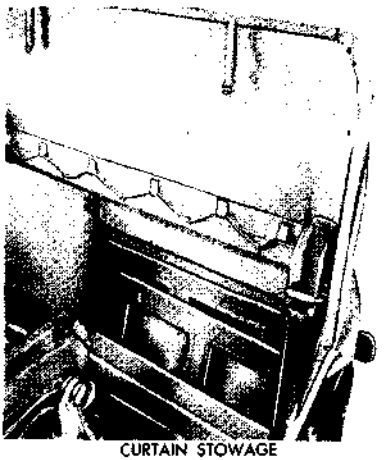
(1) DRIVER'S SEAT. Seat back is hinged to permit back to lay forward. Seat bottom may be raised.

(2) CO-DRIVER'S SEAT. Seat back is also hinged; however, back engages a spring retaining clip to hold it in upright position. Seat bottom folds back on hinge and is held in back position by a sector arm.

b. Cab Side Curtains (fig. 24). Each side of cab is equipped with a side curtain hinged at front end of cab and latched at rear.

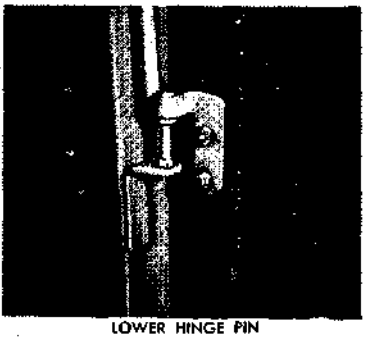


CURTAIN INSTALLED



CURTAIN STOWAGE

UPPER LATCH (INSIDE)



LOWER HINGE PIN

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Figure 24—Side Curtain Installation

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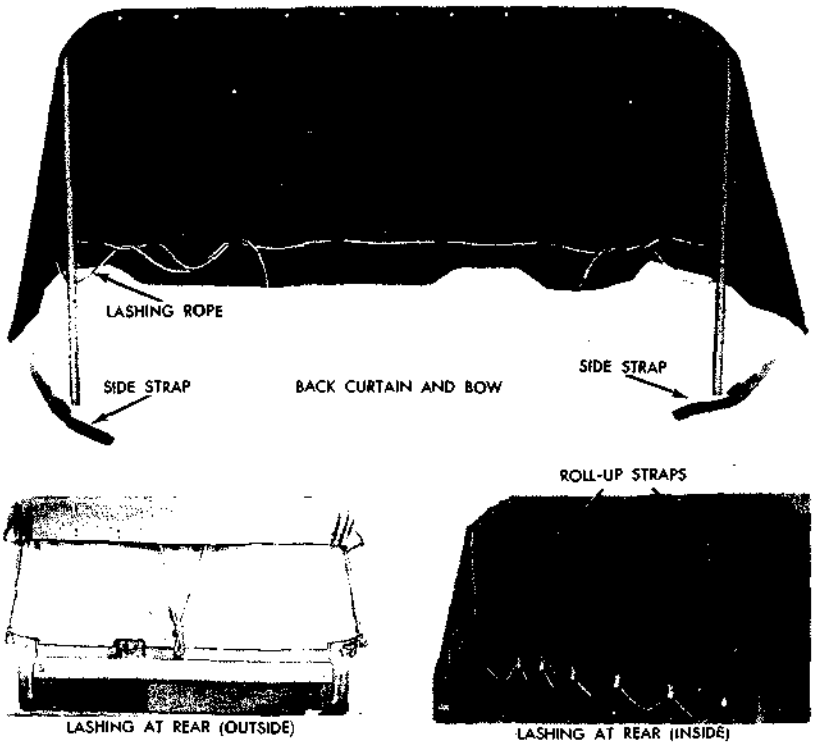

Figure 25—Top and Back Curtain Installation

Upper curtain latch can be operated from inside or outside of cab. Lower latches can be operated from inside of cab by reaching through curtain hand hole.

(1) REMOVAL. Unlatch curtain and swing open about 90 degrees. Lift curtains straight up to disengage hinge pins from hinge brackets. Lower hinge pin is flat and engages like portion of hinge bracket.

(2) INSTALLATION. Hold curtain in open position with hinge side to windshield. Insert curtain hinge pins in corresponding hinge brackets. Push downward on curtains to engage pins in brackets, then swing curtain against cab.

(3) STOWING CURTAINS. Stow curtains, when not in use, in compartment behind driver's seat back.

c. **Cab Top Deck.** Cab top deck is one-piece type with side rails (latest type) to hold top rigidly when installed.

(1) REMOVAL. Untie lashing from top bow ring nut at rear of cab on each side. Unhook rope loop from cab rear lashing hook. On latest type, disengage side rail pin from top bow at each side. Lift top deck over top bow, and pull over windshield. Remove catch

from eye at each upper corner of windshield. From either side, pull top canvas from channel in top of windshield frame.

(2) INSTALLATION. Slide front end of top deck into channel in top of windshield frame. Draw deck over rear top bow. Insert side rail pin into bow hole at each rear side. Hook rear lashing rope loop over hook at rear of cab. Hook front corners of deck over eyes on upper corners of windshield frame, then place strap hook through eyes. Lash rear sides of deck to top bow ring nut.

d. Back Curtain (fig 25). Back curtain is one-piece canvas. Top portion is attached by metal screws. Each leg of the top bow fits into a socket at inside rear of cab. The bow is held in upright position with a top bow ring nut on each side. Lashing rope, looped through lower inside end of curtain, is lashed to a series of hooks attached to cab in back of seats, with ends of ropes lashed to hooks on outside of cab at each side. Lower sides of curtain are strapped to cab at inside.

(1) REMOVAL. With top deck removed or rolled forward, unlash back curtain at sides (rope and straps), unhook rope at back of seats, then remove cotter pin from each leg of bow. Loosen each top bow ring nut, and pull bow and curtain straight up from sockets.

(2) INSTALLATION. Insert bow in sockets, then insert cotter pin into each leg of bow. Holding bow in upright position, tighten ring nut on each side of cab. Hook rear lashing rope on hooks at inside rear of cab. Lash each end of rope to hook on each side of cab. Attach side straps to loops inside of cab.

e. Positioning Top and Back Curtain for Accessibility (fig. 26).

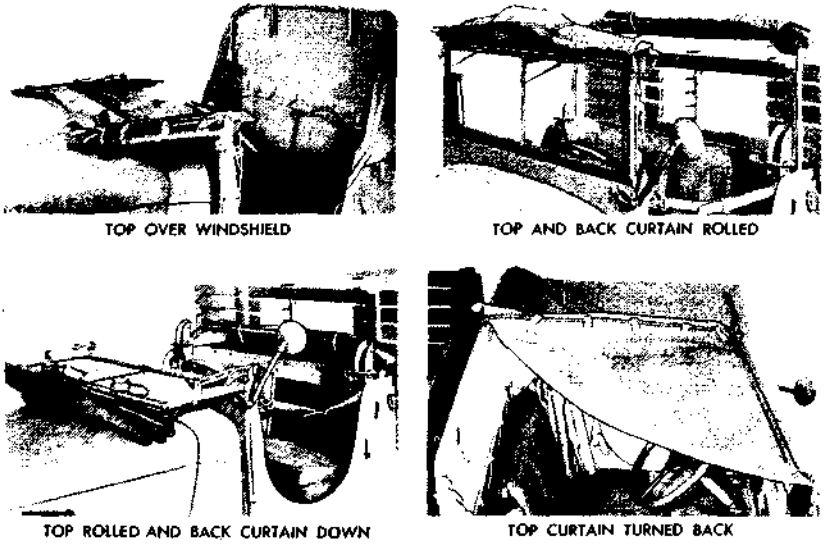

Figure 26—Top and Back Curtain Operating Positions

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OPERATION UNDER USUAL CONDITIONS

Top deck and back curtain may be placed in various positions for ventilation or accessibility.

(1) TOP DECK OVER WINDSHIELD (To Prevent Glare). Release top deck at back and fold over windshield.

(2) TOP DECK AND BACK CURTAIN ROLLED. Release top deck at back, fold side channels, then secure roll with front roll-up straps. Unhook back curtain at sides and bottom, roll up to top of bow, then secure roll with roll-up straps.

(3) TOP DECK ROLLED AND BACK CURTAIN BOW DOWN. Roll top deck and back curtain as explained in step (2) above. Unscrew side top bow ring nuts, and allow bow to slide down in sockets.

(4) TOP DECK CORNER TURNED BACK. Release rear rope and front fastener on one side. Fold one corner of top deck over top.

21. CARGO BODY TARPAULINS.

a. Tarpaulins used with cargo and cargo dump bodies, and as camouflage equipment on gas and water tank bodies, consist of a separate top tarpaulin, front end curtain, and rear end curtain. Top tarpaulin is supported by bows which are fitted into pockets in cargo racks. The methods described in following subparagraphs permit the removal, folding, and installation of tarpaulins in shortest possible time.

b. Removal (figs. 27, 28, and 29).

(1) Untie all side and rear top tarpaulin lashing ropes. If these were tied correctly, it will be only necessary to pull free end of each rope. Front and rear curtains may or may not be removed at this time.

(2) With all top tarpaulin ropes untied, make first fold on each side lengthwise until lower edge of tarpaulin is even with top buckles.

(3) Make second fold lengthwise on both sides until both folds meet.

(4) Bring one folded side over the other fold.

(5) At each end, make an equal fold toward the center.

(6) Make another equal end fold until folded tarpaulin is laying across center bow.

c. Installation. Reverse procedures as described in subparagraph **b** above.

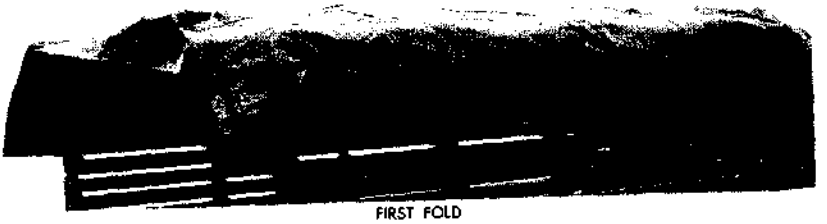
d. Stowing Tarpaulins. Do not fold or stow tarpaulins if they are wet.

e. Folding Top Tarpaulin for Ventilation. Untie all top tarpaulin ropes. At each side, fold tarpaulin *under* three folds. Straps on bows may then be lashed to buckles on tarpaulin. Tie front and rear draw ropes to lashing hooks at each end of body.

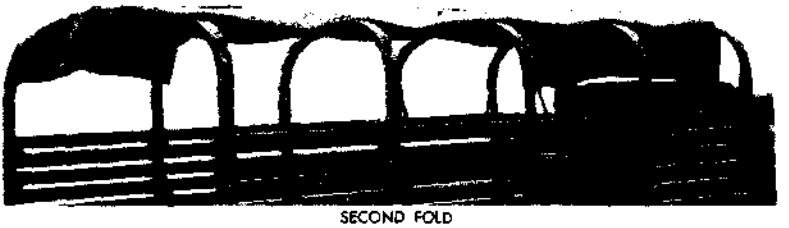
22. WINDSHIELD OPERATION.

a. Tilted Position (fig. 30). Loosen the upper adjusting thumb screw on each side. Push windshield outward at bottom to desired angle, then tighten thumb screws.

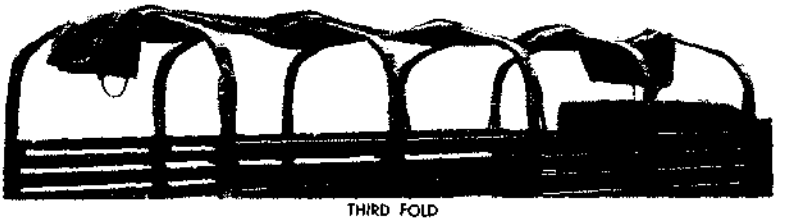
TRUCK, 2½-TON, 6 x 6



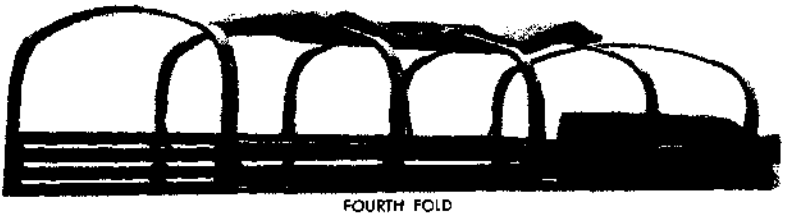
FIRST FOLD



SECOND FOLD



THIRD FOLD



FOURTH FOLD

FINAL FOLD

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Figure 27—Method of Removing Top Tarpaulin

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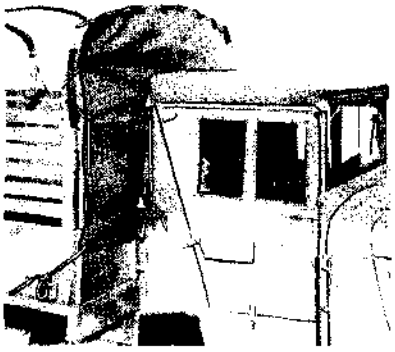
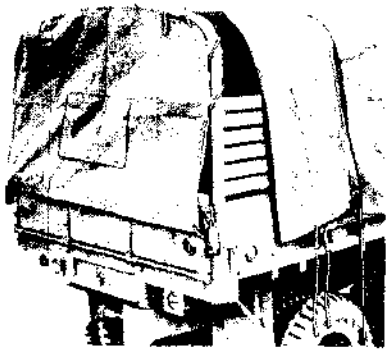
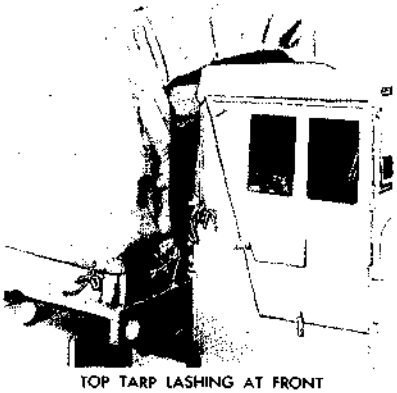


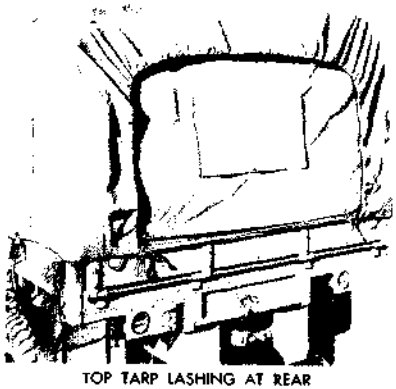
FRONT CURTAIN LASHED



REAR CURTAIN LASHED



TOP TARP LASHING AT FRONT



TOP TARP LASHING AT REAR

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Figure 28—Lashing at Front and Rear

b. **Lowered Position** (fig. 30). Cab top must be either disconnected from windshield and folded back, or unhooked from rear of cab and folded forward before windshield can be lowered. Loosen

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Figure 29—Tarpaulin Raised in Ventilating Position

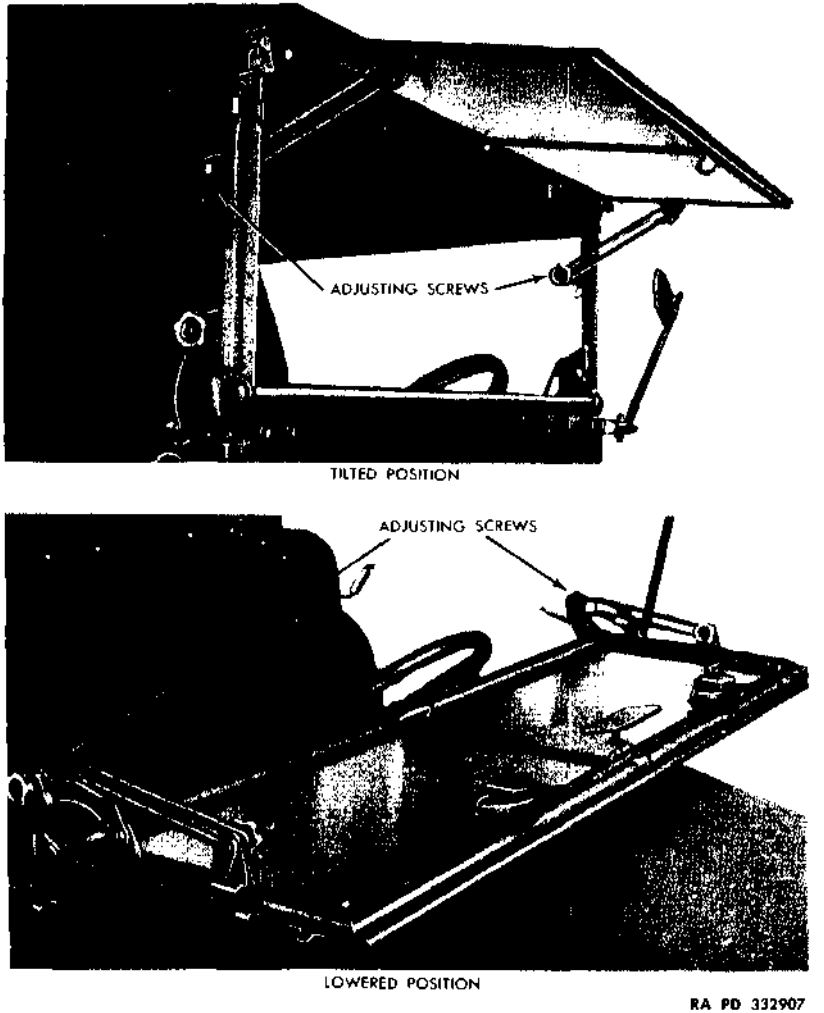

Figure 30—Windshield Operating Positions

lower thumb screw nuts. Lay windshield forward into position, then tighten thumb screw nuts.

23. TOWING THE VEHICLE.

a. Towing to Start. Engine may be started by towing vehicle with another vehicle in the following manner:

(1) Tow chain or line should be of sufficient length to permit maneuverability of both vehicles.

(2) In towed vehicle, pull throttle button out about ½ inch. Hold choke out part way if not previously used. Place transmission

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in fourth speed. Place transfer case in high. Do not engage front axle.

(3) Turn on ignition switch.

(4) While being towed for the first 100 feet, hold clutch in disengaged position. When towed vehicle speed reaches approximately 10 miles per hour, slowly engage clutch.

(5) Disengage clutch immediately after engine starts.

b. Towing Damaged Vehicles. Particular care must be exercised when towing damaged vehicles to repair bases to make certain that no additional damage occurs while vehicle is being towed.

(1) TOWING VEHICLES WITH ALL WHEELS ON GROUND.

(a) If transfer case on vehicle to be towed is not damaged, shift transmission and transfer case in neutral position. In this position, gears in transmission are not in motion; however, driving gears are revolving in transfer case, and gears will cause enough lubricant splash to provide lubrication for pocket bearings and main shaft bushings.

(b) If transfer case is damaged, propeller shafts should be disconnected at front axle pinion, forward rear axle pinion, and pillow block. Secure shafts to frame. Place bolts, nuts, and bearings in compartment in the cab.

(2) TOWING VEHICLE WITH FRONT WHEELS OFF GROUND. Whenever vehicle is to be towed with front wheels off ground, vehicle must be supported in such a manner that wheels of forward rear axle contact ground. Disconnect propeller shafts at forward rear axle and pillow block. Secure ends of shafts to frame.

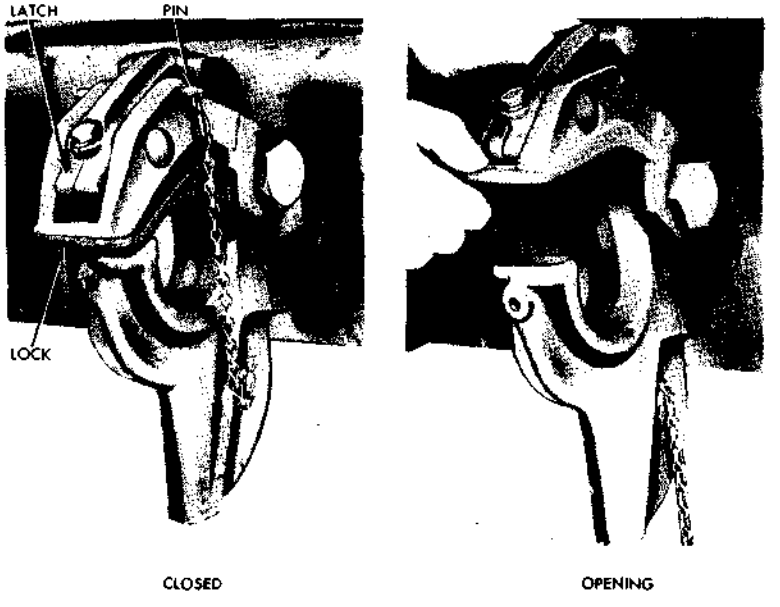

Figure 31—Pintle Hook Operating Positions

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(3) TOWING VEHICLE WITH REAR WHEELS OFF GROUND. Vehicle should be towed backward only after other methods have proven unsatisfactory. When towing vehicle backward, make certain that front axle declutching lever is placed in "OUT" or disengaged position.

c. **Use of Pintle Hook** (fig. 31). To open, remove pin, then lift up latch and pull up lock with hand. To close, push down lock. Latch will then be placed. Insert pin.

Section VI

OPERATION OF AUXILIARY EQUIPMENT

24. WINCH OPERATION.

a. **General.** Winch assembly, when used, is mounted forward of radiator between frame side rail extensions. The unit is driven by transmission power take-off through a drive shaft extending from power take-off to winch worm shaft housing. Winch may be used on short or long wheelbase chassis (CCKW-352 and 353) equipped with cargo body, and long wheelbase chassis equipped with cargo dump body (CCKW-353-H1 or H2). Winch is not used on chassis equipped with water or gas tank bodies.

b. **Controls.**

(1) POWER TAKE-OFF. The engagement of the power take-off is manually accomplished by means of a lever which extends through the floor pan in the cab (fig. 33). This lever has three operating and two neutral positions in following order from rear of cab toward front:

(a) When Winch Only Is Used (fig. 33). Low ("L"), neutral ("N"), reverse ("R"), neutral ("N"), and high ("H").

(b) When Winch and Power Hoist Are Used. Reverse ("R"), neutral ("N"), low ("L"), neutral ("N"), and high ("H").

(c) Control Lever Catch (fig. 33). A hinge plate attached to floor board beside lever provides positive means of locking lever into a neutral position. This arrangement will prevent accidental engagement of power take-off. The lever can be locked in the neutral position between high ("H") and reverse ("R") when winch only is used, and between reverse ("R") and low ("L") when winch and power hoist are used.

(2) WINCH CONTROLS. An automatic safety brake on the winch worm shaft will sustain load while the winch power take-off control lever is being shifted into various positions. A manually operated shift yoke at the winch is used to engage and disengage winch drum.

(a) Safety or Under Way Position. When vehicle is under way and winch is not operating, shift yoke must be placed into engaged position (fig. 32). Cable then will not unwind from drum while vehicle is under way.

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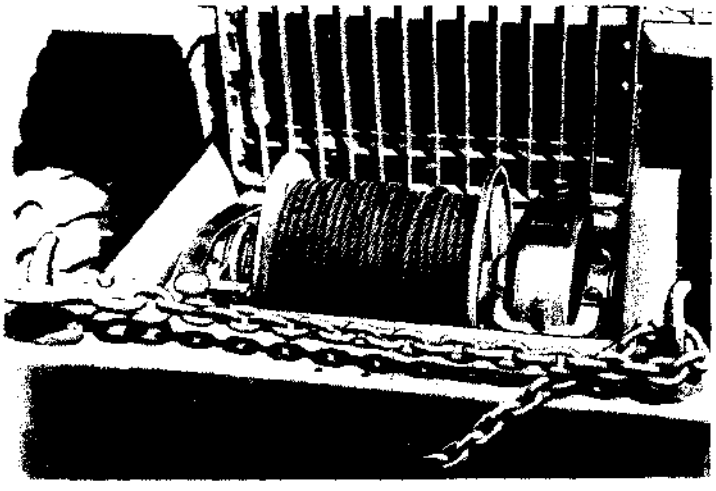
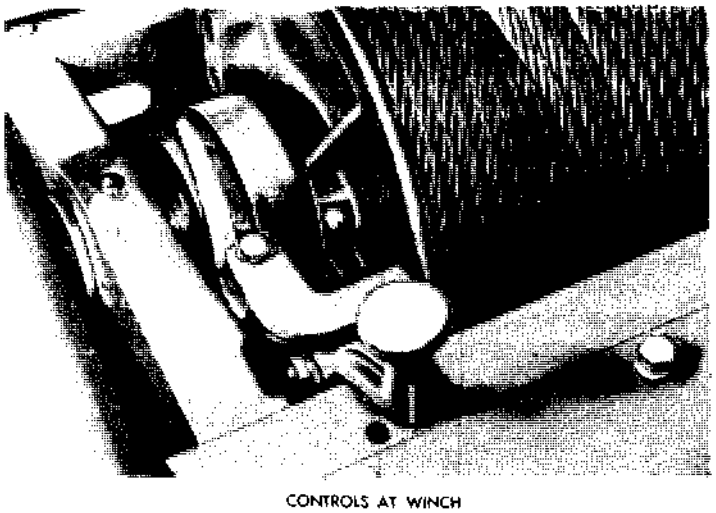


WINCH INSTALLED



CONTROLS AT WINCH

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Figure 32—Controls at Winch

(b) Hand Winding Position. When necessary to wind or unwind the cable by hand, place shift yoke into disengaged position with handle poppet engaged in hole. Cable drum may then be revolved by hand.

(c) Operating Position. When winch is to be operated by power take-off, place shift yoke into engaged position.

c. Operating Winch. Important: The winch will be more powerful with all cable off the drum before it starts to operate. Under many conditions, this is not possible; however, the best procedure

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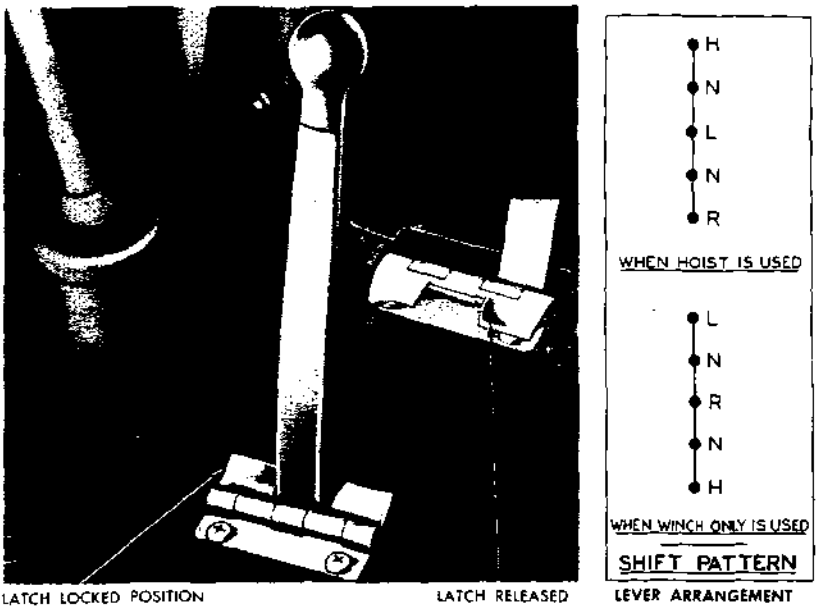

Figure 33—Winch P.T.O. Control Lever

to use is to pay-out as much cable as possible from the winch drum before starting to pull.

(1) To HOOK ON. Place shift yoke into disengaged position (fig. 32). Pull out enough cable to make hook-up.

(2) To PULL (WIND IN). After hook-up has been made, place shift yoke into engaged position (fig. 32). Depress engine clutch pedal, place winch power take-off control lever in low ("L") if load is heavy, or into high ("H") to take up slack if load is light. Release clutch pedal, then accelerate engine to proper speed (step *(a)* below).

(a) Pulling Speeds. Winch pulling speeds are based on a maximum engine speed of 1,000 revolutions per minute. This speed must not be exceeded when operating winch. Operating at a faster speed will result in excessive strains and probable failure of parts.

(b) Use of Power Take-off Low and High Ranges. Use high ("H") range when handling light loads and low ("L") range when handling heavy loads. Do not race engine when winching, particularly when handling light loads or when winding cable with no load.

(3) To LOWER (PAY-OUT).

(a) With Load. With shift yoke in engaged position, depress clutch, place winch power take-off control lever into reverse ("R") position, release clutch, and accelerate engine to desired speed.

(b) Without Load. It is not necessary to use power take-off engagement if cable is to pay-out without load. Place shift yoke in disengaged position.

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OPERATION OF AUXILIARY EQUIPMENT

(4) WINDING CABLE. Cable should not be wound on drum without some load. Winding on first layer of cable is most important. Coils of cable must be tight against each other to prevent coils on next layer from pressing down between them. Cable should be wound on drum evenly and slowly to obtain this result. After first layer is wound evenly, it is necessary to see that each additional layer starts back across drum properly. Two methods of winding cable can be used (steps *(a)* and *(b)* below).

(a) With Load on Cable. Cable should be properly attached to an anchor or tree and vehicle pulled forward by winch. A very light pressure on vehicle brake by operator while winding cable will insure a tight, neat wind.

(b) With Winding Fixture. A fixture such as illustrated in figure 34 may be used to maintain slight tension on cable when it is guided into drum. This fixture is not a special tool and can be made up locally. Two main sections can be made from heavy lumber such as 2x4 strips or larger. The guide block is of metal approximately 4x4x6 inches, split through drilled hole to permit insertion of cable and split bushing. It is tightened by means of stud with a large wing nut to obtain desired cable tension. End of fixture may be securely clamped to front bumper with a hooked bolt or C-clamp as shown. Pivot point is at ground level. This will permit swinging free arm, with guide block, back and forth to guide cable and wind it in even layers on drum.

(5) USE OF DRIVING WHEELS WITH WINCH. If vehicle is assisting itself with its own winch, all driving wheels should be utilized. Always start wheels operating the instant winch cable starts to take the load; in other words, do not start driving wheels if there is a slack in winch cable. When driving wheels are used to assist winch operation, power take-off lever must be in low ("L"), transmission in low, and transfer case in low range.

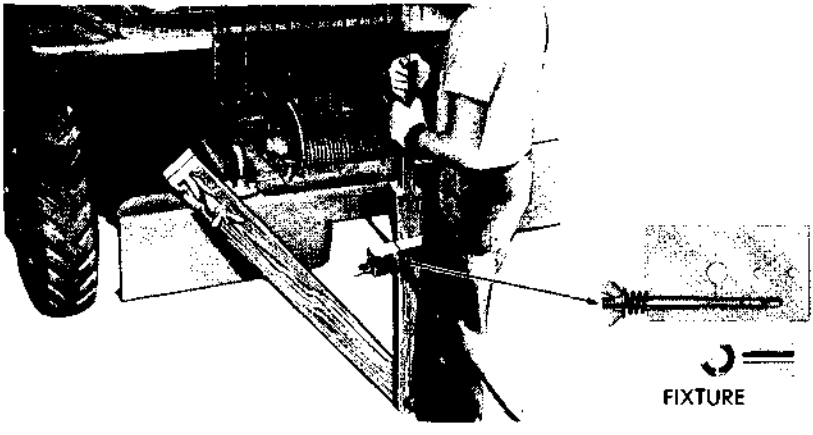

Figure 34—Use of Fixture to Wind Cable

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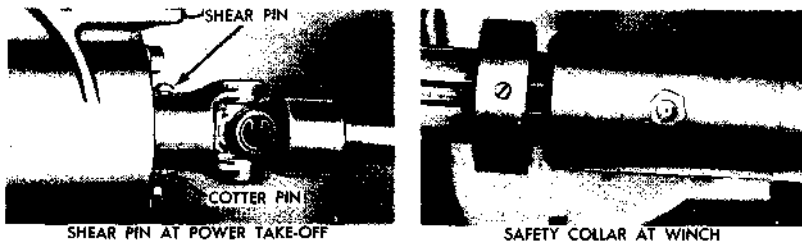

Figure 35—Safety Shear Pin Installation

(6) SAFETY SHEAR PIN REPLACEMENT. One safety shear pin is used to connect the winch front drive shaft universal joint to the winch worm shaft. This pin is designed to shear when the winch is loaded beyond its capacity. Spare pins are furnished with the vehicle and are stowed in the compartment underneath co-driver's seat. Use the regulation shear pin, do not use a substitute. Replace shear pin in following manner:

(a) Move Safety Collar (fig. 35). Loosen set screw in safety collar located at slip joint at power take-off. Slide collar away from slip joint.

(b) Remove Sheared Pin. Slide front universal joint back on winch worm shaft, at winch, until sheared portion of pin is exposed in worm shaft. With a punch, drive portions of pin from winch worm shaft and universal joint yoke.

(c) Install Shear Pin. Apply a small amount of chassis grease to end of winch worm shaft; then slide universal joint yoke over end of winch worm shaft. Aline shear pin hole in shaft with yoke. Install shear pin and secure with new cotter pin (fig. 35).

(d) Position Safety Collar. Locate safety collar so that a space of ½ inch exists between collar and yoke. Tighten collar set screw.

(7) RIGGING. Reference should be made to authoritative manuals on rigging and the use of snatch blocks. Rigging should be placed, whenever possible, to permit straight pull from winch.

25. CARGO DUMP BODY OPERATION.

a. General. The combination cargo-dump body is an all-steel body, which can be used either as a cargo or dump unit. A hydraulic hoist and subframe assembly, mounted on the chassis under the body, elevates the body when being used as a dump truck. Controls for operation of the hoist are located in the cab. Hoist pump, when engaged, is driven by transmission power take-off through drive shafts connecting power take-off with hoist pump.

b. Hoist Operation.

(1) GENERAL. Hoist should only be used when body is being used for dumping purposes. Do not operate hoist pump when vehicle is in motion. Controls for the operation of the hoist consist of two levers, located in cab. One lever is used only to engage power

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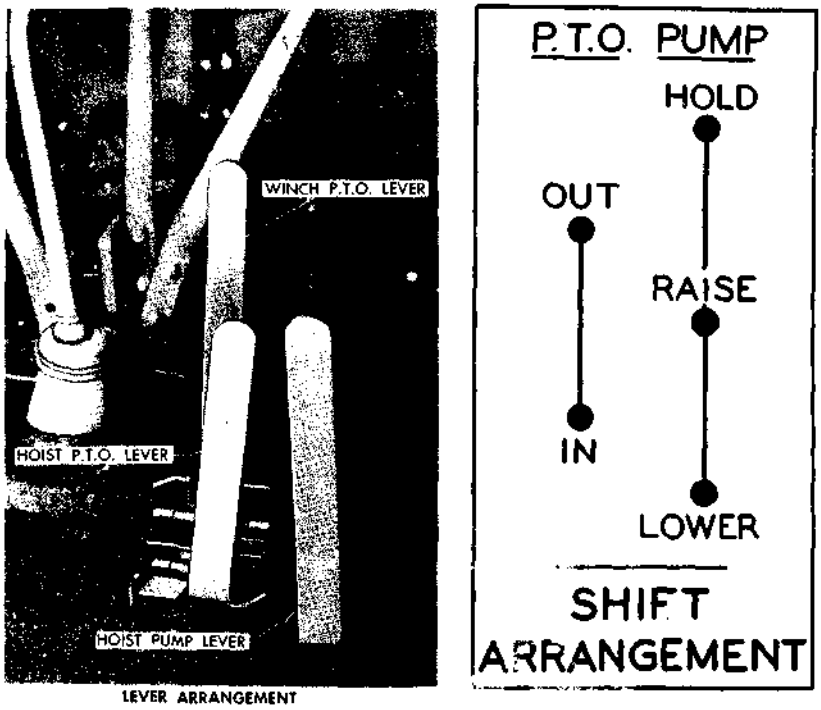

Figure 36—Hoist Control Levers and Shifting Arrangements

take-off and start pump operating. Other lever controls pump action, and is used only to raise, hold, or lower the body.

(2) TO RAISE BODY.

(a) Engage Power Take-off (fig. 36). *With engine running at slow idle,* depress clutch pedal and move power take-off hoist control lever rearward into "IN" position, then release clutch pedal.

(b) Engage Pump (fig. 36). With power take-off engaged (step *(a)* above), move hoist control valve lever ("PUMP") into center ("RAISE") position. Accelerate engine only sufficiently to raise body. Racing the engine does not increase dumping speed, and may cause damage to pump or force air into system. When hoist has reached its full stroke, it will stop automatically; however, the clutch pedal should be depressed and power take-off control lever moved to "OUT" position.

(3) TO HOLD BODY. Body can be held in any intermediate position during raising or lowering by shifting hoist control valve lever to "HOLD" position.

(4) TO LOWER BODY. Engine need not be running to lower body. Place hoist control valve lever ("PUMP") in "LOWER" position. Body will return to horizontal position. Lowering speed should not

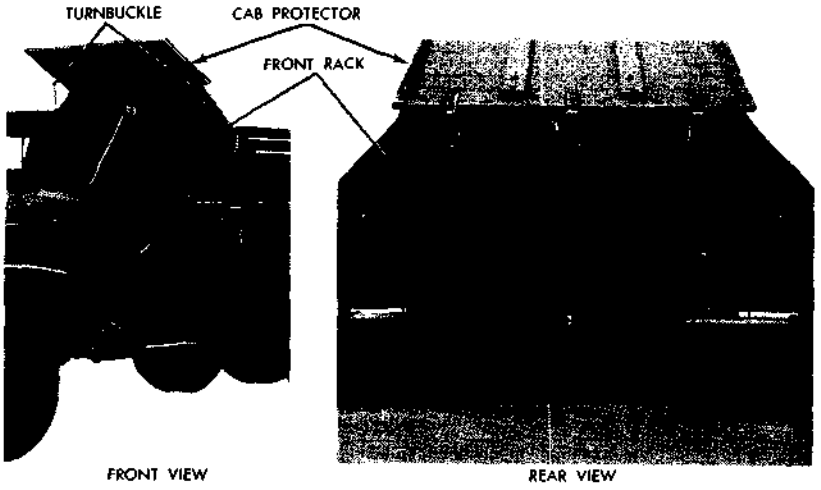

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Figure 37—Cab Protector Raised

be excessive and may be controlled by moving valve lever slightly forward.

(5) UNDER WAY. *Power take-off control lever must be in "OUT"* (not engaged), *and hoist control valve lever in "LOWER" position when truck is under way (except when spreading)* (subpar. d below).

c. **Body.**

(1) AS A DUMP BODY. Before using the vehicle as a dump truck, it is necessary that alterations be made as outlined in steps (a) through (e) following.

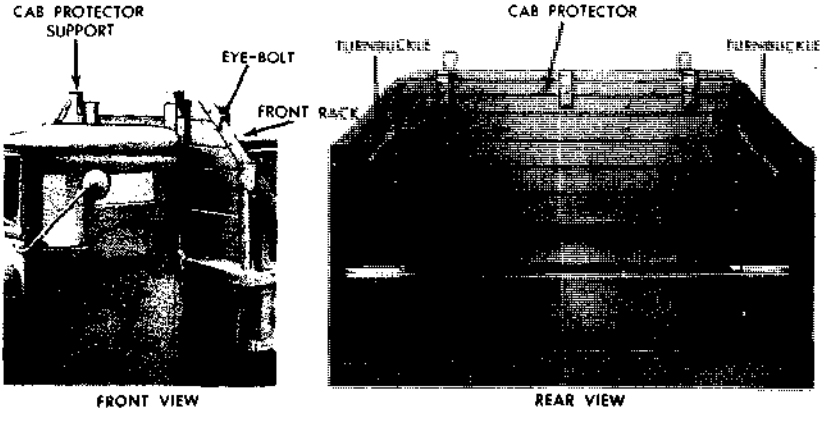

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Figure 38—Cab Protector Lowered

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OPERATION OF AUXILIARY EQUIPMENT

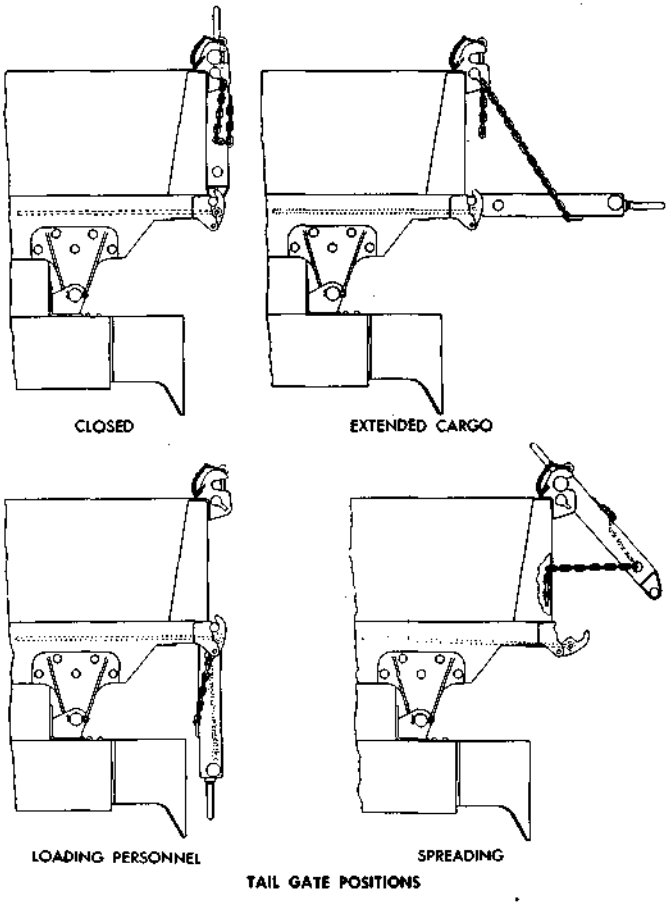

Figure 39—Tail Gate Lever and Tail Gate Positions

TRUCK, 2½-TON, 6 x 6

(a) Remove Tarpaulins. Untie and remove all tarpaulins and end curtains.

(b) Remove Seat and Side Rack Assemblies. Tag right- and left-hand assemblies for identification at installation, then remove each assembly.

(c) Adjust Cab Protector (figs. 37 and 38). Loosen cab protector turnbuckles at rear of front rack. Turn cab protector forward until it extends over top of cab. Install turnbuckle hooks through eye bolts in front rack. Tighten turnbuckle.

(d) Adjust Tail Gate (fig. 39). Tail gate is adjustable to several positions. When used as a dump body, tail gate must be locked at top with pins so that when dumped, gate will open at bottom. Tail gate chain can be positioned to control opening of gate to obtain desired spreading results.

(e) Raise Floor Partition. Raise partition in floor and lock in an upright (vertical) position (fig. 40), with bolts at each end through holes in body sides. NOTE: *It is extremely important that partition be raised, as this minimizes the possibility of overloading and distributes weight of load properly. Do not use body as dump body until partition has been raised.*

(2) AS A CARGO BODY. Before using the vehicle as a cargo truck, all items removed in steps (1) *(a)* through (1) *(e)* should be reinstalled or adjusted to their original position. Refer to figure 39 for various tail gate positions and figure 38 for cab protector in folded position.

d. Spreading. When desired, the tail gate opening can be adjusted to limit the opening, thereby limiting the flow of material being spread (fig. 39).

(1) Thread loose ends of tail gate chains into holes in rear corner post. Adjust chain length to limit tail gate opening. Install pins at each upper corner of tail gate so that gate will hinge at top.

(2) Engage power take-off *before vehicle is in motion and engine running at slow idle* as directed in subparagraph **b** (2) *(a)* above.

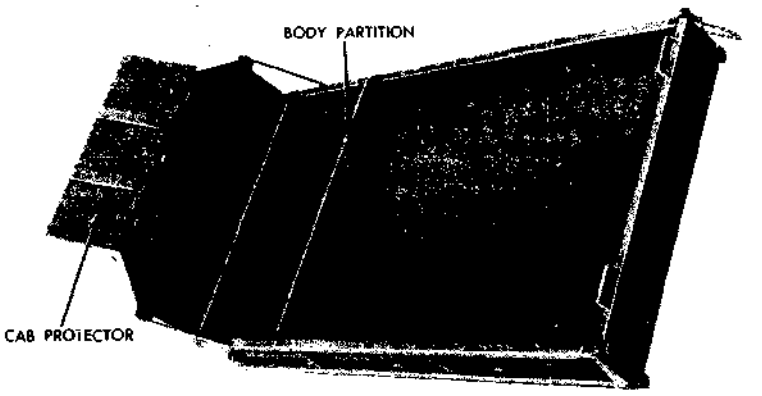

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Figure 40—Body Partition in Place

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(3) Pull tail gate control lever forward and down to unlatch tail gate. Engage pump (subpar. b (2) *(b)* above), and raise body two or three feet, or just enough so that material does not start to spill out of tail gate.

(4) Place hoist control valve lever ("PUMP") in "HOLD" position (fig. 36).

(5) Place transmission shift lever into 1st speed, transfer case into low range, then with power take-off lever still engaged, release clutch to set truck in motion. Transmission speeds used during spreading operations are dependent upon road conditions and material being spread. As a general rule, engine should not be operated at excessive speed, as this also increases pump speed and may cause damage to pump or force air into system.

(6) Raise body at intervals by moving valve control lever to "RAISE" position, then back to "HOLD" position. Repeat this operation as required to cause free flow of material.

(7) When unloaded, stop truck and disengage power take-off by moving lever to "OUT" position.

(8) Lower the body by moving valve control lever to "LOWER" position. Push tail gate lever upward and rearward to lock tail gate.

26. WATER TANK BODY OPERATION.

a. General (figs. 41 and 42). The 700 gallon water tank, mounted on long wheelbase chassis, is equipped with an auxiliary engine and pump unit. Water can be unloaded from truck by gravity or by pump. Water is loaded into the tank from any source by pumping unit. Tank is insulated and is lined with special composition. Water may be heated with portable gasoline type heater inserted directly

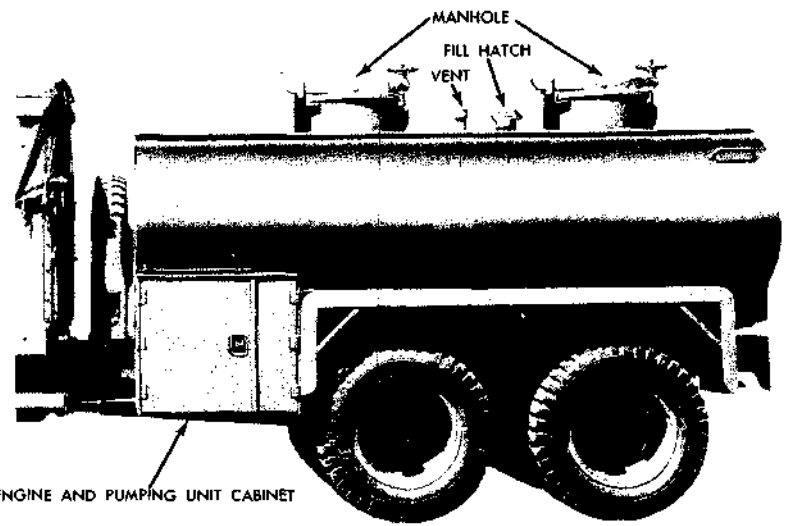

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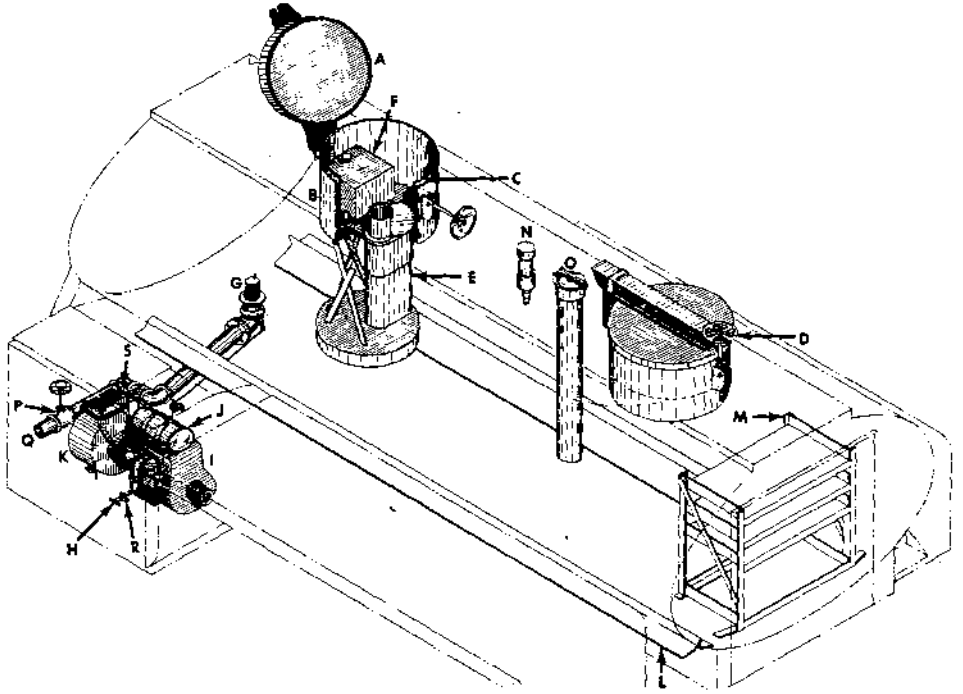
Figure 41—Water Tank Body



A MANHOLE COVER
B MANHOLE COLLAR
C MANHOLE PLUG
D HANDWHEEL
E HEATER
F HEATER GAS TANK
G EMERGENCY VALVE
H EMERGENCY VALVE OPERATOR
I PUMP ENGINE
J PUMP ENGINE GAS TANK
K PUMP
L SUCTION HOSE RACK
M EQUIPMENT CHEST
N VENT
O FILL HATCH
P GATE VALVE
Q HOSE CONNECTION NIPPLE
R STOP
S PUMP OUTLET PORT

RA PD 333013

Figure 42—Water Tank Body Controls

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into heater through a manhole, or by exhaust heat through a connection from vehicle exhaust system.

b. Equipment. Equipment cabinet at rear of body contains necessary discharge hoses and tools for the operation and maintenance of various controls. Lengths of suction hose are stowed on racks on side of body. Auxiliary engine and pumping unit is housed in compartment at left front side of body.

c. Auxiliary Engine and Pumping Unit. The pumping unit consists of a self-priming centrifugal pump mounted on a common base with, and driven by a single-cylinder, four-cycle, air-cooled gasoline engine. The impeller of the pump is attached directly to the engine crankshaft. Engine is self-lubricated and is equipped with separate fuel tank. Refer to manual which accompanies the pumping unit.

(1) AUXILIARY ENGINE OPERATION. Before auxiliary engine is started, its fuel tank and crankcase must be filled. In addition, pump controls must be set to desired position (subpar. d below), before engine is started.

(2) STARTING ENGINE.

(a) Fill crankcase of engine with seasonal grade crankcase oil (approx. 1¾ pints).

(b) Close shut-off valve in gasoline line, then fill fuel tank with a good quality gasoline (same as used in truck).

(c) Open fuel line valve, then close choke on carbureter air inlet horn. Turn choke lever away from engine.

(d) Carbureter needle valve opening is approximately ¾ to 1¼ turns. In cold weather, starting may be facilitated by opening the needle valve slightly more, then adjusting needle after engine has started.

(e) Insert knot of starter rope in the notch in starting sheave at flywheel end of engine, then wind the rope on sheave in clockwise direction. Pull briskly on rope to turn the crankshaft over.

(f) If engine does not start immediately, repeat operation (step *(e)* above). If choke in carbureter snaps open during hand cranking, close choke again for two or three turns of engine. If fuel begins to drip from carbureter, choke should be opened.

(g) When engine has started, flyball type governor will limit engine to set speed.

(3) STOPPING ENGINE. Press red stop button, located on magneto, for a few seconds until engine stops, then release pressure on button. Engine can then be restarted if desired (step (2) above).

(4) PRIMING PUMP. Remove plug at top of pump body and fill pump full of clean water. Replace plug. The pump will then reprime automatically until it is necessary to drain the priming chamber.

(5) DRAINING PUMP. During cold weather, pump housing should be drained if vehicle is to be parked. Close emergency valve and suction pipe gate valve. Place cap over end of discharge pipe. Remove plug from bottom of pump housing and drain all water from housing.

d. Operating Pump (fig. 42). Pump may be operated to dis-

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charge water from tank, to pump water into tank, or using pump unit to fill another water tank from an outside source.

(1) PUMPING FROM TANK.

(a) Connect discharge hose to outlet port.

(b) Close suction pipe gate valve.

(c) Open emergency valve (pull out handle).

(d) Start engine.

(2) PUMPING INTO TANK.

(a) Connect one end of discharge hose to outlet port and place the other in fill hatch after opening hatch cover.

(b) Connect suction hose to suction pipe nipple, then open gate valve.

(c) Close emergency valve (handle in).

(d) Start engine.

(3) USING PUMP UNIT TO FILL ANOTHER TANK.

(a) Close emergency valve (handle in).

(b) Connect suction hose to nipple, then open gate valve. Connect discharge hose to discharge port.

(c) Start engine.

e. Emptying Tank by Gravity. Place cap on discharge port. Connect suction hose to nipple, then open gate valve. Pull open emergency valve. Water will then flow out of tank through suction hose.

f. Heating Equipment.

(1) EXHAUST HEATER. The vehicle exhaust system is bypassed through a heater box in water tank. The exhaust bypass valve is manually operated by a control mounted on the dash panel to left of steering wheel. Pull control handle out to open bypass valve. CAUTION: *Always close exhaust bypass valve (handle in) when operating with empty tank. Operating with valve open while tank is empty will cause damage.*

(2) PORTABLE IMMERSION HEATER (fig. 43). A torch type portable immersion heater is installed into tank through rear manhole on some tank bodies. This heater remains in tank, and when heater stack is removed, manhole can be closed and latched. Heater operates on gasoline, kerosene, or distillate. Operate heater in following manner:

(a) Fill heater tank with fuel.

(b) Install three lengths of stack over exhaust port. Stack sections are stowed on side of body in a rack.

(c) Pull up torch from heater unit. Saturate torch with fuel, then light.

(d) Lift damper, then insert lighted torch into intake compartment, passing torch through opening in bottom damper opening into exhaust compartment. Offset in torch rod will permit this manipulation of torch. Lower damper, permitting it to rest on torch handle.

(e) Permit torch to burn in above manner for about 20 to 30 seconds; then lift damper and shift torch from exhaust compartment straight down to top of burner in intake compartment.

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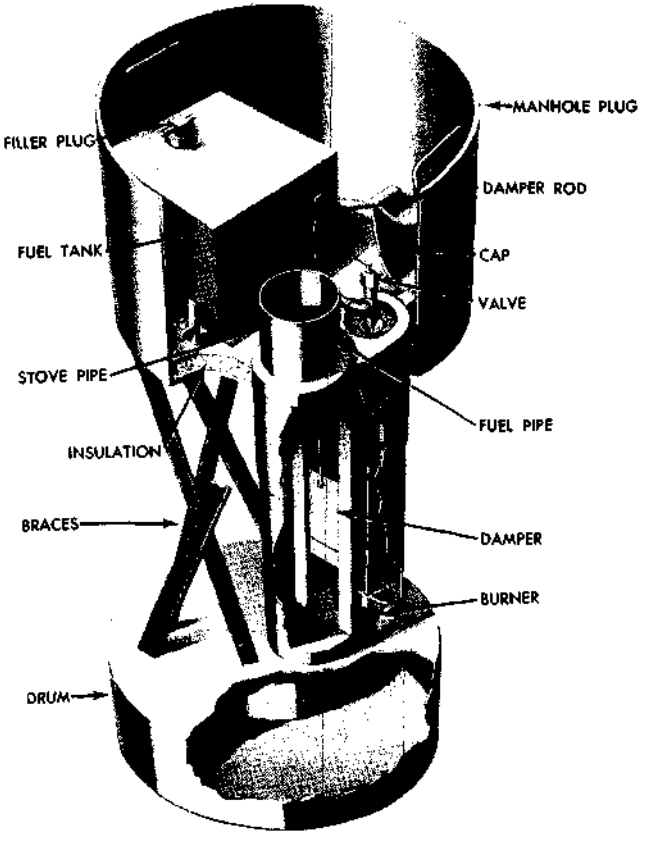


Figure 43—Immersion Heater

(f) Open fuel valve, below fuel tank, allowing a fast drip.

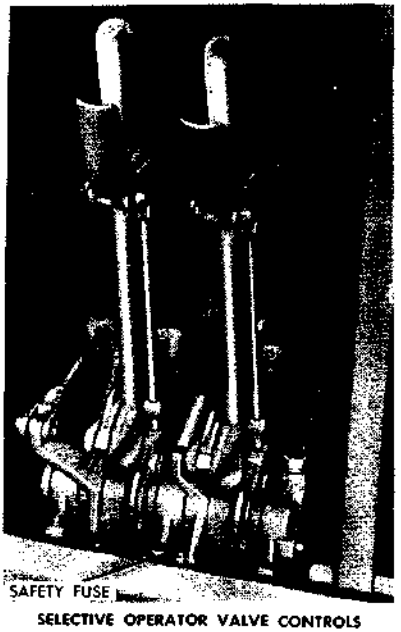
(g) After burner has operated for one minute, the fuel valve can be set for desired speed. The minimum speed is 20 drops per minute. Maximum speed is slightly under a stream. Smoke will appear from stack when speed is too fast.

(h) Heater can be lifted from manhole as a unit. When heater is removed, a manhole plug, such as used in the front manhole, must be inserted in place of heater unit.

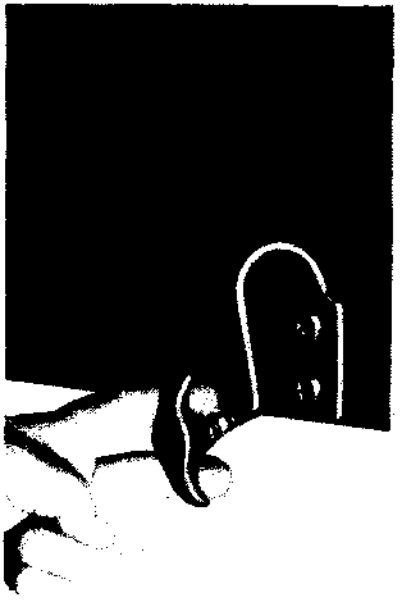
27. GASOLINE TANK BODY OPERATION.

a. General. Gasoline tank body, mounted on long wheelbase chassis (CCKW-353) comprises two tanks, each of 375 gallon capacity, together with manually operated lever controls for the independent discharging of each tank. Each tank can be filled through a manhole located at top of tank.

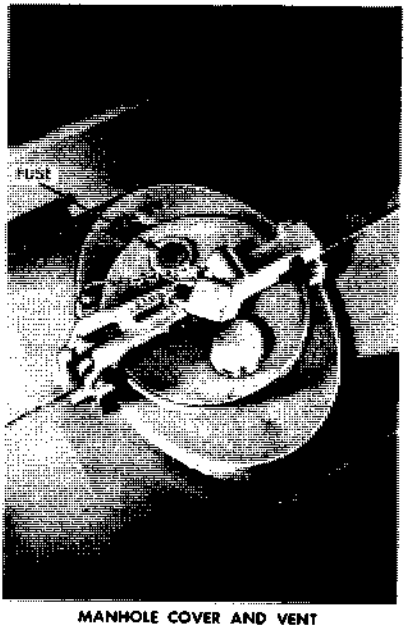
TRUCK, 2½-TON, 6 x 6



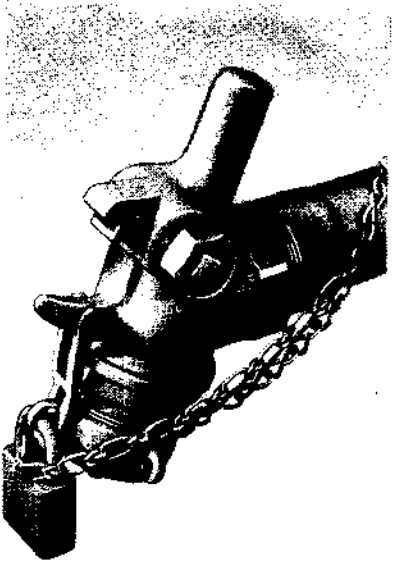
SELECTIVE OPERATOR VALVE CONTROLS



FRONT END TRIP RELEASE



MANHOLE COVER AND VENT



DISCHARGE FAUCET

RA PD 333020

Figure 44—Gasoline Tank Controls

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b. Tank Controls (fig. 44).

(1) SELECTIVE OPERATOR VALVE CONTROL. Selective operator valve controls are mounted in the right rear equipment chest and are interconnected with emergency valves on bottom side of each tank. Control levers are pulled forward when in discharge position. Levers will automatically be released to off position when door of cabinet is closed.

(2) FRONT END TRIP RELEASE. The front end trip release control handle is mounted at left front of body and is accessible to driver. When this trip release handle is pulled out, discharge of each tank is instantly sealed.

(3) DISCHARGE FAUCET. Faucet mounted at rear of body is equipped with a dust cap and locking hasp. Faucet is key operated. Spring loaded shut-off valve will hold shut when key is withdrawn.

(4) MANHOLE COVER. Manhole in each tank is equipped with a sealed, hinged type cover provided with latch which can be padlocked when in closed position. Each cover is provided with a vent, together with a fuse plug, which will provide additional vent in case of fire.

(5) SAFETY CHAIN. Each body is equipped with a safety chain of sufficient length to drag on the ground to prevent accumulation of static electricity.

(6) EQUIPMENT COMPARTMENTS. Equipment compartments on each rear side of body are furnished with door which hinges at top. Right compartment contains the selective controls, as well as space for additional equipment. Left compartment contains gage, gasoline cans and other equipment.

28. TANK BODY CAMOUFLAGE EQUIPMENT.

a. Some of the water tank and gasoline tank bodies are provided with camouflage equipment. This equipment consists of regulation cargo body bows, top tarpaulin, and rear curtain. These parts are installed in same manner as on the cargo bodies. After installation, the tank bodies have the appearance of regulation cargo bodies.

Section VII

OPERATION UNDER UNUSUAL CONDITIONS

29. COLD WEATHER OPERATION.

a. General. The operation and maintenance of these vehicles at low temperatures involve factors which do not exist at moderate temperatures. Since subzero temperatures affect both metals and lubricants, operation of the vehicles at these temperatures presents problems that demand special precautions.

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b. Gasoline. Winter grade of gasoline is designed to reduce cold weather difficulties; therefore, the winter grade of motor fuels procured under U.S. Army Specification 2-103, grade C, latest revision, will be used in gasoline engines of all vehicles. For vehicles within the continental limits of the United States, the winter grade of gasoline meeting U. S. Army Specification 2-114, grade C, will be used.

(1) STORAGE. Due to condensation of moisture from the air, water will accumulate in tanks, drums, and containers. At low temperatures, this water will form ice crystals that will clog fuel lines and carbureter jets unless the following precautions are taken.

(a) Strain the fuel through filter paper or any other type of strainer that will prevent the passage of water. CAUTION: *Gasoline flowing over a surface generates static electricity that will result in a spark unless means are provided to ground the electricity. A metallic contact between the container and the tank will be provided to insure an effective ground.*

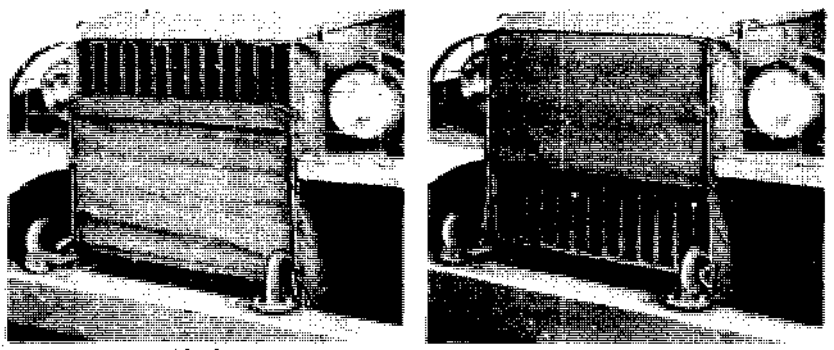
(b) Keep tank full if possible. The more fuel there is in the tank, the smaller will be the volume of air from which moisture can be condensed.

(c) Add one quart of denatured alcohol, grade 3, to the fuel tank at start of winter season, and one pint per month thereafter. This will reduce the hazard of ice formation in the fuel.

(d) Be sure that all containers are thoroughly clean and free from rust before storing fuel in them. If possible, after filling or moving a container, allow the fuel to settle 24 hours before filling vehicle tank from it. Keep all closures of containers tight to prevent snow, ice, dirt, and other foreign matter from entering.

(e) Wipe all snow or ice from dispensing equipment and from around fuel tank filler cap before removing cap to refuel vehicles.

c. Care of Engine When Not Running. For long periods of shut-down, as in bivouac, park vehicle in as sheltered a place as possible. For short shut-down periods, the vehicle should be parked in a sheltered spot out of the wind if possible. If no shelter is avail-



BOTTOM TOP

RA PD 332916

Figure 45—Positions of Radiator Shroud

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able, it will be helpful to park so that the vehicle does not face into the wind. For a shut-down period up to three hours, it will be unnecessary to use shrouds and heaters.

(1) OPERATION OF RADIATOR SHROUD. Purpose of radiator shroud is to protect engine compartment from weather when vehicle is not operating, to warm engine quickly, and to keep engine and battery temperatures normal while operating in low temperatures. During engine operation, the driver should note temperature gage and if temperature drops below normal, shroud should be adjusted accordingly. Shrould can be adjusted either from top or bottom as shown in figure 45, and tied in position with rawhide straps which are furnished with shroud.

d. Starting Instructions. Pull choke out three-quarters to full. Do not manipulate choke until engine is running, and then with caution. Prime engine as required. Disengage clutch and operate cranking motor. Continue priming as required until engine starts and carbureter cuts in. After engine has started, it must be allowed to idle until cooling system temperature begins to rise. Check battery warming coil for leaks (if vehicle is equipped with built-in heater). Regulate engine temperature by use of shutters on radiators.

30. COLD WEATHER LUBRICATION.

a. Transmission, Transfer Case, and Differentials.

(1) SAE 80 universal gear lubricant, where prescribed, is suitable for use at temperatures as low as –20° F. If consistent temperature below 0° F is anticipated, drain the gear cases while warm and refill with grade 75 universal gear lubricant which is suitable for operation at all temperatures below +32° F. If grade 75 universal gear lubricant is not available, SAE 80 universal gear lubricant, diluted with the fuel used in the engine in the proportion of one part fuel to six parts SAE 80 universal gear lubricant, shall be used. Make-up oil will be diluted in the same proportion before it is added to gear cases.

(2) After engine has been warmed up, engage clutch and maintain engine speed at fast idle for five minutes until gears can be engaged. Shift transmission into low (first) gear, and drive vehicle for 100 yards, being careful not to stall engine. This will heat gear lubricants to the point where normal operation can be expected.

b. Other Lubrication Points.

(1) REAR SPRING SEAT BEARINGS. If vehicle has been operated at least 1,000 miles, using No. 0 general purpose grease for lubrication, no special precautions are necessary for the rear spring seat (bogie) bearings. If quantities of No. 1 general purpose grease are in these bearings, it will be necessary to disassemble and wash in dry-cleaning solvent, dry, and then relubricate with No. 0 general purpose grease for satisfactory operation.

(2) WHEEL BEARINGS. Wheel bearings and grease cups using No. 2 general purpose grease shall be lubricated with the same lubricant at all times. If repacking must be performed at sufficiently low temperature that thorough hand-packing cannot be accomplished,

No. 0 general purpose grease may be used until temperature returns to above 0° F.

(3) CHASSIS POINTS. Other chassis points must be lubricated with No. 0 general purpose grease.

(4) HYDROVAC CYLINDERS. Lubricate with shock absorber fluid, light, at all temperatures.

(5) STEERING GEAR HOUSING. Drain, if possible, or use suction gun to remove as much lubricant as possible. Refill with grade 75 universal gear lubricant, or, if not available, with SAE 80 universal gear lubricant diluted with fuel used in the engine in the proportion of one part fuel to six parts SAE 80 universal gear lubricant. Make-up oil will be diluted in the same proportion before it is added to the housing.

(6) OILCAN POINTS. For oilcan points where engine oil is prescribed for above 0° F, use light preservative lubricating oil.

c. Preparation of Engines Not Equipped with Cold Weather Kits.

(1) KEEPING CRANKCASE OIL FLUID. Several methods for keeping crankcase oil sufficiently fluid for proper lubrication are listed below. Preference should be given to the different methods in the order listed, according to the facilities available.

(a) Keep the vehicle in a heated enclosure when it is not being operated.

(b) When the engine is stopped, drain the crankcase oil while it is still hot and store in a warm place until the vehicle is to be operated again. If warm storage is not available, heat the oil before reinstalling. NOTE: *Do not get the oil too hot; heat only to the point where the bare hand can be inserted without burning. Tag the vehicle in a conspicuous place in the cab to warn personnel that the crankcase is empty.*

(c) Dilute the crankcase oil. Crankcase oils may be diluted with gasoline or Diesel fuel according to their availability, with preference given to gasoline. One of the two following procedures will be used to provide the engine with properly diluted engine oil for cold starting.

(2) WHEN GASOLINE IS AVAILABLE FOR DILUENT.

(a) Fill engine crankcase to the "FULL" mark with the grade of engine oil prescribed for use at temperatures from 32° F to 0° F. Add 1½ quarts of gasoline for each 5 quarts of crankcase oil capacity. EXAMPLE: Crankcase with capacity of 10 quarts will require 3 quarts of gasoline as an oil diluent.

(b) Run the engine 5 to 10 minutes to mix the lubricant and diluent thoroughly.

(c) Stop the engine and note that the level of the diluted oil is above the normal "FULL" mark on the oil gage. This level should be marked on the gage for future reference.

(d) The presence of a large percentage of light diluent will increase oil consumption and, for that reason, the oil level should be checked frequently. Use the grade of engine oil prescribed for use

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between 32° F to 0° F to maintain the oil level to dip stick "FULL" mark during operation.

(e) If the vehicle is operated four hours or more at operating temperature, redilution will be necessary if it is anticipated that the vehicle will be left standing unprotected for five hours or more. This can be accomplished by adding engine oil prescribed for use between 32° F to 0° F to the dip stick "FULL" mark; then adding gasoline to the dilution mark on the gage described in step *(c)* above.

(3) If Diesel fuel is used as diluent, drain the crankcase while the engine is still warm and refill, using engine oil prescribed for temperatures between 32° F to 0° F diluted with grade X Diesel fuel oil in the proportion of 1½ quarts of Diesel fuel to five quarts of engine oil. The presence of a large percentage of diluent will increase oil consumption and, therefore, the oil level will be checked frequently during operation and maintained with the diluted oil to dip stick "FULL" mark.

(4) If the vehicle is to be kept outdoors, and if the crankcase cannot be drained, cover the engine with a tarpaulin. About three hours before the engine is to be started, place fire pots under the tarpaulin. A Vag Prag, Primus-type, or other type blowtorch and ordinary kerosene lanterns may be used. With due consideration for the fire hazard involved, the flame may be applied directly to the oil pan.

31. PROTECTION OF COOLING SYSTEM AND PREPARATION OF VEHICLE FOR COLD WEATHER OPERATION.

a. Protection of Cooling System.

(1) Cooling system will be protected with antifreeze compound for operation below +32° F. The following instructions apply to use of new antifreeze compound. For use of reclaimed antifreeze solutions, refer to Ordnance Field Service Technical Bulletin 700-20, dated 13 October 1942.

(2) Before adding antifreeze compound, it is necessary that the cooling system be clean and completely free from rust. If the cooling system has been cleaned recently, it may be necessary only to drain, refill with clean water, and again drain. Otherwise, the system will be cleaned with cleaning compound.

(3) Heaters, water cooled compressors, and other units in the cooling system must be cleaned in addition to the radiator and engine water jacket.

(4) All hoses must be inspected and replaced if deteriorated. Hose clamps, plugs, and petcocks must be inspected and tightened if necessary. Radiator leaks must be repaired before adding antifreeze compound. Exhaust gas or air leakage into the cooling system must be corrected.

(5) When the cooling system is clean and tight, add antifreeze compound, using the proportion of antifreeze compound to the cooling system capacity indicated below. The system should be protected to at least 10° F below the lowest expected temperature to be experienced during the winter season.

TRUCK, 2½-TON, 6 x 6

Atmospheric Temperature Degrees Fahr.	Quantity of Ethylene Glycol (Qt)	Quantity of Water (Qt)
+20	3¼	15¾
+10	4¾	14¼
0	6½	12½
− 5	7	12
−10	7½	11½
−15	8	11
−20	8½	10½
−30	9¼	9¾
−40	10	9
−50	10¾	8¼
−60	11½	7½

(6) After adding antifreeze compound, fill with water to slightly below the filler neck; then start and warm the engine to normal operating temperature.

(7) The engine should then be stopped and the solution checked with a hydrometer, adding antifreeze compound if required.

(8) In service, the coolant is to be inspected weekly for strength and color. Rusty solution should be drained, the cooling system thoroughly cleaned, and new solution of the required strength added.

(9) CAUTIONS:

(a) Antifreeze compound is the only antifreeze authorized for Ordnance material.

(b) It is essential that antifreeze solutions be kept clean. Use only containers and water that are free from dirt, rust, and oil.

(c) Use an accurate hydrometer. To test a hydrometer, use one part antifreeze compound to two parts water. This solution should produce a hydrometer reading of 0° F.

(d) Do not spill antifreeze compound on painted surfaces.

b. Electrical Systems.

(1) GENERATOR AND CRANKING MOTOR. Check the brushes commutators, and bearings. See that the commutators are clean. The large surges of current which occur when starting a cold engine require good contact between brushes and commutators.

(2) WIRING. Check, clean, and tighten all connections, especially the battery terminal. Care should be taken that no short circuits are present.

(3) COIL. Check coil for proper functioning.

(4) DISTRIBUTOR. Clean thoroughly, and clean or replace points. Check the points frequently. In cold weather, slightly pitted points may prevent engine from starting.

(5) SPARK PLUGS. Clean and adjust or replace if necessary. If it is difficult to make the engine fire, reduce the gap 0.005 inch less than normally used (par. 89). This will make ignition effective at the reduced voltages likely to prevail.

(6) TIMING. Check carefully. Care should be taken that the spark is not unduly advanced or retarded.

(7) BATTERIES.

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OPERATION UNDER UNUSUAL CONDITIONS

(a) The efficiency of batteries decreases sharply with decreasing temperatures, and becomes practically nil at −40° F. Do not try to start the engine with the battery when it has been chilled to temperature below −30° F until battery has been heated, unless a warm slave battery is available. See that the battery is always fully charged, with the hydrometer reading between 1.275 and 1.300. A fully charged battery will not freeze at temperatures likely to be encountered even in arctic climates, but a fully discharged battery will freeze and rupture at +5° F.

Specific Gravity Taken at 60 Degrees Fahr.	*Freezing Temperature Degrees Fahr.*
1.100	+18
1.120	+14
1.140	+ 8
1.160	+ 2
1.180	− 6
1.200	−17
1.220	−31
1.240	−51
1.260	−75
1.280	−92
1.300	−95

(b) Do not add water to a battery when it has been exposed to subzero temperatures unless the battery is to be charged immediately. If water is added and the battery not put on charge, the layer of water will stay at the top and freeze before it has a chance to mix with the acid.

(c) Testing Specific Gravity. Determination of specific gravity is accomplished by the use of a commercial hydrometer supplied for this purpose. These are usually calibrated to read accurately only when electrolyte is at certain specified temperature. Standards commonly used are 60° and 80° F. It is necessary to make corrections when taking readings at temperatures other than specified standard of hydrometer used. For every 10° the temperature is above the hydrometer standard, 0.004 must be added to the specified gravity reading. For every 10° the temperature is below the standard, 0.004 must be subtracted from the reading. Specific gravity readings without corrections for temperature are meaningless.

(8) LIGHTS. Inspect the lights carefully. Check for short circuits and presence of moisture around sockets.

(9) Before every start, see that the spark plugs, wiring, or other electrical equipment is free from ice.

c. Engines.

(1) Be sure that no heavy grease or dirt has been left on the cranking motor throwout mechanism. Heavy grease or dirt may keep the gears from being meshed or cause them to remain in mesh after the engine starts running. The latter will ruin the cranking motor and necessitate repairs.

(2) A full choke is necessary to secure the rich air-fuel mixture required for cold weather starting. Check the butterfly valve to see that it closes all the way, and otherwise functions properly.

(3) Carbureters which give no appreciable trouble at normal temperatures may not operate satisfactorily at low temperatures. A fuel pump which will deliver enough gasoline at normal starting speeds of 500 revolutions per minute may have leaky valves or a defective diaphragm which will prevent it from delivering the amount of fuel required to start the engine at low temperatures when turning speeds are reduced to 30 to 60 revolutions per minute. Faulty fuel pumps or carbureters should be corrected or replaced.

(4) AIR CLEANERS. At temperatures between 0°F and —40°F, remove air cleaner, disassemble, wash all parts in dry-cleaning solvent, dry thoroughly, and reassemble. Refill to correct level with OIL, hydraulic or FLUID, shock absorber, light. Check reservoir daily and fill to correct level if necessary. Every 1,000 miles, disassemble, wash, dry, reassemble, and refill with above oil. This applies also to crankcase breather air cleaner. Below —40° F, carbureter and crankcase air cleaner must be disassembled, washed, reassembled, and replaced dry.

d. Fuel System. Remove and clean strainer daily. Also drain fuel tank sump daily to remove water and dirt.

e. Chassis.

(1) Brake bands, particularly on new vehicles, have a tendency to bind when they are very cold. Always have a blowtorch handy to warm up these parts if they bind when attempting to move the vehicle. Parking the vehicle with the brake released will eliminate most of the binding. Precaution must be taken, under these circumstances, to block the wheels or otherwise prevent movement of the vehicle.

(2) Inspect the vehicle frequently. Shock resistance of metals, or resistance against breaking, is greatly reduced at extremely low temperatures. Operation of vehicles on hard, frozen ground causes strain and jolting which will result in screws breaking or nuts jarring loose. Cables should operate satisfactorily at all temperatures providing they are coated with No. 0 general purpose grease and there is no excess grease in the housing.

32. HOT WEATHER OPERATION.

a. Operation of these vehicles in high temperatures requires regular maintenance of cooling units, lubrication filtering devices, and air cleaners. In extremely high temperatures, water saving devices such as surge or overflow tanks should be employed.

b. Cooling System Maintenance.

(1) COOLING LIQUID. Formation of scale and rust in cooling system occurs more often during operation in extremely high temperatures; therefore, rust preventives should always be added to the cooling liquids (par. 107). Use only clean water. Avoid the use of water that contains alkali or other substances which may cause scale and rust formation.

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OPERATION UNDER UNUSUAL CONDITIONS

(2) CLEANING COOLING SYSTEM. Cooling system should be thoroughly cleaned and flushed at frequent intervals when operating in extremely high temperatures.

(3) FAN BELT AND WATER PUMP. Fan belt should be inspected at regular intervals and adjusted if necessary (par. 108). Water pump must be kept in good operating condition.

(4) THERMOSTAT. Check operation of thermostat (par. 110). Thermostat must open at calibrated temperature to prevent overheating of cooling liquid.

(5) HOSE CONNECTIONS. Check connections frequently for leaks.

c. Oil Filters. Oil filter elements must be checked and replaced at more frequent intervals if vehicle is operating in hot, sandy regions. Crankcase air vent cleaner must be serviced at frequent intervals.

d. Air Cleaners. If vehicle is operating extensively in sandy or dusty regions, carbureter air cleaner should be cleaned daily. If vehicle operates in dust storm areas, cleaner should be cleaned immediately after such storms occur.

e. Battery.

(1) WATER LEVEL. In torrid zones, cell water level should be checked daily and replenished if necessary with pure distilled water. If this is not available, any water fit to drink may be used. However, continuous use of water with high mineral content will eventually cause damage to battery and should be avoided.

(2) SPECIFIC GRAVITY. Batteries operating in torrid climates should have a weaker electrolyte than for temperate climates. Instead of 1.300 gravity, the electrolyte should be adjusted to around 1.210 to 1.230 for a fully charged battery. This will prolong the life of the negative plates and separators. Under this condition, battery should be recharged at about 1.160. Where freezing conditions do not prevail, there is no danger with gravities from 1.230 to 1.075.

(3) SELF-DISCHARGE. A battery will "self-discharge" at a greater rate at high temperatures if standing for long periods. This must be taken into consideration when operating in torrid zones. If necessary to park for several days, battery should be removed and stored in a cool place.

f. Operating Vehicle. In extremely high temperatures, avoid the continuous use of low gear ratios whenever possible. Frequent inspection and servicing of air cleaners, fuel filter, and oil filter should be made during operation in dusty areas. Watch the temperature and oil gages constantly. Check and replenish oil and water frequently.

g. Side Panels. *Engine side panels must not be removed to lower cab temperature or for any other reason.* The engine hood side panels form an air tunnel which directs air onto and past engine for best cooling effect. After hood side panels are removed, effectiveness of the air tunnel is lowered, and the air drawn through radiator by the fan, blows out of engine compartment without being directed

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over entire engine. The cooling efficiency is thus decreased and engine temperature raised. Hood side panels must not be removed except for access to engine for servicing or repairs.

h. Manifold Heat Control. At temperatures above 60°F, place manifold heat control into "OFF" position.

33. OPERATION ON STEEP GRADES.

a. Going Up Grades. When ascending steep grades, always shift into lower transmission speeds before vehicle begins to labor. This can be accomplished most successfully when vehicle still has sufficient momentum to permit changing gears without bringing vehicle to a stop.

(1) CAUTION: When shifting to a lower gear at any rate of vehicle speed, make sure that engine speed is "synchronized" with vehicle speed before clutch is engaged. If clutch is engaged when engine is operating at lower than relative vehicle speed, the drive line may be damaged.

b. Going Down Grades. The importance of restraining speed of vehicle and speed of engine while descending grades cannot be overemphasized. Refer to the maximum permissible road speed plate. The plate clearly states maximum speed at which truck may be safely operated in various gear ratios of transmission and ranges of transfer case. In general, it is advisable to use the same transmission speed going down hill as would be required to climb the same hill. Hold the vehicle speed not to exceed maximum shown on plate. Instructions as follows should be observed when descending grades.

(1) Keep vehicle under control at all times.

(2) It is desirable to reduce speed of vehicle with the brakes several times during the descent of a hill.

(3) Remember that possibility of overspeeding is greater when truck is loaded, therefore more caution is required.

(4) Do not use a lower gear ratio than would be required to ascend the same hill.

(5) Do not allow the vehicle to exceed the maximum permissible speed for the particular gear ratio selected.

(6) Disengage front axle before using the transmission as a brake when going down a steep hill, especially before shifting to a lower gear.

34. OPERATION ON SAND OR SOFT TERRAIN.

a. Mud. Always use tire chains and use all driving axles at ratio low enough to steadily pull vehicle out. Do not try the impossible. If stuck, winch out if vehicle is equipped with winch, or wait until assistance arrives.

b. Sand. Operation in sand requires a technique different than that used when operating in mud. The track must be "layed," not dug. Do not permit wheels to spin. If motor labors, depress clutch

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pedal immediately. Reverse and then go forward again. It may be necessary to repeat this procedure several times. If stuck in the sand, winch out. Constant spinning of the wheels will only dig in deeper.

35. PREVENTION OF DAMAGE BY SUBMERSION.

a. General. If vehicle is driven through deep water for any appreciable length of time or completely submerged in water, precautions must be taken to avoid serious damage to the engine, clutch, transmission, transfer case, axles, universal joints, winch, steering gear, battery, fuel tank, brakes, and wheel bearings.

b. If vehicle is not completely submerged but operates in fairly deep water for any length of time, particular attention must be given to the wheel bearings, brake mechanism, and axle differentials.

(1) WHEEL BEARINGS. Remove all wheel bearings and clean and repack with lubricant (par. 200).

(2) BRAKE MECHANISM. Brake mechanism should be thoroughly examined after submersion in water and all parts cleaned and lining replaced if necessary.

(3) DIFFERENTIALS. If axle differentials have been operated under water for any length of time, drain and flush differentials and refill with correct lubricant.

c. If vehicle operates in deep water which may partially submerge engine, particular attention must be given to units which have been submerged, such as brake, master cylinder, cranking motor, battery, distributor, transmission, transfer case, and winch. If clutch has been submerged, it is necessary that it be completely disassembled and cleaned thoroughly. Do not attempt to flush it.

(1) MASTER CYLINDER. Drain and flush brake system completely with alcohol, then refill with fresh brake fluid.

(2) ELECTRICAL. If cranking motor, generator, or distributor have been submerged, remove the units, clean thoroughly, wipe dry, and reinstall if tests prove that the units are functioning. If battery is submerged, check the electrolyte solution. If solution is dirty, or abnormally high, replace the battery. Check the specific gravity and if necessary, recharge or replace.

(3) TRANSMISSION, ETC. Drain lubricant, flush, and refill.

d. If vehicle has been completely submerged, each unit which has been submerged must be completely dismounted, cleaned, and lubricated. If it is known that water or dirt has entered engine, the crankcase should be drained, and engine thoroughly flushed. If engine has been submerged for any length of time, engine should be completely overhauled.

e. If vehicle is subjected to salt water, or operates near salt water, keep all exposed metal surfaces painted or thoroughly oiled. Precautions must be taken to seal the regulator and other electrical switch devices to prevent excessive corrosion. Salt water or salt air will attack all metals and will eventually corrode such parts, preventing operation.

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PART THREE—MAINTENANCE INSTRUCTIONS

Section VIII

LUBRICATION

36. LUBRICATION ORDER.

a. War Department Lubrication Order No. 504 (figs. 46 and 47) prescribes lubrication maintenance for truck, 2½-ton, 6 x 6 GMC CCKW-352 and 353.

b. A Lubrication Order is placed on or is issued with each vehicle and is to be carried with it at all times. In the event the vehicle is received without an Order the using arm shall immediately requisition a replacement from the Commanding Officer, Fort Wayne Ordnance Depot, Detroit 32, Michigan.

c. Lubrication instructions on the Order are binding on all echelons of maintenance and there shall be no deviations from these instructions.

d. Service intervals specified on the Order are for normal operating conditions. Reduce these intervals under extreme conditions such as excessively high or low temperatures, prolonged periods of high speed, continued operation in sand or dust, immersion in water, or exposure to moisture, any one of which may quickly destroy the protective qualities of the lubricant and require servicing in order to prevent malfunctioning or damage to the materiel.

e. Lubricants are prescribed in the "Key" in accordance with three temperature ranges; above +32°F, +32°F to 0°F, and below 0°F. Determine the time to change grades of lubricants by maintaining a close check on operations of the vehicle during the approach to change-over periods. Be particularly observant when starting the engine. Sluggish starting is an indication of thickened lubricants and the signal to change to grades prescribed for the next lower temperature range. Ordinarily it will be necessary to change grades of lubricants *only when air temperatures are consistently in the next higher or lower range*, unless malfunctioning occurs sooner due to lubricants being too thin or too heavy.

37. DETAILED LUBRICATION INSTRUCTIONS.

a. Lubrication Equipment.

(1) Each piece of materiel is supplied with lubrication equipment adequate to maintain the materiel. Be sure to clean this equipment both before and after use. Operate lubricating guns carefully and in such a manner as to insure a proper distribution of the lubricant. If lubrication fitting valves stick and prevent the entrance of lubricant, remove the fitting and determine cause. Replace broken or damaged lubricators. If lubricator cannot be replaced immediately, cover hole as a temporary expedient with tape to prevent the entrance of dirt. If oil lines become clogged, disassemble the line and remove the obstruction.

(2) Wipe lubricators and surrounding surface clean before applying lubricant. Where relief valves are provided, apply new lubri-

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cant until the old lubricant is forced from the vent. Exceptions are specified in notes or on the Lubrication Order. Always wipe clean metal surfaces on which a film of lubricant must be maintained by manual application, before the film is renewed.

b. Points of Application.

(1) Lubrication fittings, grease cups, oilers, and oil holes are readily located by reference to the Lubrication Order. Wipe clean such lubricators and the surrounding surface before lubricant is applied.

(2) Where relief valves are provided, apply new lubricant until the old lubricant is forced from the vent.

c. Cleaning. Use dry-cleaning solvent, or Diesel fuel oil, to clean or wash all parts. Use of gasoline for this purpose is prohibited. After washing, dry all parts thoroughly before applying lubricant.

d. Lubrication Notes on Individual Units and Parts. The following instructions supplement and repeat for clarity those notes on Lubrication Order which pertain to lubrication and service of individual units and parts.

(1) AIR CLEANERS (OIL BATH TYPE). Daily, check level and if necessary fill to level mark. Every 1,000 miles remove element and reservoir and wash all parts. Refill reservoir to level mark with used crankcase oil or (OE) engine oil, seasonal grade; except clamp mounted carbureter air cleaner which uses SAE 50 above +32° F or SAE 30 between +32°F and 0°F. From 0°F to –40°F, use (SA) shock absorber fluid, light. Below –40°F, wash and operate dry. (Element or mesh type)—Every 1,000 miles, remove element, wash, dry and reoil with used crankcase oil or (OE) engine oil, seasonal grade. From 0°F to –40°F, use (SA) shock absorber fluid, light. Below –40°F, remove oil and operate dry. (Governor air cleaner)—Every 6,000 miles remove governor air cleaner screen and felt (par. 96). Clean, dry and reoil felt with a few drops of (OE) engine oil, SAE 10. Reinstall felt and screen (par. 96).

(2) BREATHERS OR VENTS. Weekly clean dirt from breathers or vents at transfer case and axle differentials. Every 6,000 miles remove breathers and clean in dry-cleaning solvent.

(3) CRANKCASE. Daily, check level and refill to "FULL" mark with (OE) engine oil, SAE 30 above +32°F, or SAE 10 from +32° to 0°F. Below 0°F, refer to OFSB 6-11. Every 1,000 miles, remove drain plug from bottom of oil pan and completely drain case. Drain only when engine is hot. After thoroughly draining, replace drain plug and refill crankcase to "FULL" mark on gage with correct lubricant to meet temperature requirements. Run engine a few minutes, recheck level, and add oil if required. Be sure pressure gage indicates oil is circulating. Two piece oil pan has screen attached to drain plug. When drain plug is removed, clean plug and screen before replacing. Oil pan capacity, under various conditions is as follows:

Oil Capacity	*Filter*	*Element*
7½ qt	Not drained	Not removed
9 qt	Drained	Not removed
10 qt	Drained	Removed

No. 504

WAR DEPARTMENT LUBRICATION ORDER

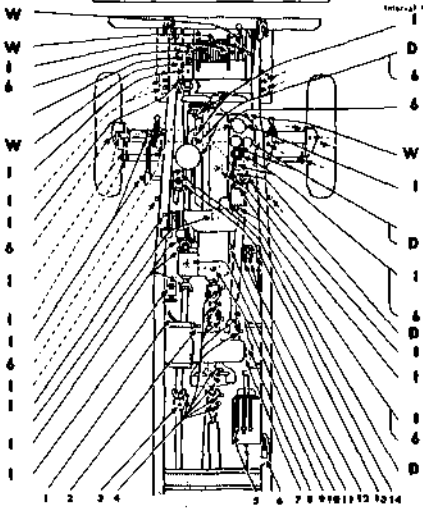
ORDNANCE DEPARTMENT

TRUCK, 2½-TON, 6x6

(GMC MODELS CCKW-352 AND CCKW-353)

SNL G-508. For detailed instructions, refer to TM 9-801.

NOTE— See Reverse Side for lubrication of BUMP BODIES.



		Lubricant	Interval
53	Winch Jaw Clutch — Clean and oil sparingly	OE W	
52	Winch Cable (See Note)	OE W	
50-51	Winch Drum and Shaft Brgs.	CG	1
49	*Winch Worm Housing Drain* — Cap. 1½ qt. Drain and refill		6
49	Winch Worm Housing Fill — Fill to plug level	GO	
49	*Winch Worm Housing Level* — Check level	W	
54	Propeller Shaft Shear Pin (See Note)	OE	1
47	Spring Shackle	CG	1
33	Universal Joint	CG	1
45-46	Front Wheel Bearings — Remove, clean and repack	WB	6
25-26-27	Universal Joint and Steering Knuckle Bearings (See Note)	CG	1
29	Tie Rod	CG	1
42	Drag Link	CG	1
30	Shock Absorber	SA	6
48	Spring Bolt	CG	1
39-40	Pedal Shaft (Some models)	CG	1
19 to 24	Clutch Pilot Bearing (See Note)	WB	
33-34	Universal and Slip Joints (See Note)	CG	1
28	Brake Master Cylinder — Fill to ½ in. from top	HB	1

Serviced From Under Hood

		Lubricant	Interval	
1	Generator 6 to 8 drops (Some models, oilers at rear only)	OE		6
D	Carburetor Air Cleaner — Check level (See Note)	OE		7-8
6	Governor Air Cleaner — Clean screen and felt, oil felt	OE		15-16
6	*Front Axle Differential Drain* — (Underneath truck) Cap. 6½ qt. banjo type; 3 qt. split type. Drain and refill (See Note)			15-16
W	Front Axle Diff. Fill and Level — (Underneath truck) Check level	GO		3
1	*Oil Filter* — Drain sediment. Every 6,000 miles, clean case, renew element (See Note)			1
	Crankcase Fill	OE		9
D	Crankcase Ventilator Air Cleaner — Check level (See Note)	OE		4
1	Distributor Shaft — Turn cap down 1 full turn, refill as required	WB		4
6	Distributor (See Note)			1
D	*Crankcase Level* — Check level			
1	Universal Joint (Underneath truck)	CG		32
1	*Crankcase Drain* — Drain and refill. Cap. including filter 9 qt. 3-pt. oil pan: 11½ qt. 1-pt. oil pan (See Note)			2
1	Starter 6 to 8 drops	OE		5
6	Starter Outboard Bearing — (To reach, remove starter)	OE		5
D	Hydrovac Air Cleaner — (Some models) Check level (See Note)	OE		9

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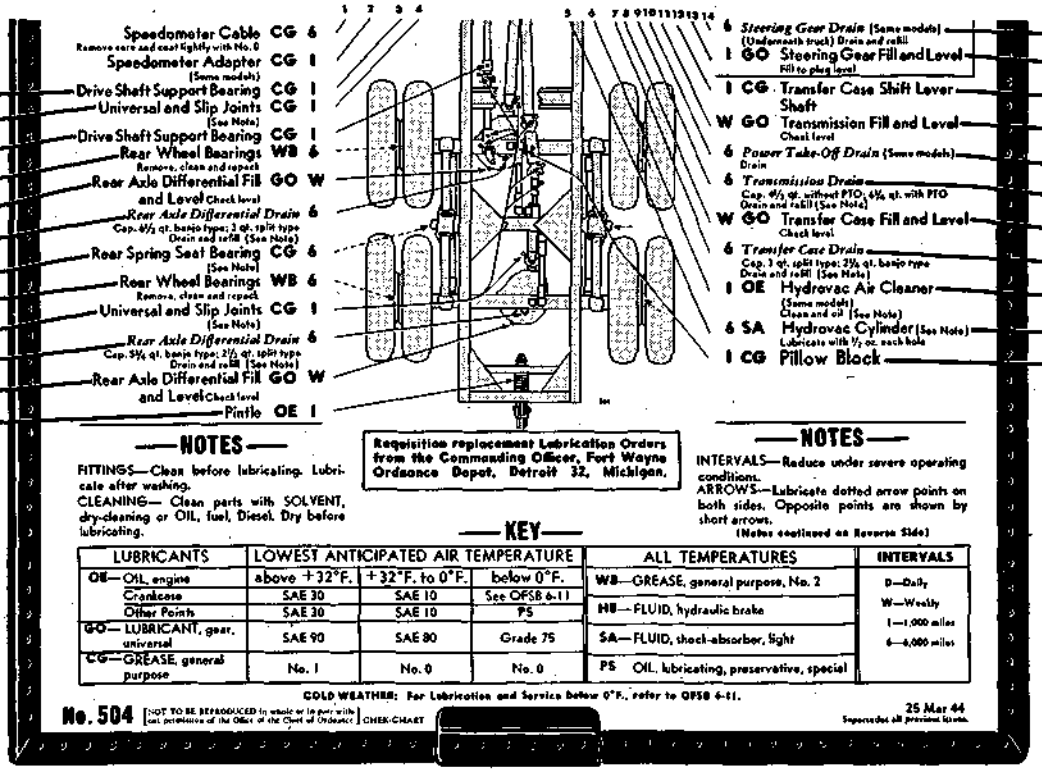


RA PD 333058B

Figure 46—Lubrication Order (Chassis)

No. 504

WAR DEPARTMENT LUBRICATION ORDER

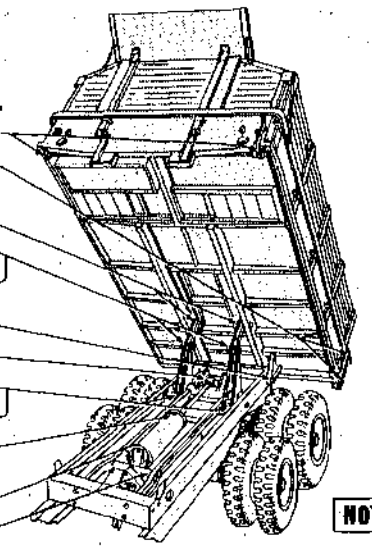
ORDNANCE DEPARTMENT

TRUCK, 2½-TON, 6x6

(GMC MODELS CCKW-352 AND CCKW-353) (DUMP BODIES)

SNL G-508. For detailed instructions, refer to TM 9-801.

CAUTION
Always place a prop or block under body before performing any service work.



	Lubricant & Interval
Control Rod Linkage Joints	OE 2W
Body Side and End Gate Cross Shafts and Rods (Also lubricate points on opposite side)	OE 2W
Link Pins (Some Hail Models)	CG 2W
Link Pins (Some Hail Models)	CG 2W
Trunnion Shaft Bearings (Gar Wood Models)	CG 2W
Body Hinge Pin (Also lubricate point on opposite side)	CG 2W
Hoist Wrist Pin	CG 2W
Lifting Lever (Hail Models)	CG 2W
Hoist Arm Links (Gar Wood Models)	CG 2W
Hydraulic Cylinder Fill and Level Cap. 14 qt. Hoist; 12 qt. Gar Wood Use SAE 10 below +32°F. (See Note)	OE 2W
Hoist Trunnion Pin (Some Hail Models)	CG 2W
Cylinder Hinge (Gar Wood Models)	CG 2W

NOTE— See Reverse Side for lubrication of TRUCK.

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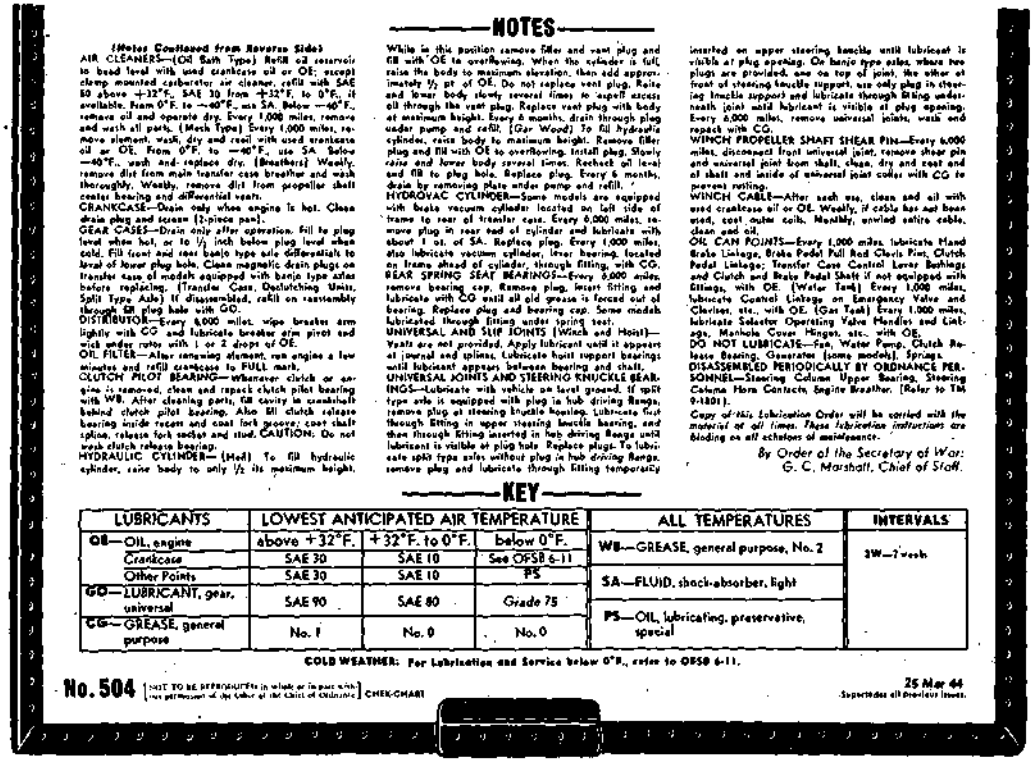

NOTES

(Notes Continued from Reverse Side)

AIR CLEANERS—(Oil Bath Type) Refill oil reservoir to bead level with used crankcase oil or OE; except clamp mounted carburetor air cleaner, refill with SAE 50 above +32°F, SAE 30 from +32°F. to 0°F, if available. From 0°F. to —40°F., use SA. Below —40°F., remove oil and operate dry. Every 1,000 miles, remove and wash all parts. (Mesh Type) Every 1,000 miles, remove element, wash, dry and resoil with used crankcase oil or OE. From 0°F. to —40°F., use SA. Below —40°F., wash and replace dry. (Breather) Weekly, remove dirt from main transfer case breather and wash thoroughly. Weekly, remove dirt from propeller shaft center bearing and differential vents.

CRANKCASE—Drain only when engine is hot. Clean drain plug and screen (2-piece pan).

GEAR CASES—Drain only after operation. Fill to plug level when hot, or to ½ inch below plug level when cold. Fill front and rear banjo type axle differentials to level of lower plug hole. Clean magnetic drain plugs on transfer case of models equipped with banjo type axles before replacing. (Transfer Case, Declutching Unit, Split Type Axle) If disassembled, refill on reassembly through fill plug hole with GO.

DISTRIBUTOR—Every 6,000 miles, wipe breaker arm lightly with CG and lubricate breaker arm pivot and wick under rotor with 1 or 2 drops of OE.

OIL FILTER—After removing element, run engine a few minutes and refill crankcase to FULL mark.

CLUTCH PILOT BEARING—Whenever clutch or engine is removed, clean and repack clutch pilot bearing with WB. After cleaning parts, fill cavity in crankshaft behind clutch pilot bearing. Also fill clutch release bearing inside recess and coat fork groove; coat shaft spline, release fork socket and stud. CAUTION: Do not wash clutch release bearing.

HYDRAULIC CYLINDER—(Hoist) To fill hydraulic cylinder, raise body to only ½ its maximum height. While in this position remove filler and vent plug and fill with OE to overflowing. When the cylinder is full, raise the body to maximum elevation, then add approximately ½ pt of OE. Do not replace vent plug. Raise and lower body slowly several times to expell excess oil through the vent plug. Replace vent plug with body at maximum height. Every 6 months, drain through plug under pump and refill. *(Gar Wood)* To fill hydraulic cylinder, raise body to maximum height. Remove filler plug and fill with OE to overflowing. Install plug. Slowly raise and lower body several times. Recheck oil level and fill to plug hole. Replace plug. Every 6 months, drain by removing plate under pump and refill.

HYDROVAC CYLINDER—Some models are equipped with brake vacuum cylinder located on left side of frame to rear of transfer case. Every 6,000 miles, remove plug in rear end of cylinder and lubricate with about 1 oz. of SA. Replace plug. Every 1,000 miles, also lubricate vacuum cylinder, lever bearing, located on frame ahead of cylinder, through fitting, with CG.

LEAF SPRING SEAT BEARINGS—Every 6,000 miles, remove bearing cap. Remove plug, insert fitting and lubricate with GO until all old grease is forced out of bearing. Replace plug and bearing cap. Some models lubricated through fitting under spring seat.

UNIVERSAL AND SLIP JOINTS (Winch and Hoist)—Yoats are not provided. Apply lubricant until it appears at journal and splines. Lubricate front support bearings until lubricant appears between bearing and shaft.

UNIVERSAL JOINTS AND STEERING KNUCKLE BEARINGS—Lubricate with vehicle on level ground. If split type axle is equipped with plug in hub driving flange, remove plug at steering knuckle housing. Lubricate first through fitting in upper steering knuckle bearing, and then through fitting inserted in hub driving flange until lubricant is visible at plug hole. Replace plugs. To lubricate split type axles without plug in hub driving flange, remove plug and lubricate through fitting temporarily inserted on upper steering knuckle until lubricant is visible at plug opening. On banjo type axles, where two plugs are provided, one on top of joint, the other at front of steering knuckle support, use only plug in steering knuckle support and lubricate through fitting underneath joint until lubricant is visible at plug opening. Every 6,000 miles, remove universal joints, wash and repack with CG.

WINCH PROPELLER SHAFT SHEAR PIN—Every 6,000 miles, disconnect front universal joint, remove shear pin and universal joint from shaft, clean, dry and coat end of shaft and inside of universal joint collar with CG to prevent rusting.

WINCH CABLE—After each use, clean and oil with used crankcase oil or OE. Weekly, if cable has not been used, coat outer coils. Monthly, unwind entire cable, clean and oil.

OIL CAN POINTS—Every 1,000 miles, lubricate Hand Brake Linkage, Brake Pedal Pull Rod Clevis Pins, Clutch Pedal Linkage; Transfer Case Control Lever Bushings and Clutch and Brake Pedal Shaft if not equipped with fittings, with OE. (Water Tank) Every 1,000 miles, lubricate Control Linkage on Emergency Valve and Clevises, etc., with OE. (Gas Tank) Every 1,000 miles, lubricate Selector Operating Valve Handles and Linkage, Manhole Cover Hinges, etc., with OE.

DO NOT LUBRICATE—Fan, Water Pump, Clutch Release Bearing, Generator (some models), Springs.

DISASSEMBLED PERIODICALLY BY ORDNANCE PERSONNEL—Steering Column Upper Bearing, Steering Column Horn Contacts, Engine Breather. (Refer to TM 9-1801).

Copy of this Lubrication Order will be carried with the material at all times. These lubrication instructions are binding on all echelons of maintenance.

By Order of the Secretary of War:
G. C. Marshall, Chief of Staff.

KEY

LUBRICANTS	LOWEST ANTICIPATED AIR TEMPERATURE			ALL TEMPERATURES	INTERVALS
	above +32°F.	+32°F. to 0°F.	below 0°F.		
OE—OIL, engine				WB—GREASE, general purpose, No. 2	2W—2 week
Crankcase	SAE 30	SAE 10	See OFSB 6-11		
Other Points	SAE 30	SAE 10	PS	SA—FLUID, shock-absorber, light	
GO—LUBRICANT, gear, universal	SAE 90	SAE 80	Grade 75		
CG—GREASE, general purpose	No. 1	No. 0	No. 0	PS—OIL, lubricating, preservative, special	

COLD WEATHER: For Lubrication and Service below 0°F., refer to OFSB 6-11.

No. 504 [NOT TO BE REPRODUCED in whole or in part without the permission of the Chief of Ordnance] CHECK-CHART

25 Mar 44
Supersedes all previous issues.

Figure 47—Lubrication Order (Hoist)

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(4) GEAR CASES. Transmission, differentials, transfer case, and winch worm housing. Weekly, check level with truck on even ground, and if necessary, add lubricant to within ½ inch of plug level when cold, or to plug level when hot, except winch worm housing, which must be filled to plug level at all times. Fill front and rear banjo type axle differentials to level of lower plug hole. If removed, refill transfer case declutching unit, used with split type axle, when reinstalled, through plug hole with universal gear lubricant, SAE 90 above +32°F to 0°F, SAE 80° from +32° to 0°F, or Grade 75 below 0°F. Clean magnetic drain plug in transfer case of models equipped with banjo axles before replacing. (Power Take-off)—Vehicles equipped with a winch or hoist are also equipped with a power take-off, mounted at left side of transmission. Some of these power take-offs are fitted with a drain plug, which should be removed whenever transmission is drained. Some models do not have drain plug in power take-off and cannot be drained, except at transmission. No filler plug is provided in power take-off, as it is lubricated by the lubricant in the transmission.

(5) DISTRIBUTOR. Every 1,000 miles, lubricate distributor shaft by turning down cup one full turn, refill as required with (WB) general purpose grease No. 2. Every 6,000 miles wipe the distributor breaker cam lightly with (CG) general purpose grease, seasonal grade. Also lubricate the breaker arm pivot with one or two drops—and wick under rotor with one or two drops of (OE) engine oil, seasonal grade or (PS) preservative lubricating oil, special, below 0°F.

(6) OIL FILTER. Every 1,000 miles, when engine is drained remove drain plug from oil filter to drain oil and sediment in filter. Every 6,000 miles, remove filter element (par. 81). Clean inside of shell with clean rag and install new element (par. 81). Run engine a few minutes and check oil level. Add oil to bring crankcase oil level up to "FULL" mark on gage.

(7) CLUTCH PILOT BEARING. Whenever clutch or engine is removed, clean and repack clutch pilot bearing with (WB) general purpose grease, No. 2. After cleaning parts, fill cavity in crankshaft behind clutch pilot bearing. Also fill clutch release bearing inside recess and coat fork groove; coat shaft spline, release fork socket, and stud. CAUTION: *Do not wash clutch release bearing.*

(8) HYDRAULIC CYLINDER. Two types of hoist equipment (Heil and Gar Wood) have been used on these vehicles and require different filling and draining instructions. *(Heil).* Every two weeks, raise body to ½ its maximum height. Place safety block under body to prevent accidental dropping. Remove filler and vent plugs separately. With the pump control lever in the "RAISE" position, operate the pump slowly, while pouring (OE) engine oil, seasonal grade, through

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filler plug opening until body is raised to its maximum height. Add about ½ pint more oil, then lower body slowly, with pump running. Slowly raise and lower the body several times to expel all air and any excess oil. With body all the way up, install filler and vent plugs. Every 6 months raise body to its maximum height, and block in place to prevent accidental dropping. Remove plug at bottom of pump to drain oil from hydraulic cylinder. During draining, pump control lever should be in "LOWER" position. Install drain plug and perform filling operation. (Gar Wood). Every two weeks, raise body to its maximum height. Place safety block under body to prevent accidental dropping. Remove filler plug at side of cylinder. Fill to overflowing with (OE) engine oil, seasonal grade. Install plug tightly. Every 6 months raise body to its maximum height and block in place to prevent accidental dropping. Remove plate at bottom of pump to drain oil from hydraulic cylinder. During draining, pump control lever should be in "LOWER" position. Install plate and perform filling operation while pump is being operated, with control lever in "RAISE" position.

(9) HYDROVAC CYLINDER. Lubricate every 6,000 miles with (SA) shock absorber fluid, light. Remove pipe plug at center of rear shell, also plug from inside elbow at center plate. Apply ½ oz of lubricant through each plug opening. Replace plugs. To insure proper spread of lubricant in cylinder, start engine and make 3 or 4 severe brake applications. Early vehicles are equipped with vacuum cylinder at left side of vehicle. Every 6,000 miles, remove plug in rear of cylinder and apply 1 oz (SA) shock absorber fluid through plug opening. Replace plug. Every 1,000 miles lubricate idler lever, ahead of vacuum cylinder, with (CG) general purpose grease, seasonal grade.

(10) REAR SPRING SEAT BEARINGS. Every 6,000 miles, remove bearing cap. Remove plug, insert fitting and lubricate with (CG) general purpose grease, seasonal grade, until all old grease is forced out of bearing. Replace plug and bearing cap. Some models are lubricated through fitting under spring seat.

(11) UNIVERSAL JOINTS AND SLIP JOINTS. (Truck)—Use (CG) general purpose grease, seasonal grade. Apply grease to universal joint until it overflows at the relief valve, and to the slip joint until lubricant is forced from the vent at the universal joint end of the spline. (Winch and Dump Hoist)—Universal and slip joints are not equipped with vents. Apply lubricant until it appears around journal and splines. Lubricate hoist support bearings until lubricant appears between bearing and shaft.

(12) UNIVERSAL JOINTS AND STEERING KNUCKLE BEARINGS. Every 1,000 miles lubricate with vehicle on level ground, with (CG) general purpose grease, seasonal grade. If split type axle is equipped

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with plug in hub driving flange, remove plug at steering knuckle housing. Lubricate first through fitting in upper steering knuckle bearing, and then through fitting inserted in hub driving flange until lubricant is visible at plug hole. Replace plugs. To lubricate split type axle without plug in hub driving flange, remove plug and lubricate through fitting on upper steering knuckle until lubricant is visible at plug opening. On banjo type axles, where two plugs are provided, one on top of joint, the other one at front of steering knuckle support, use only plug in steering knuckle support and lubricate through fitting underneath joint until lubricant is visible at plug opening. Every 6,000 miles, remove universal joints, (par. 167). Wash and repack with (CG) general purpose grease, seasonal grade. Reinstall (par. 167).

(13) WINCH DRIVE SHAFT SHEAR PIN. Every 1,000 miles lubricate both ends of pin, also between yoke and worm shaft, with (OE) engine oil, seasonal grade. Every 6,000 miles, disconnect universal joint from winch worm shaft (par. 240). Clean shaft shear pin and inside of yoke. Coat inside of yoke and winch worm shaft with (CG) general purpose grease, seasonal grade. Install universal joint to worm shaft (par. 240).

(14) WINCH CABLE. After each use, clean and oil with used crankcase oil or (OE) engine oil, seasonal grade. Weekly, if cable has not been used, coat outer coils. Monthly, unwind entire cable, clean and oil.

(15) WHEEL BEARINGS. Every 6,000 miles remove bearing cone assemblies from hub (pars. 201 and 202). Wash bearings, cones, spindle, and inside of hub and dry thoroughly. Do not use compressed air. Inspect bearing races and replace if damaged. Wet the spindle and inside of hub with general purpose grease No. 2 to a maximum thickness of 1/16 inch only, to retard rust. Lubricate bearings with general purpose grease No. 2 with a packer, or by hand, kneading lubricant into all spaces in the bearing. Use extreme care to protect the bearings from dirt, and immediately reassemble and replace wheel. Do not fill hub. The lubricant in the bearing is sufficient to provide lubrication until the next service period. Any excess might result in leakage into the drum. Adjust bearings in accordance with instructions in paragraph 199.

(16) PILLOW BLOCK. Lubricate every 1,000 miles using (CG) general purpose grease, seasonal grade, until grease flows from breather at top of housing. When housing is equipped with a plug at side, remove and clean housing and bearings (par. 177). Reassemble and adjust bearings (par. 177). Replace pipe plug at side of housing with 90° fitting (par. 177).

(17) STEERING GEAR. Every 1,000 miles remove filler plug and check level of lubricant. Add (GO) universal gear lubricant, seasonal grade, until lubricant is to level of filler plug hole. Some models are equipped with a drain plug, which should be removed every 6,000

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miles. Drain all old lubricant, install drain plug, and refill through filler plug hole.

(18) SHOCK ABSORBER. Every 6,000 miles remove plug and check level of fluid. If fluid is not up to plug level, disconnect link between arm and axle (par. 213). Fill to plug level with (SA) shock absorber fluid, light. Pump arm slowly to expel air from shock absorber. Repeat filling and pumping operations until all air is removed and fluid is at filler hole level. Install filler plug. Reconnect link between arm and axle (par. 213).

(19) BRAKE MASTER CYLINDER. Every 1,000 miles remove plug and check level of fluid. If fluid is not up to within ½ inch of filler hole, add sufficient (HB) hydraulic brake fluid, to bring fluid up to this level. Install filler plug. When it is evident that air is present in hydraulic system bleed entire system (par. 180).

(20) OIL CAN POINTS. Every 1,000 miles, lubricate pintle hook, hand brake linkage, brake pedal pull rod clevis pins, clutch pedal linkage; transfer case control lever bushings and clutch and brake pedal shaft if not equipped with fittings, with (OE) engine oil, seasonal grade, or (PS) preservative lubrication oil, special, below 0°F. (Water Tank)—Every 1,000 miles, lubricate control linkage on emergency valve and clevises, etc. with (OE) engine oil, seasonal grade or (PS) preservative lubricating oil, special, below 0° F. (Gas Tank)—Every 1,000 miles, lubricate selector operating valve handles and linkage, manhole cover hinges, etc., with (OE) engine oil, seasonal grade, or (PS) preservative lubricating oil, special, below 0°F.

(21) POINTS REQUIRING NO LUBRICATION SERVICE. Fan, water pump, clutch release bearing, generator (some models), springs.

(22) DISASSEMBLED PERIODICALLY BY ORDNANCE MAINTENANCE PERSONNEL ONLY.

(a) Steering Column Upper Bearing. Whenever steering column is removed for inspection or repair, clean and repack ball bearing with (WB) general purpose grease No. 2.

(b) Steering Column Horn Contacts. Whenever steering column is removed for inspection or repair, coat horn button contact washer lightly with (CG) general purpose grease, seasonal grade, to prevent corrosion.

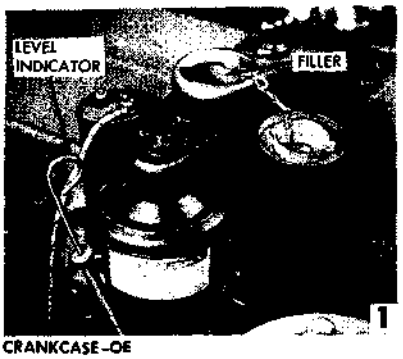
(c) Engine Breather. Every 6,000 miles or more often under severe operating conditions, remove tube between valve cover and intake manifold, also valve attached to manifold. Thoroughly clean tube and valve and reassemble.

e. Reports and Records.

(1) Report unsatisfactory performance of materiel to the Ordnance Officer responsible for maintenance.

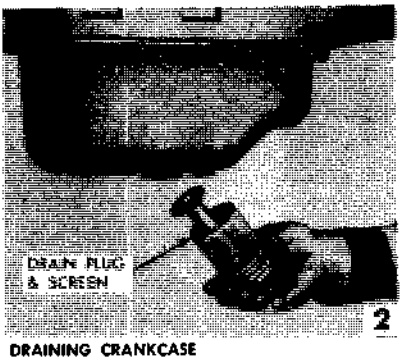
(2) A record of lubrication may be maintained in the Duty Roster (W.D., A.G.O. Form No. 6).

TRUCK, 2½-TON, 6 x 6



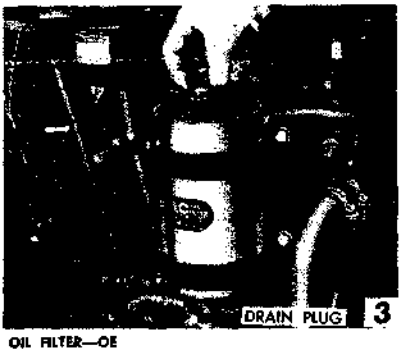
CRANKCASE—OE

Check level daily. Remove level indicator and clean with wiping cloth. Install and again remove. Oil level should be up to "Full" mark. Remove filler cap and fill or replenish through filler pipe. Install indicator and filler cap.



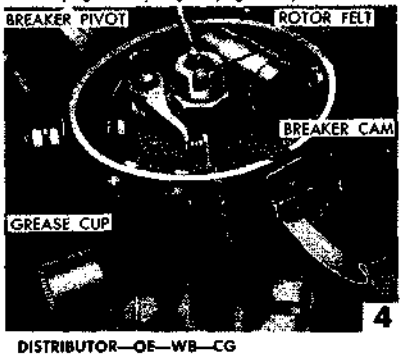
DRAINING CRANKCASE

Drain plug assembly. Drain when lubricant is warm, preferably immediately after operation. Remove drain plug and screen assembly. Clean in dry-cleaning solvent. Dry and reinstall plug assembly. Tighten plug securely.



OIL FILTER—OE

To drain, remove plug. To replace element, remove drain plug, filter cover and element. Install new military standard element, cover and drain plug. Run engine a few minutes and refill crankcase to "Full" mark on level indicator.

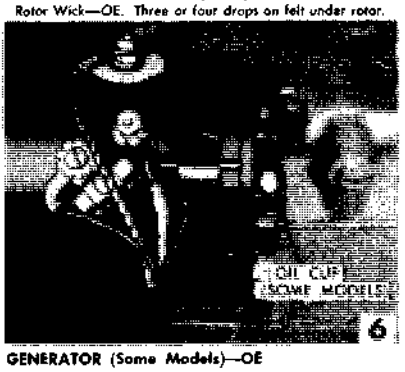


DISTRIBUTOR—OE—WB—CG

Shaft—Grease cup—WB. Turn cup down one full turn.
Breaker Cams—CG. Apply sparingly.
Breaker Pivot—OE. One drop one pivot.
Rotor Wick—OE. Three or four drops on felt under rotor.

CRANKING MOTOR—OE

Two oilers. One each end. Fill oiler at commutator (front) end. Lubricate drive end (rear) bushing, while cranking motor is removed



GENERATOR (Some Models)—OE

One oiler, on some models. Fill oiler at commutator (rear) end.

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Figure 48—Lubrication Localized Views

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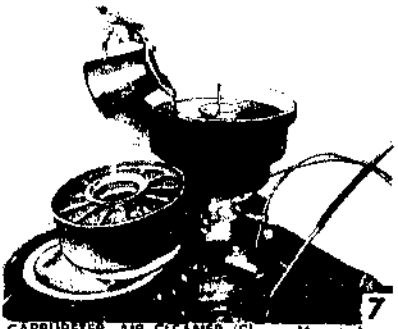
LUBRICATION



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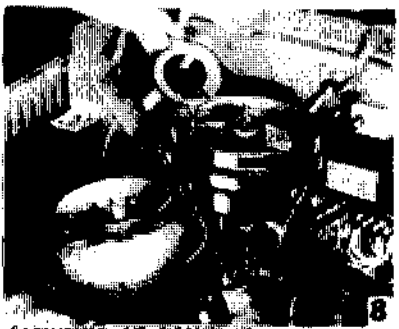
CARBURETER AIR CLEANER (Clamp Mounted Type)—OE

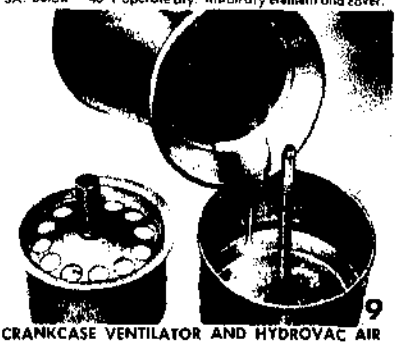
Remove cover and element. Check oil level and cleanliness. Clean in dry-cleaning solvent. Dry thoroughly. Install reservoir and fill to "oil level" mark with OE, SAE 50 above + 32 F or SAE 30 between + 32 F and 0 F. From 0 F to —40 F use SA. Below —40 F operate dry. Install dry element and cover.



8

CARBURETER AIR CLEANER (Hanger Mounted Type)—OE

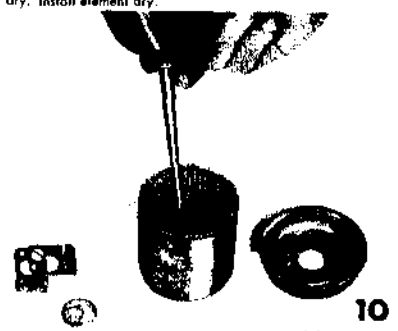
Remove cover and element assembly. Check oil level and cleanliness. Clean in dry-cleaning solvent. Dry thoroughly. Install reservoir and fill to "oil level" mark with OE, seasonal grade. From 0 F to —40 F use SA. Below —40 F operate dry. Install element dry.



9

CRANKCASE VENTILATOR AND HYDROVAC AIR CLEANER (Some Models)—OE

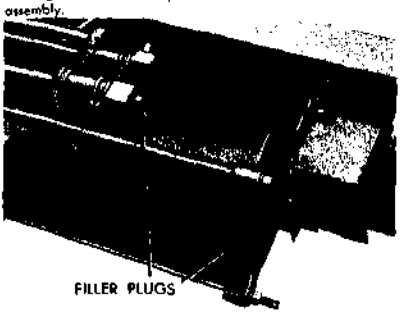
Remove reservoir and element. Check oil level and cleanliness of element and reservoir. Clean in dry-cleaning solvent. Dry thoroughly. Fill reservoir to "oil level" mark with OE, seasonal grade. Position dry element in reservoir and install assembly.



10

HYDROVAC AIR CLEANER (Some Models)—OE

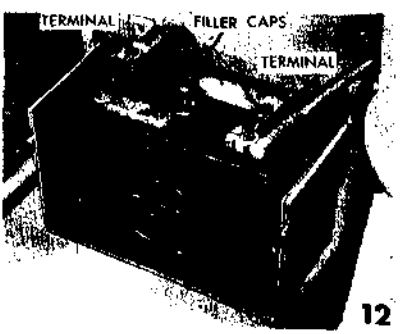
Remove air cleaner assembly and disassemble. Wash all parts in dry-cleaning solvent. Dry and dip element in new SAE 10 engine oil. Reassemble and reinstall.



11

HYDROVAC CYLINDER—SA

Two plugs (one in elbow, one at rear). Oil can. Apply one-half ounce lubricant in each hole. Apply brakes several times to distribute oil along cylinder shells.



12

BATTERY TERMINALS—CG

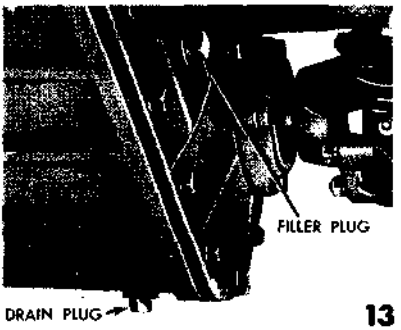
Two terminals. Inspect cable terminals. If loose or corroded, remove and clean; install and tighten securely. Coat with general purpose grease. Check water level and, if necessary, add distilled water to ⅜" above plates.

RA PD 333034

Figure 49—Lubrication Localized Views

ES18-002672 0232

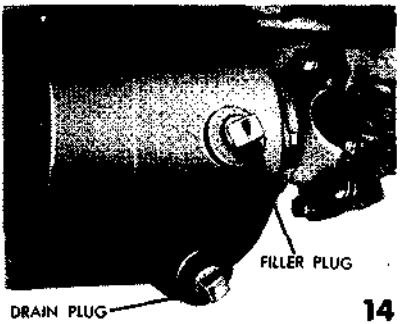
TRUCK, 2½-TON, 6 x 6



13

TRANSFER CASE—Split Axle—GO

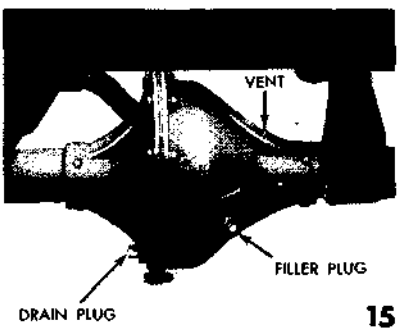
Filler and drain plugs. Pump gun. Clean vent and keep lubricant to level of filler hole. Drain when lubricant is warm, preferably immediately after operation.



14

TRANSFER CASE—Banjo Axle—GO

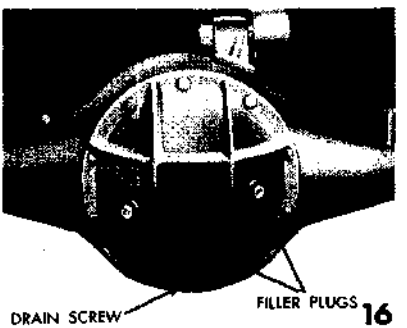
Filler and drain plugs. Pump gun. Clean vent and keep lubricant to level of filler hole. Drain when lubricant is warm, preferably immediately after operation.



15

AXLE DIFFERENTIAL—Split Housing—GO

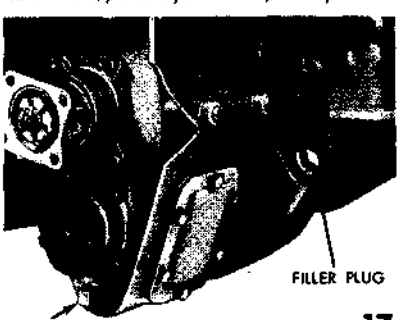
Filler and drain plugs. Pump gun. Clean vent and keep lubricant to level of filler hole. Drain when lubricant is warm, preferably immediately after operation.



16

AXLE DIFFERENTIAL—Banjo Housing—GO

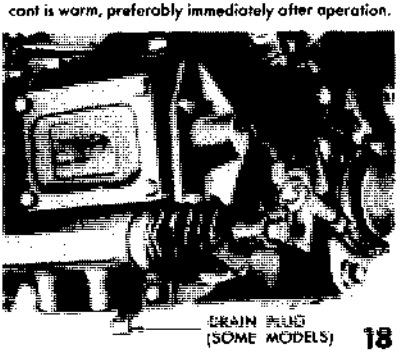
Filler plug and drain screw. Pump gun. Clean vent and keep lubricant to level of filler hole. Drain when lubricant is warm, preferably immediately after operation.



17

TRANSMISSION—GO

Filler and drain plugs. Pump gun. Keep lubricant to level of filler hole. Drain when lubricant is warm, preferably immediately after operation. Do not flush.



18

POWER TAKE-OFF

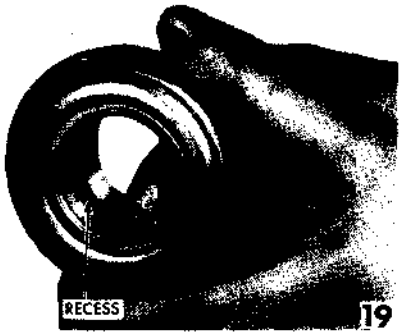
Power take-off (when used) is equipped with drain plug on late vehicles. Remove drain plug at same time transmission is drained. Reinstall plug. Power take-off is lubricated by transmission lubricant. No method of draining is provided on early vehicles, except at transmission.

RA PD 333040

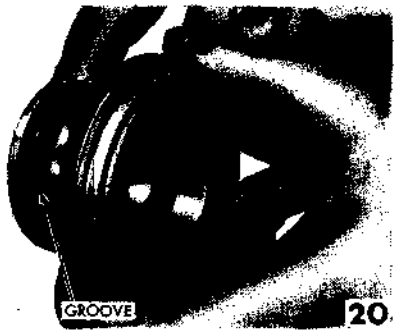
Figure 50—Lubrication Localized Views

ES18-002672 0233

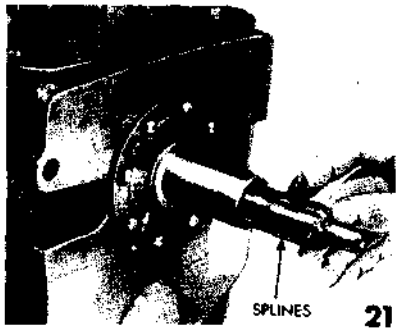
LUBRICATION



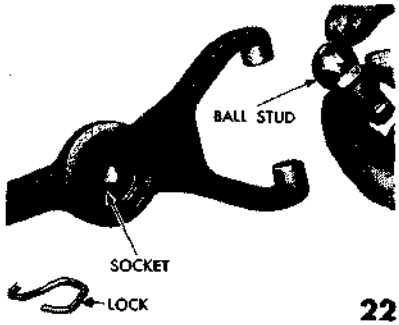
CLUTCH RELEASE BEARING SUPPORT—WB
Fill recess inside of release bearing support with grease. Lubricant should be level with edges of recess.



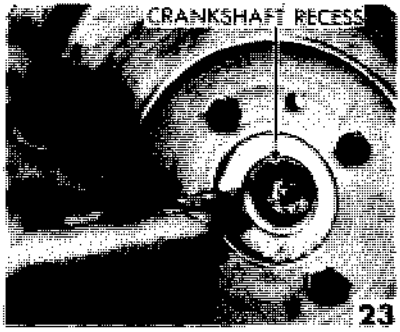
RELEASE BEARING FORK GROOVE—WB
Apply light coat of grease to fork groove in release bearing support. Do not fill groove.



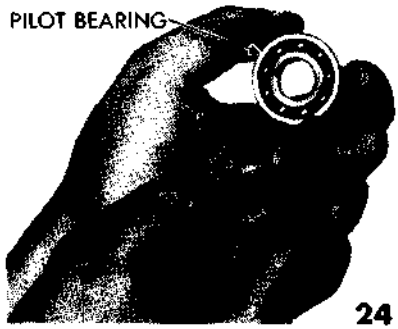
CLUTCH SHAFT SPLINES—WB
Apply light coat of grease to clutch shaft splines. Do not use excessive quantity.



CLUTCH RELEASE FORK SOCKET AND STUD—WB
Apply light coat of grease to socket in release fork and to ball surface of stud. Install stud in fork socket and secure with lock.



PILOT BEARING CRANKSHAFT RECESS—WB
Place a small amount of grease in crankshaft recess before installing pilot bearing.

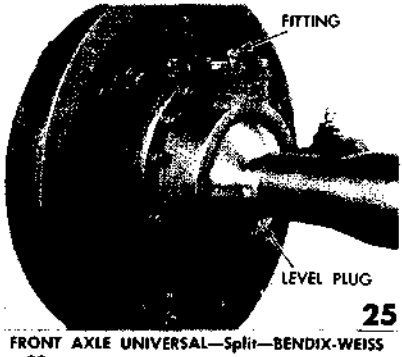


CLUTCH PILOT BEARING—WB
Hand pack bearing with grease, being sure that all balls and races are coated.

RA PD 333033

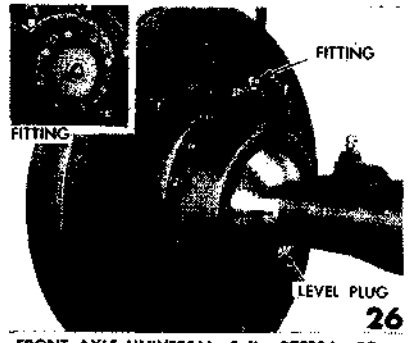
Figure 51—Lubrication Localized Views

TRUCK, 2½-TON, 6 x 6



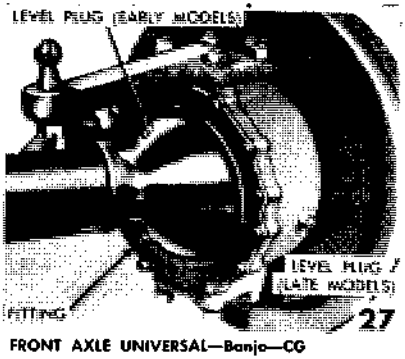
FRONT AXLE UNIVERSAL—Split—BENDIX-WEISS —CG

Two fittings and two level plugs. Pressure gun. Remove level plug and apply lubricant through fitting until visible at level plug. Replace level plug.



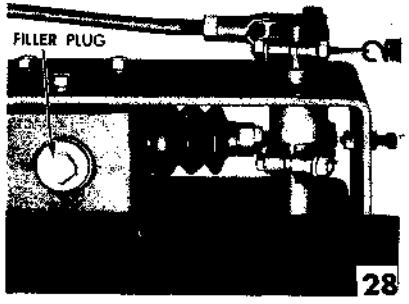
FRONT AXLE UNIVERSAL—Split—RZEPPA—CG

Two fittings and four plugs. Pressure gun. Remove level plug. Apply three or four shots through fitting. Remove drive flange plug and install temporary fitting. Lubricate through temporary fitting until visible at level hole. Remove temporary fitting and install two plugs.



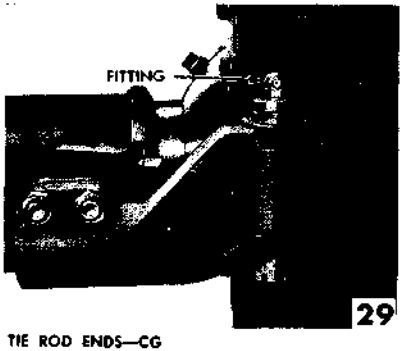
FRONT AXLE UNIVERSAL—Banjo—CG

Two fittings and two level plugs. Pressure gun. Remove level plug and apply lubricant through fitting, until visible at level plug. Replace level plug.



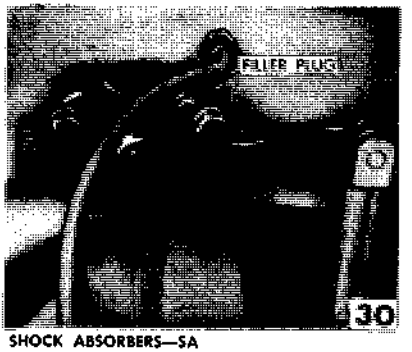
BRAKE MASTER CYLINDER—HB

Filler cap. Check level and, if necessary, add fluid until within 1" of filler hole. Bleed entire brake system, using pressure tank, if available, when evident that air is in hydraulic lines. Otherwise use pedal as pump.



TIE ROD ENDS—CG

Two fittings (one each end). Pressure gun. Apply lubricant through fittings until new grease shows at insides of yoke.



SHOCK ABSORBERS—SA

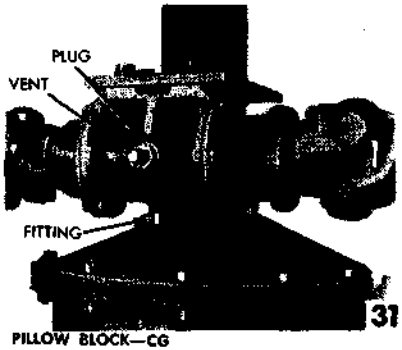
Two plugs (one each unit). Remove plug and check level of fluid. If necessary to replenish, remove link between arm and axle. Fill to capacity and pump arm to expel air. Repeat filling and pumping, until air is removed and fluid is at filler hole level. Install plug and connect link.

RA PD 333036

Figure 52—Lubrication Localized Views

ES18-002672 0235

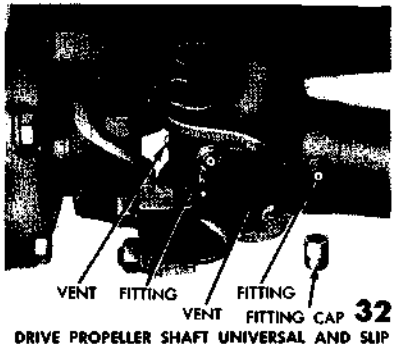
LUBRICATION



31

PILLOW BLOCK—CG

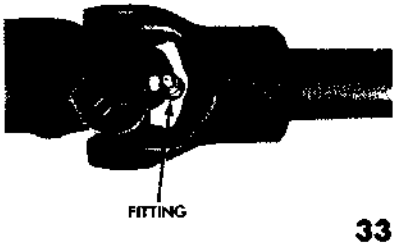
One fitting. Pump gun. Apply lubricant through fitting at side of housing, until lubricant flows from vent in plug at top of housing.



32

DRIVE PROPELLER SHAFT UNIVERSAL AND SLIP JOINTS—CG

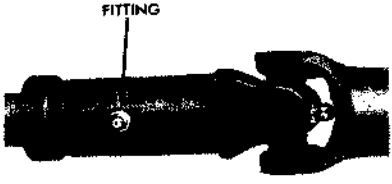
Ten universal and five slip joints. Pressure gun. Apply lubricant through fitting until new lubricant shows through relief valve when lubricating universal or through vent at end of shaft when lubricating slip joint.



33

HOIST AND WINCH PROPELLER SHAFT UNIVERSAL JOINTS—CG

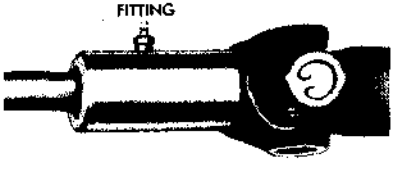
Two hoist and four winch universal joints. Pump gun. Apply lubricant through fitting until grease appears at journal.



34

WINCH DRIVE SHAFT SLIP JOINT—CG

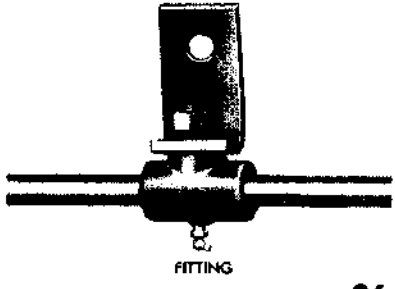
One fitting at rear of shaft. Pressure gun. Apply lubricant through fitting until grease appears between shaft and slip joint.



35

HOIST PROPELLER SHAFT SLIP JOINT—CG

One fitting at rear of shaft. Pump gun. Apply lubricant through fitting until grease appears between shaft and slip joint.



36

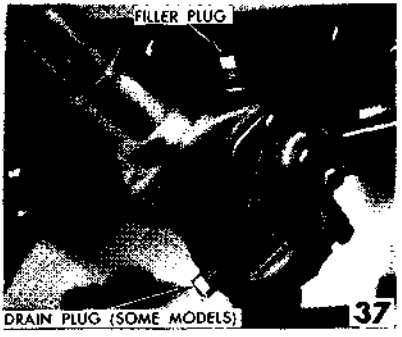
HOIST PROPELLER SHAFT SUPPORT BEARING—CG

Two fittings. Pump gun. Appy lubricant through fitting until new grease appears between bearing and shaft.

RA PD 333035

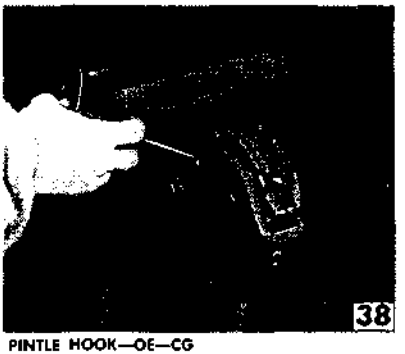
Figure 53—Lubrication Localized Views

TRUCK, 2½-TON, 6 x 6



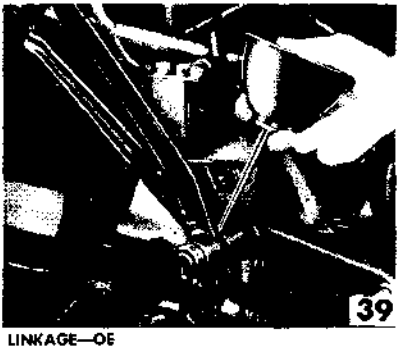
STEERING GEAR HOUSING—GO

Filler plug. Drain plug on late models. Pump gun. Remove drain plug (when used) to drain housing. Reinstall plug and fill to level of filler plug hole.



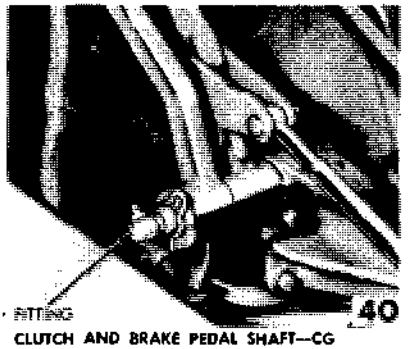
PINTLE HOOK—OE—CG

Oil can. Apply OE to pins, connections, and linkage surfaces. Remove pintle hook assembly. Clean bushings and hook assembly in dry-cleaning solvent. Lubricate bushings and hook shaft with CG, general purpose grease.



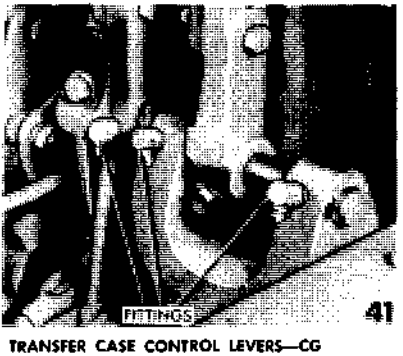
LINKAGE—OE

Oil can. Hand brake linkage, hand brake pull rod clevis pins, clutch pedal linkage. Also, clutch and brake pedal shaft and transfer case control lever, when not equipped with lubrication fittings.



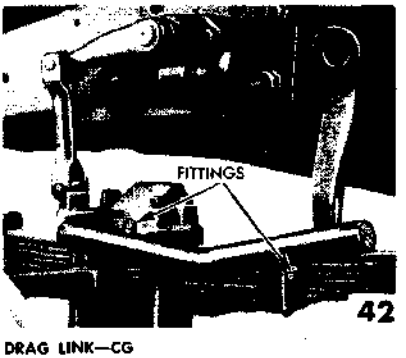
CLUTCH AND BRAKE PEDAL SHAFT—CG

One fitting. Pressure gun. Apply lubricant through fitting until new grease shows around pedals.



TRANSFER CASE CONTROL LEVERS—CG

Three fittings. Pressure gun. Apply lubricant through fittings until new grease shows around levers and bracket.



DRAG LINK—CG

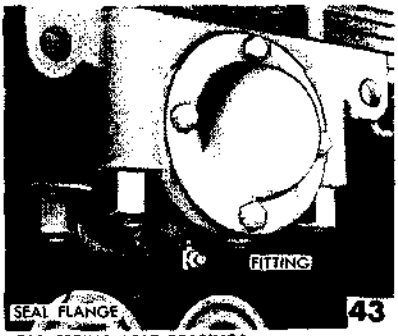
Two fittings (one each end). Pressure gun. Apply lubricant through fittings until new grease shows around seats.

RA PD 333037

Figure 54—Lubrication Localized Views

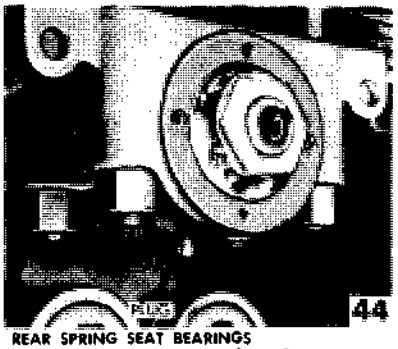
ES18-002672 0237

LUBRICATION



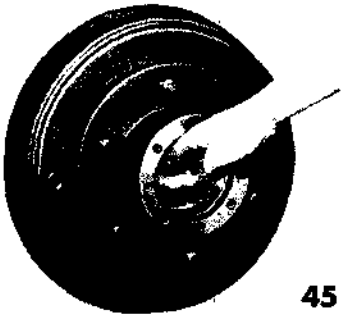
REAR SPRING SEAT BEARINGS
(Lip Type Seal on Late Models)—CG

Two fittings. Pressure gun. Apply lubricant through fitting until new grease appears between flange and seal at inside of seat.



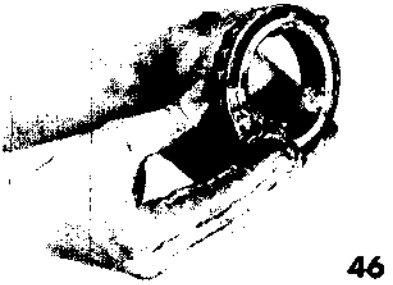
REAR SPRING SEAT BEARINGS
(Felt Type Seal on Early Models)—CG

Two spring seat caps. Remove pipe plug and install temporary fitting. Apply lubricant through fitting until new grease appears through outer bearing. Remove temporary fitting and install pipe plug. Install spring seat cap and gasket.



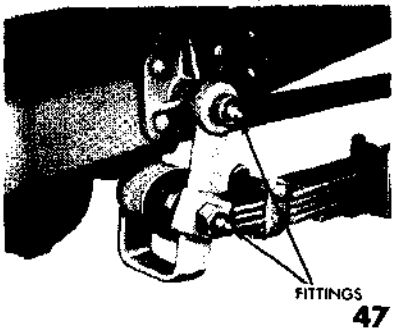
WHEEL HUBS—WB

Remove hub and bearings. Clean hub and bearings in dry cleaning solvent. Inspect bearings and, if cracked, chipped or pitted, replace with new part. Coat inside surface of hub and spindle thinly with grease to prevent corrosion. *Do not fill hub.* Reassemble and adjust bearings.



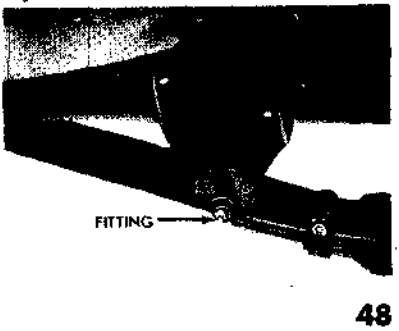
GREASE BEARING—WB—CG

Hand pack or bearing lubricator. Force grease into bearing with lubricator or, if not available, use hand method. Apply at big end of rollers until grease comes out between cage and race at small end of rollers. Smear grease around outside of cage and rollers



FRONT SPRING SHACKLES—CG

Four fittings (two each shackle). Pressure gun. Apply lubricant through fittings until new grease shows inside shackle.



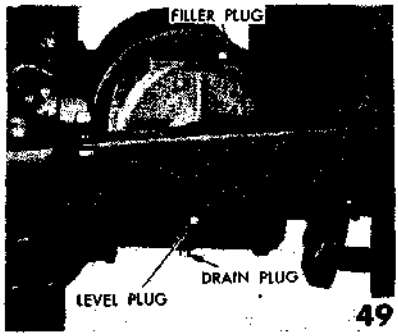
FRONT SPRING PIN—CG

Two fittings (one each side). Pressure gun. Apply lubricant through fittings until new grease shows at sides of spring.

RA PD 333041

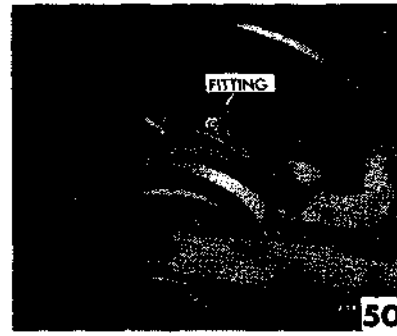
Figure 55—Lubrication Localized Views

TRUCK, 2½-TON, 6 x 6



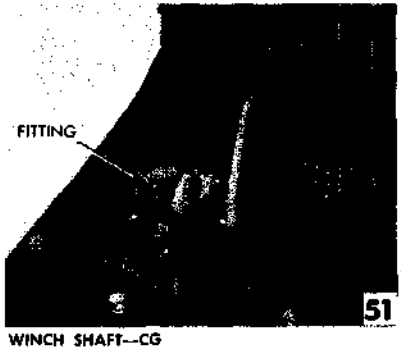
WINCH WORM HOUSING—GO

Filler, level and drain plugs. Pump gun. Lubricate through filler hole (top) until lubricant is up to level hole (side). Drain when lubricant is warm. Vent hole under name plate should be plugged.



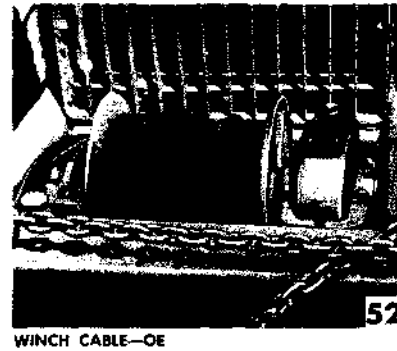
WINCH DRUM BEARING—CG

Two fittings (one each end of drum). Pressure gun with adapter included in tool kit. Apply two or three shots of lubricant through fittings.



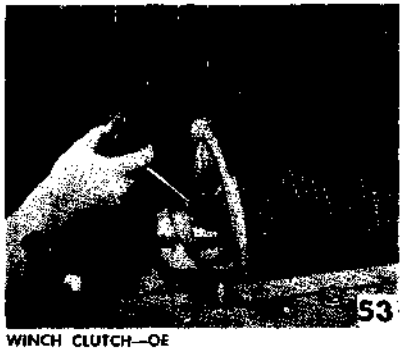
WINCH SHAFT—CG

One fitting (right end of shaft). Pressure gun with adapter included in tool kit. Apply lubricant through fitting until new grease shows at end of shaft.



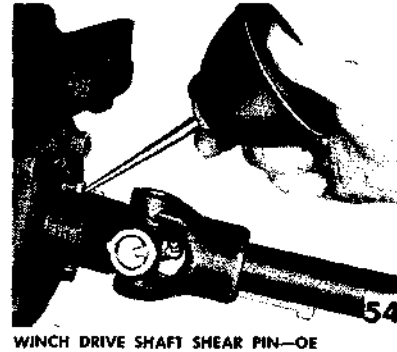
WINCH CABLE—OE

Oil can. Inspect full length of cable, and lubricate if surface is not oily or if rust is apparent.



WINCH CLUTCH—OE

Oil can. Apply lubricant to sliding surface of jaw clutch yoke groove and linkage. Clean and re-oil when clutch sticks or when inspection shows to be dry.



WINCH DRIVE SHAFT SHEAR PIN—OE

Oil can. Apply lubricant to both ends of pin and between yoke and worm shaft. If corroded condition is apparent, remove shear pin and yoke from shaft. Clean, lubricate and reassemble.

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Figure 56—Lubrication Localized Views

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Section IX

NEW VEHICLE RUN-IN TEST

38. PURPOSE.

a. When a new or reconditioned vehicle is first received at the using organization it is necessary for second echelon personnel to determine whether or not the vehicle will operate satisfactorily when placed in service. For this purpose, inspect all accessories, subassemblies, assemblies, tools, and equipment to see that they are in place and correctly adjusted. In addition, they will perform a run-in test of at least 50 miles as directed in AR 850-15, paragraph 25, table III, according to procedures in paragraph 40 below.

39. CORRECTION OF DEFICIENCIES.

a. Deficiencies disclosed during the course of the run-in test will be treated as follows:

(1) Correct any deficiencies within the scope of the maintenance echelon of the using organization before the vehicle is placed in service.

(2) Refer deficiencies beyond the scope of the maintenance echelon of the using organization to a higher echelon for correction.

(3) Bring deficiencies of serious nature to the attention of the supplying organization.

40. RUN-IN TEST PROCEDURES.

a. Preliminary Service.

(1) FIRE EXTINGUISHER. See that portable extinguisher is present and in good condition. Test it momentarily for proper operation, and mount it securely.

(2) FUEL, OIL, AND WATER. Fill fuel tank. Check crankcase oil and coolant supply, and add as necessary to bring to correct levels. Allow room for expansion in fuel tanks and radiator. During freezing weather, test value of antifreeze and add as necessary to protect cooling system against freezing. CAUTION: *If there is a tag attached to filler cap or steering wheel concerning engine oil in crankcase, follow instructions on tag before driving the vehicle.*

(3) FUEL FILTER. Inspect fuel filter for leaks, damage, and secure mountings and connections. Drain filter sediment bowl. If any appreciable amount of water or dirt is present, remove bowl, and clean bowl and element in dry-cleaning solvent. Also drain accumulated water or dirt from bottom of fuel tank. Drain only till fuel runs clean.

(4) BATTERY. Make hydrometer and voltage test of battery, and add clean water to bring electrolyte 3/8 inch above plates.

(5) AIR CLEANERS AND VENTILATORS. Inspect carbureter air cleaner and crankcase ventilator units to see it they are in good condition. Remove air cleaner reservoir and element and clean and

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service according to lubrication order, paragraph 37. Service crankcase ventilator valve according to paragraph 82.

(6) ACCESSORIES AND BELTS. See that accessories such as carbureter, generator, regulator, cranking motor, water pump, fan, and oil filters are in good condition and secure. Be sure fan and generator drive belt is in good condition and adjusted to provide ½ inch finger pressure deflection.

(7) ELECTRICAL WIRING. Examine all accessible wiring and conduits to see if they are in good condition, securely connected, and properly supported.

(8) TIRES. See that all tires, including spares, are properly inflated to 55 pounds (maximum) cool; that stems are in correct position; all valve caps present and finger-tight. Remove objects lodged in treads, carcasses, and between duals. Inspect for damage.

(9) WHEEL AND FLANGE NUTS. See that all wheel mounting and axle flange nuts or cap screws are present and secure.

(10) FENDERS AND BUMPERS. Examine fenders and bumper for looseness and damage.

(11) TOWING CONNECTIONS. Examine all towing devices to see that they are in good condition and securely mounted. Be sure pintle hook operates and latches properly.

(12) BODY, CAB, TARPAULIN. Inspect all types of bodies, (cargo, dump, and water tank) for damage, loose mountings, attachments, hardware, and condition of paint and markings. Be sure cabs are secure; that soft top and frames are in good condition; that tarpaulins, (where used) are not damaged and are installed or stowed properly. On tanks, be sure filler caps and drain valve are in good condition, that they operate properly, and do not leak.

(13) LUBRICATE. Perform a complete lubrication of the vehicle, covering all intervals, according to the instructions on the lubrication order, paragraph 37, except gear cases, wheel bearings, and other units covered in preceding procedures. Check all gear case oil levels, and add as necessary to bring to correct level. Change only if condition of oil indicates the necessity, or if gear oil is not of proper grade for existing atmospheric temperature. NOTE: *Perform items (14) to (17) during lubrication.*

(14) SPRINGS AND SUSPENSION. Inspect front and rear springs, shock absorbers and links, torque rods, and rear spring seats for looseness and damage. Check shocks and spring seats for leakage, and proper oil or fluid levels. Look for spring sag and shifted leaves.

(15) STEERING LINKAGE. Inspect steering gear case, all arms, rods and connections, column and wheel, to be sure they are in good condition, properly assembled and securely connected or mounted. Check gear case for proper oil level and leaks.

(16) PROPELLER SHAFTS, PILLOW BLOCK, AND VENT. Inspect all shafts, universal joints, and pillow block to see if they are in good condition, correctly assembled, alined, secure, and not leaking excessively at seals or vents. Be sure vent passages are not clogged.

(17) AXLE AND TRANSFER CASE VENTS. Examine these units for looseness, damage, and see that they are not clogged.

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NEW VEHICLE RUN-IN TEST

(18) CHOKE. Examine choke to be sure it opens and closes fully in response to operation of choke button.

(19) ENGINE WARM-UP. Start engine, noting if cranking motor action is satisfactory, and any tendency toward hard starting. Set hand throttle to run engine at fast idle during warm-up. During warm-up, reset choke button so engine will run smoothly, and to prevent overchoking and oil dilution.

(20) INSTRUMENTS.

(a) Oil Pressure Gage. Pressure should be 35 to 40 pounds at operating speeds and about 5 pounds at idle speed. Stop engine if pressure is not evident in 30 seconds.

(b) Ammeter. Gage should show a positive (+) charge for a period after starting, until generator restores to battery the current used in starting, then a zero or only slight charge if battery is up and with all lamps and accessories turned off.

(c) Engine Temperature Gage. Reading should increase gradually during warm-up, to normal operating range, 160°F to 185°F. Maximum safe operating temperature, 220°F (205°F at high altitudes). CAUTION: *Do not move vehicle until engine temperature has reached at least 140°F.*

(d) Fuel Gage. Gage should register the approximate amount of fuel in tank.

(21) ENGINE CONTROLS. Observe if engine responds properly to controls, and if controls operate without excessive looseness or binding.

(22) HORN AND WINDSHIELD WIPERS. See that these items are in good condition and secure. If tactical situation permits, test horn for proper operation and tone. See if wiper arms will operate through their full range and that blade contacts glass evenly and firmly.

(23) GLASS AND REAR VIEW MIRRORS. Clean all cab glass and mirrors and inspect for looseness and damage. Adjust rear view mirrors for correct vision.

(24) LAMPS (LIGHTS) AND REFLECTORS. Clean lenses and inspect all units for looseness and damage. If tactical situation permits, open and close all light switches to see if lamps respond properly.

(25) LEAKS—GENERAL. Look on ground under vehicle, and within engine compartment for evidence of fuel, oil, or water leaks, and around axles and transmission for evidence of grease leaks. Trace all leaks to their source and correct or report them.

(26) TOOLS AND EQUIPMENT.

(a) Tools. Check tool lists, paragraph 7, to be sure they are all present, and be sure they are in good condition and properly mounted or stowed.

(b) Equipment. Check On Vehicle Stowage Lists (pars. 8 and 9) to be sure all items of standard or special equipment are present, in good condition and properly mounted or stowed.

(c) Winch. Inspect winch assembly to see that it is in good condition, correctly and securely assembled and mounted and not leaking. Test operation of sliding clutch and inspect automatic brake

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mechanism for looseness or damage. Unwind winch cable and examine. Clean it with a rag saturated with thin oil or kerosene. As it is rewound evenly and tightly, apply a thin film of clean engine oil. Fasten cable chain hook securely.

(d) Hoist. Raise dump body with hoist and inspect mountings, drive, controls, pump and lines, and cylinder for looseness, damage, and leaks at pump, lines, or cylinder. Stop engine with body up and observe any tendency of body to drop. When lowering body, see that it lowers fully and that guides aline body with frame. Check or fill hoist cylinder according to lubrication order, paragraph 37.

b. Run-in Test. Perform the following procedures, (1) to (10) inclusive, during the road test of the vehicle. On vehicles which have been driven 50 miles or more in the course of delivery from the supplying to the using organization, reduce the length of the road test to the least mileage necessary to make observations listed below. CAUTION: *Avoid continuous operation of the vehicle at speeds approaching the maximums indicated on the caution plate.*

(1) DASH INSTRUMENTS AND GAGES. Do not move vehicle until engine temperature reaches 140°F. Maximum safe operating temperature, 220°F. Observe readings of ammeter, oil, temperature, and fuel gages to be sure they are indicating the proper function of the units to which they apply. Also see that speedometer registers the vehicle speed and that odometer registers total accumulating mileage.

(2) BRAKES, FOOT AND HAND. Operate brakes at various speeds during road test. Apply foot pedal sufficiently to stop vehicle in minimum distance and observe effectiveness, any pull to one side, unusual noise, chatter, and pedal travel. Stop vehicle on incline, apply parking brake and note if it holds vehicle. Note if lever has sufficient reserve after application and that pawl and sector lock applied brakes securely.

(3) CLUTCH. Note pedal free-travel (paragraph 150). Check clutch for drag when shifting into low gear. Note any unusual noise when pedal is depressed which may indicate defective release bearing. With transmission in gear, note any tendency of clutch to chatter, grab when clutch is engaged, or slippage when fully engaged under load.

(4) TRANSMISSION AND TRANSFER UNIT. Shift mechanism of transmission and power take-off, transfer and declutching unit should operate easily and smoothly and gears should operate without excessive noise and not slip out of mesh during operation.

(5) STEERING. Observe steering action for binding or looseness, and note any excessive pull to one side, wander, shimmy, or wheel tramp. See that column bracket and wheel are secure.

(6) ENGINE. Be on the alert for any abnormal engine operating characteristics or unusual noise, such as lack of pulling power or acceleration; back-firing, misfiring, stalling, overheating, or excessive exhaust smoke. Observe if engine responds properly to all controls.

(7) UNUSUAL NOISE. Be on the alert throughout road test for any unusual noise from body, cab and attachments, running gear,

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suspension units, or wheels that might indicate looseness, damage, inadequate lubrication, or under-inflated tires.

(8) HALT VEHICLE AT 10-MILE INTERVALS FOR SERVICES (9) AND (10) BELOW.

(9) TEMPERATURES. Cautiously hand-feel each brake drum and wheel hub for abnormal temperatures. Examine transmission, transfer case, and differential housings for overheating and excessive oil leaks at seals or gaskets. NOTE: *Transfer case temperatures are normally greater than other gear cases.*

(10) LEAKS. With engine running, and fuel, engine oil, and cooling systems under pressure, look within engine compartment and under vehicle for indications of leaks.

c. Vehicle Publications and Reports.

(1) PUBLICATIONS. See that vehicle Technical Manuals, Lubrication order, Standard Form No. 26 (Driver's Report-Accident, Motor Transportation) and W.D., A.G.O. Form No. 478 (HWO and Major Unit Assembly Replacement Record), are in the vehicle, legible, and properly stowed. NOTE: *U.S.A. registration number and vehicle nomenclature must be filled in on Form No. 478, for new vehicles.*

(2) REPORTS. Upon completion of the Run-in Test, correct or report any deficiencies noted. Report general condition of the vehicle to designated individual in authority.

Section X

FIRST ECHELON PREVENTIVE MAINTENANCE SERVICE

41 PURPOSE.

a. To insure mechanical efficiency, it is necessary that the vehicle be systematically inspected at intervals each day it is operated and weekly, so defects may be discovered and corrected before they result in serious damage or failure. Certain scheduled maintenance service will be performed at these designated intervals. The services set forth in this section are those performed by drivers or crew, Before-Operation, During-Operation, At-Halt, and After-Operation and Weekly.

b. Driver Preventive Maintenance Services are listed on the back of "Drivers Trip Ticket and Preventive Maintenance Service Record" WD Form No. 48 to cover vehicles of all types and models. Items peculiar to specific vehicles but not listed on WD Form No. 48 are covered in manual procedures under the items with which they are related. Certain items listed on the form that do not pertain to the vehicle involved are eliminated from the procedures as written into the manual. Every organization must thoroughly school each

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driver in performing the maintenance procedures set forth in manuals whether they are listed specifically on WD Form No. 48 or not.

c. The items listed on WD Form No. 48 that apply to this vehicle are expanded in this manual to provide specific procedures for accomplishment of the inspections and services. These services are arranged to facilitate inspection and conserve the time of the driver and are not necessarily in the same numerical order as shown on WD Form No. 48. The item numbers, however, are identical with those shown on that form.

d. The general inspection of each item applies also to any supporting member or connection, and generally includes a check to see whether the item is in good condition, correctly assembled, secure, or excessively worn.

e. The inspection for "good condition" is usually an external visual inspection to determine whether the unit is damaged beyond safe or serviceable limits. The term good condition is explained further by the following terms: Not bent or twisted, not chafed or burned, not broken or cracked, not bare or frayed, not dented or collapsed, not torn or cut.

f. The inspection of a unit to see that it is "correctly assembled" is usually an external visual inspection to see whether it is in its normal assembled position in the vehicle.

g. The inspection of a unit to determine if it is "secure" is usually an external visual examination, a wrench, hand-feel, or a pry-bar check for looseness. Such an inspection should include any brackets, lock washers, lock nuts, locking wires, or cotter pins used in assembly.

h. "Excessively worn" will be understood to mean worn, close-to or beyond serviceable limits, and likely to result in a failure if not replaced before the next scheduled inspection.

i. Any defects or unsatisfactory operating characteristics beyond the scope of first echelon to correct must be reported at the earliest opportunity to the designated individual in authority.

42. BEFORE-OPERATION SERVICE.

a. This inspection schedule is designed primarily as a check to see that the vehicle has not been damaged, tampered with, or sabotaged since the "After-Operation Service" was performed. Various combat conditions may have rendered the vehicle unsafe for operation and it is the duty of the driver to determine whether or not the vehicle is in condition to carry out any mission to which it is assigned. This operation will not be entirely omitted, even in extreme tactical situations.

b. **Procedures.** Before-Operation Service consists of inspecting items listed below according to the procedure described, and correcting or reporting any deficiencies. Upon completion of the service, results should be reported promptly to the designated individual in authority.

(1) ITEM 1, TAMPERING AND DAMAGE. Examine the vehicle, accessories, and equipment for damage, caused by tampering or

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sabotage, collision, falling debris, or shell fire since parking. Examine the interior of engine compartment for evidence of above conditions, and for loosened or damaged engine accessories or drive belt, leaking fuel, disconnected oil lines, coolant lines, and control linkage.

(2) ITEM 2, FIRE EXTINGUISHER. See that unit is in good condition, fully charged, (open filler plug to check contents) and that nozzle is not clogged. Mount extinguisher securely.

(3) ITEM 3, FUEL, OIL, AND WATER. Check amount of fuel in tank. Check crankcase oil level on dip stick. Examine coolant level in radiator. Add fuel as necessary to complete mission, or to operate vehicle to next scheduled refueling point. Add engine oil to crankcase and coolant to radiator as needed to bring to correct levels. NOTE: *Any appreciable drop in levels since the last "After-Operation Service" must be investigated, and cause corrected or reported.* During freezing weather when antifreeze solution is in use, if an excessive addition of water is needed, antifreeze value must be checked by 2nd echelon and added if necessary. Spare fuel, oil, and water cans must be full and securely mounted.

(4) ITEM 4, ACCESSORIES AND DRIVES. Examine units such as carburetor, generator, regulator, cranking motor, fan, oil filter, and air cleaner for looseness and damage. Make certain that water pump and generator drive belt is in good condition and that adjustment is satisfactory (½ inch finger pressure deflection).

(5) ITEM 6, LEAKS—GENERAL. Inspect ground under vehicle and within engine compartment for indications of fuel, engine oil, coolant, and gear oil or brake fluid leaks. Trace any leaks found to their source, and correct or report them.

(6) ITEM 8, CHOKE. As engine is started in item 7, below, observe if choke action is satisfactory.

(7) ITEM 7, ENGINE WARM-UP. Start engine noting any tendency toward hard starting; if cranking motor has adequate cranking speed, and engages and disengages without unusual noise. Set hand throttle to run engine at fast idle during warm-up, and reset choke as necessary for engine to run smoothly and to prevent overchoking and oil dilution.

(8) ITEM 9, INSTRUMENTS.

(a) Oil Gage. Oil pressure should be approximately five pounds at slow idling speed.

(b) Ammeter. With battery fully charged and all lights and accessories turned off, ammeter may show a slight positive charge with engine at fast idle. A high charge reading may be indicated immediately after starting until generator restores to battery current used in starting. High charge may be indicated for some time if battery charge is low or electric load is heavy.

(c) Engine Temperature Gage. Reading should increase gradually during warm-up period to normal operating range. Temperatures between 160°F, and 220°F (205°F at high altitudes) are satisfactory for efficient engine operation. Temperatures above 220°F (205°F at high altitudes) or below 160°F indicate a deficiency. Engine must be

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stopped and trouble located and corrected. Do not move vehicle until temperature reaches 140°F.

(d) Fuel Gage. Observe if gage registers level of fuel in tank. Ordinarily tank should have been filled during "After-Operation Service" and gage should read "FULL."

(9) ITEM 10, HORN AND WINDSHIELD WIPERS. If tactical situation permits, test horn for proper operation and tone. Test wipers to see that they operate properly, and observe whether the blades contact glass evenly and arms travel through full stroke. Inspect for damage.

(10) ITEM 11, GLASS AND REAR VISION MIRROR. Clean all glass and inspect for damage. Check adjustment of rear vision mirror and see that it is secure.

(11) ITEM 15, SPRINGS AND SUSPENSION. Examine springs, shock absorbers, torque rods, and rear spring seats and bearing caps to see that they are in good condition; that all assembly mounting nuts and screws are secure, and that shock absorbers and bearing caps are not leaking.

(12) ITEM 16, STEERING LINKAGE. Inspect steering gear housing mounting bolts, all steering rods, and all joints for looseness or damage. Examine steering gear housing for lubricant leaks.

(13) ITEM 13, WHEEL AND FLANGE NUTS. See that all wheel mounting, and axle flange nuts or cap screws, are present and secure (see paragraphs 167, 171 and 172).

(14) ITEM 14, TIRES. Examine tires including spare, for under inflation. Correct pressure is 55 pounds (maximum) cool. Inspect them for damage, and remove any embedded objects from treads and carcass and from between duals.

(15) ITEM 18, TOWING CONNECTIONS. Inspect all towing devices for looseness or damage. Be sure pintle operates freely and locks securely. See that winch cable chain and hook are in good condition and secured to front tow hooks.

(16) ITEM 19, BODY, LOAD AND TARPS. Inspect body for looseness and damage. Be sure dump body is in alinement with frame and guides; that tail gate is closed and secured. Examine filler openings and drain cocks on water tank to be sure they are closed and locked and inspect tank for leaks. Inspect cargo load for damage and proper distribution. See that tarpaulin is in good condition and that all ropes are properly lashed to body hooks.

(17) ITEM 12, LAMPS (LIGHTS) AND REFLECTORS. See that all lights and warning reflectors are clean. Examine them for looseness or damage. If tactical situation permits, open and close switches and observe if lamps respond properly. Include stop and blackout lights.

(18) ITEM 17, FENDERS AND BUMPERS. Inspect fenders, bumpers, and running boards for looseness or damage.

(19) ITEM 20, DECONTAMINATOR. Be sure decontaminator is present, fully charged and secure. Remove filler plug to check contents.

(20) ITEM 21, TOOLS AND EQUIPMENT. Be sure all items are present, serviceable, and properly mounted or stowed (Section III).

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(21) ITEM 22, ENGINE OPERATION. Before vehicle is put in motion, be sure it has reached a satisfactory operating temperature, (at least 140°F) and that it idles smoothly with choke wide open. Accelerate and decelerate engine and listen for any unusual noise. Note any unsatisfactory operating characteristics or excessive exhaust smoke.

(22) ITEM 23, DRIVER'S PERMIT AND FORM 26. Driver must have his operator's permit on his person. Check to see that accident Form No. 26, Operator's Manual, Lubrication Order,. and W.D., A.G.O. Form No. 478 are present in vehicle, legible and properly stowed.

(23) ITEM 25, DURING-OPERATION CHECK. The During-Operation Services and observations start immediately the vehicle is put in motion as follows:

43. DURING-OPERATION SERVICE.

a. While vehicle is in motion, listen for any sounds such as rattles, knocks, squeals, or hums that may indicate trouble. Look for indications of trouble in cooling system and smoke from any part of the vehicle. Be on the alert to detect any odor of overheated components or units such as generator, brakes or clutch, fuel vapor from a leak in fuel system, exhaust gas or other signs of trouble. Any time the brakes are used, gears shifted, or vehicle turned, consider this a test and notice any unsatisfactory or unusual performance. Watch the instruments constantly. Notice promptly unusual instrument indication that may signify possible trouble in system to which the instrument applies.

b. Procedures. During-Operation Services consist of observing items listed below according to the procedures following each item, and investigating any indications of serious trouble. Notice minor deficiencies to be corrected or reported at earliest opportunity, usually next scheduled halt.

(1) ITEM 27, FOOT AND HAND BRAKES. Foot brakes should stop vehicle smoothly and effectively with normal pedal pressure and return to off position immediately pedal is released. Pedal should have ½ inch free travel before meeting resistance and pedal to floor board clearances should be ½ to 1 inch when fully released. Hand brake should latch securely, and hold vehicle on reasonable incline, leaving at least 1/3 ratchet travel in reserve.

(2) ITEM 33, STEERING GEAR. Note any indication of looseness or binding, pull to one side, wandering, shimmy, wheel tramp, or unusual noise.

(3) ITEM 28, CLUTCH. Clutch should not grab, chatter or squeal during engagement or slip when fully engaged under load. Pedal should have 2½ inches free travel and never less than 1 inch before meeting resistance (see paragraph 150).

(4) ITEM 29, TRANSMISSION. Transmission and power take-off should shift smoothly, operate without unusual noise, and gears should not slip out of mesh during operation. Be sure power take-off control lever latch holds ever securely.

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(5) ITEM 30, TRANSFER. Transfer unit range gears and declutching mechanism should shift easily, operate without unusual noise, and not creep out of mesh during operation.

(6) ITEM 31, ENGINE AND CONTROLS. The driver must be on the alert for deficiencies in engine performance such as lack of usual power, misfiring or stalling, unusual noise, indications of overheating or excessive exhaust smoke. Observe if engine responds to all controls and if controls appear to be in proper adjustment and not excessively loose or binding.

(7) ITEM 32, INSTRUMENTS. Observe all pertinent instrument readings frequently during operation, to be sure they indicate or record the proper function of the unit or system to which they apply. Observe if speedometer registers vehicle speed in miles per hour, and if odometer records accumulating mileage.

(8) ITEM 34, RUNNING GEAR. Be on the alert for any unusual operating characteristics or noise from wheels, axles, or suspension units that might indicate looseness or damage or underinflated tires.

(9) ITEM 35, BODY. Note any noise or abnormal condition that might indicate shifting, loose tarpaulins or curtain , loose or damaged doors, hardware (closed type cab), floor or inspection plates or body attachments. Make certain that top, rear, and side curtains on open type cab are secure.

44. AT-HALT SERVICE.

a. At-Halt Services may be regarded as minimum maintenance procedures and should be performed under all tactical conditions even though more extensive maintenance services must be slighted or omitted altogether.

b. Procedures. At-Halt Services consist of investigating any deficiencies noted during operation, inspecting items listed below according to the procedures following the items, and correcting any deficiencies found. Deficiencies not corrected should be reported promptly to the designated individual in authority.

(1) ITEM 38, FUEL, OIL, AND WATER SUPPLY. Check the fuel, oil, and coolant supply to see that it is adequate to operate the vehicle to the next scheduled halt. If engine is hot, add coolant slowly while engine is running at a fast idle. Make sure vent in fuel tank cap is open and valve free.

(2) ITEM 47, ACCESSORIES AND BELTS. Examine all accessible units for looseness or damage. Be sure fan and generator belt deflection is ½ inch. If radio noise caused by operation of the engine has been reported, examine all wiring and radio noise suppression devices in engine compartment for damage, loose connections or mountings. Look particularly for scorched, loose or damaged resistor-suppressors at spark plugs and distributor.

(3) ITEM 48, AIR CLEANERS. If operating under extremely dusty or sandy conditions, inspect the air cleaners and breather cap to see that they are in condition to deliver clean air properly. Service if necessary.

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(4) ITEM 39, TEMPERATURES, HUBS, BRAKES, AND DRUMS. Place hand cautiously on each brake drum and wheel hub and note if it is overheated.

(5) ITEM 46, LEAKS—GENERAL. Look under vehicle and within engine compartment for indications of fuel, oil, brake fluid, or coolant leaks. Trace any leaks found to their source and correct or report them.

(6) ITEM 43, STEERING LINKAGE. Examine all steering control mechanism, arms and linkage joints for looseness or damage. Investigate any unusual condition noted during operation.

(7) ITEM 40, AXLE AND TRANSFER CASE VENTS. Inspect transfer case, transmission, and axle housing for overheating and note any excessive lubricant leaks. Wipe clean and inspect axle housing and transfer case vents for damage or clogging. Vents must be kept open.

(8) ITEM 41, PROPELLER SHAFTS. Inspect all propeller shafts and universal joints for looseness, damage, and excessive lubricant leaks. Remove any foreign matter entangled around shafts or universal joints.

(9) ITEM 42, SPRINGS AND SUSPENSIONS. Inspect for broken or shifted spring leaves, damaged or loose U-bolts, shackles, rebound clips or shock absorber bodies and linkage, or excessive shock absorber fluid leaks. Ascertain that torque rods are secure and not damaged, and rear spring seat bearing caps are tight and not leaking excessive lubricant.

(10) ITEM 44, WHEEL AND FLANGE NUTS. See that all wheel mounting and axle flange nuts or cap screws are present and secure.

(11) ITEM 45, TIRES. Inspect all tires for under inflation or damage. Remove embedded objects in treads or carcasses and from between duals. See that spare is inflated and secure in carrier.

(12) ITEM 49, FENDERS AND BUMPERS. Inspect bumpers and fenders and rear splash guards for looseness or damage.

(13) ITEM 50, TOWING CONNECTIONS. Inspect front tow hooks and rear pintle hook to be sure they are in good condition, securely mounted, and if in use, that they are properly connected. Be sure winch (when used) cable and cable chain are properly wound and secured to front tow hooks.

(14) ITEM 51, BODY LOAD AND TARPS. Inspect for indications of cab, body or load shifting and for damage, and be sure tarpaulin (when used) is properly secured.

(15) ITEM 52, GLASS. Clean all windshield, mirror, light, and warning reflector glass and inspect for damage.

45. AFTER-OPERATION AND WEEKLY SERVICES.

a. After-Operation Servicing is particularly important because at this time the driver inspects his vehicle to detect any deficiencies that may have developed and corrects those he is permitted to handle. He should report promptly, to the designated individual in authority the results of his inspection. If this schedule is performed thoroughly, the vehicle should be ready to roll again on a moment's notice. The Before-Operation Service, with a few exceptions, is then

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necessary only to ascertain whether the vehicle is in the same condition in which it was left upon completion of the After-Operation Service. The After-Operation Service should never be entirely omitted even in extreme tactical situations, but may be reduced to the bare fundamental services outlined for the At-Halt Service if necessary.

b. Procedures. When performing the After-Operation Service the driver must remember and consider any irregularities noticed during the day in the Before-Operation, During-Operation, and At-Halt Services. The After-Operation Service consists of inspecting and servicing the following items. Those items of the After-Operation Service that are marked by an asterisk (*) require additional weekly services, the procedures for which are indicated in subparagraph *(b)* of each applicable item.

(1) ITEM 55, ENGINE OPERATION. Accelerate and decelerate engine and note any tendency to miss or backfire. Listen for any unusual noise or vibration. Note any unusual exhaust smoke. Investigate and correct or report any deficiencies noted during operation.

(2) ITEM 56, INSTRUMENTS. Check all pertinent instruments to be sure all are operative and indicate normal readings. Stop engine, first allowing it to cool off for four or five minutes if it is at or beyond normal temperature.

(3) ITEM 54, FUEL, OIL, AND WATER SUPPLY. Fill fuel tanks, (see if fuel gage indicates full). Check crankcase oil and add to correct level. Add coolant to correct level. **NOTE:** *Do not overfill fuel tanks or radiator. Allow room for expansion.* In freezing weather if any appreciable amount of coolant is necessary, have antifreeze value checked and add sufficient to protect cooling system against freezing. Fill all spare fuel and water cans.

(4) ITEM 57, HORN AND WINDSHIELD WIPERS. Inspect to see that these items are secure and not damaged. If tactical conditions permit, test horn for proper operation and tone.

(5) ITEM 58, GLASS AND REAR VISION MIRROR. Clean and inspect for damage and see that mountings are secure.

(6) ITEM 59, LAMPS (LIGHTS) AND REFLECTORS. Inspect for looseness or damage. If tactical situation permits, test all lamps and switches for proper operation. Clean lenses and reflectors.

(7) ITEM 60, FIRE EXTINGUISHER. Inspect for looseness or damage and full charge. Remove filler plug to check contents. If extinguisher has been used or valves opened, report for refill or exchange.

(8) ITEM 61, DECONTAMINATOR. Inspect for looseness or damage and full charge. Remove filler plug to check contents. If used, report for refill or exchange.

(9) ITEM 62, *BATTERIES.

(a) Inspect batteries to see that they are clean, secure and not leaking or damaged. See that cell caps are finger-tight.

(b) Weekly. Clean dirt from top of battery. Inspect for bulging or leaks. If terminal connections or post are corroded, clean them

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thoroughly and apply fresh, thin coating of grease. Tighten terminal bolts if loose. Remove vent caps and check level of electrolyte. Add fresh clean water if required to bring electrolyte to proper level (see paragraph 119), take proper precautions during cold weather against freezing. Battery carrier should be secure, clean, free of rust, and well painted. If mountings are loose, tighten them cautiously so as not to damage the battery case.

(10) ITEM 63, ACCESSORIES AND BELT. Inspect units such as carbureter, generator, cranking motor, fan, water pump, distributor, regulator unit and oil filter for looseness, damage, or leaks. Check condition and adjustment of generator and water pump drive belt. Adjust, if necessary, to provide ½ inch finger pressure deflection. Investigate and correct or report any deficiencies of accessory units or drive noted during operation.

(11) ITEM 64, ELECTRICAL WIRING. Inspect all ignition wiring for looseness, damage, or deterioration of insulation. Wipe off excess grease or moisture, and perform an inspection of all accessible low voltage wiring and connections for looseness or damage. Be sure that all wiring is supported so as not to chafe against other vehicle parts. Examine all radio suppression bond strap, filter, or capacitor bolts and nuts for looseness. Inspect resistor-suppressors at spark plugs and distributor for scorching, looseness or other damage.

(12) ITEM 65, AIR CLEANERS AND BREATHER CAPS. Inspect for looseness or damage. Examine oil in reservoirs for correct level and excessive dirt. When operating in sandy or dusty conditions, clean and service air cleaners and breather caps as often as necessary, according to lubrication order. Be sure all gaskets seal properly and that joints and connections are secure.

(13) ITEM 66, *FUEL FILTER.

(a) Inspect for looseness, damage and fuel leaks.

(b) Weekly. Remove sediment bowl drain plug and drain off all accumulated dirt and water. If draining of fuel pump sediment bowl shows excessive dirt or water, remove and clean element in dry-cleaning solvent and reinstall securely.

(14) ITEM 67, ENGINE CONTROLS. Examine all engine operating control linkage for looseness, damage, excessive wear, and adequate lubrication.

(15) ITEM 68, *TIRES.

(a) Examine all tires including spares for damage and excessive wear. Remove all embedded foreign matter, such as nails, glass, or stones from treads and carcasses and from between duals. Check for proper position of valve stem and presence of valve caps. Inflate to 55 pounds (maximum) cool.

(b) Weekly. Replace badly worn or otherwise unserviceable tires. Serviceable tires which show abnormal wear should be relocated to other wheels to even wear. Apparent mechanical deficiencies causing such wear should be reported for attention by higher echelon.

(16) ITEM 69, SPRINGS AND SUSPENSIONS. Inspect all units for looseness or damage. Look for abnormal spring sag, shifted spring

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leaves, distorted torque rod or loose rod ends, and leaking shock absorbers or rear spring seat bearings.

(17) ITEM 70, STEERING LINKAGE. Inspect all steering components for looseness or damage. Examine steering gear housing and linkage joints for lubricant leakage or lack of lubrication. Investigate any unusual operating conditions noted during operation.

(18) ITEM 71, PROPELLER SHAFTS, CENTER BEARING (PILLOW BLOCK). Inspect all propeller shafts and U-joints for looseness or damage and excessive oil leaks. Remove any foreign material wound around shafts or joints. Examine center bearing (pillow block) for looseness, damage or excessive leaks.

(19) ITEM 72, *AXLE, PILLOW BLOCK, AND TRANSFER VENTS.

(a) See that all axle housing, pillow block, and transfer case vents are present, in good condition and clean. Inspect for indications of lubricant leakage from vents.

(b) Weekly. Remove all vents and clean out passages. Reinstall securely.

(20) ITEM 73, LEAKS—GENERAL. Look under vehicle for indications of fuel, engine oil, coolant, brake fluid or gear oil leaks.

(21) ITEM 74, *GEAR OIL LEVELS. (Weekly) Check gear oil levels in differentials, transfer case, transmission, winch and steering gear housing, and front axle steering knuckle supports and report if low. Correct levels are from ½ inch below, when cool, to lower edge of filler hole when hot, except winch and steering gear which should be to lower edge of filler hole at all times. If an oil change in any of these units is due, or condition warrants, drain and fill according to lubrication order, Section VIII.

(22) ITEM 76, FENDERS AND BUMPERS. Inspect front fenders, front and rear bumpers, and rear splash guards for looseness or damage.

(23) ITEM 77, TOWING CONNECTIONS. Inspect front tow hooks and rear pintle hook to see that they are in good condition and securely mounted. If in use, be sure they are properly connected, that pintle hook latch is locked and pin is in place.

(24) ITEM 78, BODY, LOAD, AND TARPAULINS (HOIST IF USED). Inspect cab carefully for damage or loose mountings or attachments. Correct or report as necessary. Examine top tarpaulin and end curtains if in use, for worn spots or other damage and see that they are secure. On *cargo bodies,* keep all body mounting bolts tight at all times in order to prevent shifting of body on chassis. Inspect all mountings spaced along body longitudinal sills which will disclose loosened or broken mounting bolts which are easily tightened or replaced. Any cargo must be properly distributed and secure. *Water tank body mountings.* The inspection of body mounting bolts and tightening is performed in the same manner as described for cargo body. See that filler caps and drain cocks are closed and secure. On vehicles equipped with *dump cargo body and hoist,* the body mounting and assembly bolts must be checked and kept tightened at all times. Examine bolts which attach wood rails to top of subframe shackles for looseness. Tighten as necessary. Make certain that body

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hinge bracket bolts are tight and hinge pins are in good condition and well lubricated. Examine packing gland nuts located at hoist pump to pump drive shafts for leaks. Pump manifold and pump valve shaft should be tightened whenever oil leaks are observed. Check oil level in hoist cylinder as directed in lubrication order (Section VIII).

(25) ITEM 79, *WINCH.

(a) Examine winch assembly for looseness or damage and excessive oil leaks at worm gear housing. See that winch drive shaft shear pin is in good condition, lubricated, and secure. Make certain that winch clutch operates freely, is lubricated, and locks securely.

(b) Weekly. If vehicle has been operated in deep water, sample lubricant for contamination. If water is present, report condition. If winch cable is dry, dirty, or wound unevenly, unwind entire length, clean, and rewind evenly, after applying oil on cable as directed in paragraph 37, Lubrication. Secure cable chain hook securely to front tow hooks.

(26) ITEM 82, *TIGHTEN.

(a) Tighten any mounting or external assembly nuts or screws where inspection of vehicle has indicated the necessity.

(b) Weekly. Tighten wheel mounting and axle flange nuts and cap screws, spring U-bolts, eye bolts, shackles and rebound clips, torque rods, shock links, U-joint companion flanges, body mountings, engine mountings, accessories or special equipment mountings, transfer case mountings, steering arms, towing connections, or any other mountings or external assembly nuts or screws which inspection or experience indicates as necessary on a weekly or mileage basis.

(27) ITEM 83, *LUBRICATE AS NEEDED.

(a) Lubricate all items such as shackles, hinges, latches, control linkage frictional joints, or any point where inspection has indicated oil can or hand greasing is needed.

(b) Weekly. Lubricate all points of the vehicle indicated on the lubrication order, Section VIII, as needing lubrication on a weekly or a mileage basis.

(28) ITEM 84, *CLEAN ENGINE AND VEHICLE.

(a) Clean dirt and grease or oil drippings from inside cab, and from engine compartment and exterior of engine. Wipe off excess dirt and grease from entire vehicle.

(b) Weekly. Wash vehicle when possible. If not possible, wipe off thoroughly. Inspect paint or camouflage pattern for rust or for bright spots which might cause light reflections. See that vehicle markings are legible unless covered for tactical reasons. CAUTION: *If vehicle is driven into water for washing, care must be taken to see that water or dirt does not get into wheel bearings, gear cases or brakes, or on engine or electrical units or wiring.*

(29) ITEM 85, *TOOLS AND EQUIPMENT.

(a) Check vehicle stowage and tool lists, Section III, to see that all items are present. Inspect items to see that they are in good condition and properly mounted or stowed.

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(b) Weekly. Clean all tools and equipment of rust or dirt and apply a preservative where necessary when possible. See that tools with cutting edge are sharp and properly protected and that all items are securely mounted or stowed.

NOTE: *When services are completed be sure all inspection plates are replaced securely.*

Section XI

SECOND ECHELON PREVENTIVE MAINTENANCE

46. SECOND ECHELON PREVENTIVE MAINTENANCE SERVICES.

a. Regular scheduled maintenance inspections and services are a preventive maintenance function of the using arms, and are the responsibility of commanders of operating organizations.

(1) FREQUENCY. The frequency of the preventive maintenance service outlined herein is considered a minimum requirement for normal operation of vehicles. Under unusual operating conditions, such as extreme temperatures, dusty or sandy terrain, it may be necessary to perform certain maintenance services more frequently.

(2) FIRST ECHELON PARTICIPATION. The drivers should accompany their vehicles and assist the mechanics, while periodic second echelon preventive maintenance services are performed. Ordinarily, the driver should present the vehicle for a scheduled preventive maintenance service in a reasonably clean condition: that is, it should be dry and not caked with mud or grease, to such an extent that inspection and servicing will be seriously hampered. However, the vehicle should not be washed or wiped thoroughly clean, since certain types of defects, such as cracks, leaks, and loose or shifted parts or assemblies are more evident if the surfaces are slightly soiled or dusty.

(3) If instructions, other than those contained in the general procedures in subparagraph (4) or the specific procedures in subparagraph (5) which follows, are required for the correct performance of a preventive maintenance service, or for correction of a deficiency, other sections of this manual pertaining to the item involved, or a designated individual in authority, should be consulted.

(4) GENERAL PROCEDURES. These general procedures are basic instructions which are to be followed when performing the services on the items listed in the specific procedures. NOTE: *The second echelon personnel must be thoroughly trained in these procedures, so that they will apply them automatically.*

(*a*) When new or overhauled subassemblies are installed to correct deficiencies, care should be taken to see that they are clean, correctly installed, properly lubricated and adjusted.

(*b*) When installing new lubricant retainer seals, a coating of the

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lubricant should be wiped over the sealing surface of the lip of the seal. When the new seal is a leather seal, it should be soaked in SAE 10 engine oil (warm if practicable) for at least 30 minutes. Then the leather lip should be worked carefully by hand, before installing the seal. The lip must not be scratched or marred.

(*c*) The general inspection of each item applies also to any supporting member or connection, and usually includes a check to see whether or not the item is in good condition, correctly assembled, secure, or excessively worn. The mechanic must be thoroughly trained in the following explanations of these terms.

1. The inspection for "good condition" is usually an external visual inspection to determine if the unit is damaged beyond safe or serviceable limits. The term good condition is explained further by the following terms: not bent or twisted, not chafed or burned, not broken or cracked, not bare or frayed, not dented or collapsed, not torn or cut.

2. The inspection of a unit to see that it is "correctly assembled" is usually an external visual inspection, to see whether or not it is in its normal assembled position in the vehicle.

3. The inspection of a unit to determine if it is "secure" is usually an external visual examination, a wrench, hand-feel, or a pry-bar check for looseness. Such an inspection should include any brackets, lock washers, lock nuts, locking wires, or cotter pins used in assembly.

4. "Excessively worn" will be understood to mean worn, close-to or beyond serviceable limits, and likely to result in a failure if not replaced before the next scheduled inspection.

(*d*) *Special Services.* These are indicated by repeating the item numbers in the columns which show the interval at which the services are to be performed, and show that the parts, or assemblies, are to receive certain mandatory services. For example, an item number in one or both columns opposite a TIGHTEN procedure means that the actual tightening of the object must be performed. The special services include:

1. Adjust. Make all necessary adjustments in accordance with the pertinent section of this manual.

2. Clean. Clean units of the vehicle with dry-cleaning solvent to remove excess lubricant, dirt, and other foreign material. After the parts are cleaned, rinse them in clean fluid and dry them thoroughly. Take care to keep the parts clean, until reassembled, and be certain to keep cleaning fluid away from rubber or other material that it would damage. Clean the protective grease coating from new parts since this material is usually not a good lubricant.

3. Lubrication. This applies either to lubrication operations that do not appear on the vehicle lubrication order, or to items that do appear on such orders, but should be performed in connection with the maintenance operations, if parts have been disassembled for inspection or service.

4. Serve. This usually consists of performing special operations, such as replenishing battery water, draining and refilling units with oil, and changing or cleaning the oil and fuel filter or cartridge.

5. *Tighten.* All tightening operations should be performed with sufficient wrench torque, (force on the wrench handle), to tighten the unit according to good mechanical practice. Use a torque-indicating wrench, where specified. Do not overtighten, as this may strip threads or cause distortion. Tightening will always be understood to include the correct installation of lock washers, lock nuts, and cotter pins provided to secure the tightening.

(e) When conditions make it difficult to perform the complete preventive maintenance procedures at one time, they can sometimes be handled in sections, planning to complete all operations within the week, if possible. All available time at halts and in bivouac areas must be utilized, if necessary to assure that maintenance operations are completed. When limited by the tactical situation, items with Special Services in the columns should be given first consideration.

(*f*) The numbers of the preventive maintenance procedures that follow are identical with those outlined on W.D., A.G.O. Form No. 461, which is the Preventive Maintenance Service Work Sheet for Wheeled and Half-Track Vehicles. Certain items on the work sheet, that do not apply to this vehicle, are not included in the procedures in this manual. In general, the numerical sequence of items on the work sheet is followed in the manual procedures, but in some instances, there is deviation for conservation of the mechanics time and effort.

(5) SPECIFIC PROCEDURES. The procedures for performing each item in the 1000-mile (monthly) and 6000-mile (six-month) maintenance procedures are described in the following chart. Each page of the chart has two columns at its left edge corresponding to the 6000-mile and the 1000-mile maintenance respectively. Very often it will be found that a particular procedure does not apply to both scheduled maintenances. In order to determine which procedure to follow, look down the column corresponding to the maintenance due, and wherever an item number appears perform the operations indicated opposite number.

6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		ROAD TEST
		NOTE: When the tactical situation does not permit a full road test, perform those items which require little or no movement of the vehicle. When a road test is possible, it should be for preferably 5 miles and not over 10 miles.
1	1	**Before-Operation Service.** Perform the Before-Operation Service as described in paragraph 42.
3	3	**Dash Instruments and Gages.**
		Oil Pressure Gage. Oil pressure should be 5 pounds at slow idle speed. CAUTION: *Stop engine if oil pressure is not indicated in 30 seconds.*
		Ammeter. Indicator may show a positive (+) charge for a short period until generator restores to battery, current used in starting engine. Time will depend on condition of charge of battery and electrical

6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		load carried. With battery fully charged and when regulator unit is cut-in, ammeter may show zero or only slight charge. Stop engine and investigate any discharge (—) reading with engine running and lights and accessories turned off. *Temperature Gage.* Reading should increase gradually during warm-up period to normal range, 160°F to 220°F CAUTION: *Do not move vehicle until engine has reached at least 140°F. Maximum safe operating temperature 220°F (205°F at high altitudes).* *Fuel Gage.* Should register amount of fuel in tank. *Speedometer.* Speedometer should indicate vehicle speed and odometer should register total accumulating mileage.
4	4	**Horns, Mirrors, and Windshield Wipers.** If tactical situation permits, test horn for proper operation and tone. Examine rear vision mirror and wipers to see that they are in good condition, secure, and that wiper blades contact glass evenly and operate through their full range.
5	5	**Brakes (Service and Parking, Feel, Side Pull, Noise and Chatter).** Operate brakes at various speeds during road test. *Service Brakes.* Apply foot pedal sufficiently to stop vehicle in minimum distance and observe effectiveness, any pull to one side, unusual noise, chatter, and pedal travel. *Parking Brake.* Stop vehicle on incline, apply parking brake and note if it holds vehicle. Note if lever has sufficient reserve after application and that pawl and sector lock applied brakes securely.
6	6	**Clutch (Free-travel, Drag, Noise, Chatter, Grab and Slip).** Note pedal free-travel (par. 150). Check clutch for drag when shifting into low gear. Note any unusual nose when pedal is depressed which may indicate defective release bearing. With transmission in gear, note any tendency of clutch to chatter, grab when clutch is engaged, or slippage when fully engaged under load.
7	7	**Transmission and Transfer Case (Lever Action, Declutching, Vibration and Noise).** Levers should move into each gear range position easily and quietly. Note any vibration that may indicate loose mounting or noise that may indicate damaged, excessively worn, or inadequately lubricated parts. On winch or hoist

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		equipped vehicle, stop vehicle, engage power hoist to see that it also shifts easily and stays in gear when in operation.
8	8	**Steering (Free Play, Bind, Wander, Shimmy, Side Pull, Column and Wheel).** With vehicle in motion, observe whether there is any indication of looseness or binding. Note any tendency to wander, shimmy or pull to one side. See that steering column and wheel are in good condition and secure.
9	9	**Engine (Idle, Acceleration, Power, Noise and Governed Speed).** Observe engine operating characteristics for following conditions: *Unusual Noises.* Listen for knocks and rattles as the engine is accelerated, decelerated and while it is under both light and heavy loads. *Acceleration and Power.* Operate the engine at varying speeds in all gear ratios, and note if vehicle has normal pulling power and acceleration. Note any tendency to stall while shifting. A slight ping during fast acceleration is normal. Continuing or heavy ping may indicate early timing, or heavy accumulation of carbon. *Governed Speed.* With the vehicle in gear, slowly accelerate engine and observe speedometer reading. See if vehicle reaches but does not exceed, the governed speed specified on caution plate.
10	10	**Unusual Noises (Attachments, Body, Cab, and Wheels).** Listen for any noise that may indicate loose or damaged attachments mounted on vehicle, loose cab or body mountings, floor plates, doors, windshield or accessories. Listen particularly for indications of loose wheel mountings.
11	11	**Brake Booster (Hydrovac) Operation.** Whenever brakes are applied, observe if the hydrovac unit appears to assist in the application satisfactorily. After stopping vehicle listen at hydrovac air cleaner unit for air movement, when brakes are applied, indicating unit is operating.
13	13	**Temperatures (Brake Drums, Hubs, Axles, Transmission, Transfer).** Cautiously hand-feel all brake drums and wheel hubs to see if they are abnormally hot. Inspect axle housing, transmission and transfer case for indications of overheating.
14	14	**Leaks (Engine Oil, Water, and Fuel).** After road test is completed, look under vheicle and in engine compartment, for indications of engine oil, coolant, or lubricant leaks. Trace any leaks found to their source and correct or report them. NOTE: *If tactical conditions permit, remove the engine compartment side panels; disconnect hood bracket, bond*

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		straps, then rest engine hood against the windshield. Engine and accessories will then be more accessible to perform maintenance operations.
		RAISE VEHICLE AND BLOCK SAFELY
17	17	**Unusual Noises (Engine, Belts, Accessories, Transmission, Transfer, Propeller Shafts and U-joints, Axles and Wheel Bearings).** With engine running, observe as follows: *Engine, Belt and Accessories.* Accelerate and decelerate the engine momentarily and listen for any unnusual noise in these units that might indicate damaged, loose, or excessively worn engine parts, drive belt or accessories. *Transmission, Transfer, Propeller Shafts and U-joints, Axles, and Wheel Bearings.* With the transmission in an intermediate gear, and front driving axles engaged, operate these units at a constant, moderate speed and observe all propeller shafts and wheels for vibration and runout, and for vibrations in other units which may indicate looseness or unbalance. Slow running wheels may indicate tight brakes or wheel bearings. Also be sure to localize, correct, or report any noise noted during road test.
52	52	**Rear Wheels (Bearings, Seals, Drive Flanges, Nuts and Cap Screws).** Inspect and service as follows: *Wheels.* Inspect wheels to see that they are in good condition and secure. *Bearings and Seals.* Check for loose wheel bearing adjustment. Revolve wheels and listen for evidence of dry or damaged bearings. Inspect around flanges and brake supports for lubricant leaks. *Drive Flanges and Nuts or Cap Screws.* Note whether they are in good condition and if nuts are tightened securely.
52		*Clean.* Disassemble rear wheel bearings and oil seals. Clean thoroughly in solvent and examine bearing cups and cones to see that they are in good condition; if machined surfaces they contact are in good condition and that there is no excessive wear. *Lubrication.* When all of the related items are to the point where the wheel bearings are to be reinstalled, lubricate the bearings (par. 200). *Adjust.* After lubricating the wheel bearings, reassemble the hub-and-drum assemblies into place and adjust the wheel bearings (par. 201 or 202).
48		**Rear Brakes (Drums, Supports, Cylinders and Cams).** Remove rear wheels and drums and inspect and service as follows: On 6000-mile maintenance the several wheel bearing and brake items up to 52 are group services and

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		overlap. Perform in best order for economy of time and orderly reassembly.
		Drums and Supports. Clean dirt and grease from drums and supports (dust shields), keeping solvent away from linings. Examine drums and supports to see that they are in good condition, securely mounted and if drums are excessively worn or scored.
		Wheel Cylinders. Note condition and mounting of wheel cylinders. Examine cylinder for corrosion and leaks. Make certain that adjusting screws and metal end covers are not corroded and screws frozen. If adjusting screws are rusted, wipe a thin film of water pump or chassis lubricant on screw threads close to end cover, work screw in and out of end cover until it is free. If metal cover and/or adjusting screws are frozen, replace wheel cylinder assembly. If leaks exist at end cover, *do not remove covers,* but replace wheel cylinder assembly.
		Cams. Make certain that adjusting pin cams are secure on adjusting pins and that pins work freely. Examine pin springs, brake shoe return springs, articulating links and pins, anchor pins and locks for good condition, secure mountings, and damage.
		Tighten. Tighten brake support (dust shield) and anchor plate cap screws and hub to drum nuts securely. Make certain drum mounting on hub is secure.
	49	**Rear Brake Shoes (Linings, Anchors, and Springs).** Examine linings through inspection holes, to see if they are so worn that rivet heads may contact drums within next 1000 miles of operation. If vehicle has been operated in deep water, mud, or loose sand, remove one right rear wheel (brake drum) and examine lining for damage. If this lining must be replaced, remove all wheels and drums, check brakes, and service if necessary (par. 184).
49		*Adjust.* Perform brake adjustment if necessary (par. 181). While rear wheels are removed, check linings to see if they are in good condition, tightly secured to brake shoes, in good wearing contact with drums, free of dirt or lubricant and not excessively worn. Also see that shoes are in good condition, properly secured to anchors, guides and retracting springs and that springs have sufficient tension to return shoes properly to released position. Thickness of lining at most worn point should be enough for at least 1000 miles of service before rivet heads are likely to contact drums.
		Clean. Clean all dirt and grease from linings with wire brush, cloth or compressed air.
49	49	*Adjust.* After items 48, 49, 52, 54 and 60 are com-

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		pleted, adjust shoes by method described in paragraph 181.
60	60	**Front Wheels (Bearings, Seals, Flanges, Axle End Play and Nuts and Cap Screws).** Inspect front wheels, bearings, seals, drive flanges, and nuts and cap screws in same manner as in item 52 for similar rear wheel items.
60		*Clean.* Disassemble, clean, and inspect the front wheel bearings and oil seals in the same manner as described in item 52, taking care to check the U-joint end play as the drive flanges are removed so that the end play adjustment may be made conveniently.
60		*Lubrication.* Apply in same manner as described in item 52.
60		*Adjust.* Adjust wheel bearings in same manner as described in item 52 and adjust brakes as described in item 49.
53	53	**Front Brakes (Hose, Drums, Supports, Cylinders, Cams).** Inspect front brake hose and drums externally to see that they are in good condition, that hose is properly supported, securely connected and not chafing or leaking.
53		Remove front wheels and inspect and service as follows:
		Drums and Supports. Clean and inspect in same manner as in item 48.
		Cylinders. Inspect in same manner as in item 48.
		Cams. Inspect in same manner as in item 48.
	54	**Front Brake Shoes (Linings, Anchors, and Springs).** Inspect in same manner as in item 49.
		Adjust. Adjust by minor method if necessary.
54		With front wheels removed, inspect shoes, linings, anchors and springs in same manner as in item 49 for 6000-mile service.
		Clean. Clean in same manner as in item 49.
54	54	*Adjust.* Adjust in same manner as in item 49 after subsequent related items to 60 inclusive are completed. Refer to paragraphs 181 and 183.
47	47	**Tires and Rims (Valve Stems and Caps, Condition, Direction, Matching, Spare Carrier).** Inspect as follows:
		Valve Stems and Caps. Observe whether all valve stems are in good condition and in correct position. Replace missing valve caps. *Do not tighten with pliers.*
		Condition. Examine all tires for cuts, bruises, breaks, and blisters. Remove embedded glass, nails, and stones. Look for irregular tread wear, flat spots,

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		cupping, feather edges, and one-side wear. Remove tires worn thin at center of tread (or other unserviceable tires) and exchange for new or retreaded tires. Any mechanical deficiencies causing such conditions should be determined and corrected or reported. Change wheel positions of tires with irregular wear to even up the wear. Front tires, worn irregularly, should be moved to rear-wheel positions.
		Direction. Directional tires and non-directional tires should not be installed on the same vehicle. Directional tires on rear wheels should be mounted so that the "V" of the chevron will point down when viewed from the front. Directional tires on front wheels, ordinarily be mounted so that the "V" of the chevrons will point up when viewed from the front.
		Matching. With the tires properly inflated, to 55-pounds (cool), inspect them to see if they are matched according to overall circumference and type of tread (par. 198).
		Spare Tire Carriers. See if spare tire carriers are in good condition and secure.
		Rims. All rims and their lock rings or flanges should be in good condition and secure.
		Tighten. Tighten all wheel rim flange or lug nuts securely.
47		*Serve.* With the tires properly inflated, measure the overall circumference of all tires including spares. Select the tires to be mounted on duals or on driving axle, so that they will not have differences in overall circumference exceeding the ¾-inch specified in current directives and bulletins. Mount all dual tires with the larger tire outside.
		NOTE: *The spares must be matched properly and mounted for use on one of the road wheels at intervals not exceeding ninety days. A convenient time to do this is during these maintenance services.*
50	50	**Torque Rods.** Inspect rods to see that they are in good condition, correctly assembled and secure.
51	51	**Rear Spring Seats and Bearings.** Inspect to see that spring seats are in good condition, secure, and not leaking lubricant.
51		*Adjust.* Adjust spring seat bearings as described in paragraph 211 b.
51		*Lubrication.* Lubricate spring seat and bearings as described in Section VIII, Lubrication.
51	51	*Tighten.* Tighten spring seat cap screws securely.
		LOWER VEHICLE
55	55	**Steering Knuckles (Joints, Bearings, Seals).** Inspect to see that knuckle housings are in good con-

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		dition. Look particularly for cracks around steering arms. See that outside knuckle felt seals and seal flanges are in good condition and secure. Remove lubrication plug and examine sample of lubricant to see if it appears to be contaminated.
55		*Clean.* Remove constant velocity U-joint assembly. Wash in dry-cleaning solvent and without disassembly of U-joint, inspect parts to see that they are in good condition and not excessively worn. Pay particular attention to U-joint washers, balls and races, axle splines, flanges and pivot bearings.
55		*Lubrication.* Pack new lubricant well into constant velocity U-joint until it fills all space between balls, cages, and races. Reassemble steering knuckle taking care to replace any unserviceable lubricant retainer seals, or gaskets.
55		*Adjust.* Use every precaution to reinstall shims and spacers in the original position from which they were removed at disassembly to insure correct pivot bearing and axle end play adjustment. See paragraph 167.
56	56	**Front Springs (Clips, Leaves, U-bolts, Hangers and Shackles).** See that they are in good condition, correctly assembled, and secure. Spring clips and bolts should be in place; spring leaves should not be shifted out of their correct position. Note if the deflection of both springs is normal and approximately the same. Test the hangers and bolts for excessive wear by means of a pry bar.
56		*Tighten.* Tighten all spring U-bolts securely and uniformly.
57	57	**Steering (Arms, Tie Rod, Drag Link, Pitman Arm, Column and Wheel).** Make certain that these items are in good condition, correctly and securely assembled, and mounted. Examine steering gear case for leaks. Test steering assembly mounting for looseness. If evident, adjust steering gear mounting (par. 204). Examine pitman arm for distortion and looseness.
57		*Tighten.* If pitman arm is loose, tighten (par. 205). Examine tie rod, drag link, and steering arms for damage, looseness, and wear. If drag link adjustment is required, adjust (par. 207). Tighten steering arm stud nuts. CAUTION: *Loosen the steering column bracket at instrument panel when tightening the steering housing mounting nuts.*
58	58	**Front Shock Absorbers and Links.** See that shock

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		absorber bodies are in good condition, secure to the frame, and not leaking. Make certain that links are not damaged or bent.
58		*Serve.* Add shock absorber fluid to shock absorbers as described in paragraph 213.
61	61	**Front Axle (Seal, Vent and Alinement).** (If front axle appears to be out of line, measure distance from front spring eye bolt to center of axle spring pad on each side. Distance should be equal within ⅜"). Inspect axle housing to see that it is in good condition and not leaking. Examine pinion shaft seal for leaks.
		Clean. Clean axle housing vent thoroughly.
62	62	**Front Propeller Shaft (Joints, Alinement, Seals and Flanges).** See that these items are in good condition, correctly and securely assembled and mounted; that the U-joints are properly alined with each other and are not excessively worn; that the slip joint is free, not excessively worn, and well lubricated, and that the seals on the U-joints and slip joint do not leak.
62		*Tighten.* Tighten all U-joint assembly and companion flange bolts securely.
73	73	**Rear Propeller Shafts.** Inspect in same manner as in item 62.
73		*Tighten.* Draw up all U-joint and companion flange bolts securely.
74	74	**Center Bearing (Pillow Block) (Seals and Mountings).** Examine pillow block (center bearing) for any excessive end play (par. 177); if evident, replace pillow block assembly. See that it is adequately lubricated and that seals are not leaking, and that the mountings are secure. If leaks exist at seals, replace pillow block assembly. Tighten pillow block mountings securely.
63	63	**Engine (Mountings, Radio Suppression Bond Straps).** They should be in good condition, securely mounted, and connected. Examine both front and rear engine mountings and note if insulators are deteriorating or separating from metal backing. If the mounting bolts are loose, tighten them properly. Take care not to overtighten any rubber insulator type mounting. Remove oil or grease from rubber type mounting.
84	84	**Exhaust Pipes and Muffler.** Examine the exhaust pipe to see that it is securely attached to the exhaust manifold, that the gasket or packing does not show visible evidence of leakage, and that pipe is clamped securely to the muffler. Inspect the muffler to see that it is in good condition and securely mounted. Check

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		the tail pipe to see that it is securely clamped to the muffler, properly supported, and not clogged. On water tank equipped vehicles, be sure exhaust by-pass valve control mechanism for tank heater box operates easily and properly; that connections, heater box and mountings are all in good condition and secure, and that insulation is intact.
64	64	**Hand Brake (Pawl and Sector, Linkage, Drum, and Lining).** Examine condition of lining on brake band. Make certain that it is not excessively worn, oil soaked, and that it is in good condition.
64		*Adjust.* Examine band to drum clearance (anchor 0.010-0.015 in., top 0.020 in., bottom 0.020 in.). If excessive, adjust (par. 193).
65	65	**Clutch Pedal (Free-travel, Linkage, and Return Spring).** Check pedal free-travel (refer to par. 150). Examine and make certain that pedal is securely mounted on shaft, that clutch operating linkage is in good condition, secure, and not excessively worn. See that return spring has proper tension to bring pedal to correct release position. Make certain that return spring bracket is not damaged and is secure.
65		*Adjust.* Set pedal-travel at 2½ inches (par. 150).
66	66	**Brake Pedal Free Travel (Linkage and Return Spring).** Examine all linkage for condition, make sure that it is secure, and no excessive wear exists at friction points. Be sure return spring has tension to bring pedal to correct release position. Check brake pedal to toe board clearance (½ to 1 inch). If clearance is not correct, adjust as described in paragraph 186.
67	67	**Brake Master Cylinder (Fluid Level, Leaks and Switch).** Inspect master cylinder to see that it is in good condition; securely mounted and connected; that it does not leak; that boot is properly installed and not damaged, and that stop light switch is securely mounted and connected.
67		*Serve.* Clean top area of master cylinder. Remove filler plug. Examine fluid level of master cylinder. Add fluid to correct level, if necessary. Make certain that vent hole in filler plug is clean.
68	68	**Hydrovac (Air Cleaner, Hose, and Cylinder).** Inspect for fluid leaks and make certain that unit is securely attached to frame side member. Examine flexible hose connections. Make sure that flexible hose is not cracked or deteriorated. Make certain that hose clamps are secure. If, during road test, Hydrovac operation indicates defective operation, test Hydrovac

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
68		assembly (par. 179).
		Clean and Service. Remove Hydrovac air cleaner, Lubrication.
		Lubrication Lubricate as directed in Section VIII, Lubrication.
68	68	**Vacuum Check Valve (Leaks and Deposits).** Test vacuum check valve for leaks and examine for damage. Disassemble and clean parts thoroughly, remove scale deposits from valve and valve seat. Examine valve seat in body for pitting and corrosion that may cause an imperfect seat. *Slight* imperfections may be removed with fine steel wool.
		Valve Stem. Inspect rubber seal attached to valve stem. Replace with new valve assembly, if deterioration is evident. Inspect the stem and stem guides in cap and body. Stem must be free in guides. Assemble and reinstall, or replace with new assembly.
71	71	**Transmission (Mounting, Seals, Power Take-off, Linkage).** Observe if transmission case, including power take-off, is in good condition, securely mounted and inspect for lubricant leaks at seals and gaskets. Examine control linkage and shift mechanism for damage or excessive wear. Examine strut rod for looseness. If necessary, adjust according to paragraph 155.
72	72	**Transfer (Mountings, Linkage, Seals, Vent).** See that case is in good condition, securely mounted, that control linkage, transmission and declutching shift mechanism is securely connected and not damaged. Look for evidence of lubrication leaks at seals and gaskets. Clean vent passage if clogged. Draw up all external assembly and mounting nuts securely.
75	75	**Rear Axle (Pinion End Play, Seals, Vent and Alinement).** Inspect in the same manner as in item 61 for front axle.
		Clean. Clean axle housing vent.
77	77	**Rear Springs (Clips, Leaves, and U-bolts).** Examine spring leaves for damage. Make certain that no leaves are broken or shifted, that spring clips are tight, and that spring is in good condition. Check spring U-bolts and spring seat clamp studs for tightness. Examine springs for sagging condition. Note if deflection of both springs is normal and approximately the same.
79	79	**Cab and Body Mountings.** Inspect all cab, cargo, tank or dump body mountings to see that they are all present, in good condition and secured.
79		*Tighten.* Tighten cab spring loaded mountings and bond straps. Steering column bracket mountings

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		must be loosened during this operation (par. 221). Tighten all loose cargo, tank or dump body mountings securely.
80	80	**Frame (Side and Crossmembers).** Inspect frame, brackets, side members, and crossmembers to see that they are in good condition, secure, and correctly alined. If the frame appears out of line, check alinement (par. 214), and report condition.
81	81	**Wiring, Conduits and Grommets.** Observe these items underneath the vehicle to see that they are in good condition, properly supported, connected and secure.
82	82	**Fuel Tank, Fittings, and Lines.** Inspect fuel tank to see that it is in good condition and securely mounted. Examine fuel tank and lines for leaks. Remove gas tank cap. Make certain that gasket in cap is in good condition, vents are clean, and that valve in cap is free. See that filler neck is in good condition and that cap fits securely.
82		**Fuel Tank Drain Plug.** Remove fuel tank drain plug and drain off accumulated water and dirt in bottom of tank. Drain only until fuel runs clear. Use necessary precautions against fire.
83	83	**Brake Lines (Fittings and Hose).** Examine all lines, fittings, and hydraulic hose under vehicle to see that they are in good condition, securely connected and supported so lines or hose will not chafe against other vehicle parts. Note if flexible.
25	25	**Radiator (Core, Shell, Mountings, Hose, Cap and Gasket, Antifreeze Record, Water Bypass Tube).** Inspect all applicable items to see that they are in good condition, secure, and not leaking. Examine condition of coolant to see if it is so contaminated that cooling system should be cleaned. If cleaning of cooling system is necessary, procede only according to current directives regarding proper procedures, cleaner, neutralizer and inhibitor, paragraph 107. Clean all insects, dirt or grease deposits from core air passages and inspect for bent cooling fins. CAUTION: *Use only a suitably shaped piece of wood or blunt instrument to straighten fins.* If antifreeze is in use, test its protective value and record in space provided on back of work sheet, Form No. 461.
25		*Tighten.* Tighten all loose radiator mountings, (par. 109), water connections and hose clamps. Give particular attention to bond straps and toothed lock washers.
18	18	**Cylinder Head and Gaskets.** Remove valve rocker arm cover. Look for cracks or indications of oil,

6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		coolant, or compression leaks around studs, cap screws, and gaskets. CAUTION: *Cylinder head bolts should not be tightened unless there is definite evidence of leaks.* Check all bolts with torque wrench. If tightening is necessary, tighten cylinder head bolts in proper sequence (fig. 64, par. 79) to 70 ft-lb torque. CAUTION: *Always recheck valve stem to rocker clearance after tightening cylinder head bolts.*
	19	**Valve Mechanism (Clearance, Lubrication, Cover Gaskets).** Adjust valve clearance only if noisy or if engine performance indicates a necessity. Correct clearances are: Intake 0.012, and exhaust 0.016 inch, at operating temperature. Be sure bond strap from valve cover to dash is in good condition and tightly connected.
19		*Adjust.* Adjust clearances. Intake 0.012 inch, exhaust 0.016 inch at operating temperature. Examine valve push rods, rocker arms, springs, retainers and keys, to see that they are in good condition, correctly assembled, secure, and that the valve mechanism is receiving adequate lubrication. Replace unserviceable cover gasket.
20	20	**Spark Plugs (Gaps and Deposits).** Remove all plugs and examine for broken insulators, excessive carbon or oxide deposits, and electrodes burned thin. Clean plugs with abrasive type cleaner. Set plug gaps to 0.026 inch by bending only grounded electrodes. NOTE: *Do not install plugs until item 21 has been performed.*
21		**Compression Test.** Test compression at cranking speed with all spark plugs removed (par. 76 c). Readings in any one engine should be 100 pounds or more. Total variation should not be more than 10 pounds. Record compression pressures in space provided on back of work sheet, Form No. 461.
31	31	**Distributor (Cap, Rotor, Shaft, Advance Units).** Observe whether distributor body and external attachments are in good condition and secure. Examine other parts as follows: *Cap, Rotor, and Points.* Remove and clean cap. Inspect cap, rotor, and breaker points, make certain that they are in good condition, secure and clean. Examine closely for cracks in cap and rotor, corrosion of terminals and connections, and burned rotor bar or contact points. See that points are alined and in correct adjustment (0.018 in.) when wide open (par. 88).

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SECOND ECHELON PREVENTIVE MAINTENANCE

6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		CAUTION: *Do not remove distributor housings. Before cleaning distributor, remove wick, lubrication cup, condenser, and primary terminal. Replace parts after cleaning distributor.* If breaker points are pitted, burned or worn excessively, replace. If points are burned, replace condenser. When cleaning points, use a fine file, flint paper (2/0), or hone (never use emery cloth) and blow out filings with compressed air.
		Shaft. Examine shaft, feeling for excessive wear in shaft or bushings.
		Centrifugal Advance. Install rotor on shaft and test distributor governor physically for normal range of movement permitted by mechanism. Note if it returns to original position when released without hang-up or binding.
		Lubrication. Lubricate cam surfaces, breaker arm pin, grease cup, and wick (sec. VIII, Lubrication).
32	32	**Coil and Wiring.** Inspect coil and all ignition wiring including shielding or conduits to see that they are in good condition, clean, securely connected and properly mounted. Be sure resistor-suppressors on spark plug and coil to distributor wires are secure and not scorched or damaged. Inspect low voltage wiring in engine compartment in same manner.
24	24	**Oil Filter and Lines.** Inspect filter and external engine oil lines to see that they are in good condition, secure, and not leaking.
		Clean and Serve. Remove filter drain plug and drain off any accumulated dirt and sludge. If a filter element change is due or if condition indicates it is necessary, replace element (par. 81).
26	26	**Water Pump, Fan and Shroud.** Inspect pump to see that it is in good condition and that blades and hub are secure. Loosen drive belt and examine fan hub and shaft for bearing wear. See that shroud is in good condition, secure, and alined so as not to interfere with fan blades.
26		*Tighten.* Tighten water pump, fan and shroud assembly and mounting nuts.
35	35	**Crankcase Breather and Filler Cap.** Inspect crankcase breather for condition. Remove oil reservoir and element, and service (sec. VIII, Lubrication). Examine filler cap gasket for good condition.
35		*Clean.* Disassemble and clean crankcase ventilation valve (par. 82).
34	34	**Air Cleaner.** Inspect carbureter air cleaner to see that

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		it is in good condition, securely mounted and connected and not leaking. Remove reservoir and element, clean in solvent, dry, fill reservoir to proper level with new or clean used engine oil and reassemble. Be sure gaskets are in place and all joints and air horn connections tight (par. 99).
37	37	**Fuel Filter and Lines.** Examine filter to see that it is in good condition, securely mounted and connected and not leaking. Examine connecting lines for damage and leaks.
		Clean. Close fuel shut-off and remove filter sediment bowl and element. Wash clean in solvent and reassemble (par. 98). Turn on fuel supply and recheck for leaks.
38	38	**Fuel Pump.** Inspect pump to see that it is in good condition, securely mounted and not leaking. Remove sediment bowl, screen, and clean and reinstall (par. 97). Fuel pump pressure test to be performed after item 40 is completed.
38		Check fuel pump pressure (par. 97).
29	29	**Drive Belt and Pulleys.** Observe generator and fan drive belt for evidence of fraying condition, excessive wear, and deterioration. Inspect all drive pulleys and hubs to see that they are in good condition and securely mounted.
		Adjust. Adjust drive belt to have ½-inch finger pressure deflection. See paragraph 108.
33	33	**Manifolds and Gaskets.** Examine manifold stud nuts for looseness. Carefully tighten manifold stud nuts if necessary, using torque wrench to 15-20 foot-pounds torque. Check heat control valve for proper climatic setting. Examine exhaust pipe flange mounting for looseness. Tighten flange bolts, if necessary. Examine for evidence of cracks in manifolds, usually indicated by carbon streaks, damaged gaskets, or evidence of exhaust leaks exist. Examine manifold for alinement and aline if necessary (par. 78). Tighten flange bolts if necessary.
33		*Tighten.* Carefully check and tighten all manifold assembly stud nuts and mounting nuts to 15-20 foot-pounds torque, using a torque wrench.
27	27	**Generator, Cranking Motor and Switch.** Inspect generator, cranking motor and cranking motor switch to see that they are in good condition, securely mounted, and that wiring connections are clean and secure.
27		Examine generator and cranking motor commuta-

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		tors and brushes to see that they are in good condition; free in holders and have sufficient spring tension, and that brush connecting wires are secure and not chafing. *Clean.* Blow out commutator end of generator and cranking motor with compressed air. If commutators are dirty, clean only with flint paper 2/0 placed over end of suitable piece of wood and again blow out with air. *Tighten.* Tighten cranking motor mounting bolts securely. See that radio noise suppression condensers on cranking motor and generator are in good condition and tight.
36	36	**Carbureter (Choke, Throttle, Linkage and Governor).** See that these units are in good condition, correctly assembled, and securely installed; that the carbureter does not leak; that the control linkage, including the choke and throttle shaft, is not excessively worn; that the choke valve opens fully when the control is in its released position; that the throttle valve opens fully when the accelerator is fully depressed, and that the governor is secure and properly sealed.
23	23	**Crankcase (Oil Level).** Check crankcase oil level and add as needed. If an oil change is due, or condition of oil indicates the necessity, drain crankcase, clean drain plug, and refill to correct level with fresh specified oil (sec. VIII, Lubrication).
39	39	**Cranking Motor (Action, Noise, and Speed).** Start engine. Note operation of cranking motor. Check for excessive operation noise and adequate cranking speed. As soon as the engine starts, it is advisable to note whether the oil pressure gage and ammeter readings are satisfactory.
40	40	**Leaks (Engine Oil, Fuel and Water).** With engine running, check all points of oil, fuel and cooling system for leaks. Examine crankcase, valve cover, timing gear cover, and clutch housing for oil leaks. Trace any leaks found to their source and correct or report them. Stop engine and after 15 minutes time allowed for engine oil to drain back into crankcase, check crankcase for proper oil level and replenish if necessary.
41	41	**Ignition Timing (Advance).** With the engine running at slow idle and timing light connected, check the ignition timing (par. 87). Also note whether

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		automatic controls advance the timing as engine is accelerated gradually.
41		*Adjust.* Adjust the ignition timing (par. 87).
42	42	**Engine and Vacuum Test.**
		Engine Idle. Adjust carbureter as described in paragraph 94.
		Vacuum Test. Take manifold reading of engine as described in paragraph 76.
22	22	**Battery (Cables, Hold Downs, Carrier, Record Gravity, and Voltage).** Inspect battery case for cracks or leaks. Clean battery thoroughly. Inspect cables, terminals, bolts, boxes, and hold downs for condition and looseness. Test specific gravity, voltage (par. 120) and record on W.D. A.G.O. Form No. 461.
22		*Test.* Perform high rate discharge test according to instructions for condition which accompany test instrument and record voltage on W.D. A.G.O. Form No. 461. Cell variation should not be more than 30 percent. Note: Specific gravity must be above 1.225 to make this test.
22	22	*Serve.* Bring electrolyte to proper level by adding distilled or clean water. Clean battery cable terminals, terminal bolts and nuts, and battery boxes and grease lightly. Inspect bolts for serviceability. Tighten terminals and hold down carefully to avoid damage to battery.
43	43	**Regulator Unit (Connections, Voltage, Current, and Cut-out).** Inspect regulator unit to see that it is in good condition, securely mounted, and connected and clean. Examine radio noise suppression filters in battery, armature and field circuits, and condensers (4) in light circuit for good condition and tight connections.
43		*Test.* Connect the low-voltage-circuit tester and observe whether the voltage regulator, current regulator, and cut-out control the generator out-put properly.
86	86	**Toe-in and Turning Stops.** Use toe-in gage to determine whether adjustment on split and banjo type axles is within 1/16-3/16 inch limits. See that wheel turning stops are present, secure, and tack welded. Turn front wheels fully in both directions and see whether turns are limited by stop and if tires clear all parts of vehicle.
87	87	**Winch (Clutch, Brake, Drive, Shear Pin, and Cable).** Check these items to see if they are in good

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6000 Mile Maint. (six-month)	1000 Mile Maint. (month-ly)	
		condition, correctly assembled, and secure. See that clutch moves freely on shaft and latches securely; that drag brake functions properly and is not damaged or excessively worn. Inspect automatic brake to see that lining is secure, not excessively worn, and that spring and adjusting nut is properly assembled. Examine drive shaft universal joints for excessive wear and looseness. Make certain that slip joint is free, not excessively worn, and well lubricated. Make certain that correct shear pin is in place and joint is free on shaft. Remove any obstructions that may have become entangled on drive shaft. Inspect cable for winding on drum, and lubrication. Make certain that cable is attached to tow hooks securely. Check safety collar clearance (par. 24). Clearance is ½ inch.
		Lubrication. Check oil level and condition in worm gear case. Use engine oil. Lubricate the winch clutch, the shaft upon which it slides, and its operating arm. As lubricant is applied, move the clutch back and forth several times to make sure that it is free.
87		*Clean and Service.* Unwind cable and inspect for broken or frayed strands, flat or rusty spots, and kinks. Clean entire length with cloth saturated in thin oil or kerosene. As cable is rewound, apply a coating of clean engine or gear oil evenly; if worm gear housing oil change is due or condition of oil indicates necessity, drain worm gear housing, and fill to correct level with specified oil as described in section VIII, Lubrication.
89	89	**Tractor to Trailer Wiring Connector.** Examine wiring connector to make certain that it is in good condition and not damaged.
93	93	**Front Bumper, Tow Hooks, and Brush Guard.** See that they are in good condition, secure, and that radiator is not obstructed. NOTE: Reinstall and secure hood side panels, if removed. Attach hood bracket and bond strap. Lower and secure hood.
94	94	**Hoods and Fasteners.** Inspect engine hood (cover) on cab, to see that it is in good condition, and that fasteners operate properly and hold hood securely.
95	95	**Front Fenders and Running Boards.** Examine fenders and running boards to see that they are in good condition and securely mounted.
96	96	**Cab (Doors, Hardware, Glass, Seats and Trim, Floor Boards, Ventilator, and Map Compartment).** Inspect these items to see that they are in good condition and secure; that the ventilator door

6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		and windshield operate properly, that doors are alined in their openings. Engage the bumpers and strikers and latch properly in closed position (closed type cabs). *Open Type Cab*. Examine cab tarpaulin top, back curtain, upper and lower side curtain assemblies, for damage. Make certain that straps, locks, tie ropes, are in good condition and not frayed, torn, or damaged and that they are secure.
98	98	**Circuit Breakers, Fuses, Junction Blocks.** Locate these units in low voltage circuits, and inspect them to see that they are in good condition, clean, and securely connected or mounted.
91	91	**Lamps (Lights) (Head, Tail, Body, Stop and Blackout).** Operate all switches and note if lamps respond. Include stop and blackout lamps. See that foot switch controls head lamp beams properly and that beams are aimed so as not to blind oncoming traffic. Examine all lights to see that they are in good condition and securely mounted and clean lenses.
91		*Adjust*. Adjust lamp unit beams as described in paragraph 121.
92	92	**Safety Reflectors.** See that they are all present, in good condition, clean and secure.
100	100	**Body (Side Panels, Tail Gate and Chains, Floor, Skid Strips, Sockets, Bows, Tarpaulins, Curtains, Troop Seats, Stowage Compartments, and Water Tank).** Examine all applicable items to see that they are in good condition, correctly assembled, and secured. See that any hinges and latches are adequately lubricated, that curtains and tarpaulins are in good condition and properly fastened. On tank equipped vehicles, inspect for looseness, leaks, or damage. See that filler covers and drain plugs and cocks seat properly and lock securely.
103	103	**Paint and Markings.** Examine the paint of the entire vehicle to see that it is in good condition. Pay particular attention to any bright spots in the finish that might cause glare or reflection. Inspect vehicle markings and identification for legibility, including identification plates and their mountings as furnished.
99	99	**Rear Splash Guards.** Examine rear splash guards for damage and make certain that they are securely mounted.
101	101	**Rear Bumpers and Pintle Hook.** Inspect rear bumper for looseness or damage. Examine pintle to see that it is in good condition and securely mounted to frame. Test pintle and latch to see if they operate

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		properly; are adequately lubricated; and if lock pin is present and securely attached by chain. Pay particular attention for broken spring or worn draw bar.
90	90	**Hoist (Mounting, Drive, Controls, Pump, Lines, and Cylinder).** Raise the body with the hoist and note whether these items are in good condition, correctly assembled, and secure; whether the hoist, controls or any lift linkage are excessively worn, and if the pump, lines, or cylinder are leaking. Stop the engine with body up and note any tendency of the body to drop. When lowering the body, see that it lowers gully and that the guides aline the body properly with the frame. *Serve.* Fill the hoist cylinders with the specified grade of oil, paragraph 246 or 247, taking care to leave the filler-plug loose until the body has been raised and lowered at least twice; then tighten it securely. While the body is raised, lubricate any grease fittings and apply a few drops of oil to the pin joints of all lifting and pump-control mechanisms.
90		*Tighten.* Tighten all hoist mounting and assembly bolts securely. Tighten the piston-rod packing nut and any pump and control valve gland nuts, taking care not to overtighten them, as this may score the shafts and cause leaks.
104	104	**Radio Bonding (Suppressors, Filters, Condensers, and Shielding).** See that all units not covered in the forgoing specific procedures are in good condition and securely mounted and connected. Be sure all additional noise suppression bond straps and toothed lock washers listed in Section XXIV, are inspected for looseness or damage, and see that contact surfaces are clean. NOTE: *If objectionable radio noise from vehicle has been reported, make tests in accordance with Section XXIV.* If cleaning and tightening of mountings and connections, and replacement of defective radio noise suppression units does not eliminate the trouble, the radio operator will report the condition to the designated individual in authority.
85	85	**Vehicle Lubrication.** If due, lubricate in accordance with Lubrication Order, section VIII, using only clean lubricant and omitting items that have had lubrication during this service. Replace damaged or missing lubrication fittings, vents, or plugs.
		TOOLS AND EQUIPMENT
131	131	**Tools (Vehicle and Pioneer).** Inspect all the standard vehicle and pioneer tools to see that they are all

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)	
		present (sec. III, Stowage List), in good condition, clean, and properly stowed or securely mounted. Also examine the tools which have cutting edge to make certain that they are sharp. Any tools mounted on the outside of the vehicle which have bright or polished surfaces should be painted or otherwise treated to prevent rust, glare, or reflection.
132	132	**Fire Extinguisher.** See that fire extinguisher (GM-217169) is in good condition, securely mounted, and fully charged. The charge may be determined by shaking extinguisher. Always make certain that nozzles are free from corrosion. Apply engine oil sparingly at nozzle opening and at handle.
133	133	**Decontaminator.** Note if it is in good condition, securely mounted and fully charged. Make the latter check by removing the filler plug. Solution must be replaced each 90 days.
134	134	**First Aid Kit (if specified).** See that it is in good condition, and that all of its items are present and properly packed. Report any deficiencies immediately.
135	135	**Publications and Form No. 26.** The vehicle and equipment manuals, lubrication order, Standard Form No. 26 (Accident-Report Form), W.D., A.G.O. Form No. 478 (MWO and Major Unit Assembly Replacement Record) must be present, legible, and properly stowed.
136	136	**Traction Devices (Chains).** Examine tire chains to be sure they are in good condition, clean, (if not in use) not excessively worn, protected against rust, and properly mounted or stowed.
137	137	**Tow (Chains, Cables, Rope, and Snatch Blocks).** See that the provided towing devices are in good condition, clean, and properly stowed. Tow chains or cables should be properly protected against rust when not in use. If snatch blocks are furnished, check to see that they operate freely.
138	138	**Spare Shear Pins.** Make certain spare shear pins are present, lubricated to prevent rust, and properly stowed.
139	139	**Fuel and Water Cans and Brackets.** Observe whether they are in good condition, secure; that the caps fit tightly and are secured to the can with a chain; and if the cans are leaking.
141	141	**Modification (MWO's Completed).** Inspect the vehicle to determine whether all Field Service Modi-

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6000 Mile Maint. (six-month)	1000 Mile Maint. (monthly)
142	142

fication Work Orders have been completed and entered on Form 478. Enter any modifications on major unit assembly replacements made during this service.

Final Road Test. Make a final road test rechecking applicable items (2) to (14) inclusive, and also be sure to recheck the transmission, transfer case, and all driving axles to see that the lubricant is at proper level and not leaking. Confine road test to the minimum distance necessary to make satisfactory observations.

NOTE: *Correct or report all deficiencies found during final road test.*

Section XII

POWER PLANT TROUBLE SHOOTING AND DIAGNOSIS

47. GENERAL.

a. Scope. The information contained in this section includes a compilation of trouble symptoms which might be encountered in the operation of the power plant, together with the possible causes and possible remedies. Only those difficulties which can be detected by the using arm are included. Whenever practical, the trouble shooting procedures are classified according to each section of the manual. In some instances, a symptom indicating trouble in one unit may be caused by difficulty in another unit; therefore, cross references to the related units are made whenever this condition exists.

b. Diagnosing Causes. The causes of trouble symptoms or faults in a vehicle of this type may be varied; therefore, a hit-and-miss search would result in a tedious guessing contest. The diagnosis of symptoms is an orderly process of eliminating causes of the symptom. An orderly process means to check the most probable or common cause first.

48. ENGINE.

a. General. The procedures which follow list engine general trouble symptoms together with diagnosis and remedial operations. These procedures are divided into three general groups which include the most common engine trouble symptoms.

Engine fails to start
Engine runs but operates improperly
Miscellaneous engine operating faults

b. Systems of the Engine. The engine must not be considered as a single unit, but rather as a group of units or systems. These

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systems, such as the fuel, cooling, electrical, lubrication, valve mechanism, and internal mechanical systems must be taken into consideration when checking the cause of and applying the remedy to common engine troubles.

49. ENGINE FAILS TO START.

a. When engine fails to start, a deficiency in one of two systems is most commonly the cause. The most probable cause is ignition system trouble, with fuel system as the next. One of the quickest methods to determine whether starting trouble is caused by the ignition system or the fuel system, is the spark test.

b. **Spark Test.** Disconnect one wire from spark plug. With ignition switch "ON" and cranking motor cranking engine, hold free end of wire about one-eighth of an inch away from engine block. Note the spark. If there is no spark, the trouble lies in the ignition system. If there is a spark, the trouble will be most commonly found in the fuel system.

c. **No Spark.** The action of the ammeter will further aid in the diagnosis of this condition. Normally the ammeter will show a slight discharge with needle oscillating between two and four amperes. Definite procedures are necessary if engine does not start when ammeter action is normal or abnormal. These procedures follow:

(1) AMMETER SHOWS NO DISCHARGE (ZERO). A zero reading on the ammeter, with ignition turned "ON" and cranking motor cranking engine, indicates that no current is flowing in the ignition primary circuit; therefore, the following checks should be made on the units of the primary circuit:

(*a*) First make sure that the ignition switch is fully turned "ON" and that wiring connections at switch are clean and tight.

(*b*) Turn on headlights to ascertain that current is flowing through ammeter. If ammeter does not show discharge, turn off headlight switch, then disconnect wire at battery side of ammeter and make flash test to determine if current is flowing to the ammeter. Check and tighten connections in circuit between cranking motor and ignition switch.

(*c*) Remove distributor cap and check condition of points and point opening. Adjust or replace points as necessary.

(*d*) Check continuity of circuit through primary wire from ignition switch to coil, then from coil to distributor. If current flows through primary wire from switch to coil, and not from coil to distributor, replace the coil. If current flows through primary wire to distributor, the trouble is in the distributor.

(*e*) Check continuity of circuit from ammeter to ignition switch, then through ignition switch with switch turned "ON." Replace wiring or switch as necessary.

(2) AMMETER SHOWS NORMAL DISCHARGE (OSCILLATING BETWEEN TWO AND FOUR AMPERES). If the ammeter oscillates between two and four amperes discharge with switch turned "ON" and cranking motor cranking engine, the primary circuit is functioning correctly; trace the secondary circuit in the following manner:

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(*a*) Remove coil to distributor high tension wire from distributor cap. Hold end of wire about three-eighths of an inch from a ground. With cranking motor cranking engine or "rocking" points, note spark. If a hot, snappy spark results, reinsert wire in distributor cap and continue with test. If a weak spark results, replace the condenser in the distributor. If a weak spark persists, replace the coil. If no spark results, check high tension wire from coil to distributor for continuity of circuit. Replace with wire known to be good.

(*b*) With high tension wire from coil to distributor inserted in distributor cap, remove cap. With cranking motor cranking engine, observe inside of cap for visible current leaks.

(*c*) Check condition of distributor cap center electrode by holding one end of a high tension wire on electrode and the other end about three-eights of an inch from a ground. Crank engine with cranking motor. Spark should jump gap from high tension wire to ground. If no spark is produced, replace the cap.

(*d*) Remove high tension wire from coil to distributor at distributor cap. Hold end of high tension wire about three-eighths of an inch from the rotor. Crank engine and watch for spark. If spark is seen, the rotor is defective and must be replaced.

(*e*) After determining that secondary current arrives at spark plug wires, test each spark plug wire for continuity of circuit. Replace wires which do not test correctly.

(3) AMMETER SHOWS CONSTANT NORMAL DISCHARGE (DOES NOT OSCILLATE). A *constant normal discharge* at the ammeter (two to four amperes), indicates that the primary circuit is not being interrupted. Check in the following sequence.

(*a*) Disconnect primary wire from coil to distributor at distributor. If ammeter drops to zero, check as explained in (*b*) through (*d*) below. If ammeter does not drop to zero, reconnect wire to distributor and disconnect at coil. If ammeter then drops to zero, the wire is defective and must be replaced. If ammeter does not drop to zero, the coil is defective and must be replaced.

(*b*) Check distributor points and adjust or replace if necessary.

(*c*) Check insulation on movable point and on distributor primary terminal. Replace points or distributor as necessary.

(*d*) Disconnect condenser pigtail. Make flash test between pigtail terminal and distributor primary wire terminal. If flash occurs, replace condenser.

(4) AMMETER SHOWS ABNORMAL DISCHARGE (OVER FOUR AMPERES) WITH IGNITION SWITCH "ON", ZERO WITH SWITCH "OFF." If the ammeter shows abnormal discharge with ignition switch "ON" and zero with switch "OFF," the trouble lies beyond the ignition switch and ahead of the primary exit at the coil. Make tests in the following sequence:

(*a*) With ignition switch "ON," disconnect wire at dead side of switch. If ammeter returns to zero, the switch is correct. If ammeter does not return to zero, the switch is defective. Replace with one known to be good. Reconnect wire to switch.

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(*b*) With switch known to be functioning properly, disconnect wire at primary entrance of coil. If ammeter returns to zero, check terminal of coil for grounded condition. If the terminal is not grounded, replace the coil. If terminal is grounded, correct grounded condition or replace coil.

(*c*) If the ammeter still shows abnormal discharge after disconnecting primary wire at coil, replace wire from switch to coil.

(5) AMMETER SHOWS ABNORMAL DISCHARGE WITH IGNITION SWITCH EITHER "ON" OR "OFF." If abnormal discharge exists with ignition switch either "ON" or "OFF," the trouble is between the ammeter and ignition switch. Shorts may also exist in lighting circuit (between ammeter and light switch) and in generator circuit. Test in following sequence:

(*a*) Remove wires from discharge side of ammeter. Ammeter should then return to zero. Touch terminal of light circuit wire to ammeter terminal. If ammeter shows discharge, trace short in wire from ammeter to light switch. If no short is present, generator circuit should be checked. If generator circuit does not cause discharge, the trouble lies either in the ignition switch or in the ammeter to ignition switch wire.

(*b*) With ammeter to switch wire disconnected at both ends, connect a jumper lead to ammeter terminal and to ignition switch terminal. If discharge still shows, replace ignition switch. If ammeter returns to zero, replace ammeter to ignition switch wire.

d. Weak Spark at Plugs.

(1) This condition may be caused by a weak battery. Check battery and charge or replace as necessary.

(2) Remove distributor cap and check condition of points. Clean up and adjust, or replace if necessary.

(3) Check condition of rotor and cap. Replace cap if electrodes are burned, or rotor if segment is burned. Make sure wires are fully seated in sockets in distributor cap.

(4) Check condenser for short and replace if necessary.

(5) Check all connections in circuit from cranking motor to distributor. Clean and tighten as necessary.

(6). Check condition of high tension wires. Replace if wet or swollen.

(7) If items (1) through (6) do not eliminate trouble, replace ignition coil.

e. Good Spark at Plugs. When engine will not start with good spark at plugs, first determine that the fuel tank is not empty, then proceed as follows:

(1) Remove float level sight plug from carbureter bowl (on engine side).

(2) If no fuel can be seen, remove drain plug from bottom of bowl. If no fuel flows out, make check as itemized in (6) below.

(3) If fuel is level with sight plug hole, failure to start may be caused by flooded combustion chambers due to excessive use of choke, or by fuel not reaching the cylinder due to a dirty carbureter. Check choke mechanism or remove carbureter and clean (par. 94).

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(4) If fuel flows out of sight plug hole, carbureter float needs adjustment (par. 94) or fuel pump pressure is excessive (par. 97).

(5) If fuel does not flow out of sight plug hole, but does flow out of drain plug hole, check fuel pump for operation (par. 97) or check adjustment of carbureter float level (par. 94).

(6) If fuel is not reaching carbureter as in (2), check fuel pump operation; check line between fuel pump and fuel filter, clean fuel filter, check lines between fuel filter and fuel tank.

50. ENGINE RUNS BUT OPERATES IMPROPERLY.

a. Continuous Mis-firing.

(1) The most common cause of this condition is dirty spark plugs. First determine that current is flowing to each plug, then remove plugs and check for dirty electrodes. Clean up and adjust spark gap, or replace plugs as necessary. Dirty plugs are an indication of faulty valve operation, or worn piston rings, allowing oil to enter combustion chamber.

(2) Inspect high tension wires. Replace if wet or if insulation is swollen or deteriorated.

(3) Remove distributor cap and check for burned electrodes or cracks. Replace cap if defective.

(4) Conditions contributing to low compression will also cause mis-firing in one or more cylinders. If remedies given in (1), (2), and (3) do not correct the trouble, check compression of all cylinders and make necessary repairs.

b. Erratic Mis-firing at Idling Speeds.

(1) One of the most common causes of mis-firing at idling speed is incorrect carbureter idling adjustment or incorrect float level adjustment. Make adjustments as required (par. 94), then check operation of choke mechanism. Free up and adjust as necessary (par. 95).

(2) Check ignition system units, starting with spark plugs, until all ignition causes are corrected or eliminated.

(3) Check for vacuum leaks at windshield wiper hose, intake manifold gasket, vacuum lines, and carbureter. Check possibility of water entering cylinder due to a leaking cylinder head gasket.

(4) If the condition still exists after making corrections (1), (2), and (3), check valve clearance and valve mechanism operation, perform engine compression test, and make necessary adjustments and repairs.

c. Mis-firing at High Speeds or Under Full Load. Mis-firing at high speeds or under full load is commonly caused by a weak secondary current in the ignition circuit. Weak valve springs, however, will also cause mis-firing at high speeds.

(1) Remove spark plugs and make sure they are the correct type. Clean up and adjust gap. Make sure that gap is same on all plugs (par. 89).

(2) Remove distributor cap and check point opening and test spring tension (par. 88). Adjust point opening and spring tension or replace points as necessary.

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(3) A weakened coil caused by shorting out of secondary winding will cause mis-firing. Replace coil with one known to be good. Leaks throughout the high tension wires will also weaken the current and cause mis-firing. Check condition of all high tension wires and replace if necessary. Make sure that sockets in distributor cap are thoroughly cleaned of corrosion and that wires are fully seated.

(4) Check operation of valve springs and replace any that are weak.

d. Backfiring.

(1) As a general rule, backfiring into the muffler indicates too rich a fuel mixture. Backfiring into the carbureter indicates too lean a mixture. Make necessary adjustments at carbureter (par. 94).

(2) Check all fuel lines for restrictions and clean air cleaner. Clean carbureter if necessary.

(3) Sticking valves or weak valve springs will also cause backfiring. Check for and correct these conditions. Make sure cylinder head gasket is in good condition.

(4) Extremely late ignition timing will cause backfiring. Check timing and make necessary adjustments (par. 87).

51. ENGINE MISCELLANEOUS OPERATING FAULTS.

a. Excessive Fuel Consumption. For a diagnosis of causes of excessive fuel consumption, refer to **FUEL SYSTEM** trouble shooting and diagnosis (par. 54).

b. Excessive Oil Consumption.

(1) The first step to be taken when an engine uses an excessive amount of oil is to make a thorough inspection for leaks. Check all oil lines and tighten connections or replace as necessary.

(2) Over speeding the engine will result in excessive oil consumption. Poor driving practices should be corrected.

(3) Worn pistons or piston rings are a common cause of excessive oil consumption. Perform engine compression test and make necessary repairs or report condition to higher authority.

(4) Overheating will cause excessive oil consumption. Refer to COOLING SYSTEM trouble shooting and diagnosis (par. 56).

(5) Remove crankcase ventilator valve and clean thoroughly to prevent sticking (par. 82).

(6) Report loose connecting rod or main bearings to higher authority.

c. Lack of Power.

(1) The primary cause of lack of power is poor compression. Perform engine compression test and make necessary correction or report condition to higher authority.

(2) Conditions in the fuel system which contribute to lack of power are covered in **FUEL SYSTEM** trouble shooting and diagnosis (par. 54).

(3) Improper ignition timing will result in a lack of power. Refer to IGNITION SYSTEM trouble shooting and diagnosis (par. 53).

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(4) Overheating also results in a lack of power. Refer to COOLING SYSTEM trouble shooting and diagnosis (par. 56).

(5) A clogged exhaust system or bent exhaust pipe or tail pipe will result in a lack of power. Check for these conditions and clean out or replace pipes as necessary.

(6) Dragging brakes or improperly inflated tires simulate a lack of power. Check for these conditions and make necessary corrections.

d. Engine Fails to Develop Maximum Permissible rpm. This condition is usually an indication that the governor is dirty and must be replaced (par. 96).

e. Operating Knocks. Noises in an engine generally termed as "operating knocks" may be caused by (1) overloading the engine, (2) carbon in the combustion chamber, (3) incorrect ignition timing, (4) low octane fuel, and (5) pre-ignition.

(1) OVERLOADING THE ENGINE. This noise occurs when an engine is placed under extreme load. Generally the noise is reduced after shifting to a lower transmission gear. This knock may be due to a combination of causes, all of which may be generally remedied by using correct transmission speeds.

(2) CARBON KNOCKS. This knocking is caused by accumulation of carbon in combustion chambers and is most noticeable when engine is hot and when engine is accelerated. The remedy is cleaning carbon from cylinder head.

(3) TIMING KNOCK. Too early ignition timing may cause a knock that may be mistaken for a carbon knock. The engine may also kick back when starting. Check the ignition timing and make necessary corrections.

(4) FUEL KNOCK. A poor grade of gasoline may cause a knock or "ping" similar to a carbon knock. Use a better grade of gasoline or readjust ignition timing (manual advance) to accomplish smooth running with grade of fuel used.

(5) PRE-IGNITION. One of the causes of pre-ignition (auto-ignition) is the use of wrong type spark plugs. Make certain that correct plugs are used. Also idle engine for 30 seconds before turning off ignition switch.

f. Mechanical Knocks. In many instances, vehicles are sent to the repair shop for major engine overhaul due to improper diagnosis of mechanical difficulty. Properly diagnosing mechanical knocks will, in many cases, result in correcting the difficulty by minor repairs or adjustments, without necessitating removal of the engine from the vehicle.

(1) Mechanical knocks are noises that result from wear or improper adjustments. These knocks are not always easy to locate accurately as no two engines have exactly the same sound with the same faulty condition. In many instances, causes of mechanical knocks will evidence themselves by other symptoms. Correct diagnosis of mechanical knocks requires experience and practice on the particular type of engine to be serviced.

(2) DIAGNOSIS OF MECHANICAL KNOCKS. The first step in analyzing a mechanical knock is to be sure that the noise is in the engine.

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If the noise can be heard with the vehicle stopped and clutch disengaged, the fault is generally in the engine. The engine should be warmed up to operating temperature. Check to see that all cylinders are firing, then try engine under load to bring out the knock. Eliminate the possible causes such as carbon and valves, then proceed as follows to localize the knocks so that corrections may be made or a proper report made to a higher authority.

(*a*) *Crankshaft and Bearing Knocks.* Loose bearings are usually indicated by heavy dull knock, more noticeable on acceleration of engine when under load. This knock can generally be located by shorting out cylinders on both sides of loose bearing. End play is usually indicated by intermittent knock which may disappear when slight pressure is put on clutch pedal.

(*b*) *Piston and Connecting Rod Knocks.* Knock caused by loose connecting rod bearing can be shorted out. Loose piston pin noise generally doubles when cylinder is shorted out. Loose piston or piston "slap" is more noticeable when engine is cold and can be generally shorted out. Broken piston pin or ring noise usually has a sharp clicking sound and cannot be shorted out.

(*c*) *Camshaft Knocks.* These knocks generally occur at half engine speed. Gear cover should be removed and play in gears and shaft checked by higher echelon.

(*d*) *Timing Gear Noises.* A "humming" noise may indicate tight gears. Loose gears and other timing gear faults may be indicated by a rattle or knock.

(*e*) *Valve Mechanism Knocks.* If valve mechanism knocks cannot be eliminated by valve clearance adjustment, report to higher authority.

(*f*) *Water Pump Knocks.* If knocks definitely point to water pump, remove assembly and replace.

(*g*) *Other Engine Noises.* Check possible sources of other noises such as loose fan blades, engine mounting, and muffler parts.

52. ENGINE LUBRICATION SYSTEM.

a. General. The most common trouble experienced with engine lubrication systems is the result of neglecting to use proper grade of oil or to keep oil to proper level. The use of oil of incorrect viscosity will contribute to several engine troubles, while neglecting to keep crankcase oil to proper level will finally result in a damaged engine. Use the correct grade of oil, keep it to proper level, and change it at regular intervals.

b. Low Oil Pressure. Low or no oil pressure is commonly caused by a clogged oil pump screen, broken oil lines, or worn main bearings. If the gage is known to be correct, and proper grade of oil is used, remove oil pan, clean screen, and examine oil pump for worn gears. Check oil lines for breaks or leaks, and make necessary corrections.

c. Excessive Oil Consumption. Refer to paragraph 51.

53. IGNITION SYSTEM.

a. General. The diagnosis of trouble symptoms in this paragraph are of those which pertain only to the ignition system. Reference

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should be made to ENGINE for a diagnosis of like symptoms. When diagnosing any ignition system trouble, the mechanic should visualize the ignition wiring diagram and keep in mind the fundamental action of the two ignition circuits, *primary* and *secondary*.

b. Engine Mis-fires.

(1) Remove spark plugs and clean and adjust point gap. Replace with new plugs if porcelain is cracked (par. 89).

(2) Remove distributor cap and check condition of points. Adjust point opening or replace points as necessary (par. 88).

(3) Check for other causes such as valves, valve springs, or poor compression and make necessary corrections.

(4) If trouble is still present, check ignition coil and condenser and replace if necessary.

c. Engine Backfires.

(1) Backfiring may be caused by crossed spark plug wires or a cracked distributor cap. Check wires and attach in correct firing order (1-5-3-6-2-4). Inspect distributor cap and replace if damaged.

(2) If trouble is still evident, check for other causes as directed in Fuel System (par. 54).

d. Excessive "Ping" (Detonation) Under Load or at High Speed.

(1) This condition can be caused by improper ignition timing or by using an inferior grade of fuel. Make sure a good grade of fuel is used and make necessary manual advance adjustment (par. 87).

(2) "Ping" or knock caused by pre-ignition cannot be corrected by retarding the spark. Pre-ignition is caused by an overheated spot such as exhaust valve head, carbon deposit, or center electrode of spark plug igniting the fuel charge before the regularly timed spark at the plug. This condition can be corrected by using spark plugs of proper heat range, correcting exhaust valve clearance, or removing cylinder head and cleaning carbon deposits from top of piston and from cylinder head.

e. Engine Overheating or Lack of Power.

(1) This condition is sometimes caused by improper ignition timing. Check timing adjustment and make necessary corrections (par. 87).

(2) If this does not eliminate the trouble, check for other causes such as defective cooling system, poor compression, wrong type oil, etc.

54. FUEL SYSTEM.

a. General. Many symptoms which might indicate fuel system trouble are in reality due to faulty ignition or valves. Before making any extensive adjustments or repairs on the fuel system, the ignition system and valve operation should be thoroughly checked.

b. Excessive Fuel Consumption. The causes of excessive fuel consumption are listed below in logical sequence.

(1) FUEL LEAKS.

(*a*) *Fuel Lines.* Inspect all fuel lines for leaks, and check and tighten all connections.

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(*b*) *Carbureter.* Fuel leaks at carbureter will be evidenced by the presence of fuel on the outside of the carbureter. Leak could be caused by loose drain plugs or improperly installed channel plugs. Tighten drain plugs or replace carbureter as necessary.

(*c*) *Fuel Pump.* Check for leaks around fuel pump bowl. Tighten knurled nut at top of bowl. If leak continues, replace gasket between bowl and pump.

(*d*) *Fuel Filter.* Leakage may occur at fuel filter bowl. Tighten cover bolt at top of filter and tighten drain plug. If leak is still present, replace bowl to cover gasket.

(2) IMPROPER CARBURETER ADJUSTMENT OR CARBURETER CONTROLS STICKING.

(*a*) Adjust idling mixture and choke controls. Install new return spring on choke control if necessary (par. 95).

(*b*) Air shutter (choke) not returning to fully open position will cause excessive fuel consumption. Soak carbureter air intake in kerosene to cut corrosion, then free up and lubricate shutter shaft.

(*c*) Adjust accelerator pump stroke for seasonal operation (par. 94).

(3) VALVE IN FUEL TANK CAP STUCK CLOSED. In extremely hot weather, this condition will cause excessive pressure in the fuel tank, which will result in excessive fuel consumption. Replace the cap if this condition is found.

(4) CARBURETER PARTS WORN. If leaks still exist after making corrections as directed in (1), (2), and (3) above, carbureter parts are worn, necessitating an overhaul of the unit. Replace carbureter with a new or rebuilt unit (par. 94).

c. Engine Idles Too Fast.

(1) Improper throttle adjustment, preventing the throttle plate from returning to closed position will cause engine to idle too fast. Properly adjust hand throttle (par. 95).

(2) Check return spring and replace with new spring if damage is apparent.

(3) Soak carbureter throttle body in kerosene to cut corrosion, then free up and lubricate throttle shaft.

d. Engine Dies When Idling.

(1) This condition is usually caused by improper carbureter idling speed or idling mixture adjustment. Make necessary adjustments (par. 94).

(2) Sticking choke control or crankcase ventilating valve will also cause engine to die. Free up and lubricate choke cable shaft and service crankcase ventilating valve.

(3) If trouble is still present, the idling circuit in the carbureter is clogged. Replace carbureter with a new or rebuilt unit (par. 94).

e. Low Fuel Pressure.

(1) Low fuel pressure is usually indicated when engine falters at high speeds. This condition may be caused by air leaking into the fuel lines. Tighten all fuel line connections and tighten fuel pump and fuel filter covers.

(2) Plugged fuel lines or clogged intake valve in fuel tank cap

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will cause low or no fuel pressure. Clean out or replace lines or cap as necessary.

(3) Test fuel pressure (par. 97).

(4) If low pressure is still evident, the fuel pump diaphragm is broken or the fuel pump valves are leaking. Replace diaphragm or valves as necessary.

(5) If the fuel pump linkage is worn excessively, replace pump (par. 97).

f. Engine Falters on Acceleration.

(1) This condition is usually caused by faulty operation of the carbureter accelerator pump or by dirt in the metering jets. In either case, the carbureter must be replaced with a new or rebuilt unit (par. 94).

(2) Air in the fuel lines will also contribute to this condition. Carefully check all lines for leaks.

g. Overheating or Lack of Power.

(1) Too lean a fuel mixture will cause the engine to overheat. Adjust carbureter (par. 94).

(2) Use of a low octane rating fuel will result in a lack of power. In this case, the ignition timing must be adjusted to compensate for the fuel used. This means that the lower the octane rating of the fuel, the more the spark must be retarded (par. 87).

55. EXHAUST SYSTEM.

a. Odor of Exhaust Fumes in Cab. The odor of exhaust fumes in the cab are an indication of leaks in the exhaust system.

(1) Check for blown out muffler and replace if necessary.

(2) Tighten all exhaust pipe connections.

(3) Check for leaking manifold gasket or cracked manifold. Replace gasket or manifold as necessary.

b. Excessive Combustion Noises. This condition is caused by a blown out muffler, loose manifold, or a blown manifold gasket. Tighten manifold or replace gasket or muffler as necessary.

56. COOLING SYSTEM.

a. General. Since the action of the cooling system controls the operating temperature of the engine, it is logical to assume that the cause of an overheated engine lies in the cooling system; however, late ignition timing or improper or insufficient lubricating oil in the engine crankcase will cause the engine to overheat, even though the cooling system is functioning properly. Check these items before making any extensive tests or repairs on the cooling system.

b. Overheating.

(1) Check for broken or loose fan belt. Replace belt or adjust to proper tension (par. 108).

(2) Check all radiator hose connections; water pump mounting bolts, seal and gasket; thermostat housing bolts and gasket, cylinder head bolts and gasket, and make necessary repairs to correct leakage.

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(3) Check radiator core for leakage and replace with new core if such a condition is found. Check for clogged air passages through radiator core and clean out if necessary.

(4) Cooling liquid may be escaping through an internal leak such as an internally cracked cylinder or block, or a defective cylinder head gasket. Such leakage would be evidenced by bubbles or foam on the oil dip stick, or by a raised oil level in the crankcase. In this case, report the condition to a higher authority.

(5) An inoperative thermostat will cause engine to overheat. Remove thermostat and test or replace with one known to be good (par. 110).

(6) Air suction or exhaust gas leakage into the system will cause rapid rusting and corrosion of engine parts, and this rust and corrosion will eventually clog the small water passages in the radiator core. In the event the cooling system is clogged, perform flushing operations (par. 107); in the event this does not clean out the system, report to higher authority.

(7) An improperly operating water pump will cause engine to overheat. To determine if the water pump is functioning properly, remove radiator filler cap, run engine at medium speed, and notice the action of the water. Do not confuse action caused by vibration with circulation; there will be a distinct noticeable current if the water pump is operating properly.

c. Overcooling. Overcooling is caused by the thermostat being stuck open. This is evidenced by the fact that the engine does not warm up to proper operating temperature. If such a condition exists, remove the thermostat and test or replace with one known to be good (par. 110).

57. STARTING SYSTEM.

a. General. If the engine fails to start after repeated and satisfactory operations of the cranking motor, cause of failure cannot be attributed to the starting system, but to other functioning systems of the engine such as the ignition system or fuel system.

b. Cranking Motor Fails to Operate.

(1) The first item to check when the cranking motor fails to operate is the battery. If the battery is run down, recharge or replace (par. 119).

(2) Loose or broken battery or ground cable will cause cranking motor failure. Thoroughly clean terminals and tighten or replace cables as necessary.

(3) Cranking motor switch contact terminal sometimes becomes corroded or burned, preventing a good contact. Check for this condition and replace switch if necessary.

(4) If, after making the above corrections, the cranking motor still fails to operate, it is in need of an overhaul and must be replaced with a new or rebuilt unit (par. 114).

c. Cranking Motor Noisy.

(1) Cranking motor noise may be due to loose mounting. Tighten

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cap screw and stud nut attaching cranking motor to clutch housing.

(2) Lubricate cranking motor.

(3) If still noisy, the cranking motor requires an overhaul and must be replaced with a new or rebuilt unit (par. 114).

d. Slow Cranking Speed.

(1) This condition may be caused by a weak battery or loose cable connections. Check for and correct these conditions.

(2) Perform line voltage tests to determine if there is excessive resistance in circuit and make necessary corrections (par. 120).

(3) If the cranking motor still operates slowly after making the above corrections, it is in need of overhaul and must be replaced with a new or rebuilt unit (par. 114).

58. GENERATING SYSTEM.

a. General. Since the generator and regulator functions are directly related, both units must be considered when checking symptoms of failure in the generator circuit. When the ammeter shows an unsatisfactory reading, make sure the ammeter is correct before making any repairs on the generating system.

b. High Charging Rate With Fully Charged Battery.

(1) Check generator to regulator ground wire for damage or loose connections.

(2) Clean and tighten all terminals and connections in generator circuit.

(3) If condition still exists, either the voltage regulator is in need of adjustment, or the generator is in need of an overhaul. In either case, replace with a new or rebuilt unit.

c. Low Battery and Low or No Charging Rate.

(1) Check all wires between generator and regulator for signs of worn insulation or other damage. Clean and tighten all connections.

(2) If this does not correct the trouble, either the generator or regulator, or both, must be replaced with new or rebuilt units.

d. Noisy Generator.

(1) Check and tighten all generator mounting bolts. Check fan belt tension and adjust if necessary (par. 108).

(2) If noise is still present, generator is in need of overhaul and must be replaced with a new or rebuilt unit.

59. CLUTCH.

a. General. The clutch is designed for maximum efficiency and long life, and with reasonable care, no operating difficulty should be encountered. Natural wear will occur, however, and must be compensated for.

b. Clutch Slipping.

(1) Improper adjustment (no pedal free-travel) will cause the clutch to slip. Adjust pedal free-travel (par. 150).

(2) If this does not eliminate the condition, it may be due to worn facings, grease on facings, clutch disc hub binding on clutch shaft, or insufficient spring tension. Any of these causes necessitate replacing the clutch assembly (par. 152).

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c. Clutch Grabbing and Chattering.

(1) This condition may be caused by improperly operating the clutch. If this is the cause, the condition may be eliminated by correcting poor driving practices.

(2) Check and tighten engine mounting bolts. Also inspect and tighten all transmission mounting bolts. See that transmission strut rod is connected and properly adjusted.

(3) If grabbing and chattering condition persists, it may be caused by grease on facings, worn splines on clutch shaft or in disc hub, facing loose on disc, or pressure plate scored or rough. Any of these conditions require replacing the clutch assembly (par. 152). When making replacement, inspect for worn splines on clutch shaft and replace transmission if this condition is found.

d. Rattling.

(1) A rattling sound, appearing to originate in the clutch, may be heard if the clutch pedal pull back spring is disconnected. Connect spring and check for continued rattling.

(2) If rattling continues, it is due to weak pressure plate retracting springs or excessive clearance between driving lugs and cover. In either case, the clutch assembly must be replaced (par. 152).

Section XIII

POWER TRAIN AND MISCELLANEOUS TROUBLE SHOOTING AND DIAGNOSIS

60. GENERAL.

a. Scope. The information contained in this section includes a compilation of trouble symptoms which might be encountered in the power train and miscellaneous units during operation of the vehicle, together with possible causes and possible remedies. Only those difficulties which can be detected by the using arm are included. The trouble shooting procedures are classified according to each section of the manual. In some instances, a symptom indicating trouble in one unit may be caused by difficulty in another unit; therefore, cross references to the related units are made whenever this condition exists.

b. Diagnosing Causes. The diagnosis of symptoms is an orderly process of eliminating causes of the symptom. An orderly process means to check the most probable or common cause first. In the following procedures, each trouble symptom is listed with a diagnosis of causes and possible remedies following in logical sequence.

61. BATTERY AND LIGHTING SYSTEM.

a. General. Reference to wiring diagram (fig. 113 or 114) will show that a single circuit from battery to main light switch is com-

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mon to all lamps on the vehicle. At main light switch this single circuit is divided into multiple circuits, each of which is common to two or more lamps (except service stop lamp). These circuits are then taken to various junction points where they are divided into individual circuits, each of which is taken to a single lamp. The return path of each circuit is through ground to battery. Dividing the circuits in this manner provides a convenient and logical method of locating the source of trouble. The use of a voltmeter or trouble lamp, and adhering to the following principles will aid in locating trouble in the lighting system.

(1) Source of trouble common to all lamps will be located in that part of the circuit common to all lamps.

(2) Source of trouble common to two or more—but not all—lamps will be located in that part of the circuit common only to the lamps affected.

(3) Source of trouble at a single lamp will be confined to the individual circuit of the lamp affected.

b. One Lamp Will Not Light. This condition is the result of an open circuit or grounded wire between the lamp ground and the feed wire junction. Open circuit or grounded wire may be caused by a burned out or broken filament; poor ground at lamp; corroded contacts or terminals; broken wire; frayed insulation; grounded or shorted terminals; defective main light switch or stop light switch (stop light only).

c. Two or More Lamps Will Not Light. The cause of this condition will be located between the main light switch and the individual lamp junction. Cause may be defective main light switch; defective individual light switch; loose or corroded terminals; broken wire.

d. All Lamps Will Not Light. The cause of this condition will be located between the point where the battery ground strap attaches to the frame and the main light switch.

(1) The cause may be a discharged battery; corroded battery terminals; corroded or broken battery cable or ground strap. These points can be checked by cranking engine with cranking motor. If cranking speed is normal, trouble lies between the cranking motor and main light switch.

(2) Other causes are loose or corroded terminals; defective main light switch; defective circuit breaker; defective ammeter; short circuit or ground at some point in system which causes the circuit breaker to operate. The only remedy is to methodically check the system until the fault is located and corrected.

(3) A vehicle not in use for some time may possibly have all lamp contacts corroded to the point where lamps are inoperative. A remote possibility of failure is that all filaments may have been broken by shock.

e. Lamps Give Insufficient Light. This condition may be caused by excessive resistance in circuit or by a discharged battery. Check condition of battery, then look for loose or corroded terminals and contacts, and frayed insulation on wires.

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f. Frequent Lamp Failure. Frequent burning out of lamps is the result of high voltage at lamps. This is caused by a defective or improperly adjusted voltage regulator.

g. Discharged Battery. A discharged battery may be caused by loose or corroded terminals in any of the electrical circuits. Check for and correct such conditions. Shorted or dry battery cells will also result in a discharged battery. Replenish water or replace battery as necessary (par. 119). Check generator charging rate and replace generator if necessary (par. 117).

h. Overheated Battery. This condition is caused by a defective or improperly adjusted voltage regulator. Replace regulator (par. 118).

62. RADIO NOISE SUPPRESSION SYSTEM.

a. Locate Source of Noise. To locate the source of radio interference emanating from the vehicle, the use of a radio receiver in the vehicle or in an adjacent vehicle will be required. Noting the type of interference present in the receiver will help determine the cause of the trouble. To determine if the noise is coming from the vehicle itself or from an outside source, drive the vehicle at least 100 feet from other vehicles. Turn engine off and turn radio on. Any noise heard will be from an outside source. Start engine. Any noise heard will come from the vehicle itself.

(1) ENGINE. Operate engine with vehicle not in motion and listen for noises in the receiver. If a crackling or clicking noise is present, accelerate the engine and turn ignition switch off with engine running at high speed. If noise stops immediately, the interference is being caused by the *Ignition Circuit* (subpar. b below). If an irregular clicking or chattering continues a few seconds after the ignition is shut off, interference is being caused by the *Generating Circuit* (subpar. c below). If the interference is in the form of a whining or whirring noise which varies with engine speed, turn the ignition off. If the tone of the sound lowers in pitch but continues for a few seconds after the ignition is turned off, it is caused by the *Generator* (subpar. d below).

(2) VEHICLE. Operate the vehicle and note whether there is any interference present in the receiver. If clicking or scratching noise is present, stop the vehicle, but leave the engine running. If noise stops when motion of vehicle stops, it may be attributed to faulty *Bonding* (subpar. e below), or loose connections in vehicle *Wiring* (subpar. f below).

b. Ignition Circuit. Make sure ignition circuit is functioning properly (par. 53). Improper spark plug gaps, improper ignition system adjustments, or worn parts will affect the suppression system. Clean and tighten all wiring connections. Tighten engine mountings. With engine running, remove and replace spark plug wires from spark plugs one at a time, listening for a lessening of the frequency of clicks in the receiver. If removal of one of the wires reduces or eliminates the interference, the spark plug suppressor is defective and must be replaced.

c. Generating Circuit. Check regulator mounting bolts and

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tighten if necessary. Internal-external toothed lock washers must be in place between regulator base and cowl to ground regulator. Test filters on cowl and replace if faulty (Sec. XXIV). Test condenser on generator and replace if faulty (Sec. XXIV).

d. Generator. Check and tighten all generator connections and mounting bolts. If noise is still present, replace generator assembly (par. 117).

e. Bonding. Check all bond straps for breaks and loose connections. Replace straps or clean and tighten connections. Internal-external toothed lock washers must be used at all bond strap connections.

f. Wiring. Inspect all wiring for worn, frayed, or otherwise damaged insulation. Replace if defective. Clean and tighten all connections.

63. TRANSMISSION.

a. Excessive Noise.

(1) Noise which seemingly comes from the transmission may be caused by another assembly such as axle, transfer case, propeller shaft universal joint, or clutch; therefore, before replacing the transmission due to noise, make sure that difficulty does not exist elsewhere.

(2) Improper or insufficient lubricant may cause transmission noise. Change or add lubricant as directed in Section VIII.

(3) Transmission noise may be caused by gears or bearings being worn, broken, or loose on shafts. These causes require replacing the transmission with a new or rebuilt unit (pars. 154 and 155).

(4) A noisy condition in the power take-off will reflect through the transmission. Check power take-off mounting nuts and tighten as necessary. Incorrect number of gaskets between power take-off and transmission will cause noise. Install correct number of gaskets (par. 157 or 158). Excessively worn power take-off gears necessitate replacing the power take-off assembly (par. 157 or 158).

b. Hard Shifting.

(1) First check for loose transmission to clutch housing cap screws. Tighten all cap screws firmly.

(2) Hard shifting may be due to improper clutch pedal adjustment, causing the clutch to fail to release. Adjust clutch pedal free travel (par. 150).

(3) If this does not eliminate the condition, it is due to scored shift rods or binding in the control cover assembly. Replace transmission assembly (pars. 154 and 155).

c. Slips Out of Gear. This condition is usually caused by weak or broken shift rod poppet springs, a bent shifting fork, or the gears in the transmission are worn excessively and the transmission assembly must be replaced (pars. 154 and 155).

64. POWER TAKE-OFF.

a. Hard Shifting.

(1) Too heavy lubricant in the transmission will cause the power

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take-off to shift hard. Drain and refill transmission with correct lubricant (Section VIII).

(2) Burred gear teeth will also cause hard shifting. If this condition is present, replace the power take-off assembly (par. 157 or 158).

b. Power Take-off Noisy. The power take-off is so closely related to the transmission that a noisy condition in the power take-off would only be detected through the transmission. Refer to paragraph 63 for a diagnosis of transmission noises.

65. TRANSFER CASE.

a. Hard Shifting.

(1) Hard shifting may not be due to any difficulty in the transfer case, but due to improper driving practices. Follow driving and shifting procedures as directed in paragraph 16.

(2) Tightness in control linkage due to rust, corrosion, dirt, or need of lubrication will cause hard shifting. Inspect, clean, and lubricate linkage.

b. Slips Out of Gear.

(1) Transfer case will slip out of gear if gears do not fully engage due to improperly adjusted control linkage. Adjust control linkage (par. 160).

(2) A weak or broken shift shaft poppet ball spring will cause transfer case to jump out of gear. This condition requires replacement of transfer case assembly (pars. 161 and 162).

c. Loss of Lubricant. This condition is caused by worn or damaged flange hubs, oil seals, or damaged gaskets. In either case, replace the transfer case assembly (pars. 161 and 162).

66. FRONT AND REAR AXLES.

a. General. An unusual noise is usually the first indication of improper functioning of axle driving parts. Noises which seem to come from the axles may be caused by some other unit such as transmission, transfer case, or tires. Some conditions in the front axle directly affect the steering of the vehicle, and are listed under Steering System (par. 70).

b. Continuous Axle Noise.

(1) This condition may be caused by some difficulty in the axle or by improperly or unevenly worn tires.

(2) To determine if noise is caused by axle or by tires, drive vehicle on soft terrain. If this stops the noise, it is being caused by the tires and not by the axle. Inflate tires to proper pressure or replace as necessary (par. 198).

(3) If noise continues on soft terrain, it is caused by worn or improperly adjusted wheel bearings, worn or improperly adjusted differential gears or bearings, or by insufficient lubricant in the differentials and steering knuckles. Add lubricant, adjust wheel bearings (par. 199), or replace axle assembly (pars. 168 and 169, or 173 and 174).

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c. **Axle Noise on Drive Only or on Coast Only.** This condition is an indication that the differential pinion and ring gear are out of adjustment or worn excessively. To correct this condition, replace complete axle assembly (pars. 168 and 169, or 173 and 174).

d. **Excessive Backlash in Axle Driving Parts.**

(1) This condition may be caused by loose axle shaft or drive flange cap screws or stud nuts, worn holes in flanges, or by worn splines on axle shafts. Tighten cap screws or stud nuts, or replace axle shafts as necessary (par. 171 or 172).

(2) If excessive backlash still exists, replace axle assembly (pars. 168 and 169, or 173 and 174).

67. PROPELLER SHAFTS.

a. **Excessive Noise or Vibration.**

(1) Need of lubrication in the universal joints will result in excessive propeller shaft noise. Lubricate all universal joints (Sec. VIII).

(2) If propeller shafts are not assembled with universal joints in the same plane, vibration will result. Check for this condition and if found, disconnect propeller shafts and place universal joints in same plane (par. 176).

(3) Check for loose pillow block mounting cap screws and tighten if necessary.

(4) Worn universal joint bearings or journals, or a sprung propeller shaft will cause vibration and noise. Check for these conditions and replace propeller shaft assembly if necessary (par. 176).

(5) Any mechanical movement has vibration periods, which do not result in noise until they tune in with some other part or unit. In this connection, loose or broken fenders, running boards, body or cab hold-down bolts, etc., should be checked as the source of noise if the above remedies do not correct the condition.

68. SERVICE BRAKE SYSTEM.

a. **Excessive Pedal Pressure and Poor Stop.**

(1) This condition is most commonly caused by normal wear of the brake linings. Correct by adjusting brake shoes (par. 181).

(2) Tighten all connections in vacuum system, and clean or replace Hydrovac air cleaner (par. 188). Inspect vacuum check valve at manifold and replace if not operating properly (par. 190).

(3) Inspect brake shoes and linings. If linings are grease soaked or worn excessively, or if the brake shoes are twisted or sprung, replace brake shoe and lining assemblies (pars. 182, 183, and 184).

(4) Check for obstructed brake lines, and clean or replace lines as necessary.

(5) Check brake pedal and linkage for bent or broken condition, and replace damaged parts.

(6) If the condition still exists after making the above corrections, the trouble lies in the Hydrovac. Replace the Hydrovac assembly (par. 188).

(7) In extremely cold weather, with the wrong type fluid in the system, the fluid will thicken and will not flow freely through the

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lines and openings. This will cause extreme pedal pressure. Drain and flush system and refill with proper fluid (par. 180).

b. Pedal Goes to Floor Board.

(1) If this condition comes about gradually, it is due to normal wear of the brake linings. Check linings and adjust (par. 181), or replace brake shoe and lining assemblies as necessary (pars. 182, 183, and 184).

(2) If the pedal goes to the floor suddenly, it may be due to a leak in the hydraulic system, or the pedal linkage has become broken or disconnected. Check for broken or leaking lines or connections, especially in the flexible lines. If a leak occurs in the front wheel brake lines, rear brakes can be used by shutting off the shut-off cock inside right-hand frame side rail. Replace lines or tighten connections as necessary, and bleed brake system (par. 180). Check for disconnected or broken pedal linkage; make necessary connections, replacements, and adjustments.

(3) Air trapped in the hydraulic system will sometimes permit the pedal to go to the floor. Bleed the entire brake system (par. 180).

c. Noisy Brakes. This condition is caused by dirty brake linings, excessively worn linings, loose lining rivets, twisted or sprung brake shoes, distorted drums, or broken brake shoe return springs. Replace brake shoe and lining assemblies (pars. 182, 183, and 184), or brake drums (par. 185).

d. Springy, Spongy Pedal Action. Brake shoes needing adjustment due to normal wear, or air in the hydraulic system will cause a springy, spongy pedal action. Check brake shoe adjustment and make necessary corrections (par. 181). If pedal action is still soft, bleed brake system (par. 180).

e. One Brake Drags.

(1) This condition may be caused by an improperly adjusted brake shoe. Check adjustment and make necessary correction (par. 181).

(2) Check brake mechanism for corrosion or binding, or for a weak or broken brake shoe return spring, and replace parts as necessary.

(3) Check wheel bearing adjustment and correct if necessary.

(4) Defective wheel cylinder cups or corroded end caps on cylinder will sometimes prevent brake shoes from returning to released position. Check for these conditions and replace wheel cylinder if necessary (par. 189).

f. All Brakes Drag.

(1) Dirt and corrosion in the brake shoe linkage or wheel cylinders is the most common cause of dragging brakes. Clean and lubricate linkage, or replace wheel cylinders as necessary (par. 189).

(2) Brakes will drag if the bypass part in the master cylinder is restricted. This port may be closed by dirt, by a swollen piston cup, or by the piston not fully returning to the rear of the cylinder due to bent or broken linkage. Make necessary adjustments or replace master cylinder (par. 187).

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(3) A defective check valve in the Hydrovac slave cylinder will also cause the brakes to drag. This condition necessitates replacing the Hydrovac (par. 188).

(4) Weak or broken brake shoe return springs will cause brakes to drag, although this condition would rarely occur at all wheels at the same time.

g. **Locked Brakes.** There are several conditions which may contribute to brakes locking. When one or more of the brakes lock, the following symptoms, causes, and remedies should be studied.

(1) WHEEL CYLINDER STICKING. Locking of brakes may be caused by sticking of the wheel cylinder piston, or rusting of the caps on wheel cylinder, preventing the return of the brake shoes after a brake application. This is generally caused by old gummy fluid or corrosion. This usually occurs on one or two brakes at a time, but never on all six brakes unless the vehicle has been stored for some time near salt water. To remedy piston sticking condition, drain all fluid and flush the entire hydraulic system with fresh fluid. Wheel cylinder assemblies which are in rusted condition must be replaced (par. 189).

(2) DIRT IN BRAKE FLUID. Dirt in the fluid may enter when refilling the master cylinder during bleeding operations. Extreme cleanliness of the fluid containers during this operation is necessary. This symptom may be diagnosed by removing the vacuum hose from the Hydrovac unit. Brakes should then release as all vacuum will then be depleted. To correct such conditions, replace the Hydrovac unit (par. 188), drain and flush the system, and fill with clean fluid (par. 180).

(3) DIRTY HYDROVAC AIR CLEANER. The valve in the Hydrovac relay valve may be stuck in open position due to sand or dust drawn in through the air cleaner. Such symptoms can also be diagnosed by removing the vacuum hose from the Hydrovac unit. To correct such conditions, it is necessary to replace the Hydrovac unit (par. 188). To avoid repeated failures, the Hydrovac air cleaner should be cleaned more often, particularly when the vehicle is operating in dusty areas.

(4) BRAKE LINKAGE OUT OF ADJUSTMENT. Locked brakes may be caused by the brake pedal linkage being out of adjustment or the brake pedal return spring weak or broken. In either case, slight pedal movement when driving over rough roads will build up the fluid pressure and apply the brakes. This condition may be diagnosed by opening the bleed screw slightly on one wheel cylinder to release the fluid pressure. Brakes should then return to the released position. If this condition exists, the pedal and linkage adjustments should be made as described in paragraph 181.

69. WHEELS, HUBS, AND TIRES.

a. **General.** When localizing wheel and tire trouble symptoms, consideration must also be taken of various related systems such as brakes, wheel alinement, and steering gear system. Deficiencies in these systems or units will affect performance of wheels, tires, and hub bearings.

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b. Excessive or Uneven Tire Wear.

(1) Unequal pressures in the tires will cause uneven tire wear. Inflate all tires to correct pressure (par. 198).

(2) Front wheel misalinement will cause excessive tire wear. Check front wheel alinement and make necessary corrections (par. 164).

(3) Bent wheels or damaged wheel bearings will result in uneven tire wear. Replace wheels or bearings as necessary.

(4) Operating vehicle on a dry, hard surfaced road with front axle engaged will result in excessive wear on the front tires.

c. Hard Steering. This condition may be caused by under-inflated tires, steering gear in need of adjustment or lubrication, front wheels out of alinement, or wheel bearings in need of adjustment. Check these items in the sequence given and make necessary corrections.

d. Wheels Pounding. Hub bearings that are damaged or in need of adjustment will produce a pounding at the wheels. A bent wheel will also cause this condition. Replace or adjust hub bearings (par. 201 or 202), or replace wheel (par. 197), as necessary.

e. Shimmy.

(1) Unevenly worn or unevenly inflated front tires will cause front wheels to shimmy. Replace tires or inflate to correct pressure as necessary (par. 198).

(2) Loose or damaged front hub bearings will also cause this condition. Adjust or replace bearings as necessary (par. 201 or 202).

(3) Any condition contributing to improper front wheel and axle alinement may cause front wheel shimmy. Front axle alinement is affected by loose steering knuckle bearings, front spring leaves broken, spring bolts, shackles, or bushings worn, spring center bolt broken, and a bent axle housing or chassis frame. Check front wheel and axle alinement and make necessary corrections (par. 164). Also check for faulty shock absorbers and replace if necessary (par. 213).

70. STEERING SYSTEM.

a. General. Proper operation of the steering system is closely related to other units in the vehicle. Hence, whenever diagnosing steering difficulties, other allied factors must also be checked. A symptom indicating possible trouble in the steering system may also be evidence of deficiency in other units, that is, front axle alinement, front spring suspension, tire inflation, wheel and tire mounting, wheel bearing adjustment, frame alinement, and brakes.

b. Hard Steering.

(1) If this condition exists on a vehicle just out of the repair shop, the worm bearings, sector gear lash, or drag link ends may be adjusted too tight. Check these adjustments and correct if necessary (par. 204). Other causes listed below will result in this condition after vehicle has been in service for some time.

(2) The most common cause of hard steering is under-inflated tires. Inflate all tires to correct pressure (par. 198).

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(3) Lack of lubrication in the steering gear or in the steering knuckle bearings will also cause hard steering. Lubricate as directed in Section VIII.

(4) Inspect drag link and replace if bent (par. 207).

(5) Front wheel and axle misalinement will cause hard steering. Check alinement and make necessary corrections (par. 164).

c. Wander or Lack of Steering Control.

(1) This condition may be caused by loose steering gear mountings, pitman arm loose on pitman shaft, or too much sector gear lash. Check these items and make necessary corrections (par. 205 or 204).

(2) Check for loose drag link ends and adjust or replace drag link as necessary (par. 207).

(3) Check front wheel and axle alinement and make necessary corrections (par. 164).

(4) If the condition still exists, the steering gear parts are worn, necessitating replacement of the steering gear assembly. Report to higher authority.

d. Road Shock Transmitted to Steering Wheel.

(1) If this condition exists on a vehicle immediately upon leaving the repair shop, it is due to the drag link, worm bearings, or sector gear lash being adjusted too tight. Check these adjustments and correct as necessary (par. 204).

(2) When the condition occurs after vehicle has been in service for some time, it may be caused by loose wheel bearings. Adjust wheel bearings (par. 199).

e. Unequal Turning Radius to Right and Left.

(1) On a vehicle just out of the repair shop, this condition would be caused by improperly adjusted steering knuckle stop screws, or by the pitman arm not being properly positioned on the pitman shaft. Remove pitman arm and install correctly (par. 205), or replace axle assembly (pars. 168 and 169).

(2) This condition will come about on a vehicle in service by worn steering knuckle stop screws, or by the drag link becoming bent. Replace drag link (par. 207) or axle assembly (pars. 168 and 169).

f. Vehicle Pulls to One Side.

(1) The most common cause of this condition is unequal tire pressures in the front tires. Inflate all tires to correct pressure (par. 198).

(2) Check for damaged or loose wheel bearings, and replace or adjust as necessary (par. 201 or 202).

(3) One front brake dragging will cause vehicle to pull to one side. Check brake shoe adjustment and correct if necessary (par. 181).

(4) Unequal toe-in will cause the vehicle to pull toward the side having the least toe-in. Check toe-in and make necessary corrections (par. 164).

71. FRONT AND REAR SPRINGS.

a. Hard Riding.

(1) This condition is usually present when the vehicle is overloaded. Refer to nomenclature plate for correct load.

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(2) Hard riding will also result from insufficient lubrication or frozen shackles. Lubricate shackles or remove and clean or replace as necessary (par. 209).

b. Over Flexible.

(1) The most probable cause of this condition is insufficient fluid in the shock absorbers. Refill shock absorbers to proper level (par. 213).

(2) Examine spring and replace if leaves are broken (par. 209 or 210).

(3) If over flexibility still exists, the shock absorbers are not operating properly and must be replaced (par. 213).

c. Spring Leaf Failure.

(1) Breakage of spring leaves is most commonly caused by overloading the vehicle or by driving at excess speed over rough terrain. Refer to nomenclature plate for correct load, and reduce speed over rough terrain when possible.

(2) Loose rebound clips will cause spring breakage. To prevent this, keep rebound clips tight.

(3) Frozen shackles due to lack of lubrication will also cause springs to break. Remove shackles and clean or replace as necessary. Lubricate as directed in Section VIII.

(4) Grabbing brakes will sometimes cause springs to break. Refer to paragraph 68 for causes and remedies of this condition.

d. Excessive Noise.

(1) Excessive spring noise may be caused by worn shackle bolts or spring eye bolts, or by worn shackle or spring eye bushings. Check for these conditions and replace bolts or springs as necessary (par. 209).

(2) Check for loose spring mounting bolts and tighten as necessary.

(3) Loose or damaged rear spring seat bearings will result in excessive noise. Examine bearings and adjust or replace if necessary (par. 211).

72. WINCH.

a. Winch Fails to Operate When Shifted into Gear.

(1) Winch will not operate if the sliding jaw clutch is disengaged from winch drum. Engage as directed in paragraph 24.

(2) If the winch still fails to operate, and the drive shaft revolves at the rear of the worm shaft housing, the shear pin is sheared off and must be replaced (par. 24).

b. Winch Fails to Hold Load. This condition is caused by the automatic brake lining being excessively worn or in need of adjustment. Adjust brake (par. 236) or replace brake band assembly (par. 237), as necessary.

c. Excessive Heat at Brake Cover. If this condition is present, the automatic brake is adjusted too tight, or the wrong type lining has been installed. Adjust brake (par. 236), or replace brake band assembly (par. 237).

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d. Winch Drum Over-runs Cable When Cable is Being Pulled Off by Hand. The automatic brake being in need of adjustment is the cause of this trouble. Adjust brake (par. 236).

e. Noisy Operation. Noisy operation is usually caused by insufficient lubrication. Add lubricant as directed in Section VIII.

73. POWER HOIST.

a. Noisy Pump. Air in the oil is the most common cause of a noisy pump. This may be caused by:

(1) Insufficient oil in cylinder. Add oil as directed in paragraph 246 or 247.

(2) Racing engine while pump is being operated. Run engine at slower speed.

(3) Failure of operator to disengage power take-off after hoist has reached extreme raised position. Move hoist control lever to "HOLD" position, then disengage power take-off.

b. Hoist Fails to Lift.

(1) This condition may be caused by insufficient oil in hoist cylinder. Check for oil leaks and make necessary corrections or replace cylinder (par. 246 or 247). If no oil leaks are found, add oil (par. 246 or 247).

(2) Check for sheared drive shaft keys and replace keys as required (par. 245).

(3) Bent or damaged hoist lifting linkage (levers and arms) will cause lifting failure. Damaged parts must be replaced.

(4) Overloading or improper load distribution will cause failure of hoist to lift.

(5) Hoist will not lift if the valve control linkage is improperly installed. Install linkage correctly (par. 244).

74. WATER TANK PUMP.

a. Refer to References in Appendix for TM covering this pump.

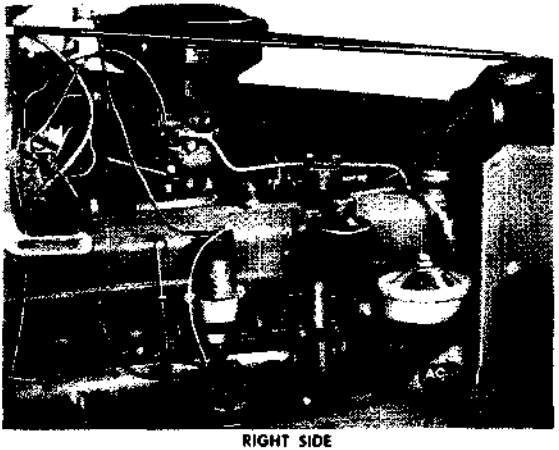
Section XIV

ENGINE DESCRIPTION, DATA, MAINTENANCE, AND ADJUSTMENT ON VEHICLE

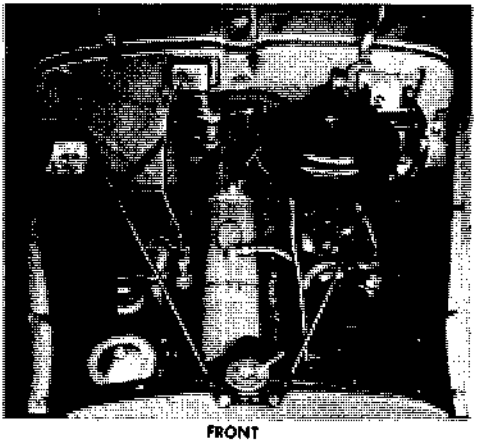
75. DESCRIPTION AND TABULATED DATA.

a. Description. The engine is a six-cylinder, in-line, valve-in-head type, three-point mounted in front of chassis. Engine and accessories are accessible for service after hood is raised. Side panel may also be removed for further accessibility (fig. 57).

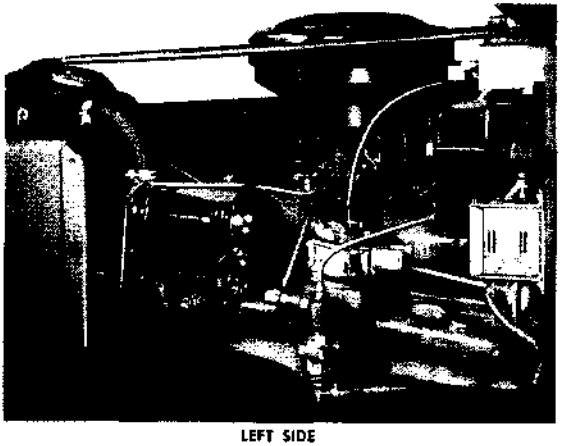
TRUCK, 2½-TON, 6 x 6



RIGHT SIDE



FRONT



LEFT SIDE

RA PD 333031

Figure 57—Engine Accessibility

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ENGINE DESCRIPTION, DATA, MAINTENANCE, AND ADJUSTMENT ON VEHICLE

b. Tabulated Data.

(1) GENERAL.

Engine type	6 cyl.—valve-in-head
Bore and stroke	$3^{25}/_{32}$ x 4 in.
Oil pan capacity	See Lubrication Order (Section VIII)
Cooling system capacity	19 qt

(2) ADJUSTMENT DATA.

Valve Clearance (hot)	
Intake	0.012 in.
Exhaust	0.016 in.
Spark plug gap	0.025 in.
Distributor point opening	0.018—0.024 in.
Cylinder Head Bolt Tightening Torque	
Preliminary (par. 79)	35 ft-lb
Final (par. 79)	70 ft-lb

76. TUNE-UP.

a. General. An engine tune-up is an orderly process of checking engine and accessory equipment to determine if they are within original specifications, and to accomplish such adjustments and repairs so that new engine performance is restored. This tune-up procedure can be accomplished at regular intervals or whenever performance of engine indicates need of such operations.

b. Vacuum Reading. Connect a vacuum gage at intake manifold at windshield wiper connection. Make carbureter idling adjustments (par. 94). With engine running at normal idling speed, the vacuum gage should read about 18 to 21 inches and pointer should be steady. An excessively fluctuating needle between 10 and 15 inches may indicate a defective cylinder head gasket or valve. An extremely low reading may indicate a leak in the intake manifold or gasket. Accelerate and decelerate the engine quickly. If the gage indicator fails to drop to approximately 2 inches as the throttle is opened, and then fails to recoil to at least 24 inches as throttle is closed, it may be an indication of diluted oil, poor piston ring sealing, or abnormal restriction in the carbureter, air cleaner, or exhaust. The above readings apply to sea level—there will be approximately a 1-inch drop for each 1,000 feet of altitude.

c. Compression Test. A compression test may also be made, in order to determine the need of internal repair before tune-up procedures are accomplished. This test will indicate condition of pistons, rings, and valve mechanism. Compression pressure depends upon cranking speeds, engine temperature, oil viscosity, compression ratio, and the condition of the engine. Make test in following manner:

(1) Remove all spark plugs. Turn ignition switch "OFF" and pull hand throttle button all the way out. Insert a compression gage in one spark plug hole. Crank engine 10 or 12 turns with cranking

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motor. Note highest gage reading while engine is being cranked. Take a reading at each cylinder in the same manner.

(2) Analyze the readings. While readings on some engines may be higher than on others due to conditions mentioned in subparagraph b above, the readings in any one engine should be reasonably high (100 lb or more), and all cylinders should show uniform readings within approximately 10 pounds.

(a) Pour a liberal amount of light engine oil through spark plug hole in cylinder having low reading. Allow sufficient time for oil to spread around rings. Take another reading. If compression is appreciably increased on piston so treated piston or rings require replacement. If no change in compression reading is noted, check valve mechanism.

(*b*) An extremely low reading in two adjacent cylinders may indicate a cylinder head gasket leak.

(c) If compression cannot be corrected with operations allocated to echelon making test, notify higher authority for proper correction.

d. Tune-up Sequence. Drain and refill crankcase, then service oil filter and crankcase vent cleaner. Proceed with following operations in sequence shown.

(1) Service and adjust spark plugs (par. 89).
(2) Clean and tighten battery and ignition cables.
(3) Test and service battery (par. 120).
(4) Service distributor cap, rotor, and points (par. 88).
(5) Check ignition timing (par. 87).
(6) Check and adjust valve clearance (par. 77).
(7) Service carbureter (par. 94), fuel filter (par. 98), air cleaner (par. 99), fuel pump (par. 97), and fuel lines (par. 100).

77. VALVE CLEARANCE AND ADJUSTMENT.

a. Preliminary. Warm up engine to operating temperature (at least 160° F). Allow engine to run at idling speed while adjustments are made.

b. Remove Valve Rocker Arm Cover. Disconnect crankcase ventilator tube from fitting at the valve rocker arm cover. Remove two valve cover retaining stud nuts, then remove valve cover.

c. Adjust Valve Clearance. With engine hot and idling, insert feeler gage (0.012 in. for intake and 0.016 in. for exhaust) between rocker arm and valve stem at each valve. Using tool similar to that illustrated in figure 58, or a wrench and screw driver, loosen rocker arm ball stud nut, and tighten or loosen stud until proper clearance is obtained. Tighten nut, and recheck clearance.

d. Install Valve Rocker Arm Cover. Check cover mating surface for distortion. Install cover over gasket, then install and tighten stud nuts just snugly. Only a very light pressure is required to prevent leakage if cover and gasket are in good condition. If a leak occurs, do not attempt to correct by excessively tightening nuts. Check gasket [(GM-6107400) G85-01-00777] for particles of dirt, breaks, or mis-location, and replace if necessary. After cover has been installed, connect ventilator tube to fitting on cover.

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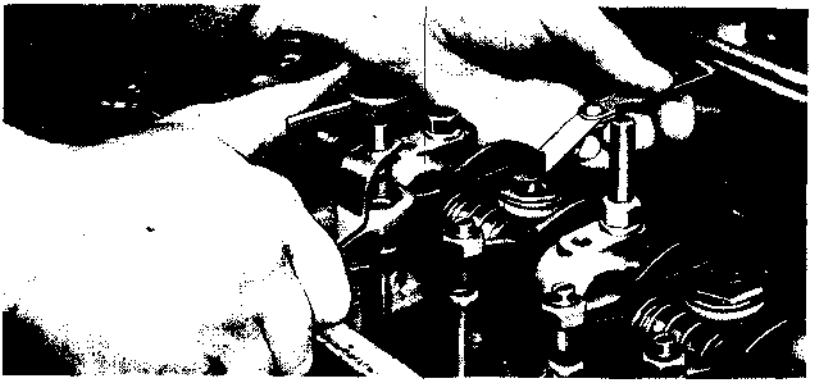

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Figure 58—Method of Adjusting Valve Clearance

78. INTAKE AND EXHAUST MANIFOLDS.

a. Description. Intake and exhaust manifolds are each one-piece type bolted together to form a complete unit. Unit is mounted to cylinder head, with gaskets and pilot rings between cylinder head and manifolds (fig. 59).

b. Removal.

(1) PRELIMINARY OPERATIONS. Remove air cleaner (par. 99) and carbureter and governor (pars. 94 and 96). Disconnect ventilator tube at valve cover and at valve in intake manifold. Unscrew ventilator valve and adapter from intake manifold. Disconnect wiper vacuum line from tee on manifold, then disconnect and remove vacuum check valve. Remove horn from intake manifold. Remove winterization primer connections at manifold if vehicle is so equipped.

(2) DISCONNECT EXHAUST PIPE. Remove three bolts from exhaust pipe and manifold flange. Separate flanges and remove gasket.

(3) REMOVE MANIFOLDS FROM CYLINDER HEAD. Remove eight manifold to cylinder head stud nuts. Remove four manifold washers and four manifold clamps. Remove two stud nuts and washers at outer ends of exhaust manifold. Pull manifold unit from cylinder head. Remove gaskets and pilot rings.

(4) SEPARATE MANIFOLDS. Remove two exhaust to intake manifold cap screws and lock washers. Remove two nuts and lock washers from exhaust to intake manifold studs.

c. Installation.

(1) INSPECTION. Inspect manifold for warped condition. Check on surface plate or with straight edge (fig. 60). Variation should not exceed $\frac{1}{32}$ inch. Check clearance between end studs and manifold stud holes. If clearance of approximately $\frac{1}{16}$ inch does not exist, file stud holes to provide necessary clearance before installing manifold. Check condition of exhaust manifold heat control valve. Remove rust, scale, carbon deposits, and any gasket material from face of cylinder head ports. Clean pilot ring seats.

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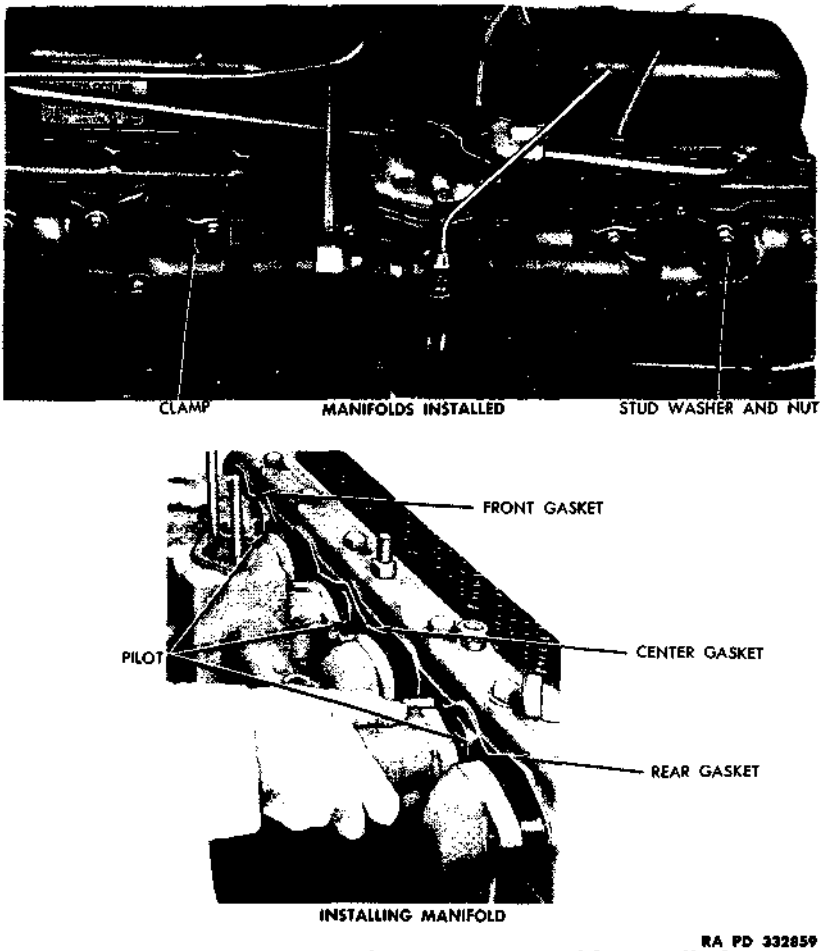

Figure 59—Intake and Exhaust Manifolds Installed

(2) ASSEMBLE MANIFOLDS. Position exhaust to intake manifold gasket [(GM-838290) G501-30-02340] over intake to exhaust manifold studs. Install two studs, nuts, and lock washers on intake to exhaust manifold studs. Install two cap screws and lock washers. Tighten cap screws and stud nuts only finger-tight.

(3) INSTALL PILOTS AND MANIFOLD GASKETS. Position pilots in cylinder head intake ports solidly and not cocked. Install three manifold gaskets—front and rear (GM-6107380), and center (GM-6107381)—on cylinder head manifold studs.

(4) INSTALL MANIFOLDS. Position manifold assembly over ends of studs and over pilot rings. Front and rear manifold studs must be centered in exhaust manifold flange holes. Clearance of approximately 1/16 inch should exist around each stud. Install washers and nuts on

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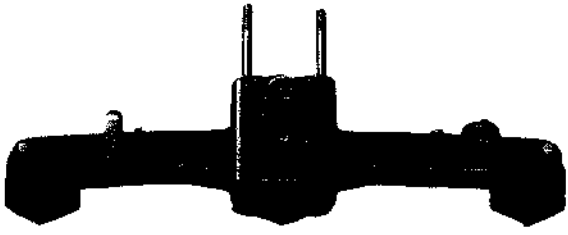
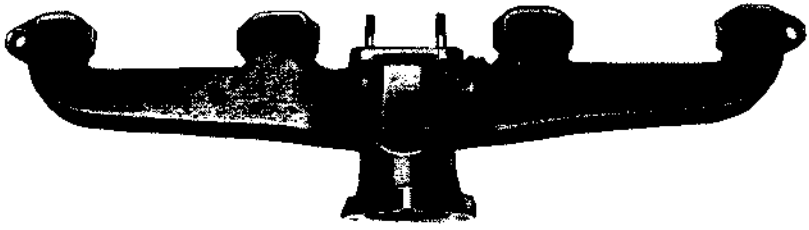
these studs. Install four manifold clamps and washers over studs. Install clamp stud nuts, making certain that clamps fit over manifold flanges evenly. Tighten all stud nuts alternately.

(5) TIGHTEN MANIFOLD ASSEMBLY. Tighten exhaust to intake manifold cap screws and stud nuts firmly.

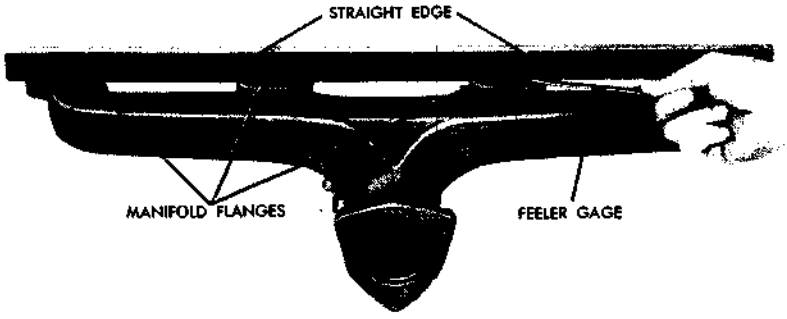
(6) CONNECT EXHAUST PIPE FLANGE. Insert the three bolts up through exhaust pipe flange and manifold. Make sure that flange seal and gasket (GM-2017499) are in place (par. 103). Install nuts on bolts and tighten firmly and alternately. Install lock nuts.



INTAKE



EXHAUST MANIFOLD DISASSEMBLED



CHECKING FLANGES

RA PD 332918

Figure 60—Intake and Exhaust Manifold Inspection

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(7) COMPLETE THE INSTALLATION. Install ventilator valve and adapter into manifold. Connect ventilator tube at valve and rocker arm cover. Install and connect vacuum check valve, then install wiper vacuum connection to tee. Install carbureter and governor (pars. 94 and 96), then air cleaner (par. 99). Install horn on intake manifold.

(8) RETIGHTEN. Run engine through warm-up period, then check tightness of manifold stud nuts.

79. CYLINDER HEAD GASKET REPLACEMENT.

a. Removal.

(1) DISCONNECT MANIFOLD. Remove ventilator tube from valve cover and ventilator valve. Remove air cleaner brace cap screw at cylinder head (when clamp-on type cleaner is used). Disconnect wiper vacuum line at manifold. Disconnect line at vacuum check valve. Disconnect gas line at carbureter, then throttle and choke connections at carbureter. Remove manifold to head stud nuts and clamps. Disconnect manifold at exhaust pipe. Pull manifold, carbureter, and air-cleaner as an assembly from head.

(2) REMOVE WATER BY-PASS TUBE. Partially drain cooling system. Disconnect water by-pass tube at rear of cylinder head, and at front at water outlet fitting.

(3) REMOVE IGNITION COIL, SPARK PLUG WIRES, AND OIL FILTER. Remove ignition coil (par. 90). Remove wires from spark plugs. Remove oil filter (par. 81).

(4) DISCONNECT OIL LINE AND THERMAL UNIT. Disconnect oil line at front of cylinder head. Remove temperature gage thermal unit from cylinder head.

(5) DISCONNECT WATER OUTLET. Remove two cap screws which attach thermostat housing to cylinder head. Remove gasket.

(6) REMOVE VALVE ROCKER ARM AND VALVE PUSH ROD COVERS. Remove valve rocker arm cover. Remove oil filler tube and bracket; then remove 13 cross-recessed cap screws which attach valve push rod cover to cylinder head and block. Remove push rod cover and gasket.

(7) REMOVE VALVE ROCKER ARM ASSEMBLY (fig. 61). Remove 10 cap screws and lock washers which attach rocker arm shaft brackets to head. Remove nuts from the two valve cover studs. Remove overflow tube located on rear bracket. Lift rocker arms, shaft, and brackets from head as an assembly. Lift valve push rods out of engine.

(8) REMOVE CYLINDER HEAD. Remove 14 cylinder head to cylinder block cap screws, then air cleaner bracket stud. Lift cylinder head straight up from block.

b. Installation.

(1) CLEAN CYLINDER HEAD AND BLOCK. Thoroughly clean gasket surface of cylinder block and head. Remove all dirt and carbon from bolt holes and from cylinder bores.

(2) POSITION CYLINDER HEAD GASKET. Place gasket (GM-2136676) carefully on cylinder block with side of gasket marked

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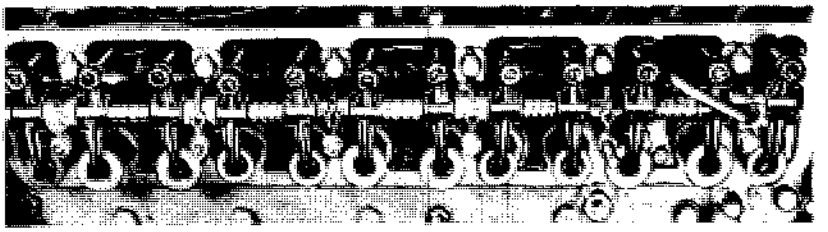
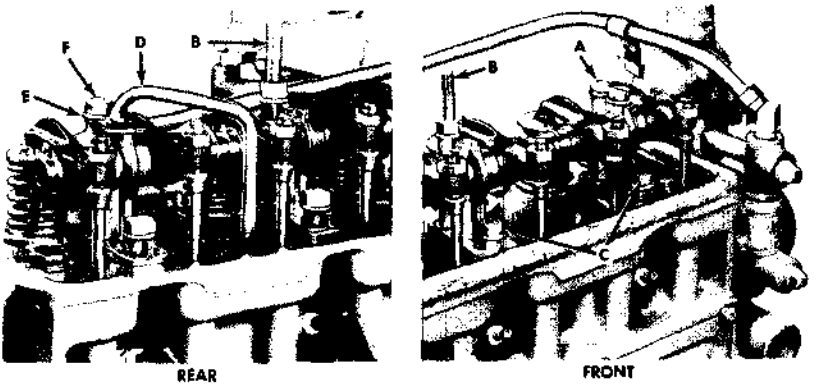


ARRANGEMENT OF ROCKER ARMS



A LEFT-HAND BRACKET SCREWS
B VALVE COVER STUDS
C RIGHT-HAND BRACKET SCREWS
D OVERFLOW PIPE
E OVERFLOW PIPE WASHER
F PIPE RETAINING SCREW

RA PD 332957

Figure 61—Valve Rocker Arm Assembly Installed

"TOP" toward cylinder head. This is essential to aline water passage holes in gasket with passages in block and head.

(3) ALINE GASKET. Maintaining alinement of cylinder head and gasket with block can be simplified by use of guide pins made from four cylinder head bolts (fig. 62). Insert the guide pins in the four end bolt holes of the block.

(4) INSTALL CYLINDER HEAD. Install cylinder head over guide pins, then lower carefully onto block. Insert all cylinder head cap screws except where guide pins are installed. Tighten just finger-tight. Use screw drive to remove guide pins, then install four cap screws in end holes finger-tight.

(5) PRELIMINARY TIGHTENING. Cylinder head cap screws must be tightened evenly and in a definite sequence to prevent distortion of head. There are two definite sequences, preliminary and final. Using sequence as shown in figure 63, start at bolt No. 1, and tighten all bolts in sequence shown with a torque wrench to 35 foot-pounds. Final tightening is described in step (7) below.

(6) INSTALL VALVE ROCKER ARM ASSEMBLY. Install push rods in place with "cup" end towards top. There are 10 cap screws which attach rocker arm brackets to head. The cap screws on left-hand side

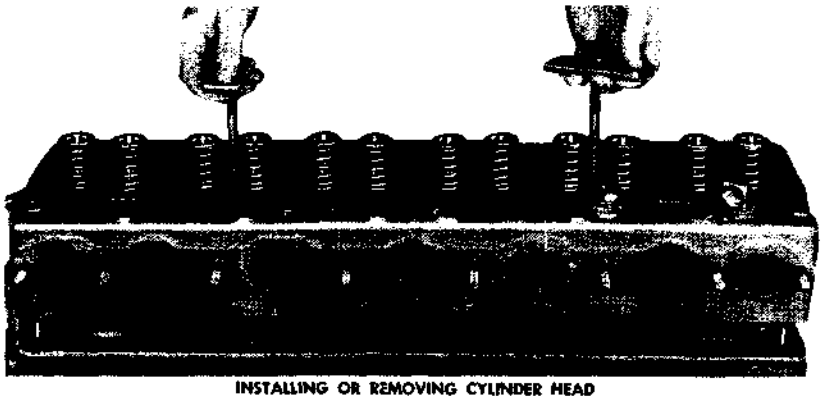
are 3¼ inches long, while those on the right-hand side are 1⅛ inches long. These must be installed in following manner.

(*a*) Locate rocker arm assembly on head in position shown in figure 61. Make certain that rocker arms are positioned over push rods correctly. Install three 3¼-inch cap screws in bracket from front to rear on left side. Tighten finger-tight. Install the two stud nuts on valve cover studs finger-tight.

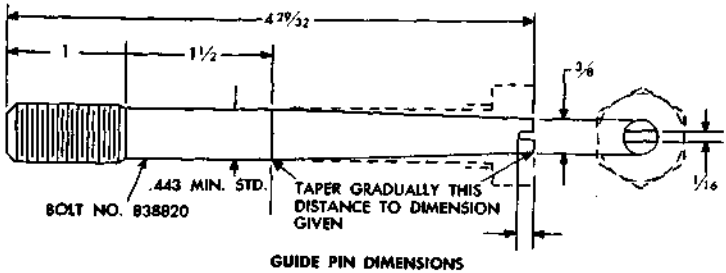
(*b*) Thoroughly coat threads of the six 1⅛-inch cap screws with joint and thread compound; then install cap screws at right-hand brackets. After all bracket screws are finally tightened, apply a small amount of compound to under side of each tapped hole accessible in spark plug recesses. NOTE: *Use of compound on right-hand bracket cap screws is only necessary on cylinder heads bearing casting or part number 6107412. On heads bearing number 2136477, the tapped holes do not extend through the spark plug recesses.*

(*c*) Install lock washer over end of left rear bracket cap screw, then install overflow pipe retainer clip over end of bolt. Position pipe gasket (GM-6107446) on rear bracket. Install cap screw and overflow pipe on rear bracket. Finally, tighten all bracket cap screws and stud nuts.

(7) FINAL TIGHTEN CYLINDER HEAD CAP SCREWS. Using sequence as shown in figure 64, tighten all cap screws to 70 foot-pounds.



INSTALLING OR REMOVING CYLINDER HEAD



GUIDE PIN DIMENSIONS

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Figure 62—Installing or Removing Cylinder Head

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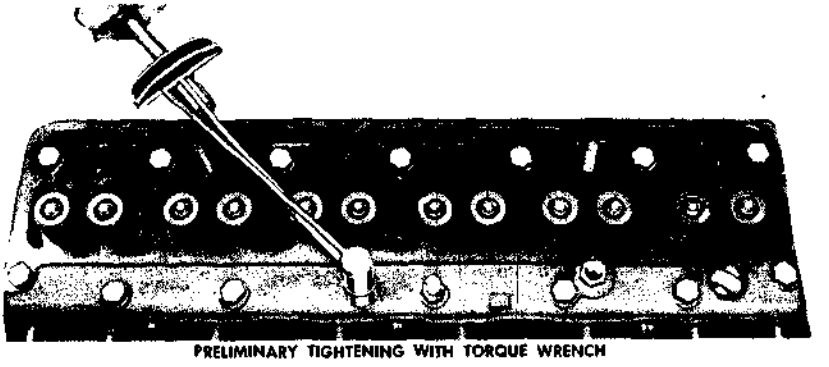


Figure 63—Preliminary Tightening Using Torque Wrench (41-W-3630)

Use special socket wrench (41-W-2964-700) with torque wrench (41-W-3630). Tighten cap screws on right side first in sequence shown, then tighten cap screws on left side. An additional check of cap screws must be made after engine has been warmed up.

(8) INSTALL PUSH ROD COVER. Install cover and gasket (GM-2135926) to block. Install oil filler tube and bracket, attach indicator tube bracket to block.

(9) COMPLETE THE INSTALLATION.

(*a*) Install oil filter (par. 81).

(*b*) Install thermal unit in head—tighten firmly.

(*c*) Install spark plug wires in correct sequence (par. 88).

(*d*) Connect oil line at front of head.

(*e*) Install ignition coil (par. 90).

(*f*) Connect manifolds to head and exhaust pipe (par. 78).

(*g*) Make throttle and choke connections at carbureter. Connect gas line to carbureter. Connect vacuum line to check valve connection. Connect wiper line. If used, install air cleaner brace to stud on head.

(*h*) Install thermostat housing to head. Use new gasket if necessary [(GM-838297) G85-31-06280].

(*i*) Install water by-pass tube at rear of head, then at by-pass fitting.

(10) WARM UP ENGINE. Fill cooling system—adjust valve clear-

ance to 0.012 inch intake and 0.016 inch exhaust (par. 77). Start engine and warm up to at least 160° F.

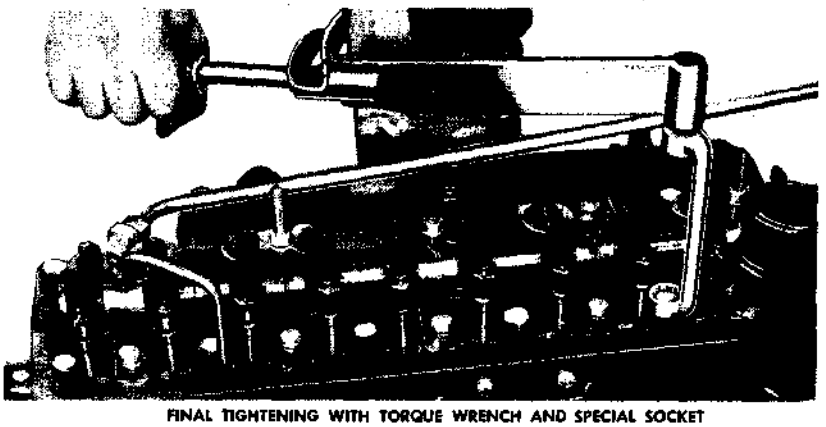
(11) RETIGHTEN CYLINDER HEAD CAP SCREWS. After engine has warmed up, check tightness of cylinder head cap screws (70 ft-lb) following sequence shown in figure 64. Recheck valve clearance and install valve cover. Install ventilator tube to cover and to ventilator valve.

80. OIL PAN.

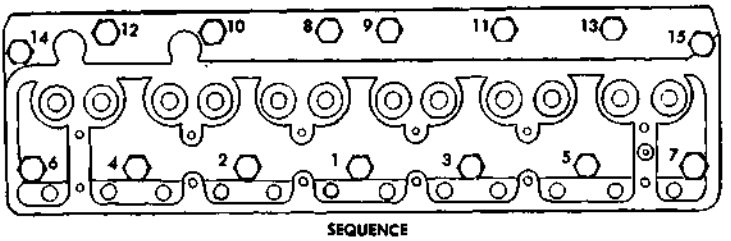
a. Description. The deep sump oil pan assembly comprises an oil pan, sump-like cover, and an oil cleaner through which the oil is circulated. The oil cleaner extends into the cover, however, it is attached to the oil pan. Do not attempt to remove oil pan and cover as an assembly. Such an attempt will damage cleaner.

b. Draining Pan (fig. 65). Remove drain plug assembly. Thoroughly clean screen and deflector before reinstalling. Check condition of plug gasket (GM-2137876).

c. Oil Pan Cover Gasket Replacement. Remove drain plug assembly. Remove cover attaching screws (fig. 66). Cover may then be lowered and gasket (GM-2137800) replaced.



FINAL TIGHTENING WITH TORQUE WRENCH AND SPECIAL SOCKET



SEQUENCE

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Figure 64—Final Tightening (Torque Wrench 41-W-3630 With Socket Wrench 41-W-2964-700)

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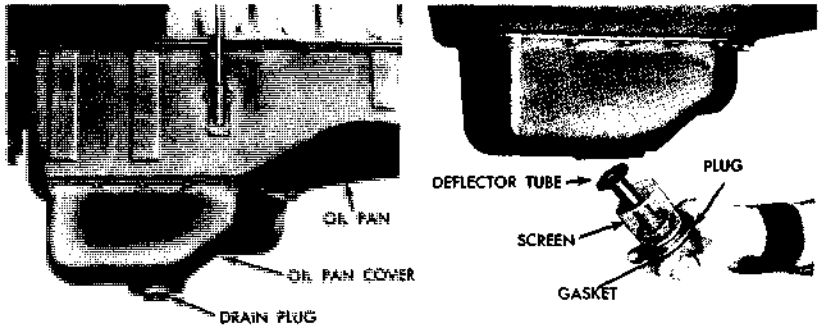

Figure 65—Oil Pan, Cover, and Drain Plug Installed

d. Oil Pan Removal.

(1) REMOVE COVER AND DISCONNECT CLEANER. Remove oil pan cover. Disconnect oil cleaner outlet connection from pump inlet (fig. 65). *Do not remove the oil cleaner from oil pan. The cleaner and oil pan must be removed as an assembly.*

(2) REMOVE UNDERPAN AND EXTENSION. Remove four cross-recessed screws which attach underpan to flywheel housing. Remove two cross-recessed screws which attach extension to housing.

(3) REMOVE OIL PAN AND CLEANER. Remove oil level indicator tube at pan. Loosen oil pan attaching screws alternately. Remove screws in same manner while supporting pan. Lower pan together with cleaner carefully.

e. Oil Pan Installation.

(1) PRELIMINARY INSTRUCTIONS. Clean cover and oil pan with dry-cleaning solvent. Discard all gaskets.

(2) INSTALL GASKETS AND SEALS. Install new right (GM-6107364) and left (GM-6107365) side oil pan gaskets on block with gasket cement. Carefully position front and rear seals (GM-2071435) (gaskets) in grooves of main bearing caps.

(3) INSTALL OIL PAN ASSEMBLY. Carefully position oil pan, making certain that front and rear seals in bearing cap grooves are not tilted or pushed out of place. Secure oil pan in position with two screws and lock washers on each side of oil pan. Install balance of cross-recessed screws finger-tight, then install the four cap screws and lock washer, one at each side of front and rear bearing caps. Install oil cleaner outlet line connection to oil pump inlet and tighten securely. Tighten screws firmly.

(4) INSTALL FLYWHEEL UNDERPAN AND EXTENSION. Position and install extension on flywheel housing with two cross-recessed screws and lock washers. Tighten screws securely. Position and install flywheel underpan to flywheel housing, with four cross-recessed screws and lock washers, then tighten screws firmly.

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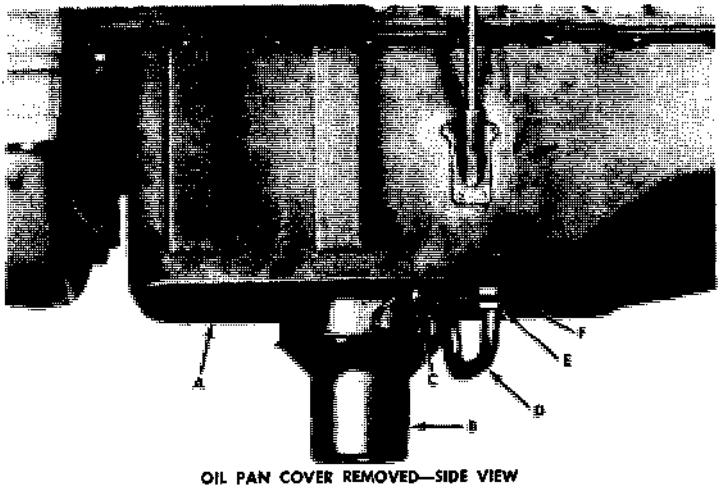
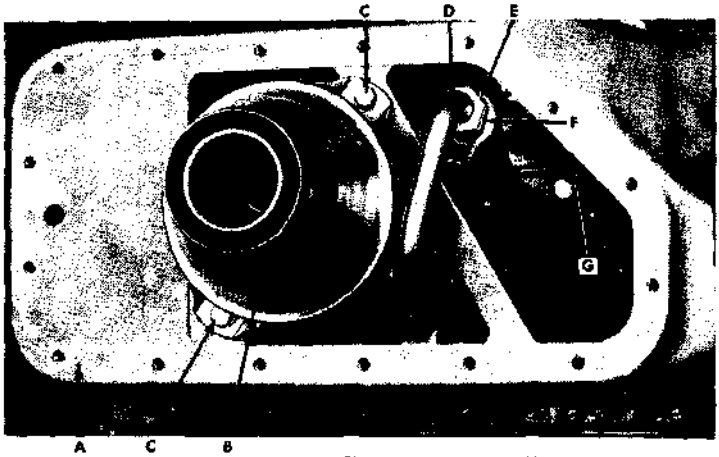


OIL PAN COVER REMOVED—SIDE VIEW



OIL PAN COVER REMOVED—BOTTOM VIEW

A OIL PAN
B OIL CLEANER ASSEMBLY
C CAP SCREW
D OIL CLEANER TO PUMP TUBE
E TUBING NUT
F TUBING NUT CONNECTOR
G OIL PUMP ASSEMBLY

RA PD 332902

Figure 66—Oil Pan Cover Removed

(5) INSTALL OIL PAN COVER. Install a new gasket (GM-2137800), using shellac, on under side of oil pan, then install oil pan cover less drain plug assembly.

(6) INSTALL DRAIN PLUG ASSEMBLY. Clean screen, deflector tube, plug. Use new gasket (GM-2137876). Make certain that screen is in good condition. Install drain plug assembly in oil pan cover and tighten securely. Install oil level indicator tube. Refill crankcase with proper lubricant.

ES18-002672 0315

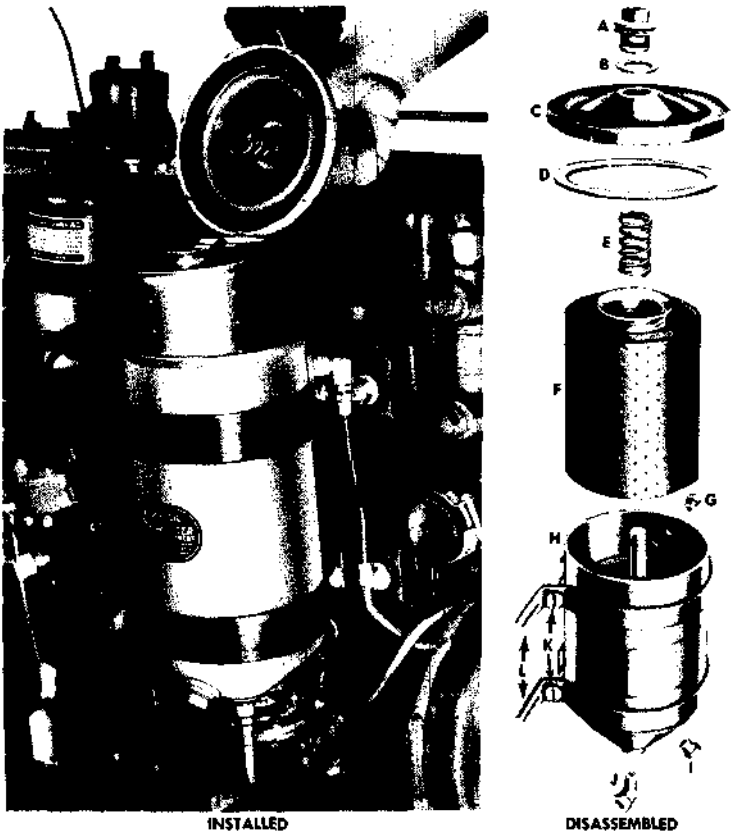
ENGINE DESCRIPTION, DATA, MAINTENANCE, AND ADJUSTMENT ON VEHICLE

81. OIL FILTER

a. Description. The replaceable element type oil filter is mounted on right-hand side of engine. A portion of the oil passing through the valve rocker arm oil line is directed through the oil filter where foreign elements are absorbed. Oil filtered in this manner is then returned directly to the engine oil pan through the fuel pump mounting.

b. Oil Filter Element Replacement (fig. 67).

(1) REMOVE ELEMENT. Remove attaching nut and lock washer and remove cover with gasket and spring. Remove drain plug and drain oil. Oil filter element may now be removed. Clean oil filter



A COVER STUD NUT
B NUT GASKET
C FILTER COVER
D COVER GASKET
E COVER SPRING
F ELEMENT
G INLET TUBE CONNECTOR
H SHELL AND STUD
I DRAIN PLUG
J OUTLET TUBE CONNECTOR
K CLAMP BOLT
L FILTER CLAMP

RA PD 332931

Figure 67—Oil Filter Installed and Disassembled

body and cover with clean rag dipped in dry-cleaning solvent. Wipe all parts dry with a clean cloth.

(2) INSTALL ELEMENT. Install drain plug in bottom of oil filter. Install new filter element [(GM-1595502) G104-15-69149] in oil filter body (with a new cover gasket (GM-1504233) in place). Install spring and cover with gasket, using cover nut and gasket [(GM-853269) G150-01-94055].

c. **Filter Assembly Replacement** (fig. 67). Remove four filter clamp to bracket screws. Disconnect inlet (GM-2137793) and outlet [(GM-2136146) G501-04-07830] tubes at bottom of filter at filter. Withdraw filter and clamp as an assembly. Loosen upper and lower clamp screws to remove filter from clamp. Reinstall in reverse manner.

82. CRANKCASE VENTILATION SYSTEM.

a. **Description.** The ventilation of the crankcase, and the removal of fuel and water vapors within the crankcase are accomplished by the circulation of air actuated by manifold vacuum. Air is drawn into crankcase through breather filter (at oil filler tube) and after circulating through the engine, the air is drawn upward and out of the engine through the valve rocker arm cover, entering combustion

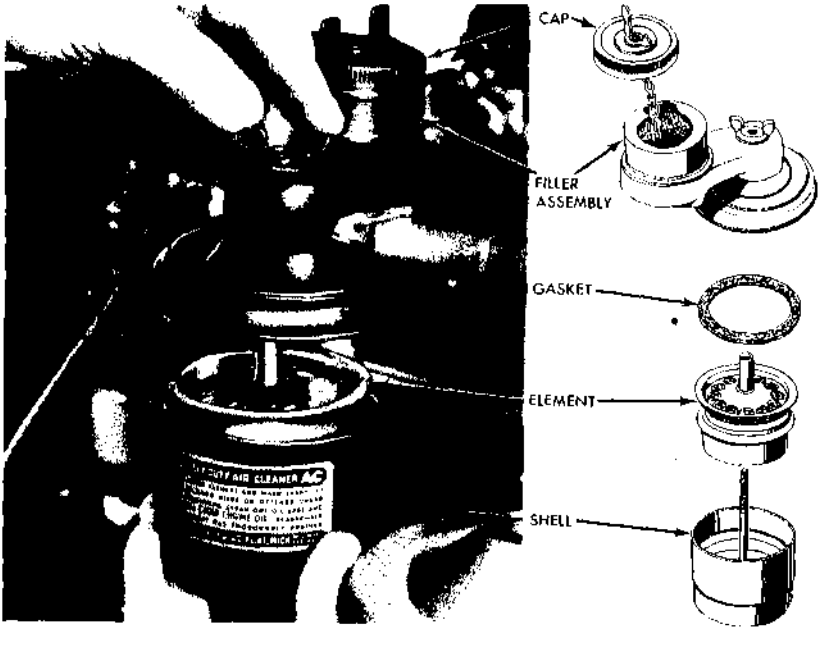


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Figure 68—Crankcase Vent Cleaner

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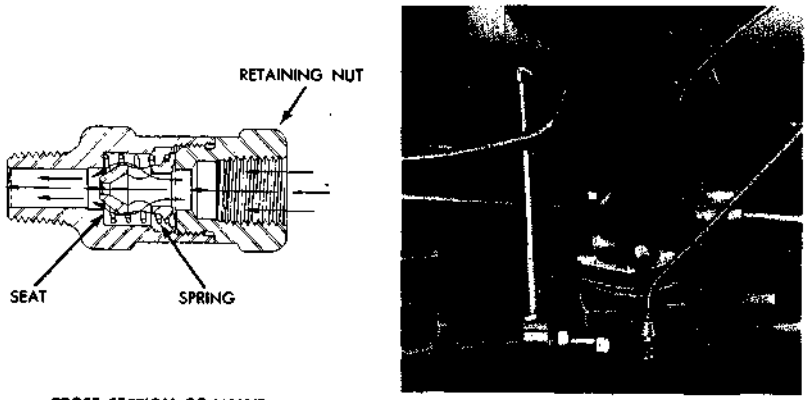

Figure 69—Crankcase Vent Tube and Valve

chamber of engine through intake manifold. The manifold vacuum tube is connected to a fitting at the center of the valve rocker arm cover. The opposite end of the tube is connected to a fitting installed at the center of the intake manifold and contains a spring loaded plunger type valve which acts as restriction for vapor flow.

b. Cleaning Ventilator Cleaner (fig. 68). Loosen wing nut, then withdraw body and element. Clean filter element and reservoir in dry-cleaning solvent and permit element to drain. Fill reservoir with seasonal grade engine oil. Dip element in same oil and allow it to drain. Check condition of breather shell gasket [(GM-1543016) G501-01-94009]. Insert element in reservoir and reinstall to adapter. Tighten wing nut firmly. Check condition of oil filler cap gasket.

c. Ventilator Tube and Valve Removal (fig. 69). Disconnect tube at rocker arm cover fitting and at valve adapter elbow. Remove valve from intake manifold tee fitting. Remove nut from valve body which permits removal of restrictor valve and spring from body. Place all valve parts in dry-cleaning solvent to loosen accumulated foreign matter. Blow parts dry and clean, using compressed air. Install spring and restrictor valve inside valve body and thread nut into body. Tighten nut securely.

d. Ventilator Tube and Valve Installation. Apply anti-seize, mica-base compound to male threads of valve. Install valve on intake manifold tee. Install tube connection on valve elbow finger-tight. Install opposite end of tube on valve rocker arm fitting, making certain that tube is alined properly, then tighten connections firmly.

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TRUCK, 2½-TON, 6 x 6

Section XV

ENGINE REMOVAL AND INSTALLATION

83. GENERAL.

a. Operation Sequence. Removal and installation procedures outlined in this section are the result of actual try-out. Sequence of the operations are such as will permit the use of several mechanics if necessary, to accomplish the various disconnect operations without interference. One mechanic may perform disconnect operations; however, two men are required when the actual dismounting and mounting operations are accomplished.

b. Facilities Required. A chain hoist, suitable hoist support or A-frame, engine sling (41-S-3832-7), and a hydraulic jack are required, in addition to regular mechanic's tools.

84. REMOVAL.

a. Preliminary (Key letters in text refer to fig. 70). Raise hood and disconnect hood bracket (B) and bond straps (A) so that hood can be rested against windshield. Disconnect dash to hood side panel bond straps (C) and remove right and left side panels. Drain cooling system at radiator and cylinder block. Drain oil from crankcase and transmission. Disconnect cranking motor cable from battery.

b. Front of Engine.

(1) DISCONNECT RADIATOR HOSES. Disconnect radiator upper and lower hoses. Open clips which attach front wiring harness to upper portion of radiator.

(2) DISCONNECT BRUSH GUARD. Remove six bolts, nuts, and internal-external toothed lock washers which attach brush guard to right- and left-hand fenders, three at each fender. Remove eight bolts, nuts, and internal-external toothed lock washers which attach brush guard to front right- and left-hand side panels, four at each side. Remove two nuts, bolts, and internal-external toothed lock washers (Z) which attach two radiator support braces to radiator support, one at each side of radiator.

(3) DISCONNECT RADIATOR AND FRONT ENGINE SUPPORT BOLTS. Remove two nuts and internal-external toothed lock washers which attach bond straps to front of radiator bottom tank. After straps are removed, reinstall nuts and washers on studs finger-tight. Remove two nuts, a washer, and spring from each radiator support bolt. Remove cotter pins, castellated nuts, and lock washers from front engine support bolts (fig. 72). Disconnect two frame to engine oil pan bond straps (V) from engine.

(4) REMOVE RADIATOR TIE ROD. Remove two nuts and internal-external toothed lock washers from tie rod at rear side of dash. Remove two screws and internal-external toothed lock washers attaching tie rod to radiator support. Lift tie rod up, pull forward, and remove from vehicle.

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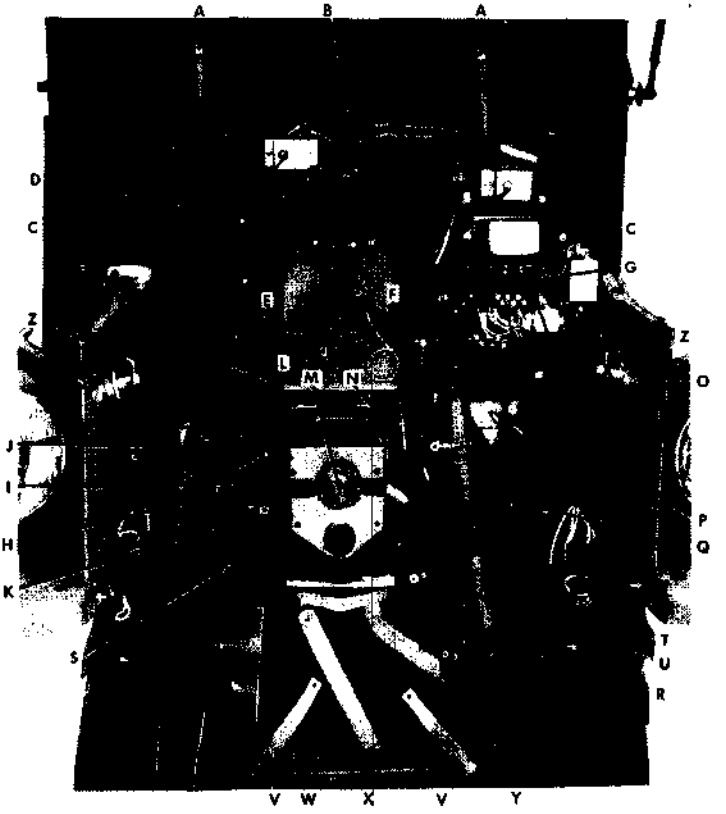
ENGINE REMOVAL AND INSTALLATION

(5) REMOVE BRUSH GUARD AND RADIATOR ASSEMBLY. Remove brush guard and radiator as an assembly by pulling assembly away from front of engine and upward away from front crossmember.

c. Right-hand Side of Engine.

(1) DISCONNECT FUEL LINES. Disconnect flexible tube at fuel pump. Disconnect metal line at rear of fuel filter (H), then spring



A DASH TO HOOD BOND STRAPS
B HOOD BRACKET
C DASH TO HOOD SIDE PANEL BOND STRAPS
D IGNITION COIL FILTER WIRE
E HAND THROTTLE CONTROL
F CHOKE CONTROL
G WINDSHIELD WIPER TUBE
H TANK TO FUEL FILTER LINE
I HYDROVAC VACUUM LINE
J CRANKING MOTOR TO AMMETER CABLE
K BATTERY TO CRANKING MOTOR CABLE
L DASH TO VALVE ROCKER ARM COVER BOND STRAP
M TRANSMISSION MAIN DRIVE GEAR SHAFT
N HEAT INDICATOR THERMAL UNIT
O ENGINE TO OIL PRESSURE GAGE TUBE
P GENERATOR TERMINAL WIRES
Q BRAKE PEDAL ROD
R EXHAUST PIPE
S RIGHT-HAND REAR ENGINE SUPPORT INSULATOR ASSEMBLY
T LEFT-HAND REAR ENGINE SUPPORT INSULATOR ASSEMBLY
U FRAME TO FLYWHEEL HOUSING BOND STRAP
V FRAME TO ENGINE OIL PAN BOND STRAPS
W ENGINE FRONT SUPPORT ASSEMBLY
X RADIATOR CUSHION
Y HORN TERMINAL WIRES
Z RADIATOR SUPPORT BRACES

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Figure 70—Items Which Must Be Disconnected to Remove Engine

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line toward frame side rail to prevent damage to line during engine removal.

(2) REMOVE FUEL FILTER. Remove two bolts, nuts, and lock washers which attach fuel filter to bracket and remove filter.

(3) DISCONNECT CRANKING MOTOR TERMINAL WIRES. Remove wires and cable from cranking motor (J and K). Reinstall washer and nut on terminal finger-tight.

(4) DISCONNECT HYDROVAC VACUUM LINE. Loosen clamp bolt and disconnect flexible vacuum line (I) at rear of cranking motor, just above flywheel housing.

(5) DISCONNECT IGNITION COIL WIRE. Remove nut which secures wire (D) to ignition coil positive (+) terminal and remove wire. Reinstall nut on coil terminal finger-tight, and loop wire around hood hinge on cowl. Disconnect radio suppression bond strap (L) from valve rocker arm cover.

d. Left-hand Side of Engine.

(1) REMOVE AIR CLEANER.

(a) *Clamp-on Type.* Loosen clamp bolt at throat of air cleaner, loosen nut at top of air cleaner brace, then lift air cleaner assembly from carbureter.

(*b*) *Flange Type.* Unscrew wing nut at center of cover, then lift cleaner off center tube.

(2) DISCONNECT CARBURETER LINKAGE AND WINDSHIELD WIPER TUBE. Disconnect choke control (F), and hand throttle control (E) from carbureter. Disconnect flexible windshield wiper tube (G) from metal tube which is attached to intake manifold.

(3) DISCONNECT WIRES FROM HORN AND GENERATOR. Disconnect wires (Y) from horn, then reinstall screws and washers finger-tight. Disconnect wires (P) from generator, then reinstall nuts and washers on respective terminals.

(4) DISCONNECT EXHAUST PIPE AND ACCELERATOR ROD. Remove bolts and nuts which attach exhaust pipe (R) to manifold, then separate pipe and flange from manifold. Remove cotter pin which secures accelerator rod in carbureter control lever and remove rod from lever.

(5) REMOVE THERMAL UNIT. Unscrew heat indicator thermal unit (N) from cylinder head. Care must be used that unit and line are not damaged.

(6) DISCONNECT OIL GAGE TUBE. Disconnect flexible oil gage tube (O), using two wrenches to prevent twisting flexible tube.

e. Inside of Cab.

(1) DISCONNECT ACCELERATOR PEDAL AND CRANKING MOTOR BUTTON. Remove cotter pin and clevis pin from accelerator pedal, then free rod from pedal. Reinsert pin in pedal and install cotter pin temporarily. Unscrew button from cranking motor cross shaft lever.

(2) REMOVE TOE BOARD PLATE. Remove screws and washers which attach toe board plate around steering column and clutch and brake pedals and remove plate and seal assembly.

(3) REMOVE FLOOR AND TOE BOARDS. Remove 12 floor board cap screws and external toothed lock washers. Remove five toe board cap screws and external toothed washers. Place transfer case shift

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levers in neutral and pull hand brake lever back; then lift seal off over levers. Move shift levers as necessary and lift out floor board. Lift toe board from cab.

(4) REMOVE CRANKING MOTOR CROSS SHAFT ASSEMBLY. Remove cotter pin and washer from cross shaft lever to cranking motor lever rod. Disconnect cranking motor lever pull back spring. Remove four cap screws and lock washers which attach cranking motor cross shaft assembly on clutch housing. Lift cross shaft and two spacer blocks away from housing. Remove cotter pin and clevis pin attaching brake pedal pull rod to brake pedal to disconnect rod from brake pedal.

f. Under Vehicle.

(1) REMOVE CLUTCH AND BRAKE PEDAL AND BRACKET ASSEMBLY. Disconnect clutch pedal pull back spring from adjusting link and unhook pedal from link. Remove two cap screws and lock washers which attach spring clip to clutch housing. Remove three cap screws and lock washers which attach pedal and bracket assembly to clutch housing and transmission and lift out pedal and bracket assembly.

(2) REMOVE FLYWHEEL UNDERPAN. Remove four screws and lock washers which attach flywheel underpan to clutch housing, then disconnect radio suppression bond strap (U).

(3) REMOVE REAR MOTOR SUPPORT BOLTS. Remove bolts on right- and left-hand sides of engine at rear motor support brackets (fig. 72).

(4) POSITION JACK UNDER TRANSMISSION. Place jack under transmission. Position jack so that it will not interfere with engine removal.

(5) DISCONNECT TRANSMISSION. Remove lock wire from heads of two clutch housing to transmission lower cap screws, accessible from inner side of housing. Remove both cap screws, then remove two clutch housing to transmission upper cap screws.

g. Withdraw Engine.

(1) Install engine sling (41-S-3832-7) on engine. Take up tension on hoist, and raise transmission jack slightly to take load.

(2) Hoist engine in short stages and at same time raise transmission slightly to prevent weight of transmission resting on transmission main drive gear shaft (M).

(3) Continue to raise engine slowly and at same time pull engine toward front to clear transmission main drive gear shaft and cowl. CAUTION: *Do not permit clutch release bearing and support assembly to drop from release fork.* When engine is raised enough to clear side support brackets, continue to hoist until oil pan will clear front crossmember. Spring front side panels apart slightly to clear engine and pull engine out from front of chassis (fig. 71).

85. INSTALLATION.

a. Preliminary Instructions (Key letters in text refer to fig. 70). Before installing engine in chassis, the engine front support assembly (W) must be removed and inspected for fit in lower retainer and upper plate.

(1) REMOVE ENGINE FRONT SUPPORT ASSEMBLY. Remove cotter pin and nut from two bolts attaching engine front support assembly

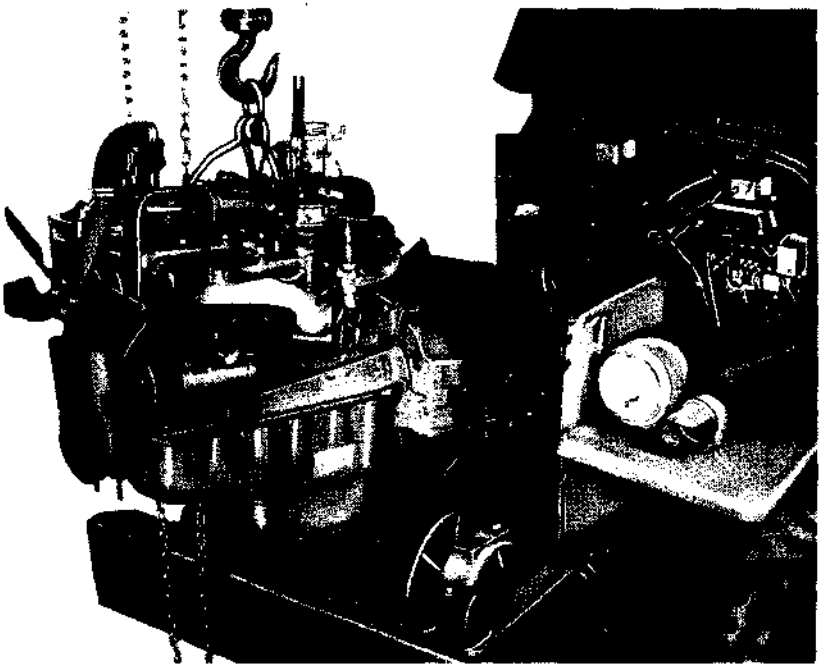

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Figure 71—Engine Removal or Installation

to front crossmember. Drive bolts up out of crossmember and support assembly and lift assembly off crossmember.

(2) CHECK CLEARANCE (fig. 72). Fit front support assembly into lower retainer and position upper plate on top. With parts held together firmly, determine if rubber support assembly fits tight between upper plate and lower retainer. Also check engine mounting bushings to be sure they project above upper plate. If rubber support is loose between upper plate and lower retainer, or if bushings do not project above upper plate, install a new support assembly. Check clearance between upper plate and lower retainer at point indicated in figure 72. If clearance is more than 5/64 inch, a new lower retainer must be installed.

(3) INSTALL ENGINE FRONT SUPPORT ASSEMBLY. Place front support assembly in lower retainer and position upper plate on top. Position the assembly on front crossmember with curved edge of upper plate toward front. Insert two bolts down through upper plate, support assembly, lower retainer, and crossmember. If used support assembly is being reinstalled, install nuts on bolts, tighten firmly, and install cotter pins. If new support assembly is being installed, clearance between upper plate and lower retainer must be checked before bolts are tightened (fig. 72). If clearance is less than 3/64 inch, file or grind top of lower retainer until proper clearance is obtained. Do not use shims. If clearance is more than 5/64 inch, install

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new lower retainer. Tighten nuts and install cotter pins. Position oil shield over front support assembly.

b. Mount Engine in Chassis. Make certain that insulators (S and T) on rear engine supports are in good condition before installing engine. Position and secure lifting hooks on engine assembly so as to properly balance engine, then lift and position engine over chassis. Carefully lower engine assembly until clutch housing recess is properly alined with transmission main drive gear shaft. Make sure clutch release bearing and support assembly is in place in clutch release fork. Push engine assembly carefully and firmly toward rear of vehicle; at the same time guide transmission shaft into clutch release bearing. While rocking engine slowly from side to side, push engine toward transmission until shaft splines engage hub of clutch disc. Lift or lower engine as necessary to seat shaft in clutch disc hub properly. Push engine assembly toward transmission until clutch housing face seats solidly against transmission case. Lower jack located under transmission, while lowering engine assembly in place.

(1) ATTACH TRANSMISSION TO CLUTCH HOUSING. Install and tighten two clutch housing to transmission lower cap screws, then two upper cap screws and lock washers. Insert lock wire through heads of lower cap screws, draw wire taut, and twist ends securely.

(2) INSTALL REAR MOTOR SUPPORT BOLTS. Aline rear motor support insulators (S and T) with brackets. With a lock washer installed over end of bolt, carefully screw each bolt into place (fig. 72). Make

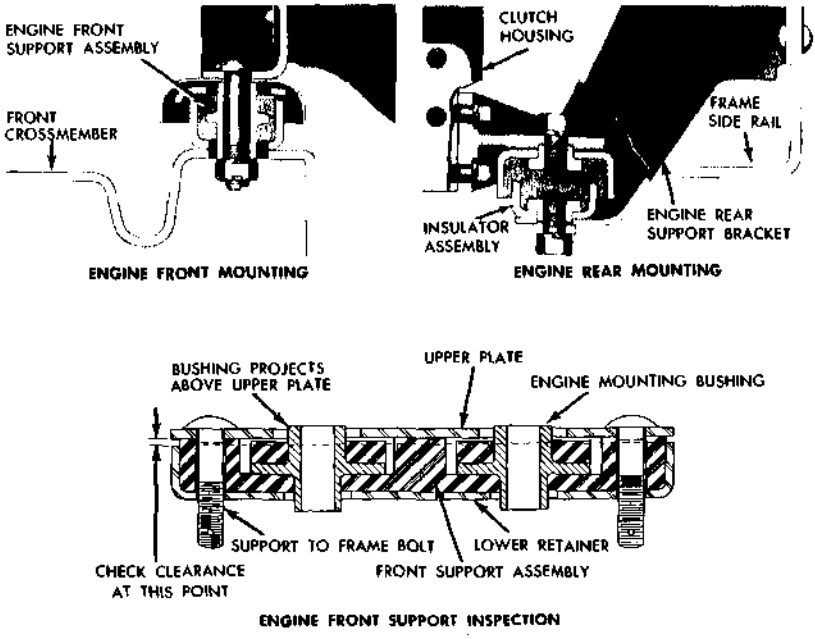

Figure 72—Engine Front and Rear Mounting

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certain that bolt threads are not crossed during this operation. Tighten bolts firmly.

(3) INSTALL FLYWHEEL UNDERPAN. Position and aline flywheel underpan on clutch housing. Attach pan in place with four screws and lock washers. Attach radio suppresssion bond strap (U) and tighten screws firmly.

(4) INSTALL CLUTCH AND BRAKE PEDAL AND BRACKET ASSEMBLY. Position pedal and bracket assembly against clutch housing and transmission, then install three cap screws and lock washers which attach bracket. Tighten cap screws firmly. Hook adjusting link onto clutch pedal and hook clutch pedal pull back spring onto adjusting link.

d. Left-hand Side of Engine.

(1) INSTALL THERMAL UNIT. Screw thermal unit (N) into cylinder head. Make certain that line attached to unit is not twisted during installation.

(2) CONNECT OIL GAGE TUBE. Connect flexible oil line to oil pressure gage tube (O). Use two wrenches while tightening connection to prevent twisting. Insert accelerator rod end in carbureter control lever, which is attached to cylinder block, then insert cotter pin in rod.

(3) CONNECT EXHAUST PIPE. Place flange seal and new gasket on top of exhaust pipe flange (R) and raise exhaust pipe flange up against exhaust manifold. Insert three bolts up through exhaust pipe flange and manifold and install nuts on bolts. Tighten nuts alternately and evenly, then install Palnuts on bolts.

(4) INSTALL WIRES ON HORN AND GENERATOR. Remove screws and lock washers from horn terminals, then position wires (Y) and reinstall screws and lock washers. Tighten screws firmly. Remove nuts and internal-external toothed lock washers from generator wire terminals and install wires (P) on respective terminals. Attach wires with washers and nuts.

(5) CONNECT CARBURETER LINKAGE AND WINDSHIELD WIPER TUBE. Install choke control housing (F) in clamp and insert wire through swivel block on choke control lever. Hook carbureter control rod through throttle lever. Install hand throttle control housing (E) in clamp and insert wire through hole in carbureter control rod. Install stop collar on end of wire and tighten screw in a collar. Install windshield wiper tube (G) on vacuum line from intake manifold.

(6) INSTALL AIR CLEANER.

(*a*) *Flange Type.* Position cleaner assembly over center tube attached to carbureter. Thread wing nut onto stud and tighten snugly.

(*b*) *Clamp-on Type.* Place air cleaner on top of carbureter and at the same time aline bolt at side of air cleaner in slot of air cleaner brace. Press assembly in place and tighten clamp bolt and brace nut.

e. Right-hand Side of Engine.

(1) INSTALL COIL WIRE AND VALVE COVER BOND STRAP. Attach radio suppression bond strap (L) on valve rocker arm cover rear stud with internal-external toothed lock washer and nut. Tighten nut firmly. Install wire (D) on ignition coil positive (+) terminal.

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(2) CONNECT CRANKING MOTOR TERMINAL WIRES. Remove nut and washer from cranking motor terminal, and install cable and wires (J and K) on terminal. Attach wires on terminal with nut and washer. Tighten nut firmly.

(3) INSTALL FUEL FILTER. Position fuel filter on bracket, and attach with two bolts, nuts, and lock washers.

(4) CONNECT FUEL LINES. Connect flexible tube at fuel pump. Position and connect metal line (H) at rear of filter.

(5) CONNECT HYDROVAC VACUUM LINE. Insert metal tube in flexible hose (I), position hose clamp, then tighten clamp bolt firmly.

f. Front of Vehicle.

(1) INSTALL BRUSH GUARD AND RADIATOR ASSEMBLY. Aline shims and radiator cushion with holes in frame front crossmember; then apply one or two short pieces of tape to hold cushion and shims in alinement when radiator assembly is installed. Carefully place brush guard and radiator assembly in position on front crossmember between the two side panels.

(2) ATTACH BRUSH GUARD. Install bolts which attach radiator support braces (Z) to radiator support; then install internal-external toothed lock washers and nuts. Install six bolts, nuts, and internal-external toothed lock washers (one under head of each bolt and nut) attaching brush guard to fenders (three on each side). Install eight bolts, nuts, and internal-external toothed lock washers (four at each side) which attach brush guard to right- and left-hand side panels in the same manner. Tighten all nuts firmly.

(3) CONNECT RADIATOR HOSES AND INSTALL TIE ROD. Install upper and lower radiator hoses, position hose clamps, and tighten clamp bolts firmly. Screw inner (forward) nuts well up on ends of tie rod. Place new internal-external toothed lock washers over ends of tie rod and insert ends of tie rod through holes in dash. Attach front end of tie rod to radiator support with two screws and new internal-external toothed lock washers. Tighten screws firmly.

(4) ATTACH RADIATOR AND FRONT ENGINE SUPPORT BOLTS. Install in following order a spring, washer, and two nuts on each radiator support bolt. Tighten nuts until springs are compressed, then back off nuts three full turns to provide proper tension on springs. Tighten lock nuts securely. Install lock washers and castellated nuts on front motor support bolts. Tighten nuts and install cotter pins. Attach radiator bond straps to bottom of radiator. Attach bond straps (V) to front of engine oil pan.

(5) INSTALL SIDE PANELS AND CONNECT HOOD. Attach left- and right-hand rear side panels with bolts, nuts, and internal-external toothed lock washers. Attach radio suppression bond straps (C). Position and install hood bracket (B) on cab cowl. Attach two radio suppression bond straps (A) with screws and internal-external toothed lock washers.

g. Inside Cab.

(1) INSTALL NUTS ON RADIATOR TIE ROD. Install nuts and new internal-external toothed lock washers on ends of tie rod. Adjust nuts on each side of dash to obtain a ¾-inch clearance between fan blades

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and bottom of radiator. After correct adjustment is obtained, tighten nuts firmly.

(2) INSTALL CRANKING MOTOR CROSS SHAFT ASSEMBLY. Position spacer blocks and cross shaft assembly on top of clutch housing. Insert cap screw, with lock washer installed, through oil pressure line clip, then through cross shaft bracket and screw into clutch housing. Install other three cap screws and lock washers which attach cross shaft assembly to clutch housing and tighten firmly. Attach brake pedal pull rod to brake pedal with clevis pin and cotter pin.

(3) INSTALL TOE BOARD AND FLOOR BOARD. A visual check must be made before toe board and floor board are installed to ascertain that all connections have been made and that all bolts, etc., are in place and tightened securely. Position toe board in cab and attach with five cap screws and external toothed lock washers. Tighten cap screws firmly. Aline levers in cab as necessary and install floor board. Attach floor board with 12 cap screws and external toothed lock washers. Install floor seal over ends of hand brake and transfer case levers.

(4) INSTALL TOE PLATE. Carefully place toe plate and seal in position around pedals and steering column, aline screw holes, and attach with screws and lock washers.

(5) INSTALL ACCELERATOR PEDAL. Remove cotter pin and clevis pin from pedal, position accelerator rod under pedal, insert clevis pin through pedal and rod and install cotter pin.

h. Final Operations. Fill cooling system, crankcase, and transmission. Connect cranking motor cable to battery.

(1) Make following adjustments.
(*a*) Clutch pedal free-travel (par. 150).
(*b*) Brake master cylinder linkage (par. 187).
(*c*) Brake pedal to toe board clearance (par. 186).
(*d*) Transmission strut rod adjustment (par. 155).
(*e*) Transfer case control rod adjustment (par. 160).
(*f*) Choke control (par. 95).
(*g*) Throttle control (par. 95).
(*h*) Adjust fan belt tension (par. 108).
(*i*) Polarize generator (par. 117).
(*j*) Tune-up engine (par. 76).

Section XVI

IGNITION SYSTEM

86. DESCRIPTION AND DATA.

a. Description (fig. 73). The ignition system consists of the source of power (battery or generator), ignition switch, ignition coil, distributor, condenser, spark plugs, and high and low tension wiring. The ignition system functions to produce and deliver high voltage surges to the correct spark plug at the correct intervals and with

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Figure 73—Ignition System Units Installed

correct timing to the engine. Each high voltage surge produces a spark at the spark plug gap to which it is delivered, so that the mixture of air and fuel in the cylinder is ignited.

b. Circuit Description (fig 74). There are two distinct electrical circuits in the ignition system, the *primary* and the *secondary*. When these electrical circuits are kept in mind, as well as the functions of the various units in the system to accomplish these circuits, a better understanding may be had of the operation of the entire system.

(1) PRIMARY CIRCUIT. The primary, or low tension circuit, includes the source of electrical energy (battery or generator), distributor contact points and circuit breaker mechanism, primary circuit of the ignition coil, and condenser.

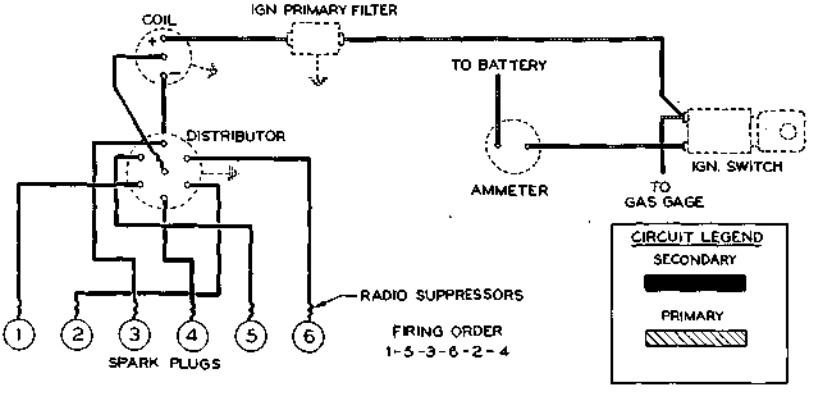

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Figure 74—Ignition System Circuits

(2) SECONDARY CIRCUIT. The secondary, or high tension circuit, includes the secondary circuit of the coil, distributor rotor and cap, high tension wiring, and spark plugs.

c. Data.

(1) DISTRIBUTOR.

Make	Delco Remy
Model	1110135
Breaker point gap	0.018-0.024 in.
Breaker arm tension	17 to 21 oz
Firing order	1-5-3-6-2-4
Initial ignition timing	5 deg before upper dead center

(2) SPARK PLUGS.

Make	AC
Type	44
Size	14MM
Point gap	0.025 in.

(3) IGNITION COIL.

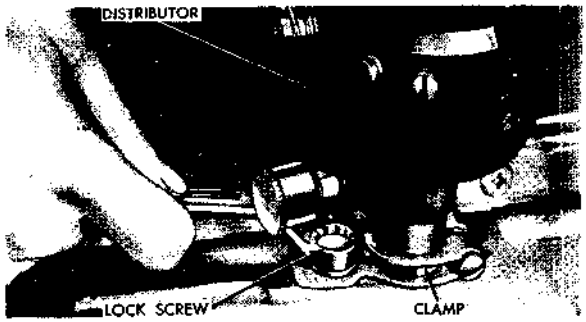
Make	Delco Remy
Model	1115149

87. IGNITION TIMING.

a. Timing the ignition system comprises (1), initial timing—setting of the distributor mechanism to permit opening of the points at correct firing intervals and (2), manual advance—retarding or advancing the point opening to compensate for the various grades of fuel which may be used. These timing factors require checking and adjustment at regular intervals or when performance of engine necessitates such action.

b. Initial Timing.

(1) LOCATE NO. 1 CYLINDER FIRING POSITION. Locate No. 1 cylinder spark plug wire on distributor cap, then place a mark on distributor body opposite No. 1 wire in cap. Remove distributor cap. Clean and adjust point opening if necessary (par. 88).



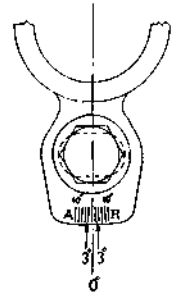


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Figure 75—Manual Advance Adjustment

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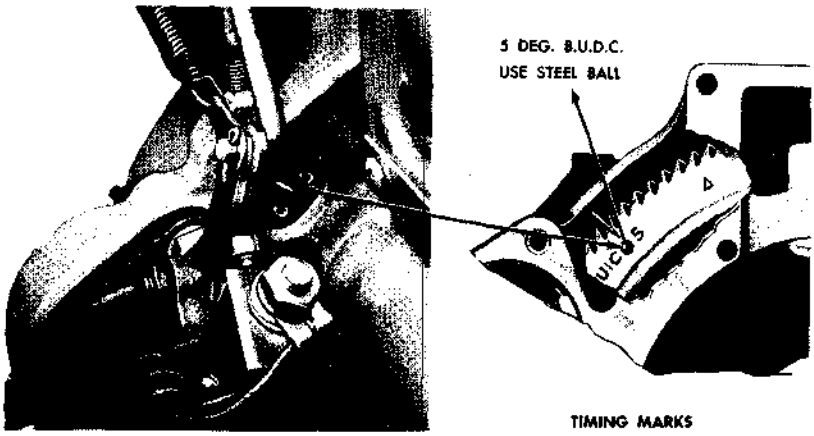

Figure 76—Flywheel Timing Marks

(2) SET MANUAL ADVANCE. Set manual advance at *zero*—halfway between "R" and "A" (fig. 75).

(3) CHECK TIMING. Do not turn ignition switch on. Have someone slowly crank engine and watch timing mark on flywheel (fig. 76). Crank engine slowly until flywheel mark is exactly in line with pointer on flywheel housing. With pointer and flywheel mark lined up, rotor should point toward mark placed on distributor body. Timing should be checked and adjusted by method described in steps (*a*) and (*b*) below.

(a) With Engine Not Running. With flywheel mark exactly in line with pointer and distributor rotor pointing to No. 1 spark plug position, points should just begin to open. Loosen clamp screw (fig. 77) and turn distributor housing in clockwise direction until points close. Disconnect the high tension wire from the coil to the distributor at the distributor cap. Turn on ignition switch and hold the end of the high tension wire ¼ inch from a ground, then turn distributor housing in a counterclockwise direction until a spark jumps the gap between the high tension wire and the ground. When the spark occurs, the points are open; holding the distributor in this position, tighten clamp screw securely. Turn ignition switch off.

(b) With Engine Running. Replace distributor cap. Attach one lead of timing light (41-L-1440) to No. 1 spark plug terminal and other lead to a convenient ground. Start engine and run at idling speed. Direct beam of timing light toward flywheel housing peephole. Timing light flashes make timing mark on flywheel appear stationary. Loosen clamp screw (fig. 77) and move distributor body clockwise or counterclockwise as necessary to synchronize flashes with flywheel mark when it is alined with pointer on flywheel housing. Tighten clamp screw.

c. **Manual Advance Adjustment (fig. 75).**

(1) DRIVE VEHICLE. After engine has been thoroughly warmed up, drive vehicle, using grade of fuel expected to be used in service. Engine should not "ping" or "clatter" excessively under load and full throttle.

(2) ADJUST MANUAL ADVANCE. A slight amount of "ping" is not objectionable. If excessive amount of knock exists, loosen cap screw (fig. 75) and turn distributor body toward "R" on distributor clamp until knock is minimized. Tighten cap screw when adjustment is made. With manual advance set at "zero," engine should perform satisfactorily when 75 octane fuel is used. It will be necessary to retard manual advance approximately three degrees when using 70-72 octane fuel and advance three degrees with 80 octane fuel. Several trials and adjustments may be necessary, as a general rule, to obtain good performance with grade of gasoline used.

88. DISTRIBUTOR, POINTS, AND CONDENSER.

a. Distributor assembly is mounted on the right-hand side of the engine and is driven from the camshaft by spiral gears. The lower end of the distributor drive shaft is tongued and engages a slot on the upper end of the oil pump drive shaft. NOTE: *Some early vehicles were equipped with a radio interference suppressor filter on the distributor. This filter may strike and break the fuel line. If a filter is found, remove and discard it.*

b. **Point Adjustment.**

(1) CLEAN POINTS. Remove distributor cap [(GM-1867722)

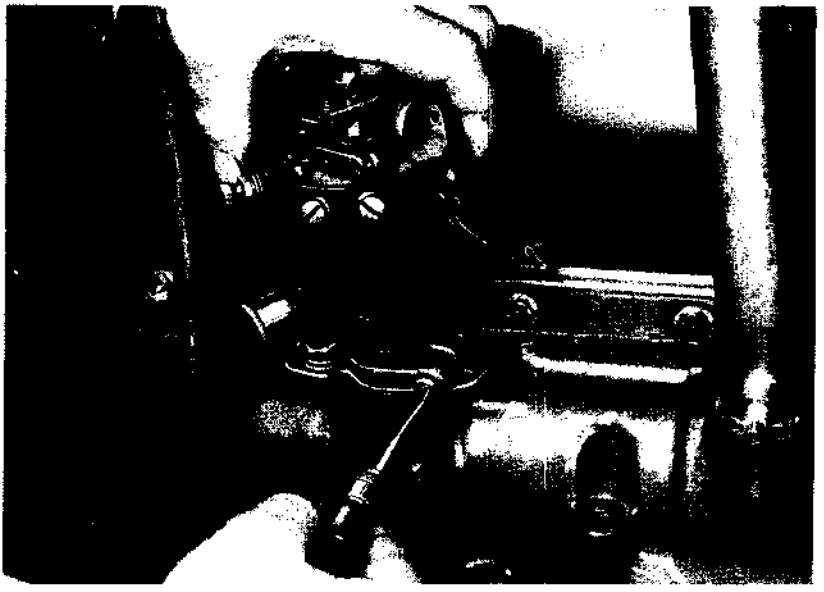

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Figure 77—Initial Timing Adjustment

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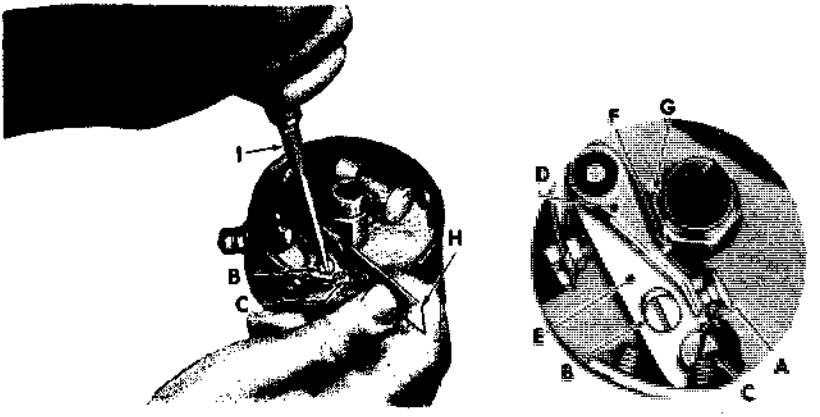

A POINT OPENING
B ECCENTRIC SCREW
C CLAMP SCREW
D BREAKER LEVER
E CONTACT POINT SUPPORT
F FIBRE RUBBING BLOCK
G CAM
H FEELER GAGE
I SCREW DRIVER

RA PD 64554

Figure 78—Distributor Points Installed

G102-04-00420] and rotor [(GM-1883500) G102-01-03121]. Clean points thoroughly, using a fine magneto type file.

(2) SET BREAKER LEVER. Hand crank engine slowly until breaker lever pad rests on a high point of distributor cam.

(a) Check Breaker Arm Spring Tension. With contact spring scale, check tension of arm spring in manner illustrated in figure

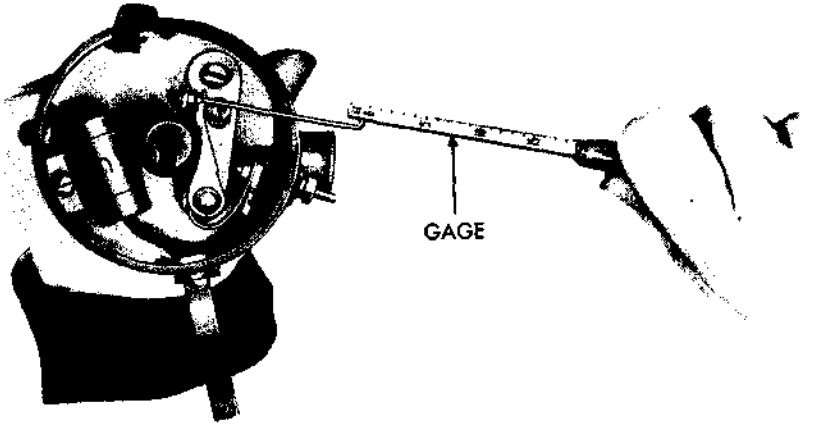

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Figure 79—Testing Breaker Lever Spring Tension

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79. If tension falls below 17 ounces, replace points as described in subparagraphs c and d below.

(b) Gage and Adjust Points (fig. 78). With a feeler gage, measure point opening. If not within 0.018 to 0.024 inch, loosen clamp screw and turn eccentric screw until gap is correct. Tighten clamp screw after adjustment is made. Reinstall rotor and cap.

c. Point Removal (fig. 78).

(1) REMOVE BREAKER LEVER. Remove cap and rotor. Loosen primary terminal nut, then remove condenser pigtail connection from terminal. Pull up on breaker lever and remove from pivot, at the same time removing end of lever spring from primary terminal.

(2) REMOVE CONTACT POINT AND SUPPORT. Remove clamp scew, then lift off contact point and support [(GM-1855720) G85-33-02520] over eccentric screw.

d. Point Installation.

(1) INSTALL CONTACT POINT AND SUPPORT. Place contact point and support assembly in position in distributor over eccentric screw. Install clamp screw and tighten securely.

(2) INSTALL BREAKER LEVER. Place breaker lever over pivot and at the same time, install end of lever spring over terminal. Install condenser pigtail connection over terminal. Tighten terminal nut securely.

(3) CHECK BREAKER LEVER SPRING TENSION. New breaker lever springs are generally stronger than required in operation. Check the tension (17-21 oz) in manner illustrated in figure 79. If neces-

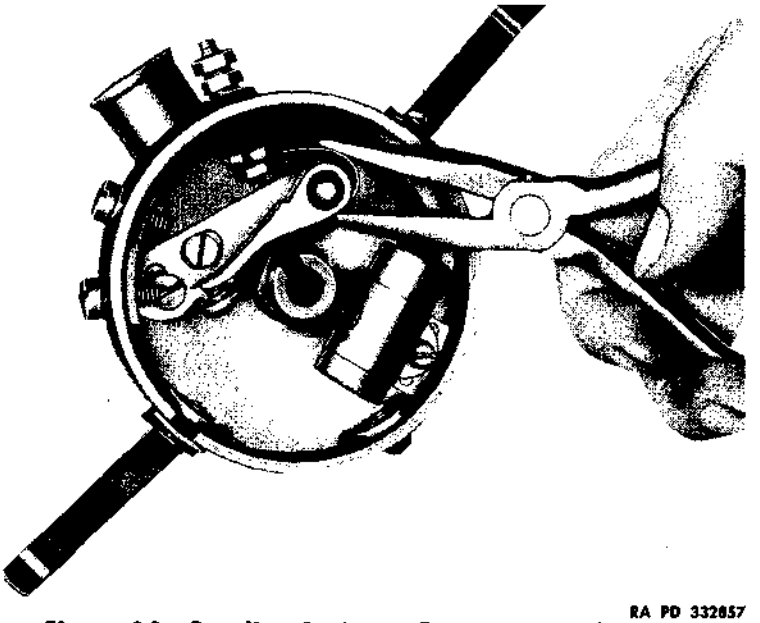

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Figure 80—Bending Spring to Decrease Tension

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sary to decrease pressure, *slightly* bend spring in manner shown in figure 80. To increase point pressure, lever arm must be removed and spring bent away from lever. Avoid excessive distortion of the spring, as only a small change in spring tension is normally required.

(4) ADJUST POINT OPENING. Adjust opening as described in subparagraph b above. Check timing.

e. Condenser Replacement.

(1) REMOVE CONDENSER. Remove distributor cap and rotor. Remove screw and lock washer attaching condenser to breaker plate. Remove nut and washer from primary terminal and remove condenser lead from terminal. Lift condenser [(GM-1869704) G102-15-39899] out of distributor.

(2) INSTALL CONDENSER. Position condenser on breaker plate and attach with screw and lock washer. Place condenser lead on primary terminal and attach with nut and washer. Install rotor and distributor cap.

f. Distributor Assembly Removal.

(1) CRANK ENGINE TO NO. 1 FIRING POSITION (fig. 81). Remove cap and wires. Crank engine until No. 1 piston is ready to fire, i.e., with rotor pointing to No. 1 spark plug wire and flywheel timing mark on position shown in figure 76. Distributor can be removed and new assembly installed readily *while engine remains in this position.* If same distributor is to be reinstalled, mark relative position of No. 1 spark plug wire on body of distributor directly opposite rotor.

(2) LOOSEN HOLD DOWN CLAMP SCREW. Loosen clamp bracket bolt (fig. 77). Lift distributor [(GM-1110135) G501-01-52015] straight up until it disengages from spiral gear. The rotor will turn a few degrees *clockwise* as gear disengages. Mark body opposite *this* rotor position. Lift distributor straight up from engine.

g. Distributor Assembly Installation.

(1) IF ENGINE HAS NOT BEEN CRANKED since removal of distributor (subpar. f (1) above), locate rotor in No. 1 firing position. If assembly is new, the No. 1 position can be determined by mark on the old distributor (subpar. f (1) above), or place the rotor in approximately the position shown in figure 81, then turn rotor slightly clockwise. As distributor is inserted into place, the spiral gear will cause rotor to turn back (counterclockwise). It may be necessary to insert the assembly several times to finally bring rotor to No. 1 firing position.

(2) If engine has been cranked since the removal of distributor, it will be necessary to again place engine with No. 1 piston in firing position. This can be accomplished as follows:

(a) Remove valve rocker arm cover. Hand crank engine and observe movement of No. 1 intake valve (second valve from the front). When it is noticed that intake valve is closing (raising up), continue to crank slowly and at same time watch flywheel timing mark peephole. Crank slowly until flywheel timing pointer is on the steel ball

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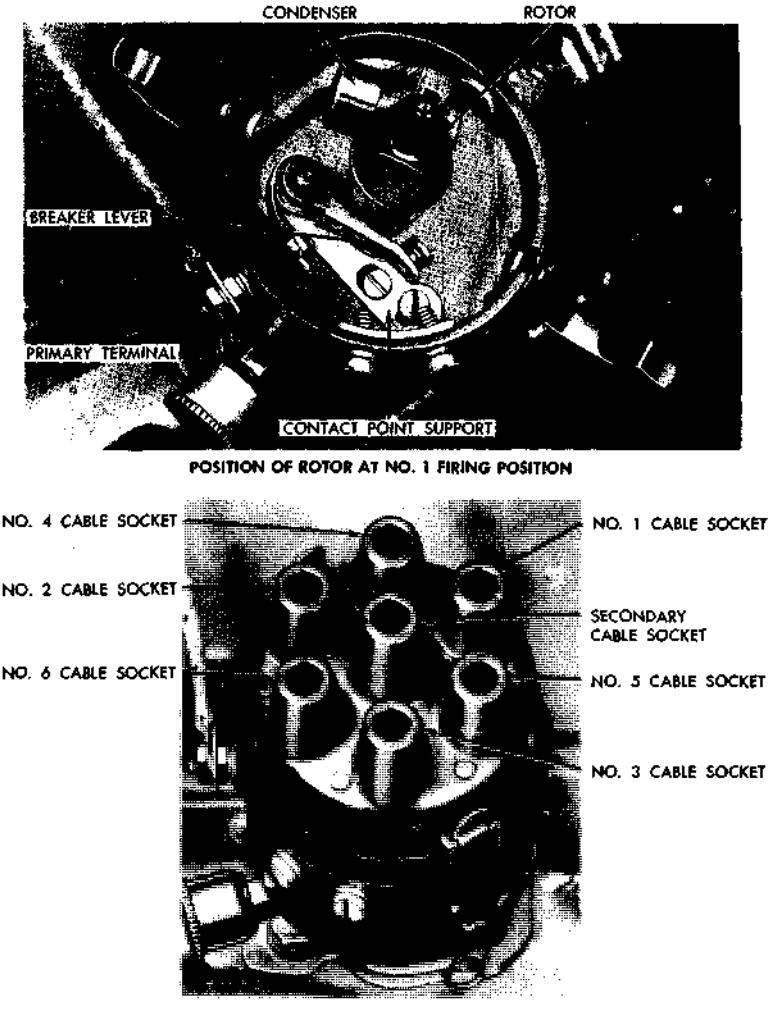

Figure 81—Plug Wire Sequence and Rotor Position

(fig. 76). Engine is then in No. 1 firing position. Position distributor rotor and insert as explained in step (1) above.

(3) CHECK OPERATING POSITION. It is important that a slight clearance be maintained between upper and lower ends of housing as shown in figure 82. When distributor is inserted into operating position, lower end of housing will contact drive gear. Before tightening clamp screw, place finger under the housing and thumb on rotor (fig. 82). While holding rotor down with the thumb, raise housing approximately 1/32 inch. Be sure to equalize clearance at top and bottom. Tighten clamp screw while distributor is in this position.

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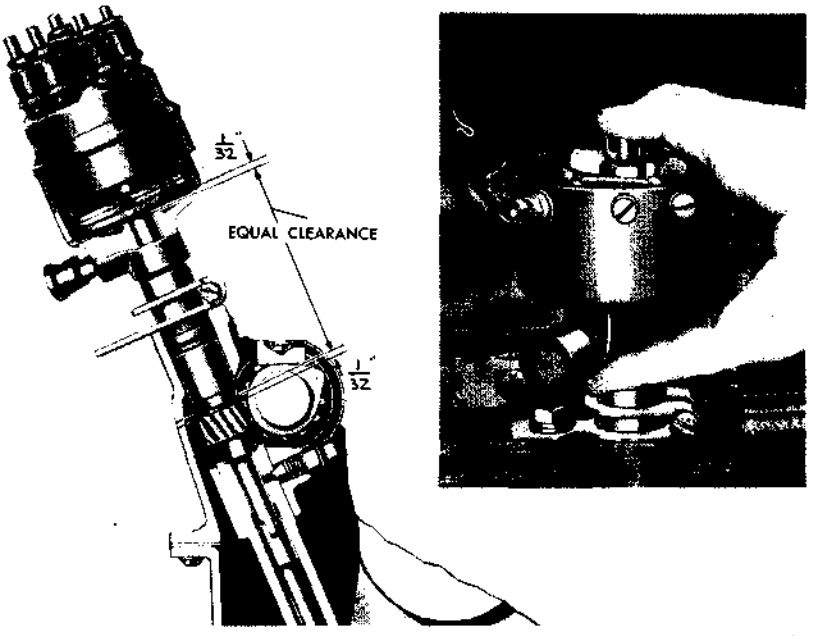

Figure 82—Distributor Operating Position

(4) CHECK POINT OPENING. Check point opening (subpar. **b** above). Install plug wires in correct sequence (1-5-3-6-2-4). Install secondary and primary wires to distributor.

(5) CHECK INITIAL TIMING. Check and adjust initial timing (par. 87 **b**), then adjust manual advance (par. 87 **c**).

89. SPARK PLUGS.

a. Removal. Remove spark plug wire assemblies from each spark plug. Use standard spark plug wrench when removing plugs (GM-1557987). Ordinary end wrenches may crack or damage porcelain.

b. Cleaning and Adjusting.

(1) CLEAN SPARK PLUGS. Spark plugs should be cleaned with standard sand blast cleaning equipment or with the use of dry-cleaning solvent. If points and porcelain are excessively burned, new spark plugs should be installed.

(2) ADJUST POINT GAP. Setting gap in a spark plug is a precision operation and should be treated as such. Proper gap provides 0.025 inch between side electrode and center electrode. When regapping is necessary, bend side electrode only, not center electrode. It is not only necessary to set gap properly, but all plugs should have same gap opening. Use a standard round feeler gage.

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c. **Installation.** Use new gasket [(GM-1556700) G122-0193970] and thread plug into cylinder head with fingers. Use standard spark plug wrench and tighten plug until it bottoms, then turn ¼ to ½ turn until firm. Do not use extreme force in tightening the plug. It is not necessary to "crush" the gasket. Examine spark plug wires carefully and make certain that the suppressors at the plugs are tight and thoroughly cleaned. Install wires to the plugs and make sure they are fully seated in distributor cap in correct firing order (1-5-3-6-2-4).

90. IGNITION COIL.

a. Ignition coil is oil filled and hermetically sealed to prevent entrance of moisture. High tension terminal is protected by porcelain insulator which has high resistance to leakage across its surface and is not damaged by any leakage which might occur.

b. **Removal.** Remove nuts and lock washers at terminals and remove wires. Remove two nuts and internal-external toothed lock washers attaching coil bracket to cylinder head. Lift coil [(GM-1115149) G85-33-00861] up and remove secondary wire from terminal at bottom of coil.

c. **Installation.** Install secondary wire on terminal at bottom of coil. Position coil and install coil bracket over mounting studs and install nuts and internal-external toothed lock washers. Tighten nuts securely. Attach distributor terminal wire (No. 14 tan-red and black cross tracer) to negative (−) terminal and (No. 14 black) to positive (+) terminal. Tighten terminal nuts securely.

Section XVII

FUEL AND AIR INTAKE SYSTEM

91. DESCRIPTION AND OPERATION.

a. **Description** (figs. 83 and 84). The fuel system comprises: fuel tank, fuel lines, fuel filter, fuel pump, carbureter, air cleaner, carbureter control linkage, and manifold heat control valve. Electrical gage system provides means of determining level of fuel in tank.

b. **Operation.** The fuel supply, stored in the fuel tank, is drawn through the fuel filter by action of the fuel pump. The fuel pump forces fuel, as required, to the carbureter where it is properly mixed with air drawn into the carbureter through an oil-bath type air cleaner. The mixture of air and fuel is drawn into the combustion chamber by the downward stroke of the piston. The manifold heat control valve provides a means in cold weather of bypassing exhaust heat around intake manifold to aid in vaporization and in hot weather directs exhaust heat away from intake manifold.

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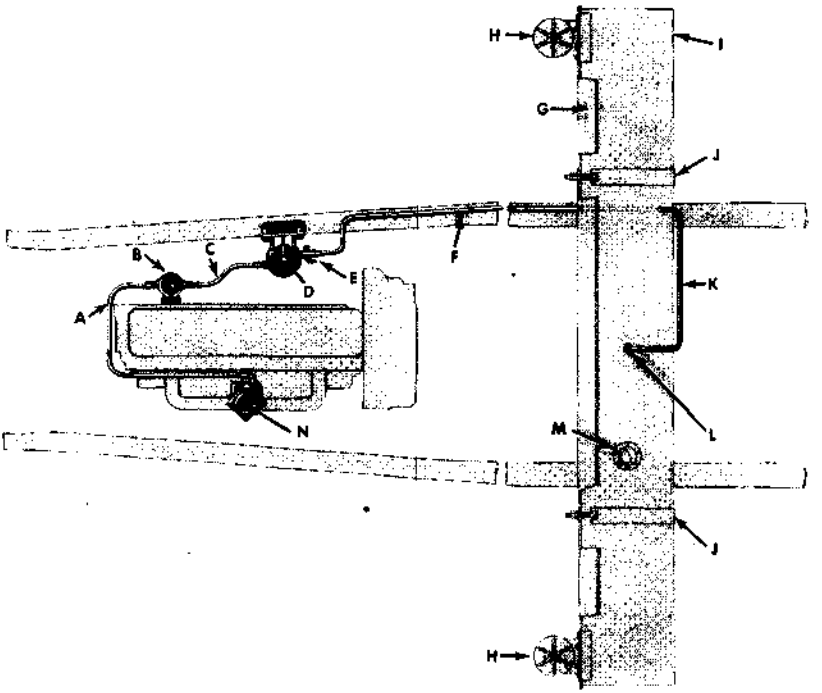
FUEL AND AIR INTAKE SYSTEM



A FUEL PUMP TO CARBURETER LINE
B FUEL PUMP
C FUEL FILTER TO FUEL PUMP HOSE
D FUEL FILTER
E SHUT-OFF COCK
F FRAME CONNECTION TO FUEL FILTER FUEL LINE
G TIRE CARRIER SUPPORT
H FILLER CAP
I FUEL TANK
J FUEL TANK MOUNTING STRAP
K FUEL TANK TO FRAME CONNECTION FUEL LINE
L FUEL TANK OUTLET FUEL LINE
M FUEL GAGE TANK UNIT
N CARBURETER

RA PD 332995

Figure 83—General Arrangement of Fuel System Units—CCKW-352

92. DATA.

a. Carbureter.

Make	Zenith
Type—Early vehicles	Die cast
Late vehicles	Cast Iron
Model—Early vehicles	28AV11
Late vehicles	30 BW 11GM
Identification—Early vehicles	2135998-9778B
Late vehicles	2137474-10046

b. Fuel Pump—Make and model ..... AC - AF

c. Fuel Filter—Make and model ..... AC - T2

d. Fuel Tank—Capacity ..... 40 gal

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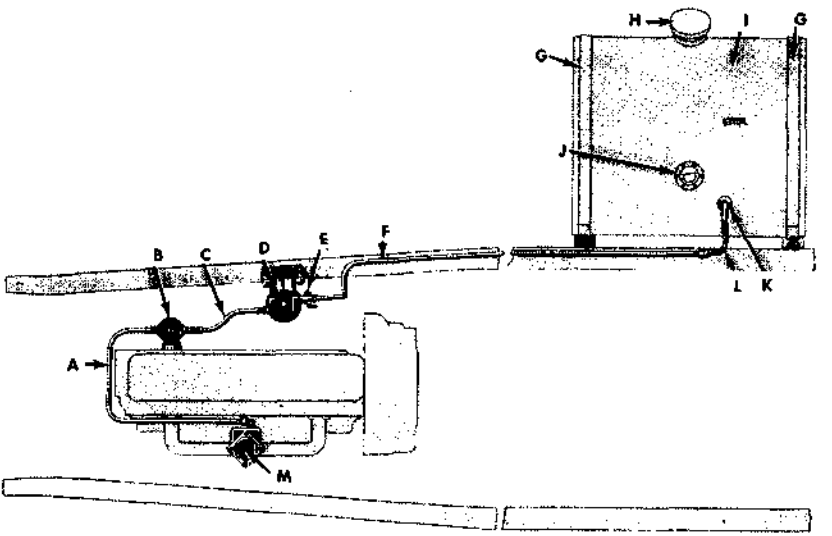
e. **Fuel Tank Filler Cap**—Make.....AC
Pressure valve opens at (lb pressure per sq in.)...1½ - 2½
Vacuum valve opens at (lb pressure per sq in.)....½ or less

f. **Air Cleaner**—Make .....AC
Type—Early vehicles.....Clamp on—oil bath
Late vehicles.....Flange mounted (high angle)—oil bath

93. MANIFOLD HEAT CONTROL.

a. Description. The manifold heat control, located in the exhaust manifold, consists of a butterfly valve and an adjusting lever (fig. 85). The function of the valve is to direct the flow of hot exhaust gases through the manifolds to aid in the vaporization of the fuel.

b. Adjustment. The valve adjusting lever has two extreme positions indicated by "ON" and "OFF." A medium setting is obtained by adjusting the valve midway between "ON" and "OFF." Loosen valve adjusting lever lock nut; then back out slotted screw until it clears recess in manifold. Move lever to proper position to obtain desired setting of valve. Tighten slotted screw into manifold recess only enough to prevent valve from rattling. Tightening screw



A FUEL PUMP TO CARBURETER FUEL LINE
B FUEL PUMP
C FUEL FILTER TO FUEL PUMP HOSE
D FUEL FILTER
E SHUT-OFF COCK
F FRAME CONNECTION TO FUEL FILTER FUEL LINE
G FUEL TANK MOUNTING STRAP
H FILLER CAP
I FUEL TANK
J FUEL GAGE TANK UNIT
K FUEL TANK OUTLET FUEL LINE
L FUEL TANK TO FRAME CONNECTION FUEL LINE
M CARBURETER

RA PD 332996

Figure 84—General Arrangement of Fuel System Units—CCKW-353

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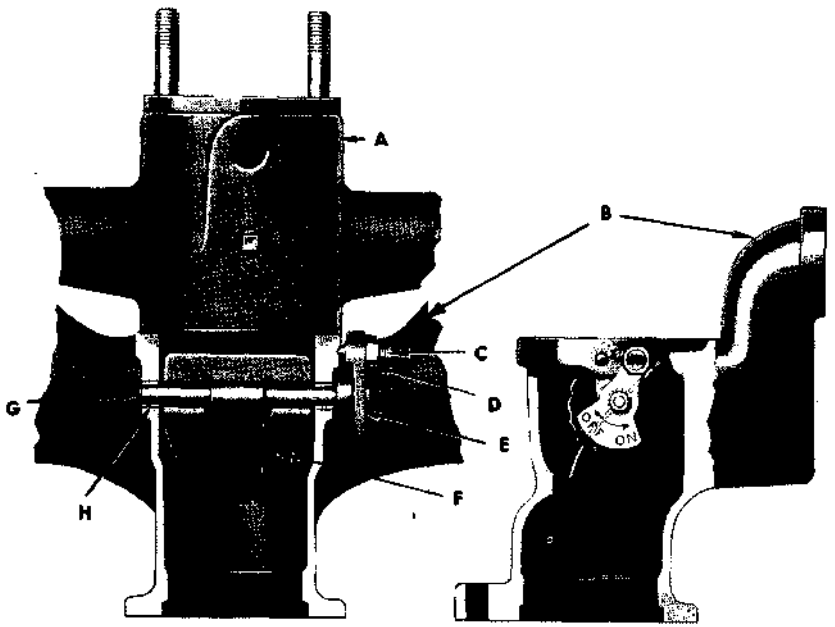

A INTAKE MANIFOLD
B EXHAUST MANIFOLD
C SET SCREW
D NUT
E LEVER
F VALVE
G SHAFT
H BUSHING

RA PD 332936

Figure 85—Manifold Heat Control

excessively may distort valve lever or shaft. Finally, tighten lock nut.

(1) SUMMER OPERATION. At air temperature of about 60° F and above, adjust valve to "OFF" position.

(2) WINTER OPERATION. At air temperature of about 30° F and below, adjust valve to "ON" position.

(3) SPRING AND FALL OPERATION. At air temperature of about 30° to 60° F and also at lower temperatures when in heavy duty operation (heavy loads, high speeds, and extensive operation in low speed gears), adjust valve to medium position. NOTE: *Medium position may be used whenever "OFF" position does not furnish sufficient heat or "ON" position supplies too much heat due to type of operation or weather conditions.* It is not expected that control valve setting will be changed every time conditions vary. However, valve should be set for average operating conditions consistent with air temperature.

94. CARBURETER.

a. Description. Two types of carbureters are used on vehicles covered by this manual, die cast and cast iron. Early vehicles were

equipped with die cast carbureter; late vehicles with cast iron carbureter (fig. 87). Both are balanced units which maintain the proper depression ratio between the air intake of the carbureter and the fuel bowl. All fuel mixture adjustments, except idling, are determined by calibration of the various jets and cannot be changed without disassembling the carbureter and changing the jets.

b. **Idling Speed Adjustment.** Warm up engine until the intake manifold is at least warm to the hand (120° F or higher). Back stop screw, on carbureter throttle lever, out (turn to left) until engine runs evenly (rolls), then turn stop screw in (to right) until engine reaches desired idling speed of approximately 400 to 450 revolutions per minute.

c. **Idling Mixture Adjustment.** Warm up engine until intake manifold is at least warm to the hand (120° F or higher). Slow engine down to idling speed (subpar. b above). Disconnect windshield wiper tube from manifold fitting and attach a vacuum gage at manifold. Turn idling screw gradually to the right until vacuum reading starts to drop, then to the left until vacuum reading starts to drop. Note the number of turns made by idling screw and set screw at center of travel. This will give a steady vacuum reading at its highest point. If engine idles too fast after this adjustment is made, adjust idling speed again (subpar. b above) and repeat above procedure. Regulation of idling mixture in no way affects function of carbureter at higher speeds. Disconnect vacuum gage, and connect windshield wiper tube.

d. **Removal Procedure.**

(1) DISCONNECT CHOKE CONTROL AND HAND THROTTLE. Remove air cleaner (par. 99). Loosen clip screws at carbureter end of choke and throttle control flexible housings. Loosen carbureter choke lever swivel screw. Pull choke control wire and flexible housing from swivel and clip. Remove collar or stop from end of hand throttle control wire. Pull hand throttle control wire and flexible housing from carbureter control rod and clip. Remove carbureter control rod from throttle lever.

(2) REMOVE CARBURETER. Disconnect carbureter fuel line by unscrewing flange nut. Remove two nuts and lock washers (carbureter to manifold) and remove carbureter (GM-2135998 die cast, GM-2137474 cast iron) from vehicle.

e. **Installation Procedure** (fig. 86). When installing carbureter, be sure correct gasket is used between carbureter and governor. This gasket [(GM-2136304) G133-01-93852] must have slots in it to allow vacuum to bypass freely between carbureter and governor housings (fig. 86).

(1) INSTALL CARBURETER. Place gasket and carbureter in position over manifold studs. Install two stud lock washers and nuts, then seal forward nut with a new seal. Place carbureter fuel line in position in carbureter fitting and install flange nut.

(2) ATTACH CHOKE CONTROL AND HAND THROTTLE. Thread choke control flexible housing and wire through clip at carbureter.

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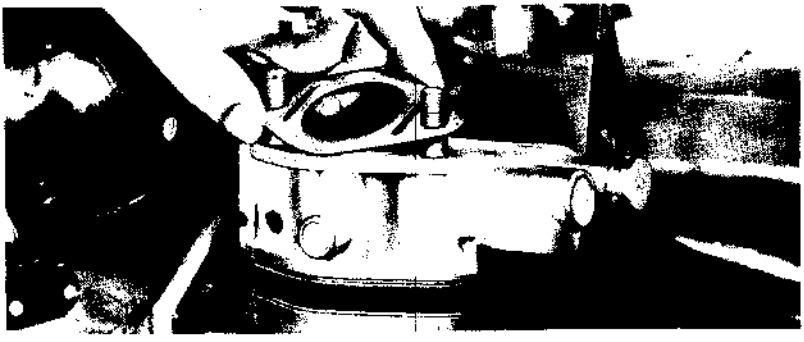

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Figure 86—Carbureter to Governor Gasket

Insert wire through choke control swivel. Fasten end of flexible housing by tightening clip set screw then adjust choke control (par. 95). Thread hand throttle control wire and flexible housing through clip at carbureter. Install carbureter control rod through hole in throttle lever. Insert wire through hole in carbureter control rod. Fasten end of flexible housing by tightening clip set screw securely. Install collar or stop on control wire then adjust hand throttle (par. 95). Install air cleaner (par. 99).

95. CARBURETER CONTROLS.

a. Description. Carbureter controls consist of a hand choke control, [(GM-1990612) G501-01-39941] hand throttle [(GM-1990564) G501-01-39940], and accelerator pedal and linkage. For removal and installation of carbureter choke control and hand throttle at instrument panel, refer to subparagraphs **b** and **c** below.

b. Carbureter Choke Control (fig. 87).

(1) REMOVAL.

(a) Disconnect Choke Control at Carbureter. Loosen set screw which clamps wire in throttle lever swivel. Remove screw and clip which clamps end of flexible housing to bracket at carbureter. Pull end of wire through lever swivel. Remove bolt to loosen bond strap at cowl.

(b) Remove Choke Control. Unscrew nut from choke control at rear side of dash panel. Pull choke control from front side of dash panel until end of flexible housing and enclosed control wire are pulled through seal at cowl and hole in dash panel.

(2) INSTALLATION.

(a) Install Choke Control at Dash Panel. Insert end of flexible housing and enclosed control wire through hole in dash panel, place lock washer and nut over end of housing and enclosed wire, and insert end of wire and housing through seal at cowl. Push choke control button against dash and tighten in place with lock washer and nut at rear side of dash panel.

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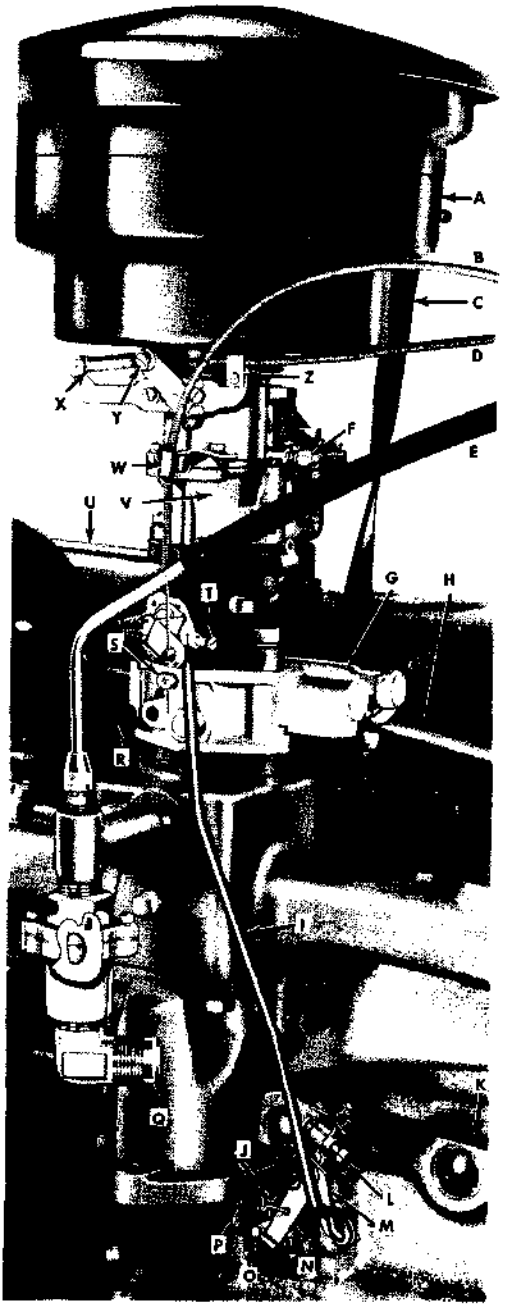
TRUCK, 2½-TON, 6 x 6



A AIR CLEANER
B HAND THROTTLE
C AIR CLEANER BRACE
D CHOKE CONTROL
E WINDSHIELD WIPER TUBE
F IDLING MIXTURE ADJUSTING SCREW
G GOVERNOR
H CYLINDER HEAD WATER BYPASS TUBE
I CARBURETER CONTROL ROD
J ACCELERATOR RETURN SPRING —INNER
K ACCELERATOR PEDAL TO CARBURETER CONTROL LEVER ROD
L CARBURETER INNER CONTROL LEVER ADJUSTING SCREW
M CARBURETER OUTER CONTROL LEVER
N CARBURETER INNER CONTROL LEVER
O CARBURETER INNER CONTROL LEVER STOP
P ACCELERATOR RETURN SPRING —OUTER
Q BRAKE VACUUM LINE CONNECTION
R CRANKCASE VENTILATOR TUBE
S HAND THROTTLE STOP COLLAR
T IDLING SPEED ADJUSTING SCREW
U CARBURETER FUEL LINE
V CARBURETER
W HAND THROTTLE CLIP
X CHOKE RETURN SPRING
Y CHOKE CONTROL SWIVEL
Z CHOKE CONTROL CLIP

RA PD 333007

Figure 87—Air Cleaner, Carbureter, and Controls Installed

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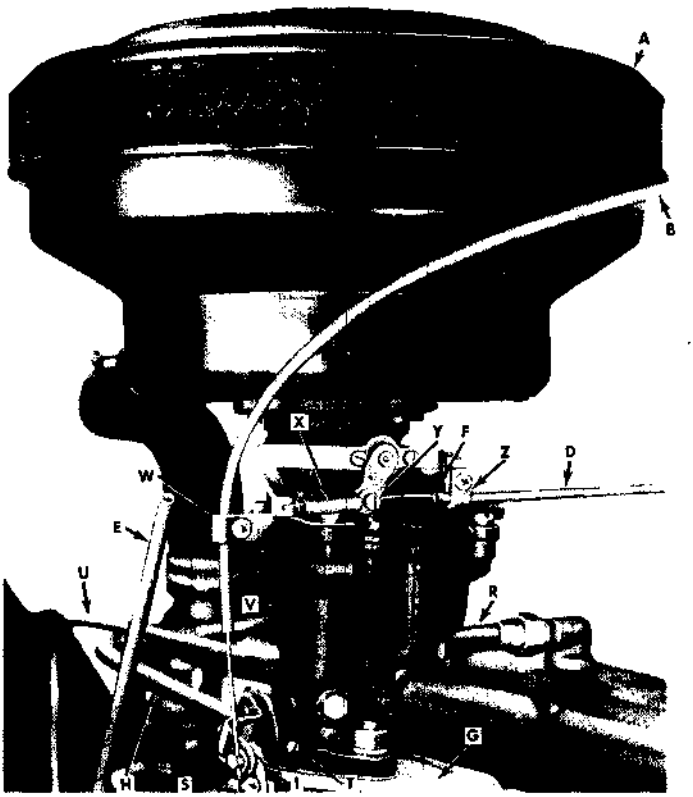

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Figure 87—Continued

(b) Connect Choke Control at Carbureter. Slide clip over end of wire and flexible housing and attach clip to bracket at carbureter with screw. Insert end of control wire through lever swivel. Tighten swivel set screw and clamp housing clip securely as described in step (3) below which covers this adjustment. Install bond strap to flexible housing at cowl.

(3) ADJUSTMENT. Tighten choke control lock nut behind instrument panel. Loosen swivel set screw at carbureter end of choke control wire. Adjust choke button so there is $\frac{1}{16}$-inch clearance between button and instrument panel. Then with carbureter choke valve (air shutter) fully opened, that is, choke control lever tight against stop, tighten swivel set screw securely. Tighten flexible housing clamp screw.

c. Hand Throttle (fig. 87).

(1) REMOVAL.

(a) Disconnect Controls at Carbureter. Loosen set screw clamping stop collar on end of control wire at carbureter and remove stop

collar. Loosen screw which clamps flexible housing in clip at carbureter. Remove bolt to loosen bond strap at cowl.

(b) Remove Throttle Control. Unscrew nut from throttle control at rear side of dash panel. Pull throttle control from front side of dash panel until flexible housing and enclosed control wire are pulled through seal at cowl and hole in dash panel.

(2) INSTALLATION.

(a) Install Throttle Control. Insert end of flexible housing and enclosed control wire through hole in dash panel, place lock washer and nut over housing and enclosed wire, and insert end of wire and housing through opening in seal at cowl. Push throttle control into place against dash panel and tighten in place with lock washer and nut at rear of panel.

(b) Connect Throttle Control at Carbureter. Fit end of flexible housing into clip at carbureter. Insert end of control wire through hole in carbureter rod and install stop collar over end of wire. Tighten set screw after locating stop collar on control wire and clamp flexible housing in clip as described in step (3) below which describes this adjustment. Bolt bond strap to flexible housing at cowl.

(3) ADJUSTMENT. Tighten hand throttle lock nut behind instrument panel. Push in throttle button as far as it will go. Loosen throttle control wire stop collar set screw, and with carbureter throttle in closed position, that is, idling speed adjusting screw tight against stop, adjust stop collar so there is ¼ inch clearance between carbureter control rod and stop collar. Tighten collar set screw securely. Also, tighten flexible housing clamp screw.

d. Accelerator Pedal and Linkage Removal Procedure (fig. 87). Instructions given here are for removing accelerator pedal and linkage progressively beginning with accelerator pedal. These parts, however, may be replaced individually if so desired.

(1) REMOVE PEDAL. From driver's compartment remove cotter pin from pedal hinge pin then remove hinge pin from pedal and bracket. Remove pedal to control rod clevis pin and withdraw pedal from vehicle.

(2) REMOVE PEDAL TO CARBURETER CONTROL LEVER ROD. From engine compartment, remove cotter pin and washer from rod at carbureter control lever (mounted to left-hand side of cylinder block.)

(3) REMOVE CARBURETER CONTROL LEVERS (AT CYLINDER BLOCK). Remove control lever outer (lighter) return spring from end of inner control lever. Remove control lever inner (heavier) return spring from outer control lever. Remove cotter pin from lower end of outer control lever to carbureter rod and remove rod from control lever. Remove nut and washer from control lever mounting stud then remove both control levers.

(4) REMOVE CARBURETER CONTROL LEVER TO CARBURETER ROD. Loosen set screw in hand throttle control wire stop collar and remove stop collar. Withdraw wire from end of rod and remove rod from carbureter lever.

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e. **Accelerator and Linkage Installation Procedure** (fig. 87).

(1) INSTALL CARBURETER CONTROL LEVERS (AT CYLINDER BLOCK). From engine compartment, place inner control lever in position in outer control lever with extension pointing downward. Assemble both levers to mounting stud and install plain washer, lock washer, and nut. Hook return springs over cylinder block pin, heavier spring on inside, then hook heavier spring into outer control lever and lighter spring into inner control lever.

(2) INSTALL CARBURETER CONTROL LEVER TO CARBURETER ROD. Install rod through control lever (at carbureter) from engine side. Insert hand throttle control wire through end of rod and install stop collar, tightening screw firmly. Insert lower end of rod through outer control lever (at cylinder block) and install washer and cotter pin. Adjust inner control lever adjusting screw to provide approximately ⅛-inch clearance between end of screw and outer lever, then tighten lock nut. Adjust hand throttle (subpar. c above).

(3) INSTALL PEDAL TO CARBURETER CONTROL LEVER ROD. Insert pedal end of rod through hole in toe board. Insert bent end of rod through upper end of inner control lever. Install washer and cotter pin. Rod must not bind. Be sure it is installed to work freely.

(4) INSTALL PEDAL. In driver's compartment, attach pedal to toe board bracket with hinge pin. Install hinge pin so that cotter pin hole in pin will line up with hole in bracket on pedal. Insert cotter pin through hinge pin and bracket on pedal. Insert clevis pin through upper bracket on pedal and control rod, then secure with cotter pin.

96. GOVERNOR.

a. **Description.** A velocity type governor, mounted between the intake manifold and carbureter, is employed to protect the engine from being operated beyond a predetermined safe and economical speed. Although the governor does control the vehicle road speed, this is not its primary purpose.

b. **Removal.** Remove carbureter (par. 94), then lift governor from carbureter to manifold studs.

c. **Installation.** Care must be taken so that governor is not installed up-side-down as its position differs with downdraft and updraft carbureters. Governor is marked with an arrow indicating carbureter side. Also, the gasket used between the governor and carbureter incorporates two slots which allow vacuum to by-pass through the governor housing for operation of the carbureter power system. Be sure this gasket [(GM-2136304) G133-01-93854] is in good condition and installed between the governor and carbureter.

(1) INSTALL GOVERNOR. Place a new insulator to governor gasket (plain) [(GM-2135995) G501-01-94026] over carbureter to manifold studs, then place governor over studs so that arrow on governor points upward (toward carbureter). Install carbureter (par. 94).

d. **Cleaning Air Filter.** Carefully pry out metal cover with a sharp pointed punch. Be careful not to damage cast projections that

hold cover in place. Pick out filter felt and inner cover. Wash felt in dry-cleaning solvent and allow to dry. Do not blow dry with compressed air. Blow dirt from stabilizer cylinder and piston by directing compressed air, in sudden bursts, through atmospheric hole in governor air filter chamber. Moisten filter felt slightly with clean oil, then install inner cover, felt, and outer cover. It may be necessary to bend outer cover in order to install it, but it can be straightened again by tapping with a ball peen hammer after it is in position in governor housing.

e. **Governor Adjustments.** The correct governed speed of the engine is 2750 revolutions per minute (no load) with engine warmed up to normal operating temperature. Use a reliable tachometer (18-T-230) or if one is not available, check governed vehicle speed while driving on a level road with transfer case in high range and transmission in direct (4th speed). Set governor to maintain 37 miles per hour, plus or minus one mile per hour. This will give maximum engine speed of 2750 revolutions per minute. If road space or local speed limits prevent checking governor at 37 miles per hour, the next lower gear position may be used by referring to "Maximum Permissible Road Speed Plate" for correct speeds, however, governor setting will be more accurate at 37 miles per hour.

(1) SPEED ADJUSTMENT. To correct governed speed, break governor seal, then turn adjusting cap as necessary to obtain 2750 revolutions per minute maximum engine speed. One complete turn will alter vehicle speed from four to five miles per hour. Check governed speed by road test and when satisfactory, reseal governor.

(2) CORRECTION OF SURGE. Surge is the intermittent deceleration and acceleration of engine speed with the throttle held wide open. Adjustment for surge must be made only to the point of removing the surge. Over adjustment will result in slow governor opening. Wrench set (41-W-1496-695), comprising a hollow wrench and an Allen wrench, is required.

(a) Break governor seal and remove adjusting cap. Insert hollow wrench into adjusting screw housing and engage lugs in adjusting screw bushing. Insert Allen wrench into hole in hollow wrench, engaging Allen wrench in adjusting screw.

(b) Turn Allen wrench clockwise one complete turn, then hold Allen wrench from turning and turn hollow wrench clockwise ¼ turn or until surge is eliminated and engine runs steadily at 2750 revolutions per minute.

(c) Road test vehicle for elimination of surge. When satisfactory adjustment has been made, reseal governor.

(3) CORRECTION OF SLOW GOVERNOR OPENING. Slow governor opening is a decided loss in speed, when load is applied, while operating with wide open throttle. Correction is made in same manner as correction for surge, step (2) above, *except* turn wrenches *counterclockwise*. Make adjustment for slow governor opening very carefully as over adjustment will cause surge.

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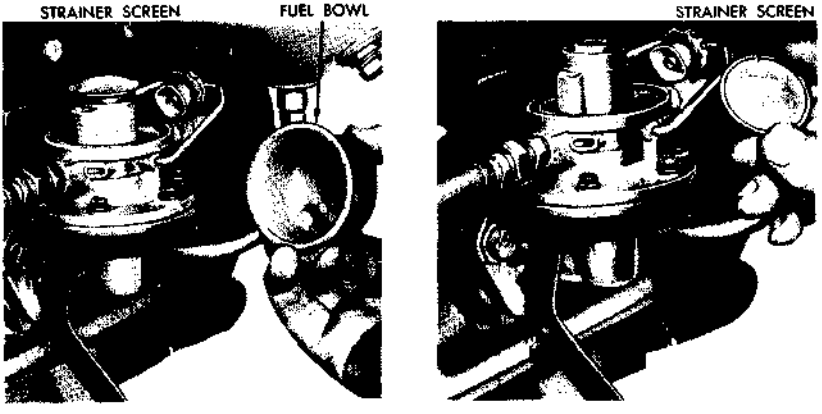


RA PD 332933

Figure 88—Servicing Fuel Pump

97. FUEL PUMP.

a. Description. The fuel pump [(GM-1537714) G85-30-04460] located at right-hand side of the engine, is a diaphragm type mechanically operated from the camshaft. In addition to camshaft operation while the engine is running, the pump is equipped with a hand operated lever which may be used to pump an initial supply of fuel into the carbureter in case the vehicle has run out of fuel, or the carbureter bowl has been emptied for any reason.

b. Cleaning. When pump fuel bowl and strainer screen are removed for cleaning, parts that are damaged or will not clean up must be replaced. Unscrew bowl clamp knurled nut, located at top of bowl, and move clamp so bowl can be removed. Lift bowl and strainer screen from pump (fig. 88) and thoroughly clean them with dry-cleaning solvent. Be sure that strainer screen [(GM-1523099) G85-30-04880] and bowl gasket [(GM-1523096) G85-30-02220] are in good condition; replace if necessary. Install strainer screen and bowl. Position bowl clamp over bowl and tighten knurled nut snugly.

c. Fuel Pump Tests. Fuel pump may be given capacity and pressure tests to determine correct operation. These two tests are separate and distinct from each other, and must be made with the pump mounted on the engine. Tests should be made before the pump is overhauled or replaced to determine condition of the unit.

(1) CAPACITY TEST. This test is to determine that a sufficient amount of fuel is flowing. Disconnect the fuel pump to carbureter line and attach a suitable bleeder hose to fuel pump outlet so that fuel may be caught in a container. With outlet of bleeder hose at carbureter level or slightly higher, flow of fuel should be approximately one pint in not over one minute operation of engine at 2000 to 2500 revolutions per minute (no load).

(2) PRESSURE TEST. Pressure test can be obtained with a standard fuel pump pressure gage attached to outlet of fuel pump. Pressure should be 3¾ pounds maximum at lowest idling speed of engine.

(3) ANALYSIS OF TESTS. If tests show a pressure not to exceed maximum (3¾ pounds) and at least the minimum flow in capacity, fuel pump operation can be considered as normal.

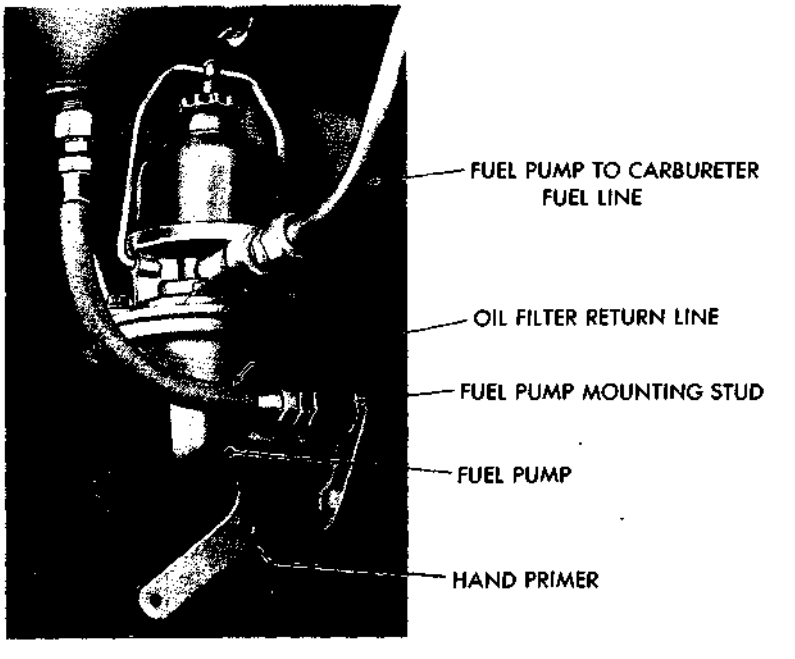
d. Removal Procedure (fig. 89).

(1) DISCONNECT FUEL AND OIL LINES. Disconnect fuel inlet hose [(GM-2123238) G501-02-17831] and outlet tube at pump, also oil return line at fuel pump forward mounting stud. Forward mounting stud is a special hollow stud to provide an oil return into crankcase.

(2) REMOVE PUMP. Remove forward mounting stud, also rearward cap screw, then remove pump from vehicle. Remove pump inlet and outlet fuel line connectors for installation in replacement pump.

e. Installation Procedure.

(1) INSTALL PUMP. Install inlet and outlet fuel line connectors in pump. Place pump in position on engine, using a new mounting gasket [(GM-838263) G104-15-93832] and install special hollow mounting stud, with copper washer, in forward position (fig. 89) and cap screw, with copper washer, in rearward position.



RA PD 64610

Figure 89—Fuel Pump Installed

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(2) CONNECT FUEL AND OIL LINES. Connect pump inlet and outlet fuel lines; also oil return line to special hollow stud. Test pump for efficient operation (subpar. c above).

98. FUEL FILTER.

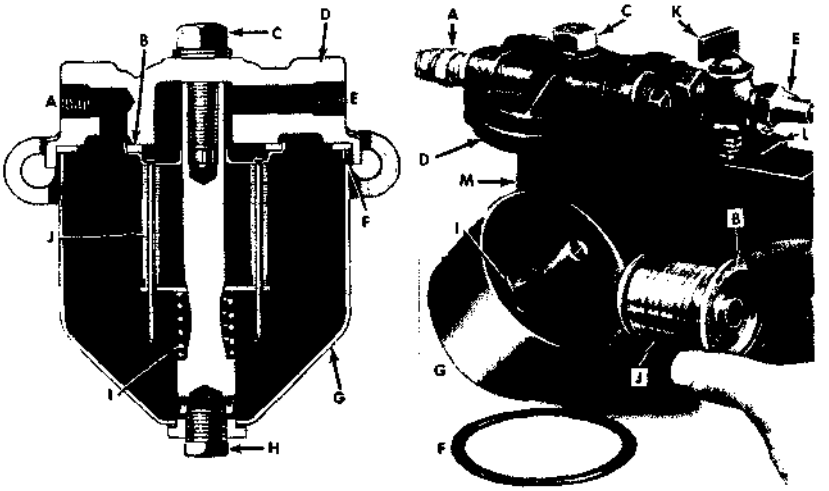
a. Description. The fuel filter (fig. 90) comprises a disk type (laminated) strainer and is mounted on the right-hand frame side rail.

b. Cleaning.

(1) REMOVE SHELL AND STRAINER. Close fuel line shut-off cock at fuel filter. Remove drain plug and allow fuel to drain from filter. Unscrew cover screw and remove filter shell with strainer. Do not lose gaskets.

(2) CLEAN FILTER. Lift strainer and spring from shell and clean all parts thoroughly in dry-cleaning solvent. Be sure all particles are removed from between disks of strainer. NOTE: *Moderate air pressure may be used on brass strainers but must not be used when cleaning paper strainers. Wipe shell dry with a clean cloth.*

(3) INSTALL STRAINER AND SHELL. Inspect strainer gasket, cover gasket, and cover screw gasket. Replace with new parts (GM-2185916-Set) if found not to be in good condition. Place spring and strainer over stem in shell. With strainer and cover gaskets in position, assemble shell to cover; then install cover screw, with gasket,



A FUEL OUTLET
B FILTER STRAINER GASKET
C COVER SCREW
D COVER
E FUEL INLET
F COVER GASKET
G SHELL
H DRAIN PLUG
I SPRING
J FILTER STRAINER
K SHUT-OFF COCK
L FILTER MOUNTING BRACKET
M FRAME SIDE RAIL

RA PD 332895

Figure 90—Fuel Filter-Assembled and Disassembled

and tighten screw sufficiently to prevent leaks. Install drain plug.

c. **Removal.** Remove drain plug and allow fuel to drain from filter. Disconnect inlet and outlet fuel lines at filter. Remove two filter to mounting bracket bolts and remove filter from vehicle. Unscrew shut-off cock and outlet line connector from filter for installation in replacement filter.

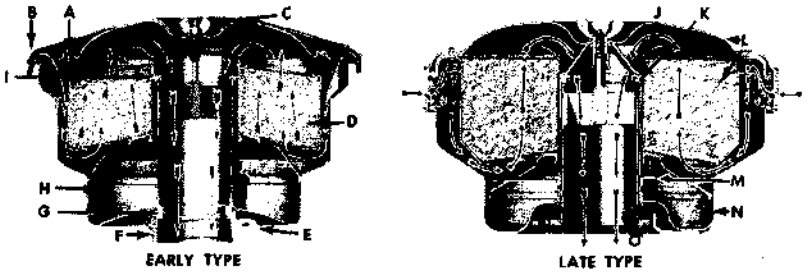
d. **Installation.** Install shut-off cock in cover opening marked "IN" and connector in opening marked "OUT." Place filter in position on mounting bracket and install two mounting bolts, lock washers, and nuts. Connect inlet and outlet fuel lines, tightening flange nut enough to prevent leaks. Be sure drain plug and cover screw are tight enough to prevent leaks and that shut-off cock is in open position.

99. AIR CLEANER.

a. **Description.** The oil bath cleaner (fig. 91) is designed to prevent dust and dirt from entering carbureter. Air entering the cleaner passes into the oil chamber. Due to impact and sudden reversal of air flow, most all of the dirt in the air is thrown into the oil and settles to the bottom of the oil reservoir. Partially cleaned air passes through a dense oil saturated mesh where the remaining dust is trapped.

b. **Removal (Clamp-on Type Air Cleaner).** Loosen bolt nut that attaches air cleaner brace to air cleaner. Loosen clamp bolt that clamps air cleaner to carbureter and lift cleaner from top of carbureter.

c. **Removal (Flange Mounted Air Cleaner).** Unscrew wing nut, at center of cleaner cover, and lift cleaner shell with element and cover as an assembly from cleaner center tube. Remove four cap screws, securing cleaner tube to carbureter, and remove tube from top of carbureter.



EARLY TYPE

A COVER GASKET
B COVER
C WING NUT
D FILTER ELEMENT
E CLAMP
F CLAMP SEAL
G THROAT GASKET
H OIL RESERVOIR

LATE TYPE

I GASKET
J GASKET
K GASKET
L COVER AND ELEMENT ASSEMBLY
M OIL LEVEL INDICATOR
N OIL RESERVOIR
O FLANGE AND TUBE

RA PD 333030

Figure 91—Air Cleaner Cross Sections

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d. Cleaning. Dust and dirt in the air entering air cleaner is loaded with minute particles of abrasive which, if permitted to enter the engine, will cause rapid wear of moving parts. Importance of keeping the air cleaner in proper condition should be impressed upon those responsible for the mechanical upkeep of the engine. Remove air cleaner and clean as directed in Lubrication, Section VIII. Condition of air cleaner cover gasket [(GM-1526517) G104-15-93762 for clamp-on type] should be checked and replaced if necessary.

e. Installation (Clamp-on Type Air Cleaner). Inspect cleaner to carbureter gasket and cleaner clamp seal. Make sure they are in place and in good condition, that is, they will form a good seal. Replace with new parts if necessary. If rustproofing oil is on new parts, remove the oil with dry-cleaning solvent and wipe seal dry with a clean cloth. Air cleaner to carbureter adapter must not be bent or distorted. Straighten if necessary. Be sure cleaner is clean and oil is at proper level.

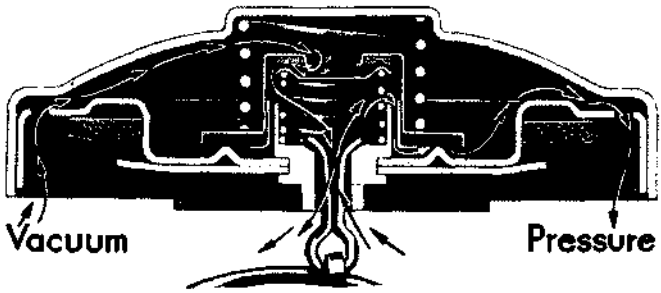
(1) INSTALL CLEANER. Place cleaner in position on top of carbureter, directing cleaner brace bolt into notch at top of brace. Press down on cleaner to compress cleaner to carbureter gasket, and hold it down firmly while tightening clamp bolt. Tighten air cleaner to brace bolt nut firmly.

f. Installation (Flange Mounted Air Cleaner). If unit to be installed is assembled, unscrew wing nut and lift shell and cover with element from center tube. Inspect cleaner shell to tube gasket and element to shell gasket. Make sure they are in place and in good condition, that is, they will form a good seal. Replace with new parts if necessary. Be sure cleaner is clean and oil is at proper level.

(1) INSTALL CLEANER. Place cleaner tube in position on top of carbureter, using a new gasket, and install four tube to carbureter cap screws with lock washers. Place shell over tube and turn it as necessary to engage bracket with flat of carbureter flange; then place element and cover into position in shell. Thread wing nut onto stud and tighten snugly.

100. FUEL TANK AND LINES.

a. Fuel Tank Description. The fuel tank is located in one of two positions, depending upon wheelbase of vehicle. The tank on 145-inch wheelbase vehicles (CCKW-352) is mounted across the frame at rear of cab inside of the tire carrier support (fig. 83). Tank is held securely in place by two mounting straps. Two filler necks are provided, one at each end of the tank, so that the tank may be filled from either side of the vehicle. The tank on 164-inch wheelbase vehicles (CCKW-353) is mounted on the frame right-hand side rail just back of the cab (fig. 84). Tank is held securely in place by two mounting brackets and two mounting straps. One filler neck is provided which incorporates an extension to be used when the tank is filled from a container. Filler cap (GM-850164) (fig. 92) is pressure type, incorporating a spring loaded pressure (relief) valve and a



RA PD 332847

Figure 92—Fuel Tank Filler Cap

spring loaded vacuum (intake) valve. This type cap completely seals end of filler neck, thus preventing fuel, in both liquid and vapor form, from being lost. Valves open only to relieve excessive pressure or vacuum, whichever condition prevails.

b. Fuel Tank Removal Procedure (145-Inch Wheelbase Vehicles).

(1) DRAIN TANK. Unscrew two drain plugs from bottom of tank (located at center and left-hand end). Allow fuel to drain from tank. Do not replace drain plugs as they will interfere with tank removal.

(2) REMOVE FUEL TANK GAGE UNIT. Remove five screws and lock washers and remove gage unit from tank.

(3) REMOVE FUEL TANK OUTLET LINE. Unscrew fuel line flange nut (at tank) and disconnect fuel line. Unscrew fuel tank outlet line retaining nut and pull outlet line from fuel tank. This is necessary to provide clearance for tank removal.

(4) REMOVE TWO FUEL TANK FILLER NECKS. Remove filler neck to tank cap screws and lock washers (six at each filler neck) and remove filler necks from tank.

(5) REMOVE TANK. Back off nuts at forward end of each mounting strap as far as possible, but do not remove them. Remove nut and washer from lower end of each mounting strap. Lift mounting straps away from tank, using a suitable bar, and withdraw tank from end of tire carrier support.

c. Fuel Tank Installation Procedure (145-Inch Wheelbase Vehicles).

(1) INSTALL TANK. Make sure that fuel tank mounting bracket antisqueak strips are in good condition and in place (install new ones if necessary), then move fuel tank into position in tire carrier support. Positioning of tank may be simplified by using a screw driver or other suitable tool to guide tank past mounting straps. Tighten nuts at forward end of each mounting strap enough to position mounting strap on tank, then install washer and nut at lower end of mounting straps and tighten them securely.

(2) INSTALL FILLER NECKS. Install two fuel tank filler necks to fuel tank, using a new gasket between filler neck and tank. Install

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cap screws with lock washers (six at each filler neck) and tighten securely.

(3) INSTALL FUEL TANK OUTLET LINE. Place fuel tank outlet line in position in tank. Be sure lower end of line engages hole in support at bottom of tank. Install outlet line retaining nut and tighten securely.

(4) CONNECT FUEL LINE. Install fuel line in fuel tank outlet line connection and tighten flange nut securely.

(5) INSTALL FUEL TANK GAGE UNIT. Place gage unit in position in tank, using a new gasket [(GM-1516061) G501-01-94010] and install five gage unit to tank screws with new gaskets under heads of screws.

(6) CONNECT FUEL GAGE WIRE. Install gage unit wire over gage unit terminal and install lock washer and nut. Install rubber protector over terminal.

(7) INSTALL FUEL TANK DRAIN PLUGS. Install two fuel tank drain plugs (at center and left-hand end of tank) and tighten securely to prevent fuel leakage.

d. Fuel Tank Removal Procedure (164-Inch Wheelbase Vehicles).

(1) DRAIN TANK. Unscrew drain plug from bottom of tank and allow fuel to drain from tank.

(2) DISCONNECT FUEL GAGE WIRE. Remove rubber protector from gage unit wire terminal and remove nut and lock washer. Then remove wire from terminal.

(3) DISCONNECT FUEL LINE. Unscrew fuel line flange nut (at tank) and disconnect fuel line.

(4) REMOVE FUEL TANK. Remove two mounting strap to mounting bracket bolt nuts and lock washers. Remove two mounting strap hinge pin cotter pins and remove hinge pins. Lift mounting straps from vehicle and tank is free to be lifted from mounting brackets.

(5) REMOVE CAP AND FILLER NECK EXTENSION. Remove filler cap. Pull extension out of filler neck as far as possible. Turn extension counterclockwise and continue to pull extension from filler neck.

(6) REMOVE FUEL TANK OUTLET LINE. Unscrew fuel tank outlet line retaining nut and remove outlet line from tank.

(7) REMOVE FUEL TANK GAGE UNIT. Remove five gage unit to tank screws and gaskets and remove gage unit from tank.

e. Fuel Tank Installation Procedure (164-Inch Wheelbase Vehicles).

(1) INSTALL FUEL TANK OUTLET LINE. Place fuel tank outlet line in position in tank. Be sure lower end of line engages hole in support at bottom of tank. Install outlet line retaining nut and tighten securely.

(2) INSTALL FUEL TANK GAGE UNIT. Place gage unit in position in tank, using a new gasket, and install five gage unit to tank screws with new gaskets under heads of screws.

(3) INSTALL FUEL TANK DRAIN PLUG. Install fuel tank drain plug and tighten securely to prevent fuel leakage.

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(4) INSTALL FUEL TANK. Make sure fuel tank mounting bracket antisqueak strips are in position, then place tank in position on mounting brackets. Position fuel tank mounting straps and install two hinge pins. Secure hinge pins with cotter pins. Install mounting strap bolts through mounting brackets and install lock washers and nuts. Tighten nuts securely to prevent any movement of tank.

(5) CONNECT FUEL LINE. Install fuel line in fuel tank outlet line connection and tighten flange nut securely.

(6) CONNECT FUEL GAGE WIRE. Install gage unit wire over gage unit terminal and install lock washer and nut. Install rubber protector over terminal.

f. Fuel Lines.

(1) DESCRIPTION. Special metal fuel lines, covered with protective looms wherever necessary, extend between the fuel tank and carbureter. Flexible hose is provided between the fuel filter and fuel pump to eliminate the possibility of fuel line breakage. A shut-off cock is provided at the fuel filter for convenience when performing service operations on the system.

(2) REPLACEMENT. Fuel lines are securely fastened in position with clips and may be readily removed or installed. Refer to figures 83 and 84 for relative positions and accessibility of various lines. Always install new lines in same position as that occupied by the lines they are replacing.

101. FUEL GAGE TEST.

a. To simplify testing of fuel gage, it is recommended that tank be approximately one-half full to prevent gage from normally reading "FULL" or "EMPTY." Refer to figure 93.

b. If Gage is Dead. If gage is dead (that is, hand remains to

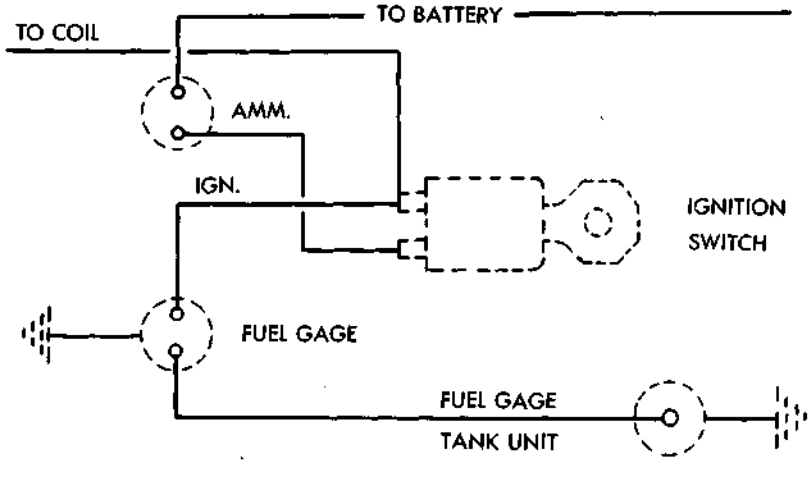

Figure 93—Fuel Gage Circuit Diagram

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left of empty) when ignition switch is turned on, current is not reaching gage. To test, connect a jumper wire from "IGN" terminal of gage to either terminal of ignition switch. If gage registers, wire from ignition switch to gage is defective and must be repaired or replaced (par. 128). NOTE: *Early vehicles incorporate a circuit breaker in the circuit between ignition switch and gage. In the event the above test shows this circuit defective, install a new wire from ignition switch direct to "IGN" terminal of gage.*

c. **If Gage is Stuck.** If gage remains in any one position (other than dead) as ignition switch is turned on and off, gage is defective or tank unit float is stuck. To test, ground tank unit terminal with a jumper wire or screw driver; if gage shows "EMPTY," replace tank unit [(GM-1515435) G508-01-93761] (par. 100); if gage does not move, replace gage (par. 140).

d. **If Gage Registers Incorrectly.** If gage registers when ignition switch is turned on, but is known to register incorrectly, this indicates that tank unit float arm is bent or distorted and tank unit must be replaced (par. 100).

e. **If Gage Registers Empty.** If gage registers "EMPTY" when ignition switch is turned on, wire from gage to tank is shorted and must be repaired or replaced (par. 128).

f. **If Gage Registers Full.** If gage registers "FULL" when ignition switch is turned on, wire from gage to tank unit is broken or tank unit is defective. To determine which, ground tank unit terminal with a jumper wire or screw driver. If gage then shows "EMPTY," replace tank unit (par. 100); if gage still shows "FULL," repair or replace gage to tank unit wire (par. 128).

Section XVIII

EXHAUST SYSTEM

102. DESCRIPTION.

a. Exhaust system (figs. 94 and 95), consists of an exhaust pipe, muffler, tail pipe, and attaching parts. The function of the exhaust system is to carry away engine exhaust gases and to muffle engine combustion noises. Two types of exhaust systems are used on vehicles covered by this publication. On vehicles equipped with heated water tanks, the exhaust system differs from the conventional exhaust system in that the exhaust pipe is insulated and an exhaust by-pass valve is installed ahead of the muffler to direct the exhaust gases through the water tank heater box.

103. EXHAUST PIPE.

a. **Conventional System** (fig. 94). The exhaust pipe extends from the exhaust manifold to the muffler and is attached to the

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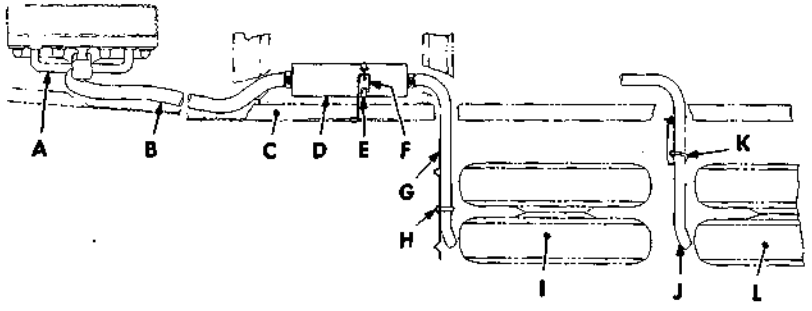

A MANIFOLD
B EXHAUST PIPE
C FRAME SIDE RAIL
D MUFFLER
E MUFFLER STRAP
F MUFFLER SUPPORT BRACKET
G TAIL PIPE (145-INCH WHEELBASE)
H U-BOLT
I FORWARD REAR WHEELS (145-INCH WHEELBASE)
J TAIL PIPE (164-INCH WHEELBASE)
K U-BOLT
L FORWARD REAR WHEELS (164-INCH WHEELBASE)

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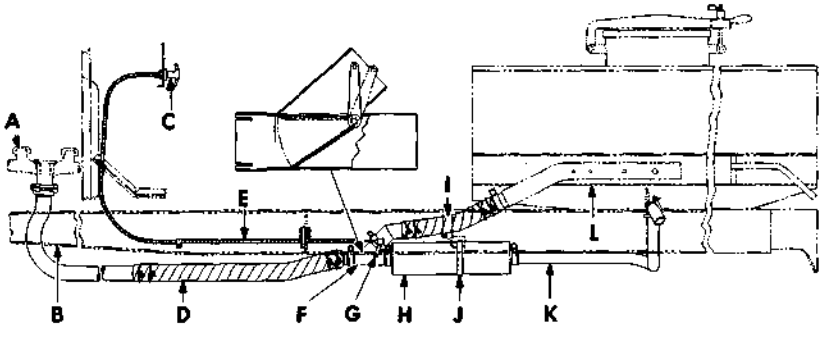
Figure 94—Exhaust System (All Vehicles Except Heated Water Tank)



A EXHAUST MANIFOLD
B FRAME SIDE RAIL
C EXHAUST BYPASS VALVE CONTROL WIRE
D EXHAUST PIPE AND INSULATION ASSEMBLY
E EXHAUST BYPASS VALVE CONTROL WIRE
F EXHAUST BYPASS VALVE ASSEMBLY
G EXHAUST BYPASS VALVE CONTROL LEVER
H MUFFLER
I EXHAUST BYPASS VALVE TO WATER TANK HEATER BOX TUBE
J MUFFLER STRAP
K TAIL PIPE
L WATER TANK HEATER BOX

RA PD 332952

Figure 95—Exhaust System (Heated Water Tank)

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manifold by three bolts, nuts and lock nuts. This connection is sealed by a gasket and flange seal (fig. 96). The rear end of the exhaust pipe is inserted in the front end of the muffler and held in place by a clamp.

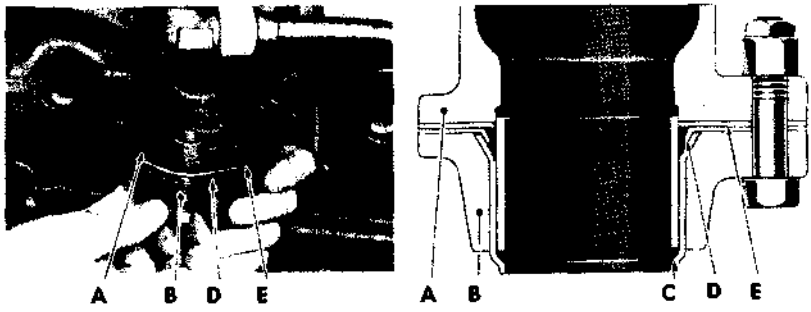
b. **Heated Water Tank System** (fig. 95). The exhaust pipe is insulated to retain the heat in the system, and is attached and sealed at the manifold in the same manner as the conventional system (fig. 96). The rear end of the exhaust pipe is inserted in the forward end of the exhaust by-pass valve assembly and attached with a clamp.

c. **Exhaust Pipe Removal** (figs. 94, 95, and 96). Loosen clamp attaching rear end of exhaust pipe to muffler or exhaust by-pass valve assembly, as the case may be. Remove lock nuts and nuts from three bolts attaching exhaust pipe flange to manifold. Remove bolts. Move exhaust pipe forward far enough to pull rear end out of muffler or exhaust by-pass valve assembly, and remove from under vehicle.

d. **Exhaust Pipe Installation** (figs. 94, 95, and 96). Make certain clamp is in place on forward end of muffler or exhaust by-pass valve, as case may be. Install exhaust pipe flange on exhaust pipe. From underneath vehicle, insert the upper end of exhaust pipe between engine and frame side rail, then insert rear end of exhaust pipe into muffler or exhaust by-pass valve. Position exhaust pipe flange, seal, and gasket (GM-2017499). Insert three bolts up through the exhaust pipe flange, seal, gasket, and manifold shown in figure 96. Install nuts on bolts and tighten alternately. Install lock nuts. Tighten clamp bolt at rear end of exhaust pipe.

104. MUFFLER AND TAIL PIPE.

a. The muffler is supported from frame side rail by a support bracket and strap. The tail pipe is attached to the muffler by a clamp. The outer end of the tail pipe is supported at the splash



A MANIFOLD
B EXHAUST PIPE FLANGE
C EXHAUST PIPE
D EXHAUST PIPE FLANGE SEAL
E EXHAUST PIPE FLANGE GASKET

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Figure 96—Exhaust Pipe to Manifold Connection

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shield by a U-bolt on the conventional exhaust system (fig. 94) and by a clip bolt on the heated water tank exhaust system (fig. 95). Two different length tail pipes are used on the conventional system, depending on the wheelbase of the vehicle.

b. Muffler and Tail Pipe Removal (figs. 94, 95, and 97).

(1) REMOVE TAIL PIPE. Loosen clamp attaching tail pipe to muffler. Remove U-bolt or clip bolt, as the case may be, attaching tail pipe to splash shield, then pull tail pipe out of rear end of muffler.

(2) REMOVE MUFFLER. Loosen clamp attaching exhaust pipe or exhaust by-pass valve assembly, as the case may be, to muffler. Remove nut and lock washer from muffler strap bolt and pull bolt out of bracket. Move muffler toward rear of vehicle to pull it off exhaust pipe or exhaust by-pass valve and remove from under vehicle.

c. Muffler and Tail Pipe Installation (figs. 94, 95, and 97).

(1) INSTALL MUFFLER. Make sure clamp is in place on forward end of muffler and slide end of muffler over end of exhaust pipe or exhaust by-pass valve assembly, as the case may be. Hold muffler against muffler support bracket and wrap muffler strap around muffler, then insert muffler strap bolt into muffler support bracket. Install nut and lock washer on bolt but do not tighten until after tail pipe is installed.

(2) INSTALL TAIL PIPE. Make sure clamp is in place on rear end of muffler, then insert forward end of tail pipe into muffler. Attach outer end of tail pipe to splash shield with U-bolt or clip bolt and tighten securely. Position muffler until the ends of exhaust pipe and

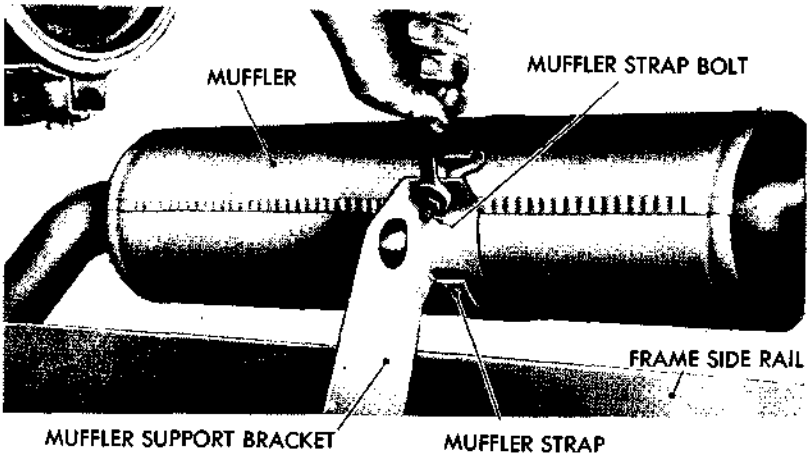

Figure 97—Muffler to Frame Mounting

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tail pipe are each inserted an equal distance into the muffler. Tighten the clamp bolt at each end of the muffler, then tighten the muffler strap bolt.

105. EXHAUST BY-PASS AND CONTROL (WATER TANK BODY).

a. The exhaust by-pass valve is installed between the exhaust pipe and muffler, and is held in place by clamps. It directs the exhaust gases, through an insulated tube, to the water tank heater box and is operated manually by a control installed on the dash panel to the left of the steering wheel.

b. **Exhaust By-Pass Valve and Water Tank Heater Box Tube Removal** (fig. 95).

(1) DETACH MUFFLER. Remove nut and lock washer from tail pipe clip bolt. Loosen clamp at forward end of muffler. Loosen muffler strap bolt and move muffler and tail pipe assembly toward rear of vehicle.

(2) REMOVE EXHAUST BY-PASS VALVE AND WATER TANK HEATER BOX TUBE ASSEMBLY. Remove cotter pin and plain washer from swivel and remove it from by-pass valve control lever. Loosen clamp attaching water tank heater box tube to heater box inlet, also clamp attaching exhaust by-pass valve to exhaust pipe. Remove exhaust by-pass valve assembly from exhaust pipe, then pull down and forward to remove water tank heater box tube off water tank heater box inlet. Remove assembly from under vehicle. Remove water tank heater box tube from exhaust by-pass valve assembly by loosening the attaching clamp.

c. **Exhaust By-pass Valve and Water Tank Heater Box Tube Installation** (fig. 95).

(1) Install clamp on lower end of water tank heater box tube, then position tube on exhaust by-pass valve assembly and tighten clamp bolt. Install clamp on upper end of water tank heater box tube, and slip tube over water tank heater box inlet. Install clamp on forward end of exhaust by-pass valve assembly, then position assembly over rear end of exhaust pipe.

(2) ATTACH MUFFLER. Install muffler and tail pipe assembly over rear end of exhaust by-pass valve assembly. Tighten muffler strap bolt. Install tail pipe clip bolt, nut, and lock washer and tighten securely. Tighten clamp bolts at both ends of exhaust by-pass valve assembly, and at upper end of water tank heater box tube.

(3) ADJUST AND CONNECT EXHAUST BY-PASS VALVE CONTROL WIRE. Push control button in driver's compartment "in." Hold valve lever on exhaust by-pass assembly in rearward position, then screw swivel on or off control wire until swivel shaft will fit into control lever freely. Install plain washer and cotter pin.

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TRUCK, 2½-TON, 6 x 6

Section XIX

COOLING SYSTEM

106. DESCRIPTION.

a. The cooling system is of the sealed type and comprises the following units: drive belt, fan, radiator, thermostat, water pump, temperature gage, pressure type filler cap, cylinder head water bypass tube, and the tubes, hose and fittings connecting the radiator to the engine and water pump. These units, when given proper maintenance, automatically control engine operating temperature. Water is drawn from the bottom of the radiator by action of the water pump and is force-circulated through the passages and water jackets in the engine and returned, through the upper connection, to the radiator where it is cooled by the action of the fan drawing air through the radiator core. A pressure cap (on radiator) maintains a pressure of approximately four pounds in the cooling system when the engine is warmed up to normal operating temperature. The temperature gage, capillary tube, and thermal unit are fabricated as an assembly. No provisions are made to repair this unit. In the event the gage fails to function properly, replace with one known to be in good condition (par. 139).

107. SERVICE.

a. **Preventive Cleaning.** In order to efficiently clean the cooling system of rust, scale, or sludge, use a cleaner followed by a neutralizer to stop the action of the cleaner. Federal stock No. 51-C-1568-500 provides cleaner and neutralizer enough to clean a cooling system of a four-gallon capacity. Neutralizing, and flushing after neutralizing, is very important as the cleaner contains a strong acid which, if not completely removed, will attack the parts of the cooling system. Also precautions should be taken not to spill any cleaning compound on the skin, clothing, or vehicle paint. CAUTION: *Do not pour cold water into cooling system when engine temperature is above 200° F. Also cold water poured into the cooling system, regardless of engine temperature, will close the thermostat and not allow the engine water jackets and passages to completely fill. Whenever filling system with cold water, always run engine until normal operating temperature is reached (thermostat opens), then add water until liquid level is visible through filler neck.*

(1) DRAIN SYSTEM. Run engine fast idle until normal engine operating temperature is reached (at least 165° F) to stir up any loose rust, scale, etc. Remove radiator filler cap, open radiator and cylinder block drain cocks, and allow cooling system to drain.

(2) CLEAN SYSTEM. Close radiator and cylinder block drain cocks. Disconnect overflow tank (if vehicle has one) and place a clean container under overflow tube to catch any overflow, which may be needed to maintain proper liquid level in the radiator. Be

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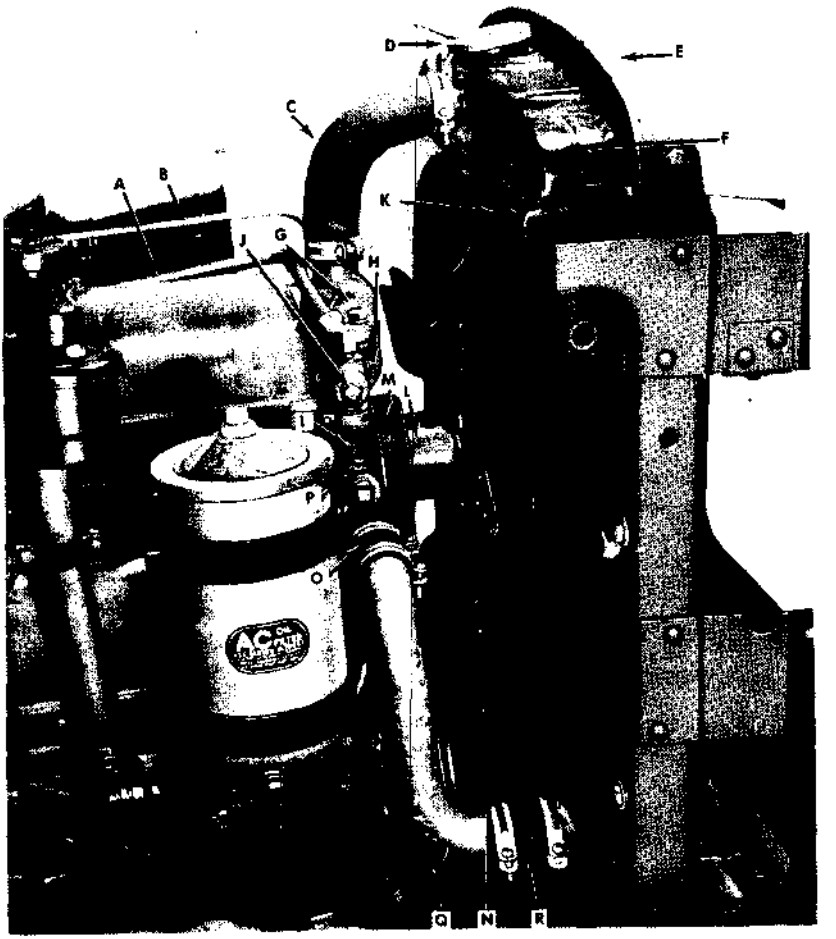
sure temperature of engine is below 200° F. Pour cleaning compound (one container to every four gallons of cooling system capacity) into radiator, then fill system with water. Install pressure type cap on radiator. If vehicle is equipped with an overflow tank, move pressure type cap from overflow tank to radiator. Start engine and run it at fast idle to heat solution to at least 180° F. Use a cardboard to cover radiator if necessary, but do not allow to boil. Con-



A CYLINDER HEAD WATER BY-PASS TUBE
B FUEL PUMP TO CARBURETER FUEL LINE
C RADIATOR INLET HOSE
D RADIATOR FILLER CAP
E RADIATOR UPPER SUPPORT
F RADIATOR
G CYLINDER HEAD WATER OUTLET
H THERMOSTAT HOUSING
1 BY-PASS TEE TO ELBOW HOSE
J BY-PASS TEE
K FAN SHROUD
L WATER PUMP PULLEY
M GENERATOR AND WATER PUMP DRIVE BELT
N FAN BLADES
O OUTLET PIPE HOSE
P WATER PUMP BY-PASS INLET ELBOW
Q RADIATOR OUTLET PIPE
R OUTLET PIPE HOSE

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Figure 98—Cooling System Units

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tinue to run engine at least 30 minutes. Stop engine, remove radiator cap, open radiator and cylinder block drain cocks, and allow system to drain completely.

(3) NEUTRALIZE SYSTEM. Close radiator and cylinder block drain cocks. Pour neutralizer (one container to every four gallons of cooling system capacity) into radiator, then fill system with water and install radiator cap. Start engine and run it at a fast idle, using radiator cover as necessary, to heat solution to at least 180° F. Continue to run engine at least 10 minutes. Remove radiator cap, open radiator and cylinder block drain cocks, and allow system to drain completely.

(4) FLUSH SYSTEM. Close radiator and cylinder block drain cocks. Fill system with clean fresh water (soft if possible), then install radiator cap. Start engine and run it at a fast idle, using radiator cover as necessary, to bring engine operating temperature to at least 180° F. Continue to run engine for at least 5 minutes. Remove radiator cap, open radiator and cylinder block drain cocks, and allow system to drain. If water drained is discolored to any extent, repeat this flushing operation. CAUTION: *Do not flush system by inserting a hose in the radiator, with the engine running and the drain cocks open. This procedure will close the thermostat and stop circulation of the water through the engine.*

(5) CLEAN RADIATOR, CAP, OVERFLOW TUBE, TANK, AND DRAIN TUBES. Clean cap by spraying a stream of water (hot if possible) through the holes in the valve cage while moving the pressure valve up and down with a blunt wooden instrument or a pencil. Clean out overflow pipe with a stream of water and rinse out overflow tank (if vehicle is so equipped), then connect overflow tank. Clean out dirt, trash, and insects imbedded in the air passages of the radiator, using compressed air or a stream of water; but do not use steam. CAUTION: *Do not hold air or water hose too close to the radiator or use too great pressure as damage to radiator may result. Clean out any stoppage in drain hose with a soft wire or straw.*

(6) FILL SYSTEM. Close radiator and cylinder block drain cocks; then fill system to suit climatic conditions as follows: If above 32° F, almost fill the system with clean fresh water (soft if possible), add a corrosion inhibitor, then fill with water until liquid level is visible through filler neck. If there is a possibility that climate below 32° F will be encountered, fill system about one-quarter full, add antifreeze enough for the lowest expected temperature (par. 31), then fill until liquid level is visible through filler neck. Install radiator cap, start engine and run it at a fast idle until temperature gage shows normal operating temperature (par. 18 **d**); then stop engine and check coolant level, adding water as necessary.

b. Air Suction and Exhaust Gas Leakage. Air circulating through the cooling system, as well as exhaust gas leaking into the system, causes rapid corrosion and rust formation which will eventually clog the system and cause overheating and loss of cooling liquid. The air may be drawn into the system due to low liquid level in the radiator, leaky water pump, or loose fitting connections. Ex-

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haust gas may be blown into the cooling system past the cylinder head gasket or through cracks in the cylinder head and block.

(1) AIR SUCTION TEST. Adjust level of cooling liquid in radiator, allowing room for expansion so as to avoid any overflow loss during test. Replace radiator cap with a plain type cap. Be sure cap gasket [(GM-846732) G103-15-93621] is in good condition and will form an airtight seal. Attach a length of rubber tube to lower end of overflow tube (this connection must be airtight). Run engine with transmission in neutral gear at a safe high speed until temperature gage stops rising and remains stationary. Without changing engine speed, put end of rubber tube in a bottle of water, avoiding kinks and sharp bends that might block flow of air. Watch for bubbles in bottle of water. The continuous appearance of bubbles indicates that air is being sucked into the cooling system. Correct condition by tightening cylinder head bolts, water pump mounting bolts, hose clamps, and fitting connections. Also examine all hose carefully and if cracked, swollen, or deteriorated in any way, replace with a new part.

(2) EXHAUST GAS LEAKAGE TEST. Start test with engine cold. Remove drive belt to prevent pump operation. Drain cooling system until cooling liquid level is at top of thermostat housing, *but no lower*. This can be determined by loosening up cylinder head outlet from thermostat housing to check level of liquid. If liquid leaks from this connection, continue to drain system until liquid no longer leaks. Remove thermostat (par. 110 **b**). Make sure thermostat housing is full of liquid (add if necessary), then with transmission in neutral gear, start engine and accelerate it several times. Watch for bubbles in water in thermostat housing while accelerating engine, also when engine speed drops back to normal. The appearance of bubbles or a sudden rise of cooling liquid indicates exhaust gas leakage into cooling system. Make test quickly before boiling starts as steam bubbles will give misleading results. If exhaust gas leakage is evident, replace cylinder head gasket, then test again. If leaks are still evident, it indicates cylinder head or block is cracked. Report to higher authority. Install thermostat (par. 110 **c**), install and adjust drive belt (par. 108), then fill radiator.

c. Rust Preventives. The cooling system must be free of rust and scale to maintain efficiency of the system. Use of inhibitors or rust preventives reduces or prevents corrosion of metals and prevents formation of scale. Inhibitors are not cleaners and do not remove rust or scale already formed. Treating the cooling system with an inhibitor consists of adding an inhibitor to the cooling liquid. The inhibitor should be renewed periodically and especially if the system has been cleaned or flushed.

108. FAN AND BELT.

a. Description. A five-bladed fan, mounted on the water pump drive pulley hub, is driven by a "V" type belt from the crankshaft pulley in conjunction with the water pump and generator.

b. Fan Removal. Remove four cap screws (fan to water pump) and remove fan blades.

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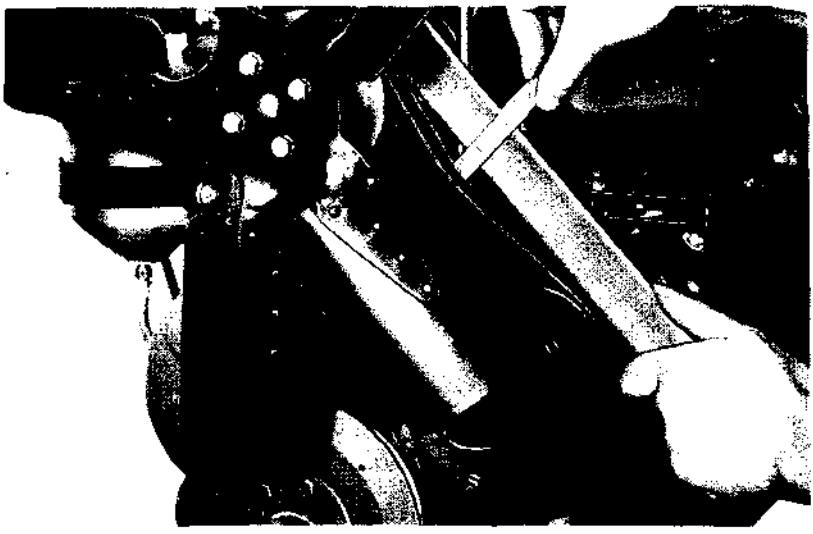

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Figure 99—Drive Belt Adjustment

c. Fan Installation. Position fan blades on water pump hub with straight edge of blades toward radiator—curved edges toward engine. This will position fan so notches in blades will provide clearance with crankshaft balancer. Install four cap screws (fan to water pump) and lock washers and tighten firmly.

d. Belt Adjustment. Loosen two generator to mounting bracket bolt nuts or through bolt nut, as case may be, then loosen generator to adjusting arm cap screw. Move generator toward or away from engine, as necessary, to obtain correct belt tension. A light pressure on belt at a point midway between generator and water pump pulleys must cause a ½-inch deflection (fig. 99). Tighten generator to adjusting arm cap screw, then tighten two generator to mounting bracket bolt nuts or through bolt nut, as case may be.

e. Belt Removal. Loosen two generator to mounting bracket bolt nuts or through bolt nut, as case may be, then loosen generator to adjusting arm cap screw. Move generator toward engine as far as it will go, then remove belt from generator, water pump, and crankshaft pulleys and remove belt [(GM-2090464) G508-01-18253] over fan blades.

f. Belt Installation. Thread belt over fan blades, then place belt over water pump, crankshaft, and generator pulleys. Adjust belt and tighten generator (subpar. d above).

109. RADIATOR ASSEMBLY.

a. Description. The radiator assembly consists of a fin and tube type core with upper and lower tanks. The radiator is mounted in a

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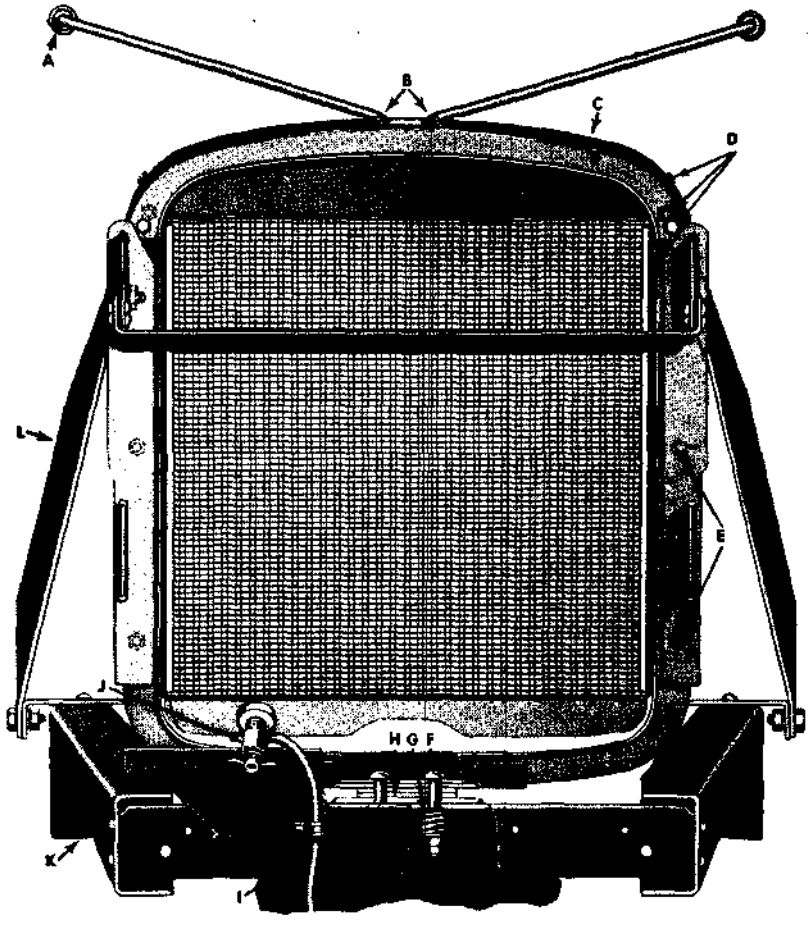

A TIE ROD ADJUSTING NUT
B TIE ROD TO UPPER SUPPORT CAP SCREWS
C RADIATOR SUPPORT
D RADIATOR UPPER SUPPORT CAP SCREWS
E FAN SHROUD AND RADIATOR TO SUPPORT CAP SCREWS
F RADIATOR LOWER SUPPORT BOLT
G SUPPORT BOLT SPRING
H RADIATOR CUSHION
I DRAIN COCK TUBE
J DRAIN COCK
K FRAME
L RADIATOR BRACE

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Figure 100—Radiator and Mounting

vertical position at the forward end of the engine. Air drawn by the action of the fan cools the cooling liquid as it flows through the radiator. A pressure type filler cap is used on the radiator.

b. Removal (fig. 100).

(1) DRAIN RADIATOR. Remove radiator cap [(GM-850033) G85-31-03620], open radiator drain cock, and allow cooling liquid to drain from radiator.

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(2) DISCONNECT BOND STRAPS. Remove nut and lock washer and disconnect radio noise suppression bond strap at right- and left-hand side of radiator lower tank. Loosen clip bolt attaching drain cock tube.

(3) REMOVE RADIATOR TIE ROD. Remove two tie rod to radiator upper support screws and internal toothed lock washers. From inside of cab, remove two tie rod to cowl nuts and lock washers and remove tie rod.

(4) REMOVE RADIATOR UPPER SUPPORT. Remove three screws and lock washers at each end of radiator upper support and remove support.

(5) DISCONNECT RADIATOR HOSE. Loosen radiator upper and lower hose clamp at radiator and disconnect upper hose [(GM-2140818) G85-30-02830] and lower hose [(GM-2140852) G501-02-17816] from radiator.

(6) REMOVE WIRING HARNESS FROM RADIATOR. Spread clips and remove wiring harness from radiator upper tank.

(7) REMOVE FAN ASSEMBLY. Remove four cap screws and lock washers which attach fan to pulley and remove fan blade assembly.

(8) REMOVE RADIATOR. Remove six fan shroud and radiator to support cap screws and internal-external toothed lock washers (three each side); then remove fan shroud. Position radiator so that cut-out in radiator flanges will clear radiator brace to support bolt nuts; then carefully push upper portion of radiator toward engine and lift radiator out of vehicle. Unscrew drain cock from radiator for installation on replacement unit.

c. **Installation** (fig. 100).

(1) INSTALL RADIATOR. Install radiator drain cock in radiator, then lower radiator into position in vehicle. Install radiator upper support, securing it with three cap screws and lock washers at each end. Place fan shroud in position against radiator and install three cap screws and internal-external toothed lock washers at each side of radiator to attach shroud and radiator to support.

(2) INSTALL FAN ASSEMBLY. Position fan blades on water pump hub with straight edge of blades toward radiator—curved edges toward engine. This will position fan so notches in blades will provide clearance with crankshaft balancer. Install four cap screws (fan to water pump) and lock washers and tighten firmly.

(3) INSTALL RADIATOR TIE ROD. Screw inner (forward) nuts well up on ends of tie rod. Place new internal-external toothed lock washers over ends of tie rod and install ends of tie rod through holes in cowl. Install two tie rod to support screws using new internal-external toothed lock washers over ends of tie rod and start (but do not tighten) outer (rearward) nuts.

(4) CONNECT RADIATOR HOSE. Install radiator upper hose over radiator inlet; lower hose over radiator outlet, and tighten hose clamps.

(5) CONNECT BOND STRAPS. Install radio noise suppression bond straps over bolts, located at right- and left-hand side of radiator lower tank, and install internal-external toothed lock washers and nuts.

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Insert drain cock tube into clip, then tighten clip bolt firmly.

(6) INSTALL WIRING HARNESS. Fit wiring harness into clips on radiator top tank and bend clips over wire.

(7) FILL RADIATOR. Close radiator drain cock, fill radiator (par. 17) and install radiator cap.

d. Adjustment (fig. 100).

(1) LOOSEN RADIATOR. Loosen (do not remove) two radiator lower support bolt nuts, accessible from underneath vehicle, also radiator brace bolt at each side of radiator near the top.

(2) ADJUST RADIATOR. Adjust tie rod nuts at cowl carefully to provide ¾ inch clearance between fan blades and bottom of radiator. Be sure all four tie rod nuts are tight at cowl. Tighten radiator brace bolt nut at each side of radiator near the top, also tighten two radiator to lower support bolt nuts until springs are compressed, then back off nuts three full turns to provide proper tension on springs, then tighten lock nuts securely.

110. THERMOSTAT.

a. Description. The thermostat is of the bellows type, mounted in the housing at the cylinder head water outlet. The thermostat comprises a restriction valve which is thermostatically operated, and is calibrated to open gradually as the engine temperature increases. The valve in the thermostat starts to open at approximately 160° F and is fully opened at approximately 185° F. When the temperature of the cooling liquid in the engine is below the calibration of the thermostat, the valve in the thermostat remains closed, restricting the flow of the cooling liquid through the radiator. However, a by-pass around the thermostat permits circulation of the cooling liquid through the engine water passages until normal operating temperature is reached. The thermostat then is open and permits full circulation of the cooling liquid.

b. Removal. Remove radiator cap, open radiator drain cock and allow cooling liquid to drain from radiator. Loosen two radiator inlet

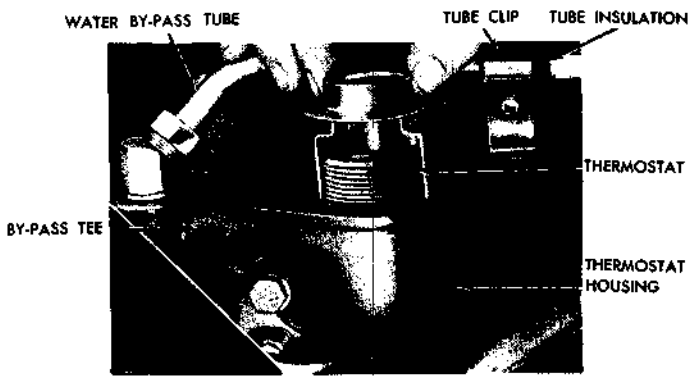

Figure 101—Thermostat Removal

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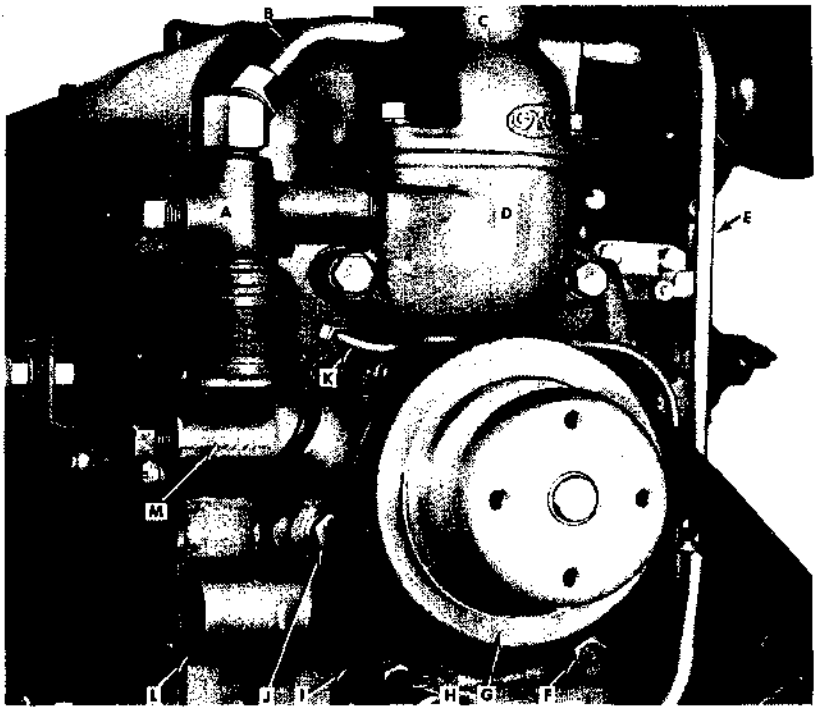

A BY-PASS TEE
B CYLINDER HEAD WATER BY-PASS TUBE
C CYLINDER HEAD WATER OUTLET
D THERMOSTAT HOUSING
E FUEL PUMP TO CARBURETER FUEL LINE
F WATER PUMP MOUNTING BOLT
G WATER PUMP PULLEY
H WATER PUMP MOUNTING BOLT
I DRIVE BELT
J WATER PUMP MOUNTING BOLT
K OIL TUBE
L WATER PUMP
M WATER PUMP BY-PASS INLET ELBOW

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Figure 102—Water Pump Mounting

hose clamps and remove hose. Remove two outlet to thermostat housing cap screws, then lift outlet from thermostat housing. Raise thermostat [(GM-3108579) G122-04-02000] from housing (fig. 101).

c. **Installation.** Place thermostat in position in housing (fig. 101). Position water outlet, with a new gasket, [(GM-838341) G85-31-06300] on thermostat housing, then install two cap screws with lock washers, assembling cylinder head water by-pass tube clip to left-hand cap screw. Be sure insulation is in place in clip. Install radiator inlet hose over cylinder head water outlet and radiator inlet and tighten hose clamps firmly. Fill radiator (par. 17).

111. WATER PUMP ASSEMBLY.

a. **Description.** A centrifugal type water pump is mounted on the cylinder block at the timing gear end of the engine. The water

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pump is a packless type and does not require a packing gland to prevent leakage around the shaft. The impeller action of the water pump forces the cooling liquid through the engine water passages, radiator, and connections. The pump is driven, in conjunction with the generator, with a belt by the engine crankshaft.

b. Removal.

(1) DRAIN SYSTEM AND REMOVE FAN AND DRIVE BELT. Remove radiator cap; then open radiator and cylinder block drain cocks and allow cooling system to drain. Remove four fan to water pump cap screws and remove fan blades. Remove drive belt (par. 108).

(2) REMOVE PUMP CONNECTIONS. Loosen radiator outlet pipe to water pump hose clamp screw at water pump and remove hose from water pump. Loosen water by-pass elbow hose clamp screws, and loosen hose [(GM-2137582) G501-02-17816] from elbow.

(3) REMOVE PUMP. Remove four water pump to cylinder block cap screws (fig. 102), and remove pump [(GM-2103002) G85-11-01740] and gasket [(GM-838137) G85-11-00960] from vehicle.

(4) REMOVE BY-PASS ELBOW. Unscrew water by-pass elbow from water pump for installation in replacement pump.

c. Installation.

(1) INSTALL BY-PASS ELBOW. Screw water by-pass elbow tightly into water pump. Coat threads of elbow with anti-seize compound, mica base.

(2) INSTALL PUMP ON ENGINE. Place a new water pump to cylinder block gasket in position, then place water pump in position on engine, directing inlet elbow into hose. Install one 1⅞-inch cap screw with lock washer in water pump bolt hole just above water inlet and tighten finger-tight. Then install remaining three cap screws with lock washers (fig. 102), assembling fuel and oil lines clip and generator adjusting arm. Tighten all four cap screws evenly and firmly.

(3) INSTALL PUMP CONNECTIONS. Tighten water by-pass elbow hose clamp screws. Install radiator outlet pipe to water pump inlet and tighten hose clamp screws.

(4) INSTALL FAN AND DRIVE BELT AND FILL SYSTEM. Install and adjust belt (par. 108). Position fan blades on water pump hub with straight edge of blades toward radiator—curved edges toward engine. This will position fan so notches in blades will provide clearance with crankshaft balancer. Install four cap screws (fan to water pump) with lock washers and tighten firmly. Close radiator and cylinder block drain cocks, then fill system (par. 17).

112. HOSE AND FITTINGS.

a. Description. Hose connections are provided at each end of the radiator outlet pipe, at the radiator inlet, and at the water by-pass inlet elbow at the water pump. A cylinder head water by-pass tube extends from the rear of the cylinder head to the water pump.

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b. **Cylinder Head Water By-pass Removal.**

(1) REMOVE RADIATOR INLET HOSE. Remove radiator cap, then open radiator and cylinder block drain cocks and allow cooling system to drain. Loosen two hose clamps, then loosen and remove hose from radiator and cylinder head connections.

(2) REMOVE CYLINDER HEAD WATER BY-PASS TUBE. Remove by-pass tube clip nut and screw. Unscrew flange nuts at each end of by-pass tube, then remove tube from tube clip and insulator.

(3) REMOVE WATER BY-PASS TEE TO WATER PUMP INLET ELBOW HOSE. Loosen hose clamps, then remove two thermostat housing to cylinder head cap screws and remove water outlet, thermostat housing, and by-pass tee as an assembly. Remove hose from water pump inlet elbow.

c. **Cylinder Head Water By-pass Installation.**

(1) INSTALL WATER BY-PASS TEE TO WATER PUMP INLET ELBOW HOSE. Place two hose clamps over hose, then install hose over water pump inlet elbow. Position gasket [(GM-838297) G85-31-06280] and water outlet, thermostat housing, and by-pass tee assembly on cylinder head, directing by-pass tee into hose; then install two housing to cylinder head cap screws with lock washers. Position hose clamps and tighten firmly.

(2) INSTALL CYLINDER HEAD WATER BY-PASS TUBE. Coat threads of by-pass tube flange nuts with anti-seize compound, mica base, then place insulator over tube. Position tube in clip at thermostat housing, with insulator under clip, then screw flange nuts into their respective fittings firmly. Install clip screw, lock washer, and nut.

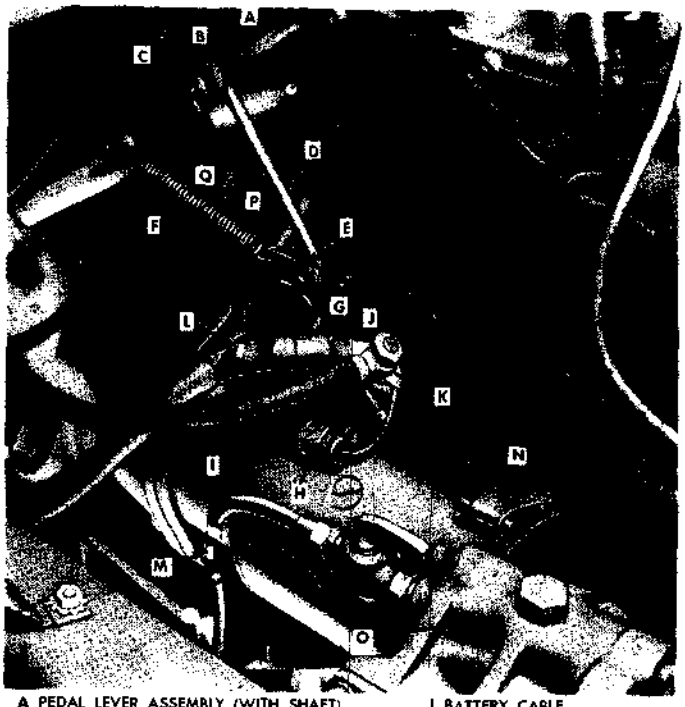
(3) INSTALL RADIATOR INLET HOSE. Place hose clamps in position over hose. Install hose over cylinder head and radiator connections, then tighten hose clamps firmly. Fill cooling system (par. 17).

Section XX

STARTING SYSTEM

113. DESCRIPTION.

a. The starting system comprises a cranking motor, switch attached to cranking motor body, pedal control linkage which actuates cranking motor switch, and cable connection to vehicle battery. The cranking motor is attached to the right-hand side of the clutch housing and is equipped with an over-running clutch drive which is manually shifted into engagement with the flywheel. The cranking motor switch, mounted on cranking motor, completes the electrical circuit between the battery and the motor when the cranking motor is being used. The upper end of the shift lever engages the switch button



A PEDAL LEVER ASSEMBLY (WITH SHAFT)
B ANTI-RATTLE SPRING
C PEDAL SHAFT BRACKET
D LEVER TO CRANKING MOTOR LINK
E PULL BACK SPRING CLIP
F PULL BACK SPRING
G CRANKING MOTOR LEVER
H CONDENSER
I CRANKING MOTOR TO AMMETER CABLE
J BATTERY CABLE
K CRANKING MOTOR SWITCH
L STUD NUT
M CAP SCREW
N BAND
O FUEL FILTER
P PEDAL SHIFT BRACKET
Q BRACKET CAP SCREWS

RA PD 333045

Figure 103—Cranking Motor Installed

after the pinion has fully engaged the flywheel gear, or when the spring is sufficiently compressed to force the pinion into mesh as soon as the armature rotates. When the engine has started, the action of the over-running clutch allows the pinion to rotate at flywheel speed; therefore the armature is not speeded up to a dangerous speed.

114. CRANKING MOTOR.

a. **Cleaning Commutator.** Remove cover band and inspect commutator for dirty condition, roughness, burned spots, and high mica. If commutator is dirty, it can sometimes be cleaned with a strip of 2/0 flint paper. Never use emery cloth to clean commutator. All dust must be blown from cranking motor after commutator has been cleaned. If commutator is rough, burned, or has high mica, cranking motor should be replaced.

b. **Switch Replacement** (fig. 103).

(1) REMOVAL.

(a) Disconnect Cables. Remove ground strap from battery. Remove cranking motor switch terminal nut, two cables, and condenser wire.

(b) Remove Switch and Condenser. Remove two screws and lock washers attaching switch to cranking motor housing. Remove condenser and cranking motor switch [(GM-820052) G85-33-03560].

(2) INSTALLATION.

(a) Install Switch and Condenser. Use two screws and lock washers to attach switch and condenser to cranking motor housing. Tighten screws securely.

(b) Connect Cables. Install cranking motor to ammeter cable, cranking motor to battery cable (GM-5275716), and condenser pigtail wire over cranking motor switch terminal. Replace lock washer and nut. Tighten nut securely. Reinstall ground strap to battery.

c. **Cranking Motor Replacement** (fig. 103).

(1) REMOVAL. Remove ground strap from battery.

(a) Remove Fuel Filter. Refer to paragraph 98 c.

(b) Remove Cables. At cranking motor, remove cranking motor to battery cable, cranking motor to ammeter cable, and condenser wire.

(c) Disconnect Linkage. Remove pedal pull back spring. Remove cotter pin which retains lever link to cranking motor lever. Withdraw link and pull back spring clip from lever.

(d) Remove Cranking Motor. Remove stud nut and lock washer at top, also bolt and lock washer at bottom which attach cranking motor to clutch housing. Pull cranking motor [(GM-1107418) G85-11-01540] straight away from housing to remove.

(2) INSTALLATION.

(a) Position Cranking Motor. Locate cranking motor in its correct position with switch at top. Install stud nut at top, and bolt at bottom, using internal toothed lock washer under nut and bolt. Tighten nut and bolt alternately until cranking motor is seated firmly in place.

(b) Install Fuel Filter. Refer to paragraph 98 d.

(c) Connect Linkage. Insert lever link into shift lever, then place spring clip over end of link. Insert and bend cotter pin. Install pedal pull back spring.

(d) Connect Cables. Clean switch terminal post and cable terminals thoroughly. Install condenser wire, battery to cranking motor cable, and cranking motor to ammeter cable to switch terminal post. Install lock washer and nut on terminal, and tighten firmly. Install ground strap to battery, then test action of cranking motor.

115. CRANKING MOTOR CONTROLS.

a. Control linkage comprises a lever and shaft assembly bolted with brackets to clutch housing, with a link connecting the cranking motor shift lever and bracket lever.

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b. **Removal** (fig. 103).

(1) REMOVE TOE BOARD. Remove cranking motor pedal button. Remove toe board. Brackets and shaft are then accessible.

(2) DISCONNECT LINKAGE. Disconnect linkage and spring [(GM-598073) G85-33-03250] at cranking motor lever.

(3) REMOVE LEVER AND SHAFT ASSEMBLY. Remove two cap screws which attach brackets on each side of clutch housing. A spacer is used under each bracket. Lever and shaft assembly may then be lifted from clutch housing.

c. **Installation** (fig. 103).

(1) INSTALL LEVER AND SHAFT ASSEMBLY. Position lever and shaft assembly on clutch housing with brackets and spacers in place. Install and tighten cap screws.

(2) CONNECT LINKAGE TO CRANKING MOTOR. Connect link and spring clip to cranking motor shift lever. Install pull back spring. Anti-rattle springs are used at link connection to bracket, and at pedal shaft bracket to shaft.

(3) INSTALL TOE BOARD. Install toe board, then install cranking motor pedal button.

Section XXI

GENERATING SYSTEM

116. DESCRIPTION.

a. Units in generating system include generator, operated in connection with fan and water pump, and a three-unit regulator which controls output of generator. Diagram of generating circuit is shown in figure 104. Complete electrical circuit description and diagrams are covered in section XXIII.

117. GENERATOR.

a. **Description and Operation.** The generator is a two-brush type, mounted on left side of engine and driven by a belt from the crankshaft pulley in conjunction with the fan and water pump. The generator is cooled by means of air, drawn through opening in rear of unit by a fan mounted with the drive pulley. Generator mountings will permit positioning of the assembly to provide proper tension on drive belt. Adjustment of drive belt is described in paragraph 108.

b. **Cleaning Commutator.** Remove cover band and inspect commutator. If dirty, clean with a strip of 2/0 flint paper. Do not use emery cloth. Blow out all dust with compressed air and install cover band. Report to proper authority if the commutator is excessively rough.

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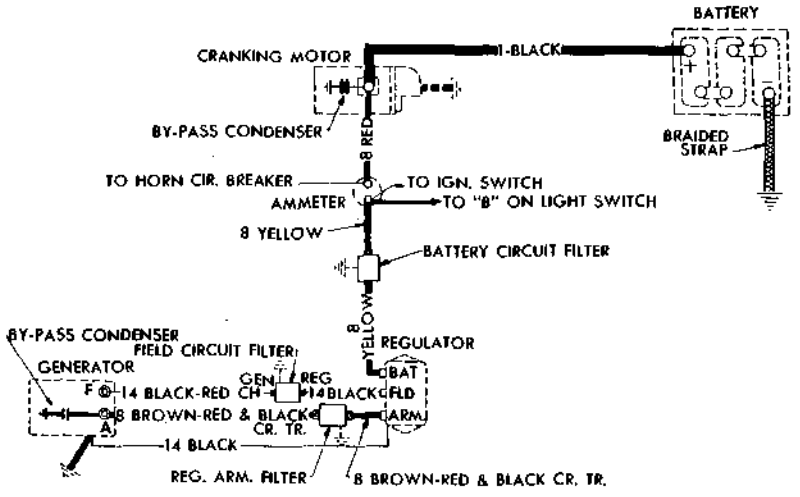

RA PD 333022

Figure 104—Generating Circuit

c. Assembly Removal.

(1) DISCONNECT WIRES. Remove ground strap at battery terminal. Remove nut, lock washer, and wire at "FLD" terminal on generator. Remove nut, lock washer, condenser pigtail, and armature wire at "ARM" terminal on generator.

(2) REMOVE CONDENSER. Remove screw and two internal-external toothed lock washers attaching condenser and ground wire ("GRD") to generator housing and lay condenser aside.

(3) LOOSEN DRIVE BELT. Remove cap screw, lock washer, and flat washer attaching generator to adjusting arm.

(4) REMOVE GENERATOR. Remove two nuts, lock washers, and bolts attaching generator to mounting bracket. On late vehicles, remove long through-bolt attaching generator to mounting bracket. Remove belt [(GM-2090464) G508-01-18253] from generator pulley and lift generator [(GM-1105864) G501-01-93910] out.

d. Assembly Installation.

(1) INSTALL GENERATOR. Lower generator into place and install two bolts (one at each end) attaching generator to mounting bracket. Install nuts and lock washers on bolts and draw up finger-tight. On late vehicles, install one through-bolt instead of two bracket bolts.

(2) INSTALL DRIVE BELT. Place belt in recess in fan pulley, crankshaft pulley, and generator pulley. Attach generator to adjusting arm using flat washer, lock washer, and cap screw. Adjust belt tension (par. 108), then tighten nuts on mounting bolts.

(3) INSTALL CONDENSER. Install condenser and ground wire (No. 14 black) on generator housing, using screw and two internal-

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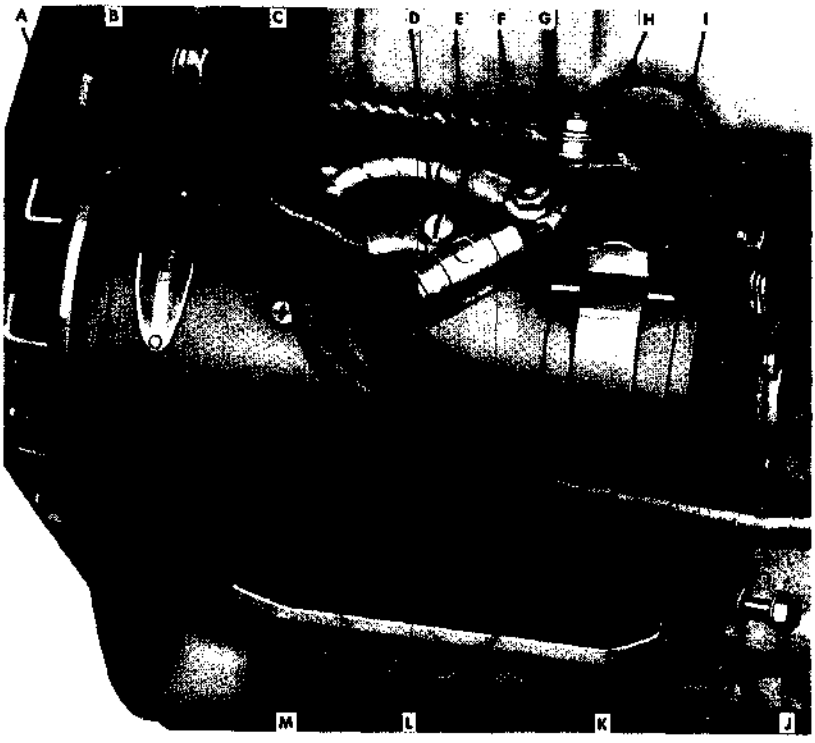


A DRIVE BELT
B ADJUSTING CAM
C ADJUSTING ARM CAP SCREW
D GROUND TERMINAL
E CONDENSER
F ARM TERMINAL
G FLD TERMINAL
H GENERATOR
I COVER BAND
J THROUGH BOLT (LATE TYPE)
K WIRING HARNESS
L MOUNTING CAP SCREWS
M MOUNTING BRACKET

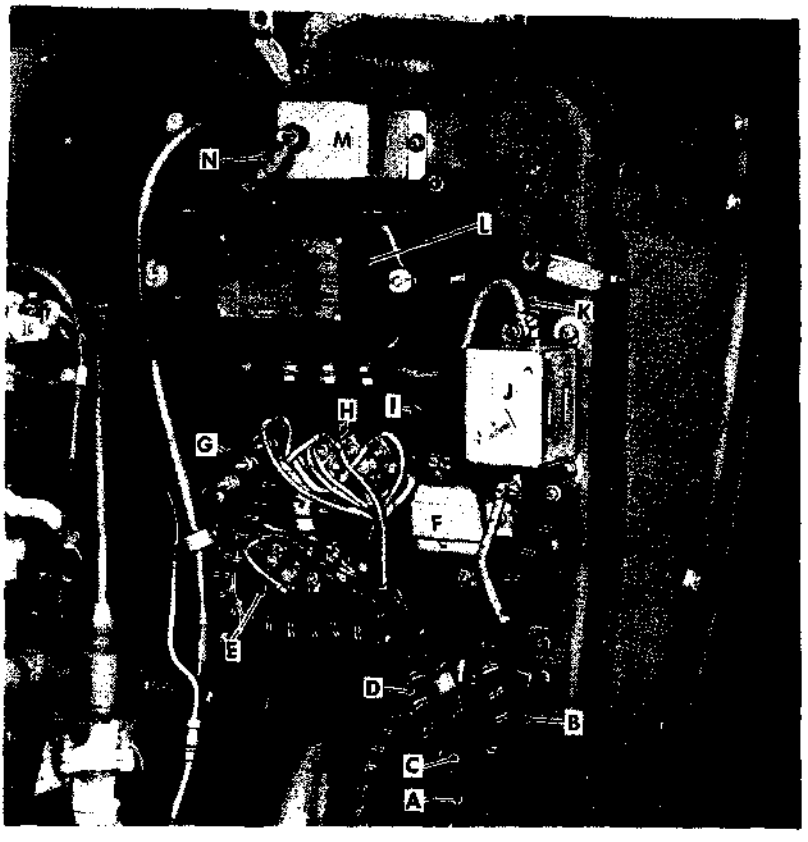
RA PD 333021

Figure 105—Generator Installed

external toothed lock washers. Be sure *two* internal-external toothed lock washers are used, one next to generator housing and one under head of screw.

(4) CONNECT WIRES. Attach condenser pigtail and armature wire (No. 8 tan-red and black cross tracer) to "ARM" terminal on generator with nut and lock washer. Attach field wire (No. 14 black-red check) to "FLD" terminal on generator with nut and lock washers. Tighten nuts securely. Install ground strap at battery.

e. **Polarizing Generator.** When generator or regulator wires have been disconnected, especially when new unit is being installed, generator must be polarized after units are installed, *before engine is started.* Failure to polarize generator will cause regulator points to vibrate excessively and burn. Remove wire (No. 14 black-red check) from "FLD" terminal at generator. Use jumper wire to



A FRONT END WIRING HARNESS
B GENERATOR TO REGULATOR WIRING HARNESS
C CHASSIS WIRING HARNESS
D CAB WIRING HARNESS
E JUNCTION BLOCK—LOWER
F FIELD CIRCUIT FILTER
G JUNCTION BLOCK—3 POST
H JUNCTION BLOCK—UPPER
I FIELD FILTER TO REGULATOR WIRE
J ARMATURE CIRCUIT FILTER
K ARMATURE FILTER TO REGULATOR WIRE
L REGULATOR
M BATTERY CIRCUIT FILTER
N BATTERY FILTER TO REGULATOR WIRE

RA PD 64766

Figure 106—Regulator Installed

momentarily connect "FLD" terminal on generator and "BATTERY" terminal on regulator. This allows a momentary surge of battery current to reach generator field, which automatically gives generator the correct polarity with respect to battery it is to charge. Attach wire to generator "FLD" terminal (subpar. **d** (4) above).

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GENERATING SYSTEM

118. REGULATOR.

a. Description. The generator regulator is a three-unit type, mounted on the cowl front panel above and to the left of the engine. The regulator unit contains a cut-out relay which automatically opens and closes the circuit between generator and battery as needs require; voltage regulator which controls generator voltage; and a current regulator which controls generator amperage output.

b. Regulator Removal (fig. 106).

(1) DISCONNECT WIRES. Remove ground strap from battery negative terminal. Remove nuts and lock washers from "ARMATURE," "FIELD," and "BATTERY" terminals on regulator and remove wires. Remove screw and lock washer attaching ground wire to regulator.

(2) REMOVE REGULATOR. Remove four nuts and lock washers from bolts attaching regulator to cowl front panel and remove regulator [(GM-1118468) G85-33-02550]. Notice that internal-external toothed lock washers are used between regulator legs and cowl.

c. Regulator Installation (fig. 106).

(1) INSTALL REGULATOR. Install regulator on cowl front panel with terminals down and attach with four bolts, nuts, and lock washers. Be sure internal-external toothed lock washers are installed between regulator legs and cowl. Tighten nuts securely.

(2) CONNECT WIRES. Install wires on terminals as follows and attach with nuts and lock washers:

"BATTERY" terminal—No. 8—yellow

"ARMATURE" terminal—No. 8—tan-red and black cross tracer

"FIELD" terminal—No. 14—black

"GROUND" terminal—No. 14—black

(3) POLARIZE GENERATOR. Correct polarization as described in paragraph 117 e.

d. Regulator Cover. Voltage regulators may become inoperative in service due to dust and moisture collecting inside regulator cover. A check of this condition discloses that improper sealing of gasket between regulator cover and base is a major contributing factor. Improper tightening of knurled nut on stud, to fasten cover tight against gasket and base, may permit dust and moisture to enter around gasket. Nut will not tighten properly against cover if stud threads are heavily plated or stud shoulder is too high. To check for and correct a leakage condition, proceed as follows:

(1) Press firmly on each end of assembled regulator cover after tightening knurled nut securely. If cover can be moved at all, it is evident that nut is bottomed without compressing cover gasket.

(2) Remove knurled nut and check stud threads for heavy plating or other accumulated material which might prevent proper tightening. Clean threads if necessary, using a ¼-28 threading die.

(3) Check to see if knurled nut bottoms on stud shoulder. If this condition is found, remove stud and grind or machine shoulder. This will allow nut to fit down over stud shoulder.

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(4) Install stud. Check condition of cover gasket and replace if damaged. Place cover in position, thread knurled nut on stud, and tighten securely by hand. Finally, press firmly on ends of cover to see if it now seats properly.

Section XXII

BATTERY AND LIGHTING SYSTEM

119. BATTERY AND CABLES.

a. Description. The battery is six volt type and is located at the right side of the vehicle at the right rear corner of the cab. Ground strap connects negative (−) terminal of battery to frame side rail. Battery to cranking motor cable connects at positive (+) terminal of battery and switch on cranking motor housing.

b. Battery Tests and Charging.

(1) TEST SPECIFIC GRAVITY IN CELLS. Use an accurate-reading hydrometer and check each cell of battery for specific gravity of battery solution. Fully charged battery should test between 1.260 and 1.300. If reading is below 1.225 under normal operating conditions, battery should be replaced with a fully charged battery. Refer to paragraph 31 for testing instructions in extreme cold, and paragraph 32 in extreme climatic conditions.

(2) TEST CELL VOLTAGE. With ignition switch "OFF," or high tension lead removed from ignition coil, operate cranking motor and quickly check each cell of battery with low reading voltmeter (17-T-5575) in manner shown in figure 107. If voltage falls below 1.7 volts at 80°F, or if there is a difference between cell reading of more than 1/10 volt, battery is at fault and should be replaced.

(3) CHARGING. When battery requires charging, it should be supplied with a charging rate of one ampere per positive plate per cell or 9.0 ampere rate. Charging should continue for two hours after the gravity and terminal voltage shows no further rise. Electrolyte temperature should not be permitted to rise above 110° F.

c. Battery Removal.

(1) REMOVE BATTERY COVER. Remove two stud nuts and pull cover outward to remove.

(2) REMOVE CABLES. Loosen negative and positive cable terminal clamp bolt nuts. Spread terminals slightly and lift from battery posts.

(3) REMOVE BATTERY. Use battery lifter strap at battery terminals to lift battery [(GM-1882853) G57-01-16050] from hanger. Do not tip battery during removal, as electrolyte fluid may be spilled.

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d. Battery Installation.

(1) INSTALL BATTERY. Select battery and test each cell (subpar. b (1) above). Use battery lifter strap at terminals and position battery in hanger. Positive (+) terminal of battery must be toward front of vehicle on long wheelbase models or toward outside on short wheelbase.

(2) ATTACH CABLES. Clean clamping surface of battery posts and cable terminals. Attach cables to respective battery terminals; ground strap to negative (−) and cranking motor cable to positive (+). Tighten clamp bolt nuts. Coat terminals with grease to prevent corrosion formation.

(3) INSTALL BATTERY COVER. Locate cover in place over hanger studs. Install two stud nuts and tighten.

e. Cables. To determine if battery cables are satisfactory, tests outlined in paragraph 120 must be made.

(1) GROUND STRAP.

(a) Removal. Remove two stud nuts and pull cover outward to remove. Remove ground strap and positive cable terminals from battery terminals by loosening terminal clamp bolt nuts. Remove terminals from battery and lift battery from hanger. Remove two nuts, lock washers, bolts, and flat washers attaching ground strap to frame. Remove strap (GM-5275715—long wheelbase), or (GM-5275713—short wheelbase).

(b) Installation. Immerse both terminals of ground strap in solution of ammonia and water to remove all traces of corrosion. Clean bolting surface of frame side rail with wire brush or by scraping. Attach strap to frame side rail, using two bolts with flat washers on outside and lock washers and nuts at inside of frame side rail. *Be sure all bolting surfaces are clean and that nuts are tight.* Position battery in hanger. Clean terminals of battery. Position ground strap terminal on negative (−) and cranking motor cable terminal on positive (+) terminals of battery. Use new clamp bolt and nut at each terminal. Tighten clamp bolt nut. Install battery cover and secure with two stud nuts.

(2) BATTERY TO CRANKING MOTOR CABLE.

(a) Removal. Remove two stud nuts and pull cover outward to remove. Remove nut and lock washer attaching cable to cranking motor switch terminal. Loosen clamp bolt nut and remove cable terminal from battery terminal. Pull cable (GM-5275716—long wheelbase) or (GM-5275714—short wheelbase) rearward to remove.

(b) Installation. Immerse both cable terminals in solution of ammonia and water to remove all traces of corrosion. Thread cable through frame side rail, then through support clips and grommets, until cable is in position along inside of frame side rail. Connect cable to cranking motor switch terminal. Install lock washer and nut. Tighten nut. Position cable terminal over positive (+) battery terminal. Use new clamp bolt and nut. Tighten clamp bolt nut. Install battery cover and secure with two stud nuts.

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(3) ENGINE GROUND STRAP.

(a) Removal. Remove cap screw, lock washer, and flat washer attaching strap to hand brake lever bracket at right side of transmission. Remove nut, lock washer, flat washer, and bolt attaching strap to right-hand motor support. Remove strap.

(b) Installation. Immerse both ends of strap in solution of ammonia and water to thoroughly clean. Wire brush points at which cable attaches. Attach strap to hand brake lever bracket, using flat washer, lock washer, and cap screw. Attach opposite end of strap to engine support, using bolt, flat washer, lock washer, and nut. Tighten mountings to obtain good ground at both ends of strap.

120. LINE VOLTAGE TESTS.

a. General. Excessive resistance caused by poor terminal connections and partial short circuits caused by defective insulation will result in abnormal voltage drop in cranking motor cable which will cause voltage at cranking motor to be so low that normal operations of cranking motor will not be obtained. Abnormal voltage drop can be detected with a low-reading voltmeter.

b. Tests.

(1) Check voltage drop between grounded battery terminal (negative) and vehicle frame. Place one prod of test voltmeter on grounded battery terminal and other on vehicle frame (fig. 107). With ignition switch "OFF," crank engine with cranking motor. If voltmeter reading is more than 1/10 volt, there is excessive resistance in this circuit and ground strap must be cleaned or replaced (par. 119 e).

(2) Check voltage drop between ungrounded battery terminal (positive) and cranking motor switch stud. Place one prod of voltmeter on ungrounded battery terminal and other on cranking motor switch stud (fig. 107). With ignition switch "OFF," crank engine with cranking motor. If voltmeter reading is more than 1/10 volt, there is excessive resistance in this circuit and terminals must be cleaned or cable replaced (par. 119 e).

(3) Check voltage drop between cranking motor housing and vehicle frame. Place one prod of test voltmeter on cranking motor housing and other on vehicle frame (fig. 107). With ignition switch "OFF," crank engine with cranking motor. If voltmeter reading is more than 1/10 volt, there is excessive resistance in this circuit. Remove and clean or replace transmission to frame ground strap (par. 119 e) or tighten cranking motor to clutch housing mountings. Remove switch from cranking motor housing and clean contact surfaces on switch and housing (par. 114 b).

121. HEADLIGHTS.

a. Description. Service headlights, mounted on right- and left-hand fenders, are double filament "sealed beam" type (fig. 110). These lights can only be illuminated when main light switch is in

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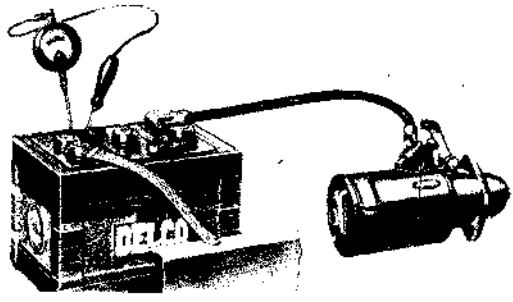
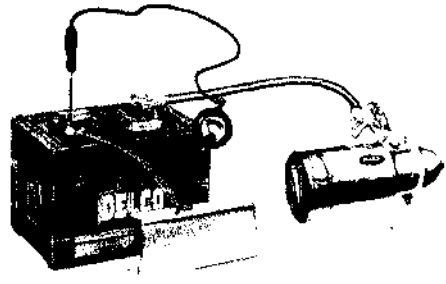
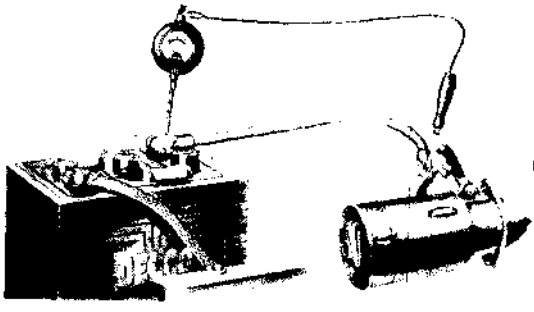
BATTERY AND LIGHTING SYSTEM



BATTERY CELL VOLTAGE TEST

VOLTAGE DROP TEST BETWEEN BATTERY GROUND TERMINAL AND FRAME





VOLTAGE DROP TEST BETWEEN UNGROUNDED BATTERY TERMINAL AND CRANKING MOTOR SWITCH

VOLTAGE DROP TEST BETWEEN CRANKING MOTOR AND FRAME

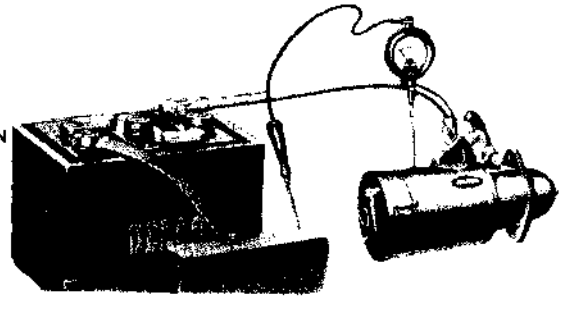


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Figure 107—Battery Cell and Line Voltage Tests, Using Low-Reading Voltmeter (17-T-5575)

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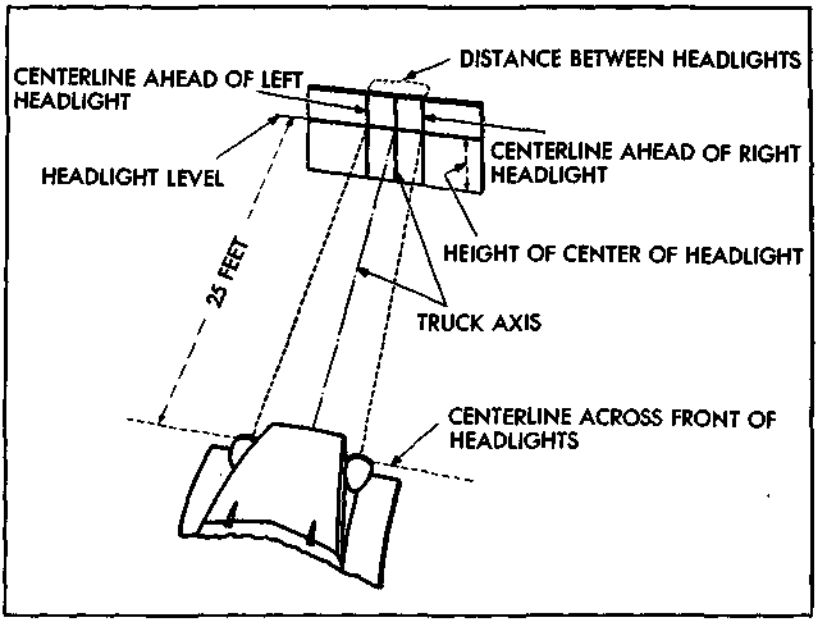

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Figure 108—Headlight Adjustment Chart

operating position (par. 12 **h**). Upper and lower beams are selected by the foot operated dimmer switch on cab toe board.

b. Aiming Adjustment. Headlights can be adjusted quickly and accurately with a headlight tester; however, if this equipment is not available, adjustment can be made as follows:

(1) POSITION VEHICLE (fig. 108). Place vehicle on level floor so that headlights are 25 feet from a smooth vertical surface, such as a door or wall, preferably of a light color. The centerline of vehicle should be at right angles to the vertical surface.

(2) LOCATE HORIZONTAL AND VERTICAL LINES (fig. 109). Measure height of headlight center from floor, then draw a horizontal line on vertical surface at this height. Locate point on this line at which projected centerline of vehicle intersects. Measure distance between headlight centers and divide this distance equally on both sides of center mark. Draw a vertical line through each of these points. The points at which these two vertical lines intersect the horizontal line represent the centers of the right and left headlights.

(3) TURN ON HEADLIGHTS. Turn on headlights at main light switch on instrument panel and select high beam with dimmer switch.

(4) ADJUST HEADLIGHTS (fig. 109). Cover one headlight while adjusting the other. Loosen nut attaching headlight to bracket on fender. Aim headlight so that beam pattern registers with horizontal and vertical lines in manner shown in figure 109, and tighten nut

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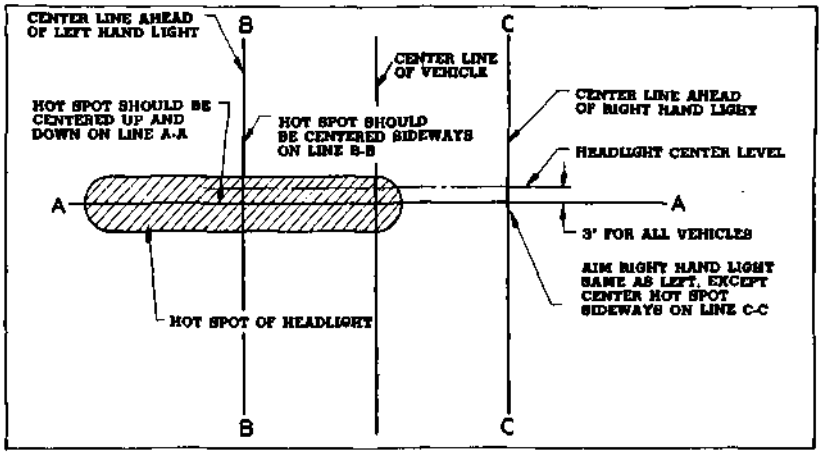

RA PD 56098

Figure 109—Headlight Aiming Pattern

securely, taking care not to change location of light beam pattern on vertical surface. Cover this light and adjust opposite headlight in the same manner.

c. **Sealed Beam Lamp-Unit Removal** (fig. 110). The complete sealed beam unit must be replaced whenever the headlight lamp burns out. The sealed beam unit comprises a lens, reflector, and lamp element sealed as a unit. Unit can be removed with assembly mounted on vehicle.

(1) REMOVE MOULDING. Remove moulding clamp screw at bottom of headlight lens and remove moulding ring.

(2) REMOVE RETAINING RING. Remove three screws attaching sealed beam unit retaining ring to headlight body and remove retaining ring.

(3) REMOVE SEALED BEAM UNIT. Pull sealed beam unit [(GM-925000) G85-01-01970] out of headlight body and pull wiring plug off prongs at rear of sealed beam unit.

d. **Sealed Beam Lamp-Unit Installation** (fig. 110).

(1) INSTALL SEALED BEAM UNIT. Press wiring plug over prongs at rear of sealed beam unit and place sealed beam unit in headlight body.

(2) INSTALL RETAINING RING. Installed sealed beam unit retaining ring and attach to headlight body with three screws.

(3) INSTALL MOULDING. Install moulding ring on headlight body with clip on ring engaged in slot at top of body. Install screw in moulding clamp at bottom of headlight lens and tighten securely.

e. **Headlight Assembly Removal** (fig. 110).

(1) DISCONNECT WIRING. Loosen two screws attaching headlight wires to junction block located on inside of fender skirt. Remove nut and lock washer attaching ground wire to junction

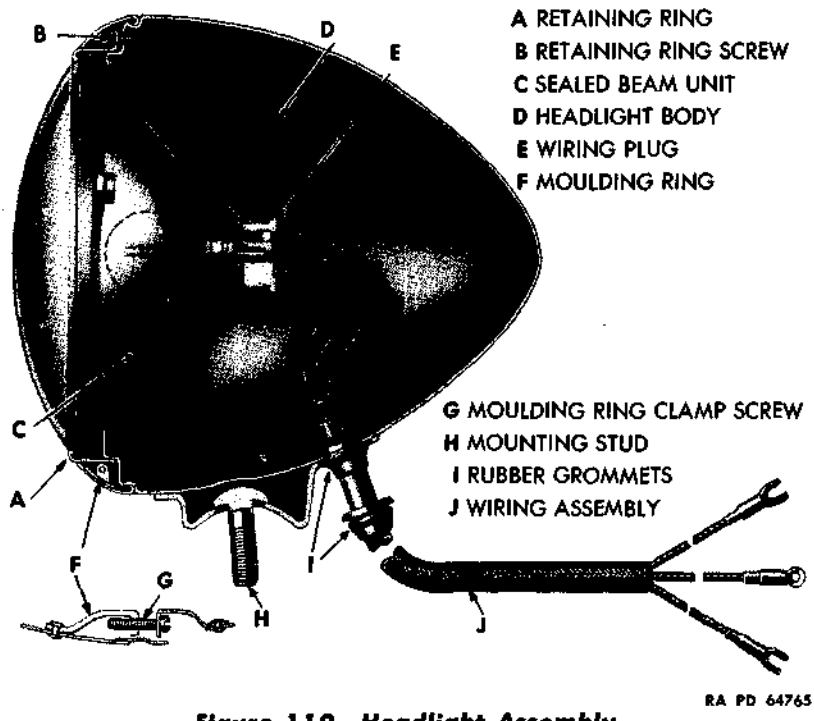

Figure 110—Headlight Assembly

block bolt, or screw and lock washer at fender skirt on late vehicles. Pull wiring out of fender skirt.

(2) REMOVE HEADLIGHT. Remove nut, lock washer, and mounting washer from bolt attaching headlight to bracket on fender. Lift headlight up and pull wiring out of fender.

f. Headlight Assembly Installation.

(1) INSTALL HEADLIGHT. Thread wiring through hole in fender and position headlight with mounting bolt through hole in headlight fender bracket. Press rubber grommet into place around wiring in fender. Install mounting washer, lock washer, and nut on mounting bolt and turn up finger-tight.

(2) CONNECT WIRING. Install wires on junction block terminals, being sure color of headlight wire matches color of harness wire (par. 128). Condenser pigtail wire must also be installed at right-hand headlight junction block. Tighten screws securely. Install ground wire connection on junction block bolt and attach with nut and lock washer. On late vehicles, position ground wire on fender skirt and attach with screw and lock washer.

(3) ADJUST HEADLIGHT. Aim headlight beam as directed in subparagraph b above.

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BATTERY AND LIGHTING SYSTEM

122. BLACKOUT DRIVING LIGHT.

a. Description. Blackout driving light (fig. 111), mounted on the left fender to the left of the headlight, is a sealed-beam type. On some vehicles, light is controlled by a push-pull type switch on the instrument panel (marked B.O. Drive) when the main light switch is in "BLACKOUT" position. On some vehicles light is controlled by rotary-type main light switch. The blackout driving light furnishes a diffused light beam of low intensity to permit limited illumination when driving under blackout conditions.

b. Blackout Driving Sealed Beam Lamp-Unit Removal (fig. 111). Sealed beam unit comprises a lens, reflector, lamp element, and beam visor sealed together as a unit. This lamp-unit may be removed with assembly mounted on vehicle.

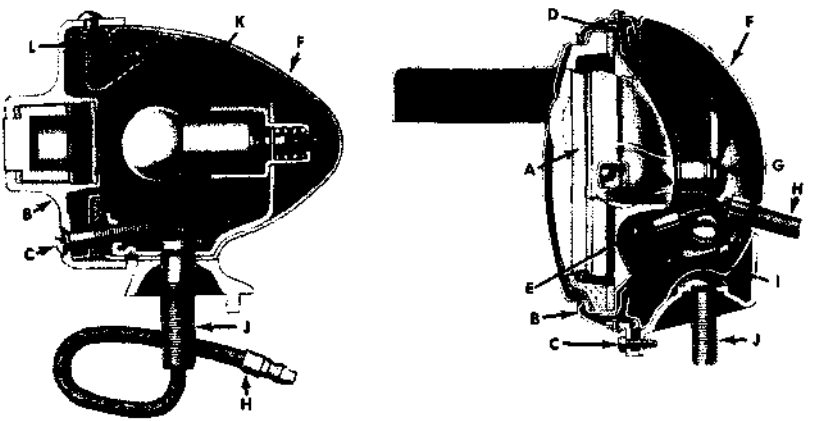
(1) REMOVE MOULDING SCREW. Remove door retaining screw at bottom of lens.

(2) REMOVE SEALED BEAM LAMP-UNIT ASSEMBLY. Pull door out at bottom and raise sealed beam lamp-unit upward to free clip at top of light body.

(3) DISCONNECT WIRES. Loosen screws attaching light wire to rear of sealed beam unit and ground wire to retaining ring, and remove wires.

(4) REMOVE RETAINING RING. Use screw driver to loosen three spring clips attaching retaining ring and sealed beam unit [(GM-5934473) M1-01-07347] in moulding.

c. Blackout Driving Sealed Beam Lamp-Unit Installation (fig. 111).



FRONT MARKER LIGHT

A SEALED BEAM LAMP UNIT
B DOOR ASSEMBLY
C DOOR SCREW
D RING ASSEMBLY
E GROUND WIRE SCREW
F BODY ASSEMBLY

BLACKOUT DRIVING LIGHT

G TERMINAL SCREW
H WIRE ASSEMBLY
I GROUND WIRE
J MOUNTING STUD
K LAMP
L DOOR GASKET

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Figure 111—Blackout Driving and Front Marker Lights

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(1) ASSEMBLE SEALED BEAM UNIT. Place door around front of sealed beam lamp-unit with split in moulding at bottom. Locate retaining ring with clips at back of sealed beam lamp-unit and force three retaining ring springs under flange of door.

(2) CONNECT WIRES. Install light wire under screw head at rear of sealed beam lamp-unit and tighten screw securely. Attach ground wire to retaining ring in the same manner.

(3) INSTALL SEALED BEAM LAMP-UNIT. Installed sealed beam unit assembly in light body with moulding clip engaged in slot at top of body. Install retaining screw at bottom of moulding.

d. Blackout Driving Light Assembly Removal (fig. 111).

(1) DISCONNECT WIRE. Loosen screw attaching blackout driving light wire to junction block located on inside of left-hand fender skirt and remove wire. Pull wire out of fender skirt and fender reinforcement.

(2) REMOVE LIGHT. Remove nut, lock washer, special washer, and external toothed lock washer from bolt attaching blackout driving light to bracket on fender. Lift light up, pulling wire out of fender.

e. Blackout Driving Light Assembly Installation (fig. 111).

(1) INSTALL LIGHT. Place light on fender with wire inserted through hole in fender and the mounting bolt through bracket. Install, in the order named, external toothed lock washer, special washer, lock washer, and nut. Draw nut up finger-tight.

(2) CONNECT WIRE. Thread wire through hole in fender reinforcement and through fender skirt. Connect wire to junction block with harness wire of matching color and tighten screw securely.

(3) ADJUST LIGHT. Hold light so the beam visor is in a horizontal position, pointing straight ahead of the vehicle, and tighten mounting nut securely.

123. BLACKOUT MARKER LIGHTS.

a. Description. Blackout marker lights (fig. 111) are mounted on the fenders at the side of each headlight, and are illuminated only when the main light switch on instrument panel is in "BLACKOUT" position. Blackout marker lights incorporate a specially designed lens and a colored filter which diffuses the light beam.

b. Door, Gasket, and Lamp Removal (fig. 111). These parts can be removed with assembly mounted on vehicle. Remove screw at bottom of marker light door. Pull door out at bottom and lift up to disengage door clip from light body. Remove door gasket from inside of body. Push lamp inward and turn to left to remove lamp from socket.

c. Door, Gasket, and Lamp Installation (fig. 111). Insert lamp in socket and turn to right. Test lamp by turning light switch on. Install door gasket in light body. Install door assembly on light body with clip on door engaging slot at top of body. Install door retaining screw at bottom of door and tighten securely.

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d. Blackout Marker Lights Removal.

(1) DISCONNECT WIRE. Disconnect blackout marker light wire from harness by pulling plug on wire out of socket on harness. Pull wire out of clip on inside of fender skirt, withdraw from hole in fender skirt, and remove from clip under fender reinforcement.

(2) REMOVE FENDER REINFORCEMENT. Remove nut and internal-external toothed lock washer from bolts at each end of reinforcement. Remove nuts, lock washers, and flat washers from two bolts attaching fender reinforcement to fender and headlight bracket. Remove reinforcement. Rear bolt will be withdrawn with reinforcement.

(3) REMOVE BLACKOUT MARKER LIGHT. Pull loom off blackout marker light mounting stud and wire. Remove nut and internal-external toothed lock washer from mounting stud. Remove blackout marker light by raising it up and pulling wire out of fender.

e. Blackout Marker Lights Installation.

(1) INSTALL BLACKOUT MARKER LIGHT. Insert blackout marker light wire and mounting stud through fender. Make sure dowel on light base is in dowel hole in fender. Slide internal-external toothed lock washer and nut over wire and install on mounting stud. Tighten nut securely. Insert wire through loom and force loom over mounting stud up to the nut.

(2) INSTALL FENDER REINFORCEMENT. Insert wire and loom through hole in fender reinforcement and position reinforcement against fender with bolt through rear end of reinforcement inserted through fender, skirt, and hood side panel bracket. Install nuts, lock washers, and flat washers on two bolts attaching reinforcement to fender and headlight bracket, being sure wire clip is in place under flat washer on rearward bolt. Draw nuts up finger-tight. Install and tighten bolts, internal-external toothed lock washers, and nuts at each end of reinforcement. Tighten the two nuts on bolts at headlight bracket.

(3) CONNECT WIRE. Install wire and loom in clip under reinforcement and insert wire through fender skirt. Be sure grommet is in place in fender skirt. Insert plug on wire into socket on harness and install wire and loom in clip on inside of fender skirt.

124. STOP AND TAILLIGHTS.

a. Description. The stop and taillights, mounted at the rear corners of the vehicle, consists of two units. The left-hand light incorporates a combination stop and tail lamp-unit in the upper portion, and a blackout taillight lamp-unit in the lower portion (fig. 112). The right-hand light incorporates a blackout stop lamp-unit in the upper portion, and a blackout tail lamp-unit in the lower portion (fig. 112). The beams of stop and taillights are diffused so that they are not visible from above.

b. Lamp-Unit Removal (fig. 112). Remove two screws attaching door to light body and remove door. Remove each lamp-unit [B.O. stop—(GM-5933121) M1-01-07408; B.O. tail—(GM-5933078)

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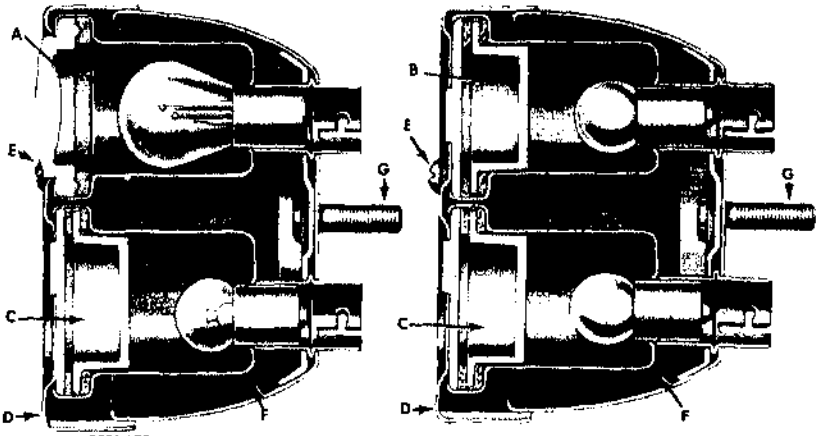

SERVICE STOP AND TAILLIGHT

A SERVICE STOP AND TAIL LAMP UNIT
B BLACKOUT STOP LAMP UNIT
C BLACKOUT TAIL LAMP UNIT
D LAMP UNIT DOOR

BLACKOUT STOP AND TAILLIGHT

E DOOR RETAINING SCREW
F LIGHT BODY
G MOUNTING STUD

RA PD 333023

Figure 112—Stop and Taillight Assemblies

M1-01-07407; stop light—(GM-5933104) M1-01-07416] from body by pulling outward.

c. **Lamp-Unit Installation** (fig. 112). Install lamp-unit into body in its correct position. Lower units on both sides are marked "BLACKOUT TAIL SIGNAL," upper right-hand unit is marked "BLACKOUT STOP SIGNAL," while upper left-hand unit is unidentified. Position door over lamp-unit and body. Install two screws and tighten sufficiently to hold door to body.

d. **Light Removal** (fig. 112). Remove wiring connectors from sockets at rear of light by pressing inward on connector, turning to left and withdrawing from socket. Remove two nuts and external toothed lock washers from studs attaching light body to bracket and remove light assembly [left—(GM-927225) M1-01-07249; right—(GM-927226) M1-01-07248].

e. **Light Installation** (fig. 112).

(1) INSTALL LIGHT ASSEMBLY. Position light assembly on mounting with studs extending through holes in bracket. Attach ground wire to mounting stud. Install nuts and external toothed lock washers on studs and tighten securely.

(2) CONNECT WIRING. Insert wiring connectors in sockets at rear of light body, press inward and turn to left to lock in position. Wires should be connected as follows: Left-hand light — double contact plug in top socket; single contact plug in lower socket. Right-hand light — No. 16 black-red tracer in upper socket; No. 16 white in lower socket. To determine color of wire, slide connector sleeve back over loom.

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125. TRAILER CONNECTOR.

a. General. A four-terminal connector or socket is used at rear end of most vehicles. Connector provides means of connecting stop and taillights on trailer with towing vehicle so that signal is the same at both vehicles.

b. Removal. Remove four nuts, lock washers, and bolts attaching connector and cover to mounting. Pull cover (also dust shield and ring on late models), rearward to remove. Remove screw, lock washer, and cover at rear of connector. Remove nut, lock washer, and wire from each of the three terminals.

c. Installation.

(1) CONNECT WIRES. Remove screw, lock washer, and cover at rear of connector. Attach three wires to following terminals; No. 12 black to "GR"; No. 16 red-black check to "SL"; No. 16 green-black check to "TL." Secure each wire to terminal with lock washer and nut. Position cover over rear of connector. Install and tighten screw with lock washer, attaching cover to connector.

(2) INSTALL CONNECTOR. Position connector against mounting bracket with socket slot at the bottom. On late models, position dust shield and ring against connector flanges. Install two lower bolts, lock washers, and nuts at bottom. Position cover against flange of connector (shield ring on late models), and install two bolts through cover bracket, (ring and dust shield on late models), connector, and mounting bracket. Install two lock washers and nuts. Tighten four mounting bolt nuts.

Section XXIII

WIRING, HARNESSES, AND CIRCUITS

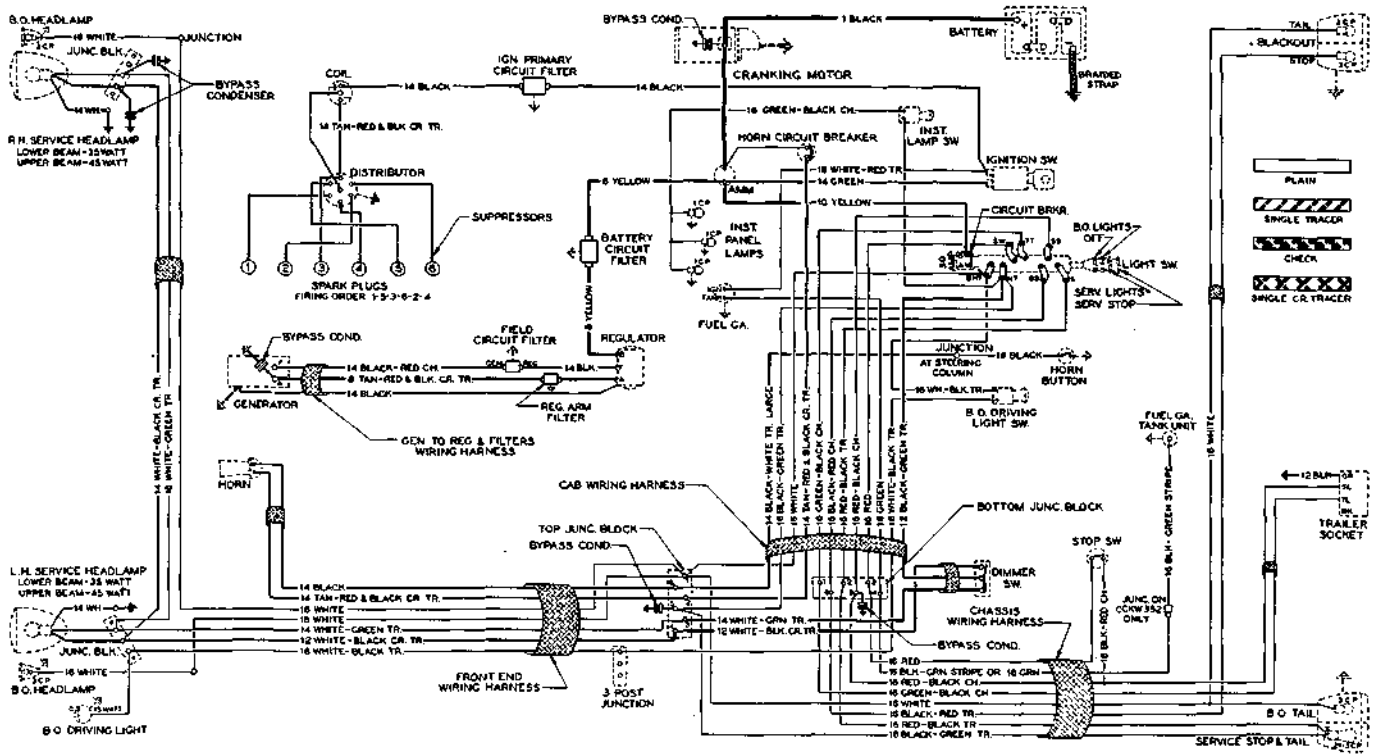
126. GENERAL.

a. The electrical system of these vehicles is six-volt type. Units used in various electrical systems are described in other sections of this manual as follows:

Ignition System ..... Section XVI
Starting System ..... Section XX
Generating System ..... Section XXI
Battery and Lighting System ..... Section XXII
Radio Noise Suppression System ..... Section XXIV
Instruments, Gages, and Switches ..... Section XXV

127. CIRCUITS.

a. Electrical system of this vehicle is divided into the following circuits; ignition, starting, generating, lighting, fuel gage, and horn. Circuit diagrams (figs. 113 and 114), illustrate in a schematic man-



RA PD 332982

Figure 113—General Wiring Diagram (Push-Pull Main Light Switch)

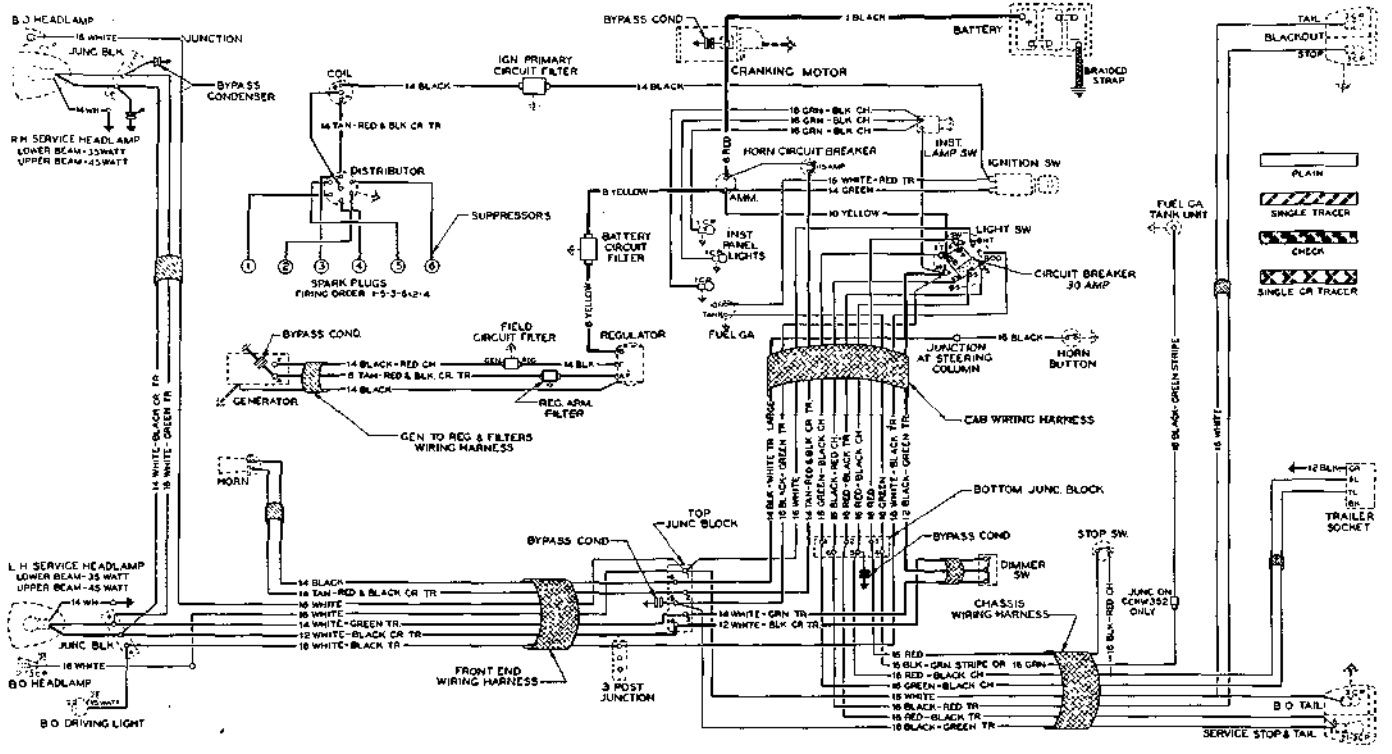
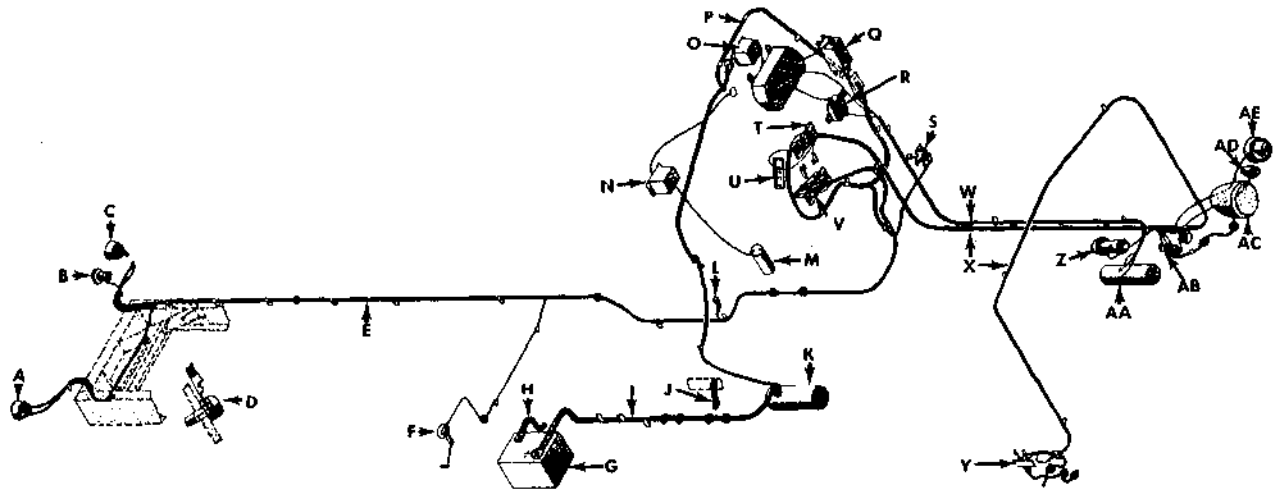


Figure 114—General Wiring Diagram (Rotary Main Light Switch)



A BLACKOUT STOP AND TAILLIGHT
B TRAILER LIGHT SOCKET
C SERVICE STOP AND TAILLIGHT
D TRAILER SOCKET GROUND
E CHASSIS WIRING HARNESS
F FUEL TANK GAGE
G BATTERY
H BATTERY GROUND STRAP
I BATTERY TO CRANKING MOTOR CABLE
J ENGINE GROUND STRAP
K CRANKING MOTOR

L STOP LIGHT SWITCH
M IGNITION COIL
N IGNITION CIRCUIT FILTER
O BATTERY CIRCUIT FILTER
P CAB WIRING HARNESS
Q ARMATURE CIRCUIT FILTER
R FIELD CIRCUIT FILTER
S HEADLIGHT DIMMER SWITCH
T JUNCTION BLOCK—UPPER
U JUNCTION BLOCK—3 POST
V JUNCTION BLOCK—LOWER

W GENERATOR TO REGULATOR AND FILTERS WIRING HARNESS
X FRONT END WIRING HARNESS
Y HEADLIGHT JUNCTION BLOCK—R.H.
Z HORN
AA GENERATOR
AB HEADLIGHT JUNCTION BLOCK—L.H.
AC HEADLIGHT
AD MARKER LIGHT
AE BLACKOUT DRIVING LIGHT

RA PD 332939

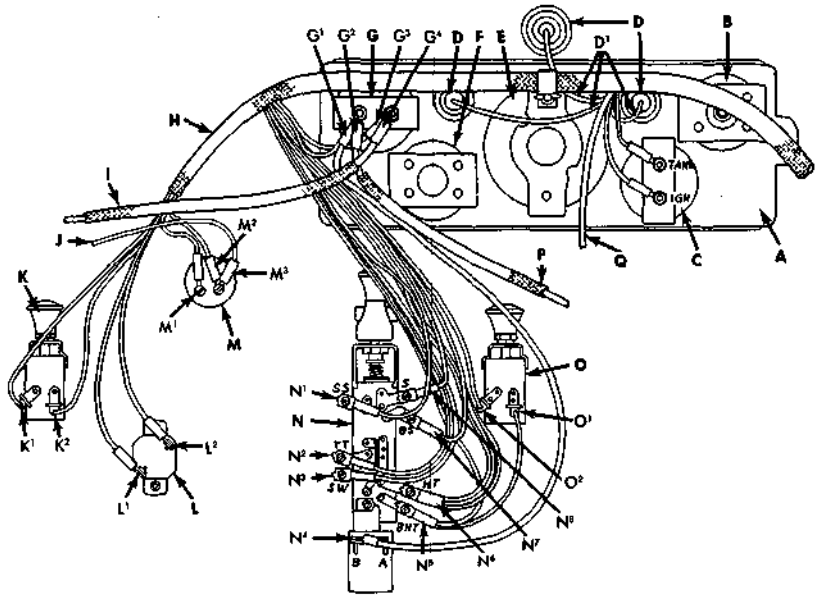
Figure 115—Arrangement of Wiring Harnesses

ES18-002672 0393

ner the various electrical circuits throughout the vehicle. Each circuit can be readily traced with a conventional test light or buzzer equipment, to establish continuity of circuit.

128. WIRING AND HARNESSES.

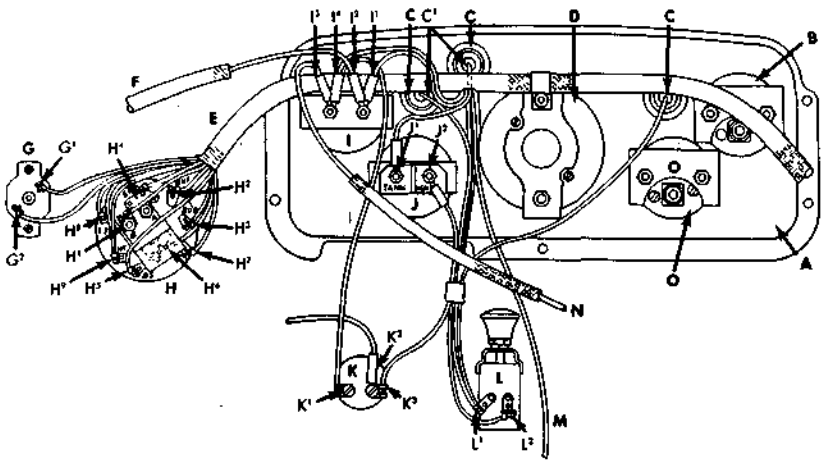
a. Location. General arrangement of various wiring harnesses and electrical units is illustrated in figure 115. Each harness is lo-



A INSTRUMENT PANEL
B WATER TEMPERATURE GAGE
C FUEL LEVEL GAGE
  C¹ "IGN" NO. 16 WHITE—RED TR.
  C² "TANK" NO. 16 GREEN
D INSTRUMENT PANEL LIGHTS
  D¹ NO. 16 GREEN BLACK CH.
E SPEEDOMETER
F OIL PRESSURE GAGE
G AMMETER
  G¹ NO. 14 GREEN WITH NO. 10 YELLOW
  G² NO. 8 YELLOW (TO BATTERY FILTER)
  G³ NO. 16 TAN—RED AND BLACK CR. TR.
  G⁴ NO. 8 RED (TO CRANKING MOTOR)
H CAB WIRING HARNESS
I AMMETER TO CRANKING MOTOR (NO. 8 RED)
J IGN. SWITCH TO PRIMARY IGN. FILTER (NO. 14 BLACK)
K INSTRUMENT PANEL LIGHT SWITCH
  K¹ NO. 16 GREEN—BLACK CH.
  K² NO. 16 BLACK—GREEN TR.
L HORN CIRCUIT BREAKER
  L¹ NO. 16 TAN—RED AND BLACK CR. TR.
  L² NO. 16 TAN—RED AND BLACK CR. TR.
M IGNITION SWITCH
  M¹ NO. 14 GREEN
  M² NO. 16 WHITE—RED TR.
  M³ NO. 14 BLACK
N MAIN LIGHT SWITCH
  N¹ "SS" NO. 16 BLACK—RED CH.
  N² "TT" NO. 16 GREEN—BLACK CH.
  N³ "SW" NO. 16 RED
  N⁴ "B" NO. 10 YELLOW
  N⁵ "BHT" No. 16 WHITE—BLACK TR. WITH NO. 16 WHITE
  N⁶ "HT" NO. 12 BLACK—GREEN TR. WITH NO. 16 BLACK—GREEN TR.
  N⁷ "BS" NO. 16 BLACK—RED TR.
  N⁸ "S" NO. 16 RED—BLACK TR.
O BLACKOUT DRIVING LIGHT SWITCH
  O¹ NO. 16 WHITE—BLACK TR.
  O² NO. 16 WHITE—BLACK TR.
P AMMETER TO BATTERY FILTER WIRE (NO. 8 YELLOW)
Q TO HORN BUTTON TERMINAL ON STEERING COLUMN (NO. 14 BLACK—WHITE TR.—LARGE)

RA PD 333025

Figure 116—Instrument Panel Wiring Connections (Push-Pull Main Light Switch)



A INSTRUMENT PANEL
B OIL PRESSURE GAGE
C INSTRUMENT PANEL LIGHTS
  C^1 NO. 16 GREEN—BLACK CH.
D SPEEDOMETER
E CAB WIRING HARNESS
F AMMETER TO CRANKING MOTOR (NO. 8 RED)
G HORN CIRCUIT BREAKER
  G^1 NO. 14 TAN—RED AND BLACK CR. TR.
  G^2 NO. 14 TAN—RED AND BLACK CR. TR.
H MAIN LIGHT SWITCH
  H^1 "B" NO. 10 YELLOW
  H^2 "BHT" NO. 16 WHITE
  H^3 "BOD" NO. 16 WHITE—BLACK TR.
  H^4 "SW" NO. 16 RED
  H^5 "BS" NO. 16 BLACK—RED TR.
  H^6 "SS" NO. 16 RED—BLACK CH.
  H^7 "S" NO. 16 RED—BLACK TR.
  H^8 "TT" NO. 16 GREEN—BLACK CH.
  H^9 "HT" NO. 12 BLACK—GREEN TR. WITH 2 NO. 16 BLACK—GREEN TR.
I AMMETER
  I^1 NO. 16 TAN—RED AND BLACK CR. TR.
  I^2 NO. 8 RED (TO CRANKING MOTOR)
  I^3 NO. 8 YELLOW (TO BATTERY FILTER)
  I^4 NO. 14 GREEN WITH NO. 10 YELLOW
J FUEL LEVEL GAGE
  J^1 "TANK" NO. 16 GREEN
  J^2 "IGN" NO. 16 WHITE—RED TR.
K IGNITION SWITCH
  K^1 NO. 14 GREEN
  K^2 NO. 14 BLACK (TO PRIMARY CIRCUIT FILTER)
  K^3 NO. 16 WHITE—RED TR.
L INSTRUMENT PANEL LIGHT SWITCH
  L^1 NO. 16 GREEN—BLACK CH. (3)
  L^2 NO. 16 GREEN—GREEN TR.
M TO HORN BUTTON TERMINAL ON STEERING COLUMN WIRE (NO. 14 BLACK—WHITE TR. LARGE)
N AMMETER TO BATTERY FILTER WIRE (NO. 8 YELLOW)
O WATER TEMPERATURE GAGE

RA PD 333026

Figure 117—Instrument Panel Wiring Connections (Rotary Main Light Switch)

cated to provide maximum accessibility for replacement or other service.

b. Splices. Whenever it is necessary to splice a wire, or repair one that is broken, always use solder to bond the splice. Use insulating tape profusely to cover all bare wires.

c. Identification. Each wire can easily be identified by its size, color, and pattern. Each wire size and color, also pattern design, is shown in figures 113 and 114. Whenever practical, a group of wires are arranged into harnesses. Wires which are included in a harness are indicated in figures 113 and 114 by showing them as passing through a loom. In several instances it has not been possible or practical to show several short wires at instrument panel within the cab wiring harness loom.

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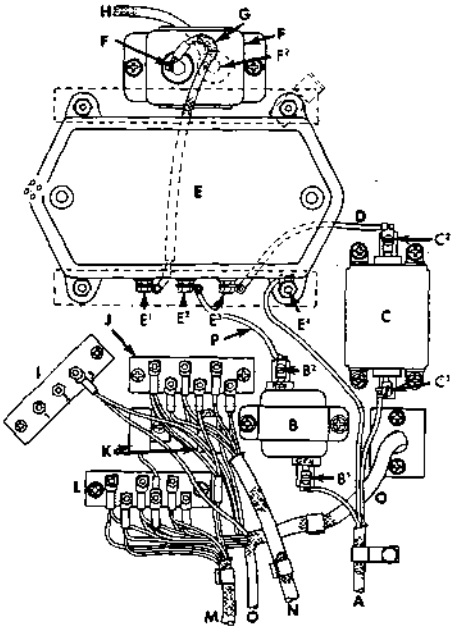
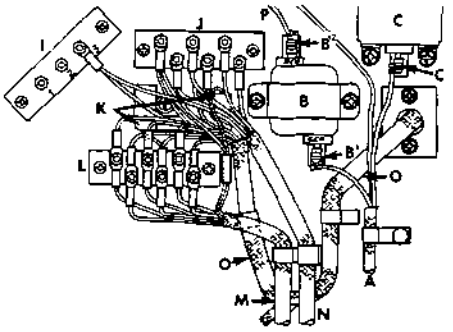


USED WITH ROTARY TYPE MAIN LIGHT SWITCH



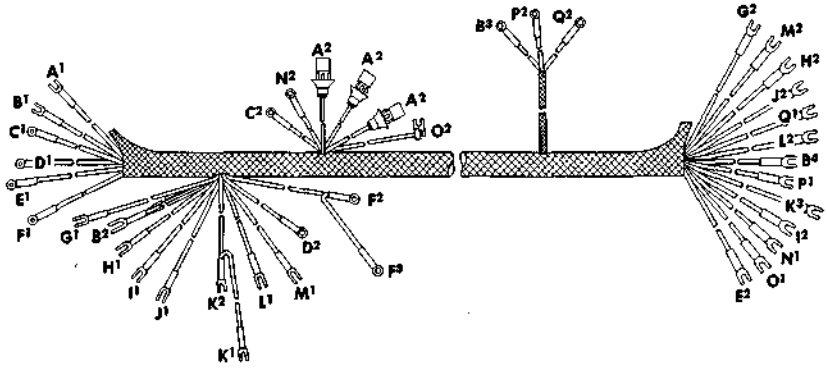
USED WITH PUSH-PULL MAIN LIGHT SWITCH

A GENERATOR TO REGULATOR AND FILTERS HARNESS
B FIELD CIRCUIT FILTER
  B¹ NO. 14 BLACK-RED CH.
  B² NO. 14 BLACK
C ARMATURE FILTER
  C¹ NO. 8 TAN-RED AND BLACK CR. TR.
  C² NO. 8 TAN-RED AND BLACK CR. TR.
D ARMATURE FILTER TO REGULATOR WIRE (NO. 8 TAN-RED AND BLACK CR. TR.)
E REGULATOR
  E¹ "BATTERY" NO. 8 YELLOW
  E² "FIELD" NO. 14 BLACK
  E³ "ARMATURE" NO. 8 TAN-RED AND BLACK CR. TR.
  E⁴ "GND" NO. 14 BLACK
F BATTERY CIRCUIT FILTER
  F¹ NO. 8 YELLOW
  F² NO. 8 YELLOW
G REGULATOR TO BATTERY FILTER WIRE
H BATTERY FILTER TO AMMETER WIRE
I 3 POST JUNCTION BLOCK
  1—VACANT
  2—VACANT
  3—NO. 16 WHITE-BLACK TR.
J UPPER JUNCTION BLOCK
  1—NO. 16 WHITE (4)
  2—NO. 14 TAN-RED AND BLACK CR. TR.
  3—NO. 14 WHITE-GREEN TR.
  4—NO. 12 WHITE—BLACK CR. TR.
  5—NO. 16 BLACK-GREEN TR. CONDENSER WIRE
  6—NO. 14 BLACK
    NO. 14 BLACK-WHITE TR. (LARGE)
K CONDENSERS
L LOWER JUNCTION BLOCK
  1—NO. 16 GREEN-BLACK CH.
  2—NO. 16 RED-BLACK TR.
  3—NO. 16 RED
  4—NO. 16 GREEN
    NO. 16 BLACK-GREEN STRIPE (LONG W.B.)
    NO. 16 GREEN (SHORT W.B.)
  5—NO. 16 RED-BLACK CH. CONDENSER WIRE
  6—NO. 16 BLACK-RED TR.
M CHASSIS WIRING HARNESS
N FRONT END WIRING HARNESS
O CAB WIRING HARNESS
P FIELD FILTER TO REGULATOR WIRE (NO. 14 BLACK)

RA PD 333046

Figure 118—Wiring Harness Connections at Junction Blocks, Filters, and Regulator

TRUCK, 2½-TON, 6 x 6

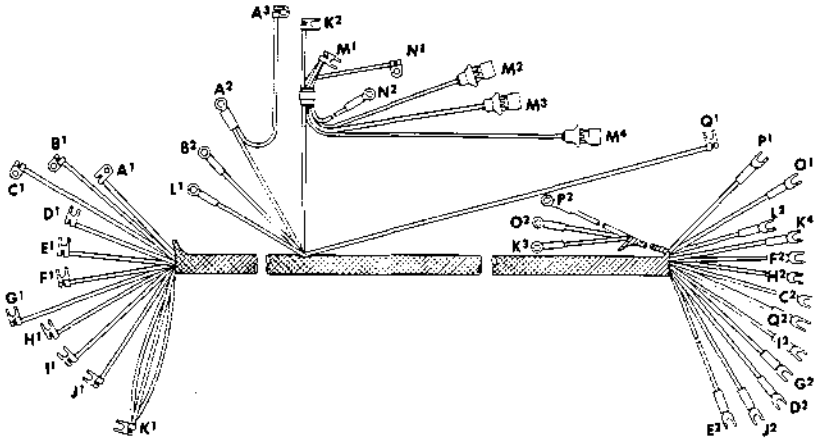


SYMBOL AND CIRCUIT	WIRE SIZE AND COLOR	TERMINAL
A^1 INSTRUMENT PANEL LIGHTS	NO. 16 GREEN-BLACK CH.	PANEL SWITCH
A^2 INSTRUMENT PANEL LIGHTS	NO. 16 GREEN-BLACK CH.	LIGHT SOCKETS
B^1 INSTRUMENT PANEL LIGHTS	NO. 16 BLACK-GREEN TR.	PANEL SWITCH
B^2 INSTRUMENT PANEL LIGHTS	NO. 16 BLACK-GREEN TR.	LIGHT SWITCH "HT"
B^3 DIMMER SWITCH FEED	NO. 12 BLACK-GREEN TR.	LIGHT SWITCH "HT"
B^3 SERVICE TAILLIGHT FEED	NO. 16 BLACK-GREEN TR.	LIGHT SWITCH "HT"
B^3 DIMMER SWITCH FEED	NO. 12 BLACK-GREEN TR.	"BATT"
B^4 SERVICE TAILLIGHT FEED	NO. 16 BLACK-GREEN TR.	NO. 5 TOP JCT.
C^1 FUEL GAGE FEED	NO. 16 WHITE-RED TR.	IGNITION SWITCH
C^2 FUEL GAGE FEED	NO. 16 WHITE-RED TR.	FUEL GAGE "IGN"
D^1 HORN FEED	NO. 14 TAN-RED & BLACK X TR.	CIRCUIT BREAKER
D^2 HORN FEED	NO. 14 TAN-RED & BLACK X TR.	AMMETER
E^1 HORN	NO. 14 TAN-RED & BLACK X TR.	CIRCUIT BREAKER
E^2 HORN	NO. 14 TAN-RED & BLACK X TR.	NO. 2 TOP JCT.
F^1 IGNITION SWITCH FEED	NO. 14 GREEN	IGN. SWITCH
F^2 IGNITION SWITCH FEED	NO. 14 GREEN	AMMETER
F^2 LIGHT SWITCH FEED	NO. 10 YELLOW	AMMETER
F^3 LIGHT SWITCH FEED	NO. 10 YELLOW	LIGHT SWITCH "B"
G^1 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	PANEL SWITCH
G^2 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	NO. 3 - 3 POST JCT.
H^1 BLACKOUT STOP LIGHT	NO. 16 BLACK-RED CH.	LIGHT SWITCH "BS"
H^2 BLACKOUT STOP LIGHT	NO. 16 BLACK-RED CH.	NO. 6 BOTTOM JCT.
I^1 STOP LIGHT SWITCH	NO. 16 RED	LIGHT SWITCH "SW"
I^2 STOP LIGHT SWITCH	NO. 16 RED	NO. 3 BOTTOM JCT.
J^1 STOP LIGHT SWITCH FEED	NO. 16 BLACK-RED CH.	LIGHT SWITCH "SS"
J^2 STOP LIGHT SWITCH FEED	NO. 16 BLACK-RED CH.	NO. 5 BOTTOM JCT.
K^1 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	PANEL SWITCH
K^2 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	LIGHT SWITCH "BHT"
K^2 BLACKOUT HEAD & TAILLIGHTS	NO. 16 WHITE	LIGHT SWITCH "BHT"
K^3 BLACKOUT HEAD & TAILLIGHTS	NO. 16 WHITE	NO. 1 TOP JCT.
L^1 SERVICE STOP LIGHT FEED	NO. 16 RED-BLACK TR.	LIGHT SWITCH "S"
L^2 SERVICE STOP LIGHT FEED	NO. 16 RED-BLACK TR.	NO. 2 BOTTOM JCT.
M^1 TRAILER TAILLIGHT	NO. 16 GREEN-BLACK CH.	LIGHT SWITCH "TT"
M^2 TRAILER TAILLIGHT	NO. 16 GREEN-BLACK CH.	NO. 1 BOTTOM JCT.
N^1 FUEL GAGE	NO. 16 GREEN	NO. 4 BOTTOM JCT.
N^2 FUEL GAGE	NO. 16 GREEN	FUEL GAGE "TANK"
O^1 HORN	NO. 14 BLACK-WHITE TR.	NO. 6 TOP JCT.
O^2 HORN	NO. 14 BLACK-WHITE TR.	STEERING COLUMN
P^1 HEADLIGHTS —DIM	NO. 14 WHITE-GREEN TR.	NO. 3 TOP JCT.
P^2 HEADLIGHTS —DIM	NO. 14 WHITE-GREEN TR.	DIMMER SW. "DIM"
Q^1 HEADLIGHTS —BRIGHT	NO. 12 WHITE-BLACK TR.	NO. 4 TOP JCT.
Q^2 HEADLIGHTS —BRIGHT	NO. 12 WHITE-BLACK TR.	DIMMER SW. "BRT."

RA PD 333009

Figure 119—Cab Wiring Harness (Push-Pull Main Light Switch)

WIRING, HARNESSES, AND CIRCUITS

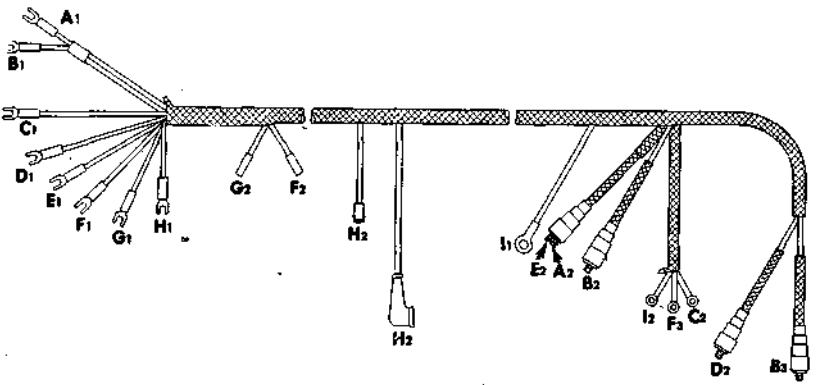


SYMBOL AND CIRCUIT	WIRE SIZE AND COLOR	TERMINAL
A^1 MAIN LIGHT SWITCH FEED	NO. 10 YELLOW	LIGHT SWITCH "B"
A^2 MAIN LIGHT SWITCH FEED	NO. 10 YELLOW	AMMETER
A^2 IGNITION SWITCH FEED	NO. 14 GREEN	AMMETER
A^3 IGNITION SWITCH FEED	NO. 14 GREEN	IGNITION SWITCH
B^1 HORN CIRCUIT BREAKER FEED	NO. 14 TAN-RED & BLACK CR. TR.	CIRCUIT BREAKER
B^2 HORN CIRCUIT BREAKER FEED	NO. 14 TAN-RED & BLACK CR. TR.	AMMETER
C^1 HORN FEED	NO. 14 TAN-RED & BLACK CR. TR.	CIRCUIT BREAKER
C^2 HORN FEED	NO. 14 TAN-RED & BLACK CR. TR.	NO. 2 UPPER JCT.
D^1 BLACKOUT LIGHTS FEED	NO. 16 WHITE	LIGHT SWITCH "BHT"
D^2 BLACKOUT LIGHTS FEED	NO. 16 WHITE	NO. 1 UPPER JCT.
E^1 BLACKOUT DRIVING LIGHT FEED	NO. 16 WHITE-BLACK TR.	LIGHT SWITCH "BOD"
E^2 BLACKOUT DRIVING LIGHT FEED	NO. 16 WHITE-BLACK TR.	NO. 3 - 3 POST JCT.
F^1 STOP LIGHT SWITCH FEED	NO. 16 RED	LIGHT SWITCH "SW"
F^2 STOP LIGHT SWITCH FEED	NO. 16 RED	NO. 3 LOWER JCT.
G^1 BLACKOUT STOP LIGHT FEED	NO. 16 BLACK-RED TR.	LIGHT SWITCH "BS"
G^2 BLACKOUT STOP LIGHT FEED	NO. 16 BLACK-RED TR.	NO. 6 LOWER JCT.
H^1 STOP LIGHT SWITCH RETURN	NO. 16 BLACK-RED CH.	LIGHT SWITCH "SS"
H^2 STOP LIGHT SWITCH RETURN		NO. 5 LOWER JCT.
I^1 STOP LIGHT FEED	NO. 16 RED-BLACK TR.	LIGHT SWITCH "S"
I^2 STOP LIGHT FEED	NO. 16 RED-BLACK TR.	NO. 2 LOWER JCT.
J^1 TRAILER TAILLIGHT FEED	NO. 16 BLACK-GREEN CH.	LIGHT SWITCH "TT"
J^2 TRAILER TAILLIGHT FEED	NO. 16 BLACK-GREEN CH.	NO. 1 LOWER JCT.
K^1 INSTRUMENT LAMP SWITCH FEED	NO. 16 BLACK-GREEN TR.	MAIN SWITCH "HT"
SERVICE TAILLIGHT FEED	NO. 16 BLACK-GREEN TR.	MAIN SWITCH "HT"
DIMMER SWITCH FEED	NO. 10 BLACK-GREEN TR.	MAIN SWITCH "HT"
K^2 INSTRUMENT LAMP SWITCH FEED	NO. 16 BLACK-GREEN TR.	PANEL SWITCH
K^3 DIMMER SWITCH FEED	NO. 12 BLACK-GREEN TR.	DIMMER SW. "BAT"
K^4 SERVICE TAILLIGHT FEED	NO. 16 BLACK-GREEN TR.	NO. 5 UPPER JCT.
L^1 FUEL GAGE	NO. 16 GREEN	GAGE "TANK"
L^2 FUEL GAGE	NO. 16 GREEN	NO. 4 BOTTOM JCT.
M^1 INSTRUMENT PANEL LIGHTS	NO. 16 GREEN-BLACK CH.	PANEL SWITCH
M^2 INSTRUMENT PANEL LIGHT	NO. 16 GREEN-BLACK CH.	LIGHT SOCKET
M^3 INSTRUMENT PANEL LIGHT	NO. 16 GREEN-BLACK CH.	LIGHT SOCKET
M^4 INSTRUMENT PANEL LIGHT	NO. 16 GREEN-BLACK CH.	LIGHT SOCKET
N^1 FUEL GAGE FEED	NO. 16 WHITE-RED TR.	IGN. SWITCH
N^2 FUEL GAGE FEED	NO. 16 WHITE-RED TR.	GAGE "IGN"
O^1 DIM HEADLIGHT FEED	NO. 14 WHITE-GREEN TR.	NO. 3 UPPER JCT.
O^2 DIM HEADLIGHT FEED	NO. 14 WHITE-GREEN TR.	DIMMER SW. "DIM"
P^1 BRIGHT HEADLIGHT FEED	NO. 12 WHITE-BLACK CH. TR.	NO. 4 UPPER JCT.
P^2 BRIGHT HEADLIGHT FEED	NO. 12 WHITE-BLACK CH. TR.	DIMMER SW. "BRT"
Q^1 HORN BUTTON	NO. 14 BLACK-WHITE TR.	STEERING COLUMN
Q^2 HORN BUTTON	NO. 14 BLACK-WHITE TR.	NO. 6 UPPER JCT.

RA PD 333000

Figure 120—Cab Wiring Harness (Rotary Main Light Switch)

TRUCK, 2½-TON, 6 x 6



SYMBOL CIRCUIT	WIRE SIZE AND COLOR	TERMINAL
A_1 SERVICE TAILLIGHT	NO. 16 BLACK-GREEN TR.	NO. 5 TOP JCT.
A_2 SERVICE TAILLIGHT	NO. 16 BLACK-GREEN TR.	CONNECTOR
B_1 BLACKOUT TAILLIGHT	NO. 16 WHITE	NO. 1 TOP JCT.
B_2 BLACKOUT TAIL-LIGHT—L.H.	NO. 16 WHITE	CONNECTOR
B_3 BLACKOUT TAIL-LIGHT—R.H.	NO. 16 WHITE	CONNECTOR
C_1 TRAILER TAILLIGHT	NO. 16 BLACK-GREEN CH.	NO. 1 BOTTOM JCT.
C_2 TRAILER TAILLIGHT	NO. 16 BLACK-GREEN CH.	TRAILER SOCKET "TL"
D_1 BLACKOUT STOP LIGHT	NO. 16 BLACK-RED TR.	NO. 6 BOTTOM JCT.
D_2 BLACKOUT STOP LIGHT	NO. 16 BLACK-RED TR.	CONNECTOR
E_1 SERVICE STOP LIGHT	NO. 16 RED-BLACK TR.	NO. 2 BOTTOM JCT.
E_2 SERVICE STOP LIGHT	NO. 16 RED-BLACK TR.	CONNECTOR
F_1 STOP LIGHT SWITCH	NO. 16 BLACK-RED CH.	NO. 5 BOTTOM JCT.
F_2 STOP LIGHT SWITCH	NO. 16 BLACK-RED CH.	STOP SWITCH
F_3 TRAILER STOP LIGHT	NO. 16 BLACK-RED CH.	TRAILER SOCKET "SL"
G_1 STOP LIGHT SWITCH	NO. 16 RED	NO. 3 BOTTOM JCT.
G_2 STOP LIGHT SWITCH	NO. 16 RED	STOP SWITCH
H_1 FUEL GAGE	NO. 16 BLACK-GREEN TR. (LONG W.B.)	NO. 4 BOTTOM JCT.
H_1 FUEL GAGE	NO. 16 GREEN (SHORT W.B.)	NO. 4 BOTTOM JCT.
H_2 FUEL GAGE	NO. 16 BLACK-GREEN TR. (LONG W.B.)	FUEL TANK UNIT
H_2 FUEL GAGE	NO. 16 GREEN (SHORT W.B.)	TANK JCT.
I_1 TRAILER SOCKET GROUND	NO. 12 BLACK	FRAME
I_2 TRAILER SOCKET GROUND	NO. 12 BLACK	TRAILER SOCKET "GR"

RA PD 333001

Figure 121—Chassis Wiring Harness

(1) The circuit and terminal connection of any individual wire, within a harness, can be determined by referring to figures 119 to 123. Example—if wire is identified as being E-1 at one end, the opposite end will be E-2. Whenever one or more wires are spliced into "E" circuit, outlet ends of these wires would then be identified as E-3 or E-4. Wire size, color, circuit, and terminal connection of each wire is listed below each wiring harness illustration (figs. 119 to 123).

d. Replacement. Each individual wire or various harness assemblies can be removed by disconnecting at junction blocks, switches,

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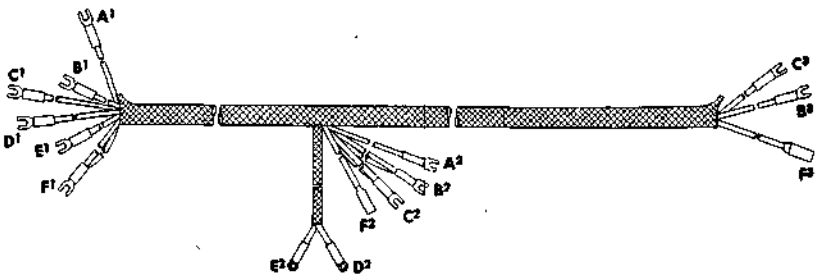
gages, or other electrical units. Remove clips and grommets necessary to accomplish removal. When wires have been disconnected and clips or grommets removed, the wire or harness can then be completely removed. When installing, locate the wire or harness in its correct position, being sure that clips and grommets are installed. Attach individual wires to the respective unit or junction block terminal. Tighten connections. Bear in mind: *A clean and tight electrical connection is a good connection.*

(1) CAB WIRING HARNESS (figs. 119 and 120). Two cab wiring harnesses have been used with these vehicles. The first (fig. 119), is used only with vehicles having a push-pull main light switch. The second (fig. 120), is used only with vehicles having a rotary main light switch. This harness, identified by yellow tracer in the loom, extends from junction blocks on front of dash (fig. 118), through hole in dash, then to instruments, gages, and switches at rear of instrument board (figs. 116 and 117). Raise engine hood to gain access to junction blocks. Remove instrument panel cluster assembly (par. 136) to gain access to electrical units terminal.

(2) CHASSIS WIRING HARNESS (fig. 121). This harness, identified by a red tracer in the loom, extends from junction blocks on front of dash (fig. 118), to stop light switch, fuel tank gage, stop and



SYMBOL AND CIRCUIT	WIRE SIZE AND COLOR	TERMINAL
A^1 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	NO. 3-3 POST JCT.
A^2 BLACKOUT DRIVING LIGHT	NO. 16 WHITE-BLACK TR.	L.H. JCT. BLOCK
B^1 HEADLIGHT —HIGH	NO. 12 WHITE-BLACK CR. TR.	NO. 4 TOP JCT.
B^2 HEADLIGHT —HIGH	NO. 12 WHITE-BLACK CR. TR.	L.H. JCT. BLOCK
B^3 HEADLIGHT —HIGH	NO. 14 WHITE-BLACK CR. TR.	L.H. JCT. BLOCK
B^3 HEADLIGHT —HIGH	NO. 14 WHITE-BLACK CR. TR.	R.H. JCT. BLOCK
C^1 HEADLIGHT —LOW	NO. 14 WHITE-GREEN TR.	NO. 3 TOP JCT.
C^2 HEADLIGHT —LOW	NO. 14 WHITE-GREEN TR.	L.H. JCT. BLOCK
C^2 HEADLIGHT —LOW	NO. 16 WHITE-GREEN TR.	L.H. JCT. BLOCK
C^3 HEADLIGHT —LOW	NO. 16 WHITE-GREEN TR.	R.H. JCT. BLOCK
D^1 HORN FEED	NO. 14 OR 16 TAN-RED AND BLACK CR. TR.	NO. 2 TOP JCT.
D^2 HORN FEED	NO. 14 OR 16 TAN-RED AND BLACK CR. TR.	HORN
E^1 HORN RETURN	NO. 14 OR 16 BLACK	NO. 6 TOP JCT.
E^2 HORN RETURN	NO. 14 OR 16 BLACK	HORN
F^1 BLACKOUT MARKER LIGHT—L.H.	NO. 16 WHITE	NO. 1 TOP JCT.
F^1 BLACKOUT MARKER LIGHT—R.H.	NO. 16 WHITE	NO. 1 TOP JCT.
F^2 BLACKOUT MARKER LIGHT—L.H.	NO. 16 WHITE	L.H. CONNECTOR
F^3 BLACKOUT MARKER LIGHT—R.H.	NO. 16 WHITE	R.H. CONNECTOR

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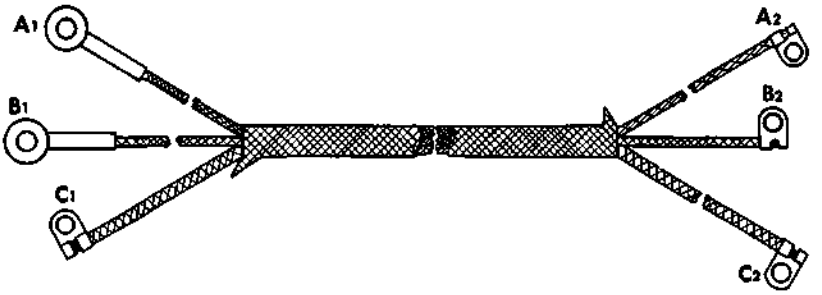
Figure 122—Front End Wiring Harness



SYMBOL CIRCUIT	WIRE SIZE AND COLOR	TERMINAL
A1 GROUND	NO. 14 BLACK	GEN. "GRD"
A2 GROUND	NO. 14 BLACK	REG. "GRD"
B1 GENERATOR FIELD	NO. 14 BLACK-RED CH.	GEN. "FLD"
B2 GENERATOR FIELD	NO. 14 BLACK-RED CH.	FIELD FILTER
C1 GENERATOR ARMATURE	NO. 8 TAN-RED AND BLACK X TR.	GEN. "ARM"
C2 GENERATOR ARMATURE	NO. 8 TAN-RED AND BLACK X TR.	ARMATURE FILTER

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Figure 123—Generator to Regulator and Filters Wiring Harness

taillights, and trailer socket. Harness is located under cab floor boards at front end, then along inside of left-hand frame side rail to the rear of vehicle.

(3) FRONT END WIRING HARNESS (fig. 122). This harness extends from junction blocks on front of dash (fig. 118) to horn, right and left headlight junction blocks, and marker light connectors. Harness is located along inside of left-hand fender skirt and over radiator to right-hand head light junction block, on inside of right-hand fender skirt.

(4) GENERATOR TO REGULATOR AND FILTERS WIRING HARNESS (fig. 123). This harness extends from generator, along inside of left-hand fender skirt, to regulator and filters on front of dash (fig. 118). Raise engine hood to gain access to harness assembly and attaching units.

Section XXIV

RADIO NOISE SUPPRESSION SYSTEM

129. DESCRIPTION AND DATA.

a. Description. Radio noise suppression is the suppression of noise disturbances in the electrical system of the vehicle, which

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would interfere with proper reception of radio signals, or permit detection of the vehicle location by highly sensitive receivers. The sources of electrical interference originate in the following: Ignition System, Generating System, Battery Circuit, Lighting System and static caused by friction.

(1) Radio frequency waves given off by these systems during operation are radiated or broadcast as radio waves, or signals, that interfere with any receiving apparatus in the vicinity. Radio noise suppression, therefore, involves the suppression of these waves at their source or confining them within an area where they cannot be picked up by the antenna of a radio.

(2) Suppression is accomplished by the use of suppressors, condensers and filters. In addition, internal and/or external toothed lock washers are used at mounting points of these units to securely ground them and thus further eliminate electrical noises. In addition to these units, engine compartment is bonded by the use of internal and/or external toothed lock washers and bond straps to form a "box" within which radio frequency waves are trapped to prevent their escape.

b. Data.

(1) FILTERS.

Make	Delco-Remy
Model	
Regulator Armature	1888263
Field Circuit	1888796
Battery Circuit	1888795
Ignition Primary Circuit	1889530

(2) CONDENSERS.

Make	Delco-Remy
Model	
Generator	1888918 or 1901731
Headlights	1889319 or 1901696
Stop and Taillights	1901696
Cranking Motor	1901681

(3) SUPPRESSORS.

Make	Delco-Remy
Model	1887829

130. BODY AND CHASSIS BONDING.

a. General. In addition to filters, condensers, and suppressors, internal-external toothed lock washers and bond straps are also used at points shown in figures 124 and 125 to eliminate static discharges from the vehicle and to form a "box" around electrical units and prevent escape of radio frequency waves. Localized views of lock washer and bond strap installations are shown in figures 126 and 127.

b. Lock Washers. Internal-external toothed lock washers are used at points indicated in figures 124 and 125. Refer to text under illustrations to determine type of mounting used at any given loca-

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TRUCK, 2½-TON, 6 x 6

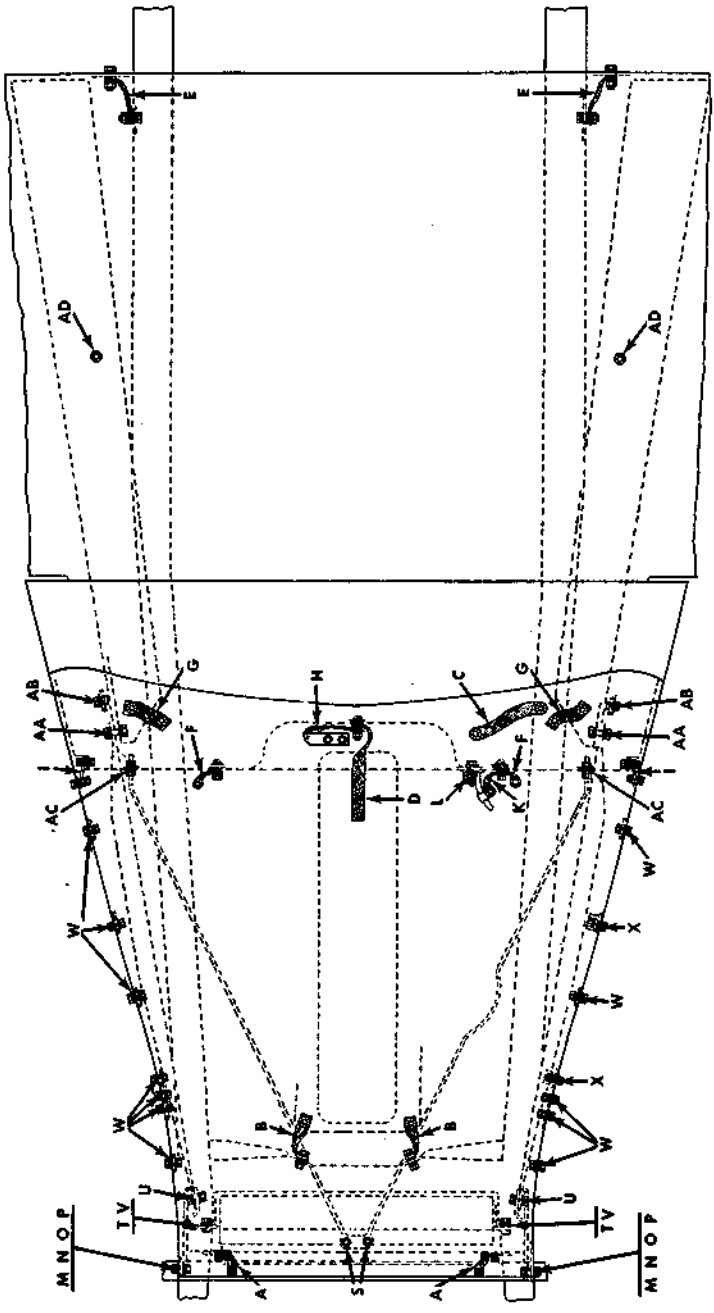

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Figure 124—Bond Straps and Toothed Lock Washer Installation (Plan View)

BOND STRAPS

SYMBOL	DESCRIPTION	MOUNTING (See fig. 127)
A	FROM—RADIATOR TANK	B-6
	TO—RADIATOR SUPPORT ASSEMBLY	B-7
	TO—RADIATOR SUPPORT—LOWER	B-8
B	FROM—ENGINE OIL PAN	B-4
	TO—FRAME	B-5
C	FROM—FLYWHEEL HOUSING	B-4
	TO—FRAME	B-5
D	FROM—VALVE COVER BOLT	B-12
	TO—DASH PANEL	B-13
E	FROM—REAR OF CAB	B-15
	TO—STEP HANGER	B-16
F	FROM—HOOD	B-1
	TO—DASH PANEL—R.H.	B-2
	TO—DASH PANEL—L.H.	B-3
G	FROM—CAB SILL	B-9
	TO—FRAME	B-9
H	FROM—DASH PANEL	B-13
	TO—THROTTLE AND CHOKE CABLES	B-14
	TO—TEMPERATURE GAGE TUBE	B-14
I	FROM—HOOD SIDE PANEL	B-2
	TO—DASH PANEL	B-2
K	FROM—SPEEDOMETER CABLE	B-11
	TO—DASH PANEL	B-3
L	FROM—OIL PRESSURE TUBE	B-17
	TO—SPEEDOMETER CABLE (SOME MODELS)	B-11
	TO—DASH PANEL	B-17

TOOTHED LOCK WASHER

SYMBOL	DESCRIPTION	MOUNTING (See fig. 126)
M	BRUSH GUARD TO SIDE PANEL	L-1
N	BRUSH GUARD TO SIDE PANEL	L-2
O	BRUSH GUARD TO SIDE PANEL	L-3
P	BRUSH GUARD TO SIDE PANEL	L-4
S	RADIATOR TIE ROD—FRONT	L-7
T	FAN SHROUD TO RADIATOR SUPPORT	L-8
U	RADIATOR SUPPORT BRACE	L-9
V	FAN SHROUD TO RADIATOR SUPPORT	L-10
W	FENDER TO SKIRT	L-11
X	FENDER TO SKIRT—L.H.	L-12
AA	RADIATOR SUPPORT BRACE TO SIDE SILL	L-15
AB	FENDER SKIRT TO COWL	L-16
AC	RADIATOR TIE ROD TO COWL	L-17
AD	CAB TO SILL	L-18

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Legend for Figure 124

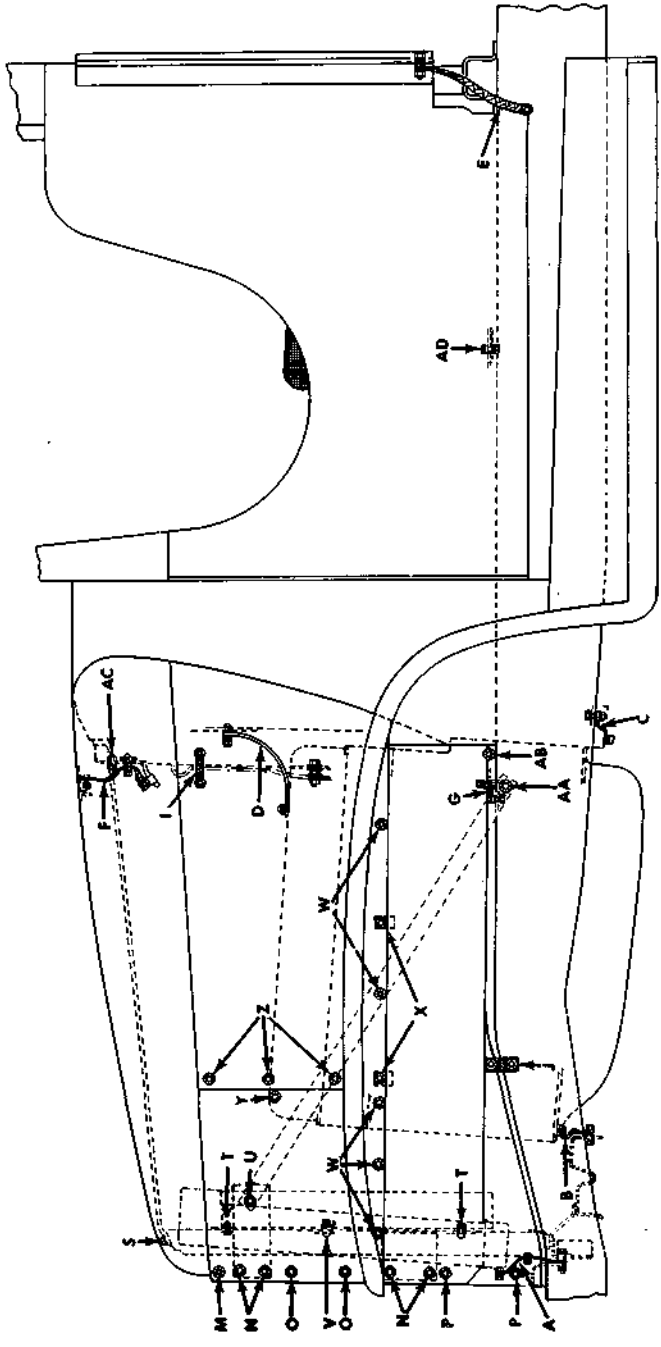

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Figure 125—Bond Straps and Toothed Lock Washer Installation (Side View)

BOND STRAPS

SYMBOL	DESCRIPTION	MOUNTING (See fig. 127)
A	FROM—RADIATOR TANK	B-6
	TO—RADIATOR SUPPORT ASSEMBLY	B-7
	TO—RADIATOR SUPPORT—LOWER	B-8
B	FROM—ENGINE OIL PAN	B-4
	TO—FRAME	B-5
C	FROM—FLYWHEEL HOUSING	B-4
	TO—FRAME	B-5
D	FROM—VALVE COVER BOLT	B-12
	TO—DASH PANEL	B-13
E	FROM—REAR OF CAB	B-15
	TO—STEP HANGER	B-16
F	FROM—HOOD	B-1
	TO—DASH PANEL—R.H.	B-2
	TO—DASH PANEL—L.H.	B-3
G	FROM—CAB SILL	B-9
	TO—FRAME	B-9
I	FROM—HOOD SIDE PANEL	B-2
	TO—DASH PANEL	B-2
J	FROM—FENDER SKIRT	B-10
	TO—FRAME	B-9

TOOTHED LOCK WASHER

SYMBOL	DESCRIPTION	MOUNTING (See fig. 126)
M	BRUSH GUARD TO SIDE PANEL	L-1
N	BRUSH GUARD TO SIDE PANEL	L-2
O	BRUSH GUARD TO SIDE PANEL	L-3
P	BRUSH GUARD TO SIDE PANEL	L-4
Q	BRUSH GUARD TO FENDER—OUTER	L-5
R	BRUSH GUARD TO FENDER—INNER	L-6
S	RADIATOR TIE ROD—FRONT	L-7
T	FAN SHROUD TO RADIATOR SUPPORT	L-8
U	RADIATOR SUPPORT BRACE	L-9
V	FAN SHROUD TO RADIATOR SUPPORT	L-10
W	FENDER TO SKIRT	L-11
X	FENDER TO SKIRT—L.H.	L-12
Y	HOOD SIDE PANEL TO SUPPORT BRACE	L-13
Z	HOOD FRONT TO REAR SIDE PANEL	L-14
AA	RADIATOR SUPPORT BRACE TO SIDE SILL	L-15
AB	FENDER SKIRT TO COWL	L-16
AC	RADIATOR TIE ROD TO COWL	L-17
AD	CAB TO SILL	L-18

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Legend for Figure 125

tion. Then refer to figure 126 for sectional views showing lock washer locations in relation to other parts used at that particular point.

(1) INSTALLATION. Whenever it is necessary to remove any mounting where lock washers are used it is extremely important that it be reinstalled exactly as indicated in figure 126. It should be noted that lock washer is used under head of bolt or screw and under nut. At points where bond straps are used, additional lock washer is used between strap and other metal surface. Whenever it is necessary to install new parts, it is extremely important that cadmium plated lock washers be used. Never substitute with plain or parkerized parts. Be sure to destroy defective parts.

c. **Bond Straps.** Bond straps are used at points indicated in figures 124 and 125. Refer to text under illustrations to determine type of mounting used at any given location. Then refer to figure 127 for sectional views showing location of lock washers and method of attaching bond strap at that particular point.

(1) INSPECTION. Inspect all bond strap attachments to be sure that bond strap materials are not broken and that mounting bolts and nuts are drawn up tight. IMPORTANT: It is extremely important that all straps be in good condition so as to form a good ground. If a single strap is damaged, broken or otherwise defective, it will result in faulty radio reception or interference with other receiving apparatus.

(2) INSTALLATION. Whenever it is necessary to remove a bond strap it is extremely important that it be reinstalled exactly as indicated in figure 127. In some instances two views are shown for a single mounting. This is necessary due to changes in the method of mounting; therefore, always compare illustrations with mounting on vehicle at time of removal and reinstall exactly as illustrated. Always

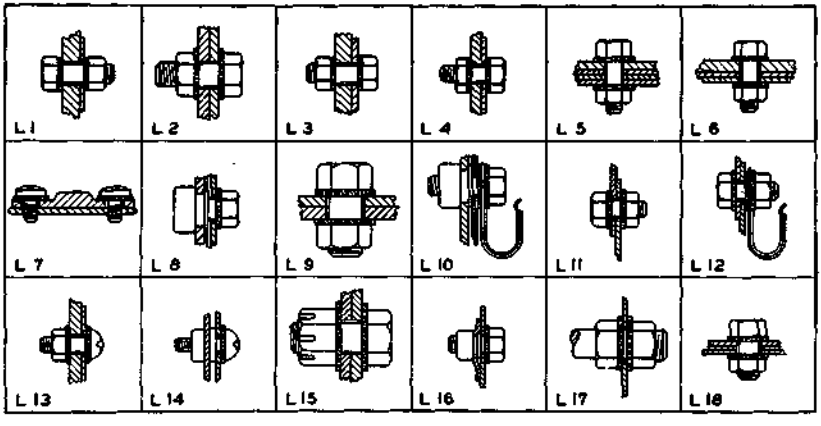

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Figure 126—Sections of Internal and/or External Toothed Lock Washer Installation

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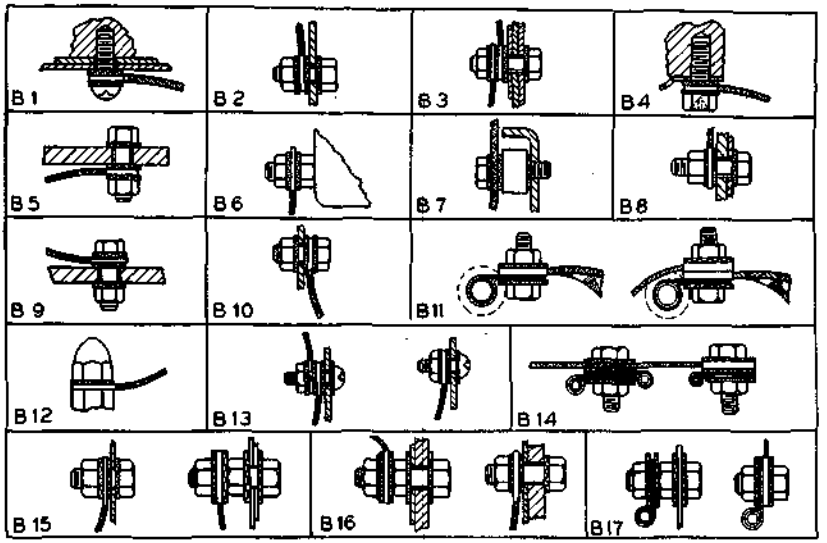

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Figure 127—Sections of Bond Strap Mountings

use cadmium plated bolts and nuts when installing bond straps. Never substitute plain or parkerized parts.

131. IGNITION CIRCUIT.

a. General. Suppression of noises arising from ignition circuit is accomplished by the use of ignition primary circuit filter, spark plug and secondary wire suppressors, also internal-external toothed lock washers at ignition coil mounting bracket.

b. Ignition Primary Circuit Filter.

(1) TEST. Filter should be tested to be sure that it provides a continuous circuit from terminal to terminal and that no internal shorts or grounds exist.

(a) Continuous Circuit Test. Disconnect wires from both terminals and connect test light between two terminals. If light does not light it indicates that there is an "open circuit" within filter, and unit must be replaced.

(b) Test for Short. Disconnect wires from both terminals and connect one test light lead to one of the terminals while other lead contacts filter body. If light works, it indicates that there is a short and unit must be replaced. Follow this same procedure on other terminal.

(2) REMOVAL.

(a) Remove Wires. Remove screw at two terminals then lift wires from terminals.

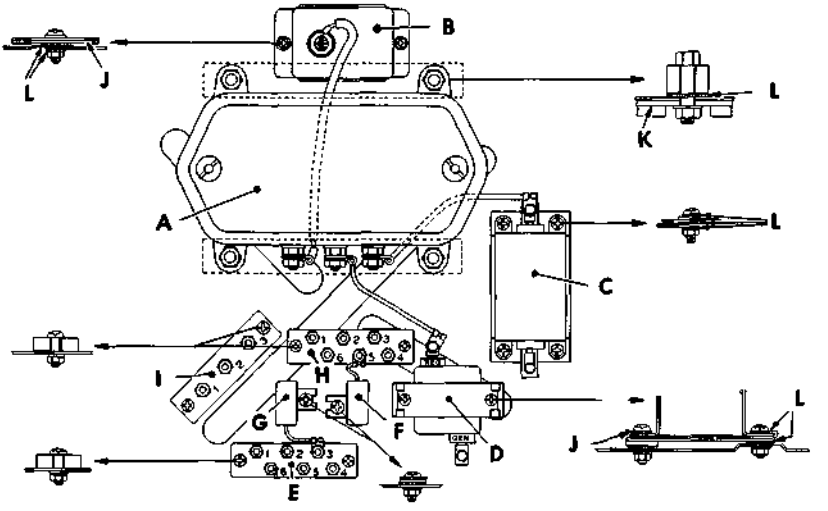
(b) Remove Filter. Remove two nuts and lock washers from mounting bolts at inside of cab dash. Remove two bolts and flat washers attaching filter to front of dash. Remove filter and mounting bracket from dash, noting that lock washer is used between filter mounting bracket and dash.

(3) INSTALLATION.

(a) Clean Mounting Surface. Clean mounting surface of filter bracket and front of dash to remove all dirt, paint, grease or other foreign matter.

(b) Install Filter. Position filter and mounting bracket against front of dash, using internal-external toothed lock washers between filter mounting bracket and dash. Install bolts through filter mounting bracket and dash, using flat washers under head of bolts. Install external toothed lock washers and nuts to bolts at inside of dash. Tighten nuts.

(c) Connect Wires. Attach ignition switch to filter and ignition coil to filter wires (No. 14 Black) to filter terminals. Use external toothed lock washer between wire terminal and filter. Tighten terminal screw.



A REGULATOR
B BATTERY CIRCUIT FILTER
C ARMATURE CIRCUIT FILTER
D FIELD CIRCUIT FILTER
E JUNCTION BLOCK—BOTTOM
F SERVICE TAILLIGHT CONDENSER
G TRAILER STOP LIGHT CONDENSER
H JUNCTION BLOCK—TOP
I JUNCTION BLOCK—3 POST
J FILTER REINFORCEMENT
K REGULATOR REINFORCEMENT
L TOOTHED LOCK WASHER

RA PD 333063

Figure 128—Regulator, Filters, and Condenser Mounting

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c. Ignition Coil. When ignition coil is removed (par. 90), it is imperative that internal-external toothed lock washers be used under mounting stud nuts at time of installation (par. 90).

132. GENERATING CIRCUIT.

a. General. Radio suppression of the generating circuit is accomplished through the use of three filters mounted on front of dash (fig. 128) and condenser at generator (fig. 129). Internal-external toothed lock washers used at regulator and filter mounting are also essential to suppression of radio noises.

b. Filters.

(1) TEST. Refer to paragraph 131 b (1) for testing procedure.

(2) REMOVAL.

(a) Remove Wires. Remove screw at two terminals, then lift wires from terminals.

(b) Remove Filter. Remove two nuts and lock washers (four at armature circuit filter) from mounting bolts at inside of cab dash. Remove bolts and lock washers attaching filter to front of dash. Remove filter and mounting bracket from dash, noting that lock washer is used between filter mounting bracket and dash. Spacer is also used at one side of field circuit filter.

(3) INSTALLATION.

(a) Clean Mounting Surface. Clean mounting surfaces of filter mounting bracket, and front of dash to remove all dirt, paint, grease or other foreign matter.

(b) Install Filter (fig. 128). Position filter and mounting bracket against front of dash, using internal-external toothed lock washer between mounting bracket and dash. Spacer is also used at one side of field filter. Install bolts through filter, mounting bracket, and dash, using external toothed lock washers under head of bolts. Install external toothed lock washers and nuts to bolts at inside of dash. Tighten nuts.

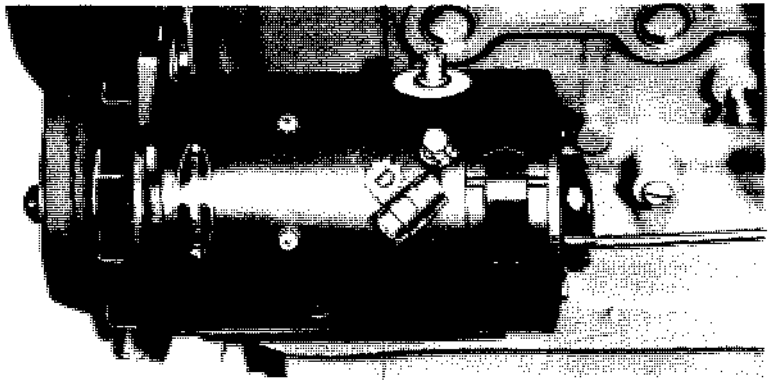

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Figure 129—Condenser Installation at Generator

(c) *Install Wires.* Attach wires to filter terminals. Refer to figures 113 and 114 for wire identification and connections. Use external toothed lock washer between wire terminal and filter. Tighten terminal screw.

c. **Condenser.**

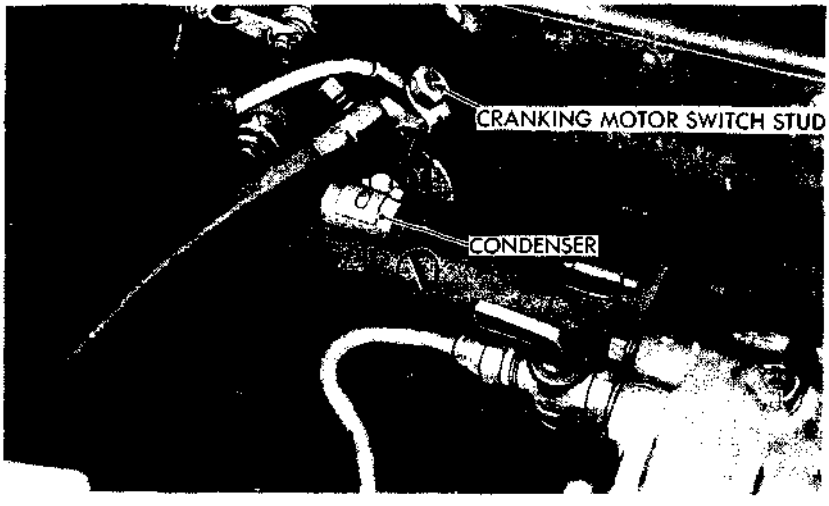
(1) REMOVAL (fig. 129). Remove nut and lock washer from generator "ARM" terminal. Lift wires from terminal. Remove screw and lock washers attaching ground wire and condenser to generator. Lift condenser from generator.

(2) TEST. Testing of condenser must be accomplished with a condenser tester (17-T-5541). Each factor affecting condenser operation must be considered when making tests. Condensers used on this vehicle should meet following specifications: Megohms 6000; Capacity 0.085 - 0.13 MFD; Flash 600 Volts DC.

(3) INSTALLATION (fig. 129). Clean all contact surfaces and wire terminals. Attach condenser and ground wire (No. 14 Black) to generator, using screw and two internal-external toothed lock washers. Tighten screw. Attach condenser pig-tail wire and armature wire (No. 8 Tan-Red and Black Cr. Tr.), to "ARM" terminal, using nut and lock washer. Tighten nut.

133. BATTERY CIRCUIT.

a. **General.** Radio suppression of the battery or cranking motor circuit is accomplished through the use of a condenser, mounted on cranking motor housing and connected to cranking motor switch



RA PD 333061

Figure 130—Condenser Installation at Cranking Motor

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(fig. 130). Condenser bypasses and grounds static waves which would flow into battery and up the lead to the radio receiver.

b. Condenser.

(1) REMOVAL (fig. 130). Remove nut and lock washer from cranking motor switch terminal. Lift condenser pig-tail wire from terminal. Remove screw and lock washer attaching condenser and switch to cranking motor housing.

(2) TEST. Refer to paragraph 132 c (2).

(3) INSTALLATION (fig. 130). Clean all contact surfaces and wire terminals. Attach condenser to cranking motor housing, using screw and internal-external toothed lock washer. Tighten screw. Position condenser pig-tail over cranking motor switch stud and install lock washer and nut. Tighten nut.

134. LIGHTING CIRCUIT.

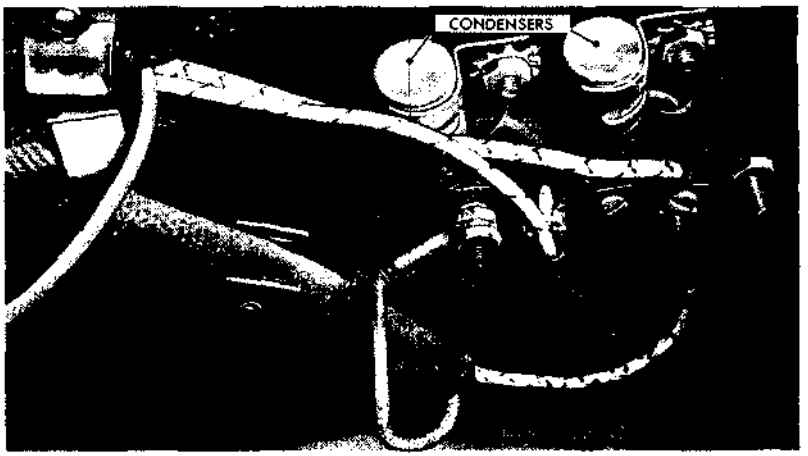
a. General. Radio suppression of lighting circuit is accomplished by use of four condensers, two at right-hand headlight junction block (fig. 131) and two at junction blocks on front of dash (fig. 128).

b. Condenser.

(1) REMOVAL (fig. 131). Remove nut and lock washer attaching condenser pig-tail to junction block terminal. Remove nut and lock washer attaching condenser to dash or fender skirt. Remove bolt, lock washers, and condenser. During removal note location and type of lock washer, so that same type can be reinstalled in its correct location.

(2) TEST. Refer to paragraph 132 c (2).

(3) INSTALLATION (fig. 131). Clean all contact surfaces and wire terminals. Locate condenser in its correct position and attach



RA PD 64719

Figure 131—Headlight Beam Condenser Installation

ES18-002672 0412

with bolt and nut. Be sure that internal-external toothed lock washers are used under head of bolt and at each side of condenser bracket; except at junction block condensers which use external toothed lock washer under nut at inside of dash. Tighten nuts securely.

Section XXV

INSTRUMENTS, GAGES, AND SWITCHES

135. GENERAL.

a. The gages and panel lights are grouped in an instrument panel which is mounted on instrument board in front of driver. The switches, circuit breaker, throttle control, and choke control are mounted along the lower edge of the instrument board.

b. **Early and Late Types.** Early vehicles were equipped with a push-pull type main light switch with a separate switch for the blackout driving light (fig. 132). Latest vehicles are equipped with a rotary type main light switch incorporating contacts for blackout driving light. Separate blackout light switch is therefore eliminated and ignition switch and main light switch are relocated (fig. 134).

c. **CAUTION:** Disconnect battery cable at battery before tightening instrument mountings or electrical connections, and when replacing units to prevent damage due to shorting the electrical circuits.

136. INSTRUMENT PANEL ASSEMBLY.

a. **Instrument Panel Removal** (figs. 15, 132, 133, and 134).

(1) DISCONNECT BATTERY CABLE. Disconnect battery cable from battery terminal before attempting removal of instrument panel.

(2) DISCONNECT THERMAL UNIT AT ENGINE. Unscrew thermo gage thermal unit from cylinder head fitting. Either drain cooling system until coolant level is below level of thermal unit, or plug cylinder head fitting immediately after removal of thermal unit. Remove bond strap, remove grommet from around capillary tube at dash, and push tube and thermal unit through hole in dash.

(3) DISCONNECT OIL PRESSURE GAGE TUBE. Unscrew tubing nut attaching oil tube to back of gage.

(4) DISCONNECT SPEEDOMETER CABLE. Unscrew knurled nut at back of speedometer head and pull cable free from speedometer. Remove nut and washer attaching wiring harness clip to speedometer mounting clamp and free harness clip from speedometer stud.

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(5) REMOVE INSTRUMENT PANEL MOUNTING SCREWS. Remove five nuts, lock washers, and screws attaching instrument panel to instrument board. Push on face of instrument panel to tilt panel downward.

(6) DISCONNECT WIRING AND REMOVE PANEL. Disconnect wiring at all terminals at back of instrument panel. Pull on wires at back of three panel lights to disconnect. Remove instrument panel from vehicle.

b. Instrument Panel Installation (figs. 15, 132, 133, and 134).

(1) POSITION INSTRUMENT PANEL IN INSTRUMENT BOARD. Position instrument panel in tilted position in instrument board from back.

(2) CONNECT WIRING. Connect wiring to fuel gage as described in paragraph 140 c (2). Connect the No. 8 yellow, No. 10 yellow, and No. 14 green wires to ammeter terminal farthest from fuel gage; connect the other wires to the other ammeter terminal. Connect panel lights by pushing socket and lamp at end of each wire into shield in instrument panel.

(3) ATTACH INSTRUMENT PANEL TO INSTRUMENT BOARD. Position instrument panel in instrument board and install five attaching screws, lock washers, and nuts.

(4) CONNECT SPEEDOMETER CABLE. Fit cable shaft tongue into fitting in speedometer head. Pull cable casing against speedometer head and connect by tightening knurled nut on speedometer head fitting. Position wiring harness and clip on speedometer head stud and install lock washer and nut.

(5) CONNECT OIL PRESSURE GAGE TUBE. Position flanged end of tube against fitting at back of oil pressure gage. Screw tubing nut on gage fitting and tighten nut carefully to prevent leakage.

(6) INSTALL THERMAL UNIT IN ENGINE. Insert thermal unit and capillary tube through hole in cowl. Screw thermal unit into cylinder head fitting and tighten firmly, then fill cooling system (par. 17). Fit grommet around capillary tube and attach to dash, then attach bond strap to tube.

137. SPEEDOMETER AND DRIVE CABLE.

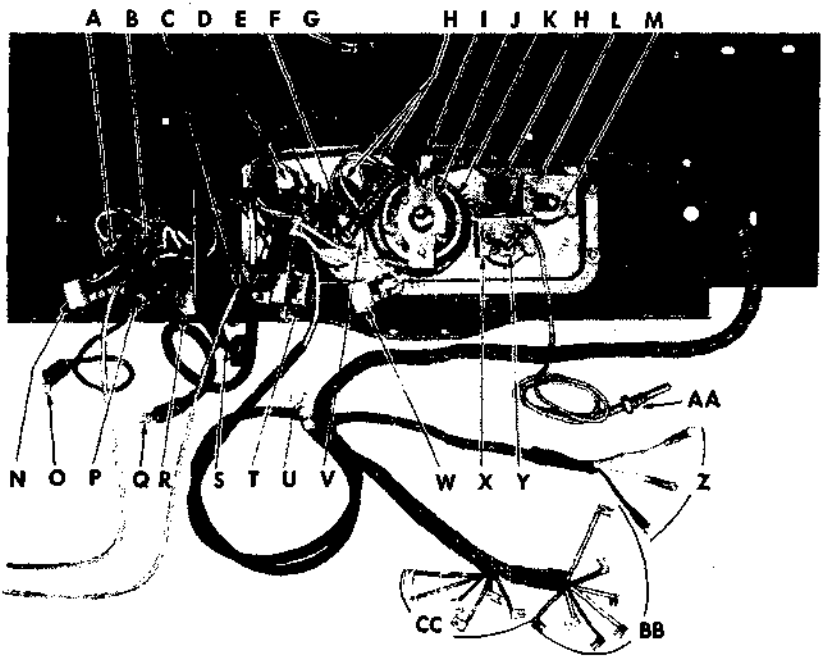
a. Speedometer Head Removal (figs. 132, 133, and 134).

(1) DISCONNECT CABLE AT SPEEDOMETER HEAD. At rear side of speedometer head, unscrew knurled nut attaching cable to head. Pull cable free.

(2) REMOVE SPEEDOMETER HEAD. Remove two nuts attaching mounting clamp to speedometer. Remove wiring harness clip. Take off mounting clamp and press on rear of speedometer head to remove from front of instrument board.

b. Speedometer Head Installation (figs. 132, 133, and 134).

(1) INSTALL SPEEDOMETER HEAD. Position speedometer head in instrument panel from front side of panel. Install mounting clamp over studs at back of speedometer. Position wiring harness clip over upper stud. Install two nuts and tighten securely.

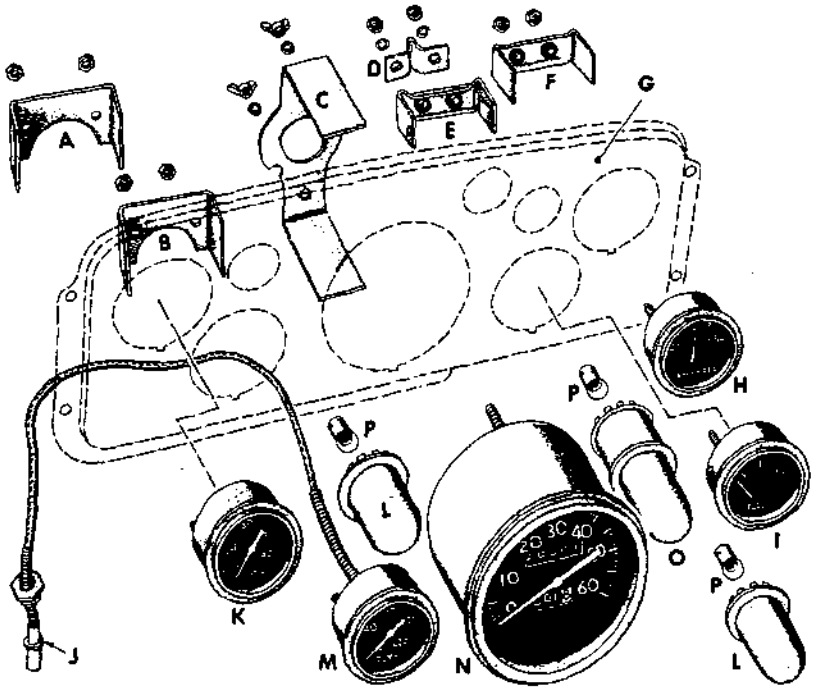


A HORN CIRCUIT BREAKER
B FUEL GAGE CIRCUIT BREAKER (EARLY MODELS)
C THROTTLE CONTROL
D AMMETER
E AMMETER CLAMP
F FUEL GAGE
G WIRING TERMINAL (TO HORN TERMINAL ON STEERING COLUMN)
H INSTRUMENT PANEL LIGHTS
I WIRING HARNESS CLIP
J SPEEDOMETER CLAMP
K SPEEDOMETER
L OIL PRESSURE GAGE CLAMP
M OIL PRESSURE GAGE
N INSTRUMENT PANEL LIGHT SWITCH
O WIRING TERMINAL (TO IGNITION PRIMARY CIRCUIT FILTER ON COWL)
P CHOKE CONTROL
Q WIRING TERMINAL (TO BATTERY CIRCUIT FILTER ON COWL)
R IGNITION SWITCH
S COWL VENTILATOR OPERATING LEVER
T MAIN LIGHT SWITCH
U WIRING TERMINAL (TO SWITCH ON CRANKING MOTOR)
V FUEL GAGE CLAMP
W BLACKOUT DRIVING LIGHT SWITCH
X WATER TEMPERATURE GAGE CLAMP
Y WATER TEMPERATURE GAGE
Z WIRING TERMINALS (TO DIMMER SWITCH)
AA TEMPERATURE GAGE THERMAL UNIT
BB WIRING TERMINALS (TO JUNCTION BLOCK ON COWL)
CC WIRING TERMINALS (TO JUNCTION BLOCK ON COWL)

RA PD 333064

Figure 132—Instrument Panel, Gages, and Switches—Rear View (Push-Pull Main Light Switch)

ES18-002672 0415



A OIL PRESSURE GAGE CLAMP
B WATER TEMPERATURE GAGE CLAMP
C SPEEDOMETER CLAMP
D FUEL GAGE FIBRE INSULATOR
E FUEL GAGE CLAMP
F AMMETER CLAMP
G INSTRUMENT CLUSTER PANEL OUTLINE
H AMMETER
I FUEL GAGE
J TEMPERATURE GAGE THERMAL UNIT
K OIL PRESSURE GAGE
L PANEL LIGHT SHIELD
M WATER TEMPERATURE GAGE
N SPEEDOMETER
O PANEL LIGHT SHIELD AND EXTENSION
P PANEL LAMP

RA PD 64639

Figure 133—Instrument Panel and Related Parts

(2) CONNECT SPEEDOMETER CABLE TO SPEEDOMETER HEAD. Insert drive shaft tongue into fitting at rear of speedometer head and pull drive shaft casing against fitting. Attach by tightening knurled nut on speedometer head.

c. **Speedometer Drive Cable Removal.**

(1) DISCONNECT CABLE AT SPEEDOMETER. Unscrew knurled nut at back of speedometer head and pull drive cable free from speedometer.

(2) REMOVE CABLE CLIPS. Remove nuts, washers, bolts, and

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clips attaching cable casing to cowl, frame side rail, and transfer case support.

(3) DISCONNECT CABLE AT TRANSFER CASE. Unscrew knurled nut attaching cable to transfer case. Pull drive cable free from transfer case.

(4) REMOVE SPEEDOMETER CABLE. Pull end of cable through dash panel after loosening grommet. Grip cable midway between ends and pull to remove cable [GM-1566712 casing; GM-1566714 (G85-30-05290) shaft] from vehicle.

d. Speedometer Drive Cable Installation.

(1) INSTALL CABLE IN VEHICLE. Position cable in vehicle between speedometer head and transfer case. Speedometer head end of cable must be inserted through cowl and grommet fitted around cable at dash.

(2) CONNECT CABLE TO SPEEDOMETER. Insert tongue end of shaft into fitting at back of speedometer head and pull shaft casing into place against fitting. Thread knurled nut to speedometer head and tighten snugly.

(3) CONNECT CABLE TO TRANSFER CASE. Fit tongue end of shaft into position in transfer case. Pull shaft casing into place against fitting at transfer case and tighten knurled nut.

(4) INSTALL CABLE CLIPS Position cable, making sure cable is not bent sharply at any point. Install cable clips, bolts, washers, and nuts attaching cable to transfer case support, frame side rail, and dash.

138. OIL PRESSURE GAGE.

a. Oil Pressure Gage Removal (fig. 133).

(1) DISCONNECT OIL TUBE. Unscrew tubing nut attaching metal oil tube to back of gage. Flexible tube [(GM-2127840) G501-02-76510] need not be disturbed unless necessary to replace.

(2) REMOVE OIL GAGE. Remove two nuts and lock washers attaching mounting clamp to gage at back of instrument panel. Remove mounting clamp and press on back of gage [(GM-1506359) G501-01-94071] to remove from driver's side of instrument panel.

b. Oil Pressure Gage Installation (fig. 133).

(1) INSTALL OIL GAGE. Position gage in instrument panel. Install mounting clamp on back of gage, then install lock washers and nuts, tightening nuts firmly.

(2) CONNECT OIL TUBE. Position flanged end of tubing against fitting on back of gage and attach with tubing nut. Tighten nut carefully to prevent leaks.

139. THERMO GAGE.

a. Thermo Gage Removal (fig. 133).

(1) DISCONNECT THERMAL UNIT AT ENGINE. Drain cooling system until coolant is below level of thermal unit, or quickly plug the opening after removal of thermal unit. Unscrew thermal unit from

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fitting in engine cylinder head. Loosen and remove bond strap and grommet around capillary tube at dash and push thermal unit through hole into cab.

(2) REMOVE THERMO GAGE. Remove two nuts and lock washers, then remove mounting clamp from back of gage. Press on back of gage [(GM-1511254) G508-01-94061] to remove from driver's side of instrument panel. Withdraw capillary tube and thermal unit through opening in instrument panel.

b. Thermo Gage Installation (fig. 133).

(1) INSTALL THERMO GAGE. Insert thermal unit and capillary tube through holes in instrument panel and dash, then position gage in instrument panel. Install mounting clamp on back of gage, then install lock washers and nuts.

(2) INSTALL THERMAL UNIT IN ENGINE. Screw thermal unit into cylinder head fitting, tightening firmly, then fill cooling system (par. 17). Fit grommet around capillary tube and attach to dash, then attach bond strap to tube.

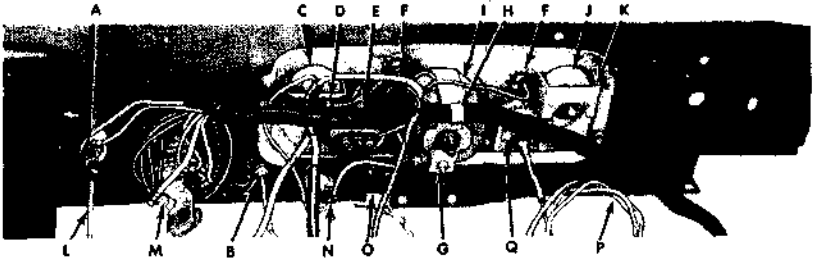
140. FUEL GAGE.

a. The fuel gage system consists of a gage in the instrument panel and a tank unit in the fuel tank, interconnected electrically. The fuel gage tank unit replacement is described in paragraph 100.

b. Fuel Gage Removal (fig. 133).

(1) DISCONNECT WIRING. Remove two nuts and lock washers attaching wiring to terminals at back of gage in instrument panel.

(2) REMOVE GAGE. Remove two nuts and lock washers attaching mounting clamp to gage, then remove mounting clamp. Press at back of gage [(GM-1516366) G85-33-01460] to remove from driver's side of instrument panel.



A HORN CIRCUIT BREAKER
B THROTTLE CONTROL
C AMMETER
D AMMETER CLAMP
E FUEL GAGE
F PANEL LIGHTS
G SPEEDOMETER CLAMP
H WIRING HARNESS CLIP
I SPEEDOMETER HEAD
J OIL PRESSURE GAGE
K OIL PRESSURE CLAMP
L CHOKE CONTROL
M ROTARY LIGHT SWITCH
N IGNITION SWITCH
O PANEL LIGHT SWITCH
P CAPILLARY TUBE
Q THERMO GAGE

RA PD 333032

Figure 134—Instrument Panel, Gages, and Switches—Rear View (Rotary Main Light Switch)

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c. **Fuel Gage Installation** (fig. 133).

(1) INSTALL GAGE. Position gage in instrument panel, install mounting clamp on back of gage, then install two lock washers and nuts.

(2) CONNECT WIRING. Connect the white wire with red tracer to the terminal marked "IGN" on gage, connect the green wire to the "TANK" terminal on the gage, then install two lock washers and nuts. NOTE: *Caution tag on back of fuel gage-wires must not be reversed or tank unit may be burned out.*

141. AMMETER.

a. **Ammeter Removal** (fig. 133).

(1) DISCONNECT WIRING. Remove two nuts and lock washers attaching wires to ammeter terminals and disconnect wires.

(2) REMOVE AMMETER. Remove two nuts and lock washers attaching mounting clamp at back of ammeter, then remove mounting clamp. Press on rear of ammeter [(GM 1500601) (G85-33-00030] to remove from driver's side of instrument panel.

b. **Ammeter Installation** (fig. 133).

(1) INSTALL AMMETER. Position ammeter in instrument panel. Install mounting clamp over terminals at back of ammeter and install two lock washers and nuts.

(2) CONNECT WIRING. Connect wires to ammeter terminals as described in paragraph 136 b (2). Be sure ammeter shows charge with engine running at moderate speed; if not, reverse wiring connections at terminals.

142. IGNITION SWITCH.

a. **Ignition Switch Removal** (figs. 15, 132, and 134).

(1) DISCONNECT WIRING. Remove two screws and lock washers from terminals at back of switch and disconnect wires.

(2) REMOVE SWITCH. Unscrew round nut from switch at driver's side of instrument board. Use spanner wrench or punch in the holes in nut to loosen nut. Push on switch from front side of panel to remove from rear side of panel.

b. **Ignition Switch Installation** (figs. 15, 132, and 134).

(1) INSTALL SWITCH. Position switch on instrument board and thread round nut on switch. Tighten round nut firmly, using spanner wrench or punch.

(2) CONNECT WIRING. Connect wires to switch terminals with two screws and lock washers.

143. MAIN LIGHT SWITCH.

a. **Push-Pull Type Switch (Early Vehicles).**

(1) PUSH-PULL TYPE SWITCH REMOVAL (figs. 15, 132, and 135).

(a) Disconnect Wiring. Remove screws and lock washers attaching wires to switch terminals.

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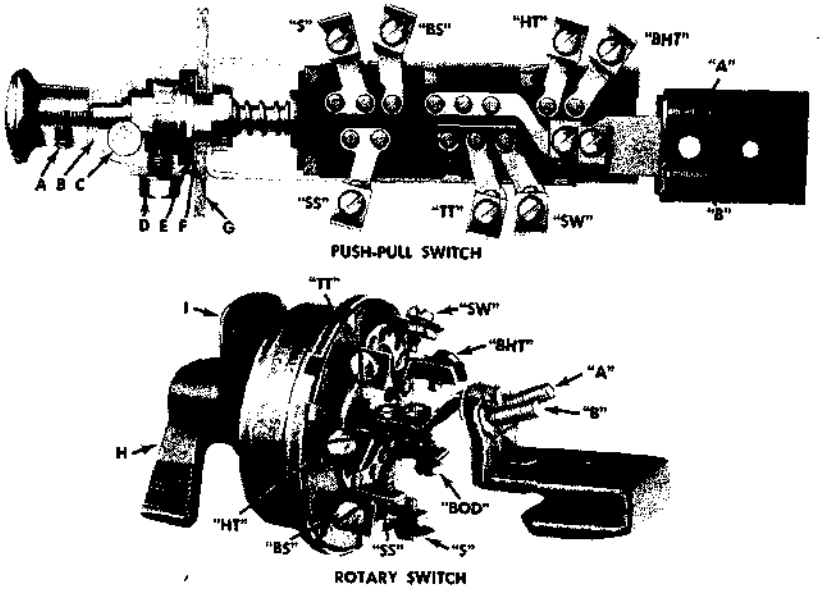

A KNOB SET SCREW
B BUSHING ASSEMBLY
C PLUNGER
D CAP SCREW
E SWITCH POST NUT
F SWITCH POST LOCK WASHER
G DASH
H SWITCH LEVER
I ESCUTCHEON PLATE

RA PD 333006

Figure 135—Main Lighting Switches

(b) Remove Switch Knob. Loosen set screw in knob and unscrew knob.

(c) Remove Switch Bushing. Loosen hex head cap screw at side of switch bushing. Press switch locking plunger and pull switch bushing off end of switch.

(d) Remove Switch. Remove nut and lock washer from switch at front of instrument board. Push on switch from front side of instrument board to remove.

(2) PUSH-PULL TYPE SWITCH INSTALLATION (figs. 15, 132, and 135).

(a) Connect Wiring to Switch. Install wires at terminals on switch, and attach with screws and lock washers. Terminal markings are shown in figure 135 and wire connections are as follows:

Terminal	*Circuit*	*Wire Size and Tracer Color*
A	Auxiliary	Not used
B	Switch to ammeter	No. 10 yellow
BHT	Switch to No. 1 top junction	No. 16 white
BS	Switch No. 6 bottom junction	No. 16 black-red tr.
HT	Switch to No. 5 top junction	No. 16 black-green tr.
	Switch to *BAT* terminal on dimmer switch	No. 12 black-green tr.

Terminal	Circuit	Wire size and tracer color
	Switch to instrument panel light switch	No. 16 black-green tr.
S	Switch to No. 2 bottom junction	No. 16 red-black tr.
SS	Switch to No. 5 bottom junction	No. 16 black-red check
TT	Switch to No. 1 bottom junction	No. 16 green-black check
SW	Switch to No. 3 bottom junction	No. 16 red

(b) Install Switch. Position switch on instrument board from back of board. Install lock washer and nut on front of switch and tighten nut firmly.

(c) Install Switch Bushing. Compress switch locking plunger and position bushing on switch. Press bushing firmly against panel and tighten hex head cap screw so bushing is locked with plunger in upright position.

(d) Install Switch Knob. Screw knob onto switch and tighten set screw firmly. Test operation of switch (par. 12).

b. Rotary Type Switch (Late Vehicles).

(1) ROTARY TYPE SWITCH REMOVAL (figs. 15, 134, and 135).

(a) Remove Switch Lever. Remove screw attaching switch lever to switch and remove lever.

(b) Remove Switch. Unscrew nut attaching switch to instrument board, then remove lock washer, flat washer, and escutcheon plate. Push on switch shaft to remove switch from back of panel.

(c) Disconnect Wiring. Remove screws and lock washers attaching wires to terminals and remove switch.

(2) ROTARY TYPE SWITCH INSTALLATION (figs. 15, 134, and 135).

(a) Connect Wiring. Install wires at terminals on switch and attach with screws and lock washers. Terminal markings are shown in figure 135, and wire connections are as follows:

Terminal	Circuit	Wire Size and Tracer Color
A	Auxiliary	Not used
B	Switch to ammeter	No. 10 yellow
BHT	Switch to No. 1 top junction	No. 16 white
BOD	Switch to No. 3 post junction	No. 16 white-black tr.
BS	Switch to No. 6 bottom junction	No. 16 black-red check
HT	Switch to No. 5 top junction	No. 16 black-green tr.
	Switch to *BAT* terminal on dimmer switch	No. 12 black-green tr.
	Switch to instrument panel light switch	No. 16 black-green tr.
S	Switch to No. 2 bottom junction	No. 16 red-black tr.
SS	Switch to No. 5 bottom junction	No. 16 red-black check
SW	Switch to No. 3 bottom junction	No. 16 red
TT	Switch to No. 1 bottom junction	No. 16 green-black check

(b) Install Switch. Position switch in instrument board, install escutcheon plate, lock washer, flat washer, and nut, then tighten nut firmly.

(c) Install Switch Lever. Position switch lever on switch shaft and attach with screw, tightening screw firmly.

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INSTRUMENTS, GAGES, AND SWITCHES

144. BLACKOUT DRIVING LIGHT SWITCH.

a. Blackout driving light switch is used only with push-pull type main light switch. Connections for blackout driving light are incorporated in rotary light switch, hence necessity for separate driving light switch is eliminated on late vehicles with rotary type main light switch.

b. Blackout Driving Light Switch Removal (figs. 15 and 132).

(1) REMOVE SWITCH KNOB. Loosen set screw in knob, then unscrew knob from switch.

(2) REMOVE SWITCH. Remove nut and lock washer attaching switch to instrument board. Press on switch at driver's side of instrument board to remove from board.

(3) DISCONNECT WIRING. Remove two screws and lock washers attaching wires to switch and remove switch.

c. Blackout Driving Light Switch Installation (figs. 15 and 132).

(1) CONNECT WIRING. Attach wires to switch with two screws and lock washers, tightening screws firmly.

(2) INSTALL SWITCH. Position switch in instrument board from back of board. Install lock washer and nut on switch, tightening nut firmly.

(3) INSTALL SWITCH KNOB. Screw knob onto switch and tighten set screw firmly.

145. PANEL LIGHTS AND SWITCH.

a. Instrument panel gages and switches are illuminated by three lights, mounted on the instrument panel and controlled by a switch mounted on the instrument board.

b. Panel Lamp and Socket Removal (figs. 15, 132, 133, and 134).

(1) REMOVE SHIELD, SOCKET, AND LAMP ASSEMBLY. Pry shield, socket, and lamp assembly out of instrument panel from front side, using screw driver.

(2) REMOVE LAMP AND SOCKET UNIT FROM SHIELD. Grip shield firmly in one hand and pull on wire with other hand to pull lamp and socket out of shield.

(3) REMOVE LAMP FROM SOCKET. Grip socket assembly in one hand and press on lamp, turning to left to free from socket. Remove lamp from socket with fingers. Socket remains attached to wiring harness.

c. Panel Lamp and Socket Installation (figs. 15, 132, 133, and 134).

(1) INSTALL LAMP IN SOCKET. Fit lamp into socket, press down, and turn to right to install in socket.

(2) INSTALL LAMP AND SOCKET UNIT IN SHIELD. Insert lamp and socket unit through hole in instrument panel from rear side. Press socket into shield until it seats firmly.

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(3) INSTALL SHIELD, SOCKET, AND LAMP ASSEMBLY. Position shield, socket, and lamp assembly at hole in instrument panel and press until shield snaps into place.

d. Instrument Light Switch Removal (figs. 15, 132, and 134).

(1) REMOVE SWITCH KNOB. Loosen set screw in switch knob and unscrew knob from switch.

(2) REMOVE SWITCH. Remove nut and lock washer attaching switch to instrument board. Remove switch from back of instrument board.

(3) DISCONNECT WIRING. Remove two screws and lock washers attaching wires to switch.

e. Instrument Light Switch Installation (figs. 15, 132, and 134).

(1) CONNECT WIRING. Attach wires to switch with two screws and lock washers, tightening screws firmly.

(2) INSTALL SWITCH. Position switch in instrument board. Install nut and lock washers, tightening nut firmly.

(3) INSTALL SWITCH KNOB. Screw knob onto switch and tighten set screw firmly.

146. HORN AND BUTTON.

a. General. The electric vibrating type horn is mounted on the intake manifold and is controlled by a button mounted in the hub of the steering wheel. Current for operation of the horn is supplied by the battery; the horn circuit is protected by an automatic type circuit breaker mounted on the back of the instrument board.

b. Horn Removal.

(1) DISCONNECT WIRING. Remove screws and lock washers attaching wires to horn terminals, then disconnect wires from horn.

(2) REMOVE HORN. Remove two nuts, lock washers, and bolts attaching horn to intake manifold and remove horn.

c. Horn Installation.

(1) INSTALL HORN. Position horn and bracket on intake manifold and attach with two bolts, nuts, and lock washers.

(2) CONNECT WIRES. Attach wires to horn terminals with washers and screws, tightening screws firmly.

d. Horn Button Removal. Remove two screws attaching horn button retainer to steering wheel, then remove retainer, horn button, contact, insulator, and spring.

e. Horn Button Installation. Position spring, insulator, contact, horn button, and retainer on steering wheel, and install two retainer screws.

f. Horn Circuit Breaker Removal (figs. 132 and 134).

(1) REMOVE CIRCUIT BREAKER FROM INSTRUMENT BOARD. Remove two screws, nuts, and lock washers attaching circuit breaker to back of instrument board.

(2) DISCONNECT WIRING. Remove two screws and lock washers attaching wires to circuit breaker, and remove circuit breaker.

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g. Horn Circuit Breaker Installation (figs. 132 and 134).

(1) CONNECT WIRING. Attach wires to circuit breaker with two screws and lock washers, tightening screws firmly.

(2) INSTALL CIRCUIT BREAKER. Position circuit breaker on back of instrument board and install two attaching screws, nuts, and lock washers.

147. DIMMER SWITCH.

a. Dimmer switch is located on the toe board riser to the left of the clutch pedal and is operated by the left foot to select the upper and lower headlight beam.

b. Dimmer Switch Removal.

(1) REMOVE SWITCH. Remove two screws and lock washers attaching switch to toe board support and withdraw switch.

(2) DISCONNECT WIRING. Remove three screws and lock washers attaching wires to switch terminals, and remove switch (GM-1997014).

c. Dimmer Switch Installation.

(1) CONNECT WIRING. Attach wires to switch with three screws and lock washers. The No. 12 black wire with green tracer must be attached to the "BATT" terminal; connect the other wires to the remaining terminals.

(2) INSTALL SWITCH. Position switch in hole in toe board support and attach with two screws and lock washers, tightening screws firmly.

148. STOP LIGHT SWITCH.

a. Stop light switch, located at the outlet end of the brake master cylinder, is operated by the hydraulic pressure in the master cylinder. Before replacing switch, connect the wires together and if stop lights are not illuminated, the cause is elsewhere than in the stop light switch.

b. Stop Light Switch Removal.

(1) DISCONNECT WIRING. Pull wires off snap terminals on switch.

(2) CAUTION: New switch should be installed immediately after removal of switch to prevent loss of brake fluid. *Do not apply brakes while switch is removed,* as brake fluid would be lost through opening; also it would be necessary to bleed the entire brake system if air were admitted into the system.

(3) REMOVE SWITCH. From under vehicle, unscrew switch (GM-1320938) from master cylinder outlet fitting.

c. Stop Light Switch Installation.

(1) INSTALL SWITCH. Thread switch into outlet fitting on brake master cylinder and tighten firmly.

(2) CONNECT WIRING. Attach a wire to each of the two terminals on the switch. Wires can be attached to either terminal.

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TRUCK, 2½-TON, 6 x 6

Section XXVI

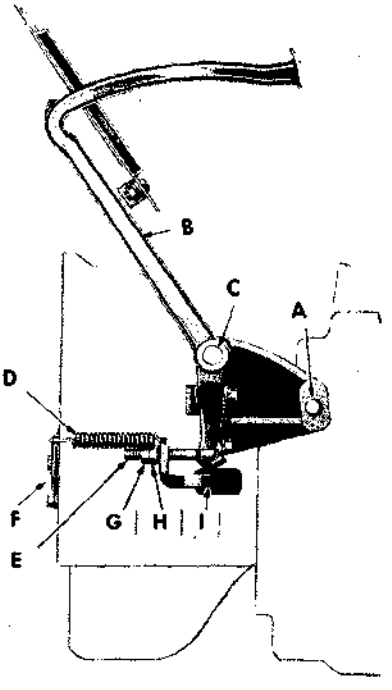
CLUTCH AND CONTROLS

149. DESCRIPTION.

a. The clutch consists of two separate assemblies—the clutch disc assembly and the clutch cover and pressure plate assembly. The driven disc transfers engine power from the flywheel to the transmission main drive gear shaft. The clutch cover and pressure plate provide attachment or release of the driven disc to the flywheel The clutch is always in "engaged" position unless purposely "disengaged" by the driver.

150. CLUTCH PEDAL FREE-TRAVEL ADJUSTMENT.

a. Clutch pedal free-travel is the movement of the pedal before the clutch starts to disengage. Pedal free-travel must be 2½ inches with new facings. As the facings wear, adjusting nuts on the adjusting link should be backed off to maintain a 2½-inch free-travel until the lock nut is at the end of the thread; then clutch may be operated until free-travel is reduced to 1 inch at which time clutch driven member assembly (with new facings) must be replaced.



A PEDAL SHAFT BRACKET
B PEDAL ASSEMBLY
C CLUTCH AND BRAKE PEDAL SHAFT
D PULL BACK SPRING
E CLUTCH PEDAL ADJUSTING LINK
F PULL BACK SPRING BRACKET
G CHECK NUT
H ADJUSTING LINK NUT
I CLUTCH RELEASE FORK ASSEMBLY (SPRING AND BALL STUD)

RA PD 64626

Figure 136—Pedal Linkage

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b. **Pedal Free-travel Adjustment.**

(1) CHECK PEDAL FREE-TRAVEL. Pedal free-travel must be checked with hand on the pedal and not with foot, as this check is very sensitive. If free-travel of clutch is less than 2½ inches, and lock nut has not already been adjusted to the end of the adjusting link threads, adjust pedal.

(2) ADJUST PEDAL (fig. 136). Loosen check nut on adjusting link, and turn adjusting nut in or out as may be required to obtain proper free-travel of foot pedal. With pedal free-travel definitely established, turn up check nut firmly against adjusting nut to prevent adjustment from coming loose, then recheck pedal free-travel. After limit of adjustment is reached, any free-travel in excess of 1 inch is satisfactory.

151. CLUTCH PEDAL AND LINKAGE.

a. Description. Clutch pedal is connected to the release fork through the linkage (fig. 136). Release fork is mounted in the clutch housing by a ball stud and support. Inner end of the fork engages a groove in the release bearing support for actuation of the release bearings.

b. Clutch Pedal and Linkage Removal (fig. 136). Remove attaching screws from toe board assembly and remove toe board to gain access to pedal and linkage. Disconnect pedal pull back spring [(GM-368244) G85-11-02090]. Loosen and remove check nut and adjusting nut, then remove adjusting link. With suitable drift, drive out pin at outer end of pedal shaft and remove collar and pedal assembly.

c. Clutch Pedal and Linkage Installation (fig. 136). Place clutch pedal over end of pedal shaft. Install collar on outer end of shaft, aline hole in collar with hole in shaft, then drive in new retaining pin. Connect adjusting link to clutch pedal with threaded end through hole in fork, then install adjusting nut and check nut, and connect pedal pull back spring. Install toe board assembly, and tighten attaching screws firmly. After toe board assembly has been installed, adjust clutch pedal free-travel (par. 150 b).

152. CLUTCH REPLACEMENT.

a. Removal.

(1) REMOVE TRANSMISSION. Remove transmission assembly (par. 154). Clutch release bearing assembly is then accessible.

(2) REMOVE RELEASE FORK AND BALL STUD ASSEMBLY. Disconnect pedal pull back spring. Loosen and remove check nut and adjusting nut, then remove adjusting link. With a ¾-inch offset open end wrench, hold ball stud support from inner side of clutch housing, then remove ball stud support from outer side of clutch housing. Release fork with ball stud can then be removed.

(3) REMOVE CLUTCH. The clutch units include clutch pressure plate assembly (includes cover, pressure plate, springs, etc.) and

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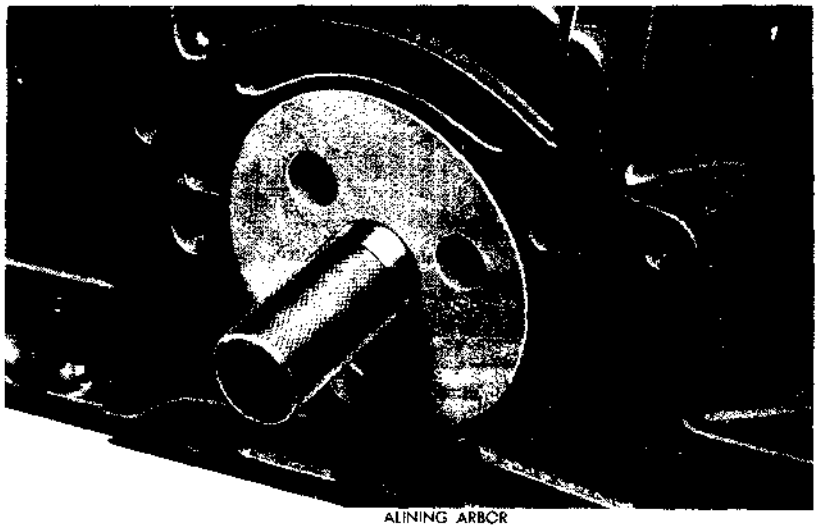
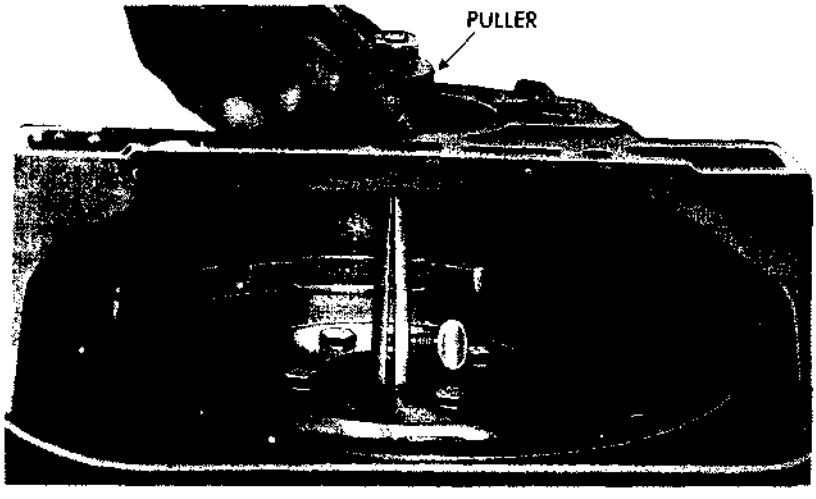


RA PD 332968

Figure 137—Use of Clutch Alining Arbor (41-A-335)

clutch driven member assembly (includes facing, torsion springs, etc.). Insert clutch alining arbor (41-A-335) (fig. 137) through clutch assembly and driven disc hub. Loosen the nine clutch cover to flywheel cap screws one turn at a time until diaphragm spring pressure is fully released; then completely remove all cap screws and withdraw alining arbor and lower clutch pressure plate assembly and clutch driven member assembly.



RA PD 332920

Figure 138—Removing Pilot Bearing (Puller 41-P-2906-15)

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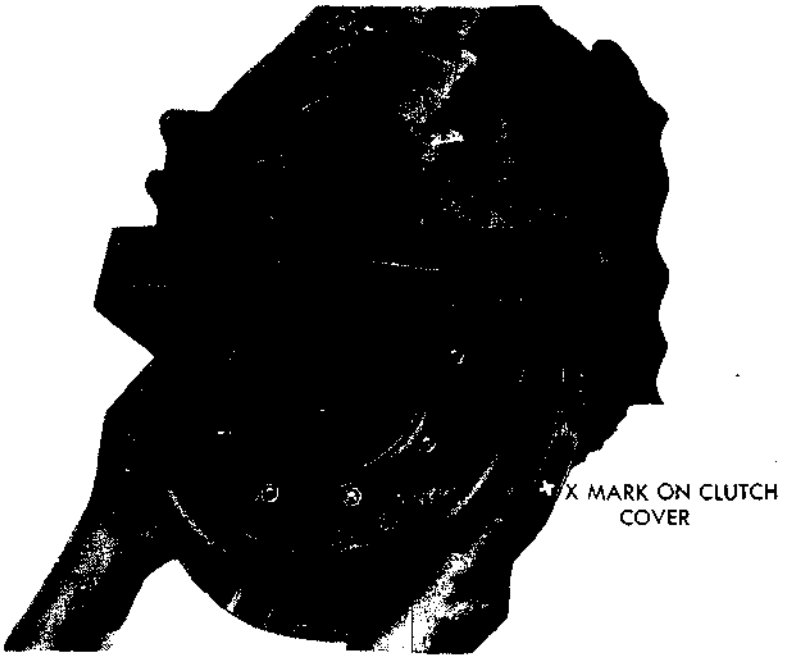

RA PD 303118

Figure 139—Removing or Installing Clutch Assembly

(4) REMOVE CLUTCH PILOT BEARING. Insert puller (41-P-2906-15) (fig. 138) in recess of crankshaft and remove bearing. Pilot bearing is shielded type and requires attention only when clutch is removed from vehicle. If damaged or broken, replace.

b. Installation.

(1) INSTALL CLUTCH PILOT BEARING. Before bearing is installed it must be lubricated as described in Section VIII. Using alining arbor (41-A-335) with three ⅝-inch washers, install pilot bearing. Care must be exercised to provide exact bearing alinment with pilot hole in flywheel housing. Install shielded side of bearing toward transmission.

(2) ATTACH CLUTCH ASSEMBLIES TO FLYWHEEL. Hand crank engine until "X" mark on flywheel is visible from underside of clutch housing. Place driven member assembly and clutch pressure plate assembly against flywheel and rotate cover until "X" mark on cover (fig. 139) alines with "X" mark on flywheel. Insert clutch alining arbor (41-A-335) in clutch assembly and driven disc (fig. 137), then install cap screws which attach cover to flywheel. Each cap screw should be tightened gradually, a turn at a time, to prevent distortion of cover as spring pressure is taken up. Withdraw alining arbor.

(3) CLEAN, LUBRICATE, AND INSTALL BALL STUD. Lift ball stud retainer spring out of fork and withdraw ball stud. Pack ball seat in fork, lubricating as specified in Section VIII, and install ball stud and

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retainer spring. Be sure to place ends of ball retainer spring downward so that spring will be completely seated in grooves in fork.

(4) INSTALL CLUTCH RELEASE FORK AND LINKAGE. Install fork and ball stud assembly, using care to see that fingers at inner end of fork are in groove of release bearing sleeve, then thread support into ball stud. Make sure ball stud and support are drawn up tightly. Attach adjusting link to clutch pedal and through fork arm, then install adjusting nut, check nut, and pull back spring.

(5) INSTALL TRANSMISSION AND ADJUST PEDAL. Install release bearing assembly and transmission assembly (par. 155), adjust clutch pedal free-travel (par. 150 b).

Section XXVII

TRANSMISSION

153. DESCRIPTION.

a. The transmission is a selective sliding gear type and provides for five speeds forward and one reverse. Fourth speed is direct, with fifth speed overdrive. Gears are selected manually by a conventional gearshift lever. The transmission assembly is bolted directly to the clutch housing. The power plant and transmission assembly is stabilized by a strut rod which is connected between the rear of the transmission and the transfer case crossmember. On models equipped with a winch or power hoist, a power take-off is attached to the left-hand side of the transmission. All vehicles have a transfer case high and low speed control cross shaft, mounted at the rear of transmission case.

154. REMOVAL.

a. **Preliminary Instructions.** Vehicles equipped with winch or power hoist have a power take-off installed on the left-hand side of the transmission. The following procedure covers removal of transmission either with or without power take-off, with differences noted in text. Key letters in text refer to figure 140. NOTE: *Transfer case high and low speed control rods, levers, and cross shaft are slightly different on vehicles equipped with banjo type axles than those on vehicles having split type axles (fig. 140); however, removal and installation procedure are the same.*

b. **Drain Lubricant.** Remove drain plug from lower rear side of transmission and allow lubricant to drain. Install plug after draining.

c. **Remove Floor Pan.** Place transfer case control levers in neutral and pull hand brake lever to rear. Lift seal off over levers. Remove 12 floor pan cap screws and lock washers and lift floor pan up over levers and out of cab.

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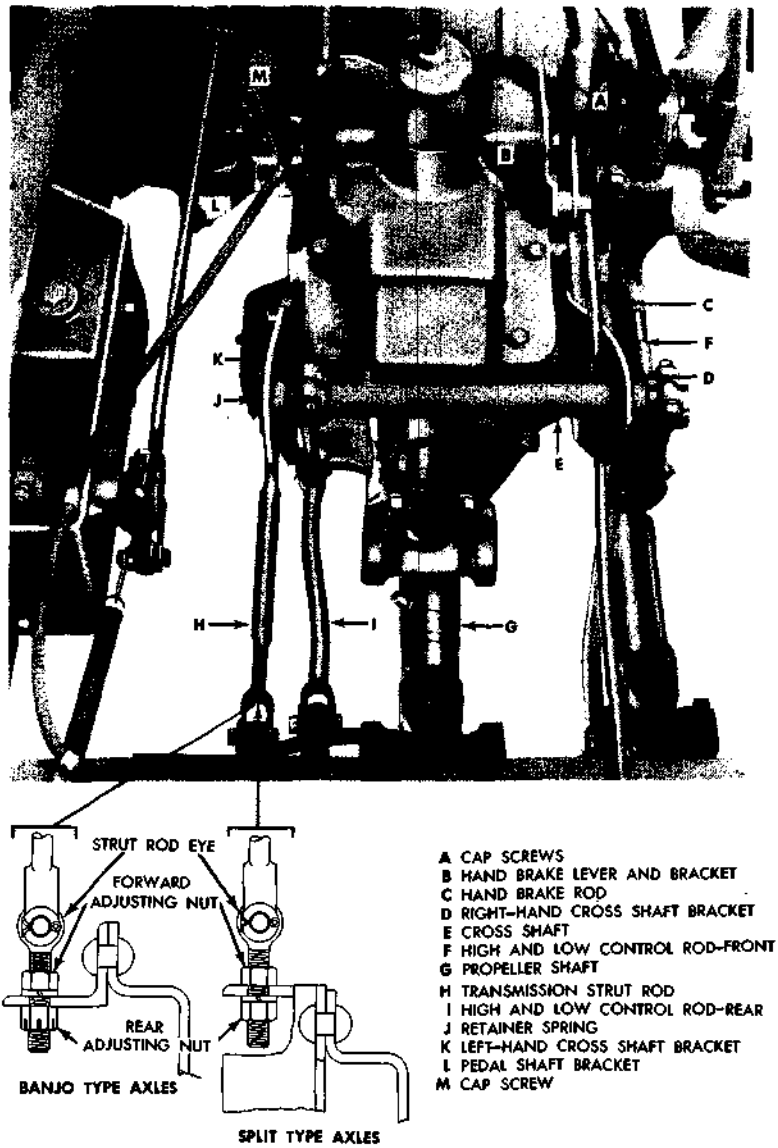
d. Remove Hand Brake Lever and Bracket. Release hand brake and remove cotter pin and clevis pin attaching hand brake rod (C) to lever. Remove two cap screws and washers (A) attaching hand brake bracket to right-hand side of transmission cover and lift



RA PD 333028

Figure 140—Transmission Assembly Installed (Split Type Axles Without Power Take-Off Shown)

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hand brake lever and bracket assembly (B) out of cab. Remove cap screw and lock washer (M) attaching speedometer cable clip to left-hand side of cover.

e. **Remove High and Low Control Lever Cross Shaft and Brackets.** Remove cotter pins and clevis pins attaching high and low control rods (F and I) to cross shaft levers. Pull retainer spring (J) from left end of cross shaft. Loosen rear nut on transmission strut rod eye (fig. 140). Remove cotter pin and clevis pin attaching strut rod (H) to left-hand cross shaft bracket (K). On vehicles without power take-off, remove two nuts and lock washers from studs attaching left-hand cross shaft bracket (K) to transmission and pull bracket off end of studs and cross shaft (E). On vehicles with power take-off, remove power take-off control lever or levers from stud in side of transmission (par. 157 or 158). Remove control lever stud, remove nut and lock washer from forward stud, and remove bracket. Remove two nuts and lock washers from studs attaching right-hand bracket (D) to transmission and remove bracket and cross shaft (E) assembly.

f. **Disconnect Propeller Shaft.** Remove four nuts, lock washers, and bolts attaching propeller shaft universal joint (G) to main drive gear companion flange. Swing shaft up and to one side and fasten with a piece of wire. Disconnect power take-off drive shaft or shafts at power take-off if used (par. 240 or 245).

g. **Remove Pedal Shaft Bracket to Transmission Cap Screw.** Remove cap screw and lock washer attaching pedal shaft bracket (L) to transmission. Loosen, but do not remove, two cap screws attaching pedal shaft bracket to clutch housing.

h. **Remove Flywheel Underpan.** Remove four cap screws attaching flywheel underpan to clutch housing and remove underpan.

i. **Remove Transmission.** Remove lock wire from two transmission to clutch housing lower cap screw heads and remove cap screws from inside clutch housing. Support transmission on a dolly jack or support from above with a hoist and chains. Remove two transmission to clutch housing upper cap screws and lock washers. With the assembly securely supported, move assembly back until main drive gear shaft clears opening in clutch housing. CAUTION: *Do not allow weight of transmission to rest on clutch disc hub and do not permit clutch release bearing and support assembly to drop from release fork.* Lower assembly and tip to one side to permit gearshift lever to clear under side of chassis and withdraw from under vehicle. Do not move clutch pedal while transmission is removed.

155. INSTALLATION.

a. **Preliminary Instructions.** The following procedure covers installation of transmission either with or without power take-off, with differences noted in text. Transfer case high and low speed control rods, levers, and cross shaft are slightly different on vehicles equipped with banjo type axles than on vehicles equipped with split

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type axles (fig. 140); however, installation procedures for both types are the same. Key letters in text refer to figure 140.

b. Install Transmission. Slide transmission under vehicle and guide gearshift lever up through floor pan opening in cab. Support transmission on a dolly jack or support from above with a hoist and chains. Make sure clutch release bearing and support assembly is in place in clutch release fork. Raise assembly until main drive gear shaft will enter release bearing and clutch disc hub and move forward against clutch housing. CAUTION: *Do not allow weight of transmission to rest on clutch disc hub.* If main drive gear splines do not mesh with splines in clutch disc hub, place transmission gearshift lever in 5th speed position and turn main drive gear shaft at rear of transmission with hand to aline splines. Install two transmission to clutch housing upper cap screws and lock washers, and inside clutch housing install two transmission to clutch housing lower cap screws. Tighten all four cap screws firmly and thread lock wire through holes in heads of lower cap screws. Twist ends of lock wire together. Remove jack from under vehicle, or remove chains as the case may be.

c. Install Flywheel Underpan. Position flywheel underpan against under side of clutch housing and attach with four cap screws and internal toothed lock washers. Frame to clutch housing bond strap must be installed under head of underpan to clutch housing left front cap screw.

d. Install Pedal Shaft Bracket to Transmission Cap Screw. Install pedal shaft bracket (L) to transmission cap screw, using lock washer. Tighten cap screw firmly, then tighten two pedal shaft bracket to clutch housing cap screws.

e. Install High and Low Control Cross Shaft and Brackets. Position right-hand bracket and cross shaft assembly (D and E) with holes in bracket over two studs in right-hand side of transmission. Install nuts and lock washers on studs and tighten firmly. On vehicle without power take-off (fig. 140), place left-hand bracket (K) over studs in left-hand side of transmission and over end of cross shaft (E). Install nuts and lock washers and tighten firmly. On vehicles with power take-off, the procedure is the same except that the rear stud is replaced with a special stud on which power take-off control lever or levers pivot. Install retainer spring (J) in groove in left end of cross shaft (E). Connect transfer case high and low control rods (F and I) to cross shaft levers, using clevis pins and new cotter pins. Adjust high and low speed control linkage (par. 160). On vehicles equipped with power take-off, install power take-off control lever or levers (par. 157 or 158).

f. Connect and Adjust Transmission Strut Rod (fig. 140). Connect forward end of strut rod (H) to left-hand cross shaft bracket, using clevis pin and new cotter pin. Adjust rod as follows:

(1) WITH BANJO TYPE AXLES, Run forward adjusting nut toward front of eye rod. Turn rear adjusting nut onto eye rod until nut fully contacts bracket, then tighten rear nut one full turn. Run forward adjusting nut back against bracket and tighten firmly.

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(2) WITH SPLIT TYPE AXLES. Run rear adjusting nut toward rear end of eye rod. Run forward adjusting nut back until nut fully contacts bracket, then turn forward nut one full turn toward front end of eye rod. Tighten rear adjusting nut firmly against bracket.

g. Install Hand Brake Lever and Bracket. Position hand brake lever and bracket assembly (B) on right-hand side of transmission cover and install two cap screws (A) with lock washer under head of rear cap screw, and ground strap, flat washer, and lock washer under head of forward cap screw. Tighten cap screws firmly. Adjust and connect hand brake rod (C) to hand brake lever (par. 193). Attach speedometer cable clip to left-hand side of cover, using cap screw and lock washer.

h. Prepare Transmission for Service. Lubricate transmission with type and quantity of lubricant as directed in Section VIII. Tighten filler and drain plugs firmly. Start engine and run transmission three or four minutes with shift lever in each position. This will definitely work lubricant into close clearances.

i. Connect Propeller Shaft. Attach propeller shaft universal joint (G) to main drive gear companion flange, using four bolts, nuts, and lock washers. Tighten nuts firmly. Connect power take-off drive shaft or shafts at power take-off if used (par. 240 or 245).

j. Install Floor Pan. Install floor pan over control levers in cab and attach with 12 cap screws and lock washers. Place transfer case control levers in neutral position, pull hand brake back, and install floor seal over ends of levers.

Section XXVIII

POWER TAKE-OFF AND CONTROLS

156. DESCRIPTION.

a. General. Power take-off assembly, mounted on left-hand side of transmission, provides two forward speeds and one reverse speed for winch operation, and one speed for operation of power hoist. Power take-off intermediate gear is constantly meshed with the transmission reverse idler gear, making it possible to use power take-off at any time the vehicle engine is operating. Power is transferred to auxiliary units through drive shafts which connect directly with power take-off output shaft. Control levers which are connected with shift shaft at power take-off are located in cab and are shifted manually. Difference in design of dual and single drive power take-off assemblies are covered in succeeding paragraphs 157 and 158. Lubricant in transmission case also lubricates power take-off assembly.

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b. Data. Two makes of single drive power take-off assemblies are used on early vehicles, both of which are similar in construction, and can be identified by referring to name plate.

(1) SINGLE DRIVE (Early Vehicles).

Type	Two-speed and reverse	
Make	Heil	Gar Wood
Models	B-360	67-Y-60000LG
Drive	Transmission	Transmission

(2) SINGLE DRIVE (Late Vehicles).

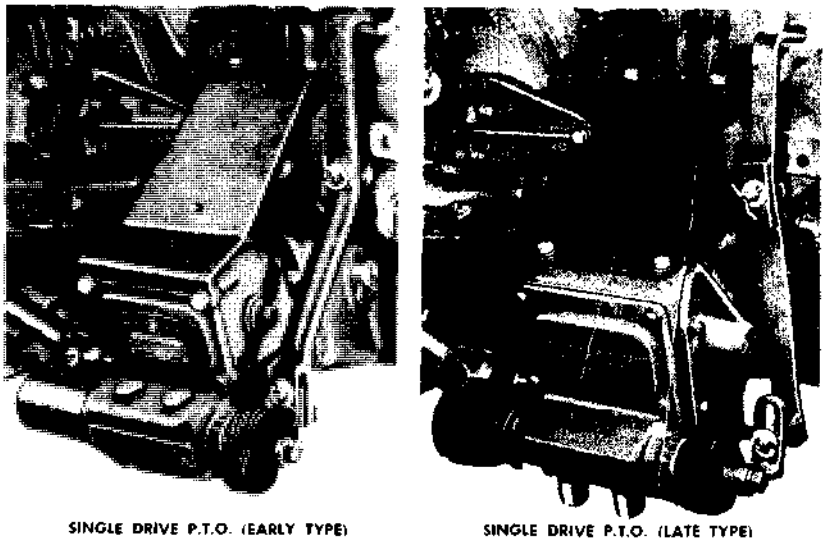
Type	Two-speed and reverse
Make	GMC
GM Part No.	2200208
Drive	Transmission

(3) DUAL DRIVE.

Type (winch drive)	Two-speed and reverse
Type (hoist drive)	One-speed
Make	GMC
Drive	Transmission

157. SINGLE DRIVE POWER TAKE-OFF AND CONTROLS.

a. General. Winch-equipped vehicles have a single drive power take-off, mounted on left-hand side of transmission. Backlash between transmission gear and power take-off intermediate gear is controlled by adding or removing gasket between the two assemblies. Single drive assembly used on late vehicles can be converted to a dual type by replacing the auxiliary drive shaft cover with an auxili-



SINGLE DRIVE P.T.O. (EARLY TYPE) SINGLE DRIVE P.T.O. (LATE TYPE)

RA PD 332990

Figure 141—Single Drive Power Take-Off Installation

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ary drive assembly. Controls for single drive power take-off consists simply of a lever which pivots on a special stud at transmission case and is connected directly with shift shaft arm on power take-off assembly. Control lever lock, attached to cab floor pan, prevents accidental engagement of power take-off which might cause serious damage to winch mechanism (fig. 33).

b. Power Take-off Removal. Removal instructions which follow apply to both the early and the late type assemblies (fig. 141), except as otherwise stated in the text. This operation is necessary when a transmission is being replaced by consent of higher authority.

(1) DRAIN LUBRICANT. Remove drain plug from power take-off gear case, remove transmission filler plug and allow all lubricant to drain into suitable receptacle. NOTE: *If assembly is not equipped with drain plug, as is the case on some early assemblies, it will be necessary to remove transmission drain plug.*

(2) REMOVE POWER TAKE-OFF TO TRANSMISSION BRACE (fig. 141). Remove floor pan retaining screws; then raise floor pan sufficiently to permit access to upper end of brace. Remove two brace to transmission cap screws and two brace to power take-off cap screws, then remove brace.

(3) DISCONNECT WINCH DRIVE SHAFT. Loosen set screw and move drive shaft stop collar forward. Loosen set screw in drive shaft rear U-joint yoke; then drive yoke off power take-off shaft. NOTE: *Thread wire through U-joint and suspend winch drive shaft from chassis to prevent slip joint from coming apart.*

(4) DISCONNECT CONTROL LEVER (Early Type). Disconnect control lever from shift shaft by removing lever to arm pin and two flat washers.

(5) DISCONNECT CONTROL LEVER (Late Type). Move control lever forward as far as possible. Loosen arm to shift shaft screw, withdraw cotter pin and remove flat washer from lower end of lever. Turn shift shaft arm away from lever, thus disengaging arm and lever. Remove washer from lower end of lever.

(6) REMOVE ASSEMBLY FROM VEHICLE. Remove six stud nuts, lock washers, and flat washers which mount assembly to transmission. Use pry bar to spring exhaust pipe away from assembly to permit removal from stud bolts. Pull assembly away from transmission until free from stud bolts and remove from vehicle. Remove gaskets, and place cloth or paper covering over opening in transmission case to prevent entance of dirt or foreign material while assembly is removed.

c. Power Take-off Installation. Installation instructions which follow apply to both the early and the late type assemblies unless otherwise stated in the text.

(1) ATTACH ASSEMBLY TO TRANSMISSION. Coat three gaskets, on both sides, with aviation type cement. Place gaskets on studs at transmission case; then place the power take-off in position at transmission case and install one flat washer, one lock washer, and a nut on each stud. Tighten nuts in successive stages until firm.

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(2) CHECK OPERATION. There should be a small amount of backlash between power take-off gear and reverse idler gear (approximately 0.005—0.008 in.) in transmission. This backlash can be checked by grasping output shaft and turning, with power take-off in gear. If backlash is excessive (noise) remove one gasket between power take-off and transmission case. If movement is not sufficient (tight), add one gasket.

(3) INSTALL POWER TAKE-OFF TO TRANSMISSION BRACE. Position brace, then install two cap screws with lock washers at each end of brace. When cap screws have been firmly tightened drop floor pan into place and install retaining screws.

(4) CONNECT WINCH DRIVE SHAFT TO POWER TAKE-OFF SHAFT. Be certain that key is in position in power take-off shaft. With keyway in U-joint yoke alined with key, push yoke onto power take-off shaft. Tighten set screw in U-joint yoke and position stop collar (par. 240).

(5) CONNECT CONTROL LEVER (Early Type). Position lower end of control lever astride shifter shaft arm and install pin with one retaining washer at each side of control lever. Secure with new cotter pin. Make sure that shifter shaft arm retaining screw is tight.

(6) CONNECT CONTROL LEVER (Late Type). With arm to shift shaft cap screw loosened to allow arm to be turned, place flat washer on lower end of lever, turn arm and move lever as necessary to engage elongated hole in arm with lower end of lever. Place flat washer on lever and against shift shaft arm, install cotter pin in lever, then tighten arm to shift shaft screw firmly.

(7) INSTALL LUBRICANT. With drain plugs securely tightened in power take-off and transmission, add lubricant (Section VIII) through transmission filler plug hole until lubricant level is up to filler plug hole. Install filler plug.

d. Winch Power Take-off Control Lever Removal (fig. 141).

(1) REMOVE FLOOR PAN. Remove transfer case control lever seal, remove floor pan retaining screws, then remove floor pan.

(2) REMOVE WINCH POWER TAKE-OFF CONTROL LEVER (Early Vehicles) (fig. 141). Remove cotter pin, clevis pin, and flat washers at lower end of control lever. Remove cotter pin and flat washer from stud at transmission, then remove control lever from vehicle. Remove special stud and lock washer from transmission. If necessary to remove arm from power take-off shift shaft, it is only necessary to remove cap screw and washers from end of shift shaft and withdraw arm.

(3) REMOVE WINCH POWER TAKE-OFF CONTROL LEVER (Late Vehicles) (fig. 141). Loosen cap screw which attaches arm to power take-off shift shaft. Remove cotter pin and flat washer from lower end of lever, then turn arm and move lever as necessary to disengage arm from lever. Remove flat washer from lower end of control lever. Remove cotter pin and flat washer from stud at transmission and remove control lever from stud. Remove special stud and lock washer from transmission case.

e. **Winch Power Take-off Control Lever Installation.**

(1) INSTALL CONTROL LEVER (Early Vehicles) (fig. 141). Install and tighten special stud at transmission case, using lock washer between stud and transfer case cross shaft bracket. If shift shaft arm has been removed, place arm on shift shaft with boot clamp washer between arm and boot, then install arm to shaft cap screw finger-tight. Be certain that retainer washer and lock washer are in place under cap screw head. Place control lever on stud at transmission and install flat washer and cotter pin. Place lower end of control lever astride shift shaft arm and install clevis pin through lever and arm, with one flat washer at each side of lever. Secure pin, using new cotter pin, and tighten arm retaining cap screw in end of shift shaft.

(2) INSTALL CONTROL LEVER (Late Vehicles) (fig. 141). Install and tighten special stud at transmission, using lock washer between stud and transfer case cross shaft bracket. Place control lever on stud, then install flat washer and cotter pin. Loosen arm to shift shaft screw sufficiently to allow arm to be turned. Place flat washer on lower end of lever and turn arm and move lever as necessary to engage elongated hole in arm with lower end of lever. Install flat washer and cotter pin at lower end of lever, then tighten arm to shift shaft screw firmly.

(3) INSTALL FLOOR PAN. Guide floor pan over control levers and into position in cab, then install retaining screws. Install transfer case control lever seal. Lock lever in neutral position.

158. DUAL DRIVE POWER TAKE-OFF AND CONTROLS.

a. **General.** Dual drive power take-off is installed on CCKW-353 (long wheelbase vehicles) equipped with winch and dump body power hoist. The assembly is mounted on transmission in same manner as single drive assembly (par. 157). Two types of controls and linkage are used in shifting the dual drive power take-off. Hoist controls and linkage used on vehicles prior to chassis serial No. 398030 (fig. 142) consists of two levers which pivot on a cross shaft mounted on brackets which are bolted to transfer case support. The hoist power take-off control lever is interconnected with auxiliary shift rod at power take-off by a short rod. The hoist pump control lever is connected with the hoist pump through rods and must be removed from vehicle whenever power take-off linkage is removed from vehicle. The winch power take-off control lever is mounted on a special stud at transmission. Linkage comprising rods and cross shaft fitted with pickup levers, connects winch control lever with power take-off shift shaft arm (fig. 143). After chassis serial No. 398029, the two control levers for shifting dual drive power take-off pivot on a special stud at transmission. Winch power take-off control lever is connected directly with power take-off shift shaft arm, while the hoist power take-off control lever is connected through a rod link with the auxiliary shift rod at power take-off (fig. 143). Two lever locks are attached to cab floor pan to prevent accidental engagement of power take-off assembly.

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b. Dual Power Take-off Removal. Removal procedure which follows is for all dual drive power take-off assemblies except as otherwise stated in text. This operation may be necessary if the transmission is being replaced by the consent of higher authority.

(1) DRAIN LUBRICANT. Remove transmission filler plug and power take-off drain plug and allow lubricant to drain into suitable receptacle.

(2) REMOVE POWER TAKE-OFF TO TRANSMISSION BRACE AND DISCONNECT WINCH DRIVE SHAFT. Accomplish operations **b** (2) and (3) of paragraph 157.

(3) DISCONNECT HOIST DRIVE SHAFT. Loosen set screw in U-joint yoke at rear of power take-off, remove drive shaft front steady bearing from support bracket, and loosen stud nut at drive shaft rear steady bearing. Pull drive shaft down and at same time pull U-joint off auxiliary drive shaft at power take-off.

(4) DISCONNECT CONTROL LINKAGE (Prior to Serial No. 398030) (fig. 142). Remove clevis pins which connect rods to power take-off shifting mechanism and allow rods to swing down and away from assembly.

(5) DISCONNECT CONTROL LEVERS (After Serial No. 398029) (fig. 143). With winch power take-off control lever moved forward to "HIGH" position, remove cotter pin and flat washer from lower end of lever. Loosen arm to shift screw and turn arm to disengage it from lever. Remove clevis pin from lower end of hoist power take-off control lever and remove lever to shift rod link by withdrawing cotter pin and removing rod link from eye in shift rod.

(6) REMOVE POWER TAKE-OFF ASSEMBLY FROM VEHICLE. Accomplish operation **b** (6) in paragraph 157.

c. Dual Power Take-off Installation.

(1) ATTACH ASSEMBLY TO TRANSMISSION AND CONNECT WINCH DRIVE SHAFT. Accomplish operations **c** (1) through (4) in paragraph 157.

(2) CONNECT HOIST DRIVE SHAFT. Be certain that key is in slot in auxiliary drive shaft at power take-off. Raise hoist drive shaft and guide drive shaft front U-joint yoke onto shaft at power take-off. Attach drive shaft front steady bearing to support bracket and tighten bearing stud nut at both the front and rear bearings. Tighten set screw in front U-joint yoke to hold joint on power take-off auxiliary drive shaft.

(3) CONNECT CONTROL LINKAGE (Prior to Serial No. 398030). Attach rods to shift rod and shift shaft at power take-off, using clevis pins secured with new cotter pins (fig. 142).

(4) CONNECT CONTROL LEVERS (After Serial No. 398029).

(a) Connect Hoist Control Lever. Place hoist power take-off control lever in the "OUT" position and engage lever lock on cab floor. Pull auxiliary shift rod out to disengaged position. If rod link (fig. 143) cannot be installed without moving shift rod, loosen rod eye lock nut and screw eye in or out, as necessary, to make possible rod link installation. Install rod link, using clevis pin to attach rod

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to lever, and two flat washers and two cotter pins at shift rod eye. Tighten rod eye lock nut at finish of operation.

(b) Connect Winch Control Lever. With arm to shift shaft cap screw loosened to allow arm to be turned, place flat washer on lower end of lever; then turn arm and move lever as necessary to engage elongated hole in arm with lower end of lever. Place flat washer on lever and against shift shaft arm, install cotter pin in lever, and tighten arm to shift shaft screw firmly. Lock lever in neutral position.

(5) INSTALL LUBRICANT. Install lubricant as directed in paragraph 157 c (7).

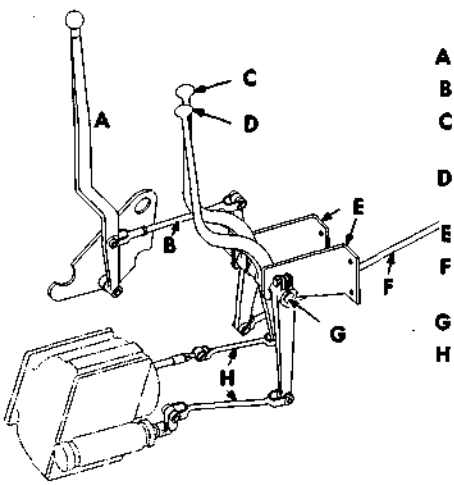
d. Controls and Linkage Removal (Prior to chassis Serial No. 398030) (fig. 142).

(1) REMOVE FLOOR PAN. Lift out transfer case control lever seal, remove floor pan retaining screws, and remove floor pan from vehicle.

(2) REMOVE WINCH CONTROL LEVER. Pull out cotter pin and remove clevis pin from yoke at cross shaft arm. Remove cotter pin and retaining washer from pivot stud at lower end of control lever and slide lever off stud. Use suitable wrench and remove pivot stud and lock washer. Remove clevis pin from rod yoke at lever and remove rod assembly from lever. Remove adjustable rod assembly from lever. Remove adjustable rod end clevis from end of rod.

(3) REMOVE POWER TAKE-OFF SHIFTER CONTROL RODS (fig. 142). Remove clevis pins from yokes at both ends of two shifter shaft control rods and remove rods from vehicle.

(4) REMOVE POWER HOIST CONTROL LEVERS AND CROSS SHAFT ASSEMBLY. Disconnect power hoist valve control rod by removing clevis pin from rod yoke at control lever. Unhook and remove brake pedal return spring. Remove four cross shaft bracket mounting bolts,



A WINCH CONTROL LEVER
B WINCH LINKAGE ROD ASSEMBLY
C HOIST PUMP VALVE CONTROL LEVER
D HOIST POWER TAKE-OFF CONTROL LEVER
E CROSS SHAFT SUPPORT BRACKETS
F HOIST PUMP VALVE CONTROL ROD
G CROSS SHAFT
H POWER TAKE-OFF SHIFTER SHAFT CONTROL RODS

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Figure 142—Dual Drive Power Take-Off Controls and Linkage (Early Type)

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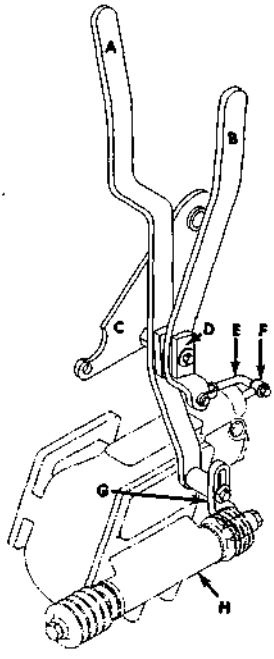

A WINCH POWER TAKE-OFF CONTROL LEVER
B HOIST POWER TAKE-OFF CONTROL LEVER
C TRANSFER CASE CONTROL CROSS SHAFT BRACKET
D SPECIAL STUD
E LEVER TO SHIFT ROD LINK
F POWER TAKE-OFF AUXILIARY DRIVE SHIFT ROD
G SHIFT SHAFT ARM
H DUAL DRIVE POWER TAKE-OFF ASSEMBLY

RA PD 333048

Figure 143—Dual Drive Power Take-Off Controls and Linkage (Late Type)

nuts, lock washers, and brake pedal return spring clip, then remove cross shaft assembly from vehicle.

(5) DISASSEMBLE CONTROL LEVERS, CROSS SHAFT, AND BRACKETS ASSEMBLY. Place assembly in vise and remove clamp bolt from one cross shaft arm, then remove arm and Woodruff key from shaft. Strip two brackets, two hoist control levers, and one spacer from cross shaft. Grip cross shaft in vise and remove clamp bolt, arm, and Woodruff key from shaft.

e. Controls and Linkage Removal (After Chassis Serial No. 398029) (fig. 143).

(1) REMOVE FLOOR PAN. Lift out transfer case control levers seal, remove floor pan retaining screws, and remove floor pan from vehicle.

(2) REMOVE CONTROL LEVERS. Remove clevis pin from lower end of hoist power take-off control lever, and withdraw cotter pin from lower end of winch power take-off control lever. Loosen arm to shift shaft cap screw; then turn shift shaft arm to disengage it from lever. Do not lose flat washers used at each side of arm. Remove cotter pin and flat washer from stud at transmission then remove both levers from stud.

(3) REMOVE TRANSMISSION STUD AND AUXILIARY SHIFT ROD LINK. With suitable wrench remove stud from transmission case.

Withdraw cotter pin from shift rod to lever link, which is connected to auxiliary shift rod eye, and remove rod link and flat washers.

f. Controls and Linkage Installation (Prior to Chassis Serial No. 398030) (fig. 142).

(1) ASSEMBLE CONTROL LEVERS, CROSS SHAFT, AND BRACKETS ASSEMBLY. Place cross shaft in vise, tap a Woodruff key into slot in shaft, and slide short cross shaft arm onto shaft and into position. Install and tighten clamp bolt in arm. Coat cross shaft with chassis grease and slide cross shaft inner bracket assembly over shaft and against cross shaft arm. Assemble hoist power take-off control lever, spacer, hoist valve control lever, and cross shaft outer bracket on cross shaft bracket assembly in order mentioned. Tap Woodruff key into slot at end of cross shaft and slide long cross shaft arm into position on cross shaft. Install and tighten clamp bolt to hold long arm in position on cross shaft.

(2) INSTALL CONTROL LEVERS, CROSS SHAFT, AND BRACKETS ASSEMBLY. Position assembly against transfer case support with mounting bolt holes alined. Place brake pedal return spring clip on longest mounting bolt and install this bolt in lower hole of inner cross shaft bracket. Install other three mounting bolts, install four nuts and lock washers on mounting bolts, and tighten securely.

(3) INSTALL POWER TAKE-OFF SHIFT SHAFT CONTROL RODS (fig. 142). Connect shorter rod between upper power take-off shift rod and lower end of hoist power take-off control lever, using clevis pins secured by new cotter pins at both ends of rod. Connect longer rod between arm on cross shaft and shift shaft arm at lower power take-off shift shaft. Install clevis pins at both ends of rod and secure with new cotter pins.

(4) CONNECT HOIST VALVE CONTROL ROD. Connect hoist valve control rod to lower end of hoist valve control lever using clevis pin and secure with new cotter pin.

(5) INSTALL WINCH CONTROL LEVER. Install "pivot" stud in bracket at left side of transmission. Position eye in lower end of winch control lever on "pivot" stud and install retaining washer and new cotter pin.

(6) INSTALL ADJUSTABLE ROD ASSEMBLY (fig. 142). Connect rod to cross shaft arm using clevis pin secured by cotter pin and start adjustable clevis on threads at other end of rod. Place power take-off in neutral position between reverse and low gear positions by sliding shift shaft forward into power take-off housing as far as it will go, then pull shaft out to first notch. Screw adjustable clevis onto rod far enough so that clevis pin can be inserted through rod yoke and control lever without movement of shift shaft.

(7) INSTALL FLOOR PAN. Guide floor pan over control levers and into position in cab then install retaining screws. Install transfer case control levers seal. Lock levers in neutral position.

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g. **Controls and Linkage Installation** (After Chassis Serial No. 398029) (fig. 143).

(1) INSTALL TRANSMISSION STUD AND AUXILIARY SHIFT ROD LINK. Place lock washer on threaded end of stud. Install stud at transmission. Install rod link in auxiliary shift rod eye with flat washer at each side of eye; then install cotter pins in holes in rod (fig. 143).

(2) INSTALL LEVERS ON TRANSMISSION STUD. Place winch power take-off (longer) lever on stud at transmission with offset in handle toward center of vehicle; then place hoist power take-off (shorter) lever on stud with offset at lower end of lever toward power take-off assembly. Install flat washer and cotter pin at stud.

(3) CONNECT WINCH POWER TAKE-OFF LEVER WITH SHIFT SHAFT ARM. Loosen arm to shift shaft cap screw sufficiently to allow arm to be turned. Place flat washer on lower end of lever and turn arm and move lever as necessary to engage elongated hole in arm with lower end of lever Place flat washer on lever against shift shaft arm and install cotter pin in lever. Tighten arm to shift shaft screw firmly.

(4) CONNECT HOIST POWER TAKE-OFF CONTROL LEVER WITH ROD LINK. Position lower end of hoist power take-off lever in yoke of rod link; then install clevis pin through yoke and lever. Secure clevis pin with cotter pin.

(5) INSTALL FLOOR PAN. Guide floor pan over control levers and into position in cab. Install retaining screws and transfer case control levers seal. Lock levers in neutral position.

Section XXIX

TRANSFER CASE AND CONTROLS

159. DESCRIPTION.

a. Transfer case is essentially a two-speed auxiliary unit consisting of a case, gears, and output shafts for transferring power to each of the three driving axles. The transfer case is located between the frame side rails just behind the transmission and is driven by the transmission through a propeller shaft. It is attached to brackets under the transfer case crossmember by cap screw. Shifting of transfer case gears is accomplished manually through levers in the cab (par. 16).

160. CONTROLS AND LINKAGE.

a. **Preliminary Instructions.** The following operations are given in logical sequence for adjusting, removing, or installing all of the controls and linkage; however, any part (or parts) may be inde-

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pendently adjusted, removed, or installed if so desired. Procedures are the same on vehicles equipped with split or banjo type axles. Refer to figures 144 and 145.

b. Declutching (Front Axle) Control Lever Adjustment.

(1) DISCONNECT CONTROL ROD. Disconnect declutching control rod from declutching control lower inner lever by removing cotter pin and clevis pin from adjustable yoke.

(2) DETERMINE POPPET BALL SEAT POSITIONS. Move declutching shifter shaft at transfer case in and out to make sure poppet ball is seating in grooves in shaft. Movement of shaft will indicate when poppet ball is seated. Leave shaft pulled out in the disengaged position.

(3) ADJUST CONTROL ROD. With declutching control lever slightly forward of a vertical position, the holes in the adjustable yoke on declutching control rod should be in alinement with the hole in the declutching control lower inner lever. Loosen lock nut behind adjustable yoke and turn yoke onto or off of rod as necessary to aline holes.

(4) CONNECT CONTROL ROD. When correct adjustment is obtained, connect declutching control rod to declutching control lower inner lever, using clevis pin and new cotter pin. Tighten lock nut behind adjustable yoke.

c. High and Low Speed Control Lever Adjustment.

(1) DISCONNECT CONTROL ROD. Disconnect high and low speed control rod (front) from high and low speed control lower inner lever by removing cotter pin and clevis pin from adjustable yoke on forward end of rod.

(2) DETERMINE POPPET BALL SEAT POSITIONS. Move high and low speed shifter shaft at transfer case in and out to make sure that poppet ball is seating in grooves in shaft. Movement of shaft will indicate when poppet ball is seated. Leave shaft in neutral position, between high and low.

(3) ADJUST CONTROL ROD. With declutching (front axle) control lever in disengaged position, set high and low speed control lever so there is a ⅛-inch clearance between this lever and the stop pad on declutching control lower outer lever. With high and low speed control lever in this position, holes in adjustable yoke on forward end of high and low speed control rod (front) should be in alinement with hole in high and low speed control lower lever. Loosen lock nut at rear of adjustable yoke and turn yoke onto or off of rod as necessary to aline holes.

(4) CONNECT CONTROL ROD. When correct adjustment is obtained, connect high and low speed control rod (front) to high and low speed control lower lever, using clevis pin and new cotter pin. Tighten lock nut behind adjustable yoke.

d. Control Rods Removal. Removal of any of the three control rods consists of removing the cotter pin and clevis pin from the yoke at each end of the rods.

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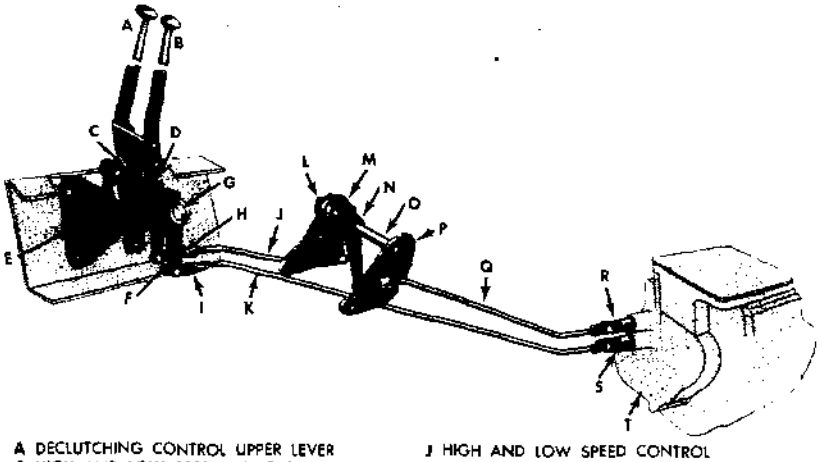
TRANSFER CASE AND CONTROLS



A DECLUTCHING CONTROL UPPER LEVER
B HIGH AND LOW SPEED CONTROL UPPER LEVER
C DECLUTCHING CONTROL LOWER OUTER LEVER
D HIGH AND LOW SPEED CONTROL LOWER LEVER
E CONTROL LEVER BRACKET
F DECLUTCHING CONTROL LOWER INNER LEVER
G CONTROL LEVER SHAFT
H HIGH AND LOW SPEED CONTROL ROD ADJUSTABLE YOKE
I DECLUTCHING CONTROL ROD ADJUSTABLE YOKE
J HIGH AND LOW SPEED CONTROL ROD (FRONT)
K DECLUTCHING CONTROL ROD
L CROSS SHAFT RIGHT-HAND LEVER
M CROSS SHAFT RIGHT-HAND SUPPORT BRACKET
N CROSS SHAFT LEFT-HAND LEVER
O CROSS SHAFT
P CROSS SHAFT LEFT-HAND SUPPORT BRACKET
Q HIGH AND LOW SPEED CONTROL ROD (REAR)
R HIGH AND LOW SPEED SHIFTER SHAFT
S DECLUTCHING SHIFTER SHAFT
T TRANSFER CASE

RA PD 332979

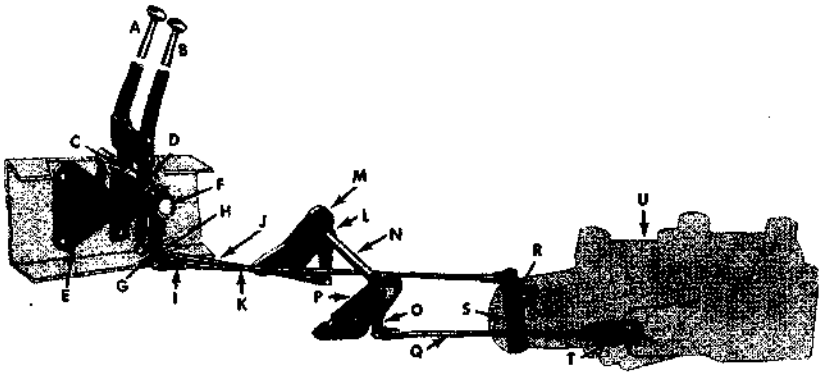
Figure 144—Transfer Case Controls and Linkage (Used with Banjo Type Axles)

e. High and Low Speed Control Cross Shaft and Brackets Removal.

(1) REMOVE RIGHT-HAND SUPPORT BRACKET AND CROSS SHAFT ASSEMBLY. Pull retainer spring from left-hand end of cross shaft. Remove two nuts and lock washers from studs attaching right-hand support bracket to transmission. Pull bracket off studs and pull cross shaft out of left-hand bracket and remove the assembly from the vehicle.

(2) REMOVE LEFT-HAND SUPPORT BRACKET. Loosen rear adjusting nut on transmission strut rod eye bolt, then remove cotter pin and clevis pin attaching forward end of strut rod to left-hand cross shaft support bracket. On vehicles without power take-off, remove two nuts and lock washers from studs attaching left-hand support bracket to transmission and pull bracket off studs. On vehicles with power take-off, remove power hoist and/or winch control levers from stud in left-hand side of transmission (par. 157 or 158). Remove control lever stud, remove nut and lock washer from forward stud, and remove bracket.

(3) DISASSEMBLE LEVERS, CROSS SHAFT, AND BRACKETS. Loosen clamp bolt in each lever and slide levers off ends of shaft. Remove Woodruff keys from shaft, then pull shaft out of bracket.



A DECLUTCHING CONTROL UPPER LEVER
B HIGH AND LOW SPEED CONTROL UPPER LEVER
C DECLUTCHING CONTROL LOWER OUTER LEVER
D HIGH AND LOW SPEED CONTROL LOWER LEVER
E CONTROL LEVER BRACKET
F CONTROL LEVER SHAFT
G DECLUTCHING CONTROL LOWER INNER LEVER
H HIGH AND LOW SPEED CONTROL ROD ADJUSTABLE YOKE
I DECLUTCHING CONTROL ROD ADJUSTABLE YOKE
J HIGH AND LOW SPEED CONTROL ROD (FRONT)
K DECLUTCHING CONTROL ROD
L CROSS SHAFT RIGHT-HAND LEVER
M CROSS SHAFT RIGHT-HAND SUPPORT BRACKET
N CROSS SHAFT
O CROSS SHAFT LEFT-HAND LEVER
P CROSS SHAFT LEFT-HAND SUPPORT BRACKET
Q HIGH AND LOW SPEED CONTROL ROD (REAR)
R DECLUTCHING SHIFT SHAFT
S DECLUTCHING SHIFT LEVER
T HIGH AND LOW SPEED SHIFT SHAFT
U TRANSFER CASE

RA PD 332989

Figure 145—Transfer Case Controls and Linkage (Used with Split Type Axles)

f. Control Levers Removal.

(1) REMOVE FLOOR PAN. Lift floor seal up over ends of transfer case control levers and hand brake lever. Remove 12 floor pan cap screws and lock washers and lift floor pan up over levers and out of cab.

(2) REMOVE UPPER LEVERS. Remove two nuts, lock washers, and bolts attaching each upper lever to lower lever and remove upper levers.

(3) REMOVE HAND BRAKE LEVER AND BRACKET. Remove cotter pin and clevis pin attaching hand brake rod to hand brake lever. Remove two cap screws and washers attaching hand brake bracket to transmission cover and lift hand brake and lever assembly out of vehicle.

(4) REMOVE TRANSMISSION COVER ASSEMBLY. On vehicles equipped with power take-off, remove power take-off support bracket by removing four cap screws, two at top and two at bottom. Remove cap screw attaching speedometer cable clip to cover. Move gearshift lever into neutral position. Thoroughly clean transmission cover with dry-cleaning solvent. Remove cover to case cap screws and lift cover assembly off from transmission case. CAUTION: *Do not change position of transmission gears while cover is removed. Cover transmission opening with cloth or paper to prevent dirt or tools from dropping into case.*

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(5) REMOVE LOWER LEVERS. Loosen clamp bolt in declutching control lower inner lever and slide lever off end of shaft. Remove Woodruff key from shaft. Slide high and low control lower lever off end of shaft. Loosen clamp bolt in declutching control lower outer lever and slide lever outward (to right) on shaft until Woodruff key is exposed. Remove Woodruff key, then slide shaft inward (toward transmission) and remove lever from right-hand end of shaft.

g. Control Levers Installation.

(1) INSTALL LOWER LEVERS. Insert control lever shaft through bracket inner bushing with keyway end of shaft toward center of vehicle. Position declutching control lower outer lever on right-hand end of shaft with stop pad toward center of vehicle. Move shaft outward (to right) through support bracket inner bushing and declutching control lever until keyseat in shaft is exposed between lever and inner bushing in bracket. Tap Woodruff key into keyseat in shaft, aline key with keyway in lever, and move shaft outward (to right) until outer end of shaft enters right-hand bushing in bracket. Place high and low speed control lower lever over left-hand end of shaft with groove in lever toward center of vehicle. Tap Woodruff key into keyseat in inner end of shaft and install declutching control lower inner lever on shaft, with key alined with keyway in lever. With inner end of shaft even with inner side of declutching control lower inner lever, tighten clamp bolt in declutching control lower inner lever. Locate shaft in support bracket so levers are free and with declutching control outer lever against inner bushing in bracket; then tighten clamp bolt in declutching control lower outer lever.

(2) INSTALL TRANSMISSION COVER ASSEMBLY. Position a new gasket on top of transmission case. Place gearshift lever into neutral position and place cover assembly over transmission case with one edge of cover resting on corresponding edge of case and other edge tilted up. Visually check alinement of shift forks in cover with collars on gears in transmission. If gears have been moved, slide them on shaft as necessary to aline collars with forks. Make sure first and reverse rocker arm is positioned to engage rocker lug on left-hand shift rod in cover, then lower cover assembly into place on transmission. Install eight cover to case cap screws, and install power take-off support bracket on left-hand side (if used). Attach speedometer cable clip to left side of cover, using cap screw and lock washer. Move gearshift lever to all positions. If gearshift lever binds, or if gears cannot be easily shifted, remove cover and recheck alinement of shift forks and collars in gears.

(3) INSTALL HAND BRAKE LEVER AND BRACKET. Position hand brake lever and bracket assembly on right-hand side of transmission cover and attach with two cap screws and lock washers. The forward cap crew also attaches the engine ground strap, using a flat washer between the ground strap and lock washer. Connect hand brake rod to hand brake lever, using clevis pin and new cotter pin, and adjust hand brake (par. 193).

(4) INSTALL UPPER LEVERS. Install upper levers on high and low speed control lower lever and declutching control lower outer

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lever, attaching each with two bolts, nuts, and lock washers.

(5) INSTALL FLOOR PAN. Install floor pan over levers in cab and attach with 12 cap screws and lock washers. Install floor seal over hand brake lever and transfer case control levers.

h. High and Low Speed Control Cross Shaft and Brackets Installation.

(1) ASSEMBLE LEVERS, CROSS SHAFT, AND RIGHT-HAND BRACKET. Insert cross shaft through right-hand cross shaft support bracket, with grooved end of shaft toward left side of vehicle. Slide anti-rattle over left end of cross shaft. Tap Woodruff key into keyseats in shaft and install cross shaft levers on shaft. Tighten clamp bolts in levers firmly.

(2) INSTALL RIGHT-HAND SUPPORT BRACKET AND CROSS SHAFT ASSEMBLY. Position right-hand bracket and cross shaft assembly with holes in bracket over two studs in right-hand side of transmission. Install nuts and lock washers on studs and tighten firmly.

(3) INSTALL LEFT-HAND SUPPORT BRACKET. On vehicles without power take-off, place left-hand bracket over studs in left-hand side of transmission and over left-hand end of cross shaft. Install nuts and lock washers on studs and tighten firmly. Install retainer spring on left-hand end of cross shaft. Connect and adjust transmission strut rod (par. 155). On vehicles with power take-off, the procedure is the same except that the rear stud is replaced by a power hoist and/or winch control lever stud. Install power hoist and/or winch control levers (pars. 157 and 158).

i. Control Rods Installation. Check clevis pins for wear and discard any that are not full size. Obtain new pins for installation. Attach high and low speed control rod (rear) to high and low speed shifter shaft at transfer case and to left-hand cross shaft lever, using clevis pins and new cotter pins. Attach high and low peed control rod (front) to right-hand cross shaft lever in same manner, with adjustable yoke toward front of vehicle. Connect declutching control rod to declutching shifter shaft, using clevis pin and new cotter pin, with adjustable yoke toward front of vehicle. Adjust controls and connect rods to their respective control levers (subpars. **b** and **c** above). Lubricate linkage as directed in Section VIII.

161. TRANSFER CASE REMOVAL.

a. Drain Lubricant. Remove drain and filler plugs and allow lubricant to drain from transfer case. After draining, install and tighten plugs.

b. Disconnect Control Rods (fig. 144 or 145). Disconnect high and low speed control rod (rear) and declutching control rod from shifter shafts at transfer case by removing cotter pins and clevis pins.

c. Disconnect Speedometer Cable. Disconnect speedometer cable from transfer case idler shaft front cap by unscrewing knurled nut with pliers and pulling cable out of speedometer driven gear shaft.

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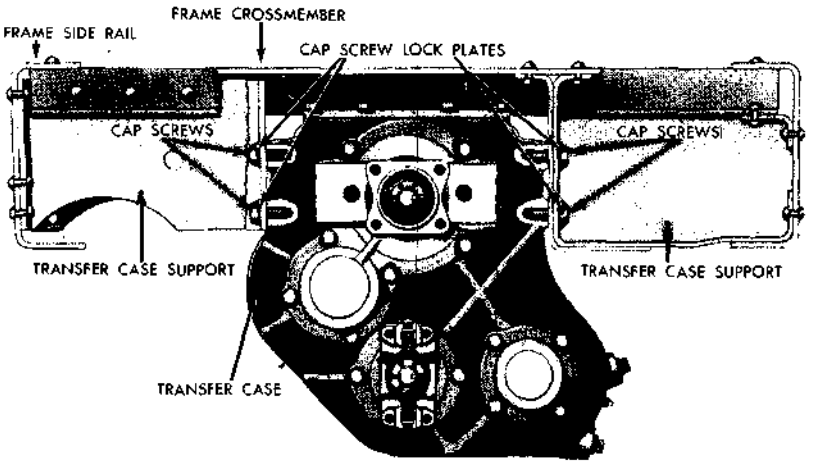

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Figure 146—Transfer Case Mounting (Used with Banjo Type Axles)

d. Disconnect Hand Brake Control Rod and Propeller Shafts. Disconnect hand brake control rod at rear of transfer case by removing cotter pin and clevis pin. Disconnect propeller shafts at transfer case, two in front and two at rear.

e. Remove Transfer Case.

(1) WITH BANJO TYPE AXLES (fig. 146). Place dolly jack under transfer case and raise into position to support case. Bend cap screw lock plates away from cap screw heads and remove eight cap screws, four on each side. Lower transfer case on jack and withdraw from under vehicle.

(2) WITH SPLIT TYPE AXLES (fig. 147). Lift co-driver's seat up and latch in raised position. Remove access plate from cab floor just to the right of the driver's seat. On late vehicles, remove spare parts container from under co-driver's seat. Position jack under transfer case and raise into position to support case. Bend cap screw lock plates away from cap screw heads and remove four cap screws, two from crossmember and two from transfer case support. Lower transfer case on jack and remove from under vehicle. Do not lose spacers from top of transfer case.

f. Remove Hand Brake Assembly. Remove hand brake assembly from rear of transfer case (pars. 194 and 195).

162. TRANSFER CASE INSTALLATION.

a. Install Hand Brake Assembly. Install hand brake assembly on rear of transfer case (pars. 194 and 195).

b. Install Transfer Case.

(1) WITH BANJO TYPE AXLES (fig. 146). Place transfer case assembly on dolly jack and roll into approximate position under

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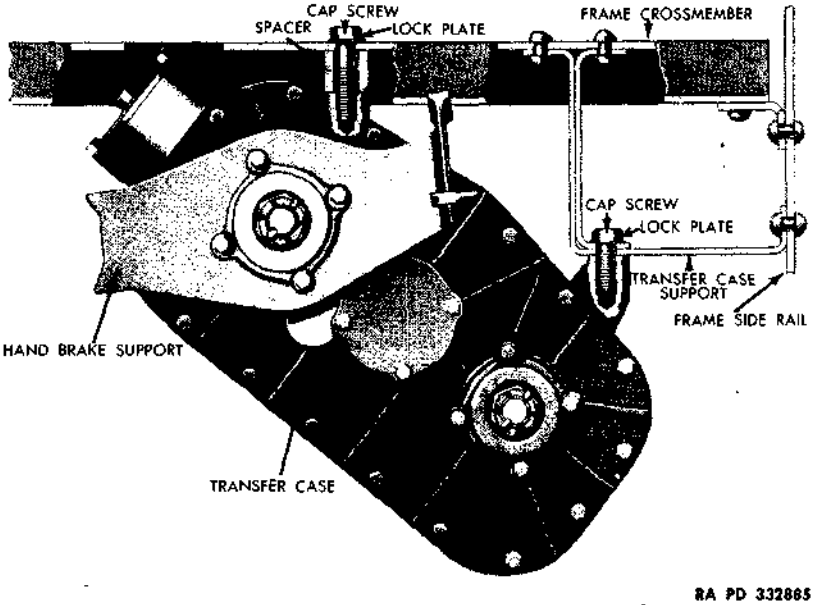

Figure 147—Transfer Case Mounting (Used with Split Type Axles)

vehicle. Raise transfer case into position between supports and aline holes in supports with threaded holes in case. With lock plates under cap screw heads, install eight cap screws, four in each side. Tighten cap screws firmly and bend lock plates against cap screw heads. Lower dolly jack and remove from under vehicle.

(2) WITH SPLIT TYPE AXLES (fig. 147). Place transfer case on dolly jack and roll into approximate position under vehicle. Raise transfer case into position, being sure spacers are in place between top of transfer case and crossmember. With lock plates installed under cap screw heads, install four cap screws, two through crossmember and spacers and two through transfer case support. Tighten cap screws firmly and bend lock plates against cap screw heads. Install access plate on cab floor and install spare parts box (if used). Lower jack and remove from under vehicle.

c. **Connect Hand Brake Control Rod and Propeller Shafts.** Connect hand brake control rod at rear of transfer case, using clevis pin and new cotter pin. Adjust hand brake (par. 193). Connect propeller shafts to transfer case, two at front and two at rear (par. 176).

d. **Connect Speedometer Cable.** Connect speedometer cable to transfer case idler shaft front cap. Be sure that tongue on end of cable meshes with speedometer driven gear shaft and tighten knurled nut with pliers.

e. **Connect Control Rods** (fig. 144 or 145). Connect high and low speed control rod (rear) and declutching control rod to their

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respective shifter shafts at transfer case, using clevis pins and new cotter pins. Adjust transfer case control linkage (par. 160).

f. **Lubricate.** Check condition of magnetic drain plug [(GM-602745) G85-32-02340], and replace if necessary. Fill transfer case to proper level with lubricant as recommended in Section VIII. Make sure drain and filler plugs are tight.

Section XXX

FRONT AXLE

163. DESCRIPTION.

a. **Description.** This section covers two types of axles, the split type and the banjo type (fig. 7, Section II). The split or two-piece type is so called since the housing is made in two pieces, bolted together at the differential. The banjo type housing is of one-piece construction. Each is a single-reduction, bevel-gear driving unit with full-floating axle shafts having constant velocity universal joints at the steering knuckles. Both types are mounted on semi-elliptic springs.

b. **Operation.** Power is transmitted from the transfer case to the front axle by a tubular propeller shaft. The engagement and disengagement of the front axle is controlled at the transfer case by a shift lever in the cab. Detailed instructions covering front axle engagement and disengagement are given in paragraph 16.

c. **Data.**

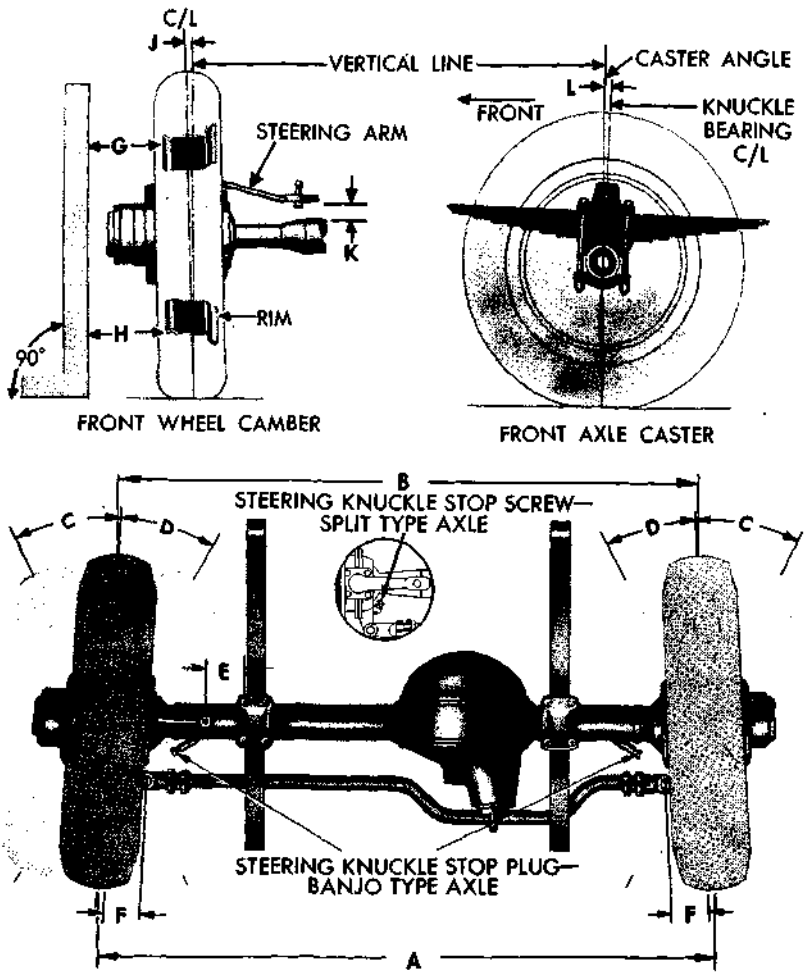
Type	*GM Number*
Banjo Type (with conventional brake drums)	3663017
Banjo Type (with demountable brake drums)	3678601
Split Type (with Bendix-Weiss universal joints)	2162378
Split Type (with Rzeppa universal joints)	2170974

164. FRONT WHEEL ALINEMENT.

a. Front wheel alinement has a major effect on steering from a standpoint of control, ease of steering, and safety. Front wheel misalinement is a major cause of premature and uneven tire wear. The factors involved in front wheel alinement are caster, camber, turning angle, and toe-in. These factors apply to both the split type and banjo type axles.

b. **Caster.** Front axle caster is the inclination of the center line through the upper and lower steering knuckle trunnions toward the rear of the vehicle (L, fig. 148). Caster is established by design and will be changed only by the shifting of the front axle on the

TRUCK, 2½-TON, 6 x 6



A MINUS B TOE-IN
C TURNING ANGLE (INSIDE)
D TURNING ANGLE (OUTSIDE)
E CENTER LINE OF STEERING ARM BALL TO OUTSIDE OF SPRING
F BRAKE FLANGE PLATE TO CENTER LINE OF TIE-ROD YOKE BOLT
H MINUS G WHEEL CAMBER (INCHES)
J WHEEL CAMBER (DEGREES)
K BOTTOM OF STEERING ARM TO TOP OF AXLE HOUSING
L CASTER ANGLE (DEGREES)

RA PD 332781

Figure 148—Front Wheel and Axle Alinement Chart

springs or by the distortion of the chassis frame or springs. There is no adjustment for caster.

c. **Camber.** Front wheel camber is the outward inclination of the wheels as viewed from the front of the vehicle, that is, the wheels are farther apart at the top than at the bottom (J, fig. 148). There is

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no adjustment for camber; however, loose wheel bearings, loose knuckle trunnion bearings, a bent steering knuckle, or bent axle housing will affect camber.

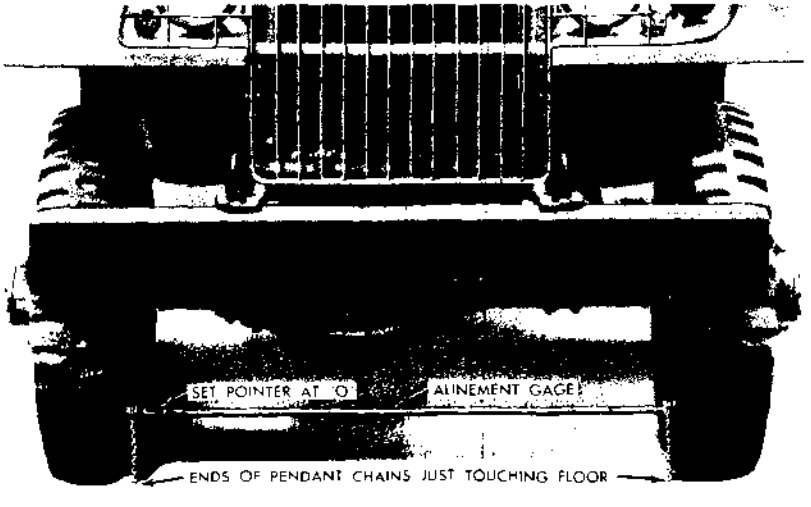
d. Turning Angle. Front wheel turning angle is the maximum angle through which the wheels may be turned from the straight-ahead position. This angle is greater for the inside wheel (C, fig. 148), than for the outside wheel (D, fig. 148).

e. Toe-in. Front wheel toe-in is the amount by which the wheels are closer together at the front than at the rear, with the wheels in a straight-ahead position. (A minus B, fig. 148.) Camber causes both wheels to have a tendency to turn outward from the vehicle. Toe-in counteracts this tendency and causes the wheels to roll straight ahead with no scuffing action.

165. TOE-IN ADJUSTMENT.

a. Toe-in Check (fig. 148). Inflate tires to correct pressure (par. 198), and place vehicle on a smooth, level surface with the wheels in straight-ahead position. Place gage (41-G-510) between the wheels ahead of the axle, with the ends of the gage bearing against the tire side walls and with both pendant chains just touching the ground. Set gage so pointer registers zero. Move the vehicle forward until gage is brought into position in back of the axle, with both pendant chains just touching the ground. The pointer will indicate the amount of toe-in or toe-out. Correct toe-in on both the banjo and split type axles is $\frac{1}{16}$—$\frac{3}{16}$ inch.

b. Toe-in Adjustment. Loose wheel bearings, worn bushings in steering knuckle supports, damaged wheels, a bent steering knuckle,



RA PD 332980

Figure 149—Checking Toe-In (Gage 41-G-510)

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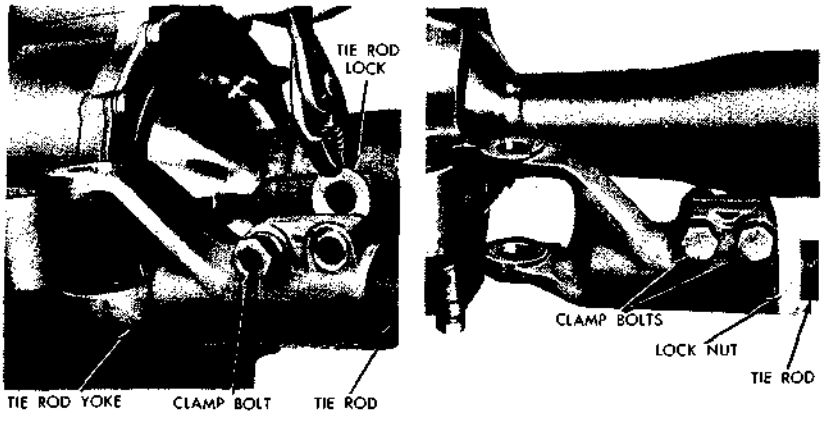

Figure 150—Tie Rod Yokes

a bent axle housing, or a bent or improperly adjusted tie rod will affect toe-in. Adjust the wheel bearings (par. 199) and replace the wheels, if damaged (par. 197), before adjusting the tie rod to correct toe-in.

(1) REMOVE TIE ROD (fig. 150). Remove tie rod (par. 166). On banjo type axles, remove the inner tie rod yoke clamp and lock from left-hand tie rod yoke and loosen all clamp bolts. On split type axles, loosen the yoke clamp bolts and loosen the lock nut at the left end yoke.

(2) ADJUST TIE ROD (fig. 151). Screw yokes onto or off of tie rod as required to correct toe-in. Toe-in will be increased about ⅛ inch by backing right-hand yoke (coarse threads) one turn further onto rod. Reversing this procedure will decrease toe-in by the same amount.

(3) CHECK ADJUSTMENT. After adjusting tie rod yokes, install tie rod yokes on steering knuckle supports (or inner flanges), and install each tie rod yoke bolt (fig. 152). It is not necessary to install nuts on yoke bolts until final adjustment has been made. Measure toe-in and readjust tie rod if necessary until toe-in measurement is correct.

(4) INSTALL TIE ROD. When adjustment is correct, reassemble tie rod yokes to steering knuckle supports (or inner flanges), install tie rod yoke bolts (fig. 152), and install nuts on bolts. Tighten nuts securely and install new cotter pins. On split type axles, tighten tie rod yoke clamp bolts and tighten lock nut at left-hand yoke (fig. 150). On banjo type axles, insert lock in left-hand tie rod yoke, making certain it is seated in keyway in tie rod, and aline hole in lock with clamp bolt hole (fig. 150). Insert clamp bolts, install nuts and lock washers, and tighten securely.

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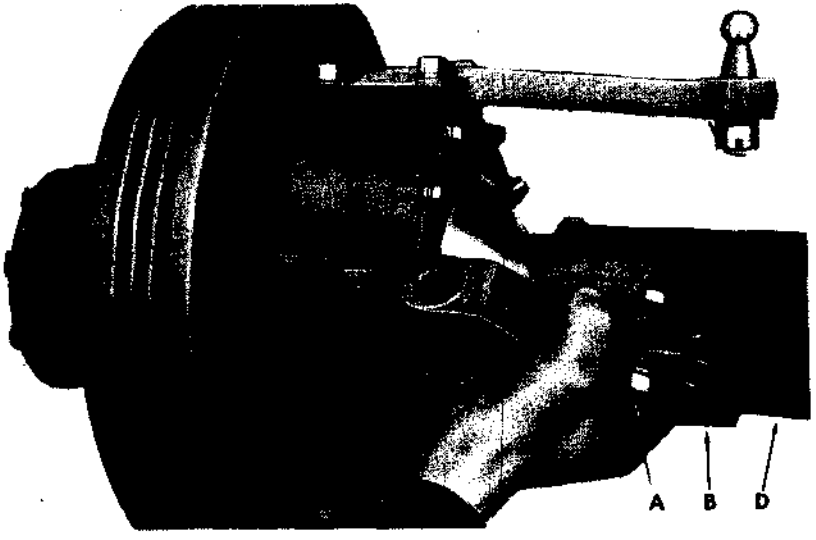
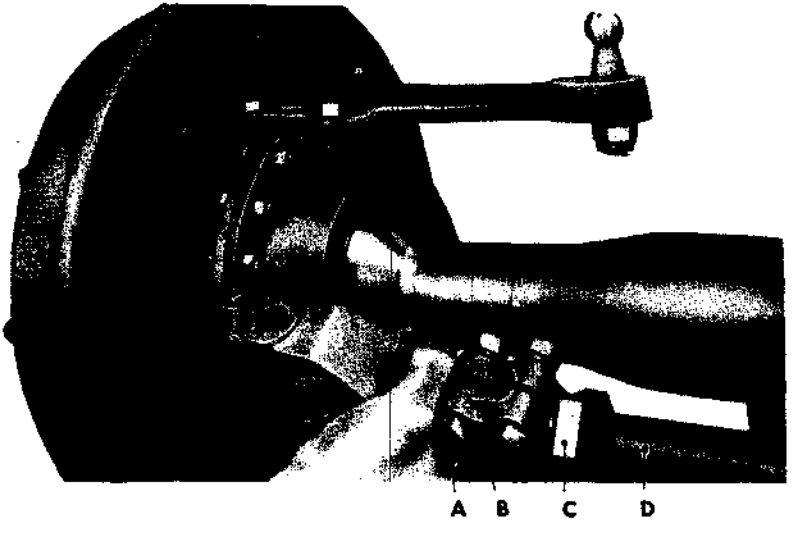
FRONT AXLE



BANJO TYPE AXLE



SPLIT TYPE AXLE

A TIE ROD YOKE CLAMP BOLT
B TIE ROD YOKE
C TIE ROD YOKE LOCK NUT
D TIE ROD

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Figure 151—Adjusting Toe-In

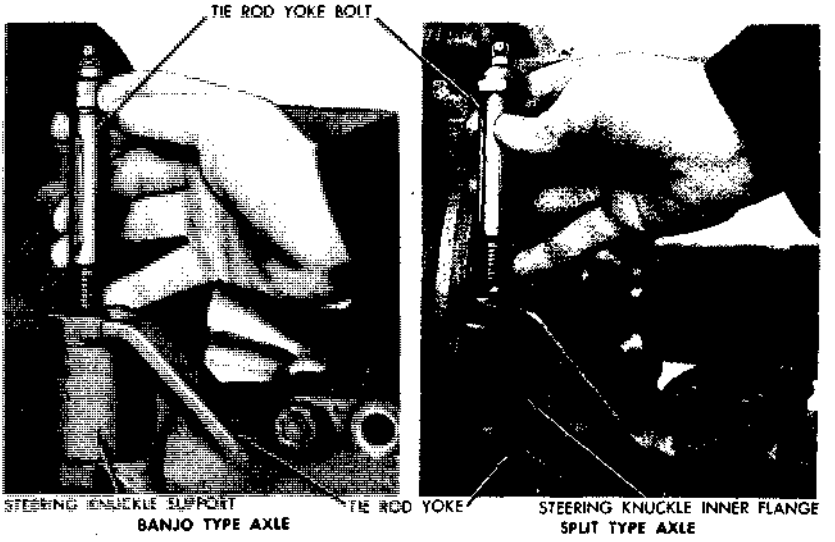

Figure 152—Installing Tie Rod Yoke Bolts RA PD 332846

166. TIE ROD.

a. The tie rod is a solid rod, threaded at each end with a double offset to clear the differential and pinion housing. The tie rod is connected to the steering knuckle supports (or inner flanges) by means of yokes, screwed onto the ends of the rod, and attached to the steering knuckle supports (or inner flanges) by tie rod yoke bolts, nuts, and cotter pins. On the banjo type axle (fig. 150), the tie rod is held in the correct relative position to the pinion housing by a lock at left end which is fitted into a keyway in the rod and held in place by the tie rod yoke inner clamp bolt. On the split type axle (fig. 150), this is accomplished by a lock nut tightened against the left end yoke. The threaded portion of each yoke is split and is held tightly on the rod by clamp bolts.

b. Removal.

(1) POSITION VEHICLE. Place vehicle on a level surface and apply hand brake. Place a jack under front axle housing and raise enough to take weight of vehicle off front wheels.

(2) REMOVE TIE ROD YOKE BOLTS. Remove cotter pin and nut from tie rod yoke bolt at each end of tie rod. Force bolts up out of tie rod yokes, and slide tie rod yokes off steering knuckle supports (or inner flanges).

c. Installation. Toe-in must be adjusted when installing tie rod. Complete instructions on adjusting toe-in and installing tie rod on both the split and banjo type axles are given in paragraph 165.

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FRONT AXLE

167. AXLE SHAFT AND UNIVERSAL JOINTS.

a. General. The following procedures are to be used only to remove the axle shaft and universal joint assemblies for cleaning and inspection (par. 46), and special lubrication operations (Section VIII). Procedures apply to both the right- and left-hand assemblies unless otherwise stated in text.

b. Axle Shaft and Universal Joint Removal (Banjo Type Axles).

(1) REMOVE WHEEL. Jack up front end of vehicle, remove wheel stud nuts, and remove wheel and tire assembly.

(2) REMOVE DRIVE FLANGE. Remove eight cap screws and lock washers (or lock plate) attaching drive flange to hub. Install two drive flange cap screws in the two tapped holes in drive flange and pull drive flange off splined outer end of axle shaft by alternately turning in the two cap screws. Remove drive flange to hub gasket [(GM-3659733) G85-31-05780].

(3) REMOVE HUB AND DRUM ASSEMBLY. Remove wheel bearing adjusting nuts and remove hub and drum assembly.

(4) REMOVE ANCHOR PLATE AND BRAKE SHOE ASSEMBLY (fig. 168). Install wheel cylinder clamp on wheel cylinder to prevent ends coming off and remove brake shoe return spring. Remove six cap screws and lock washers attaching brake shoe anchor plate to anchor plate spacer and remove anchor plate and brake shoe assembly.

(5) REMOVE ANCHOR PLATE SPACER AND OIL DEFLECTOR. Remove 12 cap screws and lock washers attaching brake shoe anchor plate spacer, inner oil deflector, brake flange plate, and steering knuckle to steering knuckle support and remove anchor plate spacer and oil deflector.

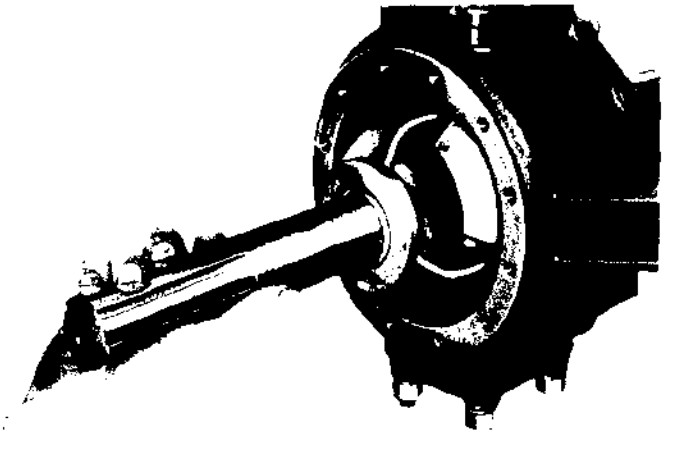

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Figure 153—Removing Axle Shaft and Universal Joint Assembly (Banjo Type Axle)

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(6) REMOVE BRAKE FLANGE PLATE AND STEERING KNUCKLE. Slide brake flange plate off steering knuckle and support it with a piece of wire to eliminate disconnecting brake hose. Remove steering knuckle and gasket from steering knuckle support.

(7) REMOVE AXLE SHAFT AND UNIVERSAL JOINT ASSEMBLY (fig. 153). Pull axle shaft and universal joint assembly out of axle housing.

c. Cleaning, Inspection, and Special Lubrication Operations (Banjo Type Axles).

(1) CLEANING. Thoroughly wash axle shaft and universal joint in dry-cleaning solvent to remove all old lubricant; also wash inside of steering knuckle support and housing outer end.

(2) INSPECTION. Inspect balls and ball races for grooved, scratched, or pitted condition. To determine if excessive play or backlash exists in the universal joint, place the assembly in a vise in a vertical position with the outer shaft up, and with vise jaws gripping the inner shaft just below the universal joint. Use soft metal or wood protectors in jaws of vise. Firmly push down on outer shaft so that it rests on center ball, and at the same time attempt to twist the joint in both directions. If any play or backlash is evident, report to higher authority. Inspect axle shaft thrust washers in steering knuckle and axle housing for excessive wear or damage. Examine axle shaft splines for nicks, cracks, or other damage. Report all worn or damaged conditions to higher authority.

(3) SPECIAL LUBRICATION. Pack new lubricant (Section VIII), well into universal joint until it fills all space between balls and universal joint yokes. Also spread lubricant on surfaces which contact thrust washers and bushing in steering knuckle.

***d.* Axle Shaft and Universal Joint Installation (Banjo Type Axles).**

(1) INSTALL AXLE SHAFT AND UNIVERSAL JOINT. Using care not to damage oil seal in housing outer end, insert axle shaft and universal joint assembly into axle housing, guiding splined end of inner shaft into splined differential side gear.

(2) INSTALL STEERING KNUCKLE. Place steering knuckle over outer end of axle shaft and position against steering knuckle support, using a new gasket between knuckle and support. Milled slot on threaded end of steering knuckle must be at the top.

(3) INSTALL BRAKE FLANGE PLATE, INNER OIL DEFLECTOR, AND BRAKE SHOE ANCHOR PLATE SPACER. Place brake flange plate, inner oil deflector, and brake shoe anchor plate spacer on steering knuckle support, and install 12 cap screws and lock washers. Anchor plate spacer must be positioned with center line through any two opposite bosses horizontal. Tighten cap screws firmly.

(4) INSTALL ANCHOR PLATE AND BRAKE SHOE ASSEMBLY. Using six cap screws and lock washers, attach anchor plate and brake shoe assembly to anchor plate spacer and tighten cap screws firmly. Install brake shoe return spring and remove wheel cylinder clamp.

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(5) INSTALL HUB AND DRUM ASSEMBLY. Install hub and drum assembly and adjust wheel bearings (par. 199).

(6) INSTALL DRIVE FLANGE. Using a new drive flange gasket coated with grease, install drive flange over splined outer end of axle shaft and position against hub. Install drive flange cap screws and lock washers, and tighten to 85 - 95 foot-pounds.

(7) INSTALL WHEEL. Install wheel and tire assembly on hub, install wheel stud nuts, and tighten firmly. Lower jacks and remove from under vehicle.

(8) LUBRICATE. Lubricate steering knuckle and universal joint (Section VIII).

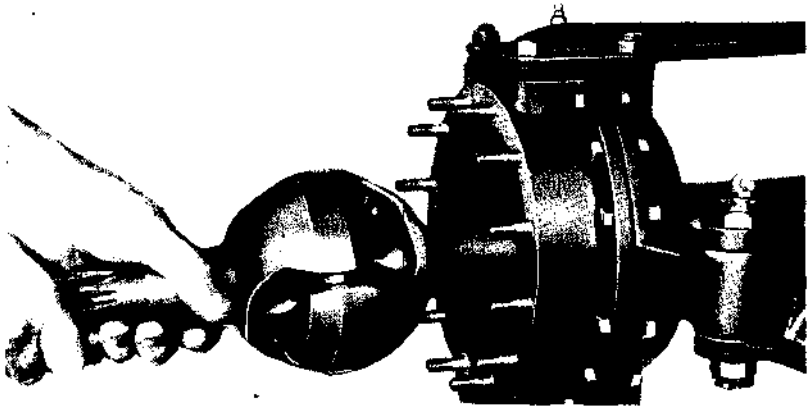
e. Axle Shaft and Universal Joint Removal (Split Type Axles). NOTE: *Two types of axle shaft and universal joints are used in split type axles—Bendix Weiss and Rzeppa. The following procedures cover both types with exceptions noted in text.*

(1) REMOVE WHEEL. Jack up front end of vehicle, remove wheel stud nuts, and remove wheel and tire assembly.

(2) REMOVE DRIVE FLANGE. Remove eight nuts and lock washers from studs attaching drive flange to hub. Remove universal joint stop bolt and stop from center of drive flange. Install two ⅜-inch cap screws in two tapped holes in drive flange. Pull drive flange off axle shaft and out of hub by alternately turning in the two cap screws. Remove drive flange to hub gasket [(GM-2144671) G57-01-94016].

(3) REMOVE HUB AND DRUM ASSEMBLY. Remove wheel bearing adjusting nuts and remove hub and drum assembly.

(4) REMOVE OIL SHIELD AND BRAKE DUST SHIELD. Remove 12 nuts and lock washers from studs attaching brake dust shield, oil shield, and steering knuckle to outer steering knuckle flange. Remove oil shield and brake dust shield; support brake dust shield with a piece of wire to eliminate disconnecting brake hose.



RA PD 64662

Figure 154—Removing Axle Shaft and Universal Joint Assembly (Split Type Axle)

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(5) REMOVE STEERING KNUCKLE. Remove steering knuckle from outer steering knuckle flange. Knuckle can be loosened from flange by tapping on side of knuckle with a brass hammer and driving wedge blocks between the knuckle and flange.

(6) REMOVE AXLE SHAFT AND UNIVERSAL JOINT ASSEMBLY (fig. 154). Withdraw axle shaft and universal joint assembly from axle housing.

f. Cleaning, Inspection, and Special Lubrication Operations (Split Type Axles).

(1) BENDIX-WEISS. The Bendix-Weiss axle shaft and universal joint assemblies used in split type axles are essentially the same as those used in banjo type axles, and procedures given under subparagraph c above apply equally to these assemblies. CAUTION: *Do not disturb spacer pins in inner ends of shafts.*

(2) RZEPPA.

(a) Cleaning. Thoroughly wash axle shaft and universal joint assembly in dry-cleaning solvent to remove all old lubricant; also wash inside of steering knuckle flanges and housing outer end.

(b) Inspection. Check universal joint for excessive wear or rough operation by mounting the assembly in a vise with universal joint bell up and vise jaws gripping the shaft just below the universal joint. Use soft metal or wood protectors in vise jaws. Swing universal joint bell through its normal operating range and note any roughness or excessive looseness. If such a condition is evident, report to higher authority. Also check splines on axle shaft and universal joint bell for nicks, cracks, or other damage.

(c) Special Lubrication. Pack new lubricant (Section VIII) well into universal joint until it fills all space between balls, cage, inner race, and universal joint bell. Also spread grease on surface of universal joint bell which contacts bushing in steering knuckle.

g. Axle Shaft and Universal Joint Installation (Split Type Axles).

(1) INSTALL AXLE SHAFT AND UNIVERSAL JOINT. Using care not to damage oil seal in axle housing near differential, insert axle shaft and universal joint assembly into axle housing, guiding splined end of inner shaft into splined differential side gear.

(2) INSTALL STEERING KNUCKLE, BRAKE DUST SHIELD, AND OIL SHIELD. Slide steering knuckle over outer end of axle shaft and position on studs in outer steering knuckle flange with milled slot in threaded end at top. Install brake dust shield and oil shield on studs and attach with 12 nuts and lock washers.

(3) INSTALL HUB AND DRUM ASSEMBLY. Install hub and drum assembly and adjust wheel bearings (par. 199).

(4) INSTALL DRIVE FLANGE. Install drive flange over splined outer end of axle shaft, using a new gasket coated with grease between flange and hub. Aline holes in flange with studs in hub and push flange in against hub. Place universal joint stop in center of drive flange, install stop bolt through stop into end of axle shaft,

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and tighten firmly. Install eight nuts and lock washers on drive flange to hub studs and tighten nuts to 58-62 foot-pounds.

(5) INSTALL WHEEL. Install wheel and tire assembly on hub, install wheel stud nuts, and tighten firmly. Lower jacks and remove from under vehicle.

(6) LUBRICATE. Lubricate steering knuckle and universal joint (Section VIII).

168. FRONT AXLE REMOVAL.

a. Both the banjo and split type axles may be removed by the same procedure with exceptions noted in text.

b. **Position Vehicle.** Place vehicle on a level surface and apply hand brake to prevent vehicle from rolling. Place a dolly jack under differential housing and raise front end of vehicle high enough to permit withdrawing axle assembly. Place blocks under frame side rails at rear of front spring hanger brackets. Lower dolly jack until entire front end weight rests on blocks. Leave dolly jack raised high enough to support axle assembly.

c. **Remove Wheels.** Remove wheel stud nuts and remove wheel and tire assembly from each side.

d. **Disconnect Propeller Shaft.** Disconnect propeller shaft at differential. Tie propeller shaft up to prevent universal joint from becoming damaged or filled with dirt.

e. **Disconnect Drag Link.** Disconnect drag link at axle steering arm (par. 207).

f. **Disconnect Flexible Brake Hoses.** Turn off the front brake shut-off cock inside of right-hand frame side rail (fig. 185). Loosen connections at frame side rails, then remove hoses from wheel cylinders.

g. **Disassemble Spring to Axle Mounting.** The spring to axle mounting is slightly different on the two types of axles, therefore, this part of removal procedure is explained separately for each axle.

(1) BANJO TYPE AXLE. Remove nuts from U-bolts on both sides, remove shock absorber link bracket and spring bumper blocks, and remove U-bolts.

(2) SPLIT TYPE AXLE. Remove four nuts from spring bolts on left side and remove shock absorber link bracket and spring bumper block, and remove spring clip bolts. On right-hand side, remove four nuts from studs and remove shock absorber link bracket and spring bumper block. (The four studs will be removed from housing after axle assembly is withdrawn from under vehicle.)

h. **Remove Axle Assembly.** Lower dolly jack until axle assembly clears under side of chassis and withdraw from under vehicle. (On split type axles, remove the four studs from axle housing at right-hand spring seat.)

TRUCK, 2½-TON, 6 x 6

169. FRONT AXLE INSTALLATION.

a. The following procedures are applicable to both the banjo and split type axles, with exceptions noted in text.

b. **Position Axle Assembly.** (If axle to be installed is split type, install four studs in tapped holes in housing at right-hand spring seat.) Place axle assembly on dolly jack and move into position under vehicle. Raise axle assembly into position against springs, being certain spring center bolt heads enter alinement holes in axle spring seats.

c. **Assemble Spring to Axle Mounting.** This operation differs on the two types of axles, and will be described separately for each type.

(1) BANJO TYPE AXLE. Install U-bolts. U-bolts of three different lengths are used. The two shortest ones are used on the left-hand mounting and the remaining two are used on the right-hand mounting. The longer of the two on the right side is used on the inside, adjacent to the differential. Install spring bumper blocks and shock absorber link brackets on U-bolts, install nuts, and tighten to 170-185 foot-pounds.

(2) SPLIT TYPE AXLE. Install spring bolts, bolt guard, spring bumper block, and shock absorber link bracket on left-hand mounting and install nuts on spring clip bolts. The bolt guard at the bottom and the shock absorber link bracket at the top necessitates using the two longer bolts at the front. On right-hand mounting, install bumper block and shock absorber link bracket on studs and install nuts. Tighten nuts on both right- and left-hand mounting to 170-185 foot-pounds.

d. **Connect Propeller Shaft.** Connect propeller shaft at differential (par. 176).

e. **Connect Flexible Brake Hoses.** Install flexible hoses in wheel cylinders and tighten connections at frame side rails. Turn front brake shut-off cock on.

f. **Connect Drag Link.** Refer to paragraph 207 for instructions on installing and adjusting drag link on steering arm ball.

g. **Install Wheels.** Install wheel and tire assemblies on hubs, install wheel stud nuts, and tighten firmly.

h. **Remove Blocks and Dolly Jack.** Raise front of vehicle with dolly jack and remove blocks from under frame side rails. Lower dolly jack and withdraw from under vehicle. Check all nuts on spring mounting bolts for tightness with full weight of vehicle resting on springs.

i. **Bleed Brakes.** Bleed front wheel brakes (par. 180).

j. **Lubricate.** Check lubrication of complete axle assembly and propeller shaft universal joint as instructed in Section VIII. Check condition of filler plug gasket [(GM-344830) G85-31-05800] and replace if necessary.

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Section XXXI

REAR AXLES

170. DESCRIPTION.

a. Description. The rear driving unit is a centrally supported unit consisting of two single-reduction, spiral-bevelled driving axles. Each axle is attached to the frame by three independent torque rods. Both driving and braking load is transferred directly to the chassis frame by these rods. Two types of axles are used, the banjo type and the split type (fig. 7). The split or two-piece type is so-called since the housing is made in two pieces, bolted together at the differential. The banjo type housing is of one-piece construction.

b. Operation. Power is transmitted from the transfer case to the forward rear (intermediate) axle by a single propeller shaft. Power to the rearward rear axle is transferred from the transfer case to a pillow block attached to the top of the forward rear (intermediate) axle, and thence to the rearward axle by another propeller shaft.

c. Data.

Type	GM Number	
	Front (Intermediate) Unit	Rear Unit
Banjo Type (with conventional brake drums)	3665609	3665610
Banjo Type (with demountable brake drums)	3678649	3678650
Split Type	2181204	2181205

171. AXLE SHAFT (BANJO TYPE AXLES).

a. Description. Axle shafts are full floating type with flanges forged at the outer ends. The axle shafts carry the driving force from the differential to the wheels. Flanges are attached to the hubs by

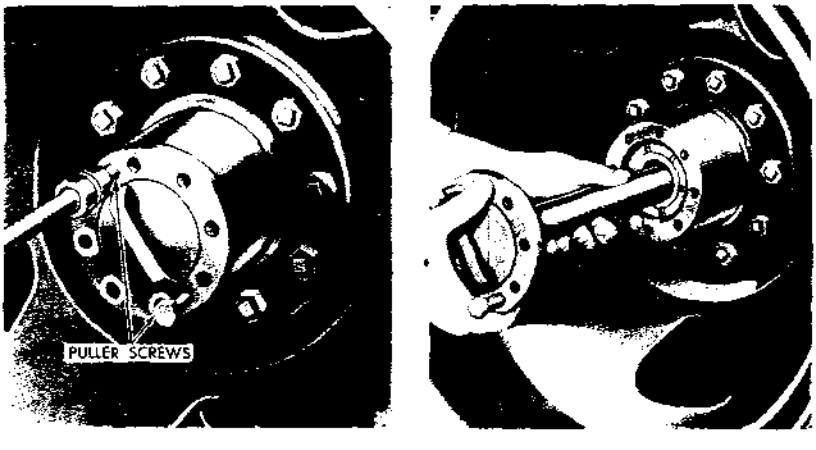

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Figure 155—Removing Rear Axle Shaft (Banjo Type Axle)

cap screws and the inner ends of the shafts are splined to the differential side gears.

b. **Removal.** Remove eight cap screws and lock washers attaching drive flange to hub. Using two of these cap screws as puller screws, thread them into the two tapped holes in flange (fig. 155). Pull shaft out by alternately turning in the two cap screws. Withdraw axle shafts from hub (fig. 155) and remove gasket [(GM 3660100) G85-31-06160].

c. **Installation.** Make sure axle shaft is clean. Slide gasket over end of shaft and hold in place on flange. Insert splined end of shaft through hub and guide splines into differential side gear. Aline holes in flange and hub and install eight cap screws with lock washers. Tighten cap screws alternately to 70-80 foot-pounds.

172. AXLE SHAFT (SPLIT TYPE AXLES).

a. **Description.** Axle shafts are full-floating type with flanges forged at the outer ends. The axle shafts carry the driving force from the differential to the wheels. Flanges are attached to the hubs by studs, nuts, and tapered dowels. Inner ends of the shafts are splined to the differential side gears.

b. **Removal** (fig. 156). Remove eight nuts and lock washers from flange to hub studs. Loosen puller screws and back lock nuts out to end of threads. Alternately turn puller screws in, pulling axle shaft and tapered dowels toward end of studs. Back puller screws out and drive axle shaft in until flange is against hub. Pull tapered dowels off studs. NOTE: *If tapered dowels are not loose, remove puller screws and remove lock nuts from screws. Install puller screws and again turn them in alternately to pull tapered dowels farther out toward end of studs. Drive axle shaft in and then remove dowels from studs.* Withdraw axle shaft from hub and remove two gaskets [(GM-2087553) G57-01-94022] and wheel bearing oil seal from studs.

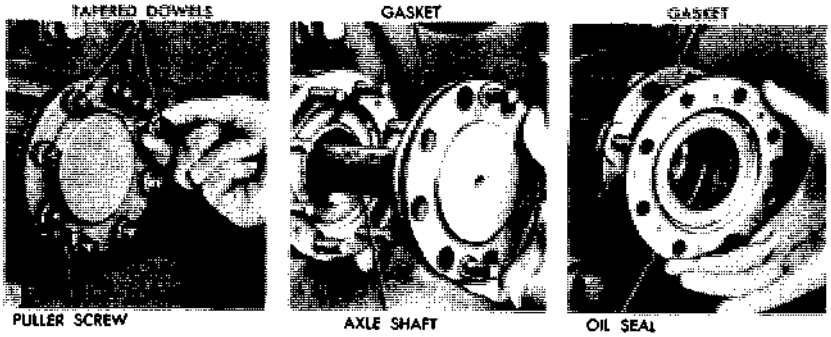

Figure 156—Rear Axle Shaft Removal (Split Type Axle)

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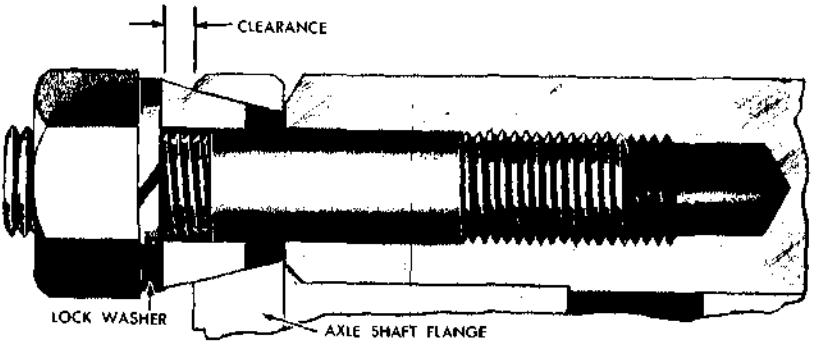

RA PD 332909

Figure 157—Axle Shaft Flange Dowel Clearance (Split Type Axle)

c. **Installation.** Inspect wheel bearing oil seal. Use a new seal if worn or damaged. Install gasket, oil seal, and another gasket on hub studs. Make sure axle shaft is clean and insert splined end of shaft through hub, guiding splines into differential side gear. NOTE: *Hub construction provides only two points against which the axle shaft puller screws may bear; axle shaft must be positioned with puller screws alined with these points.* Install tapered dowels on studs, and install nuts with lock washers. Tighten nuts alternately to 58-62 foot-pounds. Tapered dowels are split so they will compress around studs without bottoming against hub when nuts are tightened. There should be a slight clearance between lock washers and flange when nuts are tight (fig. 157). If there is no clearance, the studs, dowels, or holes in flange are worn excessively and new parts must be installed.

173. REAR AXLE REMOVAL.

a. **Preliminary Instructions.** The following procedure is applicable to either the banjo or split type axles, and to either the rearward or forward (intermediate) unit. Figure 158 shows items which must be disconnected prior to removing the rearward unit.

b. **Jack Up Rear End.** Place vehicle on a level surface and block front wheels. Place a jack under each trunnion cross shaft torque rod bracket (fig. 158), and jack up rear end. Place a dolly jack under unit to be removed and raise high enough to support unit.

c. **Remove Wheels.** Remove outer wheel nuts and remove outer wheel and tire assembly, then remove inner wheel nuts and remove inner wheel and tire assembly from each end of axle.

d. **Disconnect Brake Hose.** Loosen brake line connection at frame side rail, then unscrew flexible hose from wheel cylinder at brake flange plate (dust shield).

e. **Disconnect Propeller Shaft.** Disconnect propeller shaft at differential.

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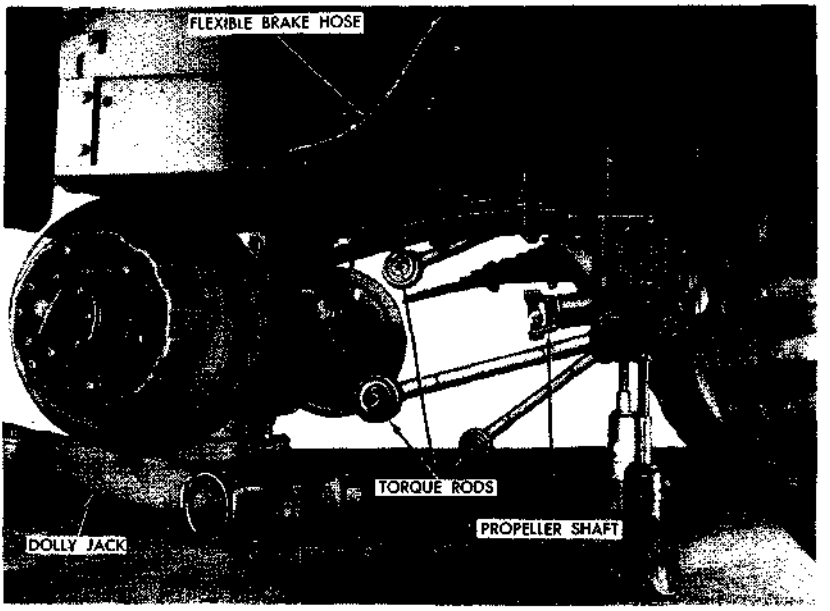

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Figure 158—Rear Axle Removal (Banjo Type Shown)

f. Remove Pillow Block (Forward Unit Only). Remove four cap screws and lock washers attaching pillow block to bracket on axle housing and tie pillow block up to prevent it from dropping when axle is removed.

g. Disconnect Torque Rods. Disconnect torque rods as directed in paragraph 212.

h. Withdraw Axle Assembly. With axle resting on dolly jack, move forward or rearward as necessary until spring ends are free of guide brackets on axle housing and withdraw the axle assembly from under vehicle (fig. 158).

174. REAR AXLE INSTALLATION.

a. Preliminary Instructions. The following procedure is applicable to either the banjo or split type axles, and to either the rearward or forward (intermediate) unit. Figure 158 shows items which must be connected after axle is positioned under vehicle.

b. Position Axle Assembly. Place axle assembly on dolly jack and move into approximate position under vehicle (fig. 158). Move axle toward rear or front of vehicle as necessary, guiding spring ends into guide brackets on axle housing. Line up holes in torque rod brackets with torque rod end pins.

c. Connect Torque Rods. Connect torque rods as directed in paragraph 212.

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d. Connect Propeller Shaft. Connect propeller shaft at differential (par. 176).

e. Install Pillow Block (Forward Unit Only). Attach pillow block to bracket on axle housing, using four cap screws and lock washers. Tighten cap screws firmly.

f. Connect Brake Hose. Install flexible brake hose into wheel cylinder at brake flange plate (dust shield) on each end of axle and tighten snugly. Tighten brake line connections at frame side rails and bleed brakes (par. 180).

g. Install Wheels. Place inner wheel and tire assemblies on hubs and install inner wheel nuts. Successively tighten opposite nuts to prevent cocking wheel on studs. Place outer wheel and tire assemblies on hubs with valve stems on opposite side of hub to the valve stems on the inner wheels. Install outer wheel nuts and tighten alternately.

h. Lubricate Axle and Remove Jacks. Lubricate axle assembly and propeller shaft universal joints as directed in Section VIII. Lower jacks and remove from under vehicle.

Section XXXII

PROPELLER SHAFTS, UNIVERSAL JOINTS, AND PILLOW BLOCK

175. DESCRIPTION.

a. Propeller Shafts and Universal Joints (fig. 159). Five propeller shafts and a pillow block transfer power from the transmission to the transfer case and three driving axles. Each shaft has a universal joint at each end to permit angular movement of shaft during rotation. Universal joint yoke is welded to shaft at one end and is splined to the shaft at the other end, forming a slip joint which permits telescopic action of shaft during operation.

b. Pillow Block (fig. 161). Pillow block, mounted on top of forward rear (intermediate) axle housing, connects the two propeller shafts which transfer power from the transfer case to the rearward rear axle. The pillow block shaft is mounted on tapered roller bearings in the pillow block. Oil seals are used at each end of the pillow block to retain lubricant.

176. PROPELLER SHAFTS AND UNIVERSAL JOINTS.

a. General. Propeller shafts are connected to their respective units either by two U-bolts or by four straight bolts, depending on the type of flange used. The following shafts are attached at both ends

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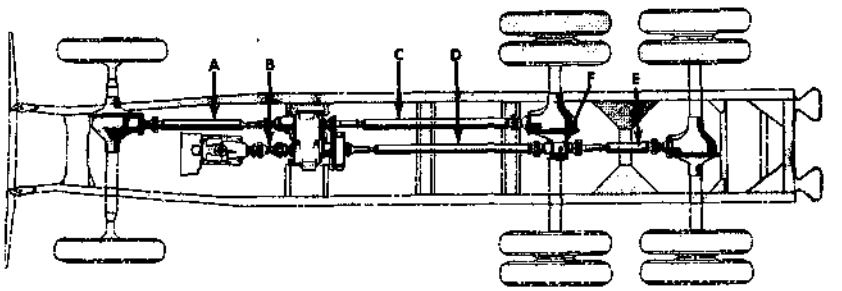
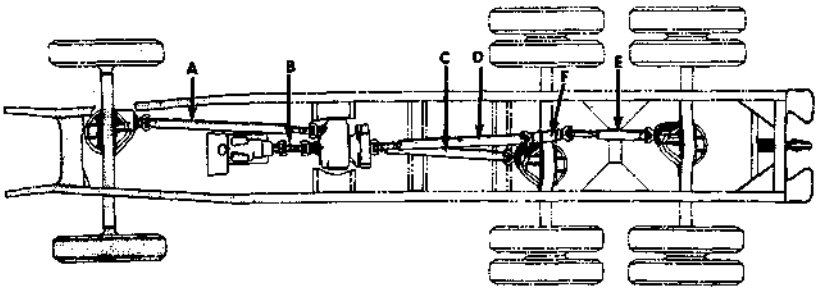
TRUCK, 2½-TON, 6 x 6



WITH SPLIT TYPE AXLE



WITH BANJO TYPE AXLE

A PROPELLER SHAFT TO FRONT AXLE
B TRANSFER CASE TO TRANSMISSION PROPELLER SHAFT
C TRANSFER CASE TO FORWARD REAR AXLE PROPELLER SHAFT
D TRANSFER CASE TO PILLOW BLOCK PROPELLER SHAFT
E PILLOW BLOCK TO REARWARD REAR AXLE PROPELLER SHAFT
F PILLOW BLOCK ASSEMBLY

RA PD 332923

Figure 159—Propeller Shaft Location

by U-bolts; transfer case to front axle; transfer case to forward rear (intermediate) axle; pillow block to rear axle. Transfer case to pillow block shaft is attached to the pillow block by U-bolts and to the transfer case by straight bolts. Transmission to transfer case shaft is attached at both ends by straight bolts. The slip joint and shaft are marked with arrows so that if the universal joint yoke is removed from the shaft, they may be reassembled in their original position with the universal joint yokes in the same plane.

b. Propeller Shaft Removal. Make certain arrows are visible (fig. 160); if not, punch mark both members so they may be reassembled in their original positions. Any shaft may be removed by disconnecting both ends as directed in step (1) or (2) below, whichever one may apply.

(1) U-BOLT TYPE. Remove four nuts and lock washers from U-bolts and remove U-bolts [(GM-2066840) G85-32-00500]. Shorten shaft by telescoping at slip joint and wrap tape around bearings and journal to prevent bearings dropping off.

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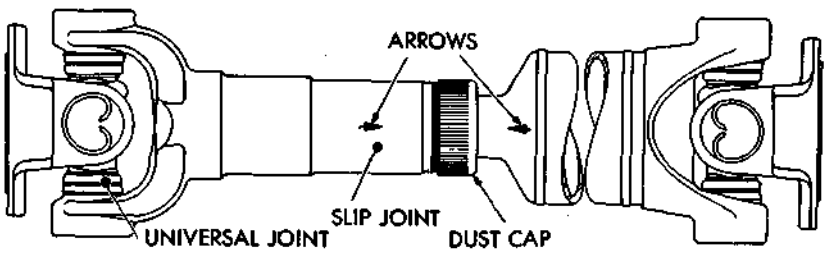

Figure 160—Universal Joint Alinement Marks

(2) STRAIGHT BOLT TYPE. Remove four nuts and lock washers from bolts attaching universal joint flange to transmission or transfer case. Remove bolts from companion flange on front or rear of transfer case [front—(GM-093420) G501-01-24271; rear—(GM-082069) G501-01-24270]. Separate flanges by telescoping shaft at slip joint.

c. **Propeller Shaft Installation.** Make sure that arrow (or marks made at removal) are alined (fig. 160). Position shaft with slip joint at input end and connect both ends as directed in step (1) or (2) below, whichever one may apply.

(1) U-BOLT TYPE. Remove tape or wrapping from bearings and journal. Make sure that bearings and journal are clean and the bearing needles are in place in bearings. Raise shaft into position and seat bearings in place in yoke. Install U-bolts around bearings and through yoke, install nuts and lock washers, and tighten snugly.

(2) STRAIGHT BOLT TYPE. Aline flanges and install four straight bolts. Install nuts and lock washers on bolts and tighten firmly.

177. PILLOW BLOCK.

a. **Check Adjustment.** Disconnect propeller shafts at each end of pillow block (par. 176 b (1)), and check pillow block shaft for end play. Shaft should spin freely in bearings and should not have more than a barely perceptible amount of end play. If end play is excessive, replace pillow block assembly.

b. **Removal** (fig. 161). NOTE: *If replacement unit is not equipped with flanges, the flanges must be removed from the old unit and installed on the replacement unit.*

(1) REMOVE PILLOW BLOCK. Disconnect propeller shafts at each end of pillow block (par. 176 b (1)). Tie propeller shafts up to prevent dirt from getting into bearings. Remove four cap screws and lock washers attaching pillow block to bracket on axle housing and lift pillow block from axle.

(2) REMOVE FLANGES (IF NECESSARY). Remove cotter pin, flange retaining nut, and washer from each end of pillow block shaft. Tap flanges off ends of shaft, using a soft metal hammer.

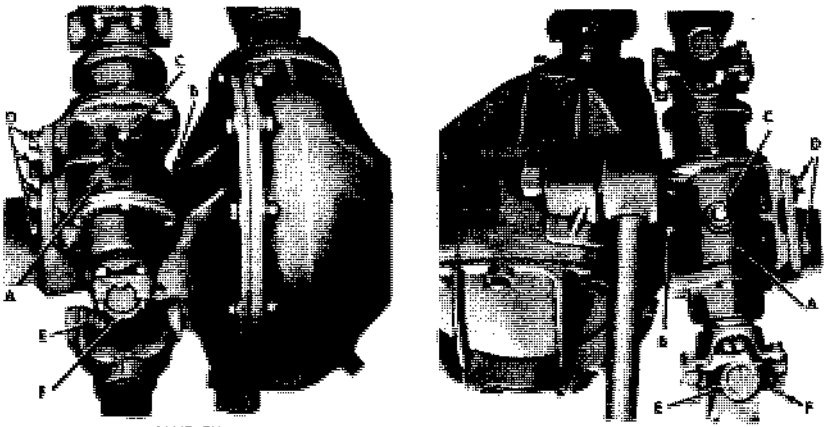

Figure 161—Pillow Block Installation

c. **Installation** (fig. 161).

(1) LUBRICATION FITTING (LATE MODELS). Pillow block assemblies on late model vehicles include a pressure fitting in place of the level plug (fig. 161). Whenever pillow block is removed for service purposes, the lubrication fitting can be installed in place of the level plug. Remove the filler plug and breather assembly, and level plug, then turn pillow block upside down, draining all lubricant. Turn shaft several times by hand and allow enough time for complete drainage. Reinstall filler plug and breather assembly in same location. Install 90 degree lubrication fitting in level plug location with end of fitting pointing toward front of vehicle and down approximately 15 degrees below horizontal position. Lubricate pillow block assembly with chassis grease as indicated in Section VIII.

(2) INSTALL FLANGES (IF NECESSARY). Loosen front and rear end cover cap screw. Seal surface on flange hub must be smooth and polished, and free of scores and nicks. Place key in keyway at each end of shaft. Install propeller shaft flange at each end of shaft, carefully sliding hub of flange through cover oil seal. Flange with dust shield must be installed on front end of shaft. Be certain outer portion of seal is not damaged or doubled back while installing the flange. Check depth of space between end of key and nut face of flange. If less than $^{9}/_{32}$-inch deep, drive key in with punch to obtain this dimension. Apply aviation type permatex to end of new cork seal and force seal into keyway against end of key. Install tongued washer and flange nut on each end of shaft, tighten solidly, and lock in place with new cotter pin. With flange nuts tightened, the compressed cork will effectively seal the keyway. Tighten front and rear cover cap screws.

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(3) INSTALL PILLOW BLOCK (fig. 161). Position pillow block at support bracket on axle housing, with dust slinger on pillow block toward front of vehicle. Install four bracket to pillow block cap screws and lock washers and tighten firmly. Connect propeller shafts at each end of pillow block (par 176 c (1)). Lubricate pillow block and universal joints as instructed in Section VIII.

Section XXXIII

SERVICE BRAKE SYSTEM

178. DESCRIPTION.

a. Description. The vacuum hydraulic operated service or foot brake system consists of an internal expanding type brake assembly comprising two brake shoe assemblies at each front wheel and at each inner wheel of the dual rear wheels. The system is comprised primarily of a manually operated foot pedal, interconnected to a hydraulic master cylinder to build up the initial hydraulic pressure; a Hydrovac power unit with related parts to increase initial hydraulic pressure as required; interconnecting hydraulic lines and fittings; and a hydraulic wheel cylinder to operate the mechanical brake shoe assembly at each wheel (fig. 162).

b. Operation. The operation of service brakes depends upon two elements: hydraulic fluid pressure and vacuum. The arrangement and mechanism of the component parts of system are such that both the hydraulic and vacuum principals must operate in conjunction with each other to finally apply brakes efficiently. The service brakes are operated simultaneously at all wheels by the manual application of the foot brake pedal.

(a) Application. The manually operated pedal, interconnected to the piston rod of the hydraulic master cylinder, forces the brake fluid under pressure from the master cylinder through pipe lines into the mechanism of Hydrovac unit, then into each wheel cylinder. When this initial pressure reaches a predetermined amount, the pressure operates the relay valve mechanism in the Hydrovac unit. The mechanism then cuts off the vacuum and admits atmospheric pressure to one side of the pistons in the power cylinder. Action of the pistons, interconnected to slave cylinder piston, then increases the hydraulic pressure to all wheel cylinders.

(b) Release. Upon release of the foot pressure at the brake pedal, initial line pressure is relieved. This decreased pressure permits the relay valve mechanism in the Hydrovac unit to close off the atmospheric pressure and open the vacuum port into the cylinders. Engine manifold vacuum creates vacuum on both sides of the Hydrovac pistons, thus permitting the spring to return the

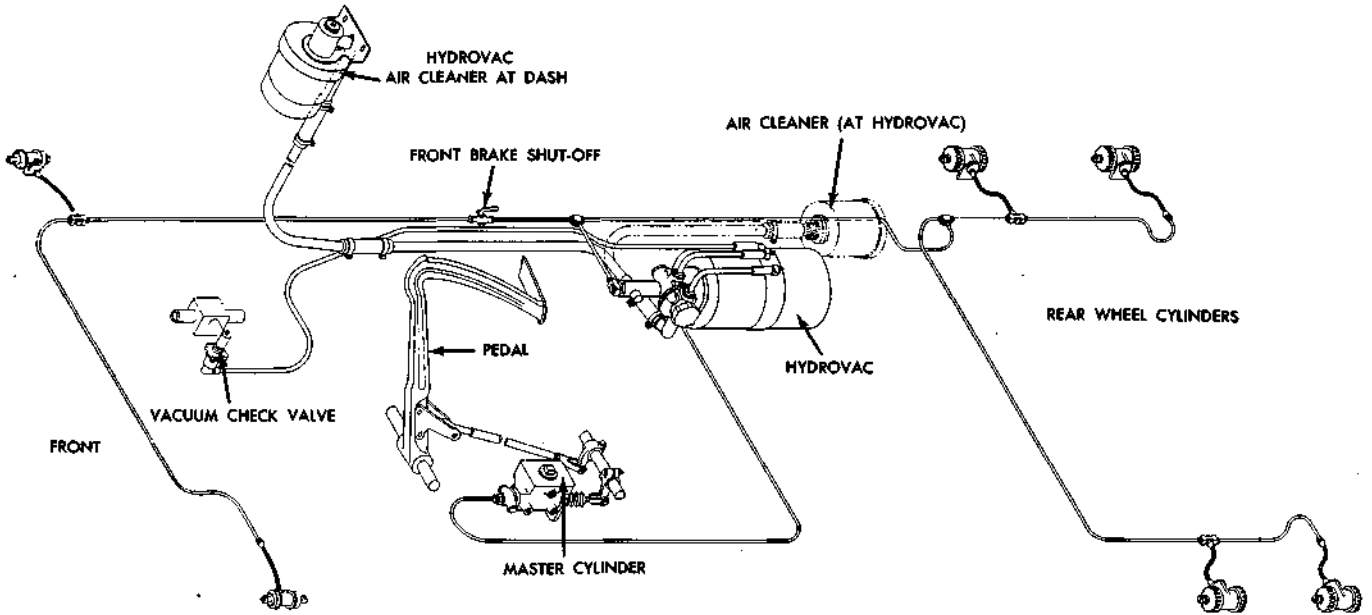

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Figure 162—Service Brake System

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pistons to the released or off position. The brake shoe return springs can then return the brake shoes and the wheel cylinders into the released position, forcing the fluid from the wheel cylinders through the lines and the Hydrovac back into the hydraulic master cylinder reservoir.

179. SYSTEM TESTS.

a. **General.** There are several tests which may be applied to the service brake system, results of which will indicate the condition of the various units in the system. Generally, the performance of the brakes, together with a few simple tests, will indicate the condition of the power unit; however, in order to correctly diagnose specific deficiencies, vacuum and pressure gages should be used as indicated in the following subparagraphs.

b. **System Performance Tests.** The following tests should be made at regular intervals to check the general performance of the brakes:

(1) WITH ENGINE RUNNING.

(a) Start the engine and allow it to idle for about 10 seconds.

(b) Depress brake pedal with about as much foot pressure as required for normal stopping. Note the approximate position of the pedal pad and the foot pressure required to hold it in this position. Measure distance between pedal pad and toe board for further check as described in (2) below.

(c) Remove foot from pedal and turn off ignition switch.

(2) WITH ENGINE STOPPED.

(a) Depress brake pedal five times to approximately the same position as noted in step (1) *(b)* above.

(b) If the *pressure* required to push the pedal to this position during the fifth application is noticeably greater than in step (1) *(b)* above, the vacuum system is operating satisfactorily. If pressure is not greater, further tests should be made.

(c) NOTE: *Generally, an increase in required foot pressure will be noted upon each of the five applications as compared to the application immediately preceding it. This is because the system vacuum is being depleted during each application while the engine is not running.*

(d) After the vacuum in the system has been completely depleted, depress brake pedal and hold foot pressure. If the pedal gradually "falls away" under foot pressure, the hydraulic brake system is leaking and an immediate check and correction must be made.

(e) If the brake pedal travels to within two inches of the floor board, there is not enough brake pedal reserve and a brake shoe adjustment is required.

(3) ROAD TEST. Road test the vehicle by making a brake application at about 20 miles per hour, noting whether the vehicle stops evenly and quickly.

(a) If the brake pedal has a spongy feel when the brakes are applied, there is air in the hydraulic system. Bleed the system.

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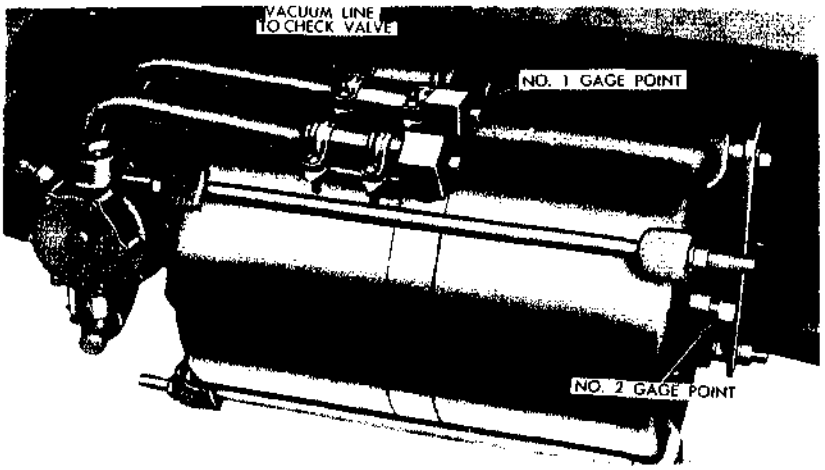

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Figure 163—Hydrovac Vacuum Leak Tests

(b) If the brakes operate satisfactorily when tested at temperature above freezing, but are ineffective and do not release properly at temperatures below freezing, report this condition to higher authority, as water may have entered the vacuum system where it may later cause more serious difficulty.

c. **Vacuum Tests** (fig. 163). Vacuum test must be made with two vacuum gages (41-G-500). Gage, which will be termed as *No. 1*, must be installed in the Hydrovac center plate center elbow. It is necessary to remove the pipe plug from this elbow for the installation. Gage, which will be termed as *No. 2*, must be installed in place of the pipe plug at the back end of the rear cylinder shell.

(1) VACUUM TEST (BRAKES RELEASED).

(a) Start the engine and leave the brake pedal in released position. Note vacuum reading on *both* vacuum gages. They should register engine manifold vacuum (at least 14 in.), and should be exactly alike. If the reading is below manifold vacuum, a leak exists in the Hydrovac unit or in the lines from the intake manifold vacuum check valve.

(b) Stop the engine and remove the gage from the Hydrovac center plate elbow (No. 1) and reinstall the plug. Remove the vacuum line from the center plate elbow next to frame side rail, and connect the gage to the vacuum line. Start the engine and note the reading on the gage. If the gage does not register manifold vacuum (at least 14 in.), the leak is in the manifold vacuum check valve or lines. Check the lines from the Hydrovac unit to the manifold check valve for loose connections, etc. If the correction of loose connections in the lines does not remedy the leak, remove the pipe connection from the vacuum check valve at the valve. Install gage and start engine. Allow the engine to idle about 10 seconds, then turn off the

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ignition switch. If the gage reading decreases more than one inch of vacuum in 15 seconds, replace the check valve.

(c) After repairing or replacing manifold check valve or vacuum lines, reinstall gage *No. 1* in the Hydrovac center plate center elbow. Reconnect the vacuum line to the elbow (next to side rail) and repeat test as described in step *(a)* above.

(d) If gages still register less than manifold vacuum, the leak exists in the Hydrovac unit, which must be replaced (par. 188).

(2) VACUUM TEST (BRAKES APPLIED).

(a) If, with the engine running and brake pedal released, both gages register manifold vacuum, depress the brake pedal and hold in the applied position. Note the reading of both gages. Gage *No. 1* (on Hydrovac center plate elbow) should continue to register manifold vacuum, while gage *No. 2* (at back end of rear cylinder shell) should drop to zero or, if a combination vacuum and pressure gage is used, to atmospheric pressure.

(b) If gage *No. 1* (on Hydrovac center plate elbow) does not continue to register manifold vacuum, replace the Hydrovac unit (par. 188).

d. Hydraulic Pressure Test. These tests may be made to determine whether or not the correct hydraulic pressure is attained. The tests require the use of a hydraulic pressure gage registering at least 1200 pounds, in addition to a vacuum gage (41-G-500). Pressure gage must be installed in bleeder hole of a wheel cylinder. If a pressure gage is not available, vacuum leakage tests as described in subparagraphs c (1) and (2) above will generally indicate which unit, Hydrovac or check valve, is defective.

(1) If proper readings of manifold vacuum and atmospheric pressure are registered on gages No. 1 and 2, with the brake pedal depressed (subpar. c (2) above), the following test should be performed to check for hydraulic fluid leaks or deficient Hydrovac unit.

(2) Stop the engine and depress the brake pedal several times to deplete the vacuum in the Hydrovac, then depress the brake pedal again and note the reading on the hydraulic pressure gage at the wheel cylinder.

(3) Start the engine and depress the brake pedal again, noting pressure gage reading. If the reading is not double the pressure reading with the engine stopped, a leak in the hydraulic system is indicated. Hold the pedal in applied position for a few minutes and note the pressure reading at various intervals. The hydraulic pressure should not drop quickly and should not drop below the reading attained at the time of brake application.

(4) A low reading or a drop of hydraulic pressure indicates a leak either in the Hydrovac slave cylinder, or in the brake lines or wheel cylinders.

(5) Inspect each brake line and wheel cylinder separately and replace all worn or damaged parts. Repeat the tests described in steps (2) and (3) above. If the hydraulic pressure is still too low or drops too rapidly, a leak at the Hydrovac slave cylinder is indicated. Replace Hydrovac unit (par. 188).

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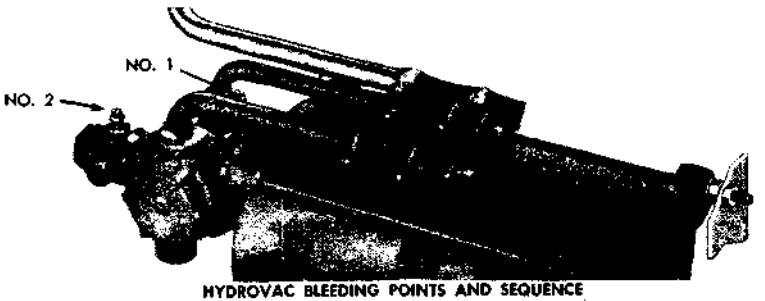
TRUCK, 2½-TON, 6 x 6

180. BLEEDING SYSTEM.

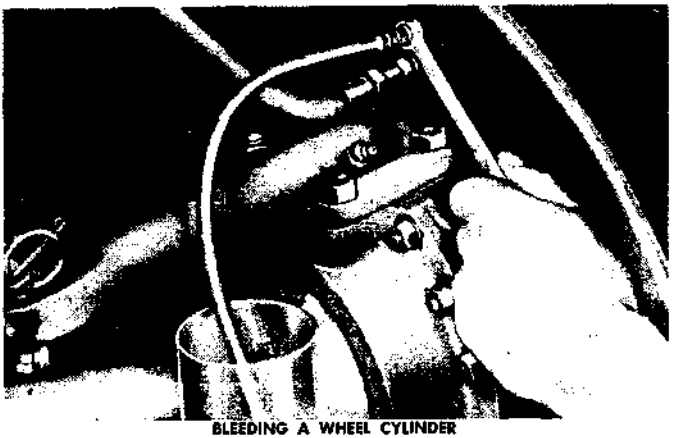
a. The hydraulic lines must be bled to expel the air which may have entered the lines in the event any of the hydraulic lines connections have been broken or disconnected. The need of bleeding the system is generally indicated by a springy, spongy pedal action.

b. Equipment. System can be bled manually or with a pressure tank. When the manual system is used, two persons are needed to accomplish the operations; one to maintain a constant supply of fluid in the master cylinder reservoir and to pump the brake pedal, the other to accomplish bleeding operations at the Hydrovac unit and the wheel cylinders. If a conventional pressure tank is used, the tank may be connected to the hydraulic master cylinder, maintaining a constant supply of fluid in the reservoir, and sufficient air pressure to force the fluid through the lines to expel air at the bleeding points.

(1) CONNECT PRESSURE TANK TO MASTER CYLINDER. If pressure tank is used, connect tank hose with proper size adapter to the master cylinder filler cap aperture. The pressure tank should contain



HYDROVAC BLEEDING POINTS AND SEQUENCE



BLEEDING A WHEEL CYLINDER

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Figure 164—Brake System Bleeding Points

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between 10 - 20 pounds air pressure and sufficient fluid to maintain constant fluid level in the master cylinder.

(2) BLEED HYDROVAC. The Hydrovac unit must be bled before bleeding the wheel cylinders and must be bled in correct sequence. Refer to figure 164 and bleed the Hydrovac at the bleeding screws in the sequence marked 1 and 2. It is not necessary to bleed the screw located on top of the slave cylinder directly above the inlet line connection. Remove bleeder cap screw and washer at each bleeder screw. Install bleeder tube (41-T-4170) in end of No. 1 bleeder screw. Place opposite end of bleeder tube in a suitable container with sufficient fluid to cover end of tube. While pumping brake pedal or with the use of air pressure in pressure tank, open bleeder screw three-quarters of a turn counterclockwise and observe flow of fluid at end of bleeder hose. Close bleeder screw firmly as soon as air bubbles stop and fluid comes out of tube in a solid stream. Repeat this operation on bleeder screw No. 2, making certain that hydraulic master cylinder has been replenished with fluid if manual system is used.

(3) BLEED WHEEL CYLINDER. Remove cap screw from wheel cylinder at backing plate and connect bleeder hose. Place the other end in a container with sufficient fluid to cover end of hose. While pumping with pedal or using pressure tank, open bleeder valve by turning three-quarters of a turn in counterclockwise direction. Close bleeder valve tightly as soon as air bubbles stop and fluid comes out in a solid stream. Repeat these operations on each wheel cylinder at the other brakes, replenishing fluid in hydraulic cylinder before each wheel cylinder is bled if using the manual system.

181. BRAKE SYSTEM ADJUSTMENTS FOR NORMAL WEAR.

a. General. Brake system adjustments necessary to compensate for normal wear are commonly confined to adjustments at the brake shoes. Other system adjustments such as brake pedal to toe board clearance and hydraulic master cylinder linkage adjustment are, as a general rule, not required to compensate for normal wear. These linkage adjustments are only necessary if linkage has been replaced or distorted as the result of collision, etc.

b. Front Brake Shoe Adjustment (fig. 165). Always check hub bearing adjustment (par. 199). A satisfactory brake adjustment cannot be obtained unless the hub bearings are in proper adjustment.

(1) ON BANJO TYPE AXLES ONLY. Remove two adjusting hole covers on backing plate, one at each side of hydraulic flexible line connection. Insert screw driver through hole in plate until screw driver engages notches on wheel cylinder adjusting cap (fig. 165). Turn adjusting cap in clockwise direction (when looking at end of cylinder) until there is a slight drag as wheel is turned by hand. Back off adjusting cap four notches to provide running clearance between brake lining and brake drum. Repeat this procedure at rearward shoe. Make adjustment at both front wheels, and make

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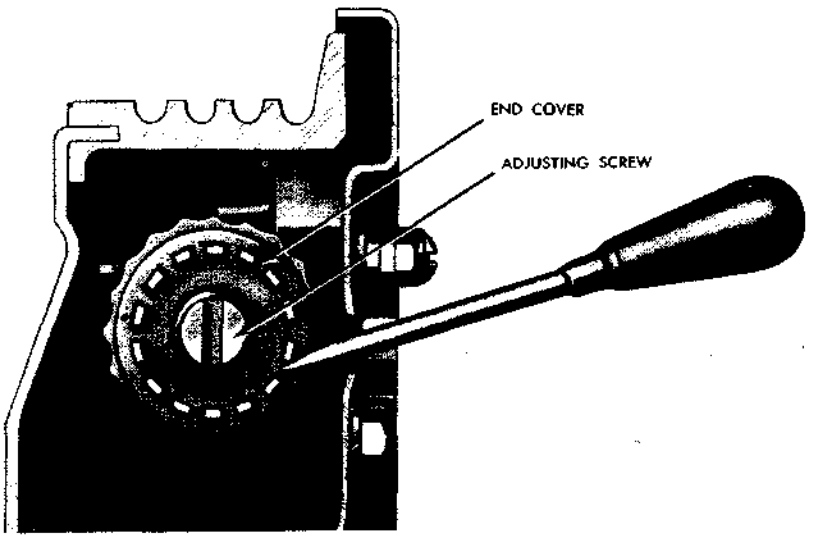
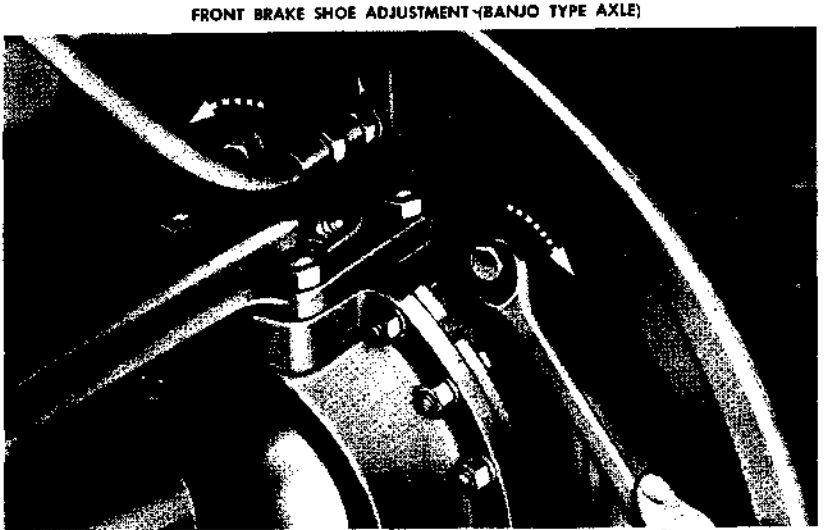
certain that brake shoe adjustments on both wheels are as uniform as possible.

(2) ON SPLIT TYPE AXLES ONLY. Adjust by turning adjusting cam on forward shoe in direction as indicated by arrows in figure 165 until brake drags slightly when wheel is revolved by hand. Back off adjusting cam just enough to allow wheel to revolve freely. Repeat this procedure at rearward shoe. Both adjustments at each wheel should be as uniform as possible. In rare instances, this man-



FRONT BRAKE SHOE ADJUSTMENT (BANJO TYPE AXLE)



FRONT BRAKE SHOE MINOR ADJUSTMENT (SPLIT TYPE AXLE)

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Figure 165—Front Brake Shoe Adjustment for Normal Wear

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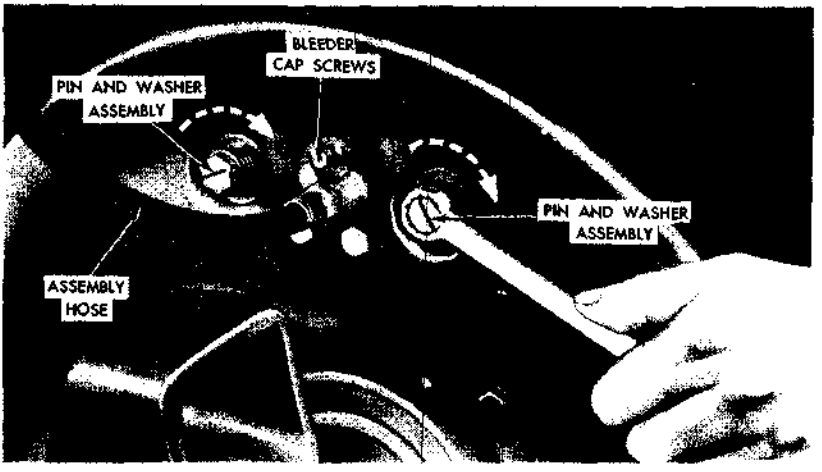

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Figure 166—Rear Brake Shoe Adjustment for Normal Wear

ner of adjustment may not give entirely satisfactory results. In such instances, a *major adjustment* must also be made as described in paragraph 183.

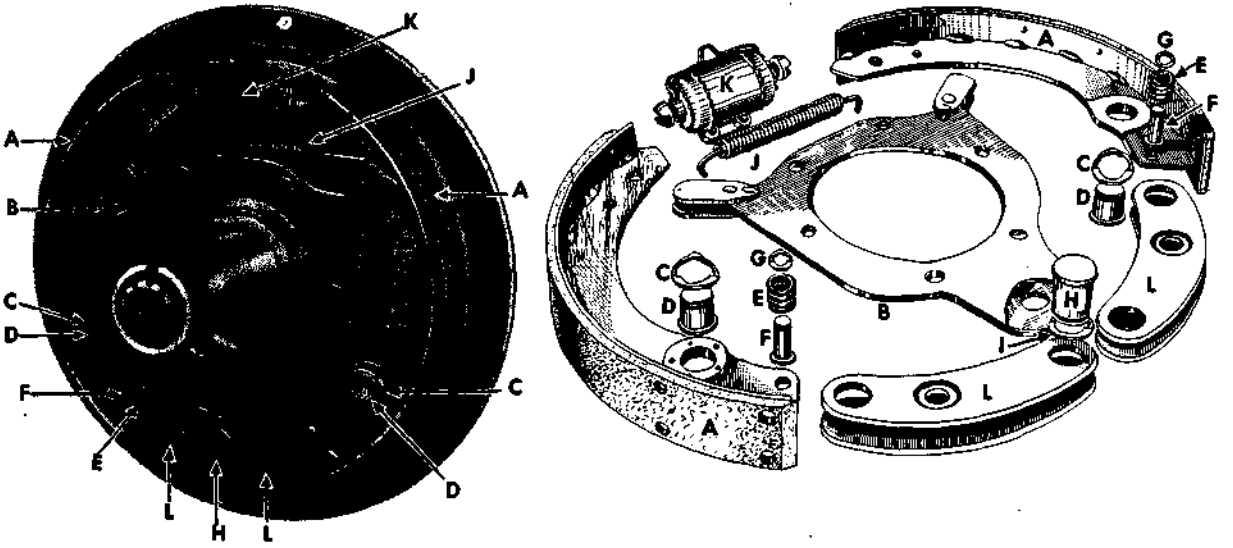
c. **Rear Brake Shoe Adjustment.** Rear brake shoes are adjusted the same on both split and banjo type axles. Install wrench on hex head of one adjusting pinion shaft. Turn adjuster in clockwise direction as indicated by arrows on figure 166 until there is a slight drag as wheel is revolved by hand. Back off adjuster three-quarters of a turn, which will provide proper running clearance between brake lining and brake drum. Repeat the procedure on the opposite adjuster. Make certain that all brake shoes on each axle are adjusted as uniformly as possible.

182. FRONT BRAKE SHOES (WITH BANJO TYPE AXLE).

a. **Description** (fig. 167). The shoe assemblies are connected to an anchor plate with articulating links and an anchor pin. Guide plates, riveted to the anchor plate near the upper ends of the shoes, hold each shoe in the proper alinement. The upper end of each shoe rests in slotted adjusting studs threaded into wheel cylinder caps. On vehicles equipped with demountable brake drums only, the drum must be removed to gain access to shoe assemblies. The hub, drum, and bearings must be removed on vehicles equipped with conventional drums.

b. **Shoe Assembly Removal.** Jack up front wheel to be serviced. Remove wheel. On vehicles equipped with demountable drums, remove drum (par. 185). On other vehicles, remove hub, drum, and bearings (par. 201).

(1) DISCONNECT SHOE LINKAGE (fig. 168). Install wheel cylinder clamp (41-C-1835) over ends of wheel cylinder. Remove return spring [(GM-2030574) G85-11-02130] with pliers (41-P-



A BRAKE SHOE AND LINING
B FRONT BRAKE SHOE ANCHOR PLATE ASSEMBLY
C FRONT BRAKE SHOE LINK PIN LOCK
D FRONT BRAKE SHOE LINK PIN
E PIN SPRING
F PIN
G PIN LOCK
H ANCHOR PIN
I ANCHOR PIN LOCK
J FRONT BRAKE SHOE RETURN SPRING
K FRONT BRAKE SHOE WHEEL CYLINDER
L FRONT BRAKE SHOE LINK

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Figure 167—Front Brake Shoe Assembly—Banjo Type Axle

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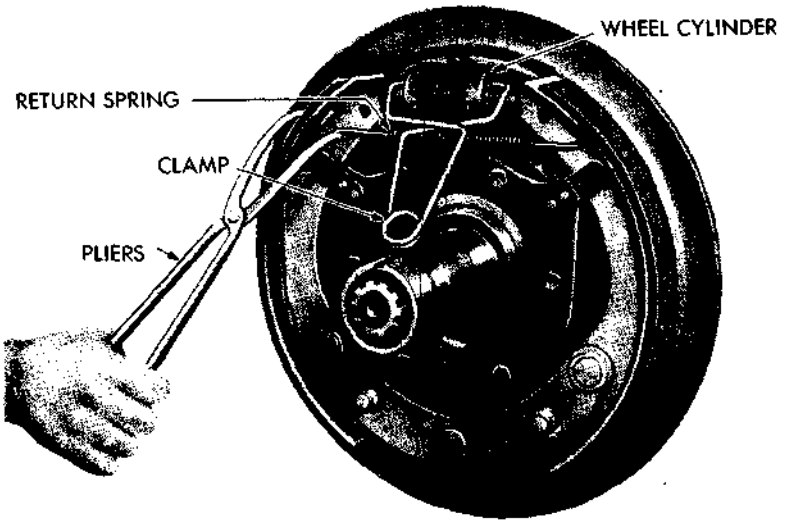

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Figure 168—Method of Clamping Wheel Cylinder and Removing Spring (Clamp 41-C-1835 and Pliers 41-P-1579)

1579). Remove anchor pin lock with screw driver, then remove anchor pin.

(2) REMOVE SHOES. Brake shoes [(GM-3660054) G85-31-13220] with the links attached, can be removed by swinging them clear of guides on anchor plate. Remove friction pin lock, pins, and springs. Remove link pin locks and pins.

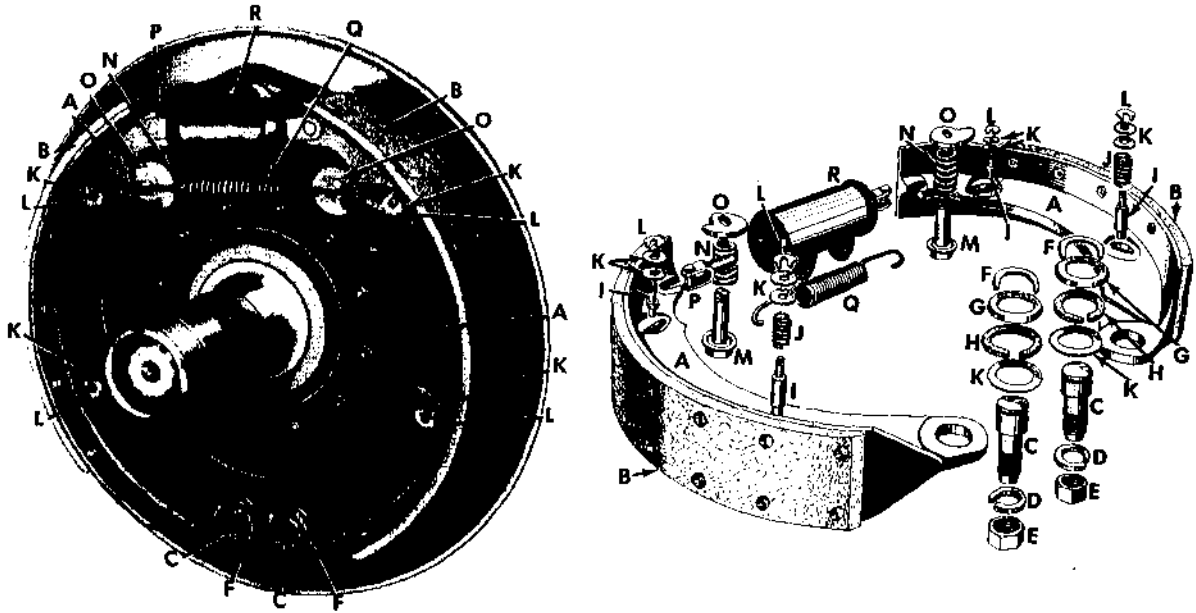
c. Brake Shoe Assembly Installation.

(1) INSTALL LINKS TO SHOES. Install brake shoe links to forward and reverse shoes. Links on reverse shoe are wider at anchor end than at shoe end. Install brake shoe link pin and lock. Install friction pin, springs, and new lock.

(2) POSITION SHOES. Position forward and reverse shoes between guide plates on anchor plate assembly. Check fit of shoes in guides. Shoes should be free without excessive side movement. Attach links to anchor plate with anchor pin and pin lock. Attach one end of return spring to one shoe, then with pliers (41-P-1579), attach other end to opposite shoe. Remove wheel cylinder clamp.

(3) INSTALL BRAKE DRUM. On vehicles with conventional type brake drums, install hub, drums, and bearings, then adjust the wheel bearings (par. 199). On vehicles equipped with demountable drums, install drums as described in paragraph 185.

(4) ADJUST. Install wheel, then adjust brake shoes as described in paragraph 181.



A BRAKE SHOE AND LINING
B BRAKE LINING
C ANCHOR PIN
D LOCK WASHER
E NUT
F ANCHOR PIN LOCK
G RETAINER
H FELT WASHER
I GUIDE PIN
J GUIDE PIN SPRING
K PLAIN WASHER
L "C" WASHER
M ADJUSTING CAM
N PIN SPRING
O ADJUSTING CAM
P YOKE
Q RETURN SPRING
R WHEEL CYLINDER

RA PD 316906

Figure 169—Front Brake Shoe Assembly—Split Type Axle

ES18-002672 0481

SERVICE BRAKE SYSTEM

183. FRONT BRAKE SHOES (WITH SPLIT TYPE AXLE).

a. Description (fig. 169). The brake shoes are anchored to the backing plate by adjustable eccentric pins at lower ends of the shoes. Adjusting cams, located near the upper ends of the shoes, bear against the brake shoes. Guide pins, two in each shoe, are riveted to the backing plate. Special washers used over pins are used on each side of the shoes and are held in place with C-washers which fit into the grooves at outer ends of the guide pins. C-washers are also used to hold the brake shoes in place on anchor pins. On vehicles equipped with split type axles, demountable brake drums are used.

b. Shoe Assembly Removal. Jack up front wheel to be serviced. Remove wheel, then remove demountable drum (par. 185).

(1) DISCONNECT SHOE LINKAGE. Install clamp (41-C-1835) over ends of wheel cylinder. Remove C-washers from anchor pins, using a ¾-inch end wrench and hammer in manner shown in figure 170. It is not necessary to remove the anchor pins. With pliers, remove guide pin lock on both shoes (fig. 171).

(2) REMOVE SHOES. With pliers (41-P-1579), remove return spring [(GM-2030574) G85-11-02130]. Pull each shoe away from wheel cylinder yoke, then pull shoes [(GM-2030568) G508-03-84922 forward and (GM-2030569) G508-03-84923 reverse] straight out to remove from anchor pins at bottom and guide pins midway on shoes.

c. Shoe Assembly Installation.

(1) POSITION BRAKE SHOES. Position brake shoes over anchor pins and guide pins. Install a flat washer over each guide pin before installing brake shoes. Make certain that wheel cylinder yokes are positioned in upper end of brake shoes properly.

(2) INSTALL BRAKE SHOE RETURN SPRING. Install one end of

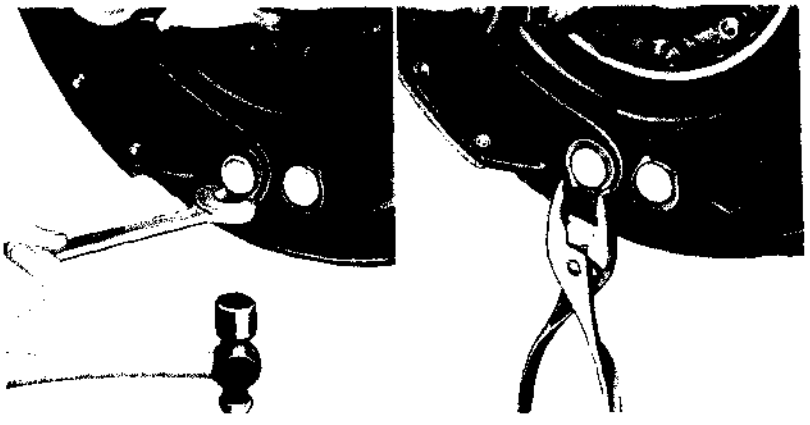
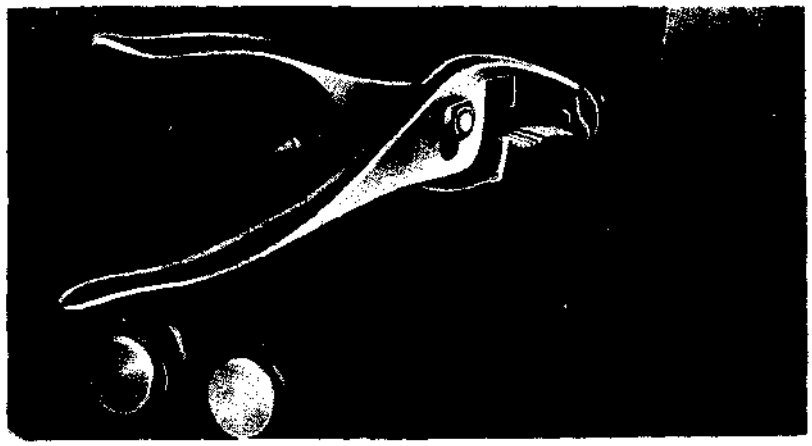
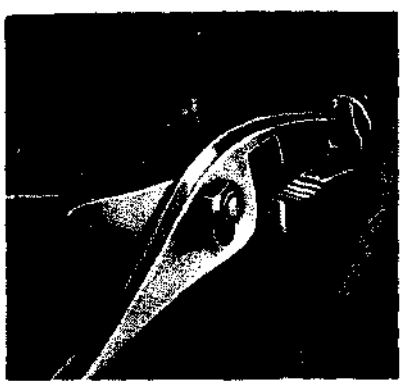


Figure 170—Removal and Installation of Anchor Pin Washers (Front Split Type Axle)



REMOVING



INSTALLING

CLAMPING

RA PD 332914

Figure 171—Removing, Installing, and Clamping Guide Pin Locks (Front Split Type Axle)

spring in brake shoe, then with pliers (41-P-1579), install other end of spring in other brake shoe. After return spring is installed, remove wheel cylinder clamp (41-C-1835) from wheel cylinder.

(3) INSTALL C-WASHERS IN GUIDE AND ANCHOR PINS. Install flat washers over guide pins, then install C-washers on guide pins (fig. 171), making certain that C-washers seat solidly and are locked securely. Install C-washers on anchor pins. Tap washer into place firmly, then lock C-washers securely (fig. 171). Turn anchor pins until marks on pins are toward each other (fig. 172). Install drum (par. 185) and wheel.

d. Major Shoe Adjustment.

(1) ADJUST FORWARD SHOE LINING CLEARANCE AT BOTTOM (fig. 172). Remove inspection cover on front of brake drum. Revolve

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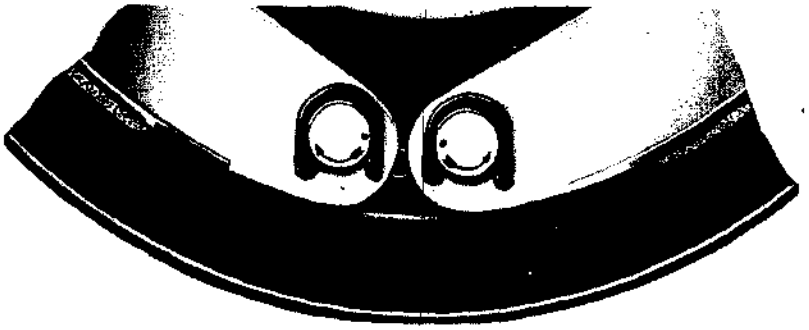
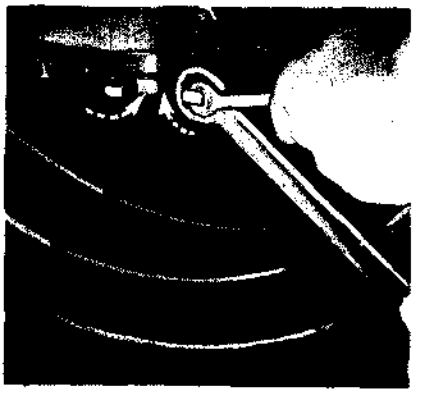


ANCHOR PIN POSITION

LINING CLEARANCE CHECK



MAJOR ADJUSTMENT

RA PD 332852

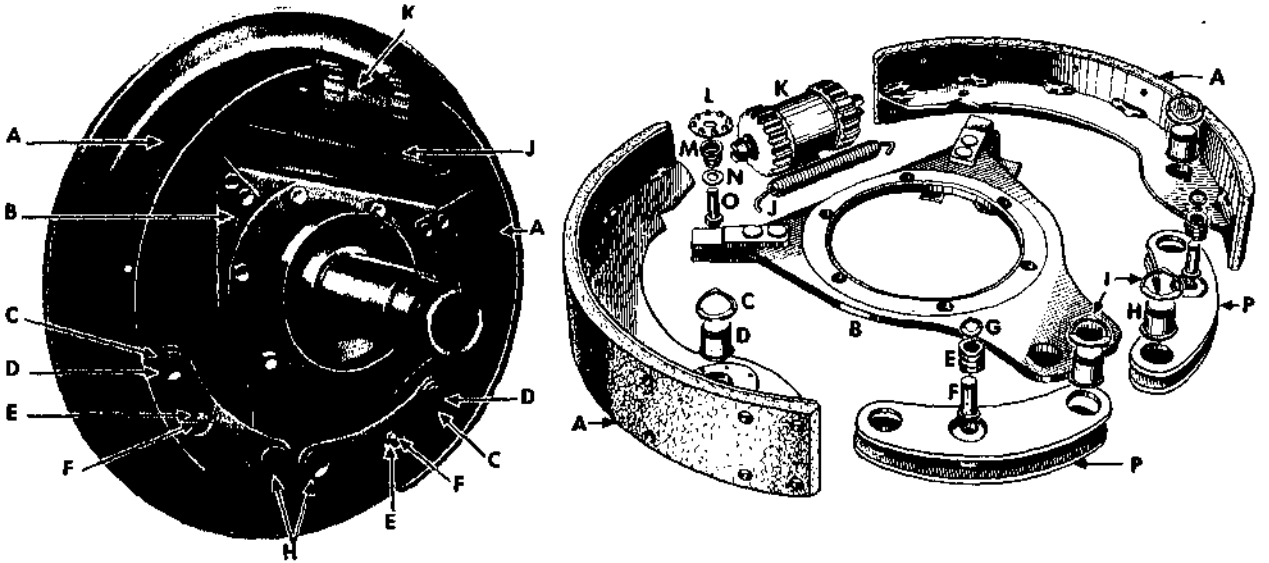
Figure 172—Position of Anchor Pin and Major Adjustment

drum until opening is about 1½ inches from end of forward brake shoe. Insert 0.010 inch feeler gage between drum and bottom or heel of shoe. Back off lock nut on anchor pin, using two wrenches, one on lock nut and the other on anchor pin. Turn anchor pin in direction shown in figure 172 until clearance of 0.010 inch is obtained.

(2) ADJUST FORWARD SHOE LINING CLEARANCE AT TOP. Revolve drum until opening is about 1½ inches from end of lining at top or toe of shoe. Insert 0.020 inch feeler gage and turn anchor pin until that clearance is obtained. Recheck lower clearance.

(3) ADJUST LINING CLEARANCE AT REVERSE SHOES. Repeat steps (1) and (2) above on reverse shoe. Make certain that adjustments at both shoes are approximately the same. Tighten anchor pin lock nuts and check all clearances again.

(4) ADJUST SHOES AT CAM. Adjust shoes at cams as described in paragraph 181. Install wheel. Install inspection cover on brake drum.



A REAR BRAKE SHOE AND LINING
B REAR BRAKE SHOE ANCHOR PLATE ASSEMBLY
C LINK PIN LOCK
D LINK PIN
E PIN SPRING
F PIN
G PIN LOCK
H REAR BRAKE SHOE ANCHOR PIN
I REAR BRAKE SHOE ANCHOR PIN LOCK
J REAR BRAKE SHOE RETURN SPRING
K REAR BRAKE SHOE WHEEL CYLINDER
L REAR BRAKE SHOE CYLINDER ADJUSTING PINION
M ADJUSTING PINION SPRING
N ADJUSTING PINION SHAFT WASHER
O ADJUSTING PINION SHAFT
P REAR BRAKE SHOE LINK

RA PD 307477

Figure 173—Rear Brake Shoe Assembly

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SERVICE BRAKE SYSTEM

184. REAR BRAKE SHOES.

a. Description (fig. 173). The rear brake shoe assemblies on both split and banjo type axles are two-shoe type and are similar in construction. The shoes are anchored to the anchor plate through articulating links and two anchor pins located at the bottom of the anchor plate. The guide plates, riveted to the anchor plates near the upper ends of the shoes, hold each brake shoe in the proper alinement. The upper end of each brake shoe rests in a slotted adjusting stud threaded in the end caps of the wheel cylinder. Vehicles with banjo type axles are equipped with either demountable or conventional (non-demountable) type brake drums, while vehicles with split type axles are equipped with demountable type drums only.

b. Brake Shoe Assembly Removal.

(1) REMOVE BRAKE DRUM, OR HUB AND DRUM. Remove wheel. On vehicles equipped with demountable type drums, remove drum (par. 185). On other vehicles, remove hub, drum, and bearings (par. 201).

(2) DISCONNECT SHOE LINKAGE. Install clamp (41-C-1835) over wheel cylinder. Remove return spring with pliers (41-P-1579). Remove anchor pin locks (fig. 174), then remove pins. Brake shoes [(GM-3660048) G85-31-13240] with links attached, may then be swung clear of guide plates.

(3) REMOVE LINKS AND FRICTION PINS. Remove link pin lock and pin from each shoe. Remove friction pin lock, spring, and pin from each shoe.

c. Brake Shoe Assembly Installation.

(1) INSTALL LINKS ON SHOES. Install links to both shoes by installing link pin and lock, and friction pin, spring, and lock on each shoe. Use new locks, if available.

(2) INSTALL SHOES. Position shoes in place at guide plates. Install anchor pins and locks. Use new locks and make sure that locks fit in grooves of pins. With pliers (41-P-1579), install return spring, then remove clamp (41-C-1835).

(3) INSTALL DRUM, OR HUB AND DRUM. If demountable drum

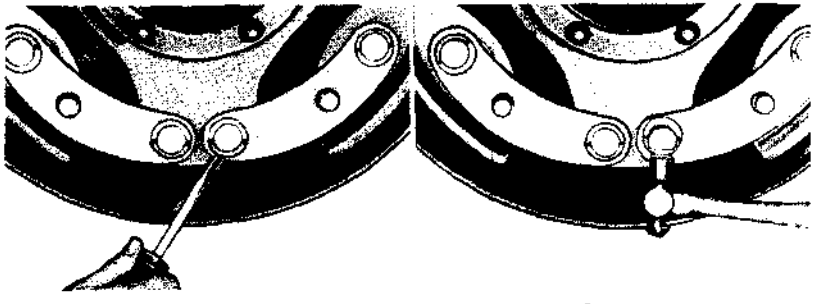

Figure 174—Removing and Installing Anchor Pin Locks

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is used, install as described in paragraph 185. On other vehicles, install hub, drum, and bearings, then adjust wheel bearings (par. 199).

(4) ADJUST. Adjust brake shoes (par. 181).

185. BRAKE DRUMS.

a. With Banjo Type Axles. Front and rear brake drums on banjo type axles are either the demountable type or conventional (non-demountable) type. The demountable type may be removed from the hub without the necessity of removing the complete hub and drum assembly. The non-demountable type drum is attached to the hub with serrated bolts and cannot be replaced until hub, drum, and bearings are removed.

(1) DRUM REPLACEMENT (NON-DEMOUNTABLE TYPE).

(a) Removal. Position hub assembly so that bolt heads are accessible. Mark the *exact center* of bolt head with a center punch, then with a ⅞-inch drill positioned on mark, drill a hole to approximate depth shown in figure 175. The hole must be deep enough so that bolt head is severed from bolt. While drilling bolt head, be certain that drill is alined correctly. Position a blunt pointed drift pin in drilled hole, then strike drift pin firmly with a hammer until bolt is driven out of hub. Perform above operation on balance of bolts, then remove drum from hub.

(b) Front Drum Installation. Position and aline drum on hub, then insert wheel bolts through drum and hub. Make certain that serrations on bolt and in hub are in alinement. Drive or press wheel bolts firmly in place. Wheel bolts must be a tight press fit.

(c) Rear Drum Installation. Position and aline drum on hub, then place gasket between inner side of drum and oil deflector. The small hole in gasket and channel in deflector must be alined with oil relief hole in brake drum. Insert wheel bolts, with bolt and hub serrations in alinement, through oil deflector, gasket, drum, and hub.

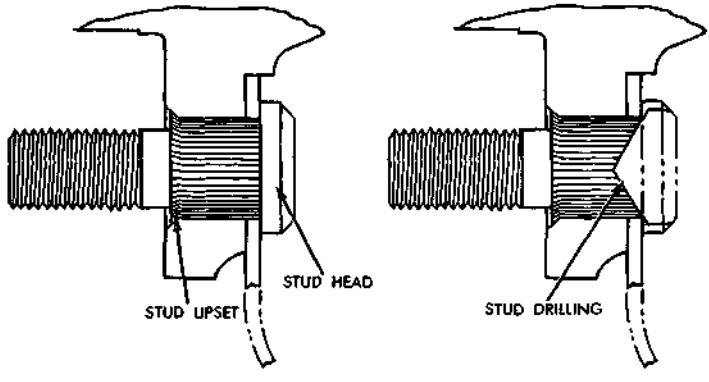

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Figure 175—Removal and Installation of Hub Bolts (Front Shown)

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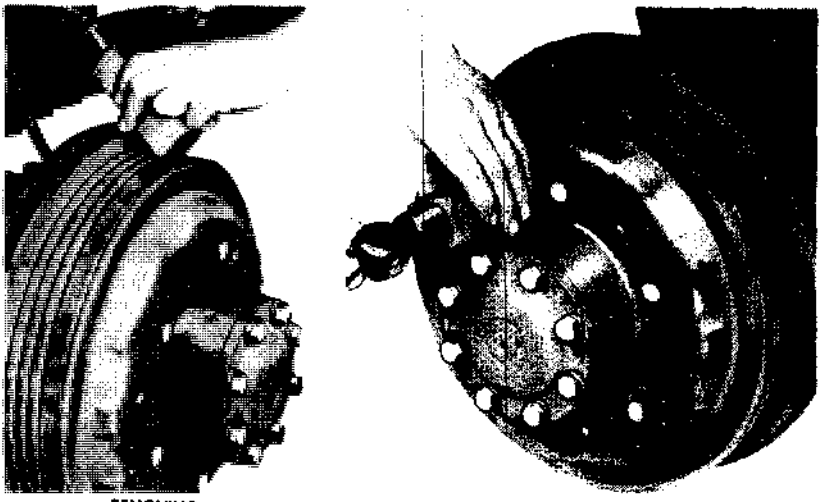

Figure 176—Removing and Installing Demountable Drum (Banjo Type Axle)

Drive or press wheel bolts firmly in place. Wheel bolts must be a tight press fit.

(2) DRUM REPLACEMENT (DEMOUNTABLE TYPE) (fig. 176). Remove three slotted countersunk head screws which attach brake drum to hub. Apply a few drops of penetrating oil through each hole in drum so that it might flow around shoulder on hub where brake drums fit. Allow penetrating oil sufficient time to act, then position a block of wood in a groove of the drum and drive drum evenly from shoulder. Reinstall by driving drum into place with a block of wood.

b. With Split Type Axles (fig. 177). Brake drums on vehicles equipped with split type axles are demountable type. The front brake drums are attached to the hub with cap screws, while the rear brake drums are attached to hub with countersunk screws.

(1) FRONT BRAKE DRUM REPLACEMENT. Remove six cap screws and lock washers which attach drum to hub adapter. Reinstall three of the cap screws in three additional puller screw holes in drum. Tighten screws alternately and evenly until drum is free. Install drum so that attaching screw holes match with those on hub adapter. Tighten cap screws evenly and firmly, using new lock washers.

(2) REAR BRAKE DRUM REPLACEMENT. Remove countersunk head screws which attach drum to hub. Apply a few drops of penetrating oil at point where drum contacts pilot shoulder of hub. Place a soft metal bar between wheel studs and strike bar sharply with hammer. This must be accomplished all around the hub until drum is loosened sufficiently to lift off of hub. When installing the drum,

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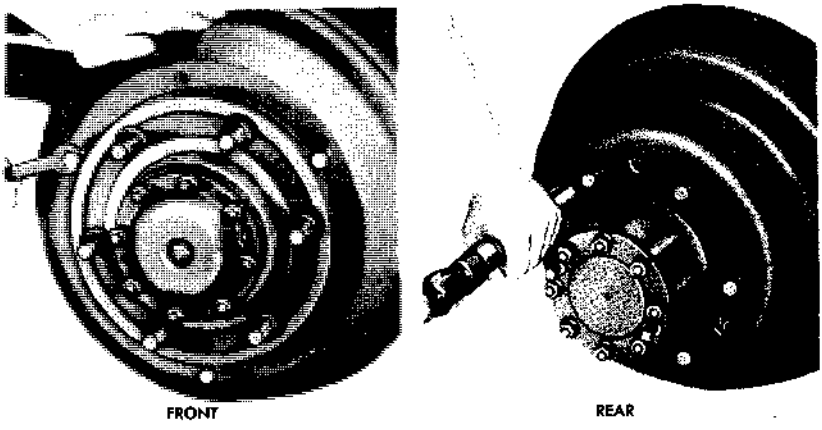

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Figure 177—Removing and Installing Demountable Drum (Split Type Axle)

position drum over ends of wheel bolts, then drive drum into place with a block of wood and hammer. Install the attaching screws and tighten firmly.

186. BRAKE PEDAL AND LINKAGE.

a. The brake pedal, mounted on a cross shaft with the clutch pedal, is linked to hydraulic master cylinder cross shaft outer lever with an adjustable pull rod. The rod can be adjusted at clevis for pedal to toe board clearance. A return spring at master cylinder end of rod returns pedal to fully released position after pedal pressure is released.

b. Pedal and Pull Rod Removal (fig. 178).

(1) DISCONNECT CLUTCH PEDAL LINKAGE. Remove floor and toe board. Disconnect clutch pedal pull back spring. Loosen check nut and adjusting nut on clutch pedal adjusting link. Unhook link from pedal.

(2) DISCONNECT BRAKE PEDAL LINKAGE. At pedal, remove clevis pin from rod yoke. At master cylinder outer lever, remove clevis pin from adjustable yoke and withdraw rod. Disconnect pedal return spring [(GM-369935) G501-03-89794].

(3) REMOVE PEDALS AND BRACKET. Remove three cap screws which attach pedal bracket to transmission and clutch housing. Bracket with pedals can then be withdrawn as an assembly.

(4) REMOVE PEDALS. Remove taper pin which attaches collar to shaft. Collar, clutch pedal, and brake pedal may then be withdrawn from shaft.

c. Pedal and Pull Rod Installation.

(1) INSTALL PEDALS TO SHAFT AND BRACKET. Install brake

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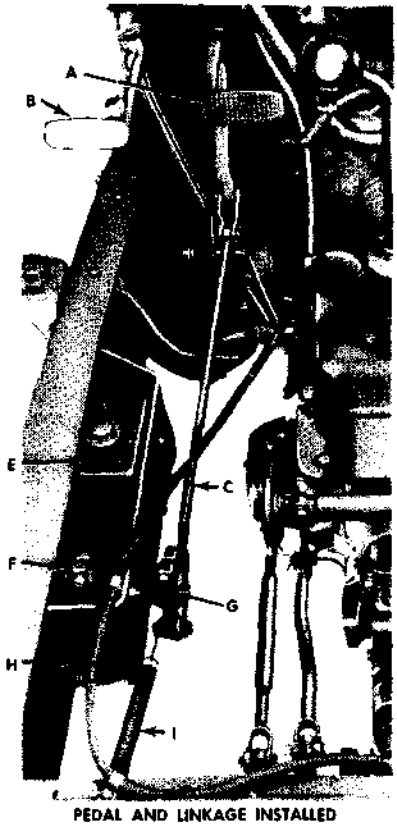
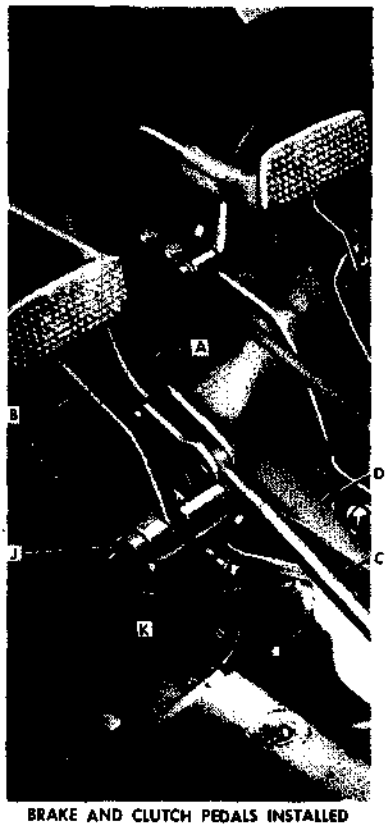


PEDAL AND LINKAGE INSTALLED



BRAKE AND CLUTCH PEDALS INSTALLED

A BRAKE PEDAL
B CLUTCH PEDAL
C PEDAL TO INNER LEVER ROD
D PEDAL BRACKET
E MASTER CYLINDER
F MASTER CYLINDER OUTER LEVER
G MASTER CYLINDER INNER LEVER
H STOP SCREW
I RETURN SPRING
J COLLAR
K COLLAR PIN

RA PD 332935

Figure 178—Brake Pedal and Linkage

pedal, then clutch pedal on shaft. Place collar over outer end of shaft and line up pin holes in shaft and collar. Install taper pin.

(2) INSTALL PEDAL AND BRACKET. Install bracket with pedals on transmission and clutch housing. Use new lock washers and tighten cap screws firmly.

(3) CONNECT CLUTCH PEDAL LINKAGE. Connect clutch pedal link to pedal. Adjust clutch pedal free-travel (par. 150).

(4) ATTACH ROD TO BRAKE PEDAL. Install pedal to master cylinder lever rod at pedal. Use new cotter pin. *Do not connect rod to master cylinder outer lever until master cylinder push rod stop screw adjustment is checked and adjusted as described in paragraph* 187 d.

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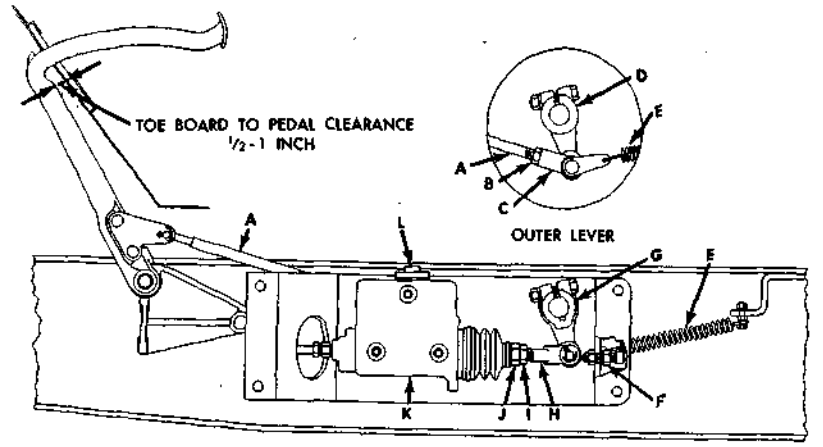
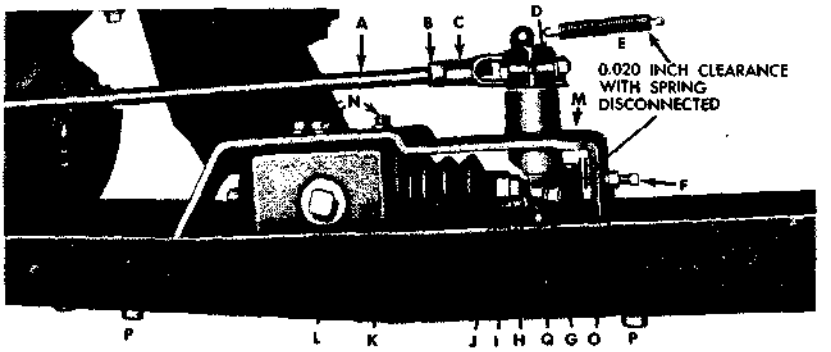


PEDAL AND MASTER CYLINDER LINKAGE



ADJUSTMENT OF STOP SCREW

A PEDAL TO INNER LEVER ROD
B ADJUSTABLE YOKE LOCK NUT
C ADJUSTABLE YOKE
D MASTER CYLINDER OUTER LEVER
E RETURN SPRING
F STOP SCREW
G MASTER CYLINDER INNER LEVER
H PUSH ROD YOKE
I YOKE LOCK NUT
J PUSH ROD NUT
K MASTER CYLINDER
L FILLER CAP
M MASTER CYLINDER BRACKET
N BRACKET TO CYLINDER CAP SCREWS
O STOP SCREW LOCK NUT
P FRAME TO BRACKET BALLS
Q LEVER SHAFT

RA PD 332934

Figure 179—Pedal and Master Cylinder Linkage

(5) CONNECT ROD TO OUTER LEVER. After master cylinder push rod stop screw is checked, connect rod to outer lever and install return spring. Check pedal to toe board clearance as described in subparagraph **d** below.

d. Pedal to Toe Board Clearance (fig. 179). Brake pedal in released position must have ½ to 1 inch clearance between pedal and underside of toe board with pedal in *fully released* position. Withdraw clevis pin at outer lever and remove clevis from lever.

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Loosen clevis lock nut and turn clevis as necessary to obtain correct clearance at toe board. Tighten clevis lock nut and reinstall to outer lever.

187. HYDRAULIC MASTER CYLINDER AND LINKAGE.

a. The hydraulic master cylinder is comprised of a hydraulic piston and a fluid reservoir. Application of the brake pedal operates push rod through linkage. When the brake pedal is applied, the movement of the pedal through the linkage operates the piston in the master cylinder assembly, displacing hydraulic fluid and building up pressure in the lines which is eventually utilized at the wheel cylinders as pressure is further increased by action of the Hydrovac unit.

b. **Master Cylinder and Linkage Removal** (fig. 179).

(1) DISCONNECT BRAKE PEDAL LINKAGE. Remove floor boards. Disconnect brake pedal return spring. Remove pedal to outer lever rod from outer lever.

(2) DISCONNECT HYDRAULIC LINE AND SWITCH WIRES. Disconnect hydraulic line at front of master cylinder [fitting gasket (GM-285059) G67-06-00810]. Remove wires from stop light switch terminals.

(3) REMOVE MASTER CYLINDER WITH BRACKET. Remove four master cylinder bracket to frame bolts and nuts. Master cylinder with bracket and levers can then be withdrawn as an assembly.

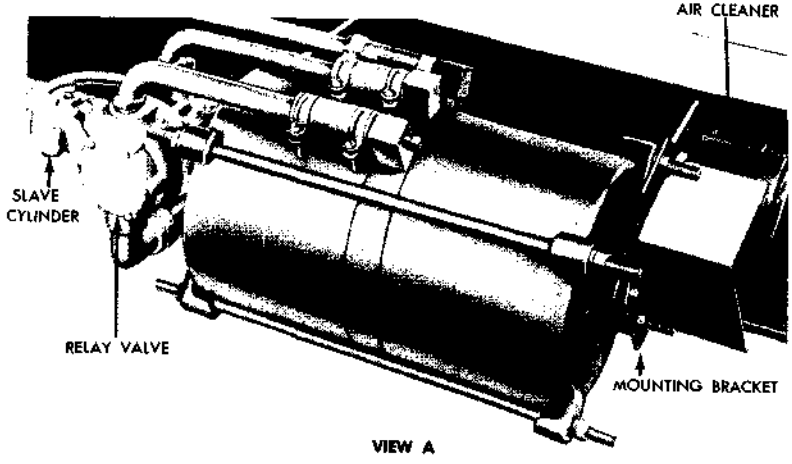
(4) REMOVE MASTER CYLINDER FROM BRACKET. Remove pin from clevis connecting cylinder push rod to inner lever. Remove six master cylinder to bracket cap screws and withdraw master cylinder (GM-21553233). Levers may be removed by loosening clamp bolts. Drive shaft from bracket to remove inner lever.

c. **Master Cylinder and Linkage Installation** (fig. 179).

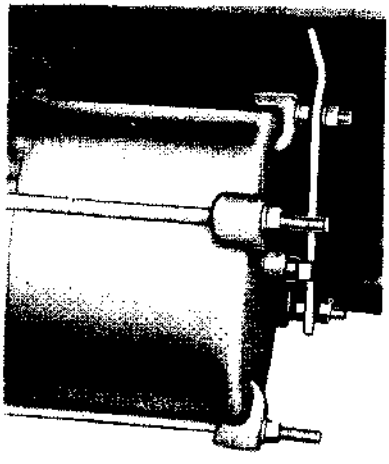
(1) INSTALL MASTER CYLINDER TO BRACKET. After shaft and inner and outer levers have been installed in bracket, attach master cylinder to bracket. Tighten attaching cap screws firmly. Attach push rod yoke to master cylinder push rod, then attach yoke to lever.

(2) INSTALL MASTER CYLINDER AND BRACKET. Install master cylinder and bracket to frame side rail. Tighten attaching bolts and nuts firmly. Install hydraulic line to front of cylinder. Connect stop light switch wires to switch. Fill cylinder with fluid. Check condition of filler cap gasket [(GM-080445) G85-31-05820].

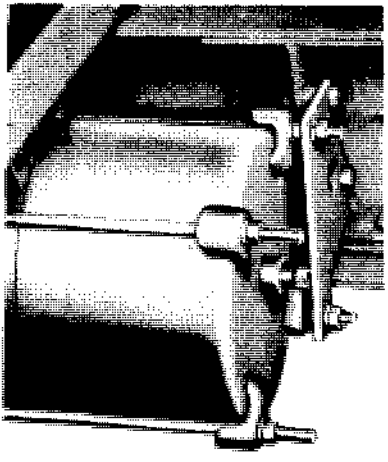
(3) ADJUST MASTER CYLINDER PUSH ROD. Loosen yoke to push rod lock nut. With one wrench on push rod nut, and another on lock nut, turn push rod until rear of piston touches stop plate in end of master cylinder. Turn push rod one additional turn (until it is loose in piston) and tighten lock nut. Piston is fully released when rear of piston contacts stop plate at rear of master cylinder barrel. If piston is not allowed to return to a fully released position, piston cup will cover by-pass hole in master cylinder, thereby preventing fluid entering master cylinder barrel on return stroke.



VIEW A



VIEW B



VIEW C

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Figure 180—Hydrovac Installed (Oil Wetted Type Cleaner Shown)

(4) IMPORTANT. *Before connecting brake pedal push rod and return spring to outer lever, stop screw at rear of master cylinder must be adjusted* as described in subparagraph d below.

(5) CONNECT LINKAGE TO OUTER LEVER. After stop screw adjustment has been made, connect pedal pull rod and spring to outer lever. Check and adjust pedal to toe board clearance (par. 186 d).

d. Master Cylinder Push Rod Stop Screw Adjustment. After master cylinder push rod is adjusted as described in subparagraph c (3) above, measure clearance between inner lever and stop screw (fig. 179). If pedal is connected to outer lever, *the return spring*

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must be disconnected before this clearance check is made. Adjust the stop screw to permit 0.020 inch clearance between screw and inner lever.

(1) IMPORTANT. If this clearance is excessive, the master cylinder piston will strike stop in cylinder too sharply. If clearance is less than 0.020 inch, the piston will not clear fluid by-pass in cylinder when brakes are released. *Do not check or adjust stop screw with return spring connected.* Always check this clearance before making pedal to toe board clearance adjustment.

188. HYDROVAC ASSEMBLY.

a. Description (fig. 180). The Hydrovac assembly, located on the inside of the right-hand frame side rail behind the transfer case, consists of a hydraulic slave cylinder, a vacuum suspended power cylinder, and a hydraulic relay valve, all assembled as one complete unit. The Hydrovac unit is so constructed that in case the vacuum power fails, brakes may be applied by hydraulic system with slightly more manual effort. An oil wetted type air cleaner on some vehicles is connected to relay valve and mounted adjacent to Hydrovac unit (fig. 181). On late vehicles, an oil bath air cleaner is mounted on engine side of dash and connected to Hydrovac with tubing (fig. 182).

b. Cleaning Hydrovac Cleaner.

(1) OIL WETTED TYPE (fig. 181).

(a) Remove Air Cleaner Shield. Remove two nuts and lock washers attaching shield to Hydrovac bracket, then remove air cleaner shield.

(b) Disassemble Air Cleaner. Remove cover retaining screw

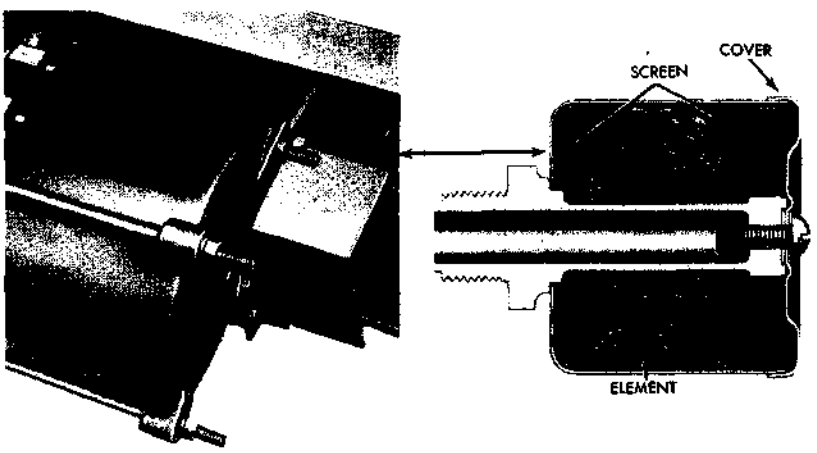

Figure 181—Oil Wetted Type Cleaner

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and washer and remove air cleaner as an assembly from air cleaner stem. Remove cover from air cleaner shell, then extract outer screen, filter hair element, and inner screen from shell.

(c) Cleaning. Immerse air cleaner parts in dry-cleaning solvent to loosen and wash out accumulated dirt. Blow all parts dry with compressed air after deposits of dirt have been removed. Immerse curled hair element in light engine oil, withdraw, and allow surplus to drain off.

(d) Assemble Air Cleaner. Install air cleaner shell over end of air cleaner stem. Install inner screen (small). Position oil treated element evenly around stem inside of shell. Install outer (large) screen with edge of screen toward cover. Install and secure cover with retaining screws and washer.

(e) Install Air Cleaner Shield. Position shield over studs of Hydrovac and attach with two nuts and lock washers.

(2) OIL BATH TYPE—DASH MOUNTED (fig. 182).

(a) Remove Cleaner. Turn body of cleaner to left until body and element can be withdrawn from bracket.

(b) Clean Element. Slush element in dry-cleaning solvent and blow dry with compressed air. Dip element into engine oil (refer to Section VIII, Lubrication).

(c) Clean and Fill Body. Slush body in dry-cleaning solvent. Wipe dry. Fill body to oil mark with engine oil (refer to Section VIII, Lubrication).

(d) Install Cleaner. Insert element into body. Attach body and element to bracket by turning it to the right on the threads.

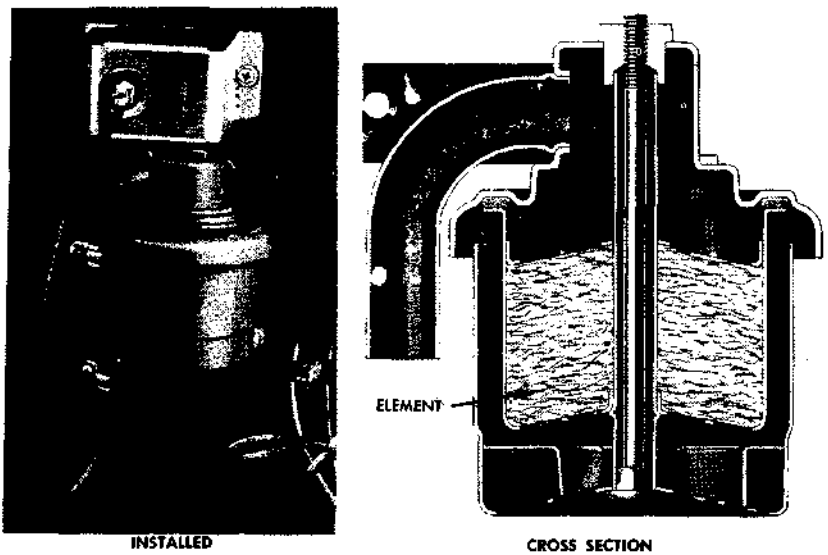

Figure 182—Oil Bath Type Cleaner

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c. **Hydrovac Assembly Removal.** NOTE: *Due to changes in vehicle design, different conditions will be encountered when removing (or installing) the Hydrovac. Difference in mountings are shown in figure 180, and will be noted in text as necessary.*

(1) DISCONNECT HYDRAULIC LINES. Disconnect hydraulic outlet line at front end of slave cylinder, and disconnect hydraulic inlet line at bottom rear of slave cylinder.

(2) DISCONNECT AIR CLEANER TUBE. Disconnect air cleaner tube at bottom of relay valve. Remove bolt attaching vacuum line clip to frame crossmember.

(3) REMOVE HYDROVAC. This procedure depends upon the type of mounting used, and upon the location of the air cleaner. Removal for each mounting shown in figure 180 will be covered separately.

(a) View A (fig. 180). Remove two nuts and lock washers attaching Hydrovac to front support bracket. Remove two nuts and lock washers attaching Hydrovac and air cleaner shield to rear support bracket. Remove air cleaner shield, then remove air cleaner from air cleaner stem. Remove nuts and lock washers from two bolts attaching Hydrovac rear mounting bracket to frame side rail, and remove bolts. Move Hydrovac back and lower onto propeller shaft. Loosen clamp attaching vacuum line hose (GM-2156846) to center plate elbow, remove line from elbow, then remove Hydrovac and rear support bracket from under vehicle. Remove rear support bracket and air cleaner tube assembly from Hydrovac cylinder studs.

(b) View B (fig. 180). This procedure is the same as step *(a)* above except that operations pertaining to Hydrovac air cleaner and tube are omitted.

(c) View C (fig. 180). Remove two nuts and lock washers attaching Hydrovac to front support bracket. Remove two nuts and lock washers attaching Hydrovac to rear support bracket. Loosen to limit of threads, but do not remove, bolts attaching front support bracket to frame side rail. Loosen to limit of threads, but do not remove, bolts attaching rear support bracket to frame side rail reinforcement. Push Hydrovac forward as far as possible, then pry back on rear support bracket until bracket clears ends of studs. Move Hydrovac back until studs clear front support bracket and lower assemby onto propeller shaft. NOTE: *In the event the brackets will not spread far enough to clear the studs, the extreme ends of the studs may be cut off.* Loosen clamp attaching vacuum line to center plate elbow, remove line from elbow, then remove Hydrovac from under vehicle.

d. **Hydrovac Assembly Installation.**

(1) INSTALL HYDROVAC. This procedure depends upon the type of mounting used, and upon the location of the air cleaner. Installation for each mounting shown in figure 180 will be covered separately.

(a) View A (fig. 180). Lift Hydrovac up onto propeller shaft and connect vacuum line to center plate elbow. Tighten clamp firmly. Place rear support bracket and air cleaner tube on cylinder studs,

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and position the assembly at the frame side rail, with the forward ends of the cylinder studs through front support bracket. Install and tighten two bolts, lock washers, and nuts attaching rear support bracket to frame side rail. Install nuts and lock washers on front ends of cylinder studs and tighten firmly. Install air cleaner on air cleaner stem. Position air cleaner shield on cylinder studs, install nuts and lock washers, and tighten firmly.

(b) View B (fig. 180). This procedure is the same as step *(a)* above except that operations pertaining to the air cleaner and tube are omitted.

(c) View C (fig. 180). Lift Hydrovac up onto propeller shaft and connect vacuum line to center plate elbow, tightening clamp firmly. Position Hydrovac with front end of studs through front support bracket, then pry back on rear support bracket until rear end of studs will enter holes in rear bracket. Tighten nuts on front and rear support brackets, then install and tighten nuts and lock washers on studs attaching Hydrovac to support brackets at both ends.

(2) CONNECT AIR CLEANER TUBE. Connect air cleaner tube to bottom of relay valve and tighten clamp firmly. Install bolt, lock washer, and nut attaching vacuum line clip to frame crossmember.

(3) CONNECT HYDRAULIC LINES. Connect hydraulic outlet line to front of slave cylinder and connect inlet line to bottom rear of slave cylinder. Tighten connections firmly.

(4) LUBRICATE HYDROVAC AND BLEED SYSTEM. Lubricate Hydrovac as directed in Section VIII, and bleed *entire* brake system (par. 180).

189. WHEEL CYLINDERS.

a. One wheel cylinder is used at each wheel to transmit the hydraulic pressure energy in the hydraulic lines to the brake shoes. The hydraulic pressure forces the wheel cylinder pistons apart and outward. The brake shoes, interconnected with the wheel cylinder assembly, are also forced outward and against the drum, thus applying the brakes.

b. Removal. On vehicles equipped with demountable drums, it is only necessary to remove drum (par. 185) to gain access to wheel cylinders. On other vehicles, remove hub, drum, and bearings. If front cylinders are to be replaced, turn off shut-off cock on right-hand frame side rail.

(1) DISCONNECT BRAKE SHOES FROM WHEEL CYLINDER. Install wheel cylinder clamp (41-C-1835) over ends of wheel cylinder. Remove brake shoe return spring, then swing brake shoes outward and away from wheel cylinder ends.

(2) REMOVE WHEEL CYLINDER (fig. 183). Remove two backing plate to wheel cylinder cap screws and lock washers. Pull cylinder away from backing plate, then disconnect flexible hose [(GM-2196415) front; (GM-2076248) G85-01-01040 rear] connections at wheel cylinder by turning wheel cylinder, while wrench holds hose connection nut. Do not twist hose during this operation.

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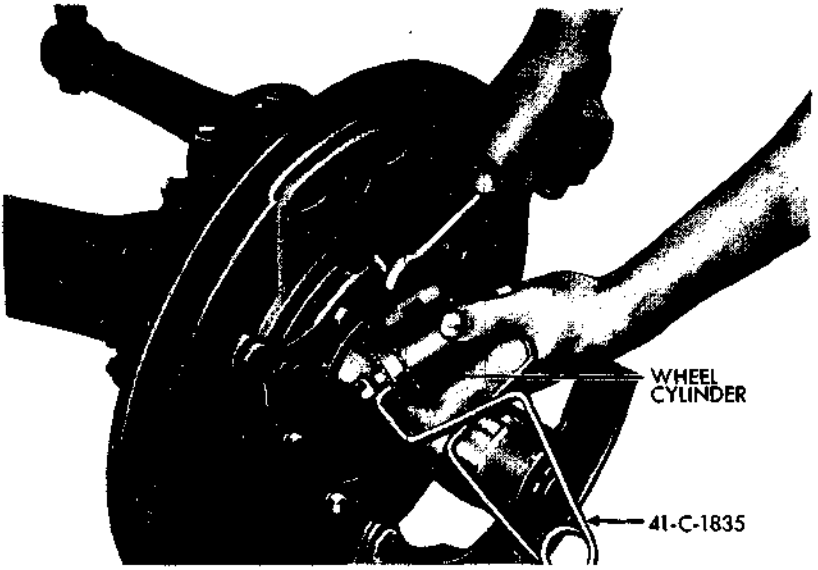

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Figure 183—Removal of Wheel Cylinder

c. **Installation.**

(1) ATTACH WHEEL CYLINDER TO BACKING PLATE. Place clamp (41-C-1835) over wheel cylinder. Install gasket [split type front only (GM-285059) G67-06-00810] over end of flexible hose with hose inserted through backing plate. Connect hose to wheel cylinder. Hold hose connection nut with wrench to prevent hose twisting, and turn wheel cylinder onto fitting. Install wheel cylinder [split type axle front (GM-2030567) G57-01-45860; banjo type front (GM-5451212) G501-01-45862; rear (GM-5451214) G501-01-45863] to backing plate with two backing plate to wheel cylinder cap screws and lock washers. Tighten cap screws securely. Position brake shoes at wheel cylinder adjusting studs, then install brake shoe return spring and remove clamp.

(2) INSTALL DRUM, OR HUB, DRUM, AND BEARINGS. Install demountable drum (par. 185) on vehicles so equipped. On other vehicles, install hub, drum, and bearings, then adjust bearings (par. 199).

(3) BLEED BRAKES. After wheel has been installed, open front brake line shut-off cock and bleed brake system (par. 180).

(4) ADJUST BRAKE SHOES. Adjust brake shoes at wheel which required cylinder replacement (par. 181).

190. VACUUM CHECK VALVE.

a. (fig. 184). The check valve is installed at the intake manifold in the vacuum line between the intake manifold and the Hydrovac unit. The purpose of the check valve is to seal the vacuum in the

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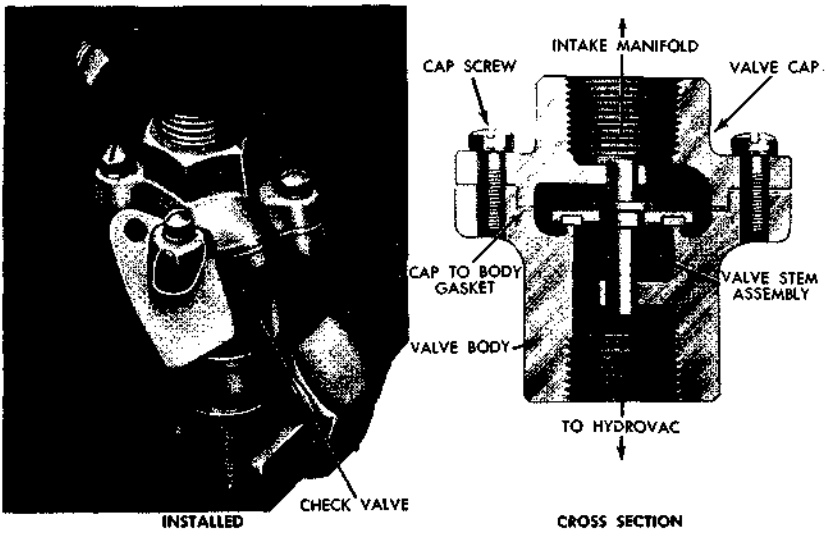

Figure 184—Vacuum Check Valve

Hydrovac and vacuum lines. Check valve mechanism seals vacuum in the lines after engine has been stopped, providing sufficient vacuum for a complete brake application.

b. Removal.

(1) DISCONNECT VACUUM LINE CONNECTION AT VALVE. Disconnect tube nut from elbow at bottom of check valve.

(2) REMOVE ELBOW. Remove elbow from bottom of check valve.

(3) REMOVE CHECK VALVE. Remove check valve from intake manifold fitting. Valve is threaded onto manifold fitting.

c. Installation.

(1) INSTALL CHECK VALVE TO MANIFOLD FITTING. Paint threads of intake manifold fitting, using anti-seize mica base compound. Install check valve to manifold fitting and tighten securely.

(2) INSTALL ELBOW. Paint male threads of elbow with anti-seize mica base compound, then install in check valve and tighten securely in proper alinment for vacuum line installation.

(3) INSTALL VACUUM LINE. Install vacuum line connection on elbow, and tighten connection. Make certain that all connections are tightened securely. Check for leaks (par. 179).

191. HYDRAULIC AND VACUUM LINES AND FITTINGS.

a. Hydraulic Lines and Fittings. The hydraulic lines between hydraulic master cylinder and Hydrovac unit and between Hydrovac unit and right- and left-hand frame side rails are metal type and clipped securely to crossmembers and frame side rails. Flexible tub-

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ing is used between frame side rail connections and each wheel cylinder. These flexible tubings are supportd with coil springs and clips attached to the frame side rails at rear and to fender skirts at front.

b. Metal Hydraulic Line Replacement. When the metal hydraulic lines within the frame side rails are replaced, make sure that all connections are tightened securely and that all lines are checked after replacement for leaks. After replacement of all hydraulic lines, bleed the system (par. 180). Metal hydraulic lines are accessible as follows:

(1) RIGHT-HAND FRONT TO LEFT-HAND FRONT BRAKE LINE. Right to left front brake line assembly is accessible along the front frame crossmember under radiator. It is clipped to the front crossmember with two clips, bolts, and nuts.

(2) SHUT-OFF COCK TO FRONT BRAKE LINE. Shut-off cock to right-hand front brake line tee line is clipped to the right-hand frame side rail and is accessible under the hood and under floor boards in the cab.

(3) FRONT WHEEL SHUT-OFF COCK (fig. 185). This shut-off cock is attached to a support on the inside of the right-hand frame side rail and is accessible under the floor boards of cab.

(4) HYDROVAC TO FRONT SHUT-OFF COCK LINE. Hydrovac to front shut-off cock line is attached to right-hand frame side rail. This line is accessible under the right-hand side of cab.

(5) MASTER CYLINDER TO HYDROVAC LINE. The master cylinder to Hydrovac line assembly extends from master cylinder along left-hand frame side rail, then along crossmember to left-hand frame side rail to tee. This line is clipped to crossmember and frame side rail with four clips, bolts, and nuts.

(6) RIGHT REAR TO LEFT REAR BRAKE LINE. Right to left rear brake line extends from right-hand tee along frame crossmember, then to left-hand tee on left-hand frame side rail. This line is clipped to crossmember with two clips, bolts, and nuts.

(7) INTERMEDIATE RIGHT-HAND BRAKE LINE. This line extends from right-hand tee to right forward rear axle brake line tee.

A FRAME SIDE RAIL
B SUPPORT BOLT
C BOLT NUT
D LOCK WASHER
E FLAT WASHER
F SHUT-OFF COCK SUPPORT
G HYDRAULIC LINE
H LINE NUT
I SHUT-OFF COCK

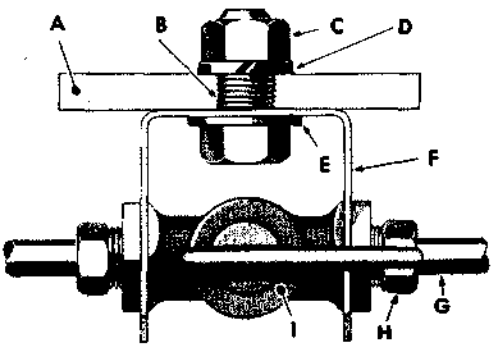

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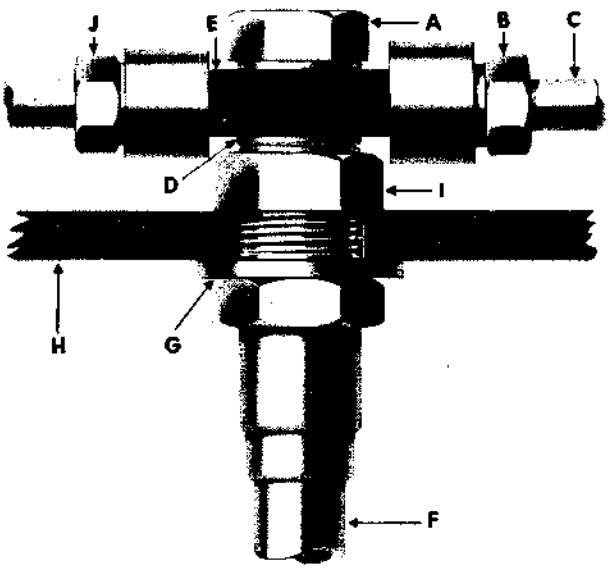
Figure 185—Front Wheel Shut-Off Cock



A TEE TO FITTING BOLT
B TUBING NUT
C HYDRAULIC METAL TUBING
D GASKET
E TUBE TEE
F FLEXIBLE HOSE
G TOOTHED LOCK WASHER
H FRAME SIDE RAIL
I LOCK NUT
J TUBING NUT

RA PD 333060

Figure 186—Frame Tee Connection

(8) REAR BRAKE LINES. The right- and left-hand rear brake lines extend along right and left frame side rails respectively from the forward rear axle brake line connections to the rearward rear axle connections. Each one of these lines is clipped to frame with two clips, bolts, and nuts.

(9) HYDROVAC TEE TO RIGHT-HAND FORWARD REAR AXLE TEE LINE. Hydrovac tee to right-hand forward rear axle tee line extends along inside of right-hand frame side rail. This line is held in place by clips, bolts, and nuts.

c. Flexible Tubing and Connection Replacement. Flexible brake lines extending from the frame side rails to the wheel cylinders at each brake assembly on right- and left-hand sides are attached at the frame side rail through special connections.

(1) TEE CONNECTION (fig. 186). Tee connections on the frame side rails at the right front wheel, and right- and left-hand forward rear wheels are of special construction. When the flexible lines between these tees and wheel cylinders are removed, it is necessary that tee attaching bolt and lock nut be removed, and hose connection pulled away from frame side rail. After this has been accomplished, the hose can be unscrewed from the wheel cylinder. Make certain

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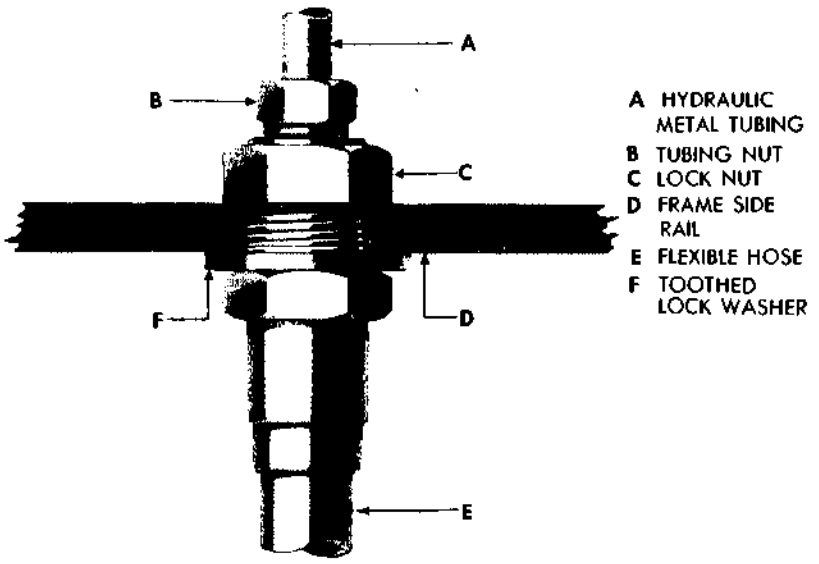

Figure 187—Frame Connection

that internal toothed lock washer and new tee gaskets (GM-231343) are positioned properly at installation.

(2) FRAME SIDE RAIL CONNECTIONS (fig. 187). The frame side rail connections at left and right rearward rear axle wheels, and left front wheels are special type. When removing the flexible lines with this type connection from wheel cylinder, it is necessary that the lock nut be removed. The flexible hose connection can then be removed from the frame side rail. After it is removed from the frame side rail, the flexible line can be removed from the wheel cylinder. When installing, make certain that a new internal toothed lock washer is used and connection is tightened securely.

d. Tube Repair. Hydraulic tubing may be cut and flared with standard flaring equipment.

Section XXXIV

HAND BRAKE SYSTEM

192. DESCRIPTION.

a. General. Manually operated hand brake lever at right of driver is connected by a rod and levers to an external contracting type brake band, mounted at rear of transfer case. Brake band assembly

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is anchored to the transfer case by supports integral with rear bearing cap. Brake drum is bolted between transfer case propeller shaft companion flange and universal joint flange yoke.

b. Operation (fig. 188). As hand brake lever is pulled back, brake rod is pulled forward, applying pressure to cam levers and adjusting bolt at brake band. Movement of cam levers and adjusting bolt draws ends of shoe toward each other, bringing lining into contact with drum. As hand brake lever is moved forward, brake rod moves to rear, transmitting movement to cam levers and adjusting bolt. Ends of band are forced apart by release springs to restore operating clearance between lining and drum.

193. ADJUSTMENT ON VEHICLE.

a. Adjustment Procedure (fig. 189). Adjust when hand brake lever reserve travel is less than one-half of the ratchet range. Operations must be performed in sequence as follows:

(1) DISCONNECT BRAKE ROD (fig. 189). Block wheel to prevent vehicle moving. Release brake by pushing hand brake lever forward as far as possible. Remove cotter pin and clevis pin attaching brake rod end to cam levers.

(2) ADJUST LINING AT ANCHOR (fig. 189). Remove lock wire at anchor screw slot. Adjust anchor screw to obtain a clearance of 0.010-0.015 inch between lining and drum at anchor. Insert lock wire through anchor bracket and slot in anchor screw, and twist end of wire to lock screw in adjusted position.

(3) ADJUST LINING AT BOTTOM (fig. 189). Loosen lock nut on locating screw. Hold screw with screw driver to prevent screw turning while adjusting nut is turned to obtain clearance of 0.020 inch between drum and lining. Tighten lock nut firmly.

(4) ADJUST LINING AT TOP (fig. 189). Loosen lock nut at lower end of adjusting bolt. Turn adjusting nut to obtain a clearance of 0.020 inch between lining and drum. Tighten lock nut firmly.

(5) ADJUST BRAKE ROD (fig. 189). Loosen brake rod end lock nut. Turn rod end as necessary to aline hole in end with holes in cam levers. Connect rod end to levers with clevis pin and secure with cotter pin. Tighten rod end lock nut firmly, then check hand brake lever for varying degrees of application. Remove blocks from wheels.

194. BRAKE DRUM.

a. Removal.

(1) DISCONNECT PROPELLER SHAFT. Block wheel to keep vehicle from moving. Push hand brake lever forward to fully released position. Remove the four nuts and lock washers from propeller shaft flange bolts at brake drum, and push bolts through drum. Telescope propeller shaft slip joint and swing shaft out of the way.

(2) LOOSEN BRAKE BAND. Remove lock wire from anchor screw, then remove anchor screw. Remove lock nut and adjusting nut from locating screw, then remove locating screw. Remove lock nut, adjusting nut, washers, and compression spring from adjusting bolt.

A BRAKE BAND ANCHOR CLIP SCREW
B BRAKE BAND ANCHOR BAR
C BRAKE BAND
D BRAKE LINING
E HAND BRAKE CAM LEVER PINS
F HAND BRAKE RELEASE SPRINGS
G HAND BRAKE ADJUSTING BOLT
H ADJUSTABLE ROD END
I HAND BRAKE SPACER LINK
J SUPPORT ASSEMBLY
K HAND BRAKE SECTOR BRACKET
L HAND BRAKE LEVER ASSEMBLY
M HAND BRAKE LEVER GRIP
N HAND BRAKE SECTOR
O LEVER ROD PAWL
P HAND BRAKE LEVER TO BRAKE ROD
Q BRAKE BAND LOCATING SCREW
R LOCATING SCREW ADJUSTING NUT AND LOCK NUT
S WASHER
T ADJUSTING BOLT NUT
U HAND BRAKE ADJUSTING BOLT
V LOCK NUT
W HAND BRAKE COMPRESSION SPRING
X HAND BRAKE DRUM
Y BRAKE BAND ANCHOR CLIP SPRING

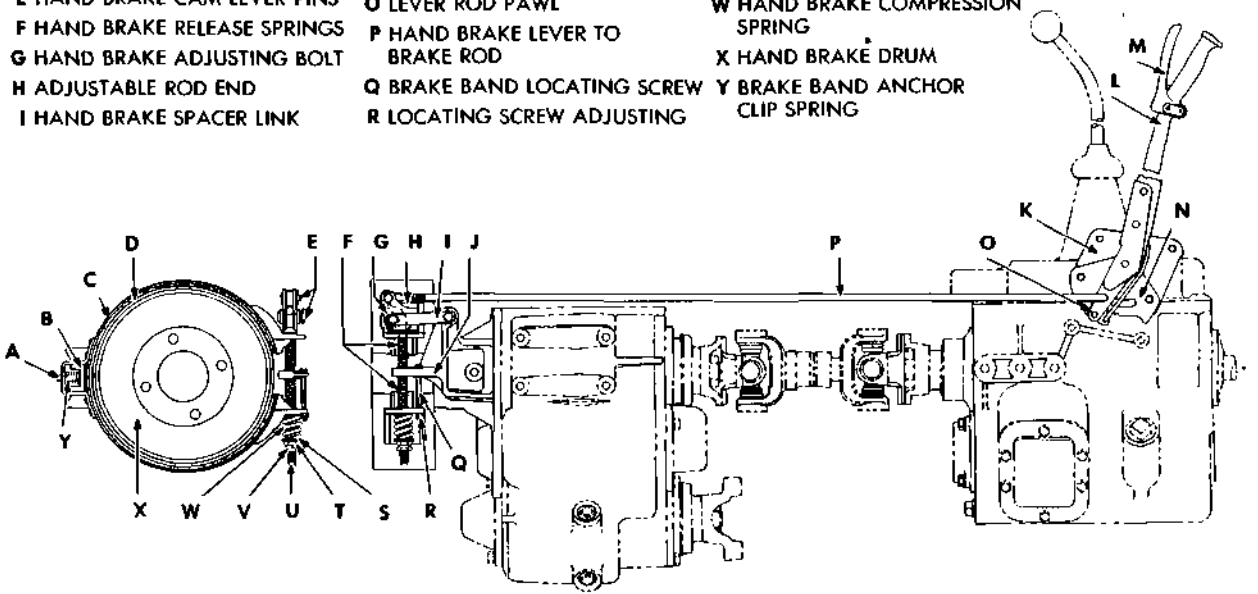

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Figure 188—Hand Brake, Lever, and Linkage

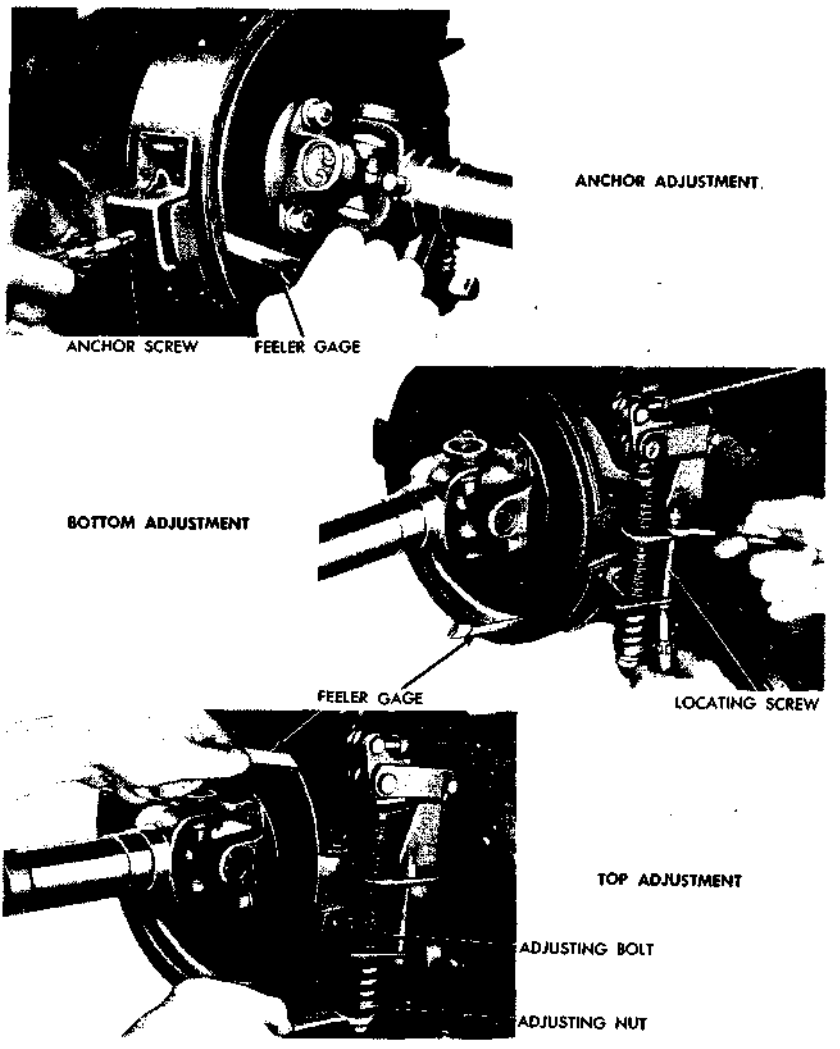

Figure 189—Hand Brake Band Adjustment

(3) REMOVE BRAKE DRUM. Pull brake band from anchor and swing band and drum to right, pivoting band on adjusting bolt. Use wood block and hammer to drive drum off transfer case companion flange if necessary. Remove drum from band. Whenever brake drum is removed, always examine condition of brake lining; replace band if lining is glazed, burnt, or excessively worn.

b. Installation.

(1) CLEAN AND INSPECT. Soak brake drum in dry-cleaning solvent, and wipe dry with clean cloth. Examine drum; replace with new

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drum if cracked or broken, or if deeply scored or grooved.

(2) INSTALL BRAKE DRUM. Position drum in band, then swing band and drum into position against transfer case companion flange. Swing brake band into position on anchor then install anchor clip spring and anchor screw. Install locating screw, then install adjusting nut and lock nut loosely on locating screw. Install compression spring, washers, adjusting nut, and lock nut on adjusting bolt.

(3) CONNECT PROPELLER SHAFT. Position propeller shaft flange to brake drum, position bolts, and install four lock washers and nuts. Make sure drum is properly alined with mating flanges, then tighten nuts firmly.

(4) ADJUST BRAKE BAND. Adjust brake band as described in paragraph 193 a.

195. BRAKE BAND.

a. Removal (fig. 188).

(1) REMOVE BRAKE DRUM. Remove brake drum as described in paragraph 194 a.

(2) DISCONNECT BRAKE LINKAGE. Remove cotter pin and hand brake cam lever clevis pin attaching linkage to adjusting bolt. Swing brake rod and spacer links out of the way.

(3) REMOVE BRAKE BAND. With band disengaged from anchor, rotate band approximately 45 degrees in a counterclockwise direction to permit removal of adjusting bolt. Remove adjusting bolt, release springs, and brake band.

b. Installation (fig. 188).

(1) INSTALL BRAKE BAND. Position brake band around brake drum. Insert adjusting bolt through upper bracket on band with hook end up, then install one release spring on bolt. Position assembly of drum and band on vehicle and insert adjusting bolt through hole in support. Swing drum and band to left side of vehicle, at same time rotating band clockwise into position.

(2) INSTALL SPRINGS AND ADJUSTMENTS. Swing brake band into position on anchor, then install anchor clip spring and anchor screw. Install bottom release spring on adjusting bolt, position bolt through bottom bracket, then install compression spring, washers, and nuts loosely. Install locating screw, then install nuts loosely on screw.

(3) CONNECT BRAKE LINKAGE. Position brake rod cam levers and spacer links to adjusting bolt. Install clevis pin and secure with cotter pin.

(4) CONNECT PROPELLER SHAFT. Connect propeller shaft as described in paragraph 194 b (3).

(5) ADJUST BRAKE BAND. Adjust brake band as described in paragraph 193 a.

196. BRAKE LINKAGE.

a. Removal (fig. 188).

(1) DISCONNECT BRAKE ROD. Block wheels to prevent movement of vehicle. Remove floor pan, then remove cotter pin attaching brake rod to hand brake lever. Remove cotter pin and clevis pin attaching brake rod end to cam levers, then remove brake rod from vehicle.

(2) REMOVE LEVER, SECTOR, AND BRACKET. Remove two cap screws and washers attaching sector bracket to transmission. Remove hand brake lever, sector, and sector bracket as an assembly from vehicle.

(3) DISASSEMBLE LEVER, SECTOR, AND BRACKET. Remove two nuts and lock washers from bolts attaching sector to sector bracket, remove two bolts and spacers, then remove sector bracket. Remove bolt and washer attaching hand brake lever to sector, then separate sector from lever.

b. Installation (fig. 188).

(1) ASSEMBLE LEVER, SECTOR, AND BRACKET. Assemble sector and lever with bolt and nut. Install two bolts through lower holes in sector bracket with flat head bolt in countersunk hole. Install a spacer on each bolt, then position bracket to sector with bolts inserted through holes in sector. Install two lock washers and nuts, and tighten nuts firmly.

(2) INSTALL LEVER, SECTOR, AND BRACKET. Position assembly of lever, sector, and bracket in vehicle. Install two cap screws and lock washers through upper holes in sector bracket into tapped holes in transmission, and tighten cap screws firmly.

(3) INSTALL BRAKE ROD. Loosen brake rod end lock nut, then position brake rod in vehicle. Hook end of rod in brake lever and install cotter pin. Turn rod end as necessary to aline hole in end with holes in cam levers. Install clevis pin and secure with cotter pin. Tighten rod end lock nut firmly. Position and install floor pan, then remove blocks from wheels.

Section XXXV

WHEELS, TIRES, AND HUBS

197. WHEELS.

a. Front.

(1) ALL VEHICLES EXCEPT CHASSIS SERIAL NO. CCKW 353-236404-2 TO 236520-2 (fig. 190). Each disc-type front wheel is mounted on six hub studs, and is held in place with inner nuts which thread directly on studs. Outer nuts, which permit installation of dual wheels, thread over inner nuts. These wheels are equipped with lock ring type rim (RH type).

(2) CHASSIS SERIAL NO. CCKW-353-236404-2 TO 236520-2 ONLY (fig. 191). On these vehicles, single disc wheel is attached to hub with six nuts. Wheel is equipped with side ring type rim (CV type) with bead lock type tire.

b. Rear.

(1) ALL VEHICLES EXCEPT CHASSIS SERIAL NO. CCKW-353-236404-2 TO 236520-2 (fig. 192). Dual rear wheels are mounted on

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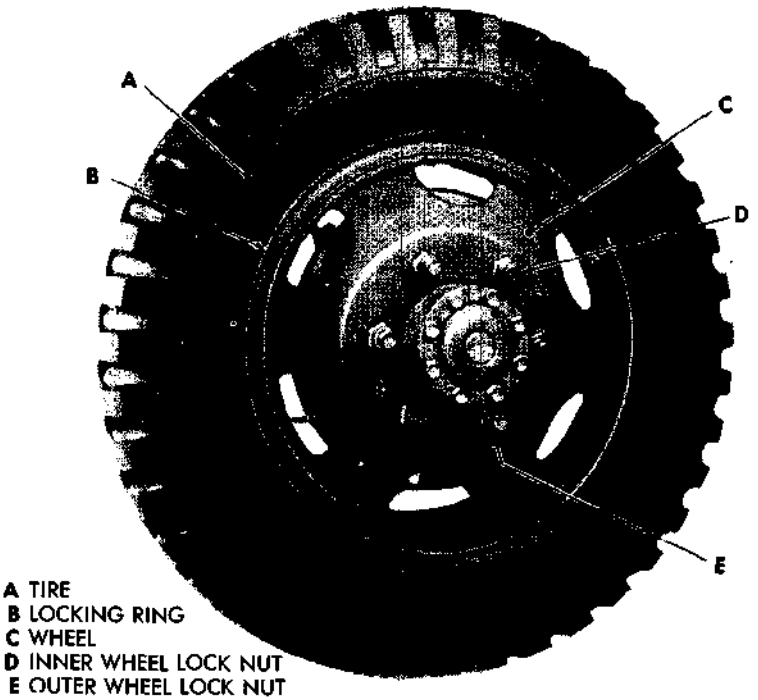


Figure 190—Front Wheel Mounting (Standard)

six stud hubs. The inner wheel is held in place with sleeve type square-headed inner nuts, which thread on hub studs. The outer wheel is mounted over inner nuts and is held in place with hex nuts which thread on inner nuts. The wheels are equipped with lock ring type rims (RH type).

(2) CHASSIS SERIAL NO. CCKW-353-236404-2 TO 236520-2 ONLY (fig. 191). On these vehicles, each single rear wheel is attached to a wheel spacer by six studs and nuts. Wheel spacer is attached to hub studs by sleeve-type nuts.

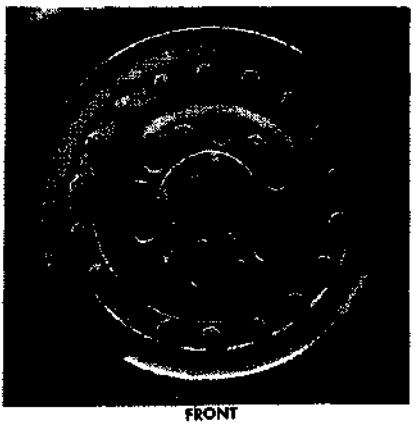
c. **Tightening Wheel Nuts.** Wheel nuts on right- and left-hand wheels are not interchangeable. Nuts for right-hand wheels are marked *R*, while nuts for left-hand wheels are marked *L*.

(1) STANDARD WHEELS.

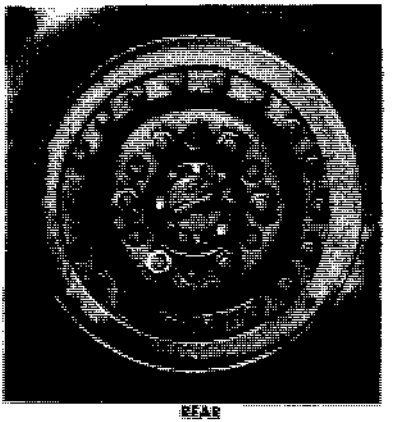
(a) Front Wheels. The inner nuts actually hold wheel in place. With wrench furnished with vehicle, tighten inner nuts (square-headed) alternately. Tighten outer (hex) nuts in same manner. *Do not use added extension on wrench.*

(b) Rear (fig. 192). Loosen outer nuts (hex), then alternately tighten inner nuts (square-headed) with wrench and extension furnished with vehicle. Tighten outer nuts (hex) in same manner.

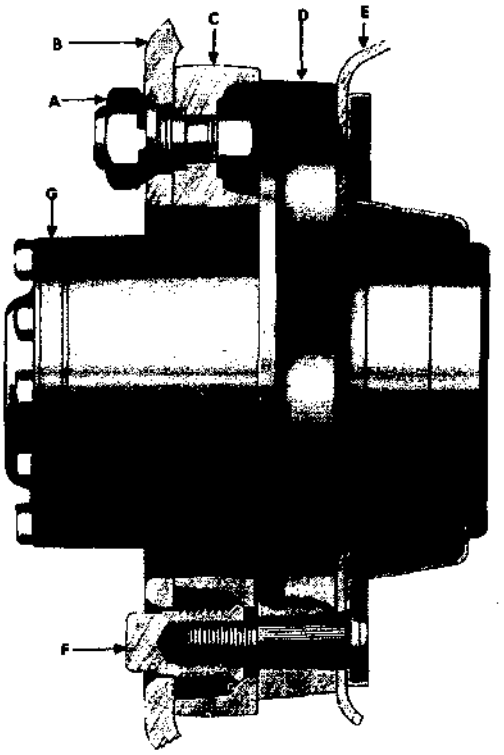
(2) WHEELS ON CHASSIS SERIAL NO. CCKW 353-236404-2 TO 236520-2 ONLY. Tighten front wheel nuts alternately with wrench



FRONT



REAR



REAR WHEEL MOUNTING

A WHEEL NUT
B WHEEL
C WHEEL SPACER
D HUB
E BRAKE DRUM
F WHEEL SPACER NUT
G AXLE SHAFT DRIVE FLANGE

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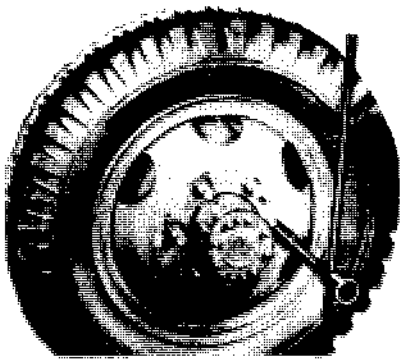
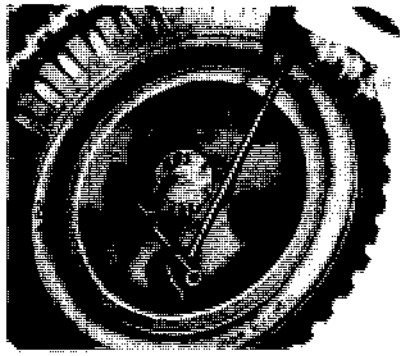
Figure 191—Front and Rear Wheel Mounting (Bead Lock Type)

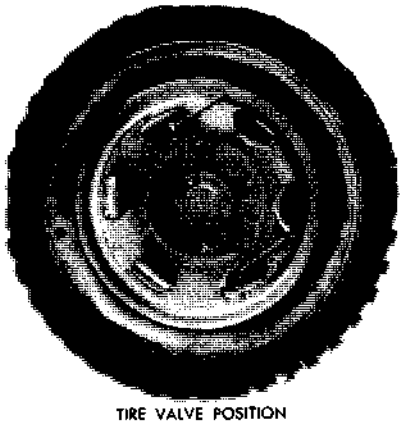


INNER

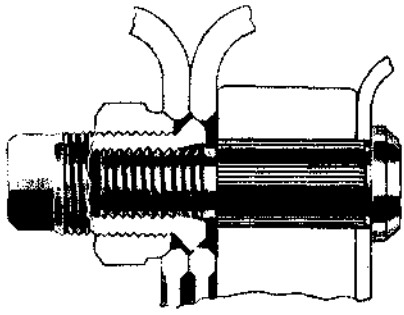


OUTER

TIGHTENING REAR WHEEL



TIRE VALVE POSITION



DUAL WHEEL MOUNTING NUTS

RA PD 332974

Figure 192—Rear Wheel Mounting (Standard)

and extension furnished with vehicle. On rear wheels, tighten the square-head spacer nuts first, then the wheel nuts. *Do not attempt to tighten or loosen side ring nuts while tire is inflated. This procedure is dangerous.*

d. Wheel Replacement.

(1) FRONT.

(a) Standard Wheel. Jack up wheel until tire clears ground. Remove inner nut [R.H.—(GM-279672) G501-03-14847; L.H.—(GM-279673) G501-03-14848], and outer nut [R.H.—(GM-279670) G501-03-14845; L.H.—(GM-279671) G501-03-14846], together by applying wrench to inner nut (square-head). Install in reverse manner and tighten as previously explained.

(b) On Chassis Serial No. CCKW-353-236404-2 to 236520-2 Only (fig. 191). Remove the six wheel nuts. Do not loosen side ring nuts.

(2) REAR.

(a) Standard Wheel (fig. 192). Remove outer nuts (hex) first; remove outer wheel. Remove all inner nuts (square-head); then remove inner wheel. When installing, install outer wheel in such a position to permit access to inner tire valve stem (fig. 192). Tighten wheel nuts as explained in subparagraph c (1) *(a)* above.

(b) On Chassis Serial No. CCKW 353-236404-2 to 236520-2 Only (fig. 191). Remove the hex wheel nuts only. Do not remove the square-head spacer nuts. After installation, tighten nuts in manner described in subparagraph c (2) above.

198. TIRES AND RIMS.

a. Standard. Pneumatic tires are held to rim with a solid clamp ring.

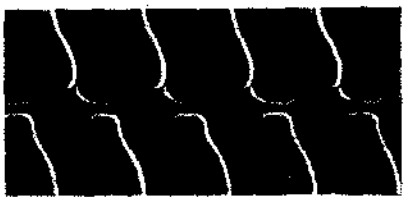
b. On Chassis Serial No. CCKW 353-236404-2 to 236520-2. These vehicles are equipped with hinged metal bead lock type rims with a side ring bolted to wheel.

c. Tire Inflation. Inflation pressure on standard tire is 55 pounds. On bead-lock tires, the pressure is 40 pounds. Tire pressure in all tires must be equal. Before tires are inflated at regular inspection, each tire should be gaged for pressure loss. When making a pressure loss check, use the same gage on all tires so that any element of gage inaccuracy will be same on all tires. If any appreciable loss is noted in any one tire, that tire should be dismounted and checked.

d. Tire Replacement. Replacement tires should be of same make, if possible, as those on vehicle. If tires do not have same outside diameter within ¼ inch, excessive tread scuffing will result. When replacement is made, make selection by measuring outside diameter. Tires may be equipped with either non-directional or directional treads (fig. 193). Non-directional tread tires may be placed in any position on wheels. Directional tread tires must be positioned as follows:

(1) FRONT. Mount with the open part of the V-tread in direction of rotation—so that open part of "V" contacts ground first.

(2) REAR. Mount so that point of "V" is toward direction of rotation.



ONE TYPE NON-DIRECTIONAL TREAD PATTERN

DIRECTIONAL TREAD TYPE PATTERN

RA PD 64520

Figure 193—Tire Tread Patterns

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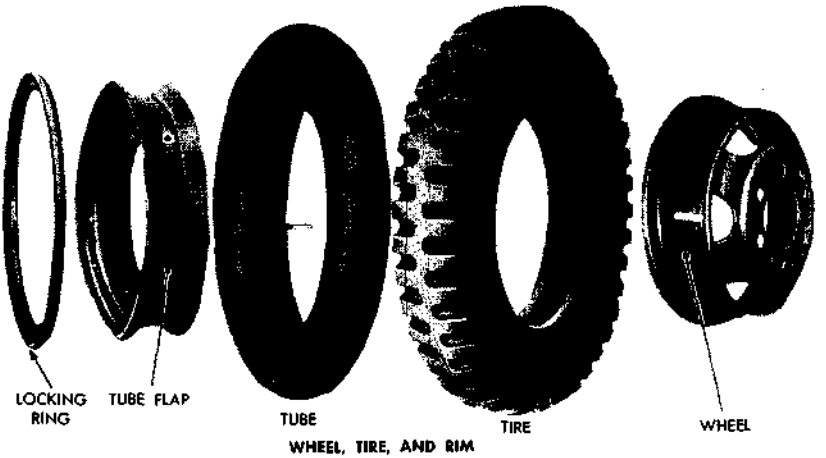

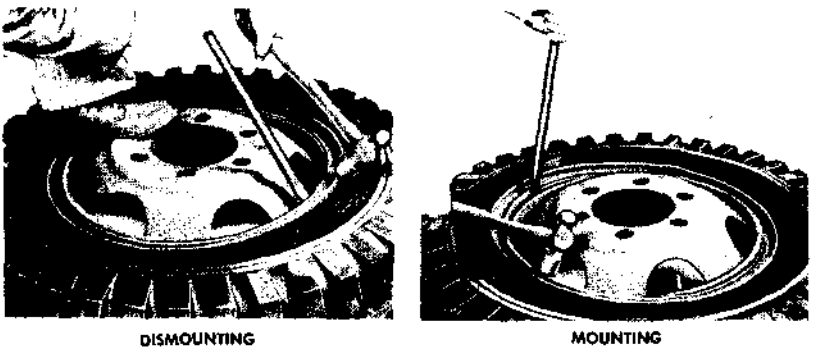

RA PD 333016

Figure 194—Standard Tire Mounting and Dismounting

e. **Dismounting and Mounting Tires (Standard Tires)** (fig. 194).

(1) DISMOUNTING. Jack up vehicle and remove wheel. Lay wheel and tire flat. Deflate tube by removing valve core. Force one side of clamp ring toward center of wheel until it drops into groove in wheel. Insert heavy screw driver into recess in clamp ring and pry this side of ring out over edge of wheel. Work ring off with tire irons and remove tire, flap, and tube.

(2) MOUNTING.

(a) Install Tube. Install tube in tire so that valve stem is at red dot on sidewall of tire. Install tire flap. Inflate tube sufficiently to prevent tube falling out or being pinched during mounting.

(b) Install Tire on Rim. Place wheel flat on floor or ground and drop tire down over wheel. Carefully insert valve stem in hole in rim pointing toward the concave side of the wheel.

(c) Install Clamp Ring. Place one edge of clamp ring over edge of rim and force entire ring over rim, using a heavy brass or

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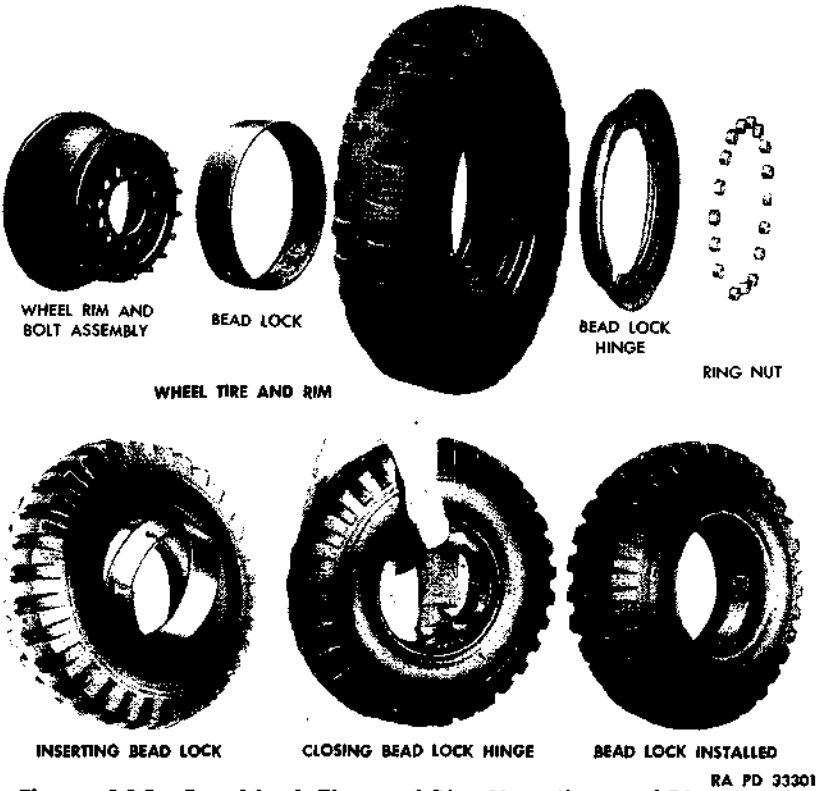

Figure 195—Bead Lock Tire and Rim Mounting and Dismounting

soft metal hammer. Be sure clamp ring is seated against rim of wheel through its whole circumference. Inflate tire to 55 pounds. Install wheel and tighten mounting nuts.

f. Dismounting and Mounting Tires—Bead Lock Type (CCKW 353-236404-2 to 236520-2 Only) (fig. 195).

(1) DISMOUNTING.

(a) Remove Wheel and Deflate Tire. Remove wheel. *Completely deflate tire. Do not attempt to remove side ring nuts until tire has been completely deflated.*

(b) Remove Side Ring. With wrench furnished with vehicle, remove the 17 hex nuts which attach ring to wheel.

(c) Remove Bead Lock. Use tire irons around bead of tire to dislodge it from rim. Lift tire, tube, and bead lock from rim. Reinstall valve core and inflate tube enough to spread tire beads. Use lock ring removing bar to pry up on bead lock at a point about eight inches from hinge. Press at point on bead lock marked, **"To collapse, press here."** After bead lock has collapsed to limit of hinge, turn lock 90 degrees in tire to provide necessary clearance at

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valve stem. Remove bead lock from casing, then deflate tube and remove.

(2) MOUNTING.

(a) Install Tube. Install tube in casing and inflate enough to hold in place.

(b) Install Bead Lock over Valve Stem. With bead lock collapsed, insert valve stem through hole in lock. Install inside of tire with plane of lock at 90 degrees to plane of tire. Collapse and press bead half-way through tire.

(c) Position Bead Lock in Tire. Inflate tube sufficiently to spring casing beads apart about same width as bead lock. Turn bead lock in tire from its 90 degree position. While working lock into position between tire beads, turn bead lock until lug near valve stem is directly under stem after bead lock is in position.

(d) Close Bead Lock Hinge. Deflate tire completely. Hold one end of lock in place with one foot, and jerk other end up sharply with both hands until hinge snaps into place. Bead lock must be centered so that its edges are below beads of tires all the way around.

(e) Install Tire on Rim. Install tire and bead lock assembly on wheel rim with valve stem pointing outward. Be sure that lug on bead lock engages valve stem slot in wheel rim.

(f) Install Side Ring. Install side ring and tighten nuts alternately with wrench furnished with vehicle. *These nuts must be tightened before attempting to inflate tire.* Inflate tire, *after* nuts have been tightened, to 40 pounds. Reinstall wheel, tighten wheel nuts.

199. WHEEL BEARING ADJUSTMENT.

a. General. All hubs are mounted on opposed tapered roller bearings which can be adjusted for wear whenever necessary. The actual method of adjustment is the same for both front and rear hubs (split or banjo type axles), however, construction of adjusting nuts, locks, lock nuts, and seals differ on the two types of axles.

b. Checking Adjustment. Jack up wheel to be checked until tire clears ground. Check the sideways "shake" of wheels. Grasp tire at top and pull back and forth, or use a long bar under tire. If bearings are correctly adjusted, movement of brake drum in relation to top of dust shield will be just perceptible, with wheel turning freely. If movement is excessive, adjustment is required as explained in subparagraphs c and d below.

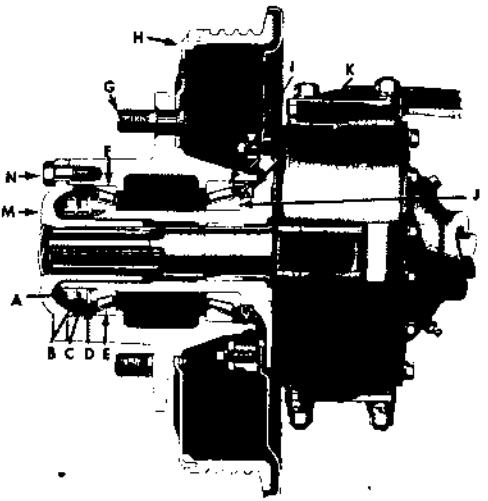
c. Front Hub Bearing Adjustment.

(1) BANJO TYPE AXLES (fig. 196).

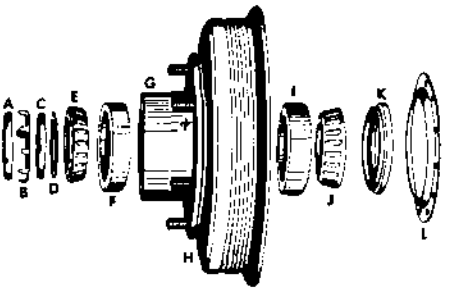
(a) Remove drive flange (par. 167 b (2)). Bend tangs of lock away from outer nut. With wrench furnished with vehicle (use notched end), remove outer nut. Remove nut lock.

(b) While turning wheel, tighten inner nut until wheel binds. Back off nut about one-eighth turn, then check adjustment.

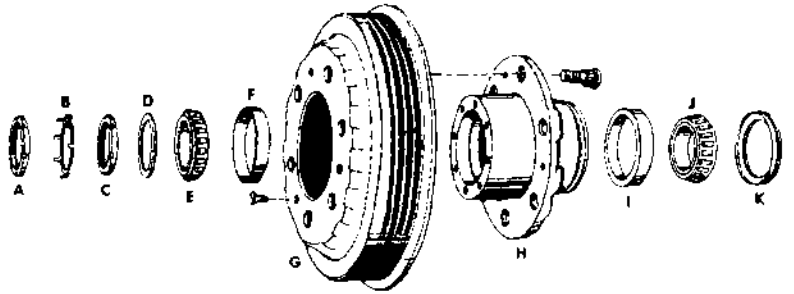
(c) Install new lock, then bend short tang of lock into a notch of inner nut. Install outer nut and tighten firmly. Check adjustment, then bend long tangs of lock over outer nut. Reinstall drive flange (par. 167 d (6)).



CROSS SECTION—CONVENTIONAL TYPE DRUM SHOWN



HUB AND DRUM COMPONENTS—CONVENTIONAL TYPE DRUM



HUB AND DRUM COMPONENTS—DEMOUNTABLE TYPE DRUM

A OUTER NUT
B LOCK
C INNER NUT
D WASHER
E OUTER CONE AND ROLLERS
F OUTER BEARING CUP
G HUB
H DRUM
I INNER BEARING CUP
J INNER CONE AND ROLLERS
K INNER BEARING OIL SEAL ASSEMBLY
L INNER OIL DEFLECTOR
M DRIVE FLANGE
N DRIVE FLANGE CAP SCREW
O GASKET

RA PD 333050

Figure 196—Front Hub and Bearings—Banjo Type Axles

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(2) SPLIT TYPE AXLES (fig. 197).

(a) Remove drive flange (par. 167 e (2)). Bend lock away from outer nut. With hex end of adjusting wrench, remove outer nut. Remove nut lock.

(b) While turning wheel, tighten inner nut until wheel binds. Back off nut about one-eighth turn, then check adjustment.

(c) Install new lock, then bend portion of lock over inner nut. Install and tighten outer nut. Check adjustment, then bend portion of lock over outer nut. Reinstall drive flange (par. 167 g (4)).

d. Rear Hub Bearing Adjustment (fig. 198).

(1) BANJO TYPE AXLES. Adjustment procedures are same as described for front hub (subpar. c (1) above) except that axle shaft must be removed (par. 171). Outer nut also includes a seal assembly.

(2) SPLIT TYPE AXLES (fig. 199). Remove axle shaft (par. 172). Remove outer oil seal and retainer. Balance of procedure is the same as described in subparagraph c (2) above. New axle shaft flange and oil seal retainer gaskets must be used when these parts are reinstalled.

200. CLEANING AND LUBRICATING WHEEL BEARINGS.

a. Whenever hubs and bearings are removed for replacement of parts or at periods indicated in paragraph 37, hubs and bearings must be cleaned and lubricated in following manner:

(1) PRELIMINARY. Remove wheels (par. 197). Remove hubs and bearings (par. 201 or 202).

(2) CLEAN AND INSPECT BEARING CONE AND ROLLER ASSEMBLIES. Immerse bearing cone and roller assemblies in dry-cleaning solvent. Clean with a stiff brush to remove all old lubricant. Blow dry with compressed air, directing air across bearings. Do not spin dry bearings with air or hands. Inspect rollers for defects and wear. Do not reinstall bearings if pitted, worn, or scored.

(3) LUBRICATE CONE AND ROLLER BEARING ASSEMBLIES. Using lubricant specified on Lubrication Order, roll or knead lubricant into rollers, completely filling spaces above and beneath cone. Use bearing lubricator if available. Wrap bearings in clean cloth if not to be installed immediately.

(4) CLEAN AND INSPECT HUBS AND BEARING CUPS. Thoroughly wash hub with dry-cleaning solvent, removing all old lubricant. Inspect condition of bearing cups. Replace if worn, distorted, or scored.

(5) LUBRICATE HUBS AND SPINDLES. Apply a thin coat (not over 1/16 in. thick) of same lubricant used on bearings to inside surface of hub, outside surface of spindle, and inner surface of drive flange. Do not pack or fill hub with lubricant as this excess may result in leakage onto brake lining.

(6) DURING AND AFTER INSTALLATION OF HUB AND BEARINGS. Install hubs and bearings as instructed in paragraph 201 or 202. During installation, coat inner bearing cage and fill space between inner bearing and inner seal with lubricant. After bearing adjust-

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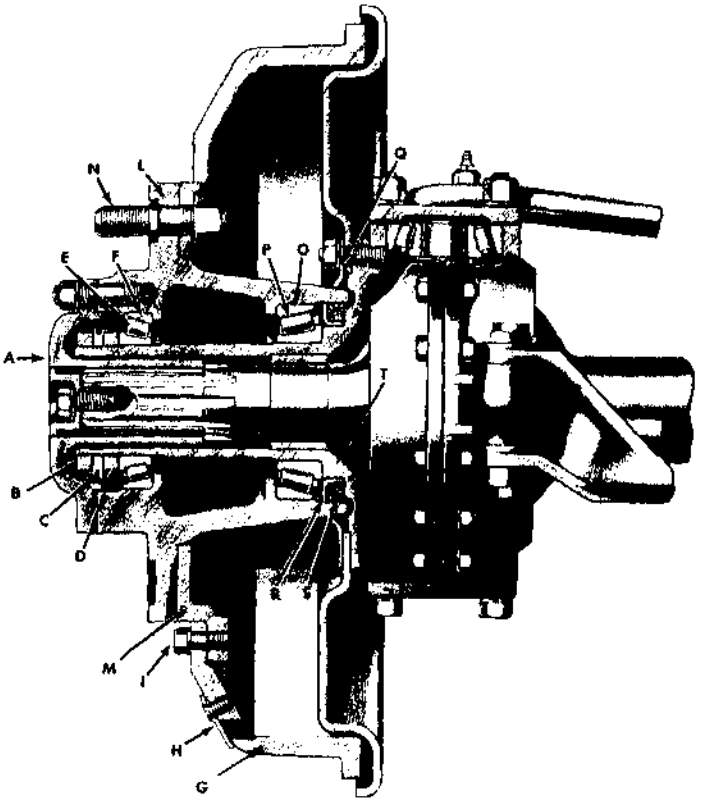
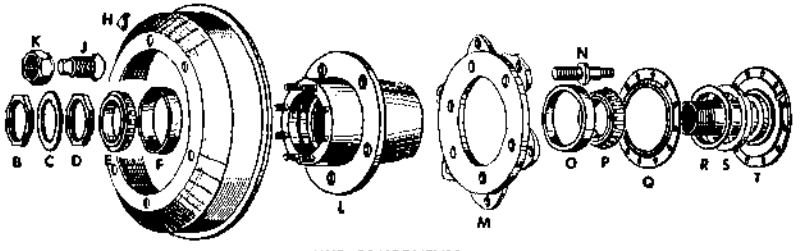


CROSS SECTION—DEMOUNTABLE TYPE DRUM



HUB COMPONENTS

A DRIVE FLANGE
B OUTER NUT
C LOCK
D INNER NUT
E OUTER CONE AND ROLLERS
F OUTER BEARING CUP
G BRAKE DRUM
H INSPECTION HOLE COVER
I DRUM CAP SCREW
J LOCKING NUT, INNER
K LOCKING NUT, OUTER
L HUB
M ADAPTER
N FRONT WHEEL STUD
O INNER BEARING CUP
P INNER CONE AND ROLLERS
Q SHIELD
R SEAL RETAINER
S SEAL
T KNUCKLE

RA PD 333029

Figure 197—Front Hub and Bearings—Split Type Axles

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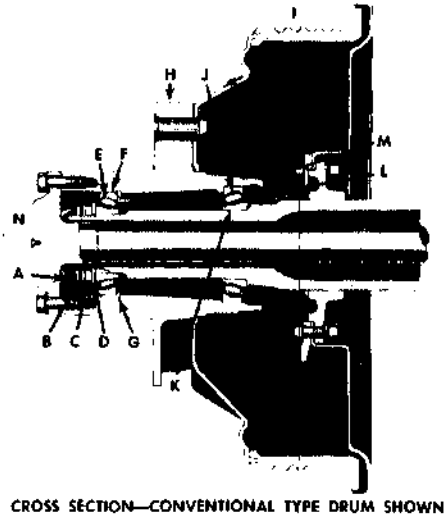
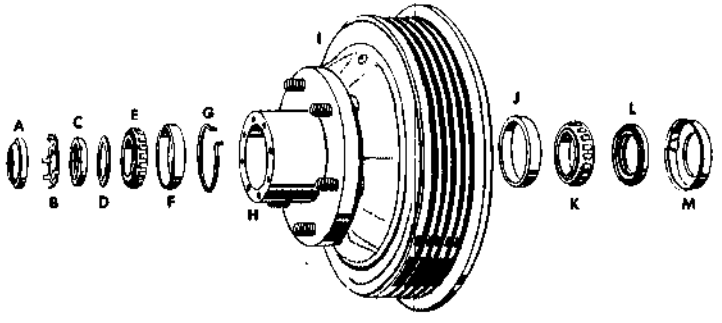
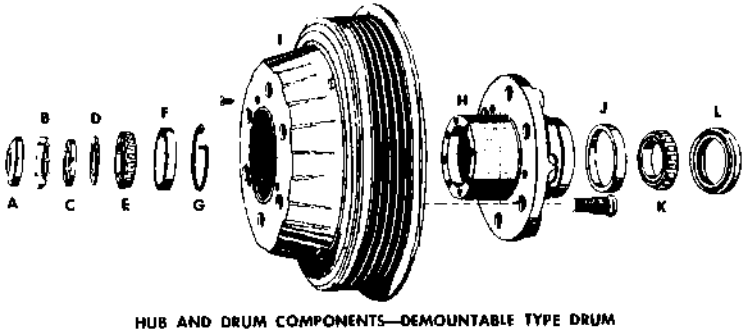
WHEELS, TIRES, AND HUBS



CROSS SECTION—CONVENTIONAL TYPE DRUM SHOWN



HUB AND DRUM COMPONENTS—CONVENTIONAL TYPE DRUM

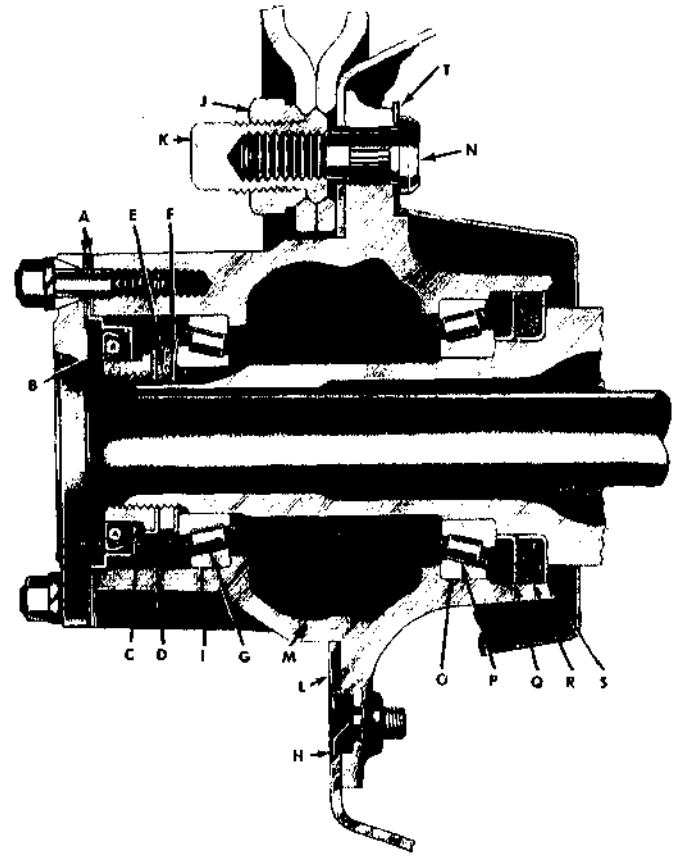


HUB AND DRUM COMPONENTS—DEMOUNTABLE TYPE DRUM

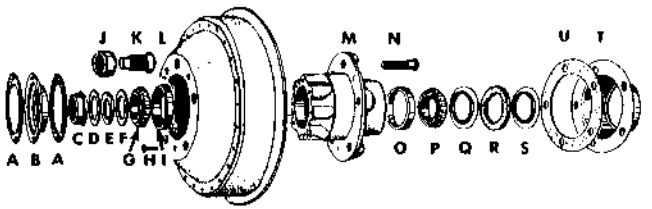
A OUTER NUT AND SEAL
B LOCK
C INNER NUT
D WASHER
E OUTER CONE AND ROLLERS
F OUTER BEARING CUP
G SNAP RING
H HUB
I BRAKE DRUM
J INNER BEARING CUP
K INNER CONE AND ROLLERS
L INNER OIL SEAL ASSEMBLY
M OIL DEFLECTOR
N AXLE SHAFT

RA PD 333051

Figure 198—Rear Hub and Bearings—Banjo Type Axles



CROSS SECTION



HUB COMPONENTS

A FLANGE GASKET
B OUTER OIL SEAL
C OUTER NUT
D LOCK
E INNER NUT
F WASHER
G OUTER CONE AND ROLLERS
H DRUM SCREW
I OUTER BEARING CUP
J OUTER LOCKING NUT
K INNER LOCKING NUT
L BRAKE DRUM
M HUB
N WHEEL STUD
O INNER BEARING CUP
P INNER CONE AND ROLLERS
Q RETAINER
R OIL SEAL
S RETAINER
T SHIELD
U GASKET

RA PD 333002

Figure 199—Rear Hub and Bearings—Split Type Axle

ES18-002672 0519

ment, fill annular space between hub wall and adjusting nut (outside of outer bearing) with lubricant.

201. HUBS AND BEARINGS—BANJO TYPE AXLES.

a. Description.

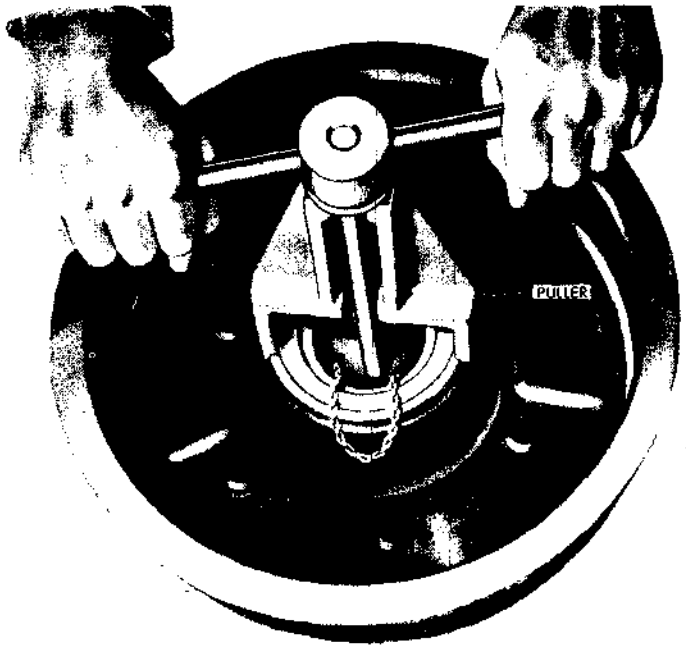
(1) FRONT (fig. 196). The hub and bearings are retained in place with inner and outer adjusting nuts, with a star lock between the two nuts. A spacer washer is used between outer bearing and inner adjusting nut. An oil seal assembly is pressed into inner end of hub.

(2) REAR (fig. 198). The hub and bearings are retained in place with an inner adjusting nut and an outer nut and seal assembly. A star lock is installed between inner and outer nuts. A spacer washer is used between outer bearing and inner adjusting nut. An oil seal assembly is pressed into inner end of hub.

b. Front Hub and Bearing Removal.

(1) REMOVE WHEEL AND DRIVE FLANGE. Remove wheel. Remove drive flange (par. 167 b (2)).

(2) REMOVE ADJUSTING NUTS, LOCK, AND SPACER WASHER. Bend tangs of lock away from outer nut. Remove outer nut and lock [(GM-3659724) G85-31-08140], then remove inner nut and spacer washer.



RA PD 332964

Figure 200—Removing Inner Cone and Rollers (Puller 41-P-2898)

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(3) REMOVE HUB AND BEARINGS. Pull hub and drum straight off from steering knuckle. Bearings, cups, and inner oil seal are withdrawn with hub and drum. Remove outer bearing cone and roller assembly [(GM-144507) G85-31-04520] with fingers.

(4) REMOVE INNER OIL SEAL AND CONE AND ROLLER ASSEMBLY. With special puller (41-P-2898), remove inner bearing cone assembly, [(GM-186574) G85-31-04500] and inner oil seal [(GM-3665138) G-85-31-12420]. The remover tool is installed in hub by tilting the plate with the chain attached, so that it may be slipped through the bearing and engage the outer race of the bearing. The plate is then held in this position by chain while threading the remover shaft into the tapped hole. The remover body is then located against the seal housing. The bearing assembly and oil seal are removed by turning the remover handle (fig. 200).

(5) REMOVE CUPS (IF NECESSARY). Use a drift through inner side of hub. With light hammer, drive on alternate sides to prevent cocking in hub. [Inner cup—(GM-186573) G85-31-05000; outer cup—(GM-142224) G85-31-05020].

c. Front Hub and Bearing Installation.

(1) CLEAN AND LUBRICATE HUB AND BEARINGS. Clean and lubricate hub and bearings as directed in paragraph 200.

(2) INSTALL CUPS. Install inner and outer cups in hub with

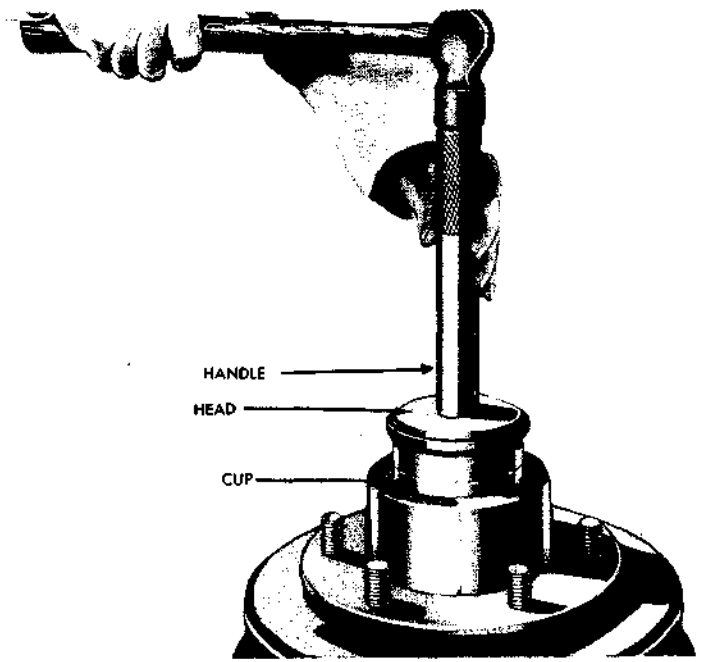

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Figure 201—Method of Installing Outer Cup—Front Hub (Driver Head 41-H-1780 and Handle 41-H-1074)

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wide side of each cup toward center of hub. Use special driver head (41-H-1780) with handle (41-H-1074) in manner illustrated in figure 201 for both cups.

(3) INSTALL INNER CONE AND ROLLER ASSEMBLY AND OIL SEAL. Install inner cone and roller assembly in hub; then install new inner oil seal into hub. Use a replacer similar to that illustrated in figure 202, or a block of wood. Flexible portion of seal must be toward bearing. Follow lubrication instructions as described in paragraph 200.

(4) INSTALL HUB AND OUTER BEARING. Install hub, then outer bearing. Install spacer washer, inner nut, lock, and outer nut. Tighten temporarily. Do not adjust bearings until wheel is installed.

(5) INSTALL WHEEL AND ADJUST BEARINGS. Install wheel, then adjust bearings as described in paragraph 199 c (1). Fill annular space between hub wall and adjusting nut with lubricant (par. 200).

(6) INSTALL DRIVE FLANGE. Install drive flange (par. 167 d (6).

d. Rear Hub Bearing Removal.

(1) REMOVE WHEEL AND AXLE SHAFT. Remove wheel. Remove axle shaft (par. 171).

(2) REMOVE ADJUSTING NUTS, LOCK, AND SPACER WASHER. Bend tangs away from outer nut, then remove outer nut and seal [(GM-3660091) G85-31-08780], lock [(GM-3660090) G85-31-08180], inner nut, and spacer washer.

(3) REMOVE HUB AND BEARINGS. Pull hub and drum straight from axle housing. Bearing cones, cups, and inner seal will be withdrawn with hub. Remove outer bearing cone [(GM-144526) G501-01-39901] from hub with fingers.

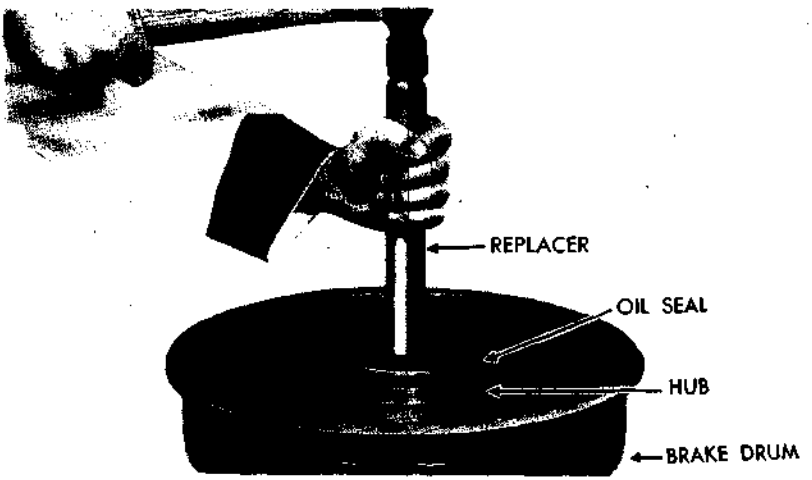
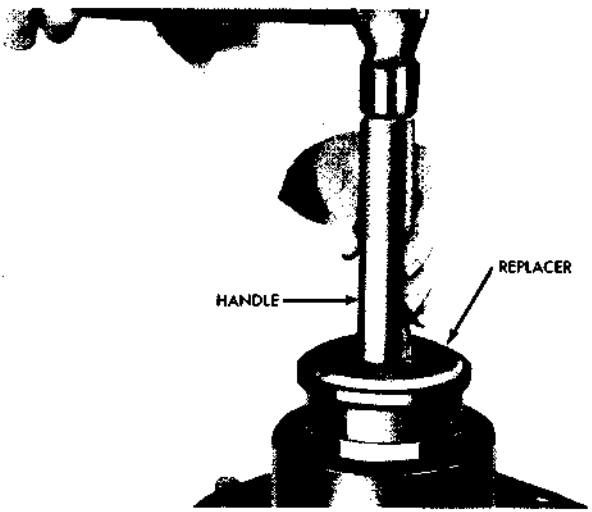


Figure 202—Installing Inner Seal



RA PD 332906

Figure 203—Method of Installing Outer Cup—Rear Hub (Handle 41-H-1511 with Replacer 41-R-2396-20)

(4) REMOVE INNER OIL SEAL AND INNER BEARING CONE ASSEMBLY. Follow instructions described in subparagraph b (4) above—[inner cone, (GM-144528) G501-01-39902; seal (GM-599847) G85-31-12560].

(5) REMOVE CUPS (IF NECESSARY). Use a drift through inner side of hub. When removing outer cup, use drift against cup and not against snap ring. Do not remove snap ring unless damaged. [inner cup (GM-127631) G501-01-43548; outer cup (GM-127627) G501-01-43547].

e. Rear Hub and Bearing Installation.

(1) CLEAN AND LUBRICATE HUB AND BEARINGS. Clean and lubricate hub and bearings as directed in paragraph 200.

(2) INSTALL CUPS. Install inner and outer cups in hub with wide side of each cup toward center of hub. On inner cup use special replacer (41-R-2396-22) with handle (41-H-1511). On outer cup use special replacer (41-R-2396-20) with handle (41-H-1511). Drive outer cup against snap ring (fig. 203).

(3) INSTALL INNER CONE AND ROLLER ASSEMBLY. Install inner cone and roller assembly into hub. If new inner oil seal is used, soak in warm engine oil until leather is pliable. Install seal into hub and lock in place by prick punching at three equally spaced points. Follow lubrication instructions in paragraph 200.

(4) INSTALL HUB AND OUTER BEARING. Install hub, then outer bearing. Install spacer washer, inner nut, lock, and outer nut and seal assembly. Tighten temporarily. Install wheel.

ES18-002672 0523

(5) ADJUST BEARINGS. Adjust bearings as described in paragraph 199 d (1). Fill annular space between hub wall and adjusting nut with lubricant (par. 200).

(6) INSTALL AXLE SHAFT. Install axle shaft (par. 171).

202. HUBS AND BEARINGS—SPLIT TYPE AXLES.

a. Description.

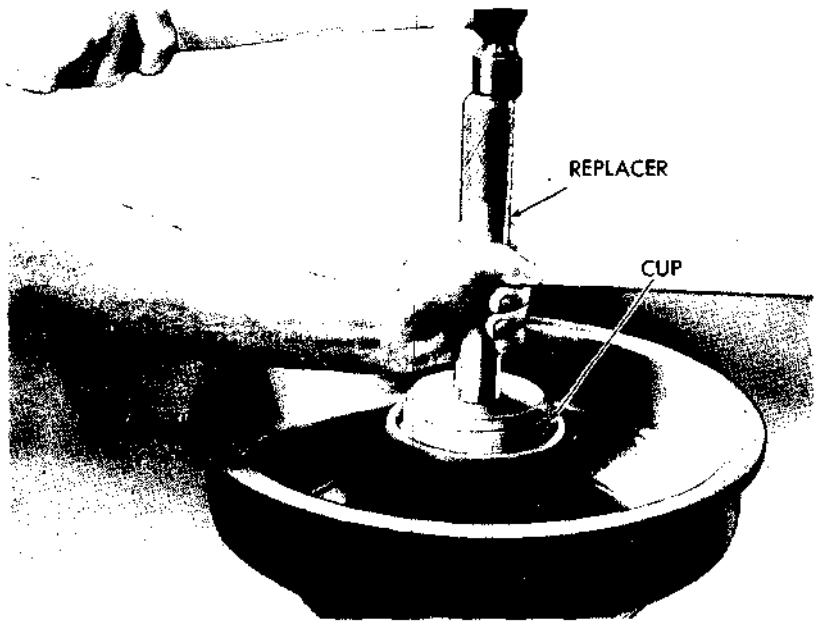
(1) FRONT (fig. 197). The hub and bearings are retained in place with an inner and outer nut, with a lock between the two nuts. An oil seal and retainer is pressed on steering knuckle at inner end of hub.

(2) REAR (fig. 199). The hub and bearings are retained in place with an inner and outer nut with a lock between the two nuts. The outer end of hub is equipped with a spring loaded oil seal assembly installed around outer nut and bolted to hub in conjunction with axle shaft flange. Inner seal is installed on axle housing tube behind inner bearing cone and roller assembly. An oil slinger is bolted directy to hub and drum.

b. Front Hub and Bearing Removal.

(1) REMOVE DRIVE FLANGE. Remove wheel. Remove drive flange (par. 167 e (2)).

(2) REMOVE ADJUSTING NUTS AND LOCK. Straighten tangs on lock. Remove outer nut, then remove lock and inner nut.



RA PD 332922

Figure 204—Installing Inner Cup (Driver Head 41-H-1780 with Handle 41-H-1074)

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(3) REMOVE HUB AND BEARINGS. Pull hub and drum assembly straight off steering knuckle. The outer bearing cone [(GM-144507) G85-31-04520] and both cups will be removed with hub.

(4) REMOVE INNER BEARING AND SEAL. Remove inner bearing cone assembly [(GM-186574) G85-31-04500]. Pry inner oil seal [(GM-2031377) G57-03-82801] and retainer from steering knuckle.

(5) REMOVE BEARING CUPS (IF NECESSARY). Inspect both inner and outer cups. If worn or pitted, use a drift through inner side of hub to remove. [inner cup—GM-186573) G85-31-05000; outer cup—(GM-142224) G85-31-05020].

c. Front Hub and Bearing Installation.

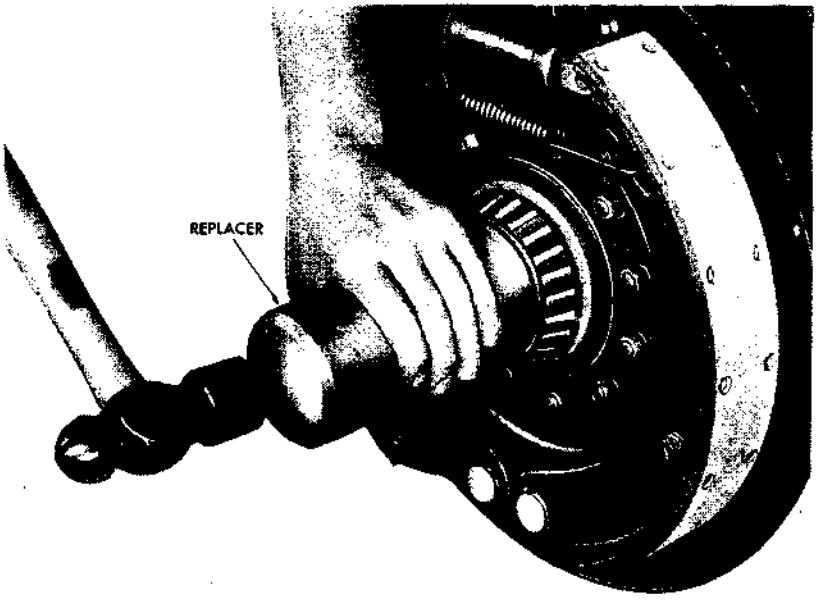
(1) CLEAN AND LUBRICATE HUB AND BEARING. Clean and lubricate as described in paragraph 200.

(2) INSTALL CUPS (fig. 204). Install inner and outer bearing cups in hub with wide side of cup toward center of hub. Use special driver head (41-H-1780) and handle (41-H-1074).

(3) INSTALL INNER SEAL AND RETAINER. With block of wood, install inner seal and retainer on steering knuckle.

(4) INSTALL INNER BEARING (fig. 205). Install inner bearing and cone assembly on spindle using special replacer (41-R-2391-83).

(5) INSTALL HUB AND DRUM ASSEMBLY. Position hub and drum over steering knuckle. Insert outer bearing cone and roller assembly



RA PD 332915

Figure 205—Installing Inner Bearing Cone and Rollers (Replacer, 41-R-2391-83)

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in place. Follow hub and bearing lubrication instructions in paragraph 200. Install inner nut, lock, and outer nut. Install wheel.

(6) ADJUST BEARINGS. Adjust bearings as described in paragraph 199 c (2), then install drive flange (par. 167 g (4)).

d. Rear Hub and Bearing Removal.

(1) REMOVE AXLE SHAFT. Remove wheel. Remove axle shaft (par. 172).

(2) REMOVE HUB AND DRUM. Remove outer oil seal |(GM-2095544) G57-03-82828|, outer nut, lock (GM-057148), and inner nut and washer. Pull hub and drum straight from axle housing. Outer bearing cone |(GM-142257) G85-01-00515| and both cups will be withdrawn with hub.

(3) REMOVE INNER BEARING CONE AND SEAL. Remove inner bearing cone assembly |(GM-142258) G85-01-00510|. A slight pry on oil seal |(GM-675758) G85-01-02465| and retainers will remove these parts.

(4) REMOVE CUPS (IF NECESSARY). Inspect cups. If worn or pitted, remove by using a drift through inner side of hub. Drive on cups on alternate sides. |Inner cup—(GM-142224) G85-31-05020; outer cup—(GM-142256)|.

e. Rear Hub and Bearing Installation.

(1) CLEAN AND LUBRICATE HUB AND BEARINGS. Clean and lubricate hub and bearings as directed in paragraph 200.

(2) INSTALL CUPS (fig. 206). Install inner and outer cups in hub, using special replacer (41-R-2396-12).

(3) INSTALL INNER OIL SEAL. Install inner seal retainer, seal, and outer retainer in place with block of wood.

(4) INSTALL INNER BEARING CONE (fig. 205). Install inner

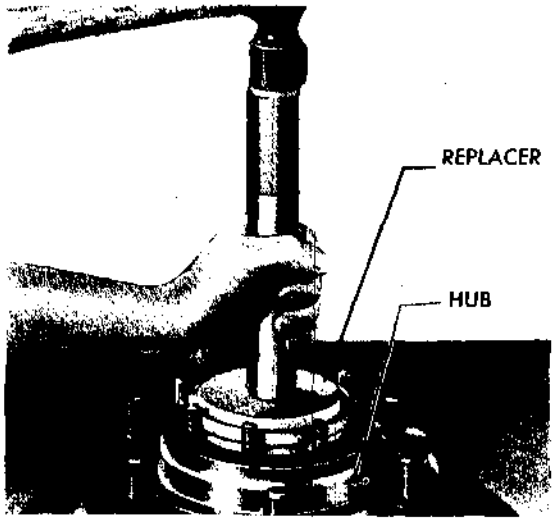

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Figure 206—Installing Outer Cup (Replacer 41-R-2396-12)

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bearing cone and roller using special replacer (41-R-2391-83).

(5) INSTALL HUB AND DRUM. Position hub and drum over axle housing. Insert outer bearing cone and roller assembly in place. Follow hub and bearing lubrication instructions as described in paragraph 200. Install inner spacer, inner nut, lock, and outer nut. Install wheel.

(6) ADJUST BEARINGS. Adjust bearings as described in paragraph 199 d (2).

(7) INSTALL OUTER OIL SEAL. Install outer oil seal and retainer, using gasket between hub and seal retainer. Install axle shaft (par. 172).

Section XXXVI

STEERING SYSTEM

203. DESCRIPTION.

a. The steering system consists of a conventional steering gear assembly, mounted on the inner side of the left-hand frame side rail and interconnected to the front axle steering arm by a pitman arm and drag link. Turning the steering wheel transmits movement through the worm, worm nut, pitman shaft gear, and pitman shaft to the pitman arm. The drag link connecting the pitman arm to the axle steering arm, transmits the movement to the front wheels through the steering arm and tie rod.

204. ADJUSTMENT ON VEHICLE.

a. Preliminary Instructions.

(1) The design of the steering gear assembly provides for three adjustments: worm bearings, sector gear lash, and steering gear mounting. These adjustments must be made in the sequence given.

(2) Loosen two nuts on steering column to dash mounting bracket to eliminate any possibility of binding. Make sure steering gear to frame side rail mounting bolts are tight.

(3) Remove lock nuts and nuts from exhaust pipe flange to manifold bolts and remove bolts. Loosen exhaust pipe to muffler clamp bolt and push exhaust pipe down and toward engine.

(4) Disconnect drag link at steering arm (par. 207).

(5) Loosen lash adjuster screw lock nut (fig. 207), and with an offset screw driver, back lash adjuster screw out a few turns.

b. Worm Bearing Adjustment (fig. 207).

(1) ADJUST WORM BEARING THRUST. Loosen lock nut on worm bearing adjusting screw and turn adjusting screw counterclockwise a few turns. Turn steering wheel gently to right or left until it stops,

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then turn wheel back one turn. CAUTION: *Approach end of gear travel cautiously to prevent damage to worm nut.* Make sure end cover screws are tight. Tighten worm bearing adjusting screw until end play is removed, then tighten lock nut.

(2) MEASURE PULL AT STEERING WHEEL RIM. Use spring scale (41-S-503) to measure pull required to keep wheel in motion. Make test with scale at rim of wheel, with the scale at right angles to the wheel spoke (fig. 208). With wheel in motion, scale should read 1 to 1½ pounds. If necessary, loosen lock nut and turn worm bearing adjusting screw in proper direction to obtain correct reading.

(3) CHECK FOR "LUMPY" ACTION. After adjusting worm bearings, check action by turning steering wheel gently from extreme right to extreme left. If any lumpy or uneven action is noted, bearings are damaged. Notify higher authority.

c. Sector Gear Lash Adjustment (fig. 207).

(1) TIGHTEN SIDE COVER SCREWS. Make sure there is backlash between gear teeth before tightening side cover screws. Backlash should have been obtained before worm bearings were adjusted (subpar. **a** (5) above). Determine backlash by grasping pitman arm and noting any free movement of pitman shaft in housing. Remove lock wire from cap screw heads, tighten cap screws firmly, and install new lock wire.

(2) LOCATE CENTER OF STEERING WHEEL ROTATION. Turn steering wheel gently from extreme right to extreme left position and count the number of revolutions. Turn wheel back exactly halfway and mark position of wheel with a piece of tape.

(3) ADJUST SECTOR GEAR LASH. Tighten lash adjuster screw until all backlash is removed. Tighten adjuster screw lock nut.

(4) CHECK ADJUSTMENT. Use spring scale (41-S-503) in same manner as described in subparagraph **b** (2) above, and note reading as wheel is pulled through center position (fig. 208). This reading

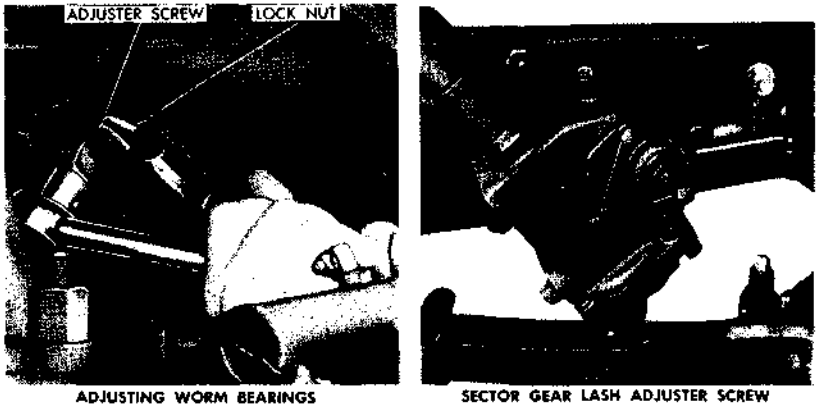

Figure 207—Steering Gear Adjustments

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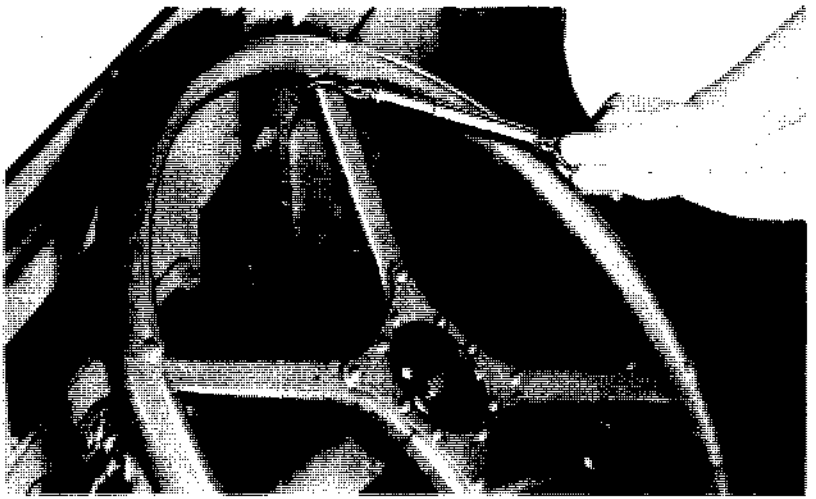

RA PD 332953

Figure 208—Checking Adjustments with Spring Scale (Spring Scale 41-S-503)

should be 2 to 2½ pounds. If necessary, tighten or loosen lash adjuster screw to obtain correct reading.

d. Steering Gear Mounting Adjustment (fig. 209). Adjust cab mounting and tighten mounting bolts (par. 221). Loosen four steering gear mounting bolts at frame side rail just enough to permit steering gear to aline itself when mounting is tightened at dash. Tighten nuts on steering column to dash mounting. Tighten steering gear mounting bolts at frame side rail with torque wrench, tightening upper front (pivot) bolt last to 160-170 foot-pounds. Install lock nuts on bolts and tighten firmly. Check wheel pull with spring scale (subpar. c (4) above). If pull exceeds 2½ pounds, binding is indicated and cab mounting must be rechecked (par. 221).

e. Final Operations.

(1) Adjust and connect drag link to steering arm (par. 207).

(2) Connect exhaust pipe to manifold (par. 103), and tighten exhaust pipe to muffler clamp bolt.

205. PITMAN ARM.

a. Removal (fig. 210). Remove nut and lock washer attaching pitman arm to pitman shaft. Disconnect drag link from pitman arm ball stud (par. 207). Install puller (41-P-2952) on pitman arm and pull arm off pitman shaft.

b. Installation (fig. 210). Set front wheels in straight-ahead position and locate steering wheel at center of travel (par. 204 c (2)). Aline serrations in pitman arm with serrations on shaft (fig. 210), and place arm over shaft so that drag link can be installed on pitman arm ball stud without changing the position of the steering

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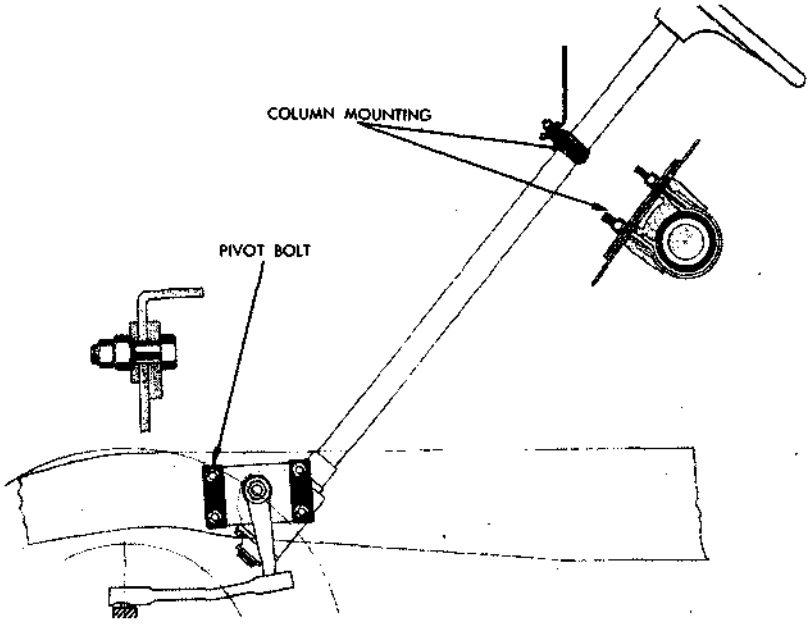

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Figure 209—Steering Gear Mounting at Frame and Dash

wheel or front wheels. Adjust and install drag link (par. 207). Install lock washer and nut on pitman shaft and tighten nut with torque wrench to 150-160 foot-pounds.

206. STEERING WHEEL.

a. Removal (fig. 211). Remove two screws attaching horn button retainer to steering wheel and remove retainer, horn button, contact, insulator, and spring. Remove steering wheel retaining nut and horn terminal plate. Assemble puller (41-P-2954) and adapter (41-A-18-251) on steering wheel in manner shown in figure 211 and pull steering wheel off worm shaft.

b. Installation. Make sure key is in place in keyseat on worm shaft. Aline keyway in steering wheel hub with key in shaft and place steering wheel on shaft. Install horn terminal plate and steering wheel retaining nut and tighten nut firmly. Install spring, insulator, contact, button, and retainer in steering wheel and attach with two screws.

207. DRAG LINK.

a. Description. The drag link assembly is made up of a tubular shaft fitted with ball socket assemblies at both ends (fig. 212). The end assemblies contain identical parts, but parts are assembled in different sequence in the two ends.

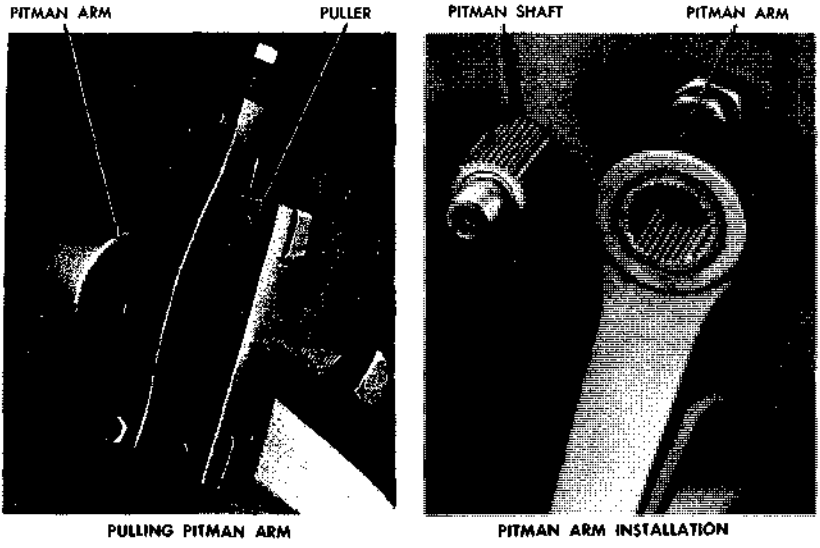

Figure 210—Pitman Arm Removal and Installation (Puller 41-P-2952)

b. Adjustment. Be sure drag link ball seats are thoroughly lubricated before making adjustment. Remove cotter pin from drag link end. Screw end plug in tight with ball in place, then back off one-quarter to one-half turn and insert new cotter pin. Repeat at other end.

c. Removal. Remove cotter pin from both ends of drag link. Back out end plugs as far as possible without removing them. Turn steering wheel in both directions to loosen ball studs in drag link ends, then pull drag link off steering arm ball stud and pitman arm ball stud. NOTE: *Drag link can be disconnected at one end only if so desired for replacing pitman arm or steering arm.*

d. Installation.

(1) CONNECT DRAG LINK TO STEERING ARM. Opening for ball stud at steering arm end is closer to end than at pitman arm end. Remove end plug from steering arm end and check order in which parts are installed (fig. 212). Correct order is: washer, spacer, safety plug, spring, inner ball seat, outer ball seat, and end plug. Pack lubricant (Section VIII) into ball seats. With inner ball seat in position (notch toward opening), place opening in drag link end over steering arm ball stud. Install outer ball seat and end plug. Do not install cotter pin until adjustment is made.

(2) CHECK ALINEMENT OF RELATED PARTS. Before connecting drag link to pitman arm ball stud, turn steering wheel **GENTLY** to extreme left and turn front wheels to left against stop screw. Hold drag link against pitman arm ball; ball should be at least one-half

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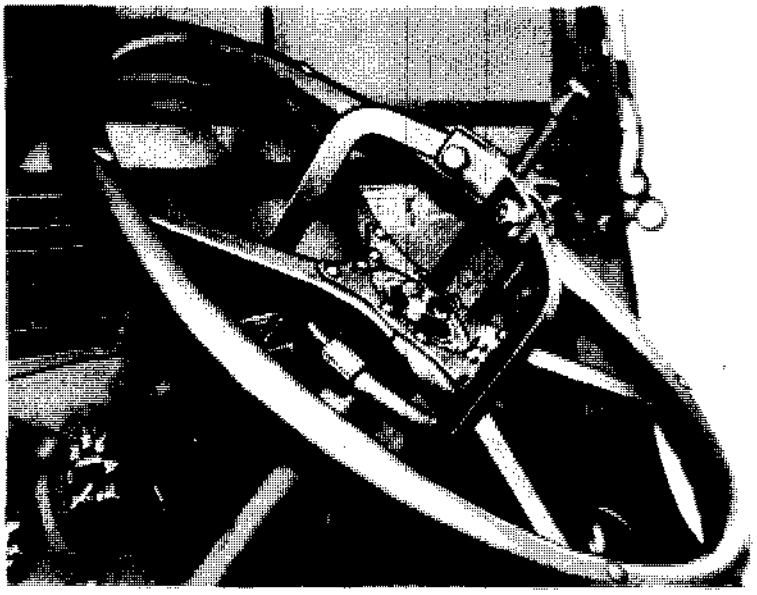

RA PD 316812

Figure 211—Pulling Steering Wheel (Puller 41-P-2954 with Adapter 41-A-18-251)

inch ahead of its position in drag link. Repeat check for extreme right turn; pitman arm ball should be at least one-half inch behind its position in drag link. If over travel of pitman arm ball is less than one-half inch either way or does not reach extreme travel of drag link socket, steering worm nut will strike steering gear housing or end cover, causing damage to worm nut and ball guides. This condition will also cause bending of end cover and loosening cover

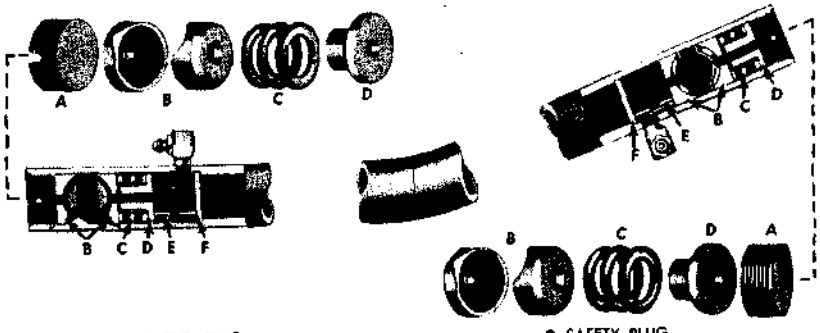

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Figure 212—Drag Link Assembly

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screws with resultant oil leaks. If such a condition is present, check the following items, replace damaged parts, or report condition to higher authority.

(a) Bent or twisted pitman arm.
(b) Bent drag link.
(c) Bent or twisted front axle steering arm.
(d) Front axle out of position on front springs.
(e) Steering knuckle stop screws out of adjustment, bent, or missing.

(3) CONNECT DRAG LINK TO PITMAN ARM. Set front wheels in straight-ahead position and locate steering wheel at center of travel (par. 204 c (2)). Remove end plug from rear end of drag link and check order in which parts are installed. Correct order is: washer, spacer, inner ball seat, outer ball seat, spring, safety plug, and end plug. With washer, spacer, and inner ball seat in place (notch in seat toward opening), pack lubricant (Section VIII) into ball opening. Place opening in side of drag link over pitman arm ball stud and install outer ball seat, spring, safety plug, and end plug in the order named. Adjust both ends of drag link (subpar. b above) and lubricate (Section VIII).

Section XXXVII

FRONT AND REAR SPRING SUSPENSION

208. DESCRIPTION.

a. The front springs are semi-elliptic type, shackled at front and pivoted at rear. The springs are mounted on axle housings with U-bolts on banjo type axles and with studs and bolts on split type axles. Rear spring suspension consists of inverted semi-elliptic springs, mounted on roller bearing spring seats, and retained with U-bolts. Slipper type spring ends are located in guide brackets on each rear axle. The ends of the springs are free to slide forward or backward to permit the springs to lengthen and retract under load compression and rebound action. Torque rods, three at each axle, interconnect the forward rear (intermediate) axle and the rearward rear axle with the trunnion brackets and vehicle frame.

209. FRONT SPRING SUSPENSION.

a. **Description.** Two types of shackles are used on these vehicles, depending upon the type of axle used.

(1) Y-TYPE SHACKLES—BANJO TYPE AXLES (figs. 213 and 214). This type shackle is attached to the bracket and spring by means of pins. The outside ends of the pins are grooved to permit installation of clamping bolts. Use of spacer is shown in figure 214.

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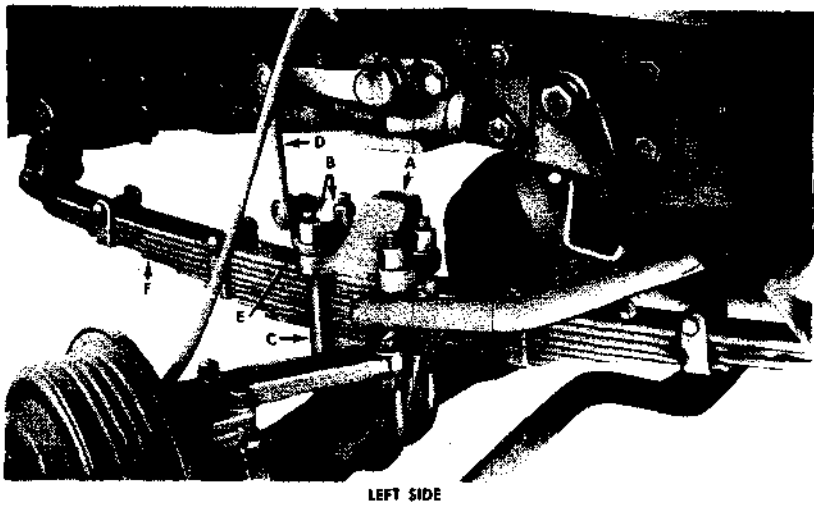
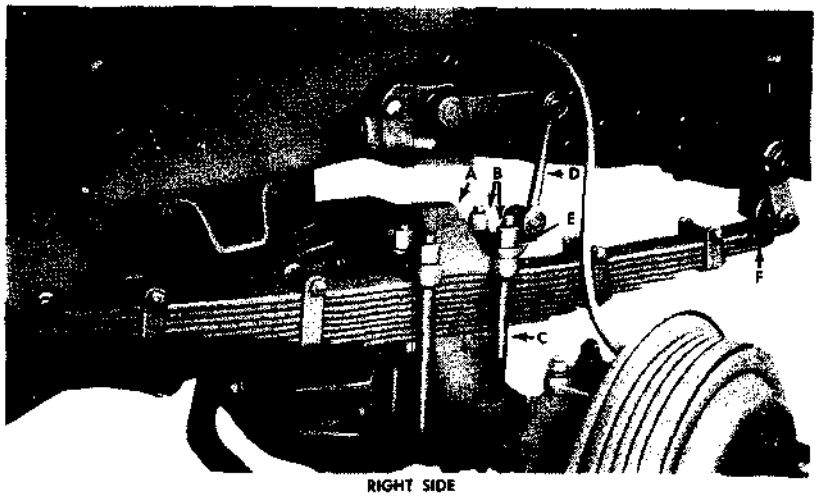


LEFT SIDE



RIGHT SIDE

A BUMPER BLOCK
B U-BOLT NUT
C U-BOLT
D SHOCK ABSORBER LINK
E SHOCK ABSORBER LINK BRACKET
F FRONT SPRING

RA PD 333027

Figure 213—Front Springs Installed—Banjo Type Axle

(2) U-TYPE SHACKLES—SPLIT TYPE AXLES (figs. 215 and 216). This type shackle is attached to the frame bracket and spring by means of shackle bolts. All upper shackle bolts are retained by nuts and cotter pins, while the lower shackle bolts may be retained by nuts and cotter pins, or the bolts may be threaded into the shackles and retained by a lock plate. These differences are shown in figure 215 and are noted, as necessary, in the text when removal or installation procedures are affected.

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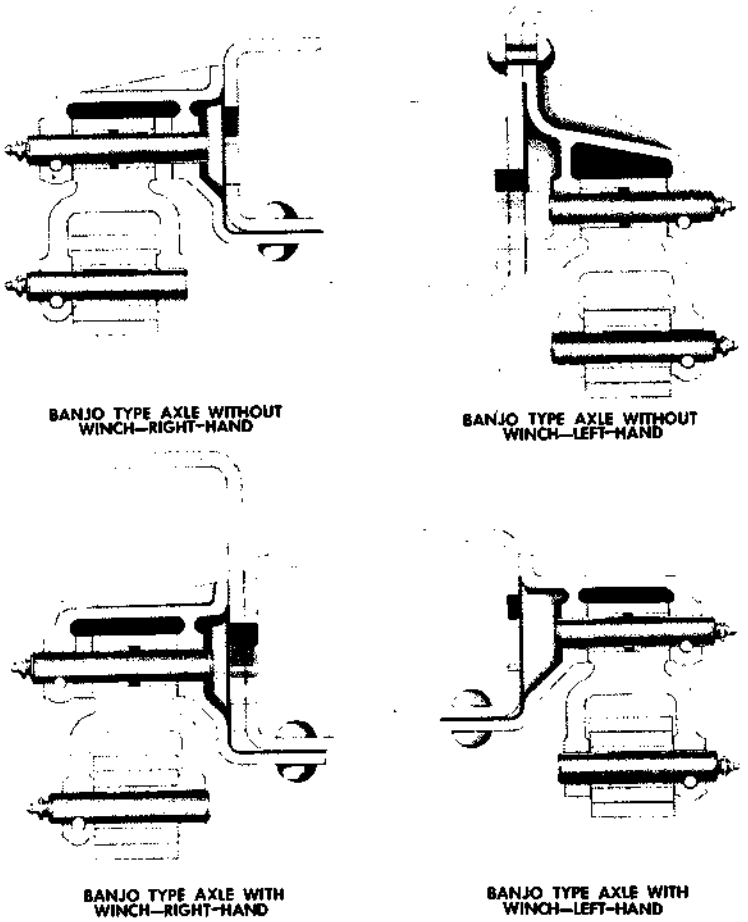

Figure 214—Front Spring Shackles—Banjo Type Axle

b. Spring and Shackle Removal (Banjo Type Axles) (figs. 213 and 214). The following procedures are in logical sequence for removing and installing all front springs, spring shackles, and shackle bolts; however, individual parts may be removed and installed separately as necessary.

(1) RAISE FRONT END OF VEHICLE. Jack up front end of vehicle until spring tension is relieved. Block rear wheels to prevent vehicle from rolling.

(2) REMOVE U-BOLTS. Remove all U-bolt nuts, remove U-bolts, shock absorber bracket, and bumper block.

(3) REMOVE SHACKLE AND PINS. Remove shackle pin clamp bolts, and drive out shackle pins. Frame is provided with a hole to facilitate driving out upper pin.

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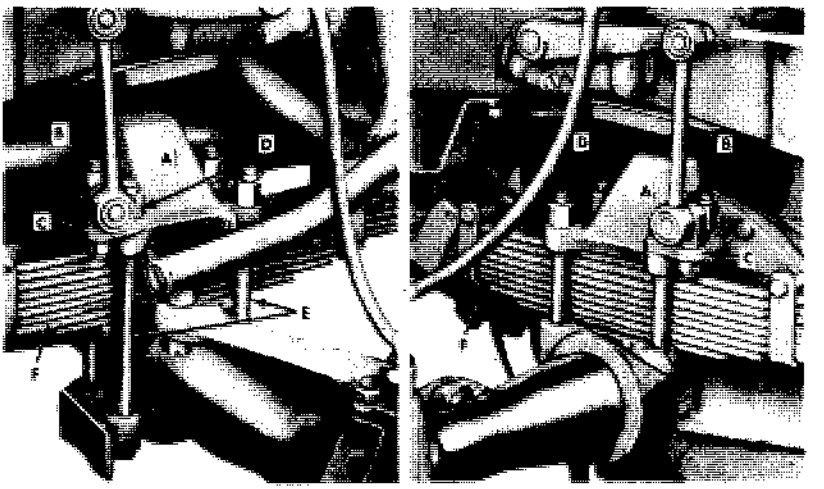

Figure 215—Front Springs Installed—Split Type Axle

(4) REMOVE REAR BRACKET BOLT. Remove cotter pin and nut from rear bracket bolt. Drive out bolt and remove spring [with winch (GM-2140052) G508-03-89810; less winch (GM-2140053) G508-03-89792] assembly.

c. Spring and Shackle Installation (Banjo Type Axles) (figs. 213 and 214).

(1) POSITION SPRING. Place spring in position and install rear bracket bolt and nut, draw nut up tight, and install new cotter pin.

(2) INSTALL FRONT SHACKLE. Line up shackle and spacer in front bracket with spacer positioned as necessary (fig. 214), then drive in upper pin. The spacer is used on outer side of right front spring with winch and on inner side of right front spring without winch. Aline hole in spring eye with lower holes in shackle and drive in lower pin. Make sure grooves in pins line up with holes in shackle. Install and tighten clamp bolts, lock washers and nuts.

(3) INSTALL U-BOLTS. Install U-bolts, bumper block, and shock absorber bracket on front springs and axle housing, then install U-bolt nuts. Tighten nuts with torque wrench to 170-185 foot-pounds and remove jack.

d. Spring and Shackle Removal (Split Type Axles) (figs. 215 and 216).

(1) RAISE FRONT END. Jack up front end of vehicle until tension on spring is relieved. Block rear wheels.

(2) REMOVE STUD OR BOLT NUTS. Four studs are used to retain right-hand spring and four bolts are used to retain left-hand

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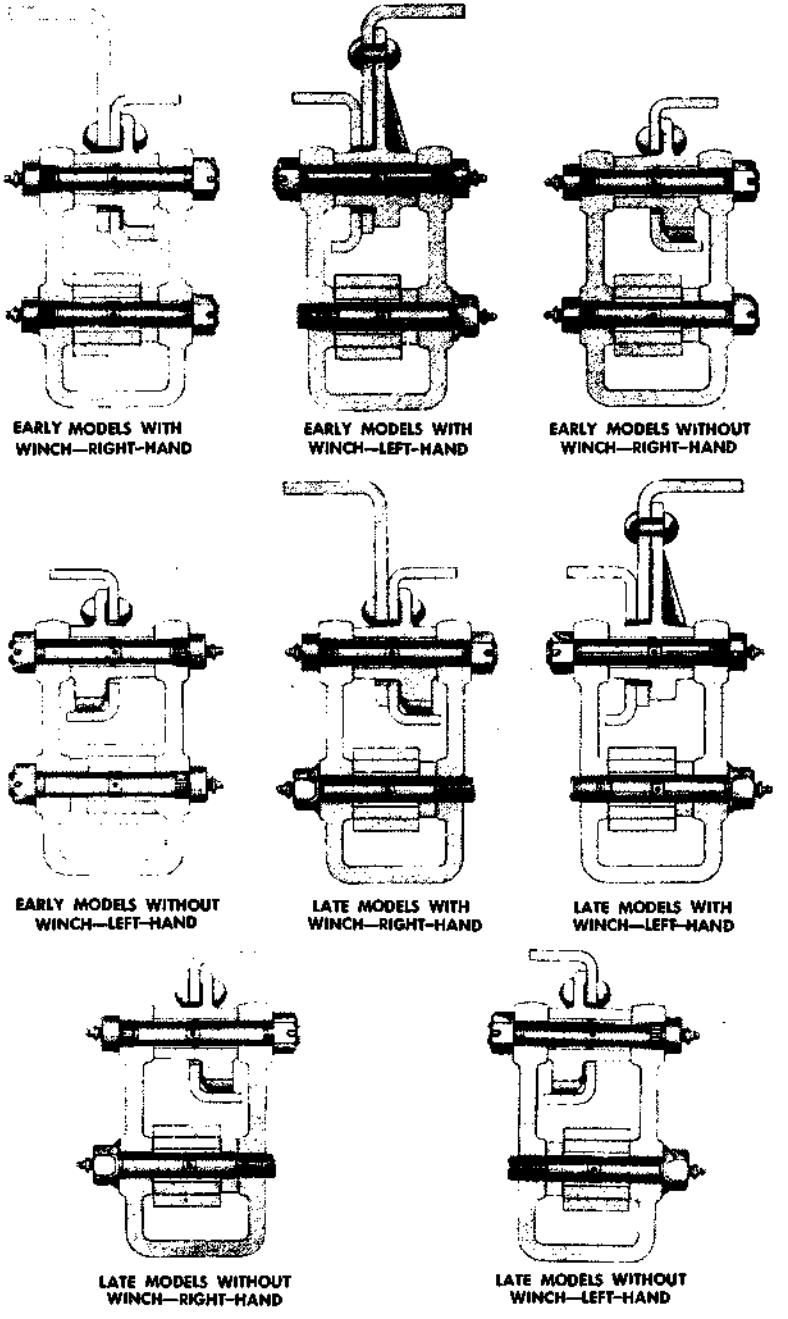
TRUCK, 2½-TON, 6 x 6



RA PD 333054

Figure 216—Front Spring Shackles—Split Type Axle

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spring. Loosen and remove nuts from either studs or bolts, then remove bumper block and shock absorber bracket.

(3) REMOVE SHACKLE BOLTS. Remove the cotter pins and nuts from shackle bolts, then use a lead hammer and a punch to drive out bolts. On the left front spring on early vehicles with winch, and on both front springs on late vehicles with or without winch, the lower bolt must be unscrewed, not driven out. Bend tangs of lock away from hex end of bolt and unscrew bolt.

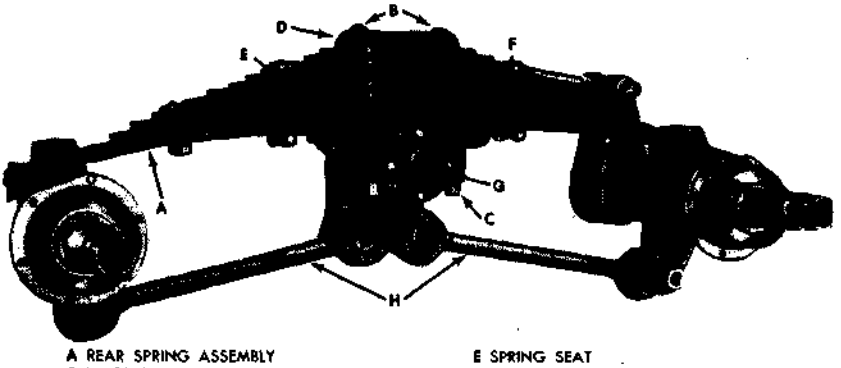
(4) REMOVE REAR BRACKET BOLT. Remove cotter pin and nut from rear bracket bolt, then use a lead hammer and a punch and drive out bolt. Spring assembly [with winch (GM-2140052) G508-03-89810; less winch (GM-2140053) G508-03-89792] may then be withdrawn.

e. Spring and Shackle Installation (Split Type Axles) (figs. 215 and 216).

(1) POSITION SPRING. Place spring in position. Install rear bracket bolt and nut, draw nut up tight, then install new cotter pin.

(2) POSITION SHACKLE. Line up holes in shackle and front bracket, install top bolt, nut, and cotter pin. Line up holes in shackle and front spring and install bottom bolt and spacer. On vehicles equipped with winch, the spacer is installed on inner side of shackle on right-hand spring, while on left-hand spring, the spacer is installed on outer side of shackle. On vehicles without winch, spacers are installed on the inner side on both front springs. Install nut on bolt or thread bolt into shackle, as the case may be (fig. 216), and draw up tight, then back off one-half turn and install cotter pin or bend lock plate against hex end of bolt.

(3) INSTALL SPRING SEAT BOLTS AND BUMPER BLOCKS. Install spring seat bolts (left front spring only). Studs are used at right front spring. Make sure that guard is installed on bottom of the two left-hand front bolts. Install bumper blocks, shock absorber



A REAR SPRING ASSEMBLY
B U-BOLTS
C U-BOLT NUTS
D U-BOLT SPACER
E SPRING SEAT
F SPRING SEAT CLAMP BOLT
G SPRING SEAT CAP
H LOWER TORQUE ROD

RA PD 333008

Figure 217—Rear Spring Installed

ES18-002672 0538

brackets, and nuts. Tighten nuts with torque wrench to 170-185 foot-pounds and remove jack.

210. REAR SPRINGS.

a. Description. The rear springs are inverted semi-elliptic type (fig. 217) with the center of spring held to the spring seat by two U-bolts. The ends of the spring ride in the spring guide brackets on the axle housings.

b. Removal (fig. 217).

(1) HOIST REAR END OF VEHICLE. Position jack under cross shaft to frame bracket and jack up vehicle enough to relieve spring tension on side to be serviced. Block wheels to keep vehicle from rolling. Loosen and remove outer wheel nuts (hex), and remove the two outer wheels on side to be serviced.

(2) REMOVE U-BOLTS. Loosen and remove U-bolt nuts and spacer. Loosen spring seat clamp bolts.

(3) REMOVE SPRING FROM VEHICLE. Force spring off seat, then slide back until front end of spring can be lifted out of bracket on forward rear axle. Raise up front end of spring and pull forward until rear end of spring clears bracket on rearward axle and remove from under vehicle.

c. Installation (fig. 217).

(1) POSITION SPRING. Place end of spring in bracket on forward rear axle and slide spring forward in bracket until rear of spring will enter bracket on rearward axle and then slide spring toward rear until center bolt drops into recess in spring seat. Make sure spring center bolt is tight. Place U-bolt spacer in position on top of spring.

(2) INSTALL U-BOLTS. Insert U-bolts in place with top of U-bolts seated in groove in spacer. Thread nuts on U-bolts and tighten with torque wrench to 200-220 foot-pounds, then tighten spring seat clamp bolts.

(3) INSTALL WHEELS. Install wheels and make certain that inner and outer wheel nuts are tight. Lower vehicle to ground and remove jack. Check tightness of spring U-bolts with spring under load.

211. REAR SPRING SEATS.

a. Description The rear spring seats are supported on the trunnion cross shaft by tapered roller bearings (fig. 218), which must be lubricated at intervals specified in Section VIII, and inspected and disassembled at intervals indicated in Section XI, if satisfactory spring operation is to be obtained. The bearings must be carefully adjusted upon reassembly.

b. Check Bearing Adjustment. Position jack under cross shaft and raise to relieve weight on spring. Remove outer wheels. Then take out U-bolts. Remove spring from spring seat and lower jack under cross shaft. Oscillate spring seat either way while pulling and pushing on seat. If seat oscillates smoothly without perceptible end play or side shake, no further inspection is required and spring can

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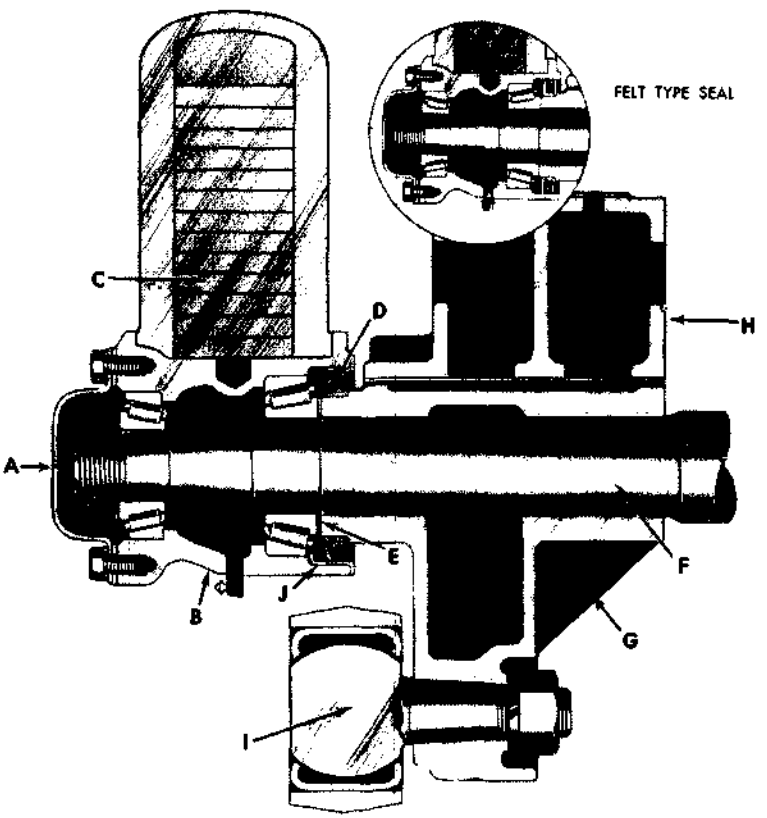
be reinstalled. If end play or side shake is noticed or if oscillation is jerky, spring seat and bearings have to be removed for further inspection.

c. **Remove Spring Seat** (fig. 218). Remove bearing cap and gasket by removing the four cap screws holding cap to seat assembly. Straighten bent-over portion of nut lock, then remove lock nut, lock adjusting nut, and washer. Remove spring seat together with outer bearing cone and roller assembly, outer and inner bearing cups and seal flange. Lift outer bearing assembly out of spring seat.

d. **Clean and Inspect Bearings and Cups.** Wash bearing cone and roller assemblies and cups thoroughly with dry-cleaning solvent, wipe bearings and cups dry and inspect them carefully. If surfaces of cups or bearing rollers are pitted, they should be replaced. A pitted



A SPRING SEAT CAP
B SPRING SEAT
C SPRING
D OIL SEAL
E BEARING SPACER
F CROSS SHAFT
G CROSS SHAFT BRACKET
H SUPPORT BRACKET
I TORQUE ROD
J OIL SEAL FLANGE

RA PD 333014

Figure 218—Rear Spring Seat Cross Section

surface is one in which small particles have broken out, leaving jagged depressions. Bearings used in spring seats roll back and forth as vehicle passes over uneven terrain, but bearing rollers always return to same relative position in cups. In fact, bearing rollers rest in this one position most of the time. Polished lines appear on bearing cups, showing "resting" position of rollers and should not be confused with pitting. These lines are spaced according to distance between line of contact and each roller. These lines are not harmful and bearings should not be replaced unless rough or jerky condition can be felt by rotating bearing roller assembly in race, or if surfaces of cups are actually pitted or broken. If bearing cups or cones are damaged, replace with new parts. Wash seal and seal flange thoroughly. Wipe dry and inspect flange for pitted or worn condition. Check tightness of flange in spring seat. Replace if necessary.

e. Remove Bearing Cups, Inner Bearing, and Seal (If Necessary).

(1) REMOVE CUPS. Drive bearing cups out of spring seat, using a punch and hammer. Be careful not to cock cups during removal to prevent damaging the seat. If seat is fitted with a seal flange (used with new lip type seal), this flange must be removed before inner cup can be removed. Remove flange by driving a chisel between flange and seat and prying out.

(2) REMOVE INNER BEARING AND SEAL. Remove inner bearing from end of cross shaft. Pry oil seal off shoulder on cross shaft bracket.

f. Install Bearing Cups. Install bearing cups in spring seat with wide edge of cup toward center of seat. Use replacer (41-R-2385-276) to drive outer cup (Timken-2720) firmly against shoulder in seat. Use replacer (41-R-2385-275) to drive inner cup (Timken-3720) against shoulder in seat.

g. Lubricate Bearings. Lubricate bearings as directed in Section VIII.

h. Install Spring Seat, Bearings, and Oil Seal (fig. 218).

NOTE: Two types of oil seals have been used on these vehicles. Early type seal consists of a felt, retainer, and washer. Late type is a lip type seal used with a seal flange. Whenever the spring seat is removed, replace the felt type seal with a new lip type seal, if available. Instructions are also given for installing felt type seal in the event the lip type seal is not available.

(1) INSTALL SEAL AND BEARING.

(a) Lip Type Seal. Apply a small amount of gasket cement (No. 1) to seal shoulder of cross shaft frame bracket and drive seal against end of shoulder with special replacer (41-R-2397-425). Be sure that cupped side of rubber seal is toward frame. Install bearing spacer on cross shaft. Install bearing cone and roller assembly, using replacer (41-R-2391-30). If seal flange was removed, coat outside of flange sparingly with gasket cement (No. 1) and press into spring seat.

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(b) Felt Type Seal. Install seal washer, felt, and retainer on cross shaft bracket. Make sure that retainer flange is under felt and away from bearing. Install inner bearing cone and roller assembly, using replacer (41-R-2391-30).

(2) INSTALL SPRING SEAT. Fill cavity between inner seal and bearing with lubricant and apply a small amount of lubricant on seal contacting surfaces. Position spring seat on cross shaft end and install outer bearing.

(3) INSTALL ADJUSTING NUT AND WASHER. Place adjusting nut washer and adjusting nut (inner) over end of cross shaft. Draw adjusting nut up to approximate adjustment. Spring seat should be oscillated while tightening to prevent grease from being squeezed out from under bearing rollers.

(4) ADJUST BEARINGS. Tighten adjusting nut until slight increase in bearing drag over original drag of bearing seal is noticed when seat is oscillated. Lubricate bearings with pressure gun (Section VIII).

(5) INSTALL BEARING CAP. When adjusting nut is tightened properly, replace adjusting nut lock and locking nut (outer). Tighten locking nut securely. Test adjustment once more to see that it has

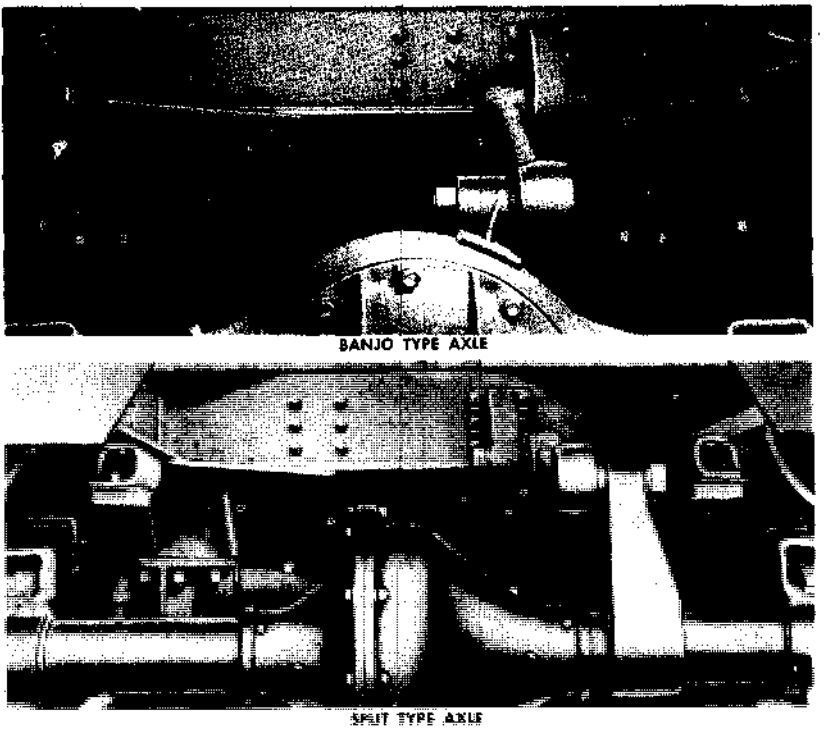

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Figure 219—Upper Torque Rods Installed

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not been changed and correct if necessary. Bend portion of nut lock over flats of adjusting nut and lock nut. Install the bearing cap and new gasket. Install and tighten the four cap screws and lock washers. Install spring (par. 210 c) and install outer wheels.

212. TORQUE RODS.

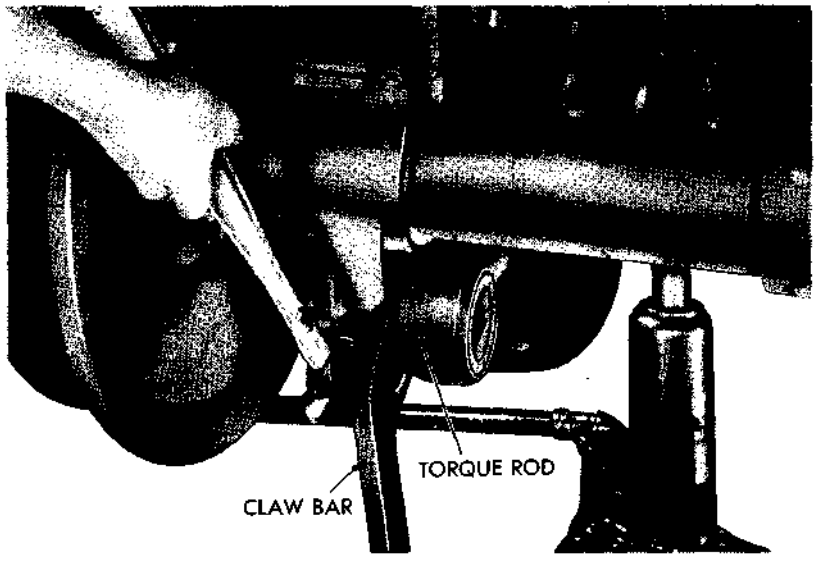
a. Description. Torque rods, three on each side, interconnect the forward rear (intermediate) axle and the rearward rear axle with the trunnion brackets and frame crossmember (figs. 217 and 219). The ball pin studs at each end of all six torque rods are mounted in special bearings. The torque rods used with split type axles are 1½ inches longer than those used with banjo type axles.

b. Removal.

(1) JACK UP VEHICLE. Place jack under spring seat and raise until tension is off springs. Remove nuts and lock washers from torque rod pins.

(2) REMOVE PINS AT EACH END OF TORQUE RODS (fig. 220). Force torque rod pins out of brackets. To start pins, insert a claw bar between bracket and hub of torque arm. Strike bottom of bracket sharply with heavy hammer while prying with claw bar. Bushing in torque rod will be damaged if excessive force is used with bar.

(3) REMOVE UPPER TORQUE ROD BRACKETS AT FRAME CROSSMEMBER. Remove upper torque rod brackets on front and rear of crossmember by removing the six nuts, lock washers, and bolts from each bracket.



RA PD 64501

Figure 220—Disconnecting Torque Rod

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c. **Installation.**

(1) INSTALL UPPER TORQUE ROD BRACKETS AT FRAME CROSSMEMBER (SPLIT TYPE AXLES). Brackets at frame crossmember for upper torque rods for split type axles are identical and either can be used at front or rear of crossmember. Position brackets on frame crossmember and insert the six attaching bolts, then install and tighten lock washers and nuts.

(2) INSTALL UPPER TORQUE ROD BRACKETS AT FRAME CROSSMEMBER (BANJO TYPE AXLES). Brackets for upper torque rods for banjo type axles are not interchangeable. Bracket attached to front of crossmember must be installed with large end of taper toward left side of frame. Bracket at rear of crossmember must also be installed with large end of taper toward left side of frame. Position brackets on frame crossmember and insert the six attaching bolts, then install lock washers and nuts. Tighten nuts securely.

(3) INSTALL TORQUE RODS. Clean all grease and dirt from torque rod pins, and see that bushings are clean and free from dirt. The two lower torque rods on each axle should be installed before top torque rods are installed. Force torque rod pin firmly into brackets, using a block of wood and hammer, and then install lock washers and nuts. Tighten securely. Lower and remove jacks.

213. SHOCK ABSORBERS.

a. **Description.** The shock absorbers, mounted on the outer side of the frame over the front axle, are used at the front end only (figs. 213 and 215).

b. **Removal.** Remove nut and lock washer from eye bolt and lift eye bolt out of bracket at spring. From inside frame, remove two nuts, lock washers, and flat washers from shock absorber to frame bolts and remove shock absorber, link, and eye assembly. Remove nut from tapered stud at each end of link, remove eye bolt from link, and remove link from shock absorber arm.

c. **Installation.** Install eye bolt on tapered stud in end of link and install nut. Insert tapered stud in other end of link through shock absorber arm and install nut. Tighten nuts firmly. Install two bolts through shock absorber and frame, install two flat washers, lock washers, and nuts on bolts and tighten firmly. Insert eye bolt through bracket at spring, install nut and lock washer and tighten.

d. **Check and Replenish Fluid.** Clean shock absorber thoroughly, then remove filler plug and check level of fluid. If fluid is below level of filler plug hole, additional fluid must be added. Remove nut and lock washer attaching lower end of link to eye bolt and pull tapered stud out of eye bolt. Fill shock absorber with fluid (Section VIII) and replace filler plug. Move shock absorber arm up and down several times to work fluid into piston cylinder. Remove filler plug and add more fluid. To provide necessary air space in shock absorber, allow fluid to drain down to the level of filler plug hole, then install filler plug with new gasket.

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TRUCK, 2½-TON, 6 x 6

Section XXXVIII

FRAME

214. DESCRIPTION.

a. General. The frame is composed of steel channel section side rails to which steel gussets, brackets, and crossmembers are riveted. Other attachments such as fuel tank brackets, battery box, step hangers, bumpers, and tire carrier are bolted in place.

b. Frame Alinement. Since the frame constitutes the "foundation" of the entire vehicle, proper functioning of the vehicle and its components is greatly dependent upon correct frame alinement. If vehicle has been in a collision, or if there is any reason to suspect a sprung, swayed, or otherwise misalined frame, report condition immediately to proper authority.

c. Checking Procedure (fig. 221). The most convenient way to check frame alinement, particularly on trucks equipped with a body, is by marking on the floor all points from which measurements are to be taken. This can be done by tacking or cementing pieces of paper securely to the floor under each point of measurement. Starting at "M," indicated on figure 221, drop a "plumb bob" from each point. Satisfactory checking is dependent upon accuracy of marks with relation to the frame. After each point shown has been marked carefully and the vehicle moved away from the layout on the floor, proceed as directed in the following steps.

(1) Check frame width at front and rear ends, using corresponding marks on floor. If widths correspond to specifications given, draw center line full length of vehicle halfway between marks indicating front and rear widths. If frame width is not correct, lay out center line as directed in step (4) below.

(2) With center line properly laid out, measure distance from it to opposite points marked over entire length of chassis. If frame is in proper alinement, measurements should not vary more than ⅛ inch at any point.

(3) To locate point at which frame is sprung, measure diagonals marked A, B, and C. If diagonals in each pair are within ⅛ inch, that part of frame included between points of measurements may be considered in alinement, and these diagonals should intersect within ⅛

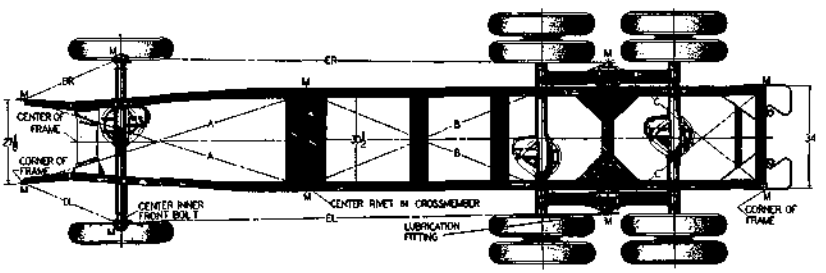
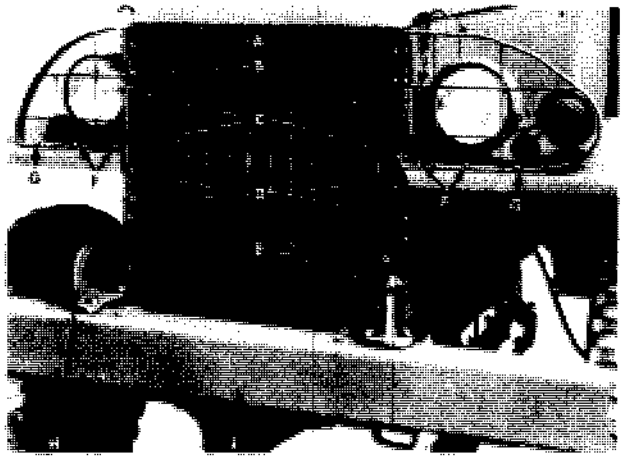
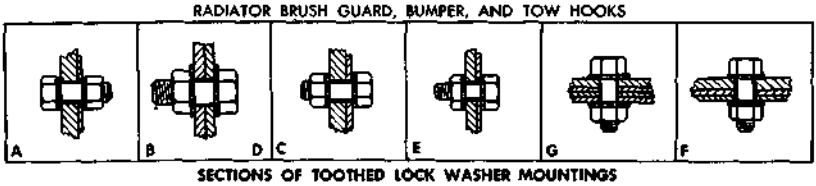


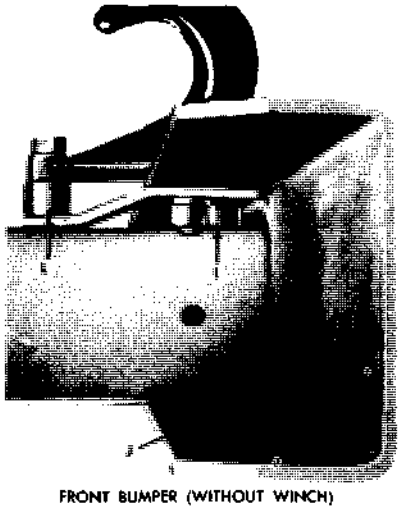
Figure 221—Frame Alinement Check Points



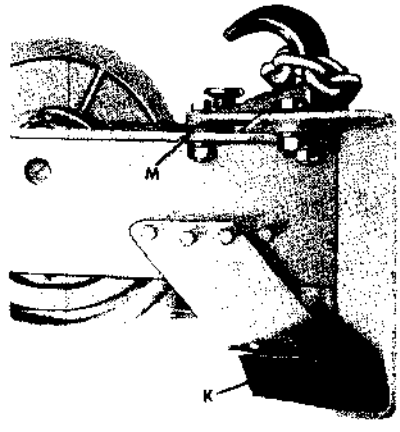
RADIATOR BRUSH GUARD, BUMPER, AND TOW HOOKS



SECTIONS OF TOOTHED LOCK WASHER MOUNTINGS



FRONT BUMPER (WITHOUT WINCH)



FRONT BUMPER (WITH WINCH)

A GUARD TO HOOD SIDE PANEL
B GUARD TO RADIATOR SUPPORT
C GUARD TO HOOD SIDE PANEL
D GUARD TO RADIATOR SUPPORT
E GUARD TO FENDER SKIRT
F GUARD TO FENDER
G GUARD TO FENDER
H FRONT TOW HOOK
I SPACER (1 1/16 INCH)
J FRONT BUMPER (WITHOUT WINCH)
K FRONT BUMPER (WITH WINCH)
L SPACER (15/16 INCH)
M SPACER (1/4 INCH)

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Figure 222—Front Bumper, Tow Hooks, and Brush Guard

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inch of center line. Variations of more than ⅛ inch indicate misalinement.

(4) If center line cannot be laid out from points at ends of frame, it can be drawn through intersection of any one pair of diagonal lines of equal length and center point of either end of frame. Center line can also be laid out through points of intersection of any two pairs of equal diagonals. If extreme front end or horn of frame is damaged, center of front end of frame can be located from point exactly midway between radiator support bolts.

(5) After it has been determined that frame is properly alined, front axle alinement with frame can be checked as directed below (fig. 221).

(a) Front axle is square with frame if ER equals EL, and DR equals DL.

(b) Front axle has shifted sideways if ER is less than EL, and DR less than DL, or vice versa.

(c) Front axle is bent, twisted, or shifted if ER is less than EL and DR is greater than DL, or vice versa.

215. BUMPERS.

a. Rear Bumpers (fig. 224). Two rear bumpers (bumperettes) are formed from steel plate and are attached to each frame rear corner.

(1) REAR BUMPER REMOVAL. Remove eye bolt and hex-head bolt attaching bumper to rear crossmember. Remove four bumper to side rail bolts then remove bumper. Removal operations are same for either right- or left-hand side.

(2) REAR BUMPER INSTALLATION. Position bumper on frame, using drifts to aline holes. Install bolts, nuts, and washers, locating eye-bolt as in figure 224, then tighten all nuts firmly. Installation is same for either bumper.

b. Front Bumpers (fig. 222). Front bumper, used on models without winch, is a pressed steel channel, bolted to front ends of frame side rails. For models with winch, a similar, but wider bumper with a cutout in lower center section is attached to frame extension with bolts and brackets.

(1) MODELS WITHOUT WINCH.

(a) Removal. Remove two bolts, nuts, and washers at front end of each tow hook then remove short spacers from between bumper gusset and side rail. Loosen each rear tow hook bolt nut and swing tow hooks to rear. Remove two bolts, nuts, and washers from top flange of bumper, remove two bolts, nuts, and washers from lower flange of bumper, then lift bumper off side rails.

(b) Installation. Position bumper on side rails with the short ($^{11}/_{16}$ in.) spacers between side rails and bumper gussets, then swing tow hooks into position. Install two bolts in each tow hook, then install washers and nuts loosely. Install two bolts attaching bumper upper flange to gusset, then install washers and nuts loosely. Install two bumper lower flange to side rail bolts, and install washers and nuts loosely. Tighten all nuts, including tow hook rear nuts, firmly.

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(2) MODELS WITH WINCH.

(a) Removal. Unhook winch chain from tow hooks, then remove two bolts, nuts, and washers at front of each tow hook. Loosen nut on each rear tow hook bolt and swing tow hooks to rear. Remove two bolts, nuts, and washers attaching bumper lower flange to bumper brackets, then remove four bumper upper flange to winch angle bolts and washers. Lift bumper off frame extensions.

(b) Installation. Position bumper on frame extensions, swing tow hooks forward, and aline holes with drifts. Loosely install four bolts with washers through bumper upper flange into winch angle. Install two bolts, nuts, and washers attaching bumper lower flange to each bumper bracket, then tighten all bolts and nuts firmly, including tow hook rear bolt nuts. Hook chain on tow hooks and engage winch to pull chain taut.

216. TOW HOOKS.

a. Front Tow Hooks (fig. 222). A right-hand and a left-hand tow hook is bolted to front end of frame side rails on models without winch, and to ends of frame extension on vehicles equipped with winch.

(1) MODELS WITHOUT WINCH.

(a) Removal. Remove three bolts, nuts, and washers, and two spacer attaching tow hook, then remove tow hook. Removal operation is same for either side.

(b) Installation. Position $^{11}/_{16}$-inch long spacer between side rail and bumper gusset then position tow hook with $^{15}/_{16}$-inch long spacer under hook rear bolt hole. Install three bolts, nuts, and washers and tighten nuts firmly. Installation is same for either side.

(2) MODELS WITH WINCH.

(a) Removal. Remove three bolts, nuts, and washers, and one spacer attaching tow hook, then remove tow hook. Removal operation is applicable to either side.

(b) Installation. Position tow hook with ¼-inch long spacer under hook rear bolt hole, then install three bolts, nuts, and washers, tightening nuts firmly. Operation is same for either side.

b. Rear Tow Hooks. Rear tow hooks are used only on vehicles equipped with water tank or gasoline tank bodies. One tow hook is bolted to side of each frame side rail near rear crossmember.

(1) REMOVAL. Remove three bolts, nuts, and washers, and one spacer, then remove rear tow hook. Removal is same for either side.

(2) INSTALLATION. Position tow hook on frame side rail with spacer under hook front bolt hole, install three bolts, nuts, and washers, and tighten nuts firmly. Installation operation is same for either side.

217. BRUSH GUARD.

a. Brush guard, made of steel rods and bars integrally welded to a rigid frame, protects radiator core, headlights, and blackout lights from damage. Guard also serves to reinforce front end sheet metal

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by tieing together fenders, radiator support, and hood side front panels.

b. On vehicles equipped with radio suppression it is important that attaching bolts be kept tightened to suppress radio interference noise.

c. **Brush Guard Removal.** Remove three bolts, nuts, and washers attaching each fender to guard (F and G, fig. 222). Remove five bolts, nuts, and washers attaching sheet metal to each side of brush guard (A, C, and E, fig. 222). Remove four bolts, nuts, and washers attaching radiator supports to each side of brush guard (B and D, fig. 222), then pull brush guard forward and remove from vehicle.

d. **Radio Noise Suppression.** Figure 222 shows location of all brush guard attaching bolts together with sectional views of bolts installed. The internal-external toothed lock washers must be used on each bolt, one under bolt head. the other under the nut, to prevent electrical radiation.

e. **Brush Guard Installation.** Position brush guard on vehicle, and aline bolt holes with drift. Install four bolts and nuts, and eight internal-external toothed lock washers attaching each side of brush guard to radiator supports (B and D, fig. 222). Install the 10 internal-external toothed lock washers, and five bolts and nuts attaching sheet metal to each side of brush guard (A, C, and E, fig. 222). Install six internal-external toothed lock washers, and three nuts and bolts attaching each fender to brush guard (F and G, fig. 222). Tighten all mounting nuts firmly.

218. SPARE WHEEL CARRIERS.

a. Three types of wheel carriers are used; the type used being dependent on wheelbase and body. The 164-inch wheelbase (model CCKW-353) with cargo or dump body has single wheel carrier mounted on left side rail back of cab and under cargo body (fig. 223). The 145-inch wheelbase (model CCKW-352) with cargo body mounts two wheels and tires vertically between cab and body. Fuel tank and tank support forms the base for this carrier (fig. 223). The 164-inch wheelbase (model CCKW-353) with tank bodies carries a single wheel and tire in vertical position between cab and tank (fig. 223).

b. **Long-wheelbase—Cargo Body.**

(1) SPARE WHEEL CARRIER REMOVAL (fig. 223). Remove lock, then remove nut from carrier to frame stud. Lift latch handle and swing wheel down, remove two spare wheel hub nuts, then remove wheel. Remove the six bolts, nuts, and washers attaching carrier brackets to frame, then remove carrier from frame.

(2) SPARE WHEEL CARRIER INSTALLATION (fig. 223). Position carrier assembly on frame and aline bolt holes with drifts. Install six mounting bolts, nuts, and washers, then tighten nuts firmly. Position spare wheel over two studs, install two hub nuts, and tighten nuts firmly. Lift wheel to horizontal position and engage latch. Install stud nut and tighten firmly, then install lock.

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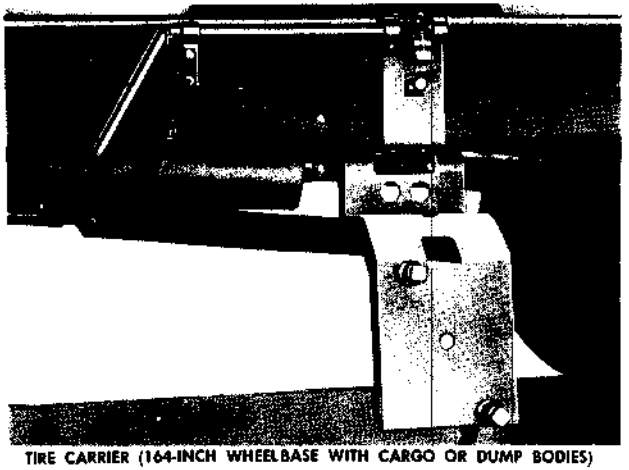
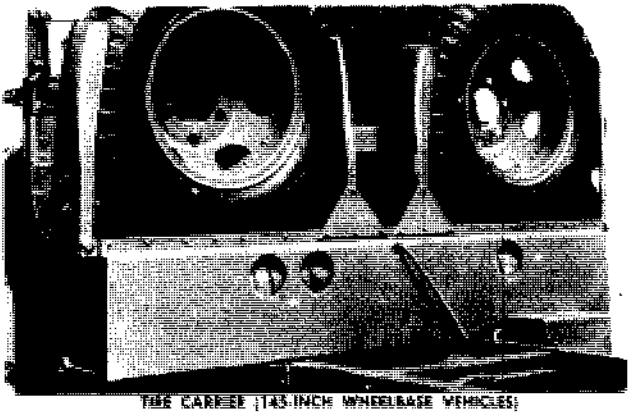
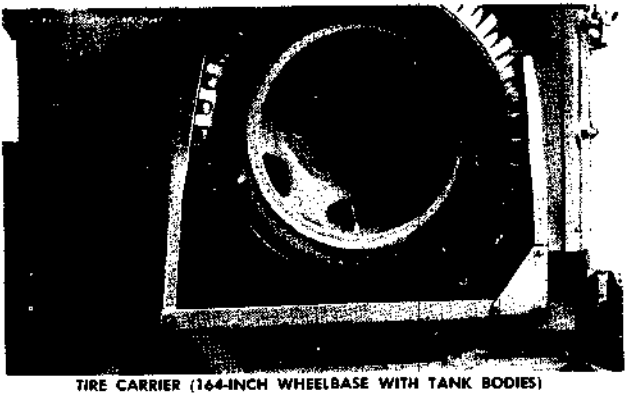
FRAME



TIRE CARRIER (164-INCH WHEELBASE WITH CARGO OR DUMP BODIES)



TIRE CARRIER (145-INCH WHEELBASE VEHICLES)



TIRE CARRIER (164-INCH WHEELBASE WITH TANK BODIES)

RA PD 332994

Figure 223—Spare Wheel Carriers

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c. **Short-wheelbase—Cargo Body.**

(1) SPARE WHEEL CARRIER REMOVAL (fig. 223). NOTE: *Spare wheel carrier support encloses the fuel tank which may be removed from carrier support either before or after removal of carrier from vehicle.* If necessary to remove fuel tank, refer to paragraph 100 for removal. Remove cargo racks from body, remove locks from carrier, then remove clamp nuts from clamp bolts. Swing clamps down, remove nuts from wheel hubs, then lift wheels from carrier. Remove both drain plugs from tank and drain tank completely. Remove 11 bolts, nuts, and washers attaching carrier to frame side rails. Disconnect fuel gage wire at tank, then unscrew fuel line nut at tank and disconnect fuel line. Withdraw gage wire and fuel line from tire carrier support, shifting tank and carrier forward on side rails, if necessary for clearance. Lift carrier and tank unit straight up to remove from vehicle.

(2) SPARE WHEEL CARRIER INSTALLATION (fig. 223). Position carrier on frame side rails and connect fuel gage wire and fuel line, shifting carrier forward or back as necessary to make connections. Aline mounting bolt holes, install 11 carrier to frame bolts, nuts, and washers, and then tighten nuts firmly. Position wheels in carrier and install one nut at hub of each wheel. Swing clamp up against tires, install and tighten clamp nuts on clamp bolts, then install locks. Install drain plugs, then install cargo racks on body.

d. **Long-wheelbase—Tank Bodies.**

(1) SPARE WHEEL CARRIER REMOVAL (fig. 223). Remove spare wheel lock, remove clamp nut and swing clamp down, then remove spare wheel. Remove eight bolts, nuts, and washers attaching carrier to frame side rails and lift carrier off chassis.

(2) SPARE WHEEL CARRIER INSTALLATION (fig. 223). Position carrier on vehicle and aline mounting bolt holes with drifts. Install eight carrier to frame bolts, nuts, and washers, and tighten nuts firmly. Position wheel and tire in carrier and swing clamp up against tire. Install and tighten clamp nut, then install lock.

219. PINTLE HOOK.

a. Pintle hook is mounted at center of rear crossmember with front end of pintle supported by a steel channel. A heavy coil spring in the assembly serves to absorb shocks in starting and towing. Keep pintle shaft nut tight enough to eliminate rattles and lubricate moving parts periodically with seasonal grade engine oil. Pintle hooks are not used on vehicles equipped with water or gasoline tank bodies.

b. Pintle Hook Removal (fig. 224). Remove six bolts, nuts, and washers attaching pintle hook front support to braces. Remove cotter pin and remove nut from pintle shaft. Slide support, spring, and sleeves from pintle shaft and pull shaft out through rear crossmember.

c. Pintle Hook Installation (fig. 224). Insert pintle shaft through rear crossmember and assemble spring and sleeves on shaft

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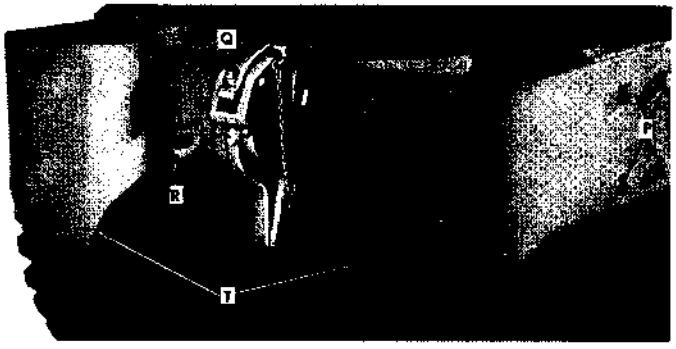
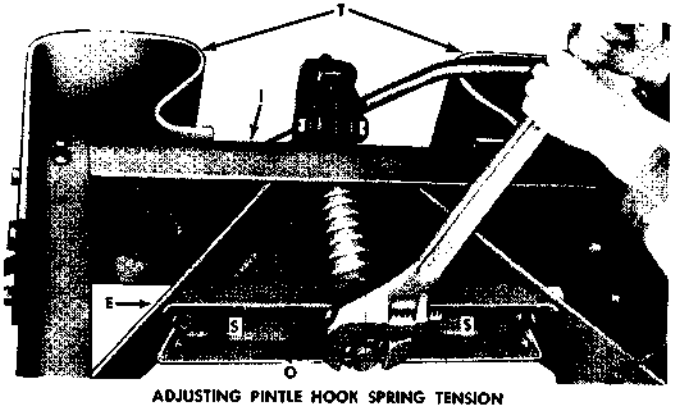
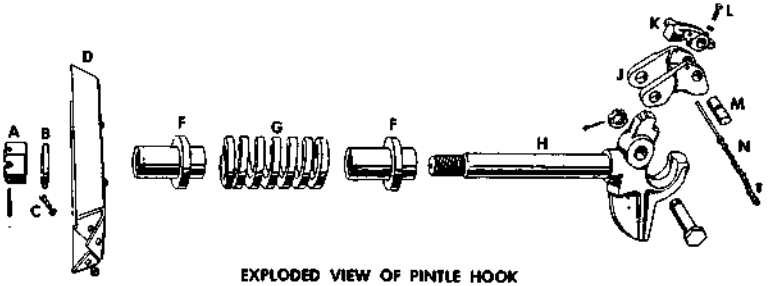
FRAME



REAR BUMPER AND PINTLE HOOK



ADJUSTING PINTLE HOOK SPRING TENSION



EXPLODED VIEW OF PINTLE HOOK

A NUT
B WASHER
C BOLT
D FRONT SUPPORT
E BRACE
F SLEEVE
G SPRING
H HOOK
I REAR CROSSMEMBER
J LOCK
K LATCH
L SCREW
M PIN
N CHAIN
O SUPPORT
P BUMPER TO SIDE RAIL BOLT
Q BUMPER TO CROSSMEMBER BOLT
R EYE BOLT
S SUPPORT TO BRACE BOLT
T BUMPER

RA PD 332947

Figure 224—Pintle Hook and Rear Bumper

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with sleeves positioned as in figure 224. Reversing either sleeve will make assembly too long or too short to properly install on vehicle; reversing both sleeves will result in extending hook 1¾ inches back from rear crossmember. Place pintle support over shaft against sleeve shoulder, install washer, and start pintle shaft nut. Insert suitable bar through pintle hook eye to prevent hook turning while tightening nut. Tighten shaft nut until support fits up against frame brace, then attach support to brace with six bolts, nuts, and washers. Adjust nut to provide just enough spring tension to prevent rattle, then secure nut with new cotter pin.

Section XXXIX

CAB AND ASSOCIATED PARTS

220. GENERAL.

a. Cab consists of an open top structure enclosing driver's compartment. The cab, of all steel construction, consists of cowl and dash panel, side panels, rear panel, seat risers, and floor pan bolted together into a unit assembly. Weather protection is provided by windshield, top deck, rear curtain, and hinged side curtains. Cab is equipped with an inside and an outside rear view mirror (head—GM-2165013), two windshield wipers, two rifle holders, and includes provision for gun mount ring.

221. CAB MOUNTINGS.

a. **Description.** Three-point type mounting, shown in figure 225, is used to attach the cab to the chassis frame. Both front corners of the cab are flexibly mounted by means of a mounting cushion between the cab and frame mounting bracket. Rear mounting consists of a single through bolt and cushions at rear center of the cab which fastens the cab to the frame cross channel. A heavy cushion spring is mounted between cab and frame cross channel at each side of the rear center mounting bolt to prevent excessive rocking movement of the cab.

b. **Mounting Adjustment.** Any change in the position of the cab in relation to the chassis frame may cause steering gear to bind (par. 204) and may change the clearance between radiator and fan (par. 109). Steering gear and cab mounting tightening procedures must be performed together and procedure must be followed in sequence given if correct mounting is to be obtained.

(1) LOOSEN STEERING COLUMN BRACKET. Loosen two nuts attaching steering column bracket at lower edge of dash panel.

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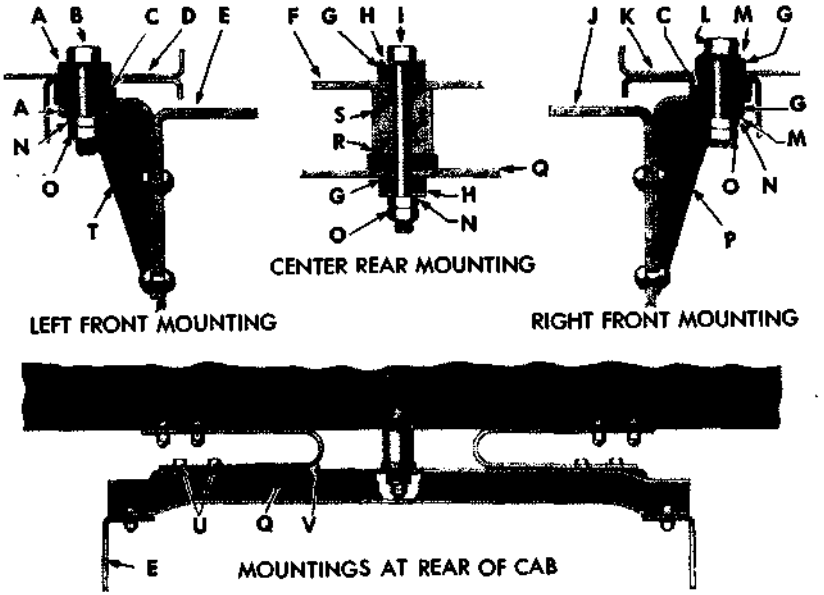
CAB AND ASSOCIATED PARTS

(2) LOOSEN STEERING GEAR FRAME MOUNTING BOLTS. Loosen, but do not remove, four bolt nuts attaching steering gear housing flange to frame left side rail.

(3) ADJUST CAB MOUNTINGS. Loosen all three cab mounting bolts (fig. 225). Inspect mountings and replace any damaged parts as described in subparagraphs c and d below. Move cab into correct position to locate squarely at all three mounting points on chassis. Tighten adjusting nut and lock nut on each of three mounting bolts, being sure not to change position of cab. Do not use lubricant on bolts and nuts.

(4) CHECK AND ADJUST RADIATOR MOUNTINGS AND CLEARANCE. Check radiator to fan clearance and adjust radiator mountings if necessary, as described in paragraph 109.



A STEEL SPACER
B LEFT FRONT MOUNTING BOLT
C LEFT AND RIGHT FRONT MOUNTING CUSHION
D LEFT FRONT CORNER OF CAB
E FRAME LEFT SIDE RAIL
F CAB REAR FLOOR
G CENTER REAR AND RIGHT FRONT MOUNTING CUSHION
H STEEL WASHER
I CENTER REAR MOUNTING BOLT
J FRAME RIGHT SIDE RAIL
K RIGHT FRONT CORNER OF CAB
L RIGHT FRONT MOUNTING BOLT
M STEEL WASHER
N ADJUSTING NUT
O LOCK NUT
P RIGHT FRONT FRAME BRACKET
Q FRAME CROSS CHANNEL
R CENTER REAR MOUNTING CUSHION
S CENTER REAR STEEL SPACER
T LEFT FRONT FRAME BRACKET
U REAR MOUNTING SPRING BOLTS
V REAR MOUNTING SPRING

RA PD 64723

Figure 225—Cab Three-Point Mounting

(5) ADJUST STEERING GEAR AND TIGHTEN MOUNTINGS. Check steering gear adjustments and tighten steering gear mountings, as described in paragraph 204. Tighten two U-bolt nuts attaching steering column to lower edge of dash panel. Tighten four steering gear housing flange to frame side rail bolts, tightening upper front or pivot bolt last. Turn steering wheel to extreme right and left positions, and if any binding is evident, repeat above operations so that steering gear and cab mountings can be tightened without causing binding.

c. Mounting Removal. Removal operations cover only removal of the three cab mounting bolts, cushions, and spacers.

(1) REMOVE CAB LEFT FRONT MOUNTING BOLT. Pry up access hole button plug from left side of cab floor. Remove lock nut, adjusting nut, and steel spacer from end of bolt accessible under cab skirt above left-hand running board. From inside cab, remove mounting bolt and steel spacer at access hole in cab floor. Raise corner of cab to relieve pressure on mounting cushion and withdraw cushion from between cab and frame bracket.

(2) REMOVE CAB RIGHT FRONT MOUNTING BOLT. Pry up access hole button plug from right side of cab floor. Remove lock nut, adjusting nut, washer, and mounting cushion from end of bolt accessible under cab skirt above right-hand running board. From inside cab, remove bolt, washer, and mounting cushion at access hole in cab floor. Raise corner of cab to relieve pressure on mounting cushion and withdraw cushion from between cab and frame bracket.

(3) REMOVE CAB REAR CENTER MOUNTING BOLT. From underneath vehicle at frame cross channel, remove lock nut, adjusting nut, washer, and mounting cushion from end of bolt. Remove two nuts, washers, and bolts attaching one mounting spring to frame cross channel. From inside cab, remove rear center mounting bolt, washer, and mounting cushion. Raise the rear corner of cab at which spring bolts were removed and withdraw mounting cushion and steel spacer.

d. Mounting Installation.

(1) INSTALL CAB REAR CENTER MOUNTING BOLT. Raise the rear corner of cab at which spring bolts were removed and position mounting cushion and steel spacer (fig. 225) and aline holes. Lower cab corner so cab rests on spacer above cushion. Install washer and mounting cushion on bolt, then insert bolt through cab floor, steel spacer, mounting cushion, and frame cross channel. Install two bolts, nuts, and washers through mounting spring and frame cross channel. Install mounting cushion, washer, and adjusting nut on end of rear mounting bolt, tightening nut firmly, then install and tighten lock nut.

(2) INSTALL CAB RIGHT FRONT MOUNTING BOLT. Raise right front corner of cab and insert mounting cushion between cab and frame mounting bracket, aline holes in cab, cushion, and bracket, then lower corner of cab. Install flat washer and cushion on mounting bolt and insert bolt through cab, mounting cushion, and frame bracket from inside cab. Install mounting cushion, flat washer, and adjusting nut on mounting bolt from under cab skirt above right

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running board. Tighten nut firmly, install lock nut and tighten. Install button plug in cab floor.

(3) INSTALL CAB LEFT FRONT MOUNTING BOLT. Raise left front corner of cab, insert mounting cushion between cab and frame bracket, aline holes, then lower cab. Install steel spacer on bolt and insert bolt through cab, cushion, and frame bracket from inside of cab. Install steel spacer and adjusting nut from under cab skirt above left-hand running board. Tighten nut firmly and install and tighten lock nut. Install button plug in cab floor.

222. WINDSHIELD.

a. Description. Windshield consists of the windshield frame and glass assembly hinged to windshield tubular support frame at the top edge by interlocking metal strips. Tubular support frame pivots at the lower corners on pins in brackets, bolted to the cab cowl at the front corners of the driver's compartment.

b. Windshield Removal (fig. 226). Windshield frame assembly can be removed without loosening or removing tubular support frame.

(1) DISCONNECT ADJUSTING ARMS AT BRACKETS. Loosen adjusting arm (upper) knobs, open windshield, then tighten knobs to hold windshield tilted open. Remove two adjusting arm to bracket screws and disengage arms from brackets.

(2) REMOVE WINDSHIELD WIPER MOTORS. Remove wiper motors as described in paragraph 223.

(3) REMOVE WINDSHIELD FRAME AND GLASS ASSEMBLY. Bend open one end of tubular frame hinge strip with screw driver (fig. 226). Open windshield wide and slide frame and glass assembly endwise sufficiently to completely disengage interlocking hinge strips.

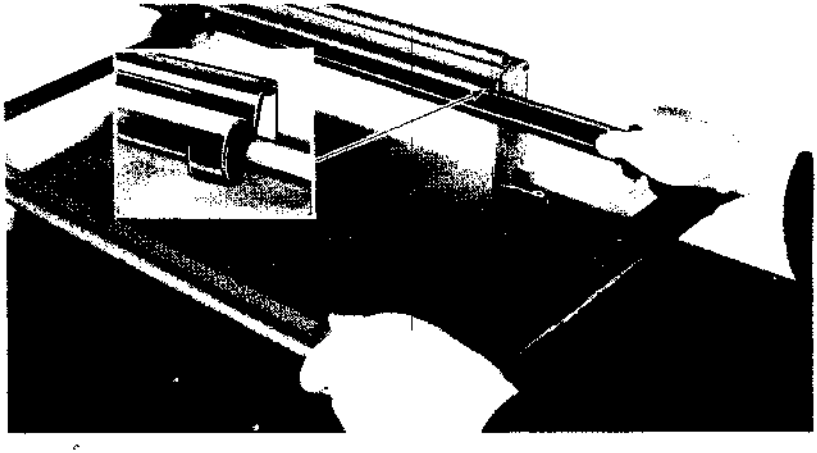

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Figure 226—Windshield Frame and Glass Removal

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c. Windshield Installation.

(1) HINGE WINDSHIELD TO FRAME. Hold windshield frame and glass in horizontal position and engage end of strip with opened end of hinge strip on tubular support frame. Slide frame and glass to proper position and close windshield. Bend opened end of tubular frame hinge strip to lock windshield in place laterally.

(2) CONNECT ADJUSTING ARMS. Open windshield sufficiently to position adjusting arms on windshield brackets. Install screw and tighten to connect each arm to bracket.

(3) INSTALL WINDSHIELD WIPER MOTORS. Install both wiper motors as described in paragraph 223.

223. WINDSHIELD WIPERS.

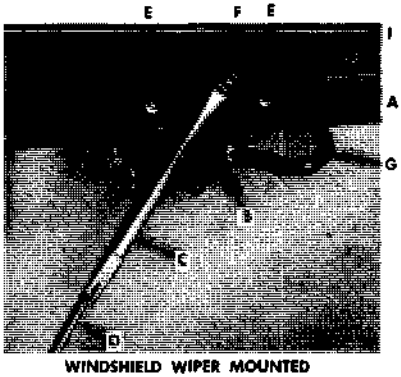
a. Description. Two identical vacuum operated windshield wipers are mounted at top of the left and right sections of the windshield. Wipers are connected to engine manifold by means of tubing and hose. Each wiper consists of a wiper motor, arm, and blade.

b. Windshield Wiper Removal (fig. 227). Procedure is same for either motor.

(1) DISCONNECT HOSE. Pull vacuum line hose loose from wiper motor.

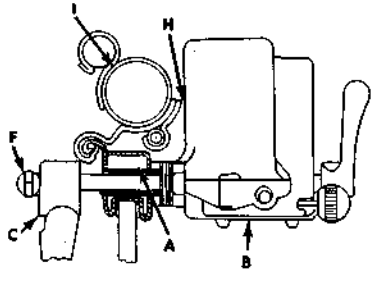
(2) REMOVE BLADE AND ARM. Remove nut [(GM-3661579) G501-03-14861] from end of wiper motor shaft and pull wiper arm (GM-2198557) and blade (GM-2198558) as an assembly from motor shaft.

(3) REMOVE WINDSHIELD WIPER MOTOR. At front side of windshield, remove the two screws attaching motor [(GM-2180781)



WINDSHIELD WIPER MOUNTED

A WINDSHIELD CROSSPIECE
B WIPER MOTOR
C WIPER ARM
D WIPER BLADE
E MOUNTING SCREWS



WIPER AND TUBULAR FRAME CLEARANCE

F ARM NUT
G VACUUM HOSE
H CLEARANCE
I TUBULAR FRAME

RA PD 332942

Figure 227—Windshield Wiper Mounted and Support Clearance

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G501-02-95848] to windshield frame. Pull motor loose from rear of windshield.

c. **Windshield Wiper Installation** (fig. 227). Procedure is the same for either motor.

(1) INSTALL WINDSHIELD WIPER MOTOR. Insert motor shaft through hole in windshield frame from rear side of windshield. Install two screws from front side of windshield to attach motor to windshield frame.

(2) CHECK MOTOR CLEARANCE. With windshield fully closed there should be some clearance between windshield wiper motor and the windshield tubular frame as shown in figure 227. If this clearance is not present, correct as follows:

(a) Remove wiper motor as directed in subparagraph **b** (3) above.

(b) Redrill wiper shaft hole in windshield frame, using a $\frac{7}{16}$-inch diameter drill or file or ream out original hole. Hole must be straight through windshield to permit installation of motor without distortion of shaft and sleeve.

(c) Reinstall motor as described in step (1) above, and recheck for clearance.

(3) INSTALL WIPER ARM AND BLADE. Install wiper arm and blade as an assembly on end of motor shaft, then install and tighten shaft to arm nut. Connect vacuum line hose to wiper motor.

d. **Wiper Blade Replacement.** Procedure is the same for either blade.

(1) REMOVE BLADE. Hold lower end of wiper arm away from windshield with one hand; with the other, pull lower end of blade outward and upward until blade is in contact with front of arm. Pull end of blade farthest from motor shaft away from motor shaft to remove blade from arm.

(2) INSTALL BLADE. With hook on blade pointing to motor shaft, and with metal part of blade in contact with forward side of arm, push blade toward shaft. Pull lower end of arm away from windshield with one hand; with the other hand, pull end closest to motor shaft outward and downward to engage blade hook in slot in arm.

224. SEATS (fig. 228).

a. **Description.** Cab seats consist of individual seats for the driver and the assistant driver. The seats are similar and are mounted on a seat riser which is bolted to the cab floor. Seat backs are hinged to lay forward on seats, while seats can also be tilted up against seat backs. A sector arm, attached to right-hand seat only, permits locking seat in upright position. Raising bottom of driver's seat affords access to stowage compartment under seat.

b. **Seat Removal.**

(1) REMOVE SEAT CUSHIONS. Pull bottom of seat back cushion forward, then tilt seat back down. Slide cushion to side to disengage

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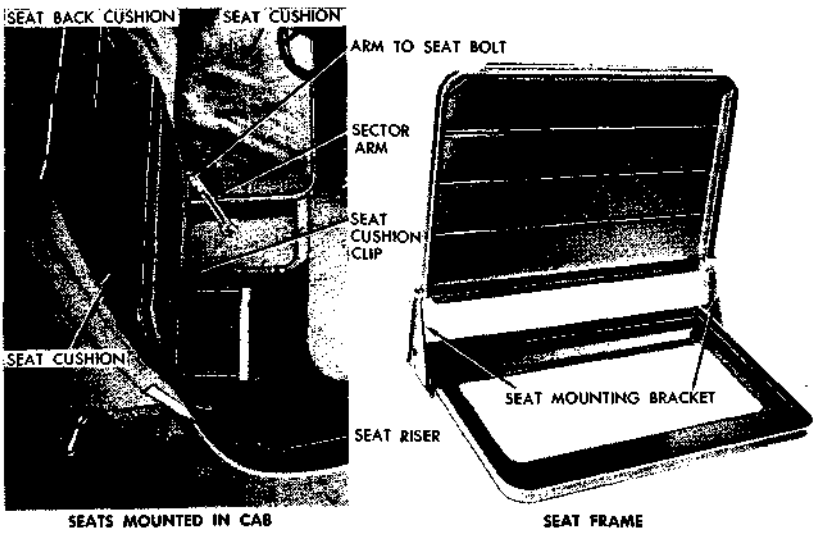

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Figure 228—Seats Installed and Seat Frame Removed

bead in back cushion from metal channel in seat back. Tilt seat bottom up against seat back, then turn seat spring latch to side by tapping with hammer. Procedure is same for either seat.

(2) DISCONNECT SECTOR ARM (RIGHT-HAND SEAT ONLY). Tilt seat bottom up, then remove bolt, nut, and washers attaching sector arm to seat bottom.

(3) REMOVE SEAT FRAME. With seat bottom raised, remove three nuts and washers attaching mounting bracket on each side of seat to seat risers. Lift seat frame assembly from cab. Procedure is same for either seat.

c. Seat Installation.

(1) INSTALL SEAT FRAME. NOTE: *Seat having sector arm mounting lug on underside of seat bottom is the right-hand seat.* Position seat frame on seat riser with mounting bracket studs through holes in seat riser. Install three washers and nuts on mounting studs at each end of seat, and tighten nuts firmly. Procedure is same for either seat.

(2) CONNECT SECTOR ARM (RIGHT-HAND SEAT ONLY). Tilt seat bottom up, then attach sector arm to lug on seat bottom with bolt, nut, and washers.

(3) INSTALL SEAT CUSHIONS. Position seat cushion on seat bottom frame, then raise seat bottom. Engage seat spring clips with seat bottom frame by tapping into position with hammer. Tilt seat back forward and engage end of bead on seat back cushion with end of metal channel on top of seat back. Slide cushion into place to completely engage bead.

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Section XL

SHEET METAL

225. ENGINE HOOD.

a. Engine hood consists of a formed and reinforced metal panel over top of engine. Hood is attached to cowl with two hinges and fastened in closed position at front end by two spring type catches.

b. **Hood Removal.**

(1) RELEASE CATCHES AND DISCONNECT HOOD SUPPORT. Lift up spring type catch at each front corner of hood and disengage from hood clip. Raise engine hood and remove the two bolts, nuts, and washers attaching support bracket to hood.

(2) DISCONNECT RADIO SUPPRESSION BOND STRAPS. Remove bolt and washers attaching two bond straps to underside of hood.

(3) REMOVE HINGE BOLTS AND HOOD. Close hood, unscrew two hinge bolts from hinges, then lift off hood.

c. **Hood Installation.**

(1) POSITION HOOD AND INSTALL HINGE BOLTS. Position hood over engine, aline hinges, and install two hinge bolts.

(2) CONNECT HOOD SUPPORT. Raise engine hood, position hood support bracket to underside of hood, then install two bolts, washers, and nuts, tightening nuts firmly.

(3) CONNECT RADIO SUPPRESSION BOND STRAPS. Connect two bond straps to underside of hood, using bolt and two internal-external toothed lock washers on each strap. Use one washer under head of bolt and the other between strap and hood. Close hood and pull up on spring type catch at each front corner of hood, engaging catch in clip attached to hood.

226. HOOD SIDE PANELS.

a. Hood side panel assembly consists of a front and rear panel at each side of engine above fender, bolted together through a reinforcing channel spot welded to front panel.

b. **Hood Side Panel Removal** (fig. 229).

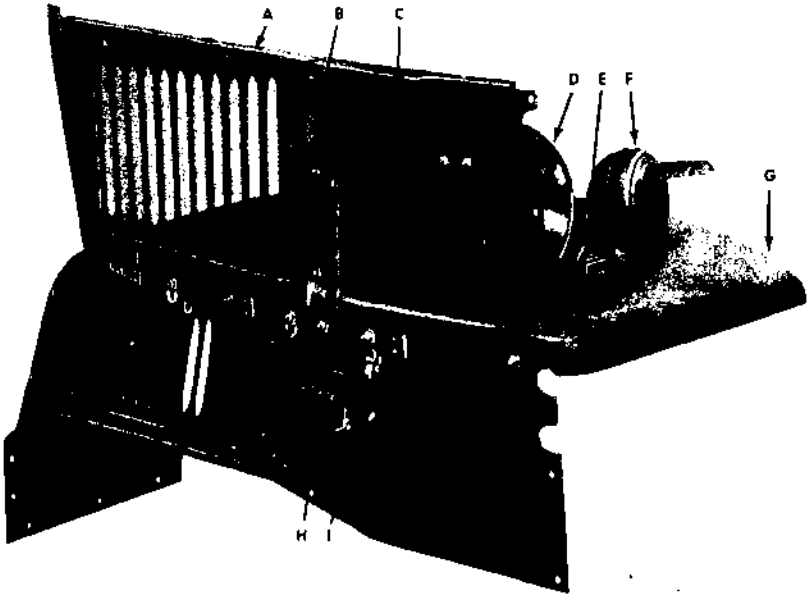
(1) REMOVE HOOD REAR SIDE PANEL. Remove three bolts attaching rear side panel to front side panel. Remove bolt, nut, and washers attaching radio suppression bond strap to upper rear corner of panel. Pry open clip at upper rear corner of panel. Lift panel straight up to remove from vehicle. Procedure is same for either side.

(2) REMOVE HOOD FRONT SIDE PANEL. Remove three bolts, nuts, and washers attaching panel to brush guard and remove bolt, nut, and washers attaching panel reinforcement to fender skirt. Remove bolt, nut, and washers attaching panel to radiator brace. Slide panel to rear, then lift straight up to remove from vehicle. Procedure is same for either side.

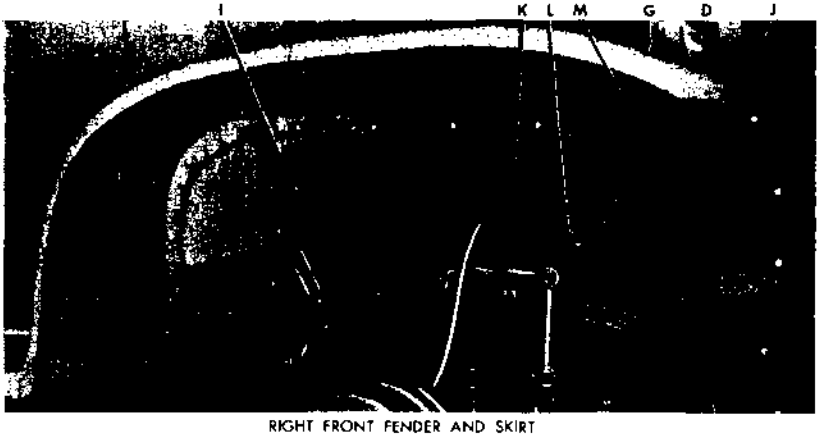
c. **Hood Side Panel Installation** (fig. 229).

(1) INSTALL HOOD FRONT SIDE PANEL. Position panel on vehicle with lower edge engaged in clip on fender skirt. Aline bolt

TRUCK, 2½-TON, 6 x 6



LEFT FRONT FENDER AND ENGINE CLOSURE PANELS



RIGHT FRONT FENDER AND SKIRT

A HOOD REAR SIDE PANEL
B REINFORCEMENT CHANNEL
C HOOD FRONT SIDE PANEL
D HEAD LIGHT
E BLACKOUT MARKER LIGHT
F BLACKOUT DRIVING LIGHT
G FRONT FENDER
H WIRING JUNCTION BLOCK
I FRONT FENDER SKIRT
J BRUSH GUARD
K BRAKE HOSE SPRING
L BOND STRAP
M FENDER REINFORCEMENT

RA PD 332897

Figure 229—Fender, Skirt, and Hood Panels

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holes and install three bolts and nuts and six internal-external toothed lock washers attaching panel to brush guard. Use one washer under head of bolt and another under nut. Install one bolt and nut and two internal-external toothed lock washers attaching panel reinforcement to skirt, using one washer under bolt head and the other under the nut. Install one bolt and nut, and two internal-external toothed lock washers attaching panel to radiator brace, using one washer under bolt head and the other washer under the nut.

(2) INSTALL HOOD REAR SIDE PANEL. Position panel with lower edge engaged in fender skirt clips and aline bolt holes. Install three bolts and internal-external toothed lock washers attaching panel to front panel reinforcement, with washers under bolt heads Connect radio suppression bond strap to upper rear corner of panel with one bolt and nut and three internal-external toothed lock washers. Use one washer under bolt head, one washer between strap and panel, and the other washer between strap and nut. Bend clip together with hammer. Procedure is same for either side.

227. FENDERS AND SKIRTS.

a. Front fender and skirt, consisting of fender and louvred metal panel at side of engine, are bolted together. Headlights and blackout lights are mounted on the front end of fenders. While either fender or skirt can be removed and replaced without removal of the other part, replacement is facilitated by removal of fender and skirt as an assembly.

b. Fender and Skirt Removal (fig. 229). Operations are same for either fender except as otherwise noted in text.

(1) DISCONNECT WIRING. Raise engine hood. Disconnect wiring harness at inside of fender skirt by loosening screws attaching harness to junction block and disconnecting blackout marker light wire at connector. Disengage wiring harness from all clips mounted on fender skirt.

(2) UNHOOK BRAKE HOSE SPRING AND DISCONNECT BOND STRAP. Unhook brake hose spring from fender skirt. Remove nut, washers, and bolt attaching radio suppression bond strap to lower edge of fender skirt.

(3) REMOVE CAP SCREWS AND BOLTS. Remove two cap screws and washers attaching fender to cowl at underside of fender. Remove bolt, nut, and washers attaching fender to cowl bracket, then remove anti-squeak from between fender and cowl. Remove bolt and washer attaching lower rear corner of fender skirt to cowl.

(4) REMOVE FENDER TO RUNNING BOARD BOLTS. Remove five bolts, nuts, and washers attaching fender to running board, then remove anti-squeak from between running board and fender.

(5) REMOVE FENDER TO BRUSH GUARD BOLTS. Remove three bolts, nuts, and washers attaching fender to brush guard.

(6) DISCONNECT WIRING AND DISASSEMBLE (fig. 230). Remove fender and skirt assembly from vehicle. Disconnect light wires from junction block at inner side of fender skirt. Loosen wire grommets

at holes in fender skirt and pull wires through skirt. Remove the six bolts, washers, and nuts attaching fender skirt to fenders. If lights are to be removed, refer to paragraphs 121, 122, and 123.

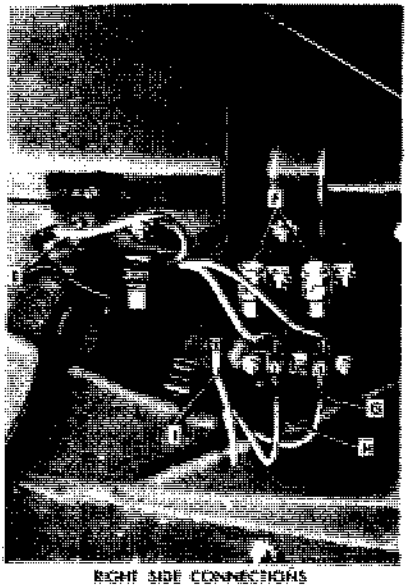
c. **Fender and Skirt Installation** (figs. 229 and 230). Installation operations are same for either fender except as noted in text. Install lights as directed in paragraphs 121, 122, and 123.

(1) ASSEMBLE FENDER AND SKIRT. Assemble fender skirt to fender with six bolts and nuts and 12 internal-external toothed lock washers, omitting bolt in third hole from front. On left front fender only, install a wiring harness clip on fourth and sixth bolt from front, using an additional internal-external toothed lock washer between clip and skirt. Thread light wiring through holes in skirt and fit grommets in place.

(2) POSITION FENDER AND SKIRT AND INSTALL BOLTS. Position fender and skirt assembly on vehicle, with lower edge of hood side panels engaged in fender skirt clips. Install anti-squeak between fender and cowl, then install two cap screws and washers attaching fender to cowl. Install bolt with washer and nut through fender and cowl bracket. Install cap screw with internal-external toothed lock washer under head attaching lower rear corner of fender skirt to cowl.

LEFT SIDE CONNECTIONS

A GENERATOR ARMATURE
B GENERATOR GROUND
C GENERATOR FIELD
D BLACKOUT DRIVE LIGHT
E BLACKOUT MARKER



RIGHT SIDE CONNECTIONS

F CONDENSER
G HEADLIGHT LOW BEAM
H HEADLIGHT HIGH BEAM
I HEADLIGHT GROUND
J HORN

RA PD 332932

Figure 230—Fender Skirt Wiring Junction Blocks

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(3) BOLT FENDER TO BRUSH GUARD. Install three bolts and nuts and six internal-external toothed lock washers attaching fender to brush guard. Use washers under bolt heads and under nuts.

(4) ATTACH FENDER TO RUNNING BOARD. Position anti-squeak between fender and running board and install 5 bolts, nuts and lock washers, and 10 flat washers attaching fender to running board.

(5) CONNECT BRAKE HOSE SPRING AND BOND STRAP. Hook brake hose spring in fender skirt. Connect radio suppression bond strap to lower edge of fender skirt with bolt, nut, and three internal-external toothed lock washers. Position washers under bolt head, under nut, and between bond strap and skirt.

(6) CONNECT WIRING (fig. 230). Connect wiring harness at junction block at inner side of fender skirt. Refer to figure 113 or 114 for wire identification and proper connections. Connect blackout marker light wire at connector. Attach wiring harness to fender skirt clips and close engine hood.

228. RUNNING BOARDS AND STEP HANGERS.

a. Running Board and Hanger Removal.

(1) REMOVE RUNNING BOARD. Remove five bolts, nuts, and washers attaching fender to running board, and remove fender to running board anti-squeak. Remove four running board to step hanger bolts, nuts, and washers. Lift running board off step hangers and remove wood spacer from front step hanger. Procedure is same for either side.

(2) REMOVE REAR STEP HANGER (fig. 231). Remove nut and washers attaching suppression bond strap to upper step hanger bolt and remove strap. Remove three bolts, nuts, and washers attaching hanger to frame and remove hanger. Procedure is same for either rear hanger.

(3) REMOVE RIGHT FRONT STEP HANGER. Remove three bolts, nuts, and washers, then remove hanger and frame spacer.

(4) REMOVE LEFT FRONT STEP HANGER (fig. 231). Hanger mounting cap screws are threaded into a tapping plate not otherwise attached to frame side rail. Following procedure must be observed to prevent dislodging plate.

(a) Remove both lower cap screws and washers, then loosen upper cap screw sufficiently to swing hanger to the rear.

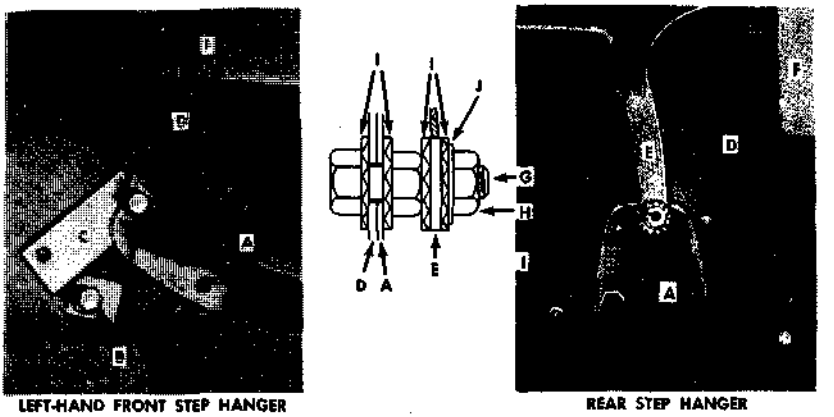
(b) Install cap screw in one of the lower holes and tighten firmly.

(c) Remove upper cap screw, hanger, and frame spacer. Cap screw in lower hole holds tapping plate in place.

b. Running Board and Hanger Installation.

(1) INSTALL LEFT FRONT STEP HANGER (fig. 231). Position spacer and hanger to side rail and install upper bolt and washer finger-tight (fig. 231). Remove lower bolt holding tapping plate and swing spacer and hanger into position. Install two lower bolts and washers, making sure hole in spacer is alined with front lower hole in hanger. Tighten all bolts firmly.

(2) INSTALL RIGHT FRONT STEP HANGER. Position hanger and



LEFT-HAND FRONT STEP HANGER

REAR STEP HANGER

A STEP HANGER
B CAP SCREW
C SPACER
D FRAME SIDE RAIL
E BOND STRAP
F CAB
G BOLT
H NUT
I TOOTHED LOCK WASHER
J FLAT WASHER

RA PD 333004

Figure 231—Step Hanger Installation

spacer on frame side rail with holes in spacer alined with upper and front lower holes in hanger. Install three bolts, nuts, and washers, tightening nuts firmly.

(3) INSTALL REAR STEP HANGER (fig. 231). Install an internal-external toothed lock washer on a long bolt, position hanger to frame, then install bolt from inside frame through upper hole of hanger. Install internal-external toothed lock washer and nut. Install two short bolts, nuts, and washers in lower holes in right rear hanger. (In left rear hanger, install a short bolt in rear lower hole and a long bolt in front lower hole.) Install internal-external toothed lock washer on upper bolt, then install bond strap, internal-external toothed washer, flat washer, and nut.

(4) INSTALL RUNNING BOARD. Position wood spacer on front step hanger, then position running board on hangers. Install two bolts, nuts, and washers to attach running board to each hanger, using longer bolts through front hangers. Position anti-squeak between running board and fender, and install five bolts, nuts, and lock washers, and 10 flat washers to attach rear end of fender to running board.

Section XLI

CARGO AND DUMP BODIES

229. GENERAL.

a. Cargo body and cargo dump body, while of similar size and appearance, differ in construction. Cargo body is of metal-reinforced

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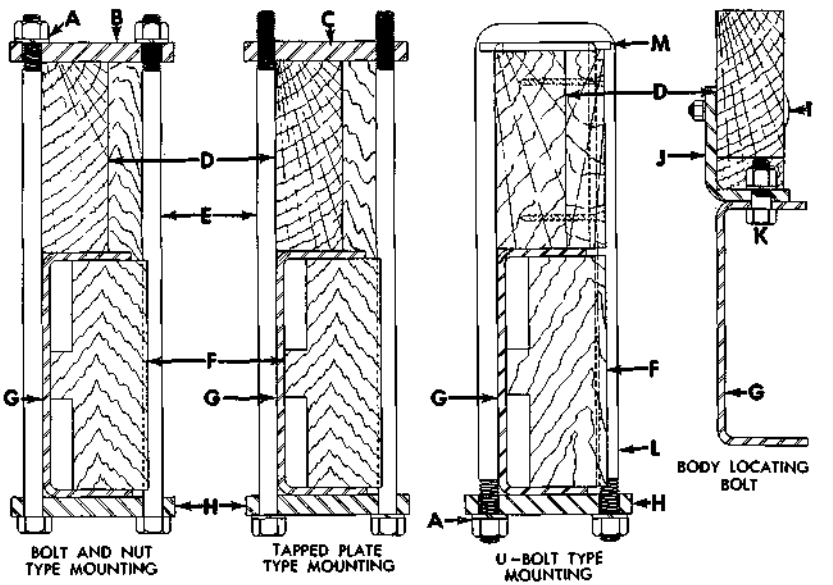
wooden construction, whereas dump body is of all-steel construction.

b. Body mountings, in general, include hold down bolts and clips attaching body longitudinal sills to chassis frame side rails, a locating bolt through rear end of each body longitudinal sill and frame side rail, and flexible mountings at front end of body (144-inch cargo body only).

230. CARGO BODY.

a. General. Two lengths of cargo bodies are used—the 108-inch body on the 145-inch wheelbase model (CCKW-352), and the 144-inch body on the 164-inch wheelbase model (CCKW-353). The 108-inch and the 144-inch bodies are similar, and comprise wooden strips, slats, and panels bolted together and reinforced by steel strips, angles, and brackets. Cargo bodies are equipped with end curtains and tarpaulin, removable tarpaulin bows, and cargo racks.

b. Wood Cargo Body Mountings. The 108-inch body (CCKW-352—145-inch wheelbase) uses two locating bolts and six mountings of any of the three types shown in figure 232. The 144-inch body



RA PD 332763

Figure 232—Sectional Views of Wood Cargo Body Mountings

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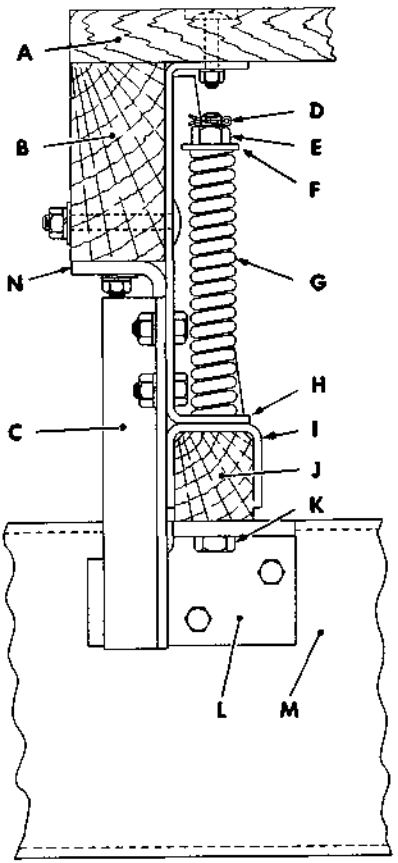
(CCKW-353—164-inch wheelbase) uses two locating bolts, four mountings of any of the types shown in figure 232, and two flexible mountings (fig. 233).

(1) BOLT AND NUT TYPE MOUNTING REMOVAL (fig. 232). Remove two nuts, lock washers, and clip plate from upper end of two mounting bolts. Remove lower clip plate and bolts, then remove wood filler block from frame side rail.

(2) BOLT AND NUT TYPE MOUNTING INSTALLATION (fig. 232). Fit wood filler block in frame side rail. Assemble two clips and one lock washer on one bolt, and start nut on threads. Position assembly of bolt and clips on sill and frame, with bolt in groove in filler block and nut at top. Install second mounting bolt through clips, then install lock washer and nut. Tighten nuts firmly and with equal tension.



A BODY FLOOR
B BODY FRONT CROSS SILL
C BODY GUIDE ANGLE
D MOUNTING BOLT COTTER PIN
E MOUNTING BOLT NUT
F MOUNTING BOLT WASHER
G MOUNTING BOLT TENSION SPRING
H MOUNTING SUPPORT PLATE
I SPACER BLOCK REINFORCEMENT
J WOOD SPACER BLOCK
K MOUNTING BOLT
L FRAME SIDE RAIL BRACKET
M FRAME LEFT SIDE RAIL
N SILL BRACKET

RA PD 316828

Figure 233—Sectional View of Body Front Corner Flexible Mounting (CCKW-353 Only)

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(3) TAPPED PLATE TYPE MOUNTING REMOVAL (fig. 232). Unscrew two bolts from tapped upper clip plate, remove bolts, lock washers, and lower clip plate, then remove tapped plate. Remove wood filler block from frame side rail.

(4) TAPPED PLATE TYPE MOUNTING INSTALLATION (fig. 232). Position wood filler block in frame side rail. Install two mounting bolts with lock washers through holes in lower clip plate, and position around frame side rail and body sill. Place tapped plate on body sill, threading bolts into tapped holes in plate. Tighten bolts firmly and with equal tension.

(5) U-BOLT TYPE MOUNTING REMOVAL (fig. 232). Remove two nuts and lock washers, and lower clip plate from U-bolt. Remove U-bolt and U-bolt plate from body sill, then remove wood filler block from frame side rail.

(6) U-BOLT TYPE MOUNTING INSTALLATION (fig. 232). Position wood filler block in frame side rail, then position U-bolt and U-bolt plate over body longitudinal sill with inner leg of U-bolt in groove in filler block. Position clip plate on U-bolt, then install two nuts and lock washers, tightening nuts firmly and with equal tension.

(7) BODY LOCATING BOLT REMOVAL (fig. 232). At rear end of body longitudinal sill, unscrew bolt from underside of frame while holding nut with wrench. Remove bolt, nut, and lock washer, but do not remove bolts attaching locating bracket to body sill.

(8) BODY LOCATING BOLT INSTALLATION (fig. 232). Aline hole in body locating bracket with hole in upper flange of frame side rail, using drift. Install bolt from underside of side rail flange, install lock washer and nut, then tighten bolt into nut while holding nut with wrench.

(9) FLEXIBLE FRONT MOUNTING BOLT REMOVAL (fig. 233). Remove cotter pin, nut, and flat washer from upper end of mounting bolt above tension spring. Remove mounting bolt and tension spring.

(10) FLEXIBLE FRONT MOUNTING BOLT INSTALLATION (fig. 233). Install long mounting bolt through frame bracket, wood spacer block, reinforcement, and support plate. Position tension spring over end of mounting bolt, and install flat washer and nut. Tighten nut sufficiently to compress spring slightly and secure nut with cotter pin.

c. Cargo Body Tailgate.

(1) TAILGATE REMOVAL (fig. 234). Unhook tailgate chains and

RA PD 332903

Figure 234—Cargo Body Tailgate

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swing tailgate down. Remove cotter pin and flat washer from one end of hinge rod. Withdraw hinge rod from hinges while supporting tailgate.

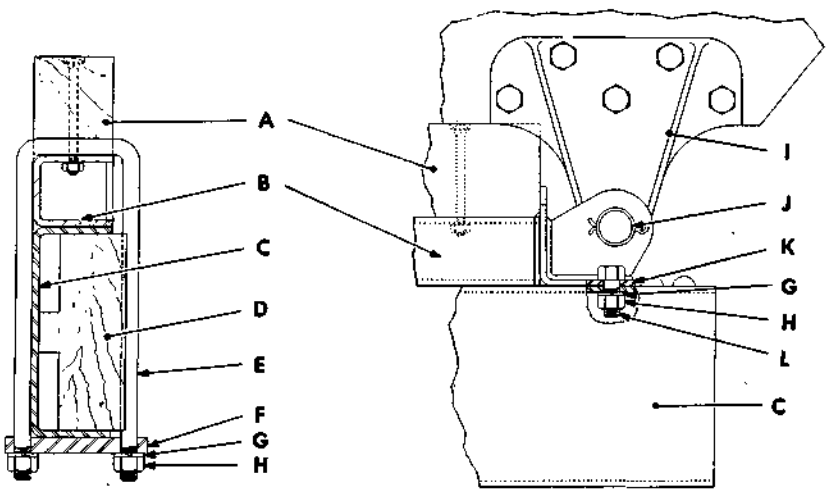
(2) TAILGATE INSTALLATION (fig. 234). Position tailgate on body and aline hinges. Insert hinge rod through hinges, then install flat washer and cotter pin on end of hinge rod.

231. CARGO DUMP BODY.

a. General. All steel dump body is hinged at rear to hoist subframe which is mounted on frame side rails. Subframe is attached to chassis with four U-bolts and two locating bolts of type shown in figure 235. Cargo dump bodies are equipped with end curtains, tarpaulin, removable tarpaulin bows, and side cargo racks.

b. Cargo Dump Body Mountings.

(1) SUBFRAME TO FRAME SIDE RAIL MOUNTING REMOVAL (fig. 235). Remove two nuts, lock washers, and clip plate from lower end of mounting U-bolt. Remove U-bolt from around subframe channel and frame side rail. Remove wood filler block from frame side rail.



U-BOLT MOUNTING

SUBFRAME LOCATING BOLT

A SUBFRAME WOOD RAIL
B SUBFRAME SIDE CHANNEL
C CHASSIS FRAME L. H. SIDE RAIL
D WOOD FILLER BLOCK
E MOUNTING U-BOLT
F CLIP PLATE
G LOCK WASHER
H BOLT NUT
I BODY HINGE BRACKET
J BODY HINGE PIN
K SUBFRAME LOCATING BRACKET
L SUBFRAME LOCATING BOLT

RA PD 64740

Figure 235—Sectional Views of Cargo Dump Body Mountings

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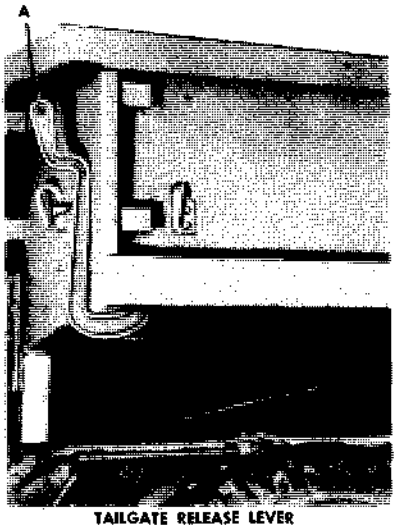
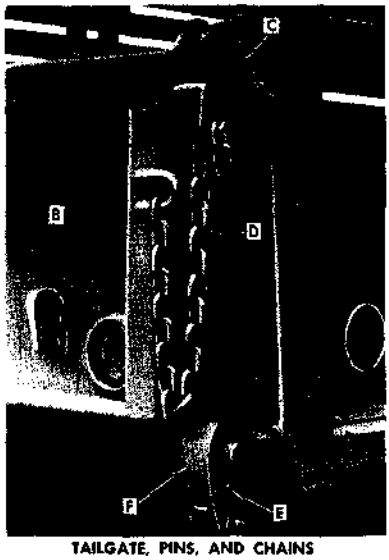
CARGO AND DUMP BODIES

(2) SUBFRAME TO FRAME SIDE RAIL MOUNTING INSTALLATION (fig. 235). Position wood filler block in frame side rail. Position U-bolt on subframe channel with inner leg of U-bolt in groove in wood filler block. Install clip plate, lock washers, and nuts on U-bolt, tightening nuts firmly and with equal tension.

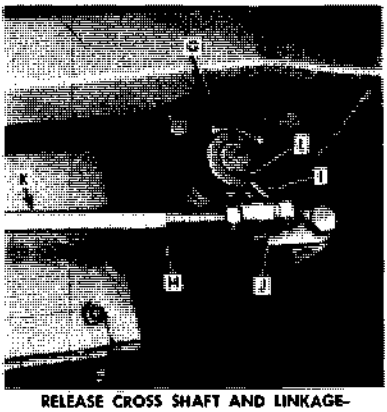


TAILGATE RELEASE LEVER



TAILGATE, PINS, AND CHAINS

RELEASE LEVER AND LINKAGE—LEFT SIDE



RELEASE CROSS SHAFT AND LINKAGE—RIGHT SIDE

A RELEASE LEVER
B TAILGATE
C UPPER HINGE PIN
D DROP CHAIN
E RELEASE ROD CLEVIS PIN
F LOCKING CLAMP
G SUPPORT BRACKET
H CROSS SHAFT
I ARM
J CLEVIS
K ROD
L KEY

RA PD 332963

Figure 236—Cargo Dump Body Tailgate and Release Linkage

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(3) SUBFRAME LOCATING BOLT REMOVAL (fig. 235). Aline hole in subframe locating bracket with hole in upper flange of frame side rail, using drift. Install bolt through locating bracket and frame side rail, install lock washer and nut, then tighten nut firmly.

(4) SUBFRAME LOCATING BOLT INSTALLATION (fig. 235). Aline hole in subframe locating bracket with hole in upper flange of frame side rail, using drift. Install bolt through locating bracket and frame side rail, install lock washer and nut, then tighten nut firmly.

c. **Cargo Dump Body Tailgate.**

(1) TAILGATE REMOVAL (fig. 236). At left front of body pull tailgate release lever downward to release tailgate lower hinge pins. Detach drop chains from body. Remove pins from upper brackets, then lift off tailgate.

(2) TAILGATE INSTALLATION (fig. 236). Position tailgate on body with upper hinge pins in brackets and insert bracket pins in brackets. At left front of body, move tailgate release lever up against body to lock bottom of tailgate to body.

d. **Tailgate Release Linkage.**

(1) RELEASE LINKAGE REMOVAL (fig. 236). Remove the three bolts, nuts, and washers attaching release lever to arm and clevis, then remove lever. Remove bolt, nut, and washer attaching clevis to right side cross shaft arm. Remove screws and washers clamping arms to cross shaft, then remove arms and keys from cross shaft, and remove cross shaft from support brackets. Remove clevis and two nuts and washers from front end of side control rod. At rear end of body, remove cotter pin attaching control rod to locking clamp, then swing clamp down. Pull rod out of guides and lower hinge bracket. Removal procedure is same for either rod.

(2) RELEASE LINKAGE INSTALLATION (fig. 236). Position cross shaft in support brackets, install arms and Woodruff keys on shaft, then tighten clamp screws firmly. Position side control rods in guides, then attach rear end of rods to locking clamps and secure with cotter pins. Install nut, washer, clevis, washer, and nut loosely on each control rod, then attach right-hand clevis to arm with bolt, washer and nut. Attach release lever to left-hand arm with two bolts, nuts, and washers, then attach clevis to lever and arm with a bolt, nut, and washer. Adjust control rod length by means of the two nuts on each rod, then tighten nuts firmly.

232. TROOP SEATS AND CARGO RACKS.

a. Description. Cargo racks and troop seats are supplied with wood cargo bodies and dump cargo bodies. Cargo racks consist of right and left side racks incorporating full length troop seats and a front rack. Side racks for cargo and dump bodies are similar, but front rack for dump bodies includes a hinged cab protector. Rack stakes fit into pockets at sides and front of body to support racks. A latch at each end of seat section holds seat in folded position as part of rack. When lock plates are released, seats fold down and are supported on hinged legs.

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b. Cargo Rack Removal.

(1) REMOVE TROOP SEATS ONLY. Remove cotter pins and hinge pins from all five hinges attaching each seat to rack stakes. Release lock plates, disengage hinges, and lift troop seat out of body.

(2) REMOVE FRONT CARGO RACK (CARGO BODY ONLY). Tarpaulins and bows must be removed before attempting to remove any of the cargo racks. Lift straight up on front rack while standing inside body. When rack stakes are clear of front stake pockets, remove rack from body.

(3) REMOVE SIDE CARGO RACKS. Lift each rack straight up to free ends of stakes from pockets at sides of body. Remove racks from vehicle.

(4) REMOVE FRONT RACK (CARGO DUMP BODY ONLY). Side cargo racks must first be removed. Remove the four bolts, nuts, and washers attaching each front rack brace to body and rack and remove braces. Lift rack straight up to remove from body.

c. Cargo Rack Installation.

(1) INSTALL FRONT RACK (CARGO DUMP BODY ONLY). Lift rack onto body and position stakes in front pockets. Push down on rack to fully engage stakes in stake pockets.

(2) INSTALL SIDE CARGO RACKS ONLY. Position each rack on body with longitudinal slots on inner side of stakes. Engage stakes in pockets and push down on rack until hinge brackets fit down against body side. On dump body, make sure that eye on each side rack engages hook in front rack.

(3) INSTALL FRONT CARGO RACK (CARGO BODY ONLY). Position front rack on body and fit rack stakes into front stake pockets. Push down on rack, at the same time engaging lock pin at each end of rack in eye in side rack.

(4) INSTALL TROOP SEATS ONLY. Position troop seats on side rack hinge brackets and aline hinge holes with drifts. Install hinge pin and cotter pin in each of five hinges for each troop seat. Fold seat up against side rack and fasten in place with seat latch at each end.

Section XLII

GASOLINE AND WATER TANK BODIES

233. GASOLINE TANK BODY.

a. General. Gasoline tank body consists of two elliptical shaped tanks of 375-gallon capacity each, mounted on a welded steel cradle. Gravity discharge through emergency valves into pipes manifolding into a rear discharge faucet is controlled by levers in the right rear compartment. Valves can be opened or closed by means of these

levers; valves can also be closed by a trip release at left front corner of body.

b. Mountings. Gasoline tank body is attached to chassis frame side rails with eight side mountings and two locating bolts as shown in figure 237.

c. Mounting Removal.

(1) REMOVE BODY TO FRAME SIDE RAIL MOUNTING (fig. 237). Remove two nuts, lock washers, and tee plate from lower end of mounting U-bolt. Remove U-bolt from around body sill and sill channel, then remove wood filler block from frame side rail.

(2) REMOVE LOCATING BOLT (fig. 237). At rear of vehicle remove nut, lock washer, and bolt attaching body sill and sill channel to chassis frame side rail.

d. Mounting Installation.

(1) INSTALL LOCATING BOLT (fig. 237). Aline holes in body sill, channel, and frame side rail with drift, then install bolt through sill channel, sill, and upper flange of frame side rail. Install lock washer and nut, and tighten firmly.

(2) INSTALL BODY TO FRAME SIDE RAIL MOUNTING (fig. 237). Fit wood filler block in frame side rail, then position U-bolt around body sill and frame side rail with inner leg of U-bolt in groove in filler block. Install tee plate, two lock washers, and nuts on U-bolt, tightening nuts firmly.

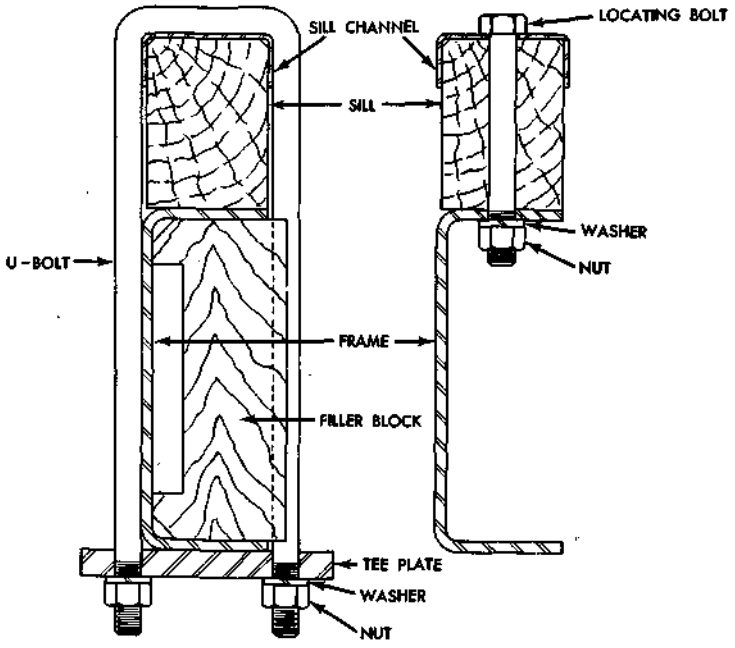

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Figure 237—Sectional Views of Gasoline Tank Body Mountings

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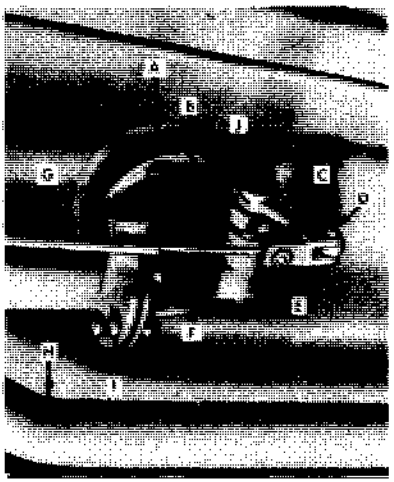
e. **Controls and Linkage.**

(1) REMOVE SELECTIVE VALVE OPERATOR (fig. 238). Disconnect trip cable from front end release lever clevis by unscrewing compression nut. Remove two cable connector nuts, then remove connectors to disconnect both valve cables. Remove the six nuts and washers, and the four bolts attaching operator assembly to cabinet, then remove operator from cabinet.

(2) INSTALL SELECTIVE VALVE OPERATOR (fig. 238). Position operator assembly in cabinet, threading cables and pipes through bearing bracket spacer. Attach operator to cabinet with four bolts, and six nuts and washers. Attach two valve cables to levers with cable connectors and nuts, making sure cables have a slight amount of slack with valves fully closed, and with valve levers in closed position. Tighten cable connector nuts firmly. Attach trip cable to release lever clevis with compression nut and sleeve, making sure cable is of correct length to insure proper trip release.

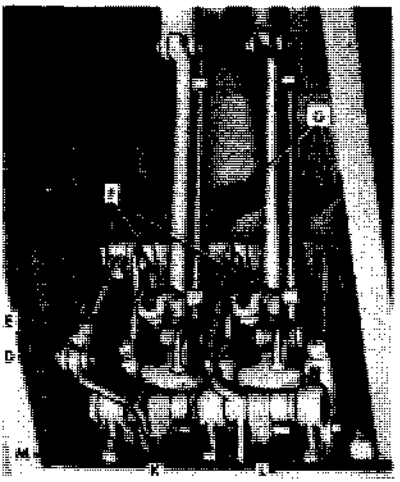
(3) REMOVE CABLE (fig. 238). Cables can be removed and replaced without removal of either selective valve operator or emergency valves. Disconnect cable at valve operator and at either valve or front end trip release as the case may be, by removing compression nuts or cable connectors. Withdraw cable from pipe.

(4) INSTALL CABLE. Squeeze or solder end of cable to prevent spreading, then apply a light coating of general purpose grease No.



EMERGENCY VALVE

A SUMP
B VALVE
C VALVE ARM
D CLEVIS PIN
E CLEVIS
F OPERATOR CABLE
G CABLE PIPE



EMERGENCY VALVE OPERATOR

H DISCHARGE PIPE
I BOLT
J CAP SCREW
K CABLE NUT
L MOUNTING BOLT
M MOUNTING NUT

RA PD 332956

Figure 238—Emergency Valve and Controls

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0 to the cable. Feed cable into the pipe from the rear compartment, until cable emerges from other end of cable pipe. Connect cable to emergency valve or to front end trip release with cable connector or compression nut. Cut cable to proper length at operator, then connect to lever with connector or compression nut. Valve cables must have slight slack with valves fully closed.

f. **Valves.** Three valves are used on the gasoline tank body—one emergency valve in the bottom of each tank and a single discharge faucet at the rear end. Faucet may be removed and replaced without necessity of dumping load providing emergency valves are closed and are in good condition. CAUTION: *Open flame must not be brought into vicinity while valves are being replaced, or while valves are removed.* Fumes in tank and lines may constitute a highly explosive mixture.

(1) REMOVE DISCHARGE FAUCET. Close both emergency valves, then open discharge faucet with faucet wrench to drain pipes. Hold rear pipe with pipe wrench; with another wrench applied to hexagon part of faucet, unscrew faucet.

(2) INSTALL DISCHARGE FAUCET. Coat pipe threads with aviation type cement. Hold rear discharge pipe with pipe wrench; with another wrench applied to hexagon part of faucet, screw faucet to pipe.

(3) REMOVE EMERGENCY VALVE (fig. 238). Empty tank from which valve is to be removed, then close both emergency valves. Disconnect operator cable from valve arm by removing cotter pin and clevis pin. Remove the six bolts, nuts, and washers attaching pipe flange to valve flange. Remove the six cap screws attaching valve to sump, then remove valve and screen as an assembly. Slide screen off valve; clean screen by immersing in dry-cleaning solvent and brushing. Removal procedure is same for either valve.

(4) INSTALL EMERGENCY VALVE (fig. 238). Clean sump flange, pipe flange, and both valve flanges to remove all traces of cement and other foreign matter. Coat all flanges with aviation type cement, install screen on valve, then position valve on sump. Attach valve to sump with six cap screws and washers, tightening screws firmly. Loosen nuts on pipe hangers to permit alinement of pipe flange to valve, then attach pipe flange to valve with six bolts, nuts, and washers. Tighten pipe hanger nuts. Attach operator cable clevis to valve arm with clevis pin and secure pin with cotter pin. Installation procedure is same for either valve.

g. **Cabinets.** A wood-lined, steel cabinet is mounted on each run board for stowage of hoses and other equipment. Right-side cabinet also houses controls for emergency valves.

(1) REMOVE CABINET. In right-side cabinet only, remove the selective valve operator as described in subparagraph e (1) above. For either cabinet, remove the four bolts, nuts, and washers attaching cabinet to run boards. If vehicle is equipped for camouflage, four bolts, nuts, and washers attaching rear board assembly to each cabinet must be removed. Lift cabinet off run board.

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(2) INSTALL CABINET. Position cabinet on run board. In right-side cabinet only, thread cables and pipes through holes in cabinet as cabinet is slid into position on run board. Aline holes with drifts, then attach cabinet to run board with four bolts, nuts, and washers. In right-side cabinet only, install selective valve operator as described in subparagraph e (2) above. If vehicle is equipped for camouflage, attach rear board assembly to cabinet with four bolts, nuts, and washers.

234. WATER TANK BODY.

a. General. Water tank body consists of an insulated tank of 750-gallon capacity supported by two steel longitudinal box sills welded to tank bottom. Tank is equipped with an equipment compartment at the rear, and a pumping unit cabinet at front left side. Pumping unit cabinet contains pumping unit, gate valve, and control for emergency valve which is located on tank bottom. Tank is used to transport potable (drinking) water, therefore, when making replacements described in following paragraphs, *use every precaution to avoid contaminating tank or contents.*

b. Mountings. Water tank body is attached to chassis frame side rails with eight mountings and two locating studs as shown in figure 239.

c. Mounting Removal.

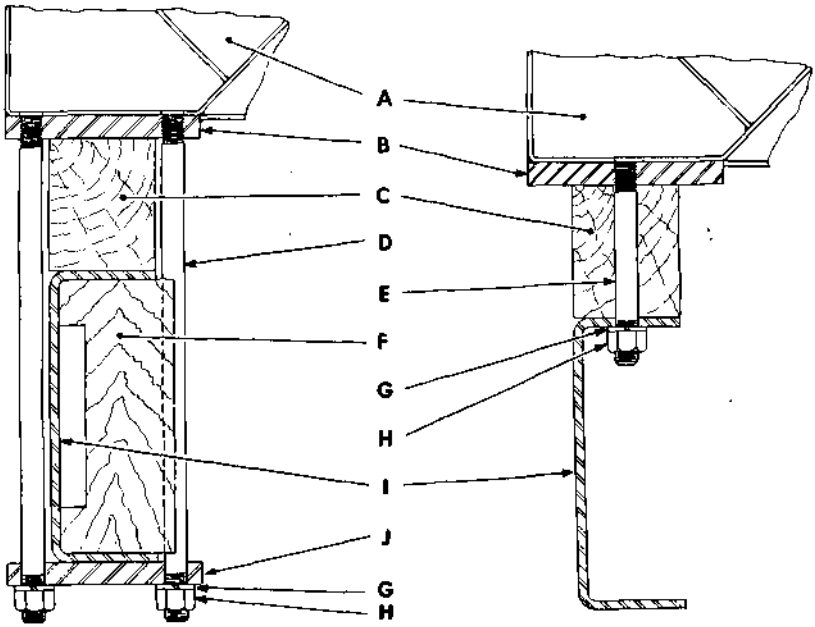
(1) REMOVE BODY TO FRAME SIDE RAIL MOUNTING (fig. 239). Remove two nuts, lock washers, and clip plate from mounting. Install nut on lower end of stud, then install a second nut tight against first nut. Use wrench on upper nut to unscrew stud from tapped plate welded to longitudinal sill at top of wood spacer rail. Remove nuts from stud. Remove second mounting stud in same manner. Remove wood filler block from frame side rail.

(2) REMOVE BODY LOCATING STUD (fig. 239). At rear end of wood spacer rail, remove nut and lock washer from locating stud at under side of frame side rail upper flange. Install nut on end of stud and install second nut tight against first nut. First nut must not be tight against frame side rail. Use wrench on upper nut to unscrew stud from tapped plate welded to longitudinal sill at top of wood spacer rail. If broken stud is to be removed, all body mountings must be removed or loosened, rear end of body raised to expose fractured end of stud, and stud unscrewed with suitable tool.

d. Mounting Installation.

(1) INSTALL BODY LOCATING STUD (fig. 239). At rear end of wood spacer rail, aline hole in frame with holes in wood spacer rail and tapped plate, using a drift. Install locating stud and screw into tapped plate welded to longitudinal sill with wrench applied to lower nut. Remove nuts from stud, install lock washer and nut on stud, then tighten nut firmly.

(2) INSTALL BODY TO FRAME SIDE RAIL MOUNTING (fig. 239). Position wood filler block in frame side rail. Screw two mounting studs into tapped plate, with inner stud in groove in wood filler block.



A WATER TANK BODY
B MOUNTING STUD TAPPED PLATE
C WOOD LONGITUDINAL SPACER RAIL
D MOUNTING STUD
E LOCATING STUD
F WOOD FILLER BLOCK
G LOCK WASHER
H STUD NUT
I FRAME LEFT SIDE RAIL
J LOWER CLIP PLATE

RA PD 64763

Figure 239—Sectional Views of Water Tank Body Mountings

Use two nuts on stud, applying wrench to lower nut, then remove nuts. Install clip plate, lock washers, and nuts, tightening nuts firmly.

e. **Valves.** Two valves are used on water tank body; a gate valve in the pumping unit cabinet and an emergency valve in bottom of tank near front. Emergency valve is similar to that used on gasoline tank body (fig. 238) and is similarly attached to tank and pipe.

(1) REMOVE GATE VALVE (fig. 240). Make sure emergency valve is closed, then remove bolts from pump flange at suction port. Remove six pipe flange bolts, nuts, and washers, then remove assembly of valve and pipes from pumping unit cabinet. Remove hose connection nipple from valve by unscrewing with pipe wrench, then unscrew valve from pipe, using pipe wrenches.

(2) INSTALL GATE VALVE (fig. 240). Apply coating of aviation type cement to pipe threads, then screw valve on pipe and hose con-

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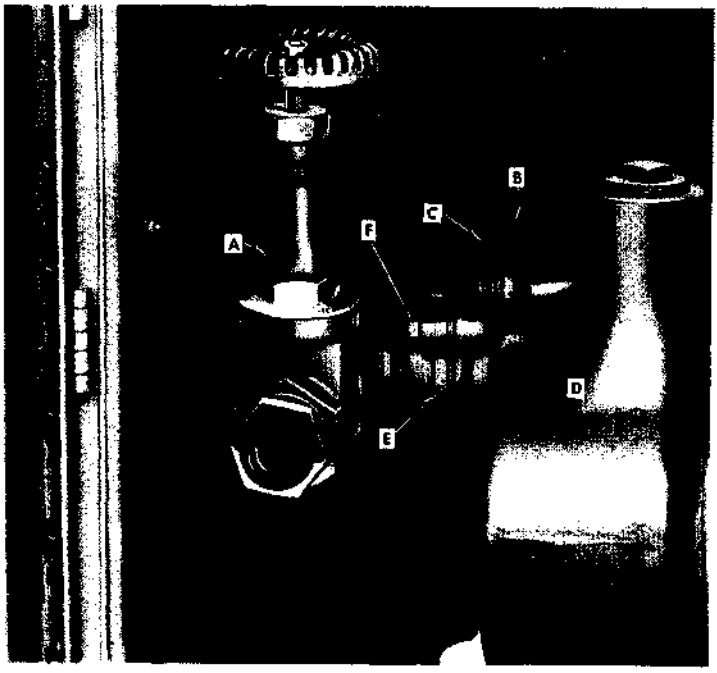

A VALVE
B PIPE FLANGE
C FLANGE BOLT
D PUMP
E SUCTION INLET
F CAP SCREW

RA PD 332976

Figure 240—Gate Valve Installed

nection nipple into valve, using pipe wrenches. Thoroughly clean pipe and pump flanges to remove all traces of cement, gasket, and foreign matter. Coat both sides of a new pipe flange gasket with aviation type cement, position gasket between flanges and attach flanges together with six bolts, nuts, and washers. Examine pump flange gasket and replace unless in good condition. Coat gasket with aviation type cement, then attach suction flange to pump with bolts and washers.

(3) REMOVE EMERGENCY VALVE. Tank must be drained before removal of valve. Remove the heating chamber bottom pan by removing 18 attaching bolts, nuts, and washers. Disconnect cable from valve arm. Remove six bolts, nuts, and washers attaching pipe flange to valve flange. Remove six cap screws and lock washers attaching valve to sump flange and remove valve. Slide screen off valve, immerse screen in dry-cleaning solvent and brush thoroughly. Wash screen in water, preferably hot water.

(4) INSTALL EMERGENCY VALVE. Thoroughly clean pipe and valve flanges to remove all traces of cement, bits of gasket, and foreign matter. Install screen on pump. Coat both sides of a new

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valve to sump gasket with aviation type cement, position gasket and valve to sump, then attach valve with six cap screws and lock washers. Coat both sides of a new pipe flange gasket with aviation type cement, position gasket between pipe flange and valve, then install six bolts, nuts, and washers attaching flanges together. Connect operator cable to valve arm. Position heating chamber bottom pan, and install with 18 bolts, nuts, and washers.

f. Pumping Unit.

(1) REMOVE PUMPING UNIT. Remove bolts from pump flange at suction port. Remove six bolts, nuts, and washers attaching pipe flanges together, then remove valve and pipes as an assembly from pumping unit cabinet. Remove the six bolts, nuts, and washers attaching pump and engine to cabinet channels. Lift unit straight up so that oil drain will clear channels, then lift unit from cabinet. Pump can be removed from engine as per maintenance instructions furnished with vehicle.

(2) INSTALL PUMPING UNIT. Lift pumping unit high enough to permit oil drain to clear cabinet channels while positioning unit in cabinet. Attach unit to cabinet rails with six bolts, nuts, and washers, and tighten nuts firmly. Thoroughly clean pipe and pump flanges to remove all traces of cement, gasket, or foreign matter. Position assembly of valve and pipes in cabinet. Coat both sides of a new pipe flange gasket with aviation type cement, position gasket between flanges and attach flanges together with six bolts, nuts, and

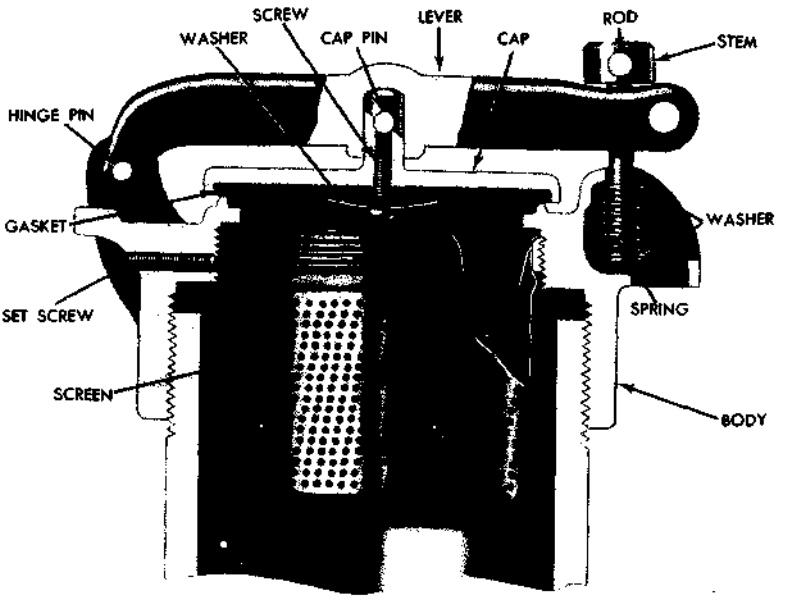

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Figure 241—Filler Hatch Assembly (Protectoseal Cap)

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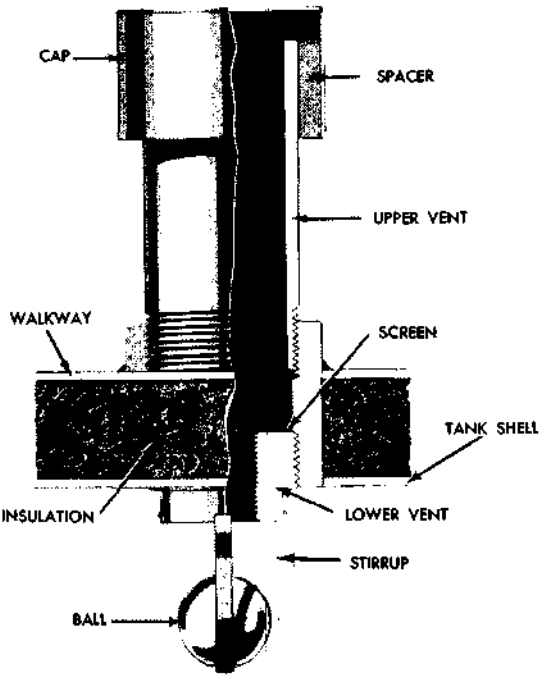
washers. Coat pump flange gasket with aviation type cement, position between suction flange and pump, then attach flange with bolts and washers.

g. Strainers. Three strainers are used on each water tank body—emergency valve strainer, filler hatch strainer, and vent strainer. Removal, cleaning, and installation of emergency valve strainer is described in subparagraph e (3) and (4) above. However, emergency valve strainer can also be replaced, without removal of emergency valve, by entering tank through manhole.

(1) REMOVE FILLER HATCH STRAINER (fig. 241). Using large pipe wrench, unscrew cap from four-inch diameter pipe projecting through walkway on top of tank. Lift assembly of cap and screen straight up to remove from body. Remove set screw from cap, then unscrew strainer screen from cap. Invert strainer and plunge rapidly up and down in a container of clean water. With strainer inverted, direct a stream of water against outside of strainer until all particles of foreign matter are dislodged and washed out. Blow strainer dry with compressed air, if available.

(2) INSTALL FILLER HATCH STRAINER (fig. 241). Screw strainer into cap, install set screw, and tighten firmly. Coat threads with aviation type cement, then screw filler hatch in place on pipe with large pipe wrench.



RA PD 332805

Figure 242—Water Tank Vent Assembly

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(3) REMOVE LOWER VENT (fig. 242). Open manhole cover and remove manhole plug. From inside tank unscrew lower vent from pipe coupling welded to tank with adjustable wrench. Slush vent in clean water, or use stream of water to remove dirt from screen, then blow with compressed air, if available.

(4) INSTALL LOWER VENT (fig. 242). Screw lower vent into coupling inside tank with adjustable wrench. Install manhole plug and close manhole cover.

h. Cabinet Doors.

(1) REMOVE PUMPING UNIT CABINET SIDE DOORS. Remove staking at each of three hinge pins with a file, then drive out pins, using drift and hammer. Removal is same for either side door.

(2) INSTALL PUMPING UNIT CABINET SIDE DOORS. Position door to cabinet, position three hinge pins in hinges and tap into place with hammer. Stake pins in place with hammer or punch. Installation procedure is same for either side.

(3) REMOVE PUMPING UNIT CABINET TOP DOOR. Remove staking from both hinge pins with a file, then drive out pins using drift and hammer. Disengage catch and lift door straight up to remove from cabinet.

(4) INSTALL PUMPING UNIT CABINET TOP DOOR. Position door on cabinet and tap hinge pins into hinges with hammer. Stake hinge pins in place using hammer or punch.

(5) REMOVE EQUIPMENT COMPARTMENT DOORS. Remove staking from hinge rod with a file. With hammer and drift, drive rod out slightly. Pull projecting end of rod with pliers to withdraw rod, or tap pliers with hammer. Removal procedure is same for either door.

(6) INSTALL EQUIPMENT COMPARTMENT DOORS. Position door to body and mate hinge halves. Insert rod in hinge and tap gently into place with hammer. Stake end of hinge rod with hammer or punch. Installation procedure is same for either door.

Section XLIII

WINCH AND CONTROLS

235. DESCRIPTION.

a. General (fig. 243). The winch is a worm driven horizontal drum type, mounted at the front end of the vehicle on frame side rail extensions. Power for operating the winch is supplied by the vehicle engine through a power take-off and winch drive shaft. The winch controls consist of a winch power take-off control lever in the cab and a sliding clutch shift yoke at the winch. The winch is equipped with a drag brake which works in conjunction with the sliding clutch to prevent the drum from overrunning the cable when cable is pulled from drum. The winch automatic brake assembly acts on the winch worm shaft to hold the load when the power supply as been cut off.

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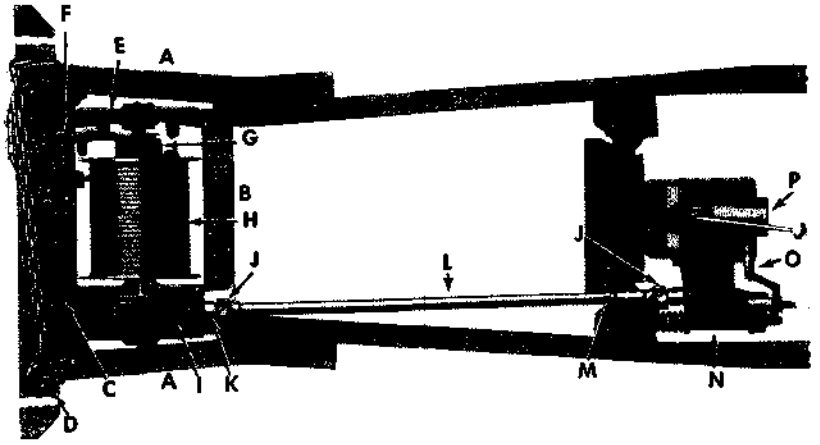
WINCH AND CONTROLS



A FRAME EXTENSION
B REAR BASE ANGLE
C FRONT BASE ANGLE
D FRONT BUMPER
E WINCH END FRAME
F SHIFT YOKE POPPET KNOB
G SLIDING CLUTCH
H CABLE
I GEAR CASE
J UNIVERSAL JOINT
K SHEAR PIN LOCATION
L DRIVE SHAFT
M STOP COLLAR
N POWER TAKE-OFF ASSEMBLY
O WINCH SHIFT LEVER
P TRANSMISSION

RA PD 316886

Figure 243—Winch System

b. Data.

Type	Worm driven—horizontal drum	
Drive	From power take-off	
Capacity	10,000 lb	
Make	Heil	Gar Wood
Vendor number	A157-E3	GW 225-6225B
Model	125G and 125G1	2 U512
Winch cable dia.	½ in.	

236. ADJUSTMENT ON VEHICLE.

a. General. Adjustments can be made to compensate for normal wearing of brake lining, and should be made whenever tests show that adjustment is necessary. A modification of gear case cover used on some Gar Wood winch assemblies is also described in this paragraph, and should be applied to prevent entrance of water into gear case.

b. Adjustment Tests.

(1) TEST DRAG BRAKE OPERATION. Disengage sliding jaw clutch. Take hold of cable and begin to pull cable off drum. Drum should cease to revolve as soon as pull is stopped. If drum overruns cable, the drag brake requires adjustment.

(2) TEST AUTOMATIC BRAKE OPERATION. Place a winch equipped vehicle at top of a steep grade. Fasten winch cable to

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another vehicle at bottom of grade. Pull vehicle up grade, using winch only. When vehicle has been pulled part way up incline, depress engine clutch pedal, and shift power take-off into neutral. Vehicle being pulled should not roll backward; if it does, the need for automatic brake adjustment is indicated. CAUTION: *Brake may become warm even though it is properly adjusted; however, if hand cannot be held on brake cover on account of heat, this indicates that brake is too tight and should be loosened.* Brake is designed to hold load, and if properly adjusted, will not become overheated. Excessive heat indicates that brake band should be relined or the brake band assembly replaced.

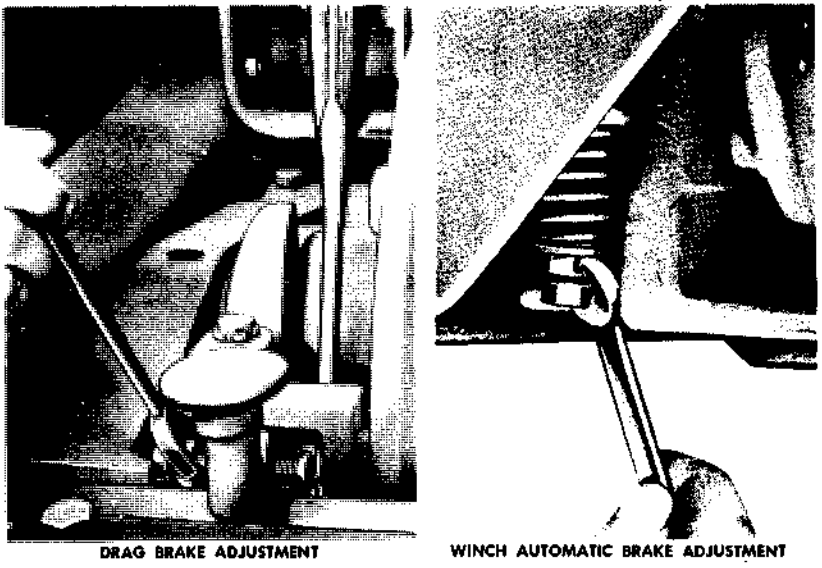
c. **Drag Brake Adjustment** (fig. 244).

(1) DISENGAGE SLIDING JAW CLUTCH. Lift poppet knob and move shift yoke to disengage sliding clutch.

(2) ADJUST DRAG BRAKE SPRING. Insert screw driver or wedge between end of tension bolt and drag brake shoe. Force tension bolt away from shift yoke to permit use of wrenches on adjusting nut and lock nut. Loosen lock nut and back off adjusting nut one full turn, then remove wedge and check adjustment (subpar. b (1) above). Repeat above process, if necessary to obtain satisfactory brake operation. When correct adjustment is obtained, turn lock nut up tight against adjusting nut. In the event a satisfactory adjustment cannot be obtained, it will be necessary to reline brake or replace drag brake shoe assembly.

d. **Automatic Brake Adjustment** (fig. 244).

(1) ADJUST BRAKE BAND SPRING TENSION. Back off lock nut,



DRAG BRAKE ADJUSTMENT — WINCH AUTOMATIC BRAKE ADJUSTMENT

RA PD 332991

Figure 244—Winch Adjustments on Vehicle

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then tighten adjusting nut one-half turn and reset lock nut against adjusting nut.

(2) TEST ADJUSTMENT. Accomplish procedure for automatic brake test (subpar. b (2) above). Repeat step (1) above if necessary to obtain correct adjustment. NOTE: *If brake will not hold load after adjustment or if it overheats when properly adjusted as indicated by test, it will be necessary to replace the brake band assembly* (par. 237).

e. **Gear Case Cover Modification** (Applicable to early Gar Wood winches only). On some vehicles equipped with Gar Wood winches a vent hole was drilled through gear case cover under the Gar Wood name plate. It has been established that in some instances water has entered the gear case through vent hole. If evidence of water is indicated when checking or draining lubricant from gear case of above mentioned winches, the following operations should be performed to prevent recurrence of this condition:

(1) DRAIN GEAR CASE AND REMOVE COVER. Remove drain plug and drain out contents of gear case. Remove six cap screws which attach worm gear case cover, then lift off cover.

(2) CLEAN GEAR CASE AND PLUG VENT HOLE. Wipe inside of gear case and gears to remove all traces of water. Coat a No. 6 (0.138 in.)-32NC-2x⅜-inch self tapping screw, or a No. 6 (0.138 in.)-32NC-2x¼-inch sheet metal screw with shellac or permatex and drive screw, from inside of cover, into small vent hole in top of cover near the filler plug. Be certain that screw is tight in hole at finish of operation.

(3) INSTALL COVER. Install cover with gasket. Tighten cover screws evenly and firmly to assure correct fit over gear case bushings.

(4) PREPARE WINCH FOR SERVICE. Replace drain plug. Remove filler plug and oil level plug and fill gear case with gear oil (Section VIII) until the oil appears at level plug hole. Install filler plug after lubricant ceases to flow from level plug hole, and install level plug.

237. AUTOMATIC BRAKE BAND ASSEMBLY.

a. **General.** When for any reason it becomes necessary to replace the winch automatic brake band, the replacement may be accomplished without removing the winch assembly from the vehicle.

b. **Automatic Brake Band Removal.**

(1) REMOVE FRONT BUMPER. Remove front bumper (par. 215 b (3)).

(2) SUPPORT WINCH ASSEMBLY. Place a jack or other suitable support under winch assembly to hold weight of winch. This is necessary because front base angle must be disconnected from frame side rail extensions.

(3) RAISE WINCH FRONT BASE ANGLE. Remove six front base angle to side rail extension bolts. Remove two front base angle to gear case cap screws and two base angle to brake case cap screws (fig. 245); then, with pry bar, force left-hand end of front base

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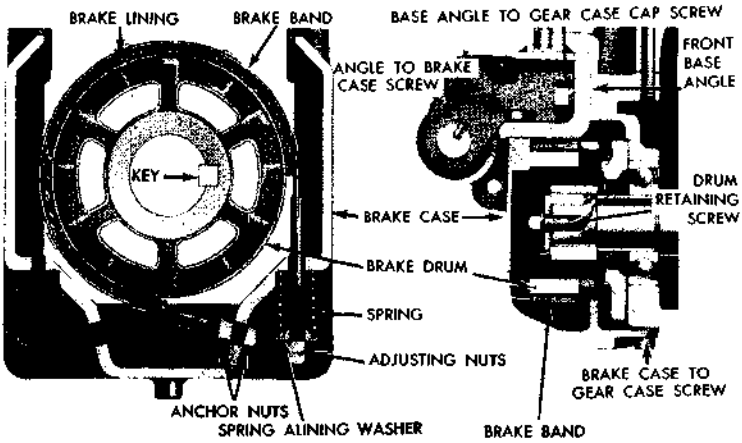

RA PD 333055

Figure 245—Sectional Views of Winch Automatic Brake Assembly

angle upward to provide clearance for brake case removal.

(4) REMOVE BRAKE CASE (fig. 245). Relieve spring tension on brake band by removing lock nut, adjusting nut, alining washer, and spring from brake band rod end. Remove two brake case to gear case cap screws then pull brake case and brake band assembly forward and remove from winch.

(5) REMOVE BRAKE BAND FROM CASE. Remove anchor nut from brake band rod end on outside of case. Lift band assembly from case and remove anchor nut which remains on threaded rod end (fig. 245).

c. Automatic Brake Band Installation (fig. 245).

(1) MOUNT BRAKE BAND ASSEMBLY IN CASE. With one anchor nut installed on end of brake band, position brake band assembly in case. Screw anchor nut on larger rod, at outside of case, until approximately two threads protrude through nut; then screw inside anchor nut down against case finger-tight.

(2) INSTALL BRAKE CASE AND BAND ASSEMBLY ON WINCH. Move brake case and band assembly over the brake drum and into position at winch assembly. Install two brake case to gear case cap screws, using lock washers. Force front base angle assembly down to position at brake case and install two base angle to brake case cap screws with lock washers. Coat base angle to gear case cap screws with aviation type cement and install cap screws with lock washers. Tighten cap screws firmly, and tighten base angle to end frame bolt. Assemble spring locating washer and nuts on adjusting end of brake band and tighten anchor nut.

(3) INSTALL WINCH MOUNTING BOLTS AND FRONT BUMPER. Install front base angle to side rail extension bolts, then install front bumper (par. 215 b (4)).

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A END FRAME
B SHIFT YOKE PIVOT PIN
C SHIFT YOKE AND DRAG BRAKE SUPPORT (INTEGRAL WITH END FRAME)
D DRAG BRAKE SHOE ASSEMBLY
E DRAG BRAKE ADJUSTING BOLT NUTS
F SPRING
G DRAG BRAKE ADJUSTING BOLT
H CABLE DRUM

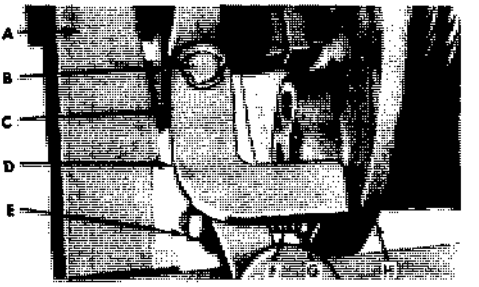

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Figure 246—Winch Drag Brake Shoe Assembly

(4) ADJUST AUTOMATIC BRAKE. Adjust automatic brake (par. 236 d).

238. DRAG BRAKE SHOE ASSEMBLY.

a. Drag Brake Shoe Assembly Removal (fig. 246). Remove cotter pin from upper end of shift yoke pivot pin, then with hammer and punch, drive pin out of drag brake shoe, shift yoke, and pin supports. Lift poppet knob and move shift yoke toward end frame as far as possible, turning drum if necessary to obtain sufficient clearance, then turn drag brake shoe and remove it from winch assembly.

b. Drag Brake Shoe Assembly Installation. With clutch shift yoke held as close as possible to end frame, and drum turned to position which will provide clearance, guide drag brake shoe down between clutch shift yoke and end of drum. Move clutch shift yoke and drag brake as necessary to aline holes through same with holes through supports on end frame. Drive shift yoke pivot pin down through brake shoe, shift yoke, and supports, then secure by installing a cotter pin through each end of pin.

239. CABLE.

a. General. Winch cable is wire rope type with hemp core. One end of cable has a 4-foot length of chain attached by means of a safety clamp.

b. Winch Cable Removal.

(1) UNWIND CABLE FROM DRUM. Disengage sliding jaw clutch, unhook chain from tow hooks, then pull cable straight out from winch by hand.

(2) DETACH CABLE FROM DRUM FLANGE. Loosen two cable clamp nuts at outer side of right-hand drum flange, then pull cable out of clamp.

c. Winch Cable Installation.

(1) ATTACH CABLE TO DRUM. Insert end of cable through clamp at inner side of right-hand drum flange, then tighten clamp nuts at outer side of right-hand drum flange.

(2) WIND CABLE ON DRUM. Wind cable on drum (par. 24).

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TRUCK, 2½-TON, 6 x 6

240. DRIVE SHAFT AND UNIVERSAL JOINTS.

a. Description. The winch drive shaft, which transfers power from power take-off to the winch assembly, is a solid type with a U-joint at each end. Forward U-joint is keyed to drive shaft and attached to winch worm shaft by a shear pin (fig. 243). Rear U-joint is keyed on power take-off shaft. Splines in rear U-joint forward yoke engage the splines at rear end of drive shaft to form a slip joint. A stop collar is installed on drive shaft ahead of slip joint to prevent drive shaft from sliding back into slip joint, thereby preventing front end of drive shaft from dropping off winch worm shaft in the event of shear pin failure.

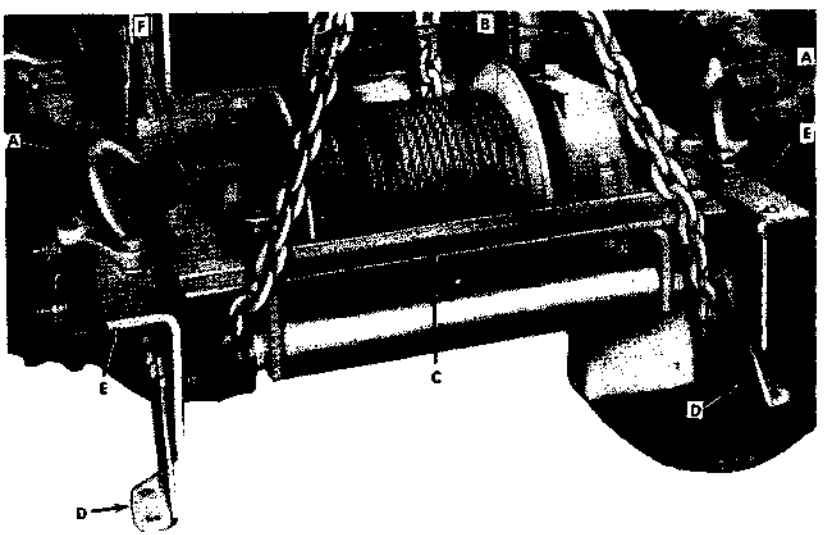
b. Drive Shaft and U-joint Removal.

(1) REMOVE DRIVE SHAFT FROM VEHICLE. Pull cotter pin and remove shear pin. Loosen safety collar set screw and move collar forward. Slide drive shaft into slip joint until front universal joint yoke is free from winch worm shaft, then pull shaft out of slip joint and remove from vehicle.

(2) REMOVE UNIVERSAL JOINT FROM POWER TAKE-OFF. Loosen set screw in universal joint yoke at power take-off and pull universal joint from power take-off shaft. Remove key.

c. Drive Shaft and U-joint Installation.

(1) INSTALL U-JOINT AT POWER TAKE-OFF. Place key in slot in power take-off shaft. With set screw loosened, install joint yoke on power take-off, then tighten set screw firmly.



A TOW HOOK
B SUPPORTING CHAIN
C FRONT BASE ANGLE
D BUMPER BRACKET
E SIDE RAIL EXTENSION
F REAR BASE ANGLE

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Figure 247—Method of Supporting Winch Assembly Prior to Removal

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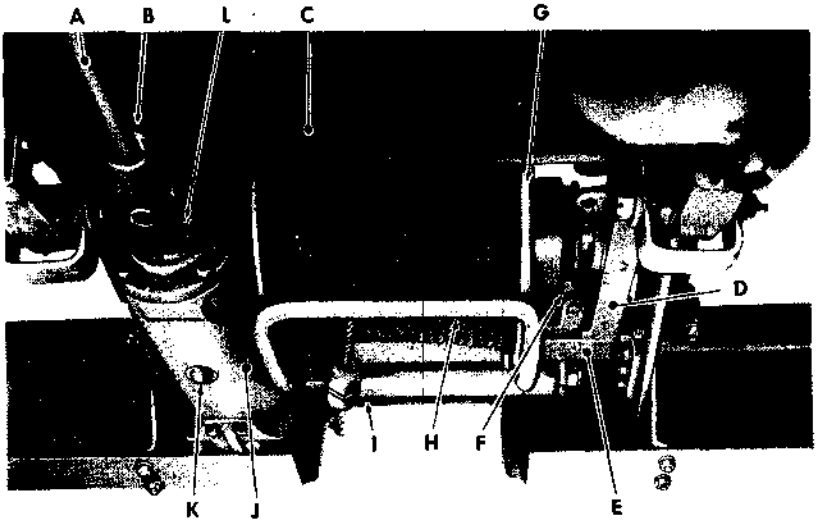
(2) INSTALL DRIVE SHAFT. Loosen stop collar set screw so collar will move freely on drive shaft. Slide collar on splined end of shaft with set screw point between two of the splines. Coat drive shaft splines and inside of front U-joint with chassis grease. Insert splined end of drive shaft into rear U-joint yoke; then push forward U-joint yoke onto winch worm shaft.

(3) INSTALL SHEAR PIN AND POSITION STOP COLLAR. Dip a regulation shear pin in engine oil and install through U-joint yoke and hole through winch worm shaft and secure with cotter pin. CAUTION: *Regulation shear pins are designed to shear whenever overload occurs; as a safety measure, never use a substitute.* Locate stop collar on drive shaft so that a space of one-half inch exists between collar and nearest point on U-joint yoke (fig. 35).

241. WINCH ASSEMBLY REMOVAL.

a. Remove Front Bumper and Brush Guard. Remove front bumper (par. 215 b (3)), and remove brush guard (par. 217 c and d).

b. Attach Hoist (fig. 247). Attach chain-fall or other hoisting equipment to winch to support the assembly while attaching parts are being removed. Chain sling may be used as in figure 247.



A WINCH DRIVE SHAFT
B DRIVE SHAFT KEY
C WINCH BASE ANGLE—REAR
D WINCH END FRAME
E WINCH BASE ANGLE—FRONT
F SLIDING JAW CLUTCH
G WINCH DRUM
H ROPE GUARD
I WINCH ROLLER
J WORM SHAFT HOUSING
K DRAIN PLUG
L SHEAR PIN

RA PD 64574

Figure 248—Winch Assembly Installed (Bottom View)

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c. **Disconnect Winch Drive Shaft.** Remove cotter pin and remove shear pin from U-joint yoke. Loosen stop collar screw and pull drive shaft toward power take-off, thereby removing U-joint from winch worm shaft. Support drive shaft by suspending by wire attached to chassis.

d. **Remove Winch Assembly from Vehicle.** Remove front base angle to side rail extension bolts. Remove rear base angle to frame side rail bolts and washers. Move winch assembly forward and away from vehicle.

242. WINCH ASSEMBLY INSTALLATION.

a. **Position Assembly at Vehicle.** Swing assembly to position, using chain-fall or other suitable hoist. Winch rear base angle must rest on forward end of frame side rails with bolt holes alined.

b. **Install Mounting Bolts** (fig. 248). Install four rear base angle to frame side rail bolts, and six front base angle to side rail extension bolts. Use lock washers under all bolt nuts and tighten firmly.

c. **Install Radiator Brush Guard and Front Bumper.** Install brush guard (par. 217 d and e) and install front bumper (par. 215 b (4)).

d. **Connect Drive Shaft.** Coat inside of forward universal joint and shear pin with chassis grease. Remove wire used to suspend drive shaft and slide U-joint yoke onto winch worm shaft. Rotate drive shaft as necessary to aline shear pin holes in yoke and worm shaft; then insert shear pin and secure with cotter pin. Move drive shaft stop collar toward power take-off until one-half inch clearance exists between collar and forward edge of U-joint yoke; then tighten stop collar screw.

Section XLIV

POWER HOIST AND CONTROLS

243. GENERAL.

a. The power hoist mechanism consists primarily of a hydraulic cylinder and pump assembly (fig. 249), mounted beneath the dump body for the purpose of raising the front end of the body for dumping the load out rear of body. The hoist mechanism is connected by propeller shafts and U-joints to power take-off auxiliary drive shaft. Levers for controlling hoist mechanism are located in cab and are connected through linkage with power take-off and hoist pump. Raising of dump body is accomplished through hydraulic pressure and leverage in lifting linkage. Hoist assemblies used on these vehicles are furnished by Gar Wood Industries and The Heil Company.

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POWER HOIST AND CONTROLS

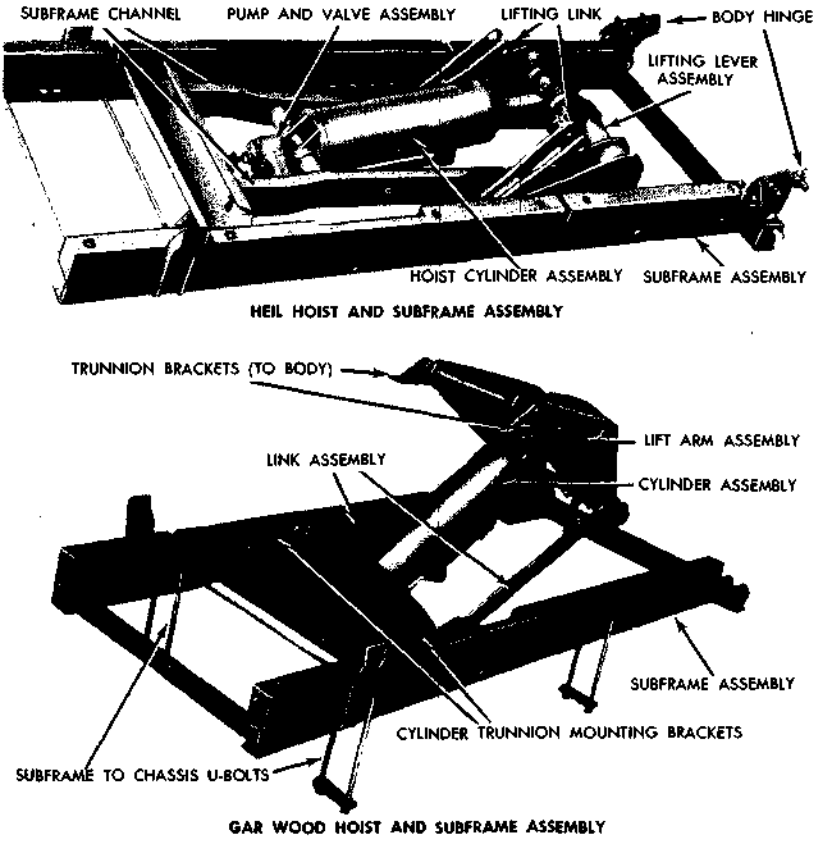

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Figure 249—Power Hoist Assembly Views

244. CONTROLS AND LINKAGE.

a. General. The power hoist—regardless of make—is controlled from the cab by two levers. One lever shifts the power take-off auxiliary drive in and out of engagement and the other lever, which is connected through rods and linkage with the control valve at hoist pump assembly, is used to control the raising and lowering of dump body. Levers and linkage used on early and late vehicles differ considerably, but both types serve the same purpose. Replacement of hoist power take-off lever and linkage, both early and late type, and hoist pump control lever used on early vehicles, is covered in Section XXVIII.

b. Hoist Pump Control Lever and Linkage Removal.

(1) REMOVE HOIST PUMP CONTROL LEVER (EARLY VEHICLES). Remove hoist pump control lever (par. 158 d (4) and (5)).

(2) REMOVE HOIST PUMP CONTROL LEVER (LATE VEHICLES). Remove clevis pin at lower end of lever which attaches rod to lever.

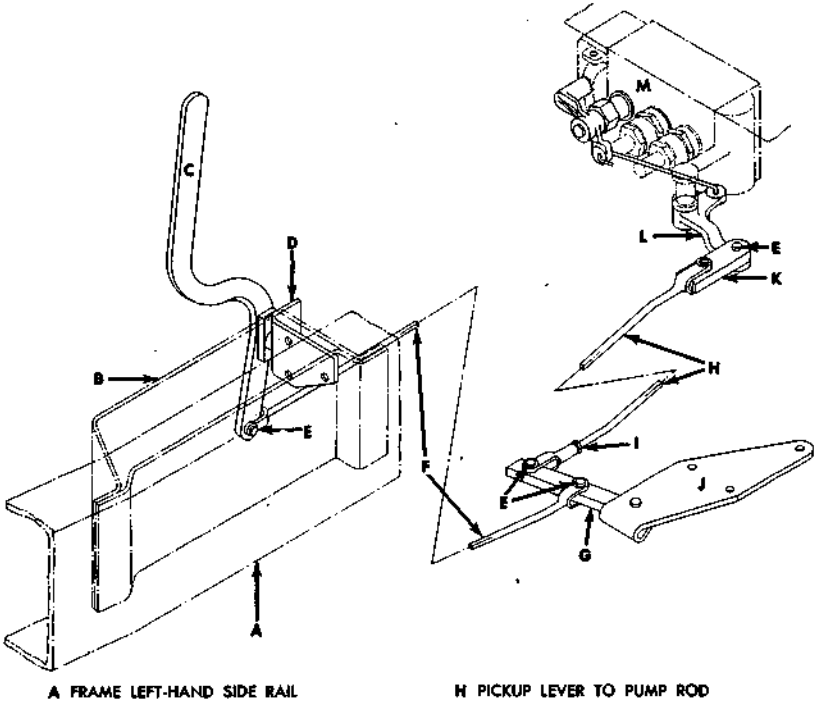
Remove three bolts which attach lever bracket to brake master cylinder bracket; to remove, pull lever and bracket assembly down and remove from under vehicle. Remove bracket from lever.

(3) REMOVE LEVER TO HOIST PUMP RODS AND LINKAGE (fig. 250). Remove clevis pins from each end of control lever to pickup lever rod; then pull rod toward rear and remove from vehicle. Remove clevis pins which attach pickup lever to pump rod and remove rod. Forward end of rod is threaded and equipped with an adjustable rod end clevis and lock nut which may be removed if necessary. Remove pin (or bolt) which attaches pickup lever to frame bracket and remove lever.

c. Hoist Pump Control Lever and Linkage Installation.

(1) INSTALL HOIST PUMP CONTROL LEVER (EARLY VEHICLES). Install hoist pump control lever (par. 158 f (1), (2), and (4)).

(2) INSTALL HOIST PUMP CONTROL LEVER (LATE VEHICLES) (fig. 250). Assemble lever to bracket; then from below vehicle, place upper end of lever through floor pan opening and raise lever and



A FRAME LEFT-HAND SIDE RAIL
B BRAKE CYLINDER BRACKET
C HOIST PUMP CONTROL LEVER
D PUMP CONTROL LEVER BRACKET
E CLEVIS PIN
F CONTROL LEVER TO PICKUP LEVER ROD
G PICKUP LEVER
H PICKUP LEVER TO PUMP ROD
I LOCK NUT
J PICKUP LEVER BRACKET
K LEVER EXTENSION
L BELL CRANK
M HOIST PUMP ASSEMBLY

RA PD 333056

Figure 250—Hoist Pump Control Linkage (Late Vehicles)

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bracket up to position at brake master cylinder bracket. Install three lever bracket to master cylinder bracket bolts and tighten firmly.

(3) INSTALL PICKUP LEVER. Position pickup lever at frame bracket and install pickup lever to frame bracket pin (or bolt). Secure pin with new cotter pin.

(4) INSTALL CONTROL LEVER TO PICKUP LEVER ROD. Insert forward end of control lever to pickup lever rod through hole in muffler support bracket and propeller shaft bearing support bracket. Connect forward end of rod to lower end of hoist pump control lever and rear end of rod to pickup lever, using clevis pins.

(5) INSTALL ROD BETWEEN PICKUP LEVER AND HOIST PUMP ASSEMBLY. With adjustable rod end clevis and lock nut installed on forward end of rod, attach rod to pickup lever and hoist pump bell crank. NOTE: *Gar Wood hoist linkage incorporates a lever extension* (fig. 250) *which attaches to rod with a clevis pin and is attached to hoist pump bell crank.* Attach rear end of rod to extension if vehicle is equipped with Gar Wood hoist or directly to bell crank if Heil hoist is used.

d. Hoist Pump Valve Control Linkage Adjustment. Spring loaded plunger is mounted in bell crank arm to locate valve in any one of three positions selected by operator, and link rod nearest hoist assembly has one adjustable rod and clevis. Make adjustment as follows:

(1) ADJUST PUMP VALVE LINKAGE. Remove clevis pin from adjustable clevis and move clevis away from idler lever. Consult "Shifting Arrangement Plate" and place hoist valve control lever in "RAISE" position. Move bell crank until plunger drops into depression at "RAISE" valve position, then adjust clevis on threaded end of rod so it can be reconnected to pickup lever without changing control lever or control valve positions. Position adjustable yoke at pickup lever and install clevis pin. Secure clevis pin with new cotter pin.

245. PROPELLER SHAFTS AND UNIVERSAL JOINTS.

a. General (fig. 251). Drive line from power take-off to hoist pump comprises three solid drive shafts connected by universal joints and supported by two steady bearings, which are attached to frame brackets. All U-joints are similar in construction except rear joint which, together with a special key in rear drive shaft, forms a slip joint. U-joint yokes are attached to drive shafts by set screws and Woodruff keys.

b. Removal. Removal of any individual shaft, U-joint, or steady bearing will be facilitated if complete drive line assembly is removed from vehicle.

(1) REMOVE STEADY BEARINGS. Remove nuts and lock washers from front and rear steady bearing studs.

(2) REMOVE DRIVE LINE ASSEMBLY. Loosen set screw attaching front U-joint to power take-off auxiliary drive shaft. Remove drive line assembly by pulling steady bearing studs from brackets;

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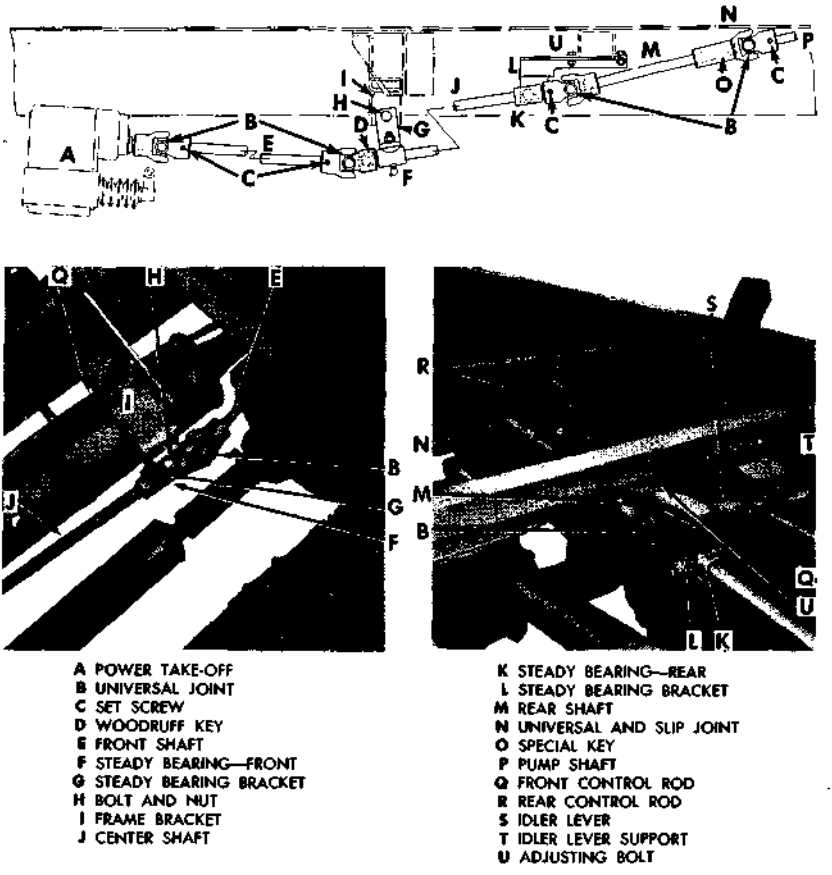

Figure 251—Hoist Propeller Shaft and Steady Bearing Installation

then moving assembly first rearward, then forward to remove front U-joint from power take-off and rear propeller shaft from slip joint. Do not lose special key out of rear shaft.

(3) REMOVE REAR U-JOINT. Loosen set screw which holds rear U-joint on hoist pump shaft, then remove joint from shaft.

(4) REMOVE U-JOINTS AND STEADY BEARINGS FROM PROPELLER SHAFTS. Remove five set screws which attach U-joints to shafts. Remove U-joints and Woodruff keys from shafts and slide the two steady bearings off center shaft.

(5) REMOVE STEADY BEARING SUPPORT BRACKETS FROM FRAME (fig. 251). Remove bolt attaching front steady bearing bracket to frame bracket, then remove bracket. Remove two bolts which attach rear steady bearing bracket to frame crossmember and remove bearing bracket from frame.

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c. **Installation.** Drive line components should be assembled on bench and the assembly then installed on vehicle to facilitate the operation.

(1) ATTACH STEADY BEARING BRACKETS TO FRAME. Attach front steady bearing bracket to frame bracket, using bolt and lock washer as in figure 251. Attach rear steady bearing bracket to frame crossmember, using two bolts, with bracket in position as in figure 251.

(2) INSTALL UNIVERSAL JOINTS TO FRONT SHAFT. Install a Woodruff key at each end of shaft (28⅝ in. long) and slide universal joint over shaft. Aline hole in yoke with hole in shaft. Install set screws and tighten. Prick punch each screw to prevent loosening.

(3) INSTALL UNIVERSAL JOINT TO REAR SHAFT. Install a Woodruff key at front end of shaft (14¼ in. long) and slide universal joint over shaft. Aline hole in yoke with hole in shaft. Install set screw and tighten. Prick punch screw to prevent loosening.

(4) ASSEMBLE CENTER SHAFT. Slide two steady bearings over center shaft (47½ in. long). Install a Woodruff key at each end of shaft. Connect front and rear shafts to center shaft by sliding universal joints over ends. Aline hole in yoke with hole in shaft. Install set screw and tighten. Prick punch screw to prevent loosening.

(5) INSTALL U-JOINT AT PUMP. Install a Woodruff key in pump shaft and slide universal joint over shaft. Aline hole in yoke with hole in shaft. Install set screw and tighten. Prick punch screw to prevent loosening.

(6) INSTALL UNIVERSAL JOINT AT POWER TAKE-OFF. Install a Woodruff key in power take-off shaft. Loosen set screw in universal joint on end of front shaft. Aline slot in universal joint yoke with Woodruff key in power take-off shaft, then slide joint over shaft. Aline set screw with flat spot on shaft and tighten set screw. Prick punch head of screw to prevent loosening.

(7) ATTACH REAR STEADY BEARING. Install special Hi-Pro key at end of rear shaft. Raise propeller shaft sufficiently to insert end of shaft into universal joint slip yoke at pump. Insert rear steady bearing stud into support bracket on frame crossmember. Install lock washer and nut on stud.

(8) ATTACH FRONT STEADY BEARING. Raise propeller shafts as necessary to insert front steady bearing stud into support bracket, attached to frame bracket. Install lock washer and nut on stud.

(9) ADJUST DRIVE LINE CLEARANCE. Carefully inspect propeller shafts and universal joints to be sure they do not rub against muffler, brackets, or crossmembers. When necessary, use flat washers between steady bearing and bracket at rear, also between steady bearing bracket and frame bracket at front. Rear support bracket at crossmember can also be adjusted slightly to provide greater drive line clearance by loosening bolts attaching bracket to crossmember. Be sure bolts are again tightened when clearance has been obtained.

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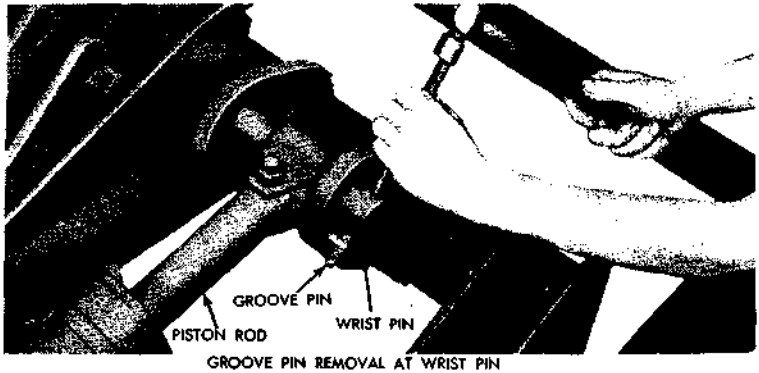
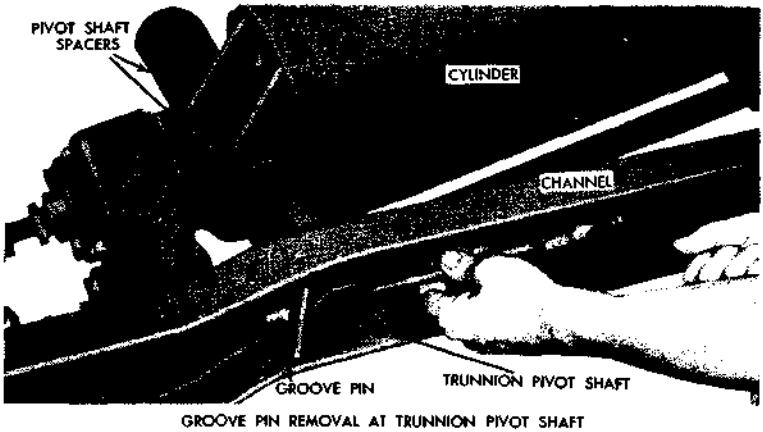
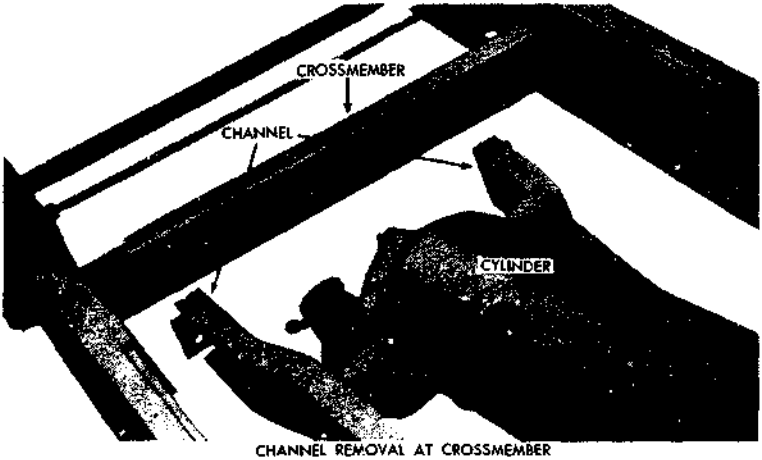
TRUCK, 2½-TON, 6 x 6



GROOVE PIN REMOVAL AT WRIST PIN



GROOVE PIN REMOVAL AT TRUNNION PIVOT SHAFT



CHANNEL REMOVAL AT CROSSMEMBER

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Figure 252—Heil Hoist Cylinder Removal

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POWER HOIST AND CONTROLS

246. CYLINDER ASSEMBLY (HEIL HOIST).

a. General. The cylinder assembly used on Heil hoists is attached to the lifting mechanism by a tie bar which connects the piston rod to a wrist pin (fig. 252). Forward end of cylinder to which the pump assembly is attached is supported on a trunnion pivot shaft.

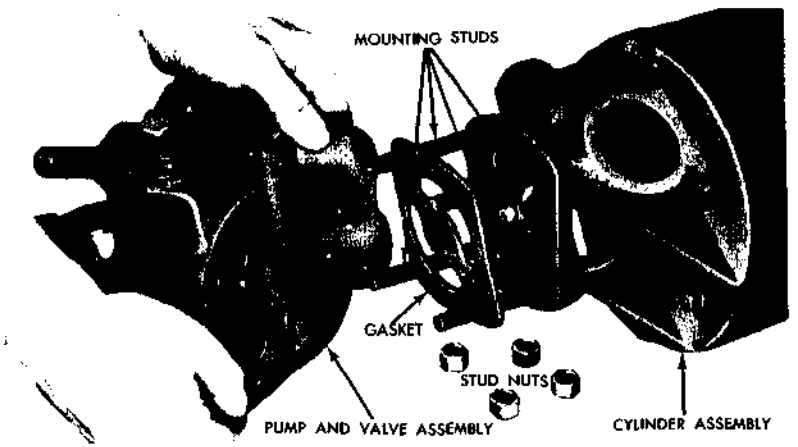
b. Cylinder Removal (fig. 252).

(1) RAISE BODY AND DISCONNECT PROPELLER SHAFT. Raise body and block securely to prevent dropping, then place pump control lever in "LOWER" position. Loosen set screw in U-joint yoke at pump shaft, remove nut and lock washer from rear steady bearing stud, then remove stud from bracket. Pull down on rear propeller shaft and at the same time remove joint yoke from pump shaft. Remove cotter pin and clevis pin which attach control rod to pump lever.

(2) REMOVE HOIST WRIST PIN. Use hammer and punch to drive groove pin from wrist pin and bracket (fig. 252). Use a heavy drift and sledge hammer and drive wrist pin from lever assembly and piston rod tie bar.

(3) REMOVE CYLINDER AND PUMP ASSEMBLY. Drive groove pin out of trunnion pivot shaft. Remove four nuts, lock washers, and bolts attaching two channels to subframe crossmember. Spread channels (fig. 252) and lift cylinder and pump assembly from vehicle. Remove pivot shaft and spacers from cylinder.

(4) REMOVE PUMP ASSEMBLY FROM CYLINDER. Support cylinder assembly so that fluid can be drained from pump. Remove drain plug from pump body and drain fluid into suitable receptacle —rotate pump shaft to force out all fluid. Remove four nuts and lock washers from studs attaching pump to cylinder manifold. Remove pump assembly and discard the gasket.



RA PD 332836

Figure 253—Heil Hoist Pump Installation At Cylinder

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c. Cylinder Installation.

(1) ATTACH PUMP ASSEMBLY (fig. 253). Place a new pump to cylinder gasket over studs and against cylinder manifold. Position pump assembly on studs with drain plug at bottom, and install four stud nuts and lock washers.

(2) POSITION CYLINDER AT SUBFRAME. Position cylinder assembly inside subframe members with oil filler hole on top and piston rod toward rear.

(3) INSTALL TRUNNION PIVOT SHAFT. Install pivot shaft through trunnion at rear of cylinder and position spacer on each end of shaft. Move two channels together so that ends of pivot shaft will enter holes in channels. Install groove pin through pivot shaft and into angle bracket. Drive groove pin tightly into shaft. Attach channels to subframe crossmember, using four bolts with nuts and lock washers.

(4) INSTALL HOIST WRIST PIN. Insert wrist pin through lifting lever and piston rod tie bar. Insert groove pin through angle bracket and into hole in wrist pin. Drive groove pin in tightly.

(5) CONNECT PROPELLER SHAFT AND CONTROL ROD. Raise rear propeller shaft upward, and at the same time guide the rear U-joint rear yoke onto pump shaft. Be sure key is in slot in pump shaft. Insert rear steady bearing stud through hole in support bracket and install stud nut and lock washer. Tighten set screw in rear U-joint yoke. Attach control rod to pump lever, using clevis pin and cotter pin. NOTE: *After installation is completed, inspect and adjust drive line as directed in paragraph* 245 e (9).

(6) FILL HYDRAULIC CYLINDER. Whenever pump assembly has been removed or cylinder disassembled, it is necessary that system be refilled with recommended hydraulic fluid (Section VIII).

(a) Remove the special vent plug in top of cylinder. Start engine and engage power take-off. Place hoist pump control lever, located in cab, in "RAISE" position. Pour fluid through opening with the pump running slowly until the body raises to its full height. When body has reached its full height, add about one-half pint more fluid.

(b) With power take-off still engaged and pump running, move control lever into "LOWER" position. Lower the body slowly until all the way down. Do not replace special vent plug at this time.

(c) Move control lever to "RAISE" position and again raise body slowly. Repeat raising and lowering operations several times to allow any surplus fluid to drain out. Install vent plug when body is in fully raised position.

247. CYLINDER ASSEMBLY (GAR WOOD HOIST).

a. General (fig. 249). The cylinder assembly, mounted between subframe members, consists of a cylinder with trunnion, cylinder head, and piston and rod assembly. The cylinder trunnion is supported at each subframe member by a trunnion mounting bracket. Piston rod is connected to lift arm cross head by a bolt.

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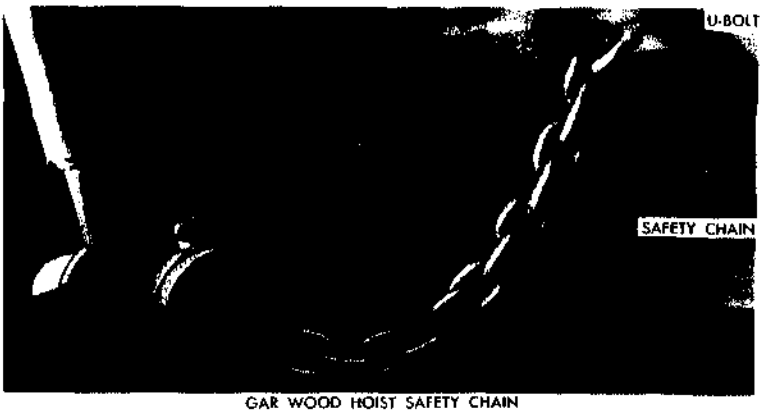
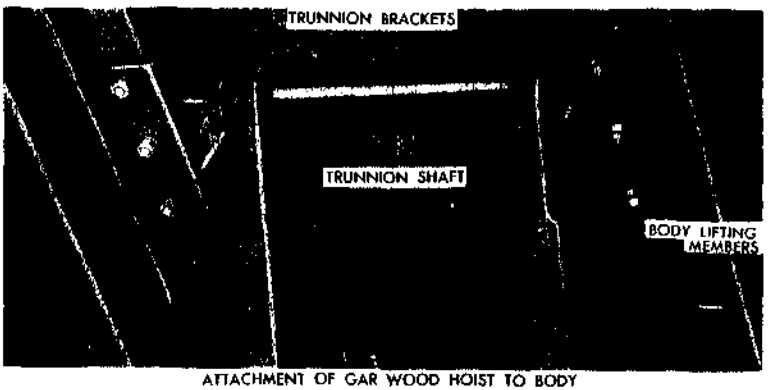


GAR WOOD HOIST SAFETY CHAIN



ATTACHMENT OF GAR WOOD HOIST TO BODY

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Figure 254—Trunnion Bracket and Safety Chain Installations at Dump Body (Gar Wood Hoist)

b. Cylinder Removal (fig. 249). Removal of cylinder can be accomplished with body mounted on vehicle. Cylinder, pump, and lifting linkage should be removed as an assembly, then disassembled on bench.

(1) RAISE BODY AND DISCONNECT PROPELLER SHAFT. Accomplish procedure given in paragraph 246 b (1).

(2) DISCONNECT LIFTING LINKAGE FROM BODY (fig. 254). Lay suitable blocking across hoist subframe to support rear end of assembly while removing trunnion brackets and safety chain U-bolt. Remove six trunnion brackets to body bolts and remove nuts from U-bolt which attaches safety chain to body understructure.

(3) REMOVE WOOD SILLS FROM SUBFRAME (fig. 249). Remove wood sill center section, bolted to each side of subframe, to permit access to trunnion bracket bolt heads.

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(4) REMOVE TRUNNION BRACKET TO SUBFRAME BOLTS. Remove four trunnion bracket to subframe bolts at each side of subframe.

(5) LIFT ASSEMBLY FROM VEHICLE. If personnel are available, three or four men can easily lift the cylinder and lifting linkage from vehicle; otherwise, attach suitable tackle and lift the assembly from vehicle.

(6) REMOVE LIFTING LINKAGE FROM CYLINDER (fig. 255). Remove hoist cylinder trunnion brackets. Remove piston rod to cross head bolt, then force cross head off piston rod. Remove bolts attaching link retaining collars to lifting arm trunnion shaft, then remove collars and links from the assembly. Set lifting linkage aside until ready to install cylinder.

(7) REMOVE PUMP FROM CYLINDER (fig. 257). Place hoist valve lever in "LOWER" position. Remove plate from bottom of pump and drain all fluid from assembly. Unscrew packing nut, attaching pump manifold to cylinder manifold, then move packing and nut away from cylinder. Remove five cap screws and washers attaching pump to cylinder manifold. Remove pump assembly and discard gaskets used between pump and cylinder. Replace plate which was removed for draining.

c. Cylinder Installation.

(1) INSTALL PUMP ASSEMBLY ON CYLINDER. Coat both sides of pump to cylinder body gaskets with aviation type cement. With new packing and packing nut in position on pump manifold (fig. 257), and pump to cylinder gaskets positioned on pump, attach pump to cylinder, using five cap screws and flat washers, with avia-

A PISTON ROD TO CROSS HEAD BOLT
B LIFT ARM
C COLLAR
D COLLAR RETAINING BOLT
E HOIST CYLINDER
F LINK

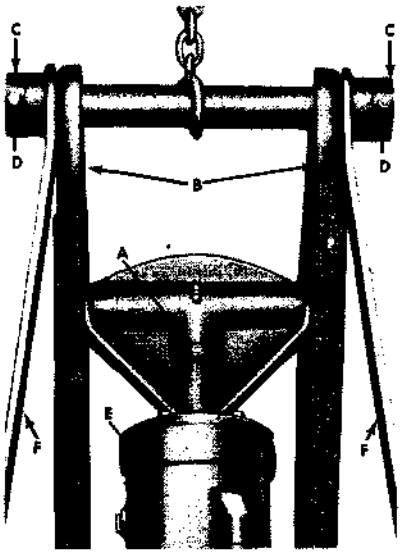

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Figure 255—Lifting Linkage to Cylinder Assembly Connections

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tion type cement under cap screw heads and on washers. Tighten cap screws evenly and alternately, then tighten packing nut on cylinder manifold threads.

(2) INSTALL LIFTING LINKAGE ON CYLINDER AND PUMP ASSEMBLY. Place cylinder and pump assembly on bench in operating position (with pump assembly below cylinder trunnion). Lay lifting arm linkage assembly on bench with trunnion bracket shaft resting on top of cylinder, then assemble cross head to piston rod and install bolt and nut. Slide links into position on cylinder trunnion and lift arm trunnion shaft, then install trunnion shaft collars and secure with bolts, nuts, and lock washers (fig. 255).

(3) INSTALL CYLINDER, PUMP, AND LIFTING LINKAGE ASSEMBLY IN VEHICLE. Place blocking as in subparagraph **b** (2) above, to support rear end of cylinder assembly. If personnel are available, three or four men can lift the assembly into position in hoist subframe; otherwise attach suitable tackle and swing the assembly into place in vehicle. As the cylinder is lowered into the subframe, place one cylinder trunnion mounting bracket on each cylinder trunnion. Attach trunnion mounting brackets to subframe, using four bolts with nuts and lock washers, placing bolt heads at outer side of subframe. Install wood sill center section at each side of subframe.

(4) CONNECT PROPELLER SHAFT AND CONTROL ROD. Accomplish procedure as given in paragraph 246 **c** (5).

(5) FILL HYDRAULIC CYLINDER AND ATTACH LIFTING LINKAGE TO BODY. Whenever pump assembly has been removed from cylinder, or hydraulic fluid drained from hoist for any reason, it is necessary to refill the hoist hydraulic system with recommended fluid (Section VIII).

(a) Remove filler plug at side of hoist cylinder. Place control valve lever (in cab) in "LOWER" position.

(b) With piston rod forced into cylinder as far as possible, add hydraulic fluid slowly to filler plug level; then install filler plug.

(c) Start engine, shift hoist power take-off lever to "IN" position and slowly operate hoist pump with the hoist pump valve lever in "RAISE" position. When piston rod has moved lifting linkage sufficiently to allow the attaching of trunnion brackets to body lifting member, place valve control lever in "HOLD" position.

(d) Attach trunnion brackets (fig. 254) to body lifting members, using three bolts with lock washers and nuts at each bracket; then with hoist, raise body sufficiently to relieve weight from blocking used to support body.

(e) With hoist fully raised, again remove filler plug from cylinder, fill cylinder to plug level, and reinstall plug.

(f) Repeat lowering, raising, and filling procedure until oil remains at filler plug hole level when body is in fully raised position. Raise and lower body slowly to prevent foaming of oil which creates air pockets.

(6) ADJUST PUMP VALVE LEVER STOP SCREW. Stop screw is provided in pump manifold to control pump valve opening at the lowering position.

(a) With hoist power take-off lever in the "IN" position and valve control lever in "LOWER" position, quickly accelerate engine. Note if body has a tendency to rise, in which case the stop screw must be turned down further until body does not move.

248. PUMP ASSEMBLY (HEIL HOIST).

a. General. Hoist pump and valve assembly is attached directly to forward end of hoist cylinder. Valve operating linkage, comprising a bell crank, support bracket, valve operating lever, and link, are included in the pump assembly. Adjustable packing glands are provided at pump drive shaft and valve operating shaft.

b. Pump Packing Glands. Two packing glands are utilized to prevent fluid leakage at pump assembly. Both glands are adjustable for normal packing wear, and are accessible with the pump installed on vehicle. Whenever adjustment fails to stop leakage, the glands must be repacked.

(1) PACKING GLAND ADJUSTMENT (fig. 256).

(a) Tighten the packing nut as necessary to stop leak around valve shaft; however, if valve linkage does not operate freely after adjustment, the necessity for packing replacement is indicated.

(b) To stop leakage at pump drive gear shaft, tighten stud nuts at packing gland alternately one-half turn at a time, until the leak is stopped or gland contacts pump body. Repack gland if leak continues after tightening nuts at gland.

(2) GLAND PACKING REPLACEMENT.

(a) Replace Packing at Pump Valve Shaft. Loosen lock nut and set screw at valve control lever and remove lever and key from

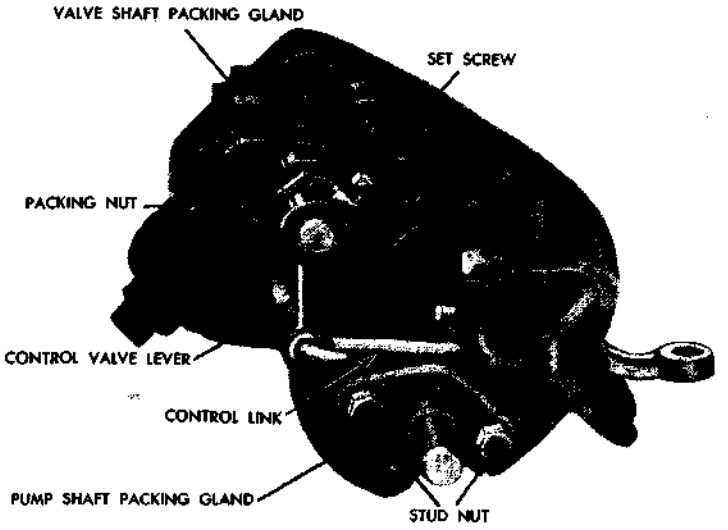

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Figure 256—Heil Hoist Pump Assembly

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shaft. Remove packing gland nut and remove all old packing from gland. Slide new packing onto shaft and into gland. Thread packing nut into gland to force packing into place, then with key in shaft, install valve control lever on shaft.

(b) Replace Packing in Drive Gear Shaft Gland. Place dump valve control lever in "HOLD" position, remove plug, and drain fluid from pump. Disconnect propeller shaft from pump (par. 246 **b** (1)). Remove stud nuts at packing gland, then remove gland from shaft and remove all old packing from gland. Do not lose packing retaining ring. Place new packing around shaft and against pump housing cover. Push packing retaining ring onto shaft, then install gland and stud nuts. Tighten nuts evenly as in step **b** (1) *(b)* above to firmly compress packing around shaft. Reconnect propeller shaft and install hydraulic fluid (par. 246 **c** (6)).

c. Pump Removal. Pump may be removed from vehicle without removing cylinder, body, or subframe.

(1) DISCONNECT PROPELLER SHAFT. Disconnect propeller shaft as directed in paragraph 246 **b** (1).

(2) REMOVE PUMP ASSEMBLY. Remove drain plug from pump body and allow all fluid to drain from pump—rotate pump shaft to expel all fluid. Remove four nuts from studs which attach pump to cylinder. Remove pump assembly and discard gasket.

d. Pump Installation (fig. 256).

(1) ATTACH PUMP ASSEMBLY. Coat a new pump to cylinder gasket with aviation type cement, then place gasket over studs and against cylinder. Position pump assembly on studs and install nuts and lock washers.

(2) CONNECT PROPELLER SHAFT AND CONTROL ROD. Connect propeller shaft and control rod as directed in paragraph 246 **c** (5).

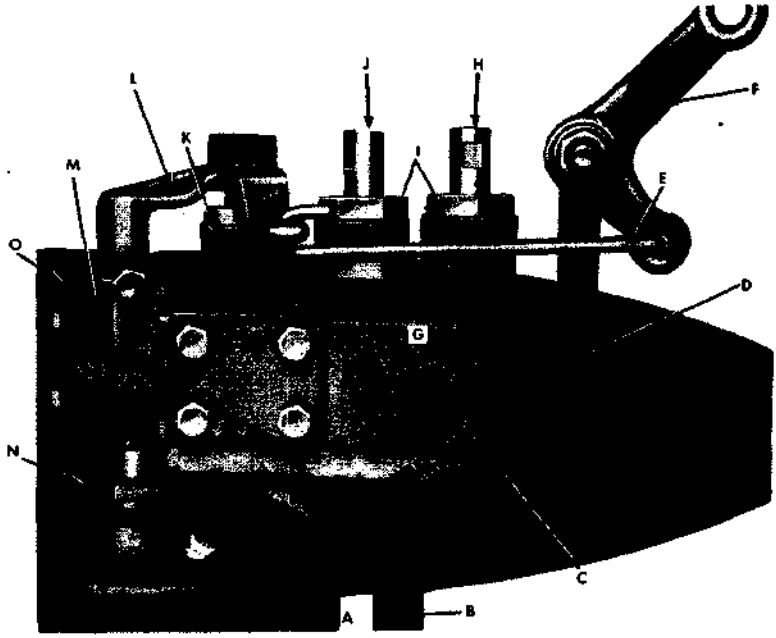
(3) INSTALL HYDRAULIC FLUID. Fill hydraulic cylinder as directed in paragraph 246 **c** (6).

249. PUMP ASSEMBLY (GAR WOOD HOIST).

a. General. Hoist pump assembly is attached by cap screws to the cylinder trunnion, and pump manifold is connected to cylinder through the use of packing, held in place by a packing nut (fig. 257). Propeller shaft from power take-off is connected to drive shaft (H, fig. 257), and hoist pump valve is operated by linkage which is connected to lever in vehicle cab. Pump is accessible for servicing and replacement with hoist assembly and body installed on the vehicle.

b. Pump Packing Glands (fig. 257). Packing glands are utilized to prevent fluid leakage at following four points: at pump assembly pump manifold (N), pump valve shaft (K), drive gear shaft (H), and idler gear shaft (J). Lock nuts (G) are used at gear shafts to prevent loosening of packing nuts.

(1) PACKING NUT ADJUSTMENT. In the event of leaks at any of the packing nuts, make adjustment as follows: If packing nut is locked by lock nut, back off lock nut first. Tighten packing nuts by turning clockwise as necessary to stop fluid leakage. Lock adjust-



A CYLINDER
B LOW PRESSURE PIPE
C PUMP ASSEMBLY
D CONTROL BRACKET
E CONTROL LINK
F CONTROL BELL CRANK
G LOCK NUTS
H DRIVE SHAFT
I PACKING NUTS
J IDLER SHAFT
K VALVE PACKING NUT
L VALVE LEVER
M PUMP MANIFOLD
N MANIFOLD TO TRUNNION PACKING NUT
O CYLINDER TRUNNION

RA PD 332792

Figure 257—Gar Wood Hoist Pump Installed on Cylinder

ment by screwing lock nut up tightly against packing nut. If leak continues after adjustment, it will be necessary to replace packing.

(2) GLAND PACKING REPLACEMENT (fig. 257). Packing at pump manifold to cylinder connection does not require replacement except when pump or cylinder assembly is being replaced. If leak develops at that point, tighten packing nut.

(a) Preliminary Instructions. Before attempting any of the succeeding operations, raise dump body to full height and block securely. Place hoist valve control lever in "HOLD" position, remove plate at bottom of pump body, and drain fluid from pump into convenient receptacle.

(b) Replace Packing at Pump Valve Shaft. Loosen valve lever to pump shaft set screw, then remove lever and key from shaft. Do not lose spring and plunger from lever. Remove packing nut. Remove all old packing from nut. Place new packing around shaft, reinstall packing nut, and tighten sufficiently to prevent leak. Place key in shaft, then with spring and plunger in place in lever, and lever control link attached, install valve lever on shaft. Fill hy-

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draulic cylinder as directed in paragraph 247 c (5).

(c) Replace Packing at Pump Gear Shaft. Procedure is same for replacing packing at the pump drive gear shaft and idler gear shaft.

1. Disconnect propeller shaft from pump (par. 246 b (1)). Loosen lock nut, then remove packing nut from shaft. Remove all old packing remaining in nut.

2. Place new packing around shaft, then install packing nut and adjust as directed in step (1) above. Connect propeller shaft as directed in paragraph 246 c (5).

3. Fill hydraulic cylinder as directed in paragraph 247 c (5).

c. Pump Removal (fig. 257). Hoist pump may be removed from vehicle without removing cylinder, body, or subframe.

(1) RAISE AND BLOCK BODY. Raise body as necessary to permit access to cap screws at upper side of cylinder trunnion, then securely block body in raised position.

(2) DRAIN HYDRAULIC FLUID. Place pump valve control lever in "LOWER" position, remove plate from lower side of pump assembly, and allow fluid to drain. NOTE: *To make certain that all hydraulic fluid has drained out, start engine and run hoist pump slowly with the hoist valve control lever in the "RAISE" position. Replace plate on pump after draining.*

(3) DISCONNECT PROPELLER SHAFT AND CONTROL ROD. Disconnect propeller shaft and control rod as directed in paragraph 246 b (1).

(4) REMOVE PUMP ASSEMBLY. Remove pump assembly as directed in paragraph 247 b (7).

d. Pump Installation.

(1) INSTALL PUMP ASSEMBLY ON CYLINDER. Install pump assembly on cylinder as directed in paragraph 247 c (1).

(2) CONNECT PROPELLER SHAFT AND CONTROL ROD. Connect propeller shaft and control rod at pump as directed in paragraph 246 c (5).

(3) FILL HYDRAULIC CYLINDER. Fill hydraulic cylinder as directed in paragraph 247 c (5).

APPENDIX

Section XLV

SHIPMENT AND TEMPORARY STORAGE

250. GENERAL INSTRUCTIONS.

a. Preparation for domestic shipment of the vehicle is the same as preparation for temporary storage or bivouac. Preparation for shipment by rail includes instructions for loading and unloading the

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vehicle, blocking necessary to secure the vehicle on freight cars, number of vehicles per freight car, clearance, weight, and other information necessary to properly prepare the vehicle for rail shipment. For more detailed information and for preparation for indefinite storage, refer to AR 850-18.

251. PREPARATION FOR TEMPORARY STORAGE OR DOMESTIC SHIPMENT.

a. Vehicles to be prepared for temporary storage or domestic shipment are those ready for immediate service but not used for less than thirty days. If vehicles are to be indefinitely stored after shipment by rail, they will be prepared for such storage at their destination.

b. If the vehicles are to be temporarily stored or bivouacked, take the following precautions.

(1) LUBRICATION. Lubricate the vehicle completely (par. 37).

(2) COOLING SYSTEM. If freezing temperature may normally be expected during the limited storage or shipment period, test the coolant with a hydrometer and add the proper quantity of antifreeze to afford protection from freezing at the lowest temperature anticipated during the storage or shipping period. Completely inspect the cooling system for leaks.

(3) BATTERY. Check battery and terminals for corrosion and if necessary, clean and thoroughly service battery (par. 119).

(4) TIRES. Clean, inspect, and properly inflate all tires. Replace with serviceable tires, tires requiring retreading or repairing. Do not store vehicles on floors, cinders, or other surfaces which are soaked with oil or grease. Wash off immediately any oil, grease, gasoline, or kerosene which comes in contact with the tires under any circumstances.

(5) ROAD TEST. The preparation for limited storage will include a road test of at least 5 miles, after the battery, cooling system, lubrication, and tire service, to check on general condition of the vehicle. Correct any defects noted in the vehicle operation before the vehicle is stored, or note on a tag attached to the steering wheel, stating the repairs needed or describing the condition present. A written report of these items will then be made to the officer in charge.

(6) FUEL IN TANKS. It is not necessary to remove the fuel from the tanks for shipment within the United States, nor to label the tanks under Interstate Commerce Commission Regulations. Leave fuel in the tanks except when storing in locations where Fire Ordinances or other local regulations require removal of all gasoline before storage.

(7) EXTERIOR OF VEHICLE. Remove rust appearing on any part of the vehicle with sandpaper. Repaint painted surfaces whenever necessary to protect wood or metal. Coat exposed polished metal surfaces susceptible to rust, such as winch cables, chains, and in the case of track-laying vehicles, metal tracks, with medium grade

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preventive lubricating oil. Close firmly all cab doors, windows, and windshields. Vehicles equipped with open type cabs with collapsible tops will have the tops raised, all curtains in place, and the windshield closed. Make sure tarpaulins and window curtains are in place and firmly secured. Leave rubber mats, such as floor mats, where provided, in an unrolled position on the floor, and not rolled or curled up. Equipment such as pioneer and truck tools, tire chains, and fire extinguishers will remain in place in the vehicle.

(8) INSPECTION. Make a systematic inspection just before shipment or temporary storage to insure all above steps have been covered and that the vehicle is ready for operation on call. Make a list of all missing or damaged items and attach it to the steering wheel. Refer to "Before Operation Service" (par. 42).

(9) ENGINE. To prepare the engine for storage, remove the air cleaner from the carbureter. Start the engine and set the throttle to run the engine at a fast idle, pour 1 pint of medium grade preservative lubricating oil, Ordnance Department Specification AXS-674, of the latest issue in effect, into the carbureter throat, being careful not to choke the engine. Turn off the ignition switch as quickly as possible after the oil has been poured into the carbureter. With the engine switch off, open the throttle wide and turn the engine five complete revolutions by means of the cranking motor. If the engine cannot be turned by the cranking motor with the switch off, turn it by hand or disconnect the high-tension lead and ground it before turning the engine by means of the cranking motor. Then reinstall the air cleaner.

(10) BRAKES. Release brakes and chock the wheels or tracks.

c. Inspections in Limited Storage.

(1) Vehicles in limited storage will be inspected weekly for conditions of tires and battery. If water is added when freezing weather is anticipated, recharge the battery with a portable charger or remove the battery for charging. Do not attempt to charge the battery by running the engine.

252. LOADING AND BLOCKING FOR RAIL SHIPMENT.

a. Preparation. In addition to the preparation described in paragraph 251, when Ordnance vehicles are prepared for domestic shipment, the following preparation and precautions will be taken.

(1) EXTERIOR. Cover the body of the vehicle with a canvas cover supplied as an accessory.

(2) TIRES. Inflate pneumatic tires from 5 to 10 pounds above normal pressure.

(3) BATTERY. Disconnect the battery to prevent its discharge by vandalism or accident. This may be accomplished by disconnecting the positive lead, taping the end of the lead, and tying it back away from the battery.

(4) BRAKES. The brakes must be applied and the transmission placed in low gear after the vehicle has been placed in position with a brake wheel clearance of at least 6 inches (fig. 258). The vehicles

will be located on the car in such a manner as to prevent the car from carrying an unbalanced load.

(5) All cars containing Ordnance vehicles must be placarded "DO NOT HUMP."

(6) Ordnance vehicles may be shipped on flat cars, end door box cars, side door box cars, or drop end gondola cars, whichever type car is the most convenient.

b. Facilities for Loading. Whenever possible, load and unload vehicles from open cars under their own power, using permanent end ramps and spanning platforms. Movement from one flat car to another along the length of the train is made possible by cross-over plates or spanning platforms. If no permanent end ramp is available, an improvised ramp can be made from railroad ties. Vehicles may be loaded in gondola cars without drop ends by using a crane. In case of shipment in side-door cars, use a dolly type jack to move the vehicles into position within the car.

c. Securing Vehicles. In securing or blocking a vehicle, three motions, lengthwise, sidewise, and bouncing, must be prevented. There are two approved methods of blocking the vehicles on freight cars, as described below. When blocking dual wheels, all blocking will be located against the outside wheel of the dual.

(1) METHOD 1 (fig. 258). Place two blocks (F, fig. 258), one across the front and one across the rear of the front wheels. Place one block "F" to the front of the forward rear wheels and one block "F" to the rear of the rearward rear wheels. These blocks must be at least eight inches wider than the over-all width of the vehicle at the car floor. Place sixteen cleats "E" against blocks "F" as shown in figure 258. Place one cleat "B" against the outside of each front wheel on the top of blocks "F." Place two cleats "C" against the outside of the rear wheels on the top of block "F" as shown in figure 258. Nail the cleats to each block "F" with two 40-penny nails. Pass six strands, two wrappings, of No. 8 gage, black annealed wire (D, fig. 258) through the spokes of the wheels and the stake pockets. Tighten the wires enough to remove slack. If a box car is used, apply this strapping in similar fashion and attach it to the floor by the use of blocking or anchor plates. This strapping is not required when gondola cars are used.

(2) METHOD 2 (fig. 259). Place eight blocks "A" to the front and to the rear of each front wheel and to the front of each forward rear wheel, and to the back of each rearward rear wheel (fig. 259). Nail heel of the block to the car floor with five 40-penny nails, and toenail that portion of the block under the tire to the car floor with two 40-penny nails. Place two cleats "B" against the outside face of each front wheel. Place two cleats "C" against the outside face of the rear wheels. Nail the lower cleats to the car floor with three 40-penny nails and the top cleat to the cleats below with three 40-penny nails. Pass six strands, two wrappings, of No. 8 gage, black annealed wire (D, fig. 259) through the spokes of the wheels and the stake pockets. Tighten the wires enough to remove slack. If

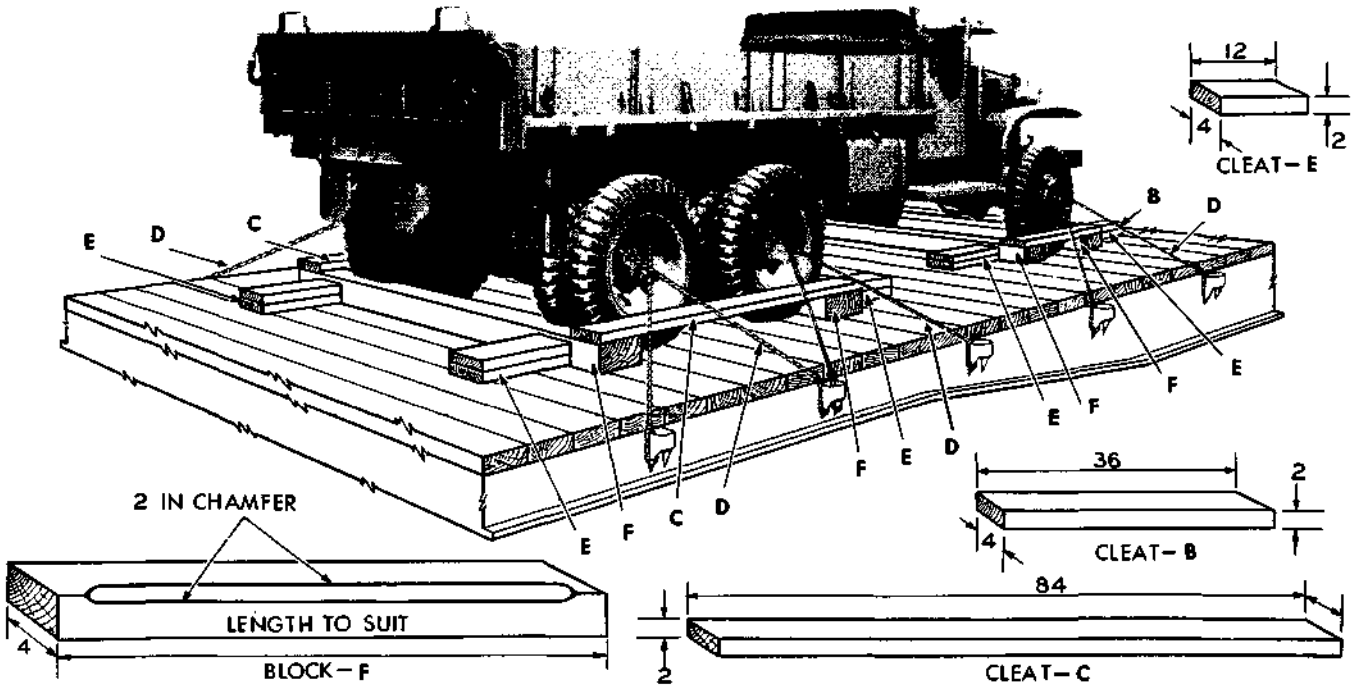

Figure 258—Method 1 for Blocking Truck on Freight Cars

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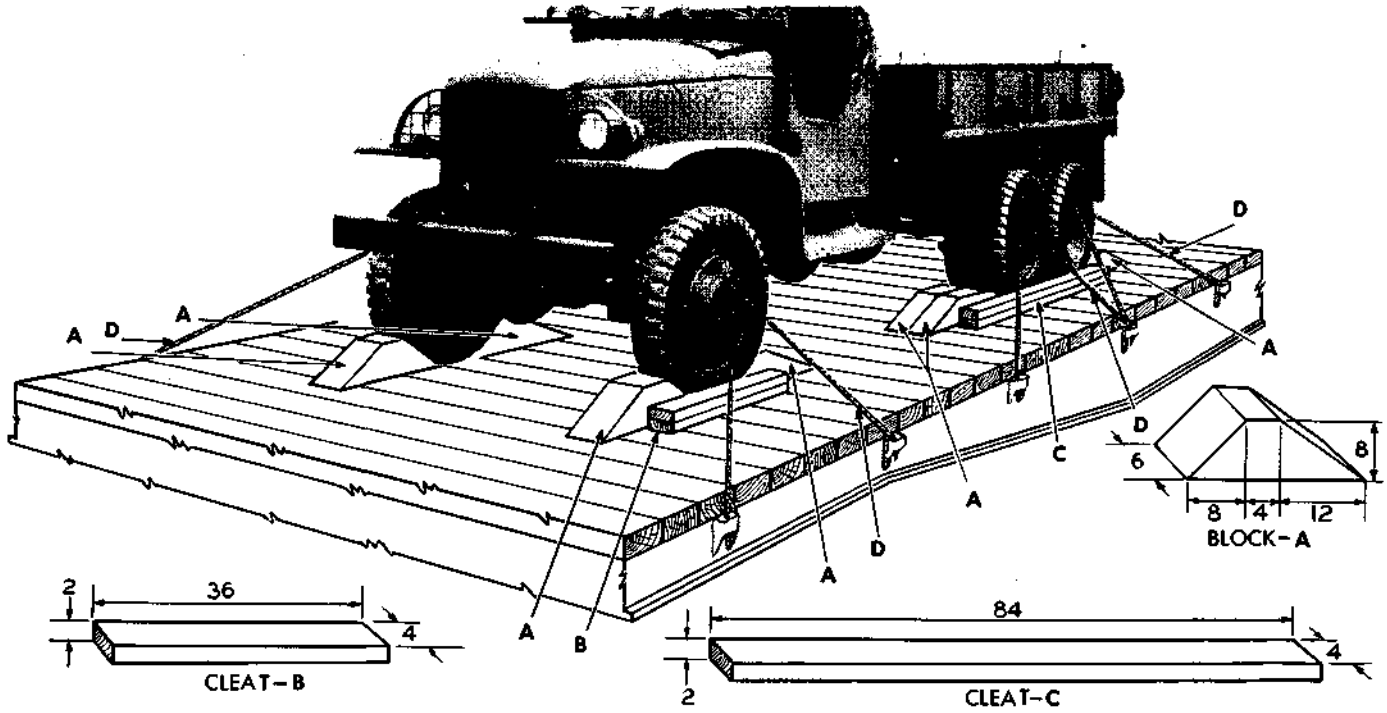

Figure 259—Method 2 for Blocking Truck on Freight Cars

a box car is used, apply this strapping in similar fashion and attach it to the floor by the use of blocking or anchor plates. This strapping is not required when gondola cars are used.

d. Shipping Data.

Length, overall CCKW-352 Cargo Body without winch		231 in.
Length, overall CCKW-352 Cargo Body with winch		244⅞ in.
Length, overall CCKW-353 Cargo Body without winch		256¼ in.
Length, overall CCKW-353 Cargo Body with winch		270⅛ in.
Length, overall CCKW-353 Cargo Dump Body		272¾ in.
Length, overall CCKW-353 D1 Gasoline Tank Body		253½ in.
Length, overall CCKW-353 G2 Water Tank Body		253½ in.
Width, overall (all bodies) Maximum		91 in.
Height, overall (all bodies) Maximum		119 in.
Shipping Weight CCKW-352 and 353 Cargo Body without winch		15,700 lb
Shipping Weight CCKW-352 and 353 Cargo Body with winch		16,400 lb
Shipping Weight CCKW-353 Cargo Dump Body		11,950 lb
Shipping Weight CCKW-353 Cargo Dump Body		10,750 lb
Shipping Weight CCKW-353 G2 Water Tank Body		12,025 lb
Approximate floor area occupied per vehicle:		
CCKW-352	Cargo Body wo/winch	146 sq ft
	Cargo Body w/winch	155 sq ft
CCKW-353	Cargo Body wo/winch	162 sq ft
	Cargo Body w/winch	171 sq ft
Cargo Dump Body		173 sq ft
Gasoline Tank Body and Water Tank Body		161 sq ft
Approximate volume occupied per vehicle:		
CCKW-352	Cargo Body wo/winch	1,448 cu ft
	Cargo Body w/winch	1,536 cu ft
CCKW-353	Cargo Body wo/winch	1,606 cu ft
	Cargo Body w/winch	1,693 cu ft
Cargo Dump Body		1,710 cu ft
Gasoline Tank Body and Water Tank Body		1,589 cu ft

Section XLVI

REFERENCES

253. PUBLICATIONS INDEXES.

a. The following publications indexes should be consulted frequently for latest changes to or revisions of the publications given

in this list of references and for new publications relating to materiel covered in this manual:

Introduction to Ordnance Catalog (explains SNL system)	ASF Cat. ORD-1 IOC
Ordnance publications for supply index (index to SNL's)	ASF Cat. ORD-2 OPSI
Index to ordnance publications (lists FM's, TM's, TC's and TB's of interest to Ordnance personnel, MWO's, OPSR's, BSD, S of SR's, OSSC's and OFSB's. Includes alphabetical listing of Ordnance major items with publications pertaining thereto)	OFSB 1-1
List of publications for training (lists MR's, MTP's, T/BA's, T/A's, and FM's, TM's, and TR's concerning training)	FM 21-6
List of training films, film strips, and film bulletins (lists TF's, FS's, and FB's by serial number and subject)	FM 21-7
Military training aids (lists graphic training aids, models, devices, and displays)	FM 21-8

254. STANDARD NOMENCLATURE LISTS.

Truck, 2½-ton, 6x6 (GMC) CCKW-352 and 353	SNL G-508
Cleaning, preserving and lubrication materials, recoil fluids, special oils, and miscellaneous related items	SNL K-1
Soldering, brazing and welding materials, gases and related items	SNL K-2
Tool sets—Motor transport	SNL N-19

255. EXPLANATORY PUBLICATIONS.

a. Fundamental Principles.

Automotive electricity	TM 10-580
Lubrication of Ordnance materiel	TM 9-2835
Basic maintenance manual	TM 38-250
Driver's manual	TM 10-460
Electrical fundamentals	TM 1-455
Military motor vehicles	AR 850-15
Motor vehicle inspections and preventive maintenance service	TM 9-2810
Precautions in handling gasoline	AR 850-20
Standard military motor vehicles	TM 9-2800
The internal combustion engine	TM 10-570

b. Maintenance and Repair.

Cleaning, preserving, lubricating and welding materials, and similar items issued by the Ordnance Department	TM 9-850

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REFERENCES

Cold weather lubrication, and service of combat vehicles and automotive materiel	OFSB 6-11
Maintenance and care of pneumatic tires and rubber treads	TM 31-200
Ordnance maintenance: Body and power train for 2½-ton, 6x6, truck (GMC, CCKW-353 and 352)	TM 9-1801
Ordnance maintenance: Power plant for 2½-ton, 6x6, amphibian truck (DUKW-353) and 2½-ton, 6x6, truck (GMC, CCKW-353 and 352)	TM 9-1802A
Ordnance maintenance: Carbureters (Zenith)	TM 9-1826C
Ordnance maintenance: Electrical equipment (Delco Remy)	TM 9-1825A
Ordnance maintenance: Vacuum brake systems (Bendix BK)	TM 9-1827B
Ordnance maintenance: Hydraulic brakes (Wagner)	TM 9-1827C
Ordnance maintenance: Fuel pumps	TM 9-1828A
Ordnance maintenance: Speedometers, tachometers and recorders	TM 9-1829A

c. Protection of Materiel.

Camouflage	FM 5-20
Chemical decontamination, materials and equipment	TM 3-220
Decontamination of armored force vehicles	FM 17-59
Defense against chemical attack	FM 2140
Explosives and demolitions	FM 5-25

d. Storage and Shipment.

Ordnance storage and shipment chart, group G—Major items	OSSC-G
Registration of motor vehicles	AR 850-10
Rules governing the loading of mechanized and motorized army equipment also major caliber guns, for the United States Army and Navy, on open top equipment published by Operations and Maintenance Department of Association of American Railroads.	
Storage of motor vehicle equipment	AR 850-18

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U. S. GOVERNMENT PRINTING OFFICE · 0 1948

Introductions

Why Are We Here?

Accident Investigated by NTSB

- Amphibious Passenger Vehicle (APV)
- DUCK 6 of Ride the Ducks Seattle
- Lane Crossover Collision With Motorcoach on State Route 99, Aurora Bridge, Seattle, Washington
- Occurred on September 24, 2015
- 5 Fatalities and 71 individuals injured

National Highway Traffic Safety Administration Overview

NHTSA's Mission

- To save lives, prevent injuries, and reduce traffic-related healthcare and other economic costs.

Rulemaking Authority from Congress

- Congress generally delegates rulemaking authority to a regulatory agency by enacting an "enabling" statute that:
  - Includes a provision delegating rulemaking authority to the agency with respect to a specified policy goal, e.g., vehicle safety; and
  - Specifies the factors that the agency must consider in deciding what rule to adopt.
- The Administrative Procedure Act (APA) generally establishes the process the agency must follow to establish a rule.
- NHTSA's main enabling statute is the National Traffic and Motor Vehicle Safety Act ("Vehicle Safety Act").

Vehicle Safety Act Requirements

- One of NHTSA's enabling statutes.
- To establish a Federal Motor Vehicle Safety Standard (FMVSS), must show that the FMVSS:
  - meets a safety need;
  - is practicable (technologically and economically); and
  - states its requirements in a way that permits compliance to be determined in an objective fashion.
- FMVSSs must be performance-oriented.
- FMVSSs must be appropriate for each vehicle type to which they apply.

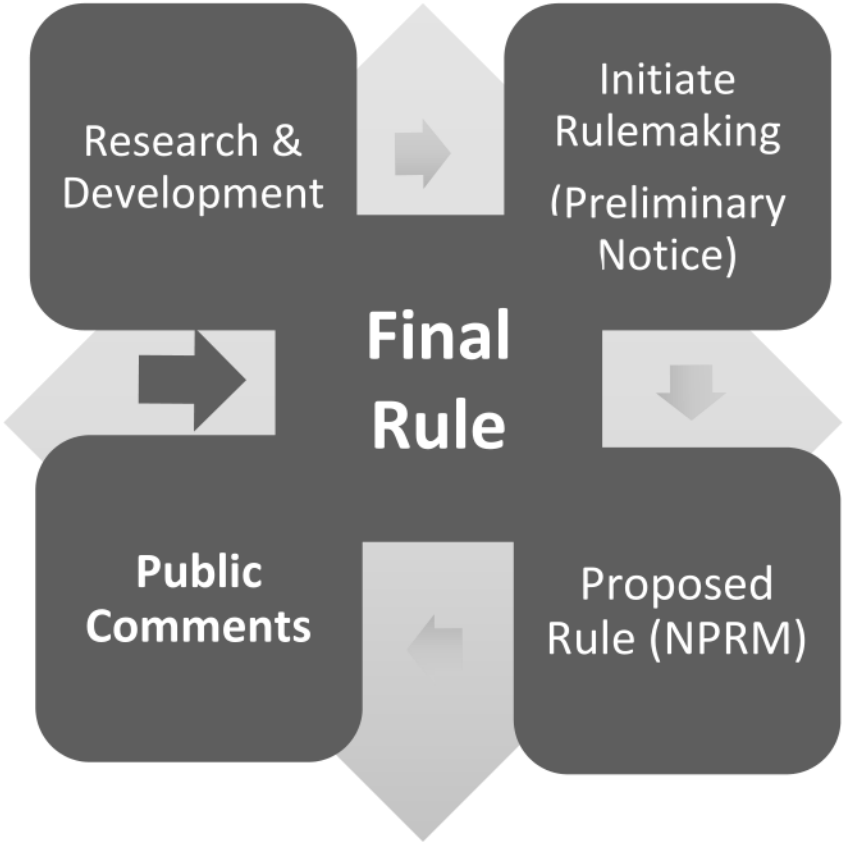
Meeting the Need for Safety

- NHTSA generally uses crash data and research to show that there is a safety need and that the regulation will address that need.
- Examples of NHTSA's crash information sources:
  - Fatality Analysis Reporting System (FARS)
    - Data on all fatal traffic crashes in the U.S.
  - National Automotive Sampling System (NASS)
    - More detailed, nationally representative data from police reports on fatal and nonfatal traffic crashes.
- Research to identify countermeasures and develop performance requirements and test procedures to evaluate their effectiveness.

Practicability

- Relates to the technical and economic feasibility of the standard.
- Establishes the outer boundary of what reasonable burdens can be imposed on the industry.
- Also considers whether or not the public is likely to accept and use the likely methods of compliance with the FMVSS.

Typical NHTSA Rulemaking Steps



Medium- and Heavy-Duty (MD/HD) Vehicle Fuel Efficiency and GHG Stds MYs 2014 – 2018/19+

BACKGROUND

- The Energy Independence and Security Act of 2007 requires that NHTSA establish a fuel efficiency program for on-road medium- and heavy-duty vehicles.

SUMMARY

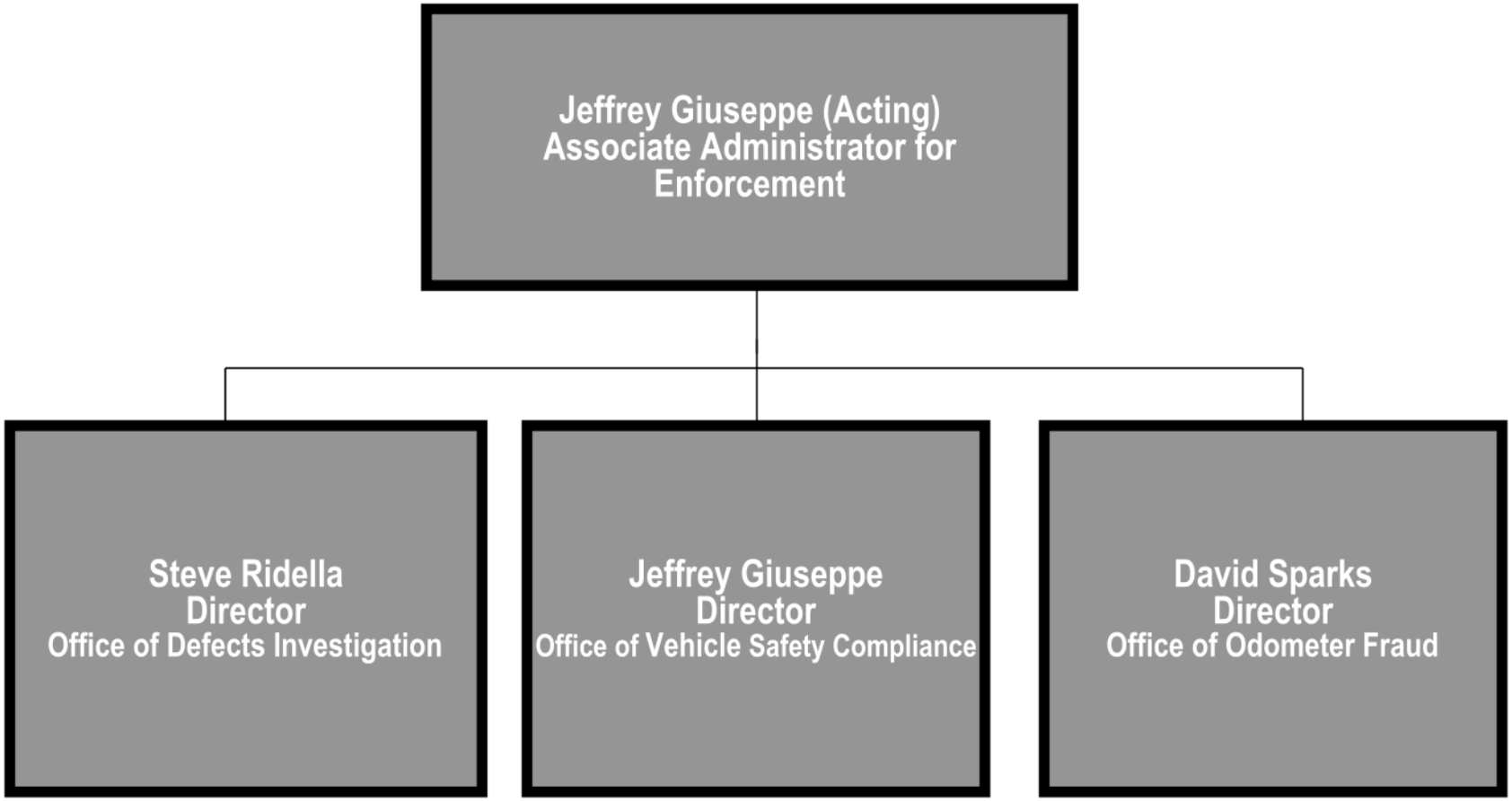
- NHTSA developed fuel efficiency standards and EPA developed GHG emissions standards in joint rulemaking.

STATUS

- Final rule was published September 15, 2011 (76 FR 57105).

Vehicle Safety Enforcement Program

Enforcement Program at NHTSA



Enforcement Responsibilities

Three primary types of enforcement:

- **Vehicle safety**: recalls for **defective** or **noncompliant** vehicles or equipment
- **Fuel economy**: civil penalties for violations of CAFE standards by manufacturers
- **Odometer fraud**: criminal prosecution of offenders

Vehicle Safety Enforcement

- Basic principles:
  - **Self-certification:** manufacturers must certify that their vehicles and equipment comply with the Federal Motor Vehicle Safety Standards (FMVSS).
  - **Prohibition:** a person may not manufacture for sale, offer for sale, introduce into commerce, or import a noncompliant vehicle or equipment.
  - **Importers <u>are</u> manufacturers:** Statutory definition of "manufacturer" states this, so importers share duties of manufacturers.

Vehicle Safety Enforcement

- Basic principles (continued):
  - **Duty to recall:** a manufacturer must do a recall (i.e., notify owner and provide remedy for the entire population of affected vehicles or equipment) if it learns of a safety defect or noncompliance or if NHTSA decides there is a defect or noncompliance.
  - **NHTSA may order a recall.**
  - **Defect** that creates an unreasonable risk to safety warrants a recall.
  - **Fully compliant vehicles or equipment may contain safety defects.**

Other Enforcement Tools

- **Civil penalties**
  - Current limits**: $21,000** per violation with a maximum of **$105,000,000** for a related series of violations
  - Chief Counsel issues penalty demand letter, negotiates with respondent, and considers statutory criteria (gravity of violation, size of business) and litigation risk in determining amounts
- **Injunctive relief** for violations of statute is available, but statute encourages NHTSA to provide notice and an opportunity to remedy the defect or noncompliance before seeking relief
- **Criminal penalties** are available for false reporting with intent to mislead NHTSA about defects that have caused death or serious injury (supplements basic false statement statute, 18 USC 1001)

Office of Defects Investigation

- "Defect related to motor vehicle safety" is a problem in performance, construction, a component, or material that creates an unreasonable risk to safety
- Nearly all recalls are voluntary: manufacturer either initiates recall on its own or is influenced to do so by NHTSA's investigation.
- NHTSA can order manufacturer to conduct recall after an opportunity for a hearing.
- NHTSA can seek enforcement of its order in court, where NHTSA must prove existence of a defect that creates an unreasonable safety risk.

Defects Enforcement

- Office of Defects Investigation screens many sources of information about possible defects to identify likely candidates for investigation:
  - Complaints (nearly 50,000 per year): Auto Safety Hotline, letters, e-mail, vehicle owner questionnaire on Internet
  - Manufacturer notices, bulletins, advisories
  - Foreign recall reports
  - Early warning reports (death or injury incidents, damage claims, warranty claims, consumer complaints, field reports): huge volume of data
  - Petitions from public

Defects Enforcement

- Mechanical or electronic failures posing a safety risk

- Examples:
  - Stalling
  - Brake light switch
  - Fires
  - Tire failures
  - Fuel leaks
  - Ball joint fracture

Office of Vehicle Safety Compliance

- Manufacturers must comply with nearly 60 motor vehicle and equipment standards covering subjects such as crashworthiness (air bags, roof crush, etc.) and crash avoidance (brakes, ESC)
- OVSC purchases new vehicles and equipment and tests them for compliance with the FMVSS
- Requests and reviews manufacturer's certification data (manufacturers have duty to certify that their vehicles or equipment comply with standards)
- In the event of an apparent noncompliance, OVSC conducts investigations that may lead to a safety recall campaign and could result in the collection of civil penalties from the manufacturer
- OVSC also plays a vital role in rulemaking by developing compliance test procedures for inclusion in safety standards

Fuel Economy Enforcement

- OVSC administers CAFÉ fuel economy enforcement program
- Energy Policy and Conservation Act of 1975 (49 USC Chapter 329) authorizes NHTSA to collect civil penalties for violations of CAFE standards
- Penalty formula: [$5.50] X [each 1/10 of a mile per gallon by which the fuel economy standard exceeds the mileage achieved by the manufacturer's fleet] X [the number of vehicles in that fleet]
- Penalties can be offset by credits earned for exceeding the standard
- NHTSA bases penalty and credit determinations on final reports submitted by EPA
- Limited bases for compromising penalties: prevent insolvency; act of God, strike, or fire; FTC makes finding on effect on competitiveness
- Collect CAFE civil penalties (about $13 million each year)

- **Medium & Heavy Duty Fuel Efficiency Standards**

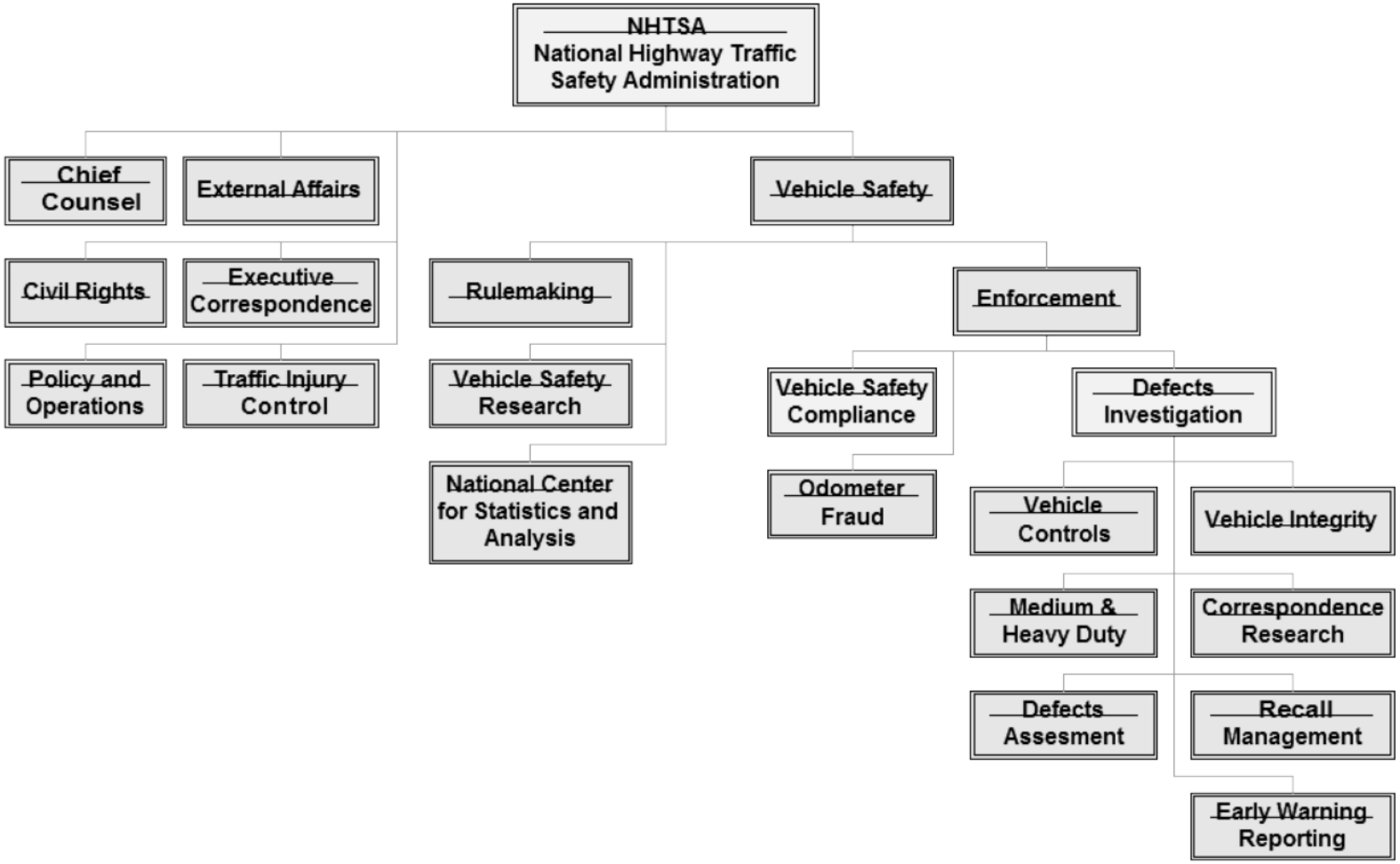
Office of Odometer Fraud Investigation

- Conduct criminal investigations concerning possible violations of odometer fraud laws
- Investigators are law enforcement officers who work closely with Department of Justice prosecutors
- Investigations have resulted in more than 250 convictions, plus millions of dollars in court ordered restitution

NHTSA Org Chart

Locating the

Office of Defects Investigation (ODI)

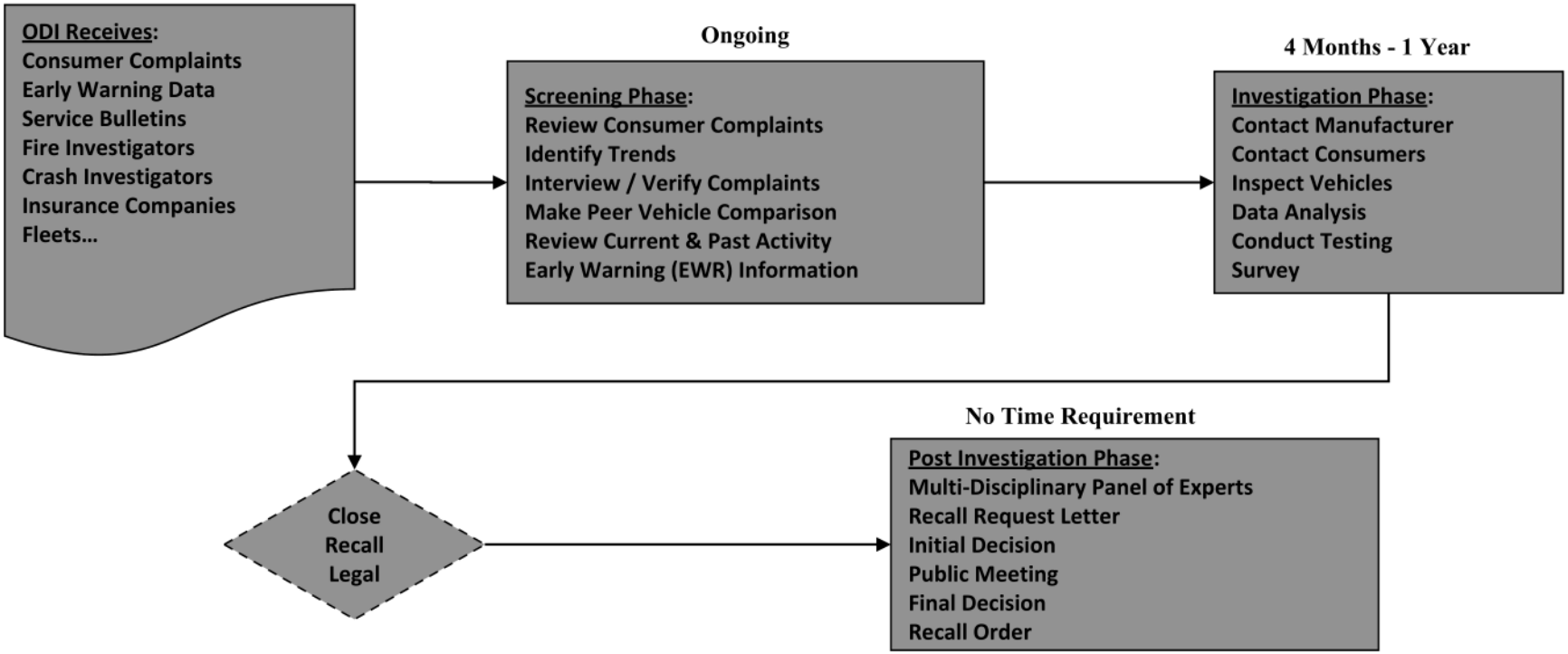


ESI

Safety vs. Compliance Defects

- **Non-Compliance Defect**: defect where a motor vehicle or covered motor vehicle equipment fails to meet one or more Federal Motor Vehicle Safety Standards (FMVSS) contained in 49 CFR Part 571.
- **Safety-Related Defect**: any defect in performance, construction, a component, or material that results in an unreasonable risk of accident or an unreasonable risk of death or injury in an accident.
  - A safety-related defect may exist on a vehicle even though it meets all FMVSS requirements.
  - A safety-related defect includes nonoperational safety.

Investigative Process



Code of Federal Regulations, Title 49

- Title 49 CFR - Transportation is one of fifty titles comprising the United States Code of Federal Regulations (CFR).
- Title 49 contains the regulations that vehicle manufacturers must meet.
- Parts relating to NHTSA's mission include:
  - 49 CFR Part 571, contains FMVSS
  - 49 CFR Part 573, defect and non-compliance reporting
  - 49 CFR Part 576, record retention
  - 49 CFR Part 577, defect and non-compliance notification
  - 49 CFR Part 578, civil penalties
  - 49 CFR Part 579, (TREAD Act) reporting requirements
    - Subpart A – General (Includes 579.5) Independent of production volume
    - Subpart B – Safety Recalls & Campaigns in Foreign Countries
    - Subpart C – Reporting of Early Warning Information (EWR) Dependent on production volume

Safety Act & Implementing Regulations

- A manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicabile
- The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report”

49 CFR 573.6 – Defect and noncompliance information report. (Recall notice)

- Each manufacturer shall furnish a report to the NHTSA for each defect in his vehicles or in his items of original or replacement equipment that he or the Administrator determines to be related to motor vehicle safety, and for each noncompliance with a motor vehicle safety standard in such vehicles **or items of equipment** which either he or the Administrator determines to exist.

- Each report shall be submitted not more than **5 working days** after a defect in a vehicle or item of equipment has been determined to be safety related, or a noncompliance with a motor vehicle safety standard has been determined to exist.

Duty to Notify

- A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS
- Notification must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573

Duty to Remedy

- When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a **duty to remedy** the motor vehicle
  - Within a “reasonable time”
  - According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related
- Manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fails to comply with applicable FMVSS

Identifying Information

- Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA
- Manufacturers must report this information no later than 30 days after manufacturing begins

Violations

- A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty
- Separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act

49 CFR Part 576 – Record Retention OEM and Component Suppliers

- Scope: Part 576 establishes requirements for the retention by manufacturers of motor vehicles **and of motor vehicle equipment**, of claims, complaints, reports, and other records concerning alleged and proven motor vehicle or motor vehicle equipment defects and malfunctions that may be related to motor vehicle safety.

- Purpose: The purpose of Part 576 is to preserve records that are needed for the proper investigation, and adjudication or other disposition, of possible defects related to motor vehicle safety and instances of nonconformity to the motor vehicle safety standards and associated regulations.

- Basic Requirement: Retain records for a period of five calendar years from the date on which they were generated or acquired by the manufacturer.

49 CFR 579.5 (Subpart A) – Notices, bulletins, customer satisfaction campaigns, consumer advisories, and other communications

- Independent of production volume
- Manufacturers must submit to NHTSA a copy of all notices, bulletins, and other communications sent to more than one manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser regarding any defect in its vehicles or items of equipment.
  - Defects here mean any failure or malfunction beyond normal deterioration in use, or any failure of performance, **or any flaw or unintended deviation from design specification**s, whether or not such defect is safety-related.
- **Manufacturers** must also submit furnish to NHTSA a copy of each communication relating to a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment, that the manufacturer issued to, or made available to, more than one dealer, distributor, lessor, lessee, other manufacturer, owner, or purchaser, in the United States.
- Information and sample index: http://www-odi.nhtsa.dot.gov/mc/

49 CFR 579 (Subpart C) – Reporting of Early Warning Information (EWR)

- Dependent on production volume
- Possible Reporting Categories
  - Production Information
  - Death and Injury
  - Aggregate Data
    - Warranty Claims, Field Reports, Property Damage, Consumer Complaints
  - **Field Reports**
- 579.21 Reporting requirements for MFRs > 5,000 light vehicles annually.
- 579.22 Reporting requirements for MFRs > 5,000 heavy, > 500 Emergency, >**100 Buses annually**.
- 579.23 Reporting requirements for MFRs > 5,000 motorcycles annually.
- 579.24 Reporting requirements for MFRs > 5,000 trailers annually.
- 579.25 Reporting requirements for MFRs > 0 child restraint systems annually.
- 579.26 Reporting requirements for MFRs of tires.
- **579.27 Reporting requirements for MFRs of Low Volume or Equipment**.
- 579.28 Due dates for reports and other miscellaneous provisions.
- 579.29 Manner of reporting.

Early Warning Information

- NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer
- Also required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports

Field report

- **Field report** means a communication in writing, including communications in electronic form, from an employee or representative of a manufacturer of motor vehicles or motor vehicle equipment, a dealer or authorized service facility of such manufacturer, or an entity known to the manufacturer as **owning or operating a fleet**, to the manufacturer regarding the ***failure, malfunction, lack of durability, or other performance problem of a motor vehicle or motor vehicle equipment***, or any part thereof, produced for sale by that manufacturer and transported beyond the direct control of the manufacturer, regardless of whether verified or assessed to be lacking in merit, but does not include any document covered by the attorney-client privilege or the work product exclusion.

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- § 579.27 Reporting requirements for manufacturers of fewer than 100 buses annually, for manufacturers of fewer than 500 emergency vehicles annually, for manufacturers of fewer than 5,000 light vehicles, medium-heavy vehicles (other than buses and emergency vehicles), motorcycles or trailers annually, for manufacturers of original equipment, and for manufacturers of replacement equipment other than child restraint systems and tires.
- (a)Applicability. This section applies to all manufacturers of vehicles with respect to vehicles that are not covered by reports on light vehicles, medium-heavy vehicles and buses, motorcycles, or trailers submitted pursuant to §§ 579.21 through 579.24 of this part, to all manufacturers of original equipment, to all manufacturers of replacement equipment other than manufacturers of tires and child restraint systems, and to registered importers registered under 49 U.S.C. 30141(c).

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- (b)Information on incidents involving deaths. For each reporting period, a manufacturer to which this section applies shall submit a report, pertaining to vehicles and/or equipment manufactured or sold during the calendar year of the reporting period and the nine calendar years prior to the reporting period (four calendar years for equipment), including models no longer in production, on each incident involving one or more deaths occurring in the United States that is identified in a claim against and received by the manufacturer or in a notice received by the manufacturer which notice alleges or proves that the death was caused by a possible defect in the manufacturer's vehicle or equipment, together with each incident involving one or more deaths occurring in a foreign country that is identified in a claim against and received by the manufacturer involving the manufacturer's vehicle or equipment, if it is identical or substantially similar to a vehicle or item of equipment that the manufacturer has offered for sale in the United States. The report shall be organized such that incidents are reported alphabetically by make, within each make alphabetically by model, and within each model chronologically by model year. If a manufacturer has not received such a claim or notice during a reporting period, the manufacturer need not submit a report to NHTSA for that reporting period.
- (c) For each incident described in paragraph (b) of this section, the manufacturer shall separately report the make, model, and model year of the vehicle or equipment, the VIN (for vehicles only), the incident date, the number of deaths, the number of injuries for incidents occurring in the United States, the State or foreign country where the incident occurred, each system or component of the vehicle or equipment that allegedly contributed to the incident, and whether the incident involved a fire or rollover, as follows:

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- (1) For light vehicles, the system or component involved, and the existence of a fire or rollover, shall be identified and coded as specified in § 579.21(b)(2) of this part.
- (2) For medium-heavy vehicles and buses, the system or component involved, and the existence of a fire or rollover, shall be identified and coded as specified in § 579.22(b)(2) of this part.
- (5) For original and replacement equipment, a written identification of each component of the equipment that was allegedly involved, and whether there was a fire, in the manufacturer's own words.
- (6) For original and replacement equipment, if the production year of the equipment is unknown, the manufacturer shall specify the number “9999” in the field for model or production year.

Service Bulletins to NHTSA

- Manufacturers are required to submit copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment sent to more than one manufacturer, distributor, dealer, owner or purchaser

Best Practice Ideas

- Submit 579.5 reports stating you have nothing to report.
  - Manufacturers should submit a negative report to the TSB portal for those months in which a TSB was not published. This allows an examiner reviewing the data to be aware that someone took the time to report “No TSB’s” for a given month, rather than remaining silent, which after several months may create concerns that TSB’s are not being submitted. While this suggestion is not required by NHTSA, it is a quality control mechanism which manufacturers may want to consider.
- Supplier / OEM warranty relationships.
  - Suppliers and OEMs should have a working relationship or agreement where identifying potential safety defects is possible. Manufacturers are responsible for meeting the requirements of Part 576. In order to do this, either or both the OEM and suppliers should maintain and have access to the required records.
- Manufacturers should be monitoring their own data for signs of potential defect.

Best Practice Ideas (Cont)

- There should be an easy, clearly advertised method for employees to report potential safety issues.
- There should be a process for periodically reviewing issues identified by all means and deciding if a defect exists. This process should include getting back to the defect identifier and informing them of the review outcome.
- The review panel should be multi disciplinary.
- The decisions made by the review panel should be documented and records retained for future reference.
- The processes developed for meeting the tread act requirements should be documented and appropriate personnel trained in their use.

Armed Forces Vehicles

49 C.F.R. § 571.7(c)

- Vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS
- This does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle
- "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in ... the intended or actual use, design or sale . ... " of the vehicle. See NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

Not Knowing the Regulations Is Not a Defense

- APV manufacturers must comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and even if they act on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules are applicable to the amphibious vehicles it manufactured.
- Nonetheless, as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense for an APV manufacturer

NHTSA Manufacturer Requirements Guide for Applicable Laws & Regulations

49 U.S.C. sec. 30102 Definitions

(a)(5) **"manufacturer"** means a person –

(A) Manufacturing or assembling motor vehicles or motor vehicle equipment; or

(B) Importing motor vehicles or motor vehicle equipment for resale

49 U.S.C. sec. 30102 Definitions

(a)(6) **“motor vehicle”** means –

a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line

49 U.S.C. sec. 30102 Definitions

(a)(7) **"motor vehicle equipment"** means –

(A) Any system, part, or component of a motor vehicle as originally manufactured;

(B) Any similar part or component manufactured or sold for replacement or improvement of a system, part, or component, or as an accessory or addition to a motor vehicle; or

(C) Any device or an article or apparel (except medicine or eyeglasses prescribed by a licensed practitioner) that is not a system, part, or component of a motor vehicle and is manufactured, sold, delivered, offered, or intended to be used only to safeguard motor vehicles and highway users against risk of accident, injury, or death

Full Requirements of 49 USC Ch. 301

https://www.gpo.gov/fdsys/browse/collectionUScode.action

- Select most recent year available
- Select Title 49, Subtitle VI, Part A
- Click PDF link to Chapter 301

49 C.F.R. Parts 500-599

http://www.ecfr.gov

- Select Title 49 “Transportation”
- Select parts 500-571 or 572-599 “National Highway Traffic Safety Administration, Department of Transportation”

49 C.F.R. Part 579 – Reporting of information & Communications about Potential Defects

- repeating regular monthly and quarterly reporting requirements

NHTSA Defect Communications Reporting Requirements

49 CFR sec. 579.5

- Vehicle & equipment manufacturers required to submit a copy of **all notices, bulletins, and other communications** issued by manufacturer in regard to any defect, **whether or not it is safety-related,** to NHTSA […]
- Each violation – civil penalties of up to $21,000 / day

Who must Submit Defect Communications?

- Motor vehicle **manufacturers**
- Motor vehicle **assemblers**
- Motor vehicle **equipment manufacturers**
- Motor vehicle **equipment assemblers**
- Importers of motor vehicles for **resale**
- **Any subsidiary or affiliate**, and any subsidiary or affiliate of a parent corporation, of any of the above

How Should Defect Be Submitted?

- A readable copy of ***all notices, bulletins, and other communications***
  - that are sent to more than one ***manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser*** in the United States,
  - regarding **any defect in its vehicles or items of equipment** (including any failure to malfunction beyond normal deterioration in use, or any failure of performance, or any flaw or unintended deviation from design specifications), whether or not such defect is safety-related.
- Must be accompanied by an **index**
- **5 working days** after the end of the month in which they are issued

How Should Defect Be Submitted?

- Must be accompanied by an **index**
- **5 working days** after the end of the month in which they are issued
- **Submit** to: mailto:tsb@dot.gov

Am I a "Manufacturer"? A Decision Tree.

YES, I am a **"Vehicle Manufacturer"**

Must meet the following requirements of 49 USC Ch. 301 & Title 49 of CFR

49 USC Ch. 301 & Title 49 of CFR

- 30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicles
- 30120 Remedies for defects and noncompliance
- 30122 Making safety devices and elements inoperative
- 30170 Criminal penalties
- 551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
- 563 Event data recorders*
- 565 Vehicle Identification Number (VIN)
- 567 Certification
- 568 Vehicles manufactured in two or more stages – All incomplete, intermediate, and final state manufacturers of vehicles manufactured in two or more stages
- 566 Manufacturer identification
- 571 Federal Motor Vehicle Safety Standards (FMVSS)
- 573 Defect and noncompliance responsibility and reports
- 576 Record retention

49 USC Ch. 301 & Title 49 of CFR

- 577 Defect and noncompliance notification
- 578 Civil and criminal penalties
- 579.5 Communications
- 579.11 Foreign campaign reporting responsibilities
- 579.28 Due date of reports and other miscellaneous provisions
- 579.29 Manner of reporting
- 541-543 Theft prevention*
- 581 Bumper standards*
- 525, 526, 529, 531, 533, 535, 537, 538 Fuel economy*
- 583 Domestic content labeling
- 575 Consumer information
- * (only apply to certain motor vehicles types)

What type of Vehicle do I manufacture & What is my annual production?

- 579.21 – 5,000 or more light vehicles
- 579.22 – 100 or more buses, 500 or more emergency vehicles, 5,000 or more medium-heavy vehicles
- 579.23 – 5,000 or more motorcycles annually
- 579.24 – 5,000 or more trailers annually
- 579.27 – Fewer than 100 buses, 500 emergency vehicles, or 5,000 light vehicles

Am I a “Manufacturer”?

YES, I am a **“Equipment Manufacturer”**

Must meet the following requirements of 49 USC Ch. 301 & Title 49 of CFR

49 USC Ch. 301 & Title 49 of CFR

- 30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicle equipment
- 30120 Remedies for defects and noncompliance
- 30122 Making safety devices and elements inoperative
- 30170 Criminal penalties
- 551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
- 573 Defect and noncompliance responsibility and reports
- 576 Record retention
- 577 Defect and noncompliance notification
- 578 Civil and criminal penalties
- 579,5 Communications
- 579.11 Foreign campaign reporting responsibilities
- 579.27 Reporting requirements for manufacturers of equipment
- 579.28 Due date of reports and other miscellaneous provisions
- 579.29 Manner of reporting

14 pieces of equipment covered by FMVSS

- tires
- rims
- brake hoses
- brake fluid
- seat belt assemblies
- lighting equipment
- glazing
- motorcycle helmets
- child seats
- CNG containers
- platform lift systems for the mobility impaired
- rear impact guards for trailers
- triangular reflective warning devices
- pressure vessels / explosive devices

Do I manufacturer equipment covered by FMVSS?

- 30115 Certification of compliance
- 566 Manufacturer identification
- 571 Federal Motor Vehicle Safety Standards (FMVSS)
- 574 Tire identification and recordkeeping
- 575.103 Truck-camper loading
- 579.25 Child restraint system
- 579.26 Tires
- 588 Child restraint systems recordkeeping requirements

Federal Motor Vehicle Safety Standards

FMVSS

- Motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery
- Certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer
- Manufacturers are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale

FMVSS Std. 101: Controls and Displays – Passenger Cars (eff. 1-1-68)

- Requires that essential controls be located within reach of the driver when the driver is restrained by a lap belt and upper torso restraint, and that certain controls mounted on the instrument panel be identified

FMVSS Std. 101: Controls and Displays – Buses (APV)

- Passenger Cars (eff. 1-1-72), Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-72)
  - All manually operated controls must be identified by words.
- Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-72)
  - Except for foot-operated controls or manually operated controls mounted on steering column, the identification of essential controls and displays must be illuminated whenever the headlamps are lit.
- Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-80)
  - Certain essential hand-operated controls and certain displays must be identified by a symbol, and such identification be illuminated.

Identification and Illumination of Controls

Column 1	Column 2	Column 3	Column 4
Hand Operated Controls	Identifying Words or Abbreviation	Identifying Symbol	Illumination
Master Lighting Switch	Lights	[5]	—
Headlamps and Tail lamps	(Mfr. Option)[2]	(Mfr. Option)[2]	—
Horn	Horn	[4]	—
Turn Signal	—	[3] [5]	—
Hazard Warning Signal	Hazard	[5]	Yes
Windshield Wiping System	Wiper or Wipe		Yes
Windshield Washing System	Washer or Wash		Yes
Windshield Washing and Wiping Combined	Wash-Wipe or Washer–Wiper		Yes
Heating and or Air Conditioning Fan	Fan		Yes
Windshield Defrosting and Defogging System	Defrost, Defog or Def.		Yes
Rear Window Defrosting and Defogging System	Rear Defrost, Rear Defog, Rear Def., or R-Def		Yes
Identification, Side Marker and or Clearance Lamps	Marker Lamps or MK Lps	[2] [5]	Yes
Manual Choke	Choke	—	—
Engine Start	Engine Start[1]	—	—
Engine Stop	Engine Stop[1]	—	Yes
Hand Throttle	Throttle	—	—
Automatic Vehicle Speed	(Mfr. Option)	—	Yes
Heating and Air Conditioning System	(Mfr. Option)	(Mfr. Option)	Yes

[1] Use when engine control is separate from the key locking system.
[2] Separate identification not required if controlled by master lighting switch.
[3] The pair of arrows is a single symbol. When the controls for left and right turn operate independently, however, the two arrows may be considered separate symbols and be spaced accordingly.
[4] Identification not required for vehicles with a GVWR greater than 10,000 lbs., or for narrow ring-type controls.
[5] Framed areas may be filled.

FMVSS Std. 102

FMVSS Std. 102: Transmission Shift Position Sequence, Starter, Interlock, and Transmission Braking Effect

(eff. 1-1-68)

- Specifies the requirements for the transmission shift lever sequence, a starter interlock, and for a braking effect of automatic transmissions, to reduce the likelihood of shifting errors, starter engagement with vehicle in drive position, and to provide supplemental braking at speeds below 40 km/h (25 mph)

FMVSS Std. 103: Windshield Defrosting and Defogging Systems

(eff. 1-1-88)

- Specifies requirements for windshield defrosting and defogging systems

FMVSS Std. 104: Windshield Wiping and Washing Systems

(eff. 1-1-88)

- Specifies requirements for windshield wiping and washing systems

FMVSS Std. 105: Hydraulic and Electric Brake Systems

(eff. 1-1-68)

- Specifies requirements for vehicles equipped with hydraulic and electric service brake systems and associated parking brake systems to ensure safe braking performance under normal conditions and emergency conditions
- **Multipurpose Passenger Vehicles, Trucks and Buses (eff. 3-1-99) Multipurpose passenger vehicles, trucks and buses with a GVWR greater than 4,536 kg (10,000 lbs.)**
  - must be equipped with an antilock brake system and meet additional stopping distance requirements.

FMVSS Std. 106: Brake Hoses

(eff. 1-1-68)

- Establishes performance and labeling requirements for hydraulic, air, and vacuum brake hoses, brake hose assemblies, and brake hose fitting for all motor vehicles.
- Purpose is to reduce brake system failure from pressure or vacuum loss due to hose or hose assembly rupture

FMVSS Std. 108: Lamps, Reflective Devices, and Associated Equipment

(eff. 1-1-68 for vehicles 2,032 mm (80 or more inches) in width and eff. 1-1-69 for all other vehicles)

- Specifies requirements for original and replacement lamps, reflective devices, and associated equipment.
- Purpose is to reduce traffic crashes and deaths and injuries resulting from traffic crashes, by providing adequate illumination of the roadway, and by enhancing the conspicuity of motor vehicles on the public roads so that their presence is perceived and their signals understood, both in daylight and in darkness or other conditions of reduced visibility

FMVSS Std. 111: Rearview Mirrors

(eff. 1-1-68)

- Specifies requirements for the performance and location of inside and outside rearview mirrors
- Purpose is to reduce the number of deaths and injuries that occur when the driver of a motor vehicle does not have a clear and reasonably unobstructed view to the rear

FMVSS Std. 113: Hood Latch System

(eff. 1-1-69)

- Establishes the requirement for providing a hood latch system or hood latch systems

FMVSS Std. 116: Motor Vehicle Brake Fluids

(eff. 1-1-68, amended 3-1-72)

- Specifies requirements for fluids for use in hydraulic brake systems of motor vehicles, containers for these fluids, and labeling of the containers.
- Purpose is to reduce failures in the hydraulic braking systems of motor vehicles which may occur because of the manufacture or use of improper or contaminated brake fluid

FMVSS Std. 119: New Pneumatic Tires for Motor Vehicles with a GWVR of More than 4,536 Kilograms (10,000 pounds) and Motorcycles

(eff. 3-1-75)

- Establishes performance and marking requirements for tires for use on motor vehicles with a GVWR of more than 10,000 pounds and motorcycles
- Purpose is to provide safe operational performance levels for tires used on motor vehicles other than passenger cars, and to place sufficient information on the tires to permit their proper selection and use

FMVSS Std. 120:

FMVSS Std. 120: Tire Selection & Rims & Motor Home/Recreation Vehicle Trailer Load Carrying Capacity (eff. 8-1-76)

- Specifies tire and rim selection requirements, rim marking requirements and motor home/recreation vehicle trailer load carrying capacity information
- Purpose is to provide safe operational performance by ensuring that vehicles to which it applies are equipped with tires of adequate size and load rating and with rims of appropriate size and type designation, and by ensuring that consumers are informed of motor home/recreation vehicle trailer load carrying capacity

FMVSS Std. 121: Air Brake Systems

(eff. 1-1-75)

- Establishes performance and equipment requirements for braking systems on vehicles equipped with air brake systems
- Purpose is to insure safe braking performance under normal and emergency conditions.

FMVSS Std. 124: Accelerator Control Systems

(eff. 9-1-73)

- Establishes requirements for the return of a vehicle's throttle to the idle position when the driver removes the actuating force from the accelerator control, or in the event of a severance or disconnection in the accelerator control system
- Purpose is to reduce deaths and injuries resulting from engine over speed caused by malfunctions in the accelerator control system

FMVSS Std. 125: Warning Devices

(eff. 1-1-74)

- Establishes requirements for devices, without self contained energy sources, that are designed to be carried in motor vehicles and used to warn approaching traffic of the presence of a stopped vehicle, except for devices designed to be permanently affixed to the vehicle
- Purpose is to reduce deaths and injuries due to rear end collisions between moving traffic and disabled vehicles

FMVSS Std. 205: Glazing Materials

(eff. 1-1-68)

- Specifies requirements for glazing materials for use in motor vehicles and motor vehicle equipment
- Purpose is to reduce injuries resulting from impact to glazing surfaces, to ensure a necessary degree of transparency in motor vehicle windows for driver visibility, and to minimize the possibility of occupants being thrown through the vehicle windows in collisions

FMVSS Std. 207: Seating Systems

Passenger Cars (eff. 1-1-68); Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 1-1-72)

- Establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact

FMVSS Std. 208: Occupant Crash Protection

- Specifies performance requirements for the protection of vehicle occupants in crashes
- Purpose is to reduce the number of deaths of vehicle occupants, and the severity of injuries, by specifying vehicle crashworthiness requirements in terms of forces and accelerations measured on anthropomorphic dummies in test crashes, and by specifying equipment requirements for active and passive restraint systems

FMVSS Std. 209: Seat Belt Assemblies

(eff. 3-1-67)

- Specifies requirements for seat belt assemblies
- Requirements apply to straps, webbing or similar material, as well as to all necessary buckles and other fasteners and all hardware designed for installing the assembly in a motor vehicle, and to the installation, usage, and maintenance instructions for the assembly

FMVSS Std. 210: Seat Belt Assembly Anchorages

- Establishes requirements for seat belt assembly anchorages to insure their proper location for effective occupant restraint and to reduce the likelihood of their failure
- Requirements apply to any component, other than the webbing or straps, involved in transferring seat belt loads to the vehicle structure

FMVSS Std. 213: Child Restraint Systems

(eff. 4-1-71, amended 1-1-81)

- Specifies requirements for child restraint systems used in motor vehicles and aircraft
- Purpose is to reduce the number of children killed or injured in motor vehicle crashes and in aircraft

FMVSS Std. 217: Bus Emergency Exits and Window Retention and Release

(eff. 9-1-73)

- Establishes requirements for the retention of windows other than windshields in buses, and establishes operating forces, opening dimensions, and markings for bus emergency exits
- Purpose is to minimize the likelihood of occupants being thrown from the bus and to provide a means of readily accessible emergency egress

FMVSS Std. 302: Flammability of Interior Materials

(eff. 9-1-72)

- Specifies burn resistance requirements for materials used in the occupant compartments of motor vehicles
- Purpose is to reduce deaths and injuries to motor vehicle occupants cause by vehicle fires, especially those originating in the interior of the vehicle from sources such as matches or cigarettes

FMVSS Std. 403: Platform Lift Systems for Motor Vehicles

- Specifies requirements for platform lifts used to assist persons with limited mobility in entering or leaving a vehicle
- Purpose is to prevent injuries and fatalities to passengers and bystanders during the operation of platform lifts installed in motor vehicles

FMVSS Std. 404: Platform Lift Installations in Motor Vehicles

- Specifies requirements for vehicles equipped with platform lifts used to assist persons with limited mobility in entering or leaving a vehicle
- Purpose is to prevent injuries and fatalities to passengers and bystanders during the operation of platform lifts installed in motor vehicles

Part 554: Standards Enforcement and Defects Investigation

Part 554: Standards Enforcement and Defects Investigation

- Establishes procedures for enforcing Federal motor vehicle safety standards and associated regulations, investigating possible safety-related defects, and making non-compliance and defect determinations
- Purpose is to inform interested persons of the procedures followed by the National Highway Traffic Safety Administration in order more fairly and effectively to implement 49 U.S.C. Chapter 301

Part 556: Vehicle Identification Number (VIN) Requirements

Part 556: Vehicle Identification Number (VIN) Requirements

- Sets forth procedures, pursuant to section 157 of the Act, for exempting manufacturers of motor vehicles and replacement equipment from the Act's notice and remedy requirements when a defect or noncompliance is determined to be inconsequential as it relates to motor vehicle safety
- Purpose of this part is to enable manufacturers of motor vehicles and replacement equipment to petition the NHTSA for exemption from the notification and remedy requirements of the Act due to the inconsequentiality of the defect or noncompliance as it relates to motor vehicle safety, and to give all interested persons an opportunity for presentation of data, views, and arguments on the issues of inconsequentiality

Chart 1 - General VIN Format

1st Section			2nd Section					3rd	4th Section							
Identifies Manufacturer and Type of Vehicle			Identifies Vehicle Attributes (Now includes Vehicle Make)					Check Digit	MY	Plant	Number sequentially assigned in Positions 12-17 if a High-Vol. Manu. or in Positions 15-17 if a Low-Vol. Manu.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		"9" if low-vol. manu.									WMI if low-vol. manufacturer (<1,000 of a given type each year)					
						@@						###	###	###	###	###
						if car, and MPV and truck ≤ 10,000 lbs.						if car, and MPV and truck ≤ 10,000 lbs.				
													###	###	###	###
@@ means that VIN Characters are: A,B,C,D,E,F,G,H,J,K,L,M,N,P,R,S,T,U,V,W,X,Y,or Z ## means that VIN Characters are: 0,1,2,3,4,5,6,7,8, or 9													For vehicle not a car, and MPV and truck ≤ 10,000 lbs.			

Part 566: Manufacturer Identification

- Requires manufacturers of motor vehicles, and of motor vehicle equipment to which a motor vehicle safety standard applies, to submit identifying information and a description of the items they produce
- Purpose is to facilitate the regulation of manufacturers under the National Traffic and Motor Vehicle Safety Act, and to aid in establishing a code numbering system for all regulated manufacturers

Obtaining a World Manufacturer Identifier

- A manufacturer that intends to assemble motor vehicles in the United States must obtain a WMI from the Society of Automotive Engineers (SAE).
- NHTSA has a contract with that organization to assign WMIs to manufacturers that assemble motor vehicles in the United States.
- Manufacturers must contact the SAE directly (and not NHTSA) to request the assignment of a WMI.

An Example of the Establishment of VIN numbers

RTDI VIN Numbers

Updated: 2/13/2017

				Identifies Manufacturer and Type of Vehicle			Identifies Vehicle Attributes (Now includes Vehicle Make)					Check Digit	MY	Plant	Number sequentially assigned in Positions 15-17 if a Low-Vol. Manu.					
Production Number	**APV Design**	**Location**	**Build Year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
SD-01	Stretch Duck	Branson MO	1996	1	R	9	R	S	0	A	H	0	T	B	8	3	4	S	0	1
SD-02	Stretch Duck	Branson MO	1997	1	R	9	R	S	0	A	H	9	V	B	8	3	4	S	0	2
SD-08	Stretch Duck	Branson MO	1999	1	R	9	R	S	0	A	H	8	X	B	8	3	4	S	0	8
SD-03	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	5	Y	B	8	3	4	S	0	3
SD-04	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	7	Y	B	8	3	4	S	0	4
SD-12	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	6	Y	B	8	3	4	S	1	2

ESI

Part 567: Certification

Part 567: Certification

(eff. 8-31-69)

- Specifies the content and location of and other requirements for the label or tag to be affixed to motor vehicles and items of motor vehicle equipment manufactured after August 31,1969. The certificate will provide the consumer with information to assist him or her in determining which of the FMVSS are applicable to the vehicle or item of vehicle equipment, and its date manufacture
- An amendment effective Jan. 1, 1973, required gross vehicle weight (GVWR) information on the certification label

Part 573: Defect and Noncompliance Responsibility and Reports

Part 573: Defect and Noncompliance Responsibility and Reports

(eff. 10-1-71)

- Specifies manufacturer requirements for reporting safety-related defects to the National Highway Traffic Safety Administration; for providing quarterly reports on defect notification campaigns; for providing copies of communications with dealers and purchasers concerning defects; and for maintaining owner lists

Part 576: Record Retention

Part 576: Record Retention

- Establishes requirements for the retention by manufacturers of motor vehicles and of motor vehicle equipment, of claims, complaints, reports, and other records concerning alleged and proven motor vehicle or motor vehicle equipment defects and malfunctions that may be related to motor vehicle safety
- Purpose is to preserve records that are needed for the proper investigation, and adjudication or other disposition, of possible defects related to motor vehicle safety and instances of nonconformity to the motor vehicle safety standards and associated regulations

Part 577: Defect and Noncompliance Notification

Part 577: Defect and Noncompliance Notification

(eff. 3-26-73)

- Sets forth requirements for manufacturer notification to owners, dealers, and distributors of motor vehicles and items of replacement equipment about a defect that relates to motor vehicle safety or a noncompliance with a Federal motor vehicle safety standard

Part 579: Reporting of Information and Communications about Potential Defects

Part 579: Reporting of Information and Communications about Potential Defects

(eff. 9-30-78)

- Allocates between motor vehicle and equipment manufacturers the responsibilities under the 1974 Motor Vehicle and School Bus Safety Amendments for recalling and remedying defective motor vehicles and equipment or motor vehicles and equipment not built in compliance with the law

Example of Index of Manufacturer (MFR) Communications

Index of Manufacturer (MFR) Communications

Manufacturer:	Sample Auto Company
Date Range:	01/01/2014 - 10/31/2014
Date Submitted:	01/01/2017

[The effect of the defect or noncompliance should be described below.]

No.	MFR Communication ID	MFR Communication Date	Make	Model	Model Year	Concise Summary (2000 character limit)
1	14-AC-002-1	06/01/2014	Sample	Super	2010	This Technical Service Bulletin provides a diagnostic troubleshooting guide and list of replacement service parts for the Remote Engine Start (RES) accessory.
					2011	
					2012	
				X-500	2010	
					2011	
		06/19/2014		Megacar	2012	
			Example	Presidential	2013	
					2014	
2	WMI-RZX7Q-10	10/24/2014	Sample	X-500	2008	This communication is informing all general, sales, service and parts managers and warranty administrators that SAC will begin mailing final Customer Notification Letters for Recall Campaign 124: Front coil spring fractures, starting October 24, 2014.
					2009	

Part 580: Odometer Disclosure Requirements

Part 580: Odometer Disclosure Requirements

(eff. 3-1-73 and 4-29-89)

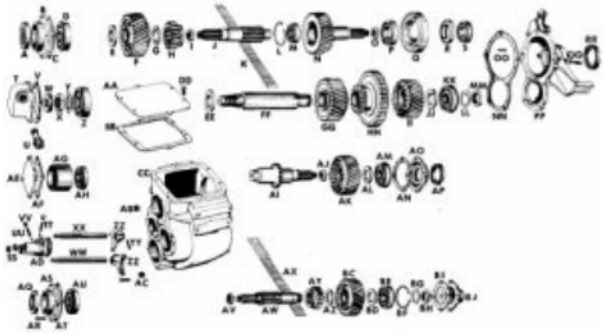
- Requires a person who transfers ownership of a motor vehicle to give the transferee a written disclosure of the mileage the vehicle has traveled

DUKW Tech

What does DUKW stand for?

D=First year of production code "D" is for 1942
U=Body style "U" utility truck (amphibious)
K=Front wheel drive. GMC still used that on trucks into the mid 1980's (K5 Chevy Blazer)
W=Two rear driving wheels (tandem axle)

The DUKW is capable of carrying a 2 1/2 ton payload over land or water. It is equipped with a GMC 270 cubic inch 6 cylinder gasoline engine. It has a 5 speed transmission with a 2 speed transfer case. This gives a total of 10 forward speeds and 2 in reverse. It has 6 wheel drive, a water propeller and a 10 ton winch. All or any of these can be run separately or together in any combination. Top speed on land is 50 to 55 mph while on the water top speed is only 6 mph (land miles per hour not knots). It also has a tire inflation system with a 2 cylinder air compressor and air storage tank. This allows the driver to inflate or deflate any one or all six tires at the same time from the dashboard. The dashboard also has a tire pressure gauge so that air pressure can be monitored. The front brake lines are protected in steel conduit with barbed wire cutters on the outside. The DUKW weighs 7 1/2 tons empty and is 31 feet long. DUKWs were manufactured from 1942 to 1945 by General Motors



Exploded view of the DUKW and CCKW (banjo axle) main transfer case

Technical Specifications

GMC DUKW-353 Based on CCKW-353 Trucks
Type: Truck 2½ ton, 6×6, Amphibian
Engine: GMC 270, 6-cylinder, I-I-W-F, 4417 cc, 77.5 KW @ 3000 rpm
Transmission: 5F1R, 2 gear ratios
Maximum Speed: 72 km/h on roads, 6 knots in water
Length: 9456 mm
Width: 2517 mm
Height: 2695 mm
Wheelbase: 4167 mm, Bogie Centers 1118 mm
Weight: 6840 kg
Payload: 2268 kg, 25 Troops, or 12 Stretchers
Armament: .50 cal. AA Machine Gun (optional)
Crew: Commander and Driver
Production: 1942–1945

The XM147 DUKW "Super Duck" was an Army amphibious vehicle built in a two-year period and tested at Aberdeen Proving Ground from 1956 to 1957.
The Super DUKW was based upon the post WW2 M135/211 GMC automatic power train.

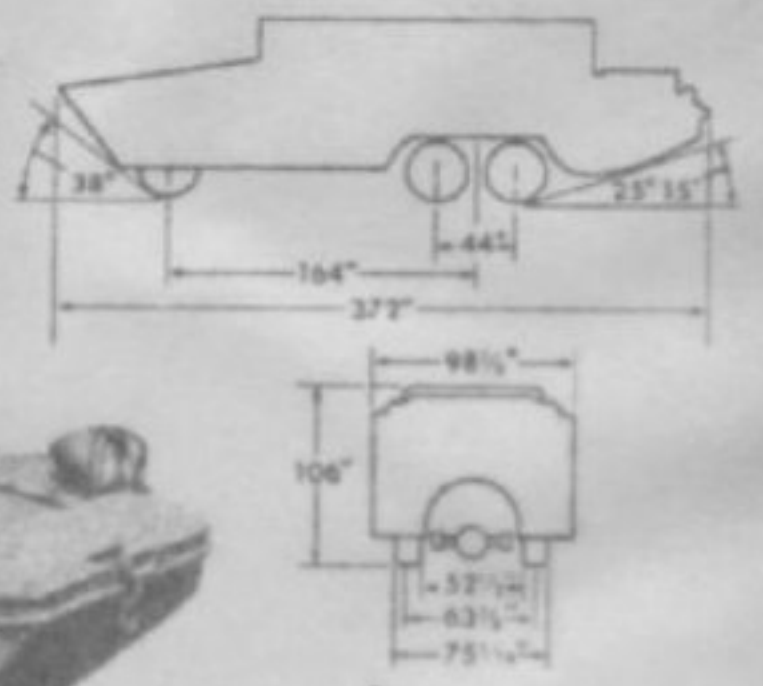
BANJO axles were manufactured by GM, SPILT axles were manufactured by TIMKEN. The majority of CCKW's have SPLIT axles. DUKW's all had BANJO axles.

Banjo Type (with conventional brake drums) PN 3663017
Banjo Type (with demountable brake drums) PN 3678601

RDTI
Replaced GMC 270 engine with GMC 366
Replaced 5F1R transmission with M465 or AT545
Replaced Banjo style axle (PN 3678601 or 3663017) with M211 or M135 axles from XM147 "Super Duck" vehicles built in the mid 1950s.

TRUCK, 2½-TON, 6 x 6, AMPHIBIAN

RA PD 346947



Technical Manuals: 9-802, 9-1802A, 9-1802B, 9-1802C, 9-1825A, 9-1826C, 9-1827B, 9-1827C, 9-1828A, 9-1829A
Parts List: SNL G-501

Manufacturer: General Motors Truck and Coach Div. (GMC).

Classification: Standard.

Armament: Provision for installation of M36 truck mount for antiaircraft machine guns.

Purpose: To transport cargo or personnel on land or water.

This vehicle is popularly known as "The Duck."

GENERAL DATA

Crew:		2
Weight (lb): Net—14,880	Payload—5,175	Gross—20,055
Rear axles: Gear ratio		6.5:1
Tires: Ply—10		Size 11.00 x 18
Pressure (lb) for normal terrain		Front—40; rear—40
Tread (center to center) (in.):		Front—62⅜
Shipping dimensions: Unerated (sq ft) 260.9		(cu ft) 2,236
Vehicle dimensions (in.):		
Water line length		344
Loaded freeboard: At coaming		Front—29; rear—29
At deck		Front—24; rear—16
Loaded draft		Front—42; rear—51
Ground clearance		(in.) 11½
Pintle height, loaded		(in.) 49⅞
Cargo space (cu ft):		
To top of coaming		198
Under tarp bows		385
Electrical system:		(volts) 6
No. of batteries		1
Capacities:		
Air compressor		(qt) 1½
Fuel (72 octane gasoline)		(gal) 40
Cooling system		(qt) 20
Crankcase (refill)		(qt) 12½
Tranamission	(qt) Main—6½; auxiliary—4½	
Differentials (each)		(qt) 6½
Transfer case		(qt) 4½
Winch (load capacity)		(lb) 10,000
Brakes: Mfr.—GMC	Type—hydraulic hydrovac	
Dimensions (in.)	Front—2; rear—3	
Transmission: Speeds		5
(Gear ratio: High—.799 over; Low—6.06:1; 4th speed—direct)		
Transfer case: Speeds		2
(Gear ratio: High—1.16:1; Low—2.63:1)		
Auxiliary transmission: Speeds		2
(Gear ratio: High—2.57:1; Low—1.34:1)		

PERFORMANCE

Maximum computed gradability:	(percent) 55
Turning radius:	
Right (ft)	Land—35; water—12½
Left (ft)	Land—36; water—17½
Fuel consumption (loaded):	(mpg) 6
Cruising range (loaded):	(mi) 240
(On water: At top speed, 2nd gear (mi) 30; 3rd gear (mi) 50)	
Allowable speed: (on land)	(mph) 50

ENGINE

Manufacturer: GMC	Model 270
Type: Valve-in-head, 4 cycles	
No. of cylinders:	(in line) 6
Displacement:	(cu in.) 269.5
Bore:	(in.) 3⅝
Stroke:	(in.) 4
Maximum governed speed:	(rpm) 2,750
Brake horsepower:	91.5 at (rpm) 2,750
Torque:	216 ft-lb at (rpm) 1,400

ADDITIONAL DATA

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RESTRICTED

A-4477

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THE DUKW

ITS OPERATION AND USES

G-3 SECTION, AP&SC

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RESTRICTED: Dissemination of restricted matter.—The information contained in restricted documents and the essential characteristics of restricted material may be given to any person known to be in the service of the United States and to persons of undoubted loyalty and discretion who are cooperating in Government work, but will not be communicated to the public or to the press except by authorized military public relations agencies. (See also par. 18b, AR 380-5, 28 Sep 1942.)

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Instructors Reading this Document

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N-4477

HEADQUARTERS UNITED STATES ARMY FORCES, PACIFIC OCEAN AREAS

15 October 1944

MANUAL: The DUKW: Its Operation and Uses.

The Standing Operating Procedures and technical data outlined in this manual are the results of practical study and recent experience in the European and Pacific Theaters. They are published to provide up-to-date information designed to promote the most efficient utilization of DUKWs in current and future operations. Intended primarily for the guidance of DUKW operating personnel, this manual is also valuable for officers planning amphibious assault operations, as well as those charged with supply activities in undeveloped ports.

By Command of Lieutenant General RICHARDSON:

O N Thompson

O. N. THOMPSON,
Colonel, AGD.
Adjutant General.

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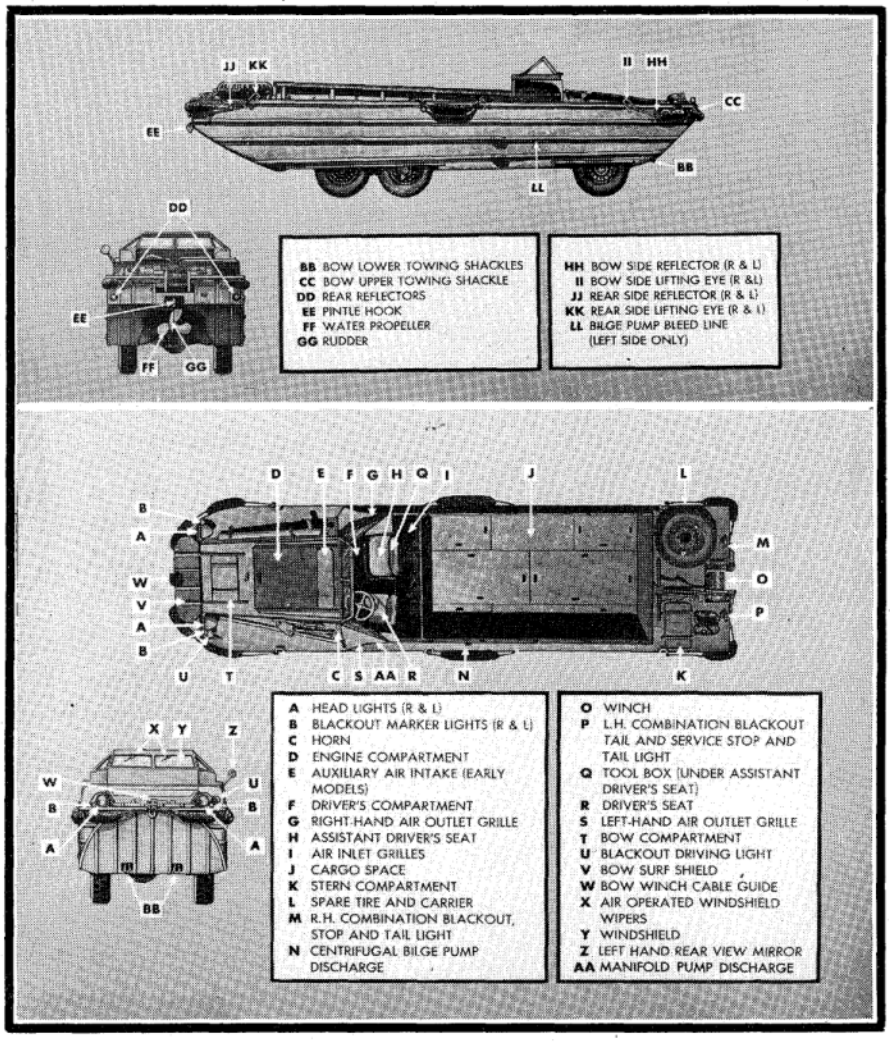
CHAPTER I
GENERAL DESCRIPTION

1. *General*: The DUKW described herein is an amphibious conversion of the standard Army 2½-ton 6x6 truck. Thus the DUKW has similar automotive characteristics to the parent truck. In addition, it is equipped with an integral water-tight welded steel hull. The thickness of the bow is approximately ⅛", the bottom approximately 3/32", and the sides approximately 1/16". For land operations the vehicle uses six driving wheels



Location of Various Parts

—driven by a six cylinder valve-in-head gasoline engine developing approximately 90 horse-power net. For water operations the DUKW is driven by a 25-in. diameter, 14-in.

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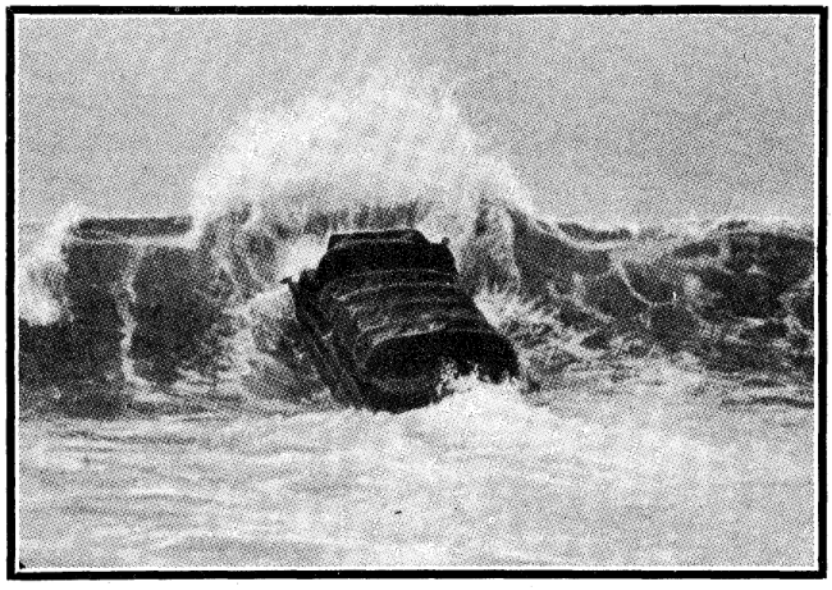
pitch, three-bladed weedless propeller, driven by the engine through the transmission and a water propeller transfer case. As a truck, the front wheels are steered in the conventional manner. When operating in the water, steering is accomplished by a rudder interconnected to the truck steering gear. There are two propeller shaft-driven bilge pumps of approximately 250 gallons per minute total capacity, and in addition there is a 25 gallon per minute hand pump.

2. *Capabilities*: a. In the absence of adequate port facilities, the DUKW provides a most effective means of moving supplies from ship to dump, rail head or transfer point on shore.

b. Large volumes of cargo can be moved through restricted beaches. Congestion at beach is eliminated as is the slow, difficult and dangerous cargo handling from beached boat to land conveyance.



DUKW In Heavy Surf

c. Beach performance is excellent, far exceeding that of other wheeled equipment. This results from use of large desert type tires with tire pressure controllable by driver while the DUKW is in motion.

d. Surf performance is excellent due to low center of gravity and simultaneous traction in water and on land. A ten-foot surf can be negotiated safely.

e. The DUKW can negotiate offshore bars, reefs and coral which present an obstacle to landing craft.

f. Each DUKW is equipped with a power winch with 10,000 pound line pull, and may be fitted with an "A" frame to serve as a temporary crane with a 5,000 lb. capacity.

3. *Limitations*: a. The DUKW is not an assault vehicle. Its relatively light skin affords no protection from enemy fire.

b. DUKWs must operate in areas free from soft mud, swamps, marshes, quicksand, stumps, wreckage, wire, large rocks and boulders.

c. Limited water speed makes long water hauls unprofitable.

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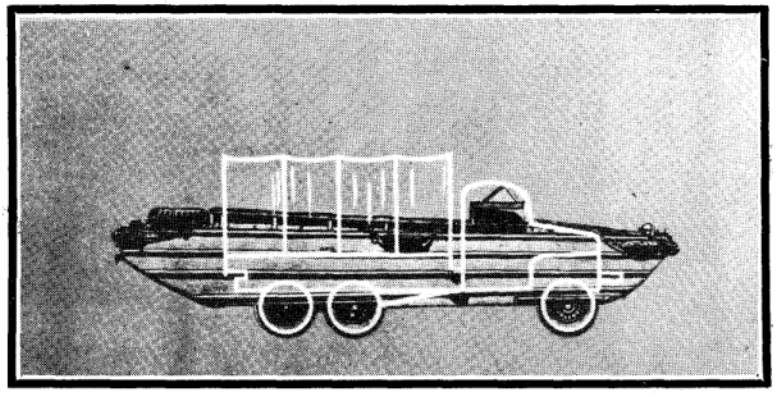
d. Limited reverse power and the fact that bilge pumps operate only when propeller shaft is turning forward, make special DUKW mooring system imperative. (See Chapter XV.)

e. Size of vehicle is small and freeboard low in comparison to loads carried. Therefore, size and number of drafts and position of cargo must be suited to existing conditions.

f. Design requires that all cargo be put in or out *over* the side. The advantages of a ramp or even a truck's tail gate are not available.



DUKW Compared To 2½ Ton Land Truck

4. *Cargo Space*: Cargo space is 149" long, 82" wide, and approximately 28" deep. It has a ¾" plywood removable floor which should be protected by the use of dunnage for any cargoes producing concentrated loads. Cargo space can be covered by a tarpaulin, either directly over the cargo or over removable steel bows. Capacity is 5,000 to 10,000 pounds of cargo, depending on conditions of operation. (See paragraph 156 for details.) If carrying personnel, the capacity is 25 fully equipped combat troops.

5. *Crew*: The normal crew is two men, consisting of the driver, who can completely operate the vehicle, plus an assistant driver or gunner.

6. *Armament*: Each DUKW has sockets for installation of a scarf ring mount which can carry a .50 caliber machine gun. The present Army T/O supplies 13 machine guns and mounts per company of 50 DUKWs.

7. *Characteristics Of The DUKW*:

a. Dimensions:

Length Overall	31′ 0″
Height—top up	8′ 11″
Height—top and windshield down	7′ 6″
Width—overall	8′ 4″
Ground Clearance—hull	1′ 5″

b. Freeboard and Draft—5,000 lb. load

Freeboard to deck—bow	1′ 11″
Freeboard to deck—rear	1′ 3″
Freeboard to coaming	2′ 6″
Draft to front wheels	3′ 8″
Draft to rear wheels	4′ 4″

c. Weights:

Fully equipped—no pay load—15,000 pounds.

Loaded, 20,000 to 25,000 pounds, depending on load.

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d. Maneuverability:
Turning circle on land—70′ diameter.
Turning circle on water—40′ diameter.

e. Performance:
On land: 50 m. p. h. maximum, and average consumption of gas, 4.0 gals. per hr.
Afloat: 5000 pound load, smooth water.
2nd Gear, 2500 RPM—6.0 Land Mi. Speed using 6.8 gal. gas per hr.
2nd Gear, 2200 RPM—5.3 Land Mi. Speed using 4.4 gal. gas per hr.
3rd Gear, 1000 RPM—4.8 Land Mi. Speed using 3.2 gal. gas per hr.
3rd Gear, 800 RPM—4.0 Land Mi. Speed using 1.6 gal gas per hr.
Reverse Maximum, 2.2 miles per hr.

CHAPTER II

EMPLOYMENT AND SPECIAL USES

8. *Cargo Over Undeveloped Beaches*: The prime function of DUKWs is to handle cargo from ship directly to dump or transfer point, over undeveloped beaches.

9. *Cargo In Damaged Ports*: Where dock facilities are damaged or blocked, DUKWs can unload from ship to transfer point, warehouse or rail head using a prepared landing spot. The smooth water afforded by the harbor together with easy (prepared) landing allows maximum loads to be carried, and affords most efficient operations.

10. *Division of Work With Landing Craft*: The DUKW can operate over offshore bars, shoals and coral which preclude the use of landing craft. The low center of gravity, the combined traction and steering on land and water, and the elimination of need for stopping in the breakers, makes possible operation of DUKWs in surf too heavy for landing craft. Where both DUKWs and landing craft are using the same beach, a suitable landing should be marked for the DUKWs, and boats kept off that spot.

11. *Division of Work With LVT*: In operations where both LVTs and DUKWs are used, the work should be apportioned so the LVTs do the assault work for which their armor makes them suitable, and for operations involving mud, swamps, wire, heavy brush and all land impassable to wheeled vehicles. DUKWs are not suitable for assault work under fire, but should do the supply work, as they can maneuver better at ship's side, and can operate ashore with a minimum of damage to roads and communications.

12. *Division of Work With Land Trucks*: DUKWs are much better suited to sand and beach operations. Trucks should be used for all possible land operations beyond two miles from the beach, primarily to permit DUKWs to perform water operations where the trucks can not be used, and secondarily because the trucks are lighter, shorter, easier to maneuver, and require less maintenance. Also because the small heavier tires of the trucks are less vulnerable to shell splinter damage, and the truck's ability to use chains is a help where heavy mud is encountered.

13. *Use of Landing Mat*: Where sand is soft, landing mats should be used to reduce chance of DUKWs becoming stuck at water's edge, also to keep axles and brakes out of the sand which will reduce necessity of otherwise heavy brake maintenance.

14. *Landing of 105MM Howitzer and Ammuintion From LSTs*: Details are given in Chapter XX.

15. *Casualty Evacuation*: DUKWs can carry 12 stretcher cases with attendant, or up to 40 walking wounded, direct from field dressing station to hospital ship. Casualties may be protected from sun and spray by use of tarpaulins. If LSTs are used for hospital work, the DUKWs can drive straight up the ramp without loss of time. When placing stretcher cases in DUKWs, the first two should be placed crosswise on forward end of cargo floor heads to the left. The next four should be placed longitudinally on floor, feet against rear bulkhead. Next, four stretchers should be placed heads to left, across coamings starting at rear end of cargo space. The last two should be placed on coaming over first two that were loaded. All stretchers on coamings should be lashed so they will not shift. DUKWs delivered after May 1944 are furnished with four removable coaming extension boards, which may be temporarily clamped on coamings to secure stretchers.

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16. *Special Uses*: In addition to the uses listed above, there are numerous special uses for which DUKWs have been employed. Any load up to 7500 pounds with center of gravity not aft of center of cargo space or above deck level can be carried if it will fit in the cargo space. A 5000 pound load can have center of gravity 18" above deck level, provided it is not aft of center of cargo space. When loads are excessive, and where center of gravity is higher than desirable, extra precautions must be taken to seal out water which, when in the bilge, will slosh from side to side and decrease the stability.

17. *Personnel*: Twenty-five combat equipped troops can be carried, together with mortars or machine guns, and up to 1500 pounds of ammunition. The ammunition boxes can be arranged to form seats all around the sides of the cargo space.

57mm Anti-tank Gun in DUKW

18. *SCR-399 Radio, or Message Center*: The house for this unit, or similar message center unit, should be placed in the DUKW cargo space against the forward cargo bulkhead with the heavy end of the unit forward. However, since the regular door of the radio housing cannot be swung open while the unit is in the DUKW, a special water tight door must be cut in the roof of the radio house to permit entry and servicing. If generators are carried, they must be over rear deck, clear of access to rear hatch, and mounted as

high as possible to keep out of water. Before installing main unit in cargo space, bilge must be thoroughly cleaned, painted and treated with rust preventative (see paragraph 70). Bilge pump system, if chassis number is below 4203, must be modified as per TB ORD 5 Section II, cleaning, rescreening and raising intakes 2" above floor. Tube extensions must be fitted on grease fittings on propeller shaft thrust bearing, propeller shaft stuffing box and Higgins bilge pump, leading to marked fittings accessible in aisleway. After installing shack in cargo space, a cover must be fitted to tightly close gap around sides and rear coaming, with access openings to permit operation of two rear drain valves. If generators are installed over rear deck, in order to reduce weight on stern, spare tire must be mounted over aisleway or forward face of shack, and anchor must be mounted *in* forward compartment against inner face of bow. Watertight canvas covers must be fitted to protect generators (which should also be waterproofed) during water trip.

19. *Precision Equipment—Radars—Searchlights*: Numerous articles that must be taken ashore without being subjected to worse than spray, can be landed to great advantage in DUKWs.

20. *Miscellaneous Light Artillery*: Any field piece equivalent to or smaller than a 105mm howitzer may be carried in a DUKW. Ammunition and/or personnel may be added to bring the load up to limit for conditions encountered. Two 37s or smaller pieces can be carried, crossing their trails in cargo space, removing breech guard from first gun loaded.

Howitzer wheel chocks (paragraph 216) are placed upside down and backwards to raise wheels enough for gun barrel to clear windshield base. Howitzer sling is rigged around axles inside of wheels, and around neck of lunette, to rear of positioning plate, as shown in picture above. Place board below trail to protect cargo floor.

21. *Reconnaissance*: A DUKW is extremely suitable for exploring beaches to determine suitable landing spots. The ease with which it can run from dry land into deep water affords a quick method of exploring, sounding and charting.

22. *Carrying Water:* In extremely favorable conditions, two 250-gallon water trailers can be carried— one forward with lunette over windshield, and one rear with lunette over rear deck. Use 105mm wheel chocks (see paragraph 216). In normal conditions only one trailer should be carried, placed in forward end of cargo space with lunette to the rear. A 600-gallon water tank can be carried in forward end of cargo space. In all cases, keep tanks chock full while afloat—a partially full tank allows the water to swash from side to side and is dangerous to stability.

23. *155MM Ammunition*: Thirty-three rounds can be placed in two rows across the forward end of cargo space. Behind these, 11 clover leaves of 3 charges each can be placed, with fuzes as needed.

24. *40MM Bofors AA Guns*: By removing forward cargo bulkhead, and blocking forward end of cargo floor (which would otherwise be unsupported) a Bofors AA gun can be carried in a DUKW with lunette over rear deck. It is advisable to carry 1000 pounds of ammunition *below forward corners* of cargo floor (before placing gun on board) to insure maximum stability of the DUKW. 20mm Navy AA guns may also be carried in DUKWs.

25. *Pallet Mounted M45 QUAD .50 Caliber AA*: When trailer mounted, this unit is known as M51 and must be landed in LCM or larger craft. By removing mount from trailer and placing on 6'x5' sled pallet, the unit can be landed in a DUKW and can fire during transit.

26. *Firing 105MM Howitzer from DUKW*: (See paragraph 234).

27. *Rocket Firing from DUKWs*: Rocket Launcher Mark 7 permits firing 144 4.5" barrage rockets from a DUKW, either afloat or ashore. California Institute of Technology Type 7 Model 1 Launcher permits similar firing of 42 7.2" barrage rockets.

28. *Smoke Generators*: The units commonly mounted on 2½-ton trucks can be used on DUKWs. In that way they can be transported to whatever location is desired (seaward or on land) to lay protective smoke covering.

29. *Watering Land Tracks*: On some soft beaches where traction is bad for DUKWs and land trucks, DUKWs can perform valuable service by watering the tracks. On its way to shore, each DUKW collects some water in its hull by opening the drain valves for

Lifting a Jeep with an "A" Frame.

Note carefully the way sling is rigged. Rear part goes under the frame but must lead *over* the rear drive shaft. Use two 17 foot slings or 38 feet of a mooring line, as shown above.

15 seconds, then closing them again. The drain valves are opened as the soft sand is reached and the DUKW drives forward. This is also a good means of laying dust on dry roads. Water should not be taken into the DUKW if the surf conditions are bad, if the landing is difficult or if very heavily loaded.

30. *Small Vehicles*: (See paragraph 202). A jeep, or if desired, a jeep with a 37mm gun on top of it, can be carried. Also, a ¼-ton amphibian or an M29C (Weasel) can be carried when water is too rough for them to operate on their own bottom.

31. *Salvage*: The DUKW, with its power winch, "A" frame and towing ability is well suited to improvised salvage work. The air compressor and tire pumping hose are useful in conjunction with diving equipment. A DUKW while using an "A" frame afloat must be stablized by being rigidly secured to another DUKW.

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CHAPTER III

TRAINING AND PERSONNEL

32. *Training Period*: The DUKW is a specialized weapon, and personnel intended to operate it requires special DUKW training for a minimum period of three weeks. Personnel should have had truck operating experience and, if possible, stevedore training.

33. *Officer Training*: In order to be able to make decisions which will increase the efficiency of DUKW operations, DUKW Company officers require a considerably greater amount of training than enlisted personnel.

34. *Subjects*: Subjects taught should be as follows: Land driving, entering and leaving water, water driving, coral reef operations, anchoring and towing, mooring, cargo handling at shipside, cargo handling ashore, compass correction, winching, handling of artillery, operations with LSTs, DUKW control, first second and third echelon maintenance, and also any special techniques which local conditions and special missions may require.

35. *Facilities*: Training facilities include a cargo ship, an LST, cargo of various types and artillery. Training site should include a good beach having occasional medium to heavy surf, some coral reefs, dunes of soft sand, and rough inland trails.

36. *Personnel Strength*: It is necessary that sufficient personnel is trained to man and maintain their vehicles at all times. During operations DUKWs will usually be required to work around the clock over long periods. Therefore a minimum of three men should be trained as drivers for each vehicle. An average of two mechanics for every five DUKWs is necessary in the maintenance section. (See Chapter XIV—Round the Clock Operations.)

CHAPTER IV

MODIFICATIONS AND PREPARATIONS OF DUKWs BEFORE OPERATING

37. *General*: Thorough accomplishment of the modifications and preparations described in this chapter will enable DUKWs to perform their mission with minimum demands upon maintenance personnel and a minimum need for spare parts. Additional important information, particularly applying to DUKWs built during 1943, can be found on TB ORD 5, "Emergency Field Maintenance for 2½ ton Amphibian Truck", War Department, 31 December 1943. Items included in TB ORD 5 and in the first eleven items described below can be readily accomplished with materials available at any staging area.

38. *Steering Gear Adjustment to Prevent Shear Pin Failure*: (Applies to all DUKWs above chassis #1505).

a. Failures are caused by a faulty adjustment which caused the rudder linkage at the stern to reach the end of its travel before the steering gear is stopped by the front axle stoppers. This occurs most frequently when afloat, at which time the front axle drops, allowing the steering gear to turn further to the left than when on land.

b. The faulty adjustments may be in one or more of the following:

(1) Front axle stop—for left turn.
(2) Adjustment of steering cable where attached to tiller in stern.
(3) Incorrect rotational position of cable spool on steering column.

c. To insure against shear pin failures, all DUKWs will be checked and adjusted in sequence given below:

(1) Set front wheels straight ahead on level ground.
(2) Check that steering wheel marker pins are at top center. Relocate pins if necessary.
(3) Check that there are 3¾ turns of cable above and 3¾ turns of cable below center attachment on steering column spool. Remove shear pin and rotate spool on steering column if necessary. If cables have been improperly wound on spool, it may be necessary to unrig one or both ends of cable and re-wind them on spool. (Note that there must be 7½ turns of cable on spool).
(4) Check position of rudder linkage as is shown on page 486 TM 9-802, dated 1 September 1943, Figure 264. Adjust cable attachments to tiller lever if necessary to secure proper position.
(5) Check that main portion of rudder blade is straight ahead (exclusive of offset tab at trailing edge). Straighten or replace rudder and rudder control lever assembly if necessary, to secure this alignment.
(6) Turn steering wheel *full hard left,* exerting approximately a fifty (50) pound pull, and hold it *full* left. In this position there should be *not less than* 1½ inches free travel remaining at end of slot in rudder control lever. If less than 1½ inches free travel is secured, then build up left front axle stop bolt so that steering wheel cannot be turned beyond the position which gives 1½ inches free travel. (Before making permanent stop adjustment, jack up

front axle and turn wheel again *full hard left* to be certain that in this position rudder control lever does not overrun.) Maximum front wheel angle should not be reduced to less than 27 degrees left. If checks (1), (2), (3), (4), (5) above have been accurately followed, front wheel angle will be limited at 28 degrees.

d. If faulty adjustment has been found, always remove and inspect shear pin. Replace pin with new one if it is nicked or partially sheared.

e. On receipt of this information, all DUKWs above chassis #1505 will be carefully checked as outlined above, and adjusted as necessary. At the same time, steering cables will be carefully inspected, particularly at attachments to tiller, also in way of the sheaves, and on spool on steering column. Turn steering wheel full left and full right while inspection is being made. Replace cable if rusted, nicked, or rough or frayed. All sheaves, and cable in way of sheaves and on spool, should be well lubricated.

f. The instructions outlined in c, d, and e above should be made part of the regular *Monthly Maintenance.*

39. *Permanent Sealing of Auxiliary Air Intakes*: (Applies to all DUKWs until they are manufactured *without* auxiliary air intake in rear portion of engine hatch.) After two full years of operation, it has been thoroughly proven that the DUKWs will cool satisfactorily with this auxiliary air intake closed. Simple expedients to improve cooling are given in paragraph 72. In addition, many unnecessary accidents and much unnecessary engine maintenance has resulted from the auxuliary air intake being opened or being forced open in rough water. The cure is simple and very important. The seal of the auxillary air intake must be put in good condition so the opening will not leak. Then the air intake must be closed and clips welded on it, or locking lugs tack welded so that it cannot be opened and will not open itself in spite of vibration and the force of the surf. Be careful not to burn the seal during the welding, otherwise a bothersome leak will be created. Remove and discard dash instruction plate regarding auxiliary air intake on DUKWs fitted with the plate.

40. *Propeller Guard*: (Applies to all DUKWs.) To minimize damage to propeller from rough coral, rocks and wreckage, the guard shown on next page has proven very successful. Before making the welds to hull, care must be used to clean out the rear compartments thoroughly to prevent fire hazard. Welders must be very careful not to burn through hull bottom or tunnel sides, or a dangerous leak may be created.

41. *Primary Wire Insulation*: (Applies to all DUKWs.) Refer to page 210 TM 9-802. 1 September 1943. Note part E in figure 101, the insulated terminal on the ignition shield on the right hand side of the engine, slightly back of the middle. The primary ignition wire leads to this terminal. When this wire shorts across to the body of the ignition shield, the engine will cut out. To prevent this, the conection should be cleaned, then wrapped with rubber insulating tape and painted with suitable insulating compound. Then, even if water and dirt get on this connection, the engine will not cut out.

42. *Plug Racks in Driver's Compartment*: (Applies to all DUKWs not so fitted — production installation started approximately with June 1944 deliveries.) To minimize danger from attempts at water operation with bottom plugs missing, racks and stencils pictured in the accompanying drawings are to be installed on windshield base. See paragraph 71 regarding proper use of all plugs.

43. *Modified Drain Plug Wrench*: (Applies to all DUKWs not so fitted.) To speed up and simplify plug removal and installation, and to eliminate loss, it has been found prac-

tical to frabricate the several plug removal wrench inserts into a single tool as shown in the drawing. Convenient brackets for this should be fitted in driver's compartment.

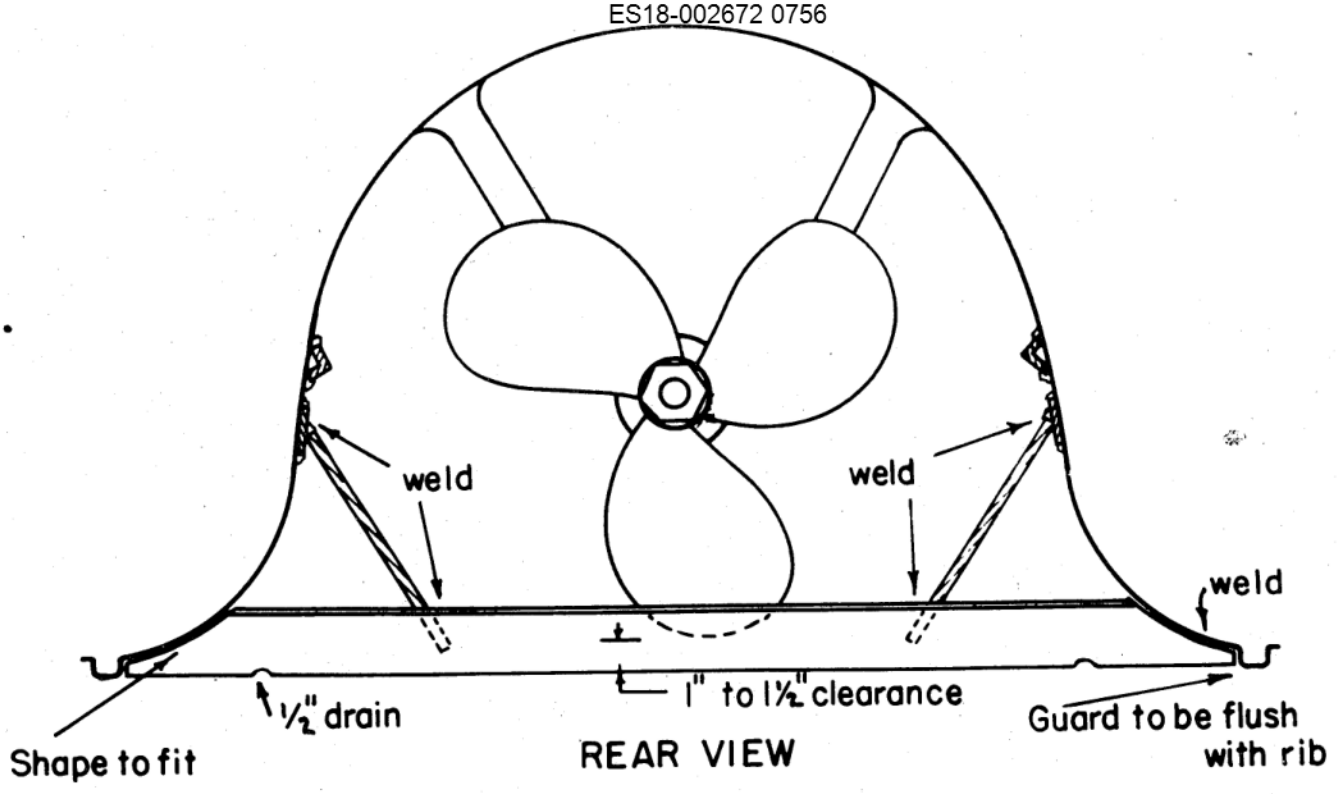
44. *Shorten Trap Bows to Facilitate Proper Stowage*: (Applies to DUKWs delivered in 1943 and first half of 1944.) Proper tarp bow stowage has been a bothersome problem. Starting in June 1944 tarpaulin bows were shortened 3" each leg. The original bows were approximately 38 inches high, if standing up on a smooth floor, from the floor to the top of the bows. This should be reduced to 35 inches. This reduced height makes it practical to stow the bows in the forward compartment. Put them in one at a time through the forward hatch, pushing them in the left cooling air passageway until the other end will clear the hatch. Then swing them back so they lay flat against the inside of the front of the hull with each end of the bows in the corners immediately forward of the front wheel cut outs. This stowage could be accomplished with the full length bows, but in order to get them in, the first end of the bow had to be slide back in the air outlet passage and then temporarily extend into the driver's compartment *through* the driver's compartment heater slot, after which the bows could be centered as described above. This was too laborious to be practical. Some of the bows have been stowed under the air intake grating in the aisleway, but this location interferes with bilge inspection and access, and to some extent, with the inflow of cooling air. Sometimes bows have been racked behind the driver's compartment or in either end of the cargo space. This definitely interferes with loading cargo at ship's side. The correct answer is short bows in the forward compartment. While on this subject, it is mandatory for the safety and operation of the DUKW that other equipment not be stored in the forward compartment, or air passages on each side of the engine. The heat of the engine cooling air, plus the heat of the exhaust piping is almost certain to start a fire. Keep the bow compartment clear except for the short tarpaulin bows and the cab top type bow when not in use.

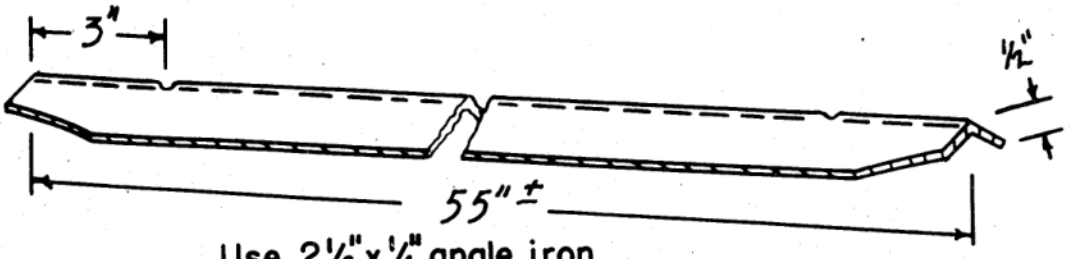
45. *Additional and Relocated Fender Eyes*: (Applies to DUKWs delivered in 1943 and first quarter of 1944). For details see paragraph 109.

46. *Rear Axle Brake Hose Protectors*: (Applies to all DUKWs). All necessary details for fabrication and installation can be procured under MWO G-508 W-1 from Office of the Ordnance Officer, CPBC, APO 456 c/o Postmaster, San Francisco, California. By the installation of 6 sharpened blades on each DUKW, the possibilities of wire, cargo binders, or rope damaging any of the 4 rear brake hose are virtually eliminated. See paragraph 52 below regarding Front Brake Hose Protection.

47. *Daily and Weekly Driver Maintenance Plates*: (Applies to all DUKWs not so fitted). Reproductions of Daily and Weekly Driver Maintenance plates shown in paragraph 64 and 66 should be affixed in a conspicuous position in the driver's compartment and protected with a clear lacquer or similar water proof protection.

48. *Front Drain Valve Reach Rod*: (Applies to DUKWs between chassis #2004 and #4206). DUKW chassis numbers between 2004 and 4206 are equipped with four hull drain valves. The two rear valves and the center valve are just like those in all later DUKWs. The forward valve is in the same hull position, but its handle is shorter and can be reached only after opening the engine hatch. This results in hull damage by reluctance to drain as often as when handle is more readily accessible, and in addition, on entering the water it is impossible to check that front valve is closed, without opening engine hatch. The installation of a reach rod to driver's compartment as installed in all later DUKWs eliminates the difficulty. Details are shown on next page. Parts temporarily removed from a new DUKW may be used as a guide.





Use 2½" x ¼" angle iron
1 per DUKW

Fig. 1

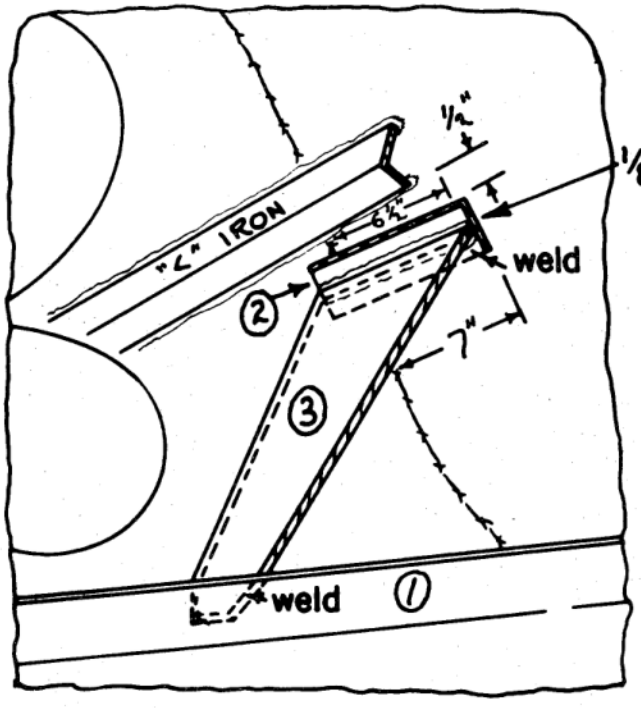
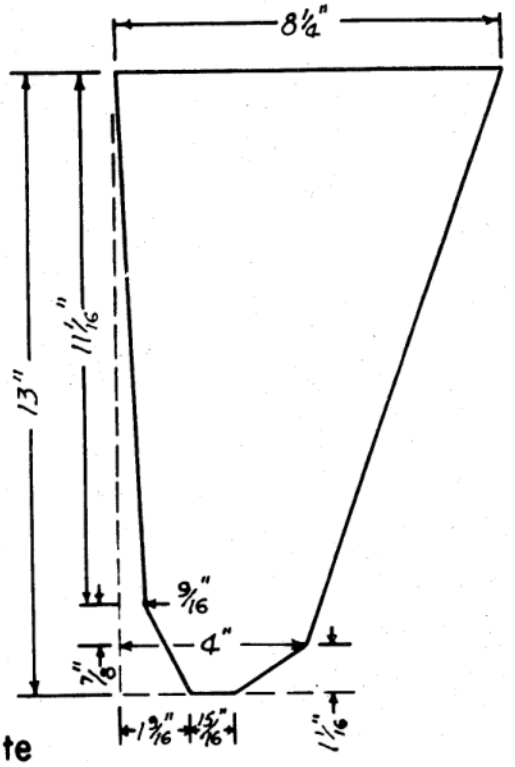


Fig.2

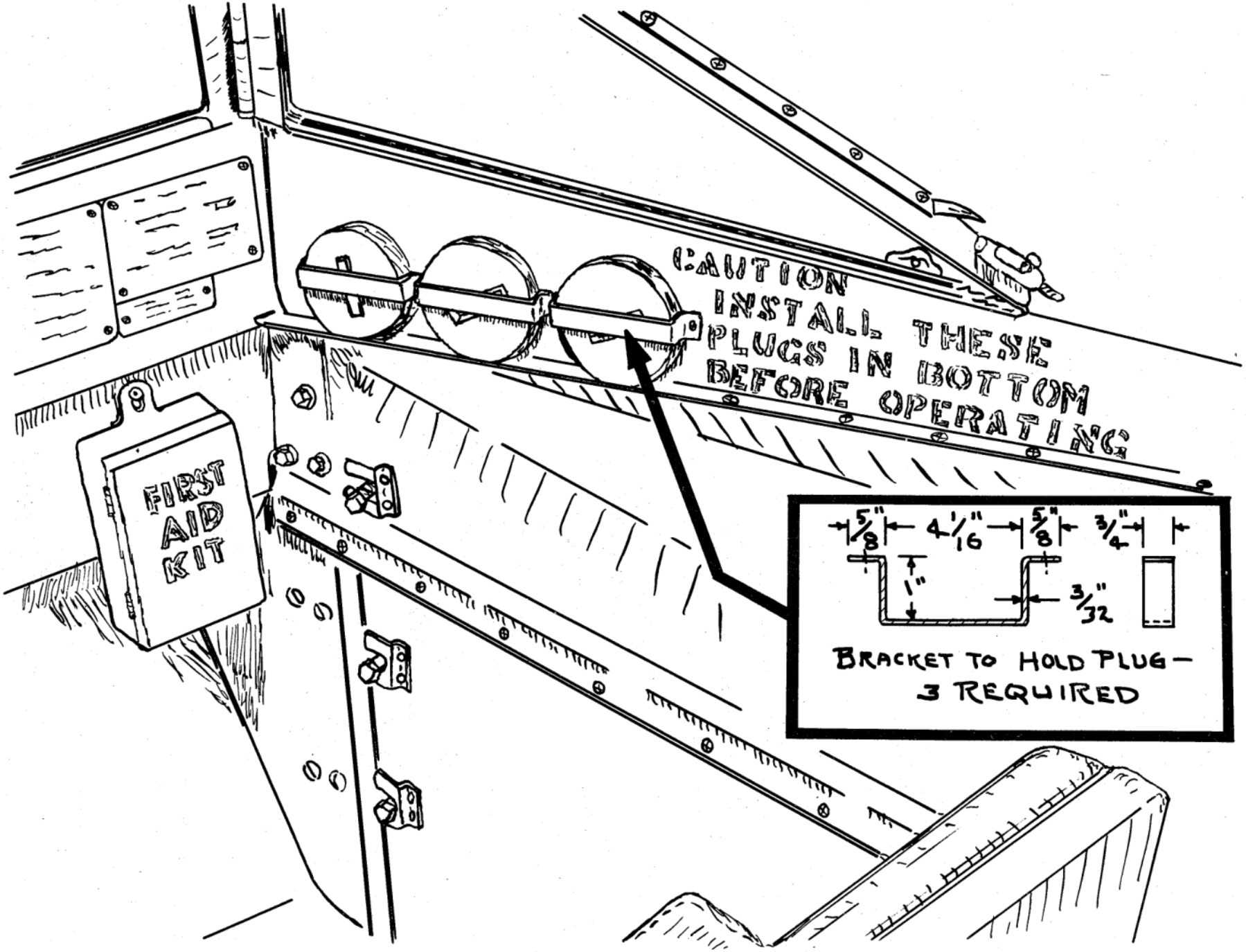
⅛" x 2" x 9¼" black strap iron
2 per DUKW

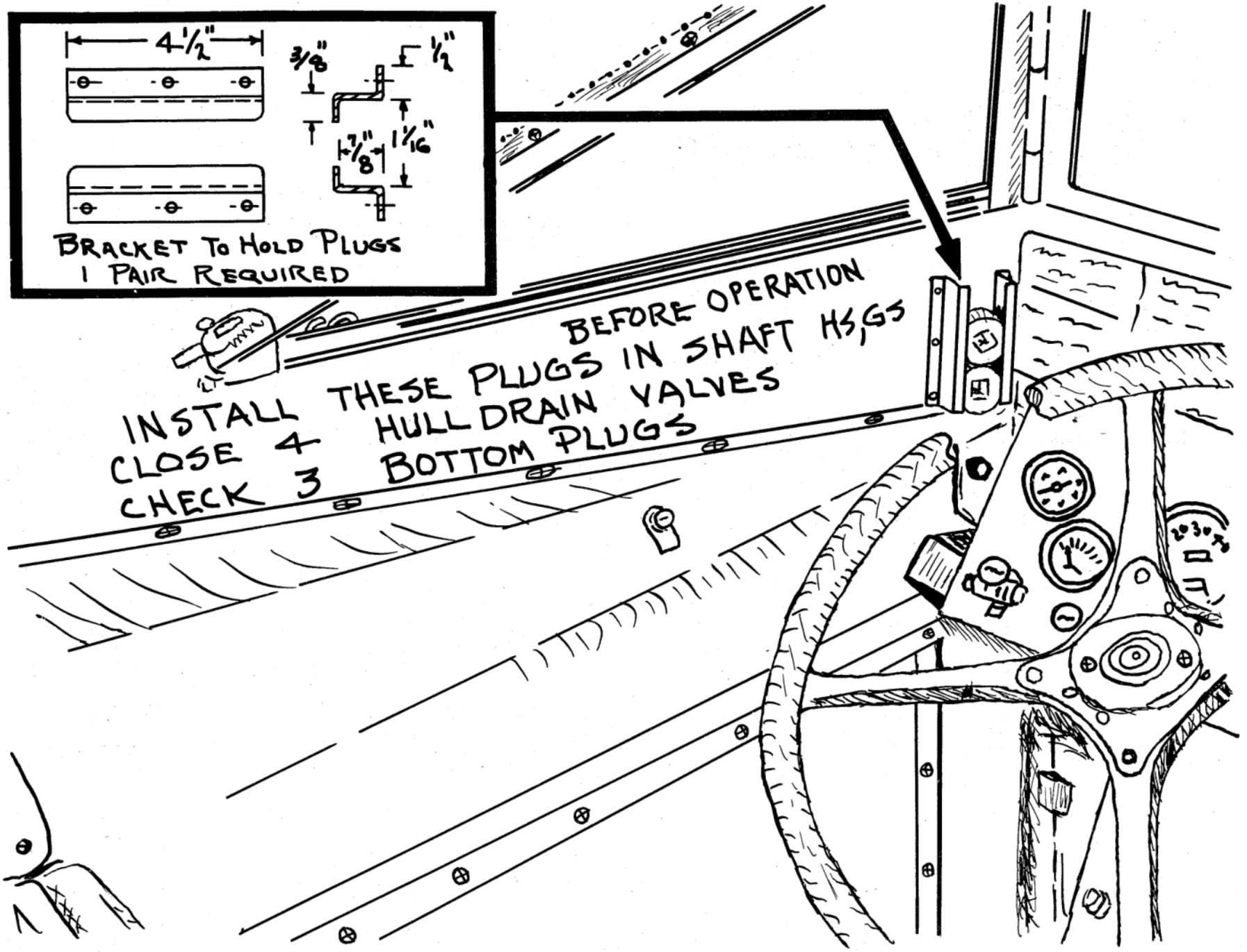


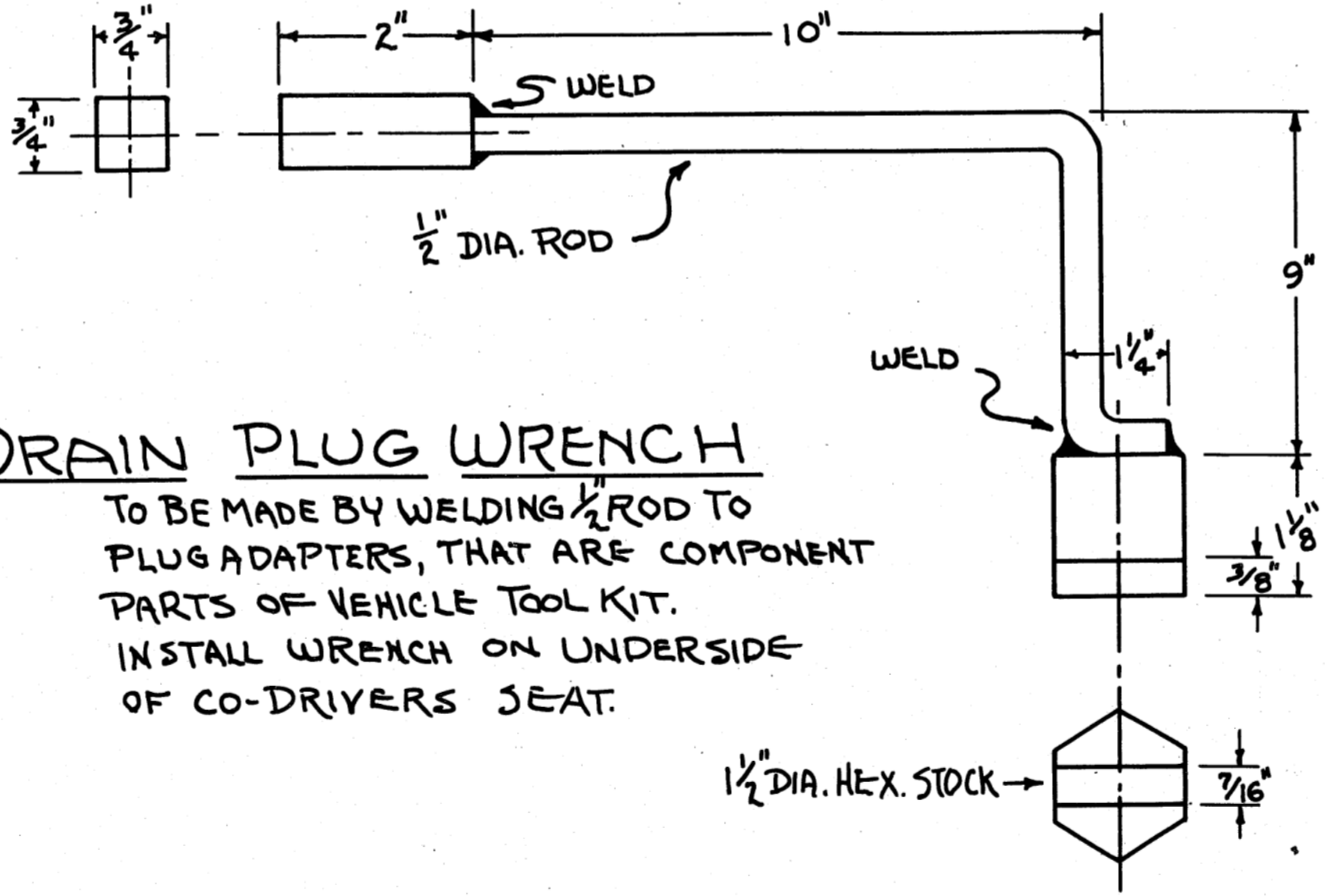
Use ¼" steel plate
2per DUKW

Fig.3

PROPELLER GUARD FOR DUKW


CAUTION
INSTALL THESE
PLUGS IN BOTTOM
BEFORE OPERATING
FIRST
AID
KIT
5/8"
4 1/16"
5/8"
3/4"
1"
3/32"
BRACKET TO HOLD PLUG —
3 REQUIRED


4 1/2"
3/8"
1/2"
1 7/8"
1 1/16"
BRACKET TO HOLD PLUGS
1 PAIR REQUIRED
BEFORE OPERATION
INSTALL THESE PLUGS IN SHAFT HS,GS
CLOSE 4 HULL DRAIN VALVES
CHECK 3 BOTTOM PLUGS



DRAIN PLUG WRENCH

TO BE MADE BY WELDING 1/2" ROD TO PLUG ADAPTERS, THAT ARE COMPONENT PARTS OF VEHICLE TOOL KIT.

INSTALL WRENCH ON UNDERSIDE OF CO-DRIVERS SEAT.

49. *Air Compressor Lubrication Modifications*: (Applies to all DUKWs above chassis 2005 and through deliveries during first half of 1944). FS MWO G-501 W-30 covers 4 seperate improvements to air compressor lubrication system. The first improvement was an extension of the breather (at about chassis #5069), which raised the breather about 5" from its original position just above the top of the crankcase to the final position abreast of cylinder head. At chassis #8329 (May 1944) the original flat base plate from crankcase was replaced by an interchangeable dished base plate having approximately ¼" additional oil depth. At the same time the oil pump intake was extended downwards to provide adequate lubrication at temporarily lower levels of oil. In June 1944 a new filler plug was used having wing-nut ears and an attached dip stick in place of the earlier type of screw plug. Until the added protection can be obtained from the above modifications special care must be used to *maintain oil level to the top of the fill hole at all times.*

50. *Conversion of Forward Pump from Oberdorfer to Gould*: (This applies to DUKWs 2505 to 4205). On DUKW with 2 speed propeller transfer case, it is relatively easy to convert from Oberdorfer belt driven gear pump to Gould chain driven self-priming centrifical pump. Much maintenance will be eliminated and safer operations result from the conversion. The following parts are the minimum required to make the change. Until such time as they are available, all modifications to Oberdorfer forward pump system as covered in Section II TB ORD 5 should be thoroughly accomplished to insure the best possible results from the Oberdorfer system.

1-GM-2199846	Pump, Bilge Forward Assy. (GDP 2510-1½)
1-GM-2200901	Sprocket, Driven, Forward Bilge Pump
1-GM-2200902	Sprocket, Drive, Forward Bilge Pump
4-GM-2103149	Bolt, Forward Bilge Pump Drive, Sprocket to Hub
1-GM-2200830	Hub, Forward Bilge Pump Drive Sprocket
1-GM-2200471	Chain, Drive, Forward Bilge Pump Assy.
1-GM-2202737	Bracket, Hanger, Forward Bilge Pump (GDP-232-107)
1-GM-2200834	Bracket, Support, Forward Bilge Pump Assy.

51. *Central Tire Control Hub Fittings*: (This applies to DUKWs with compressor in forward compartment, having all built-in parts of central tire pressure control but shipped short of external linkage from hull to wheels). Kit is available under FS MWO G-501 W-23, containing all parts necessary to complete installation.

52. *Front Brake Hose Protectors*: (This applies to all DUKWs.) Kit is available under G-501 W-28. This kit not only protects front brake hose from wire or other damage, but by its cutting action, will clear wires which might otherwise damage external tire control linkage when wrapping around front wheels. The kit eliminates the otherwise advisable precaution of shutting off front brakes before operating in wire-strewn areas.

53. *Steps in Preparing DUKWs for Operation after Modifications are Completed*:

a. Record vehicles by W number on Maintenance Schedule.

b. Log Book (Form #7255) installed on each vehicle.

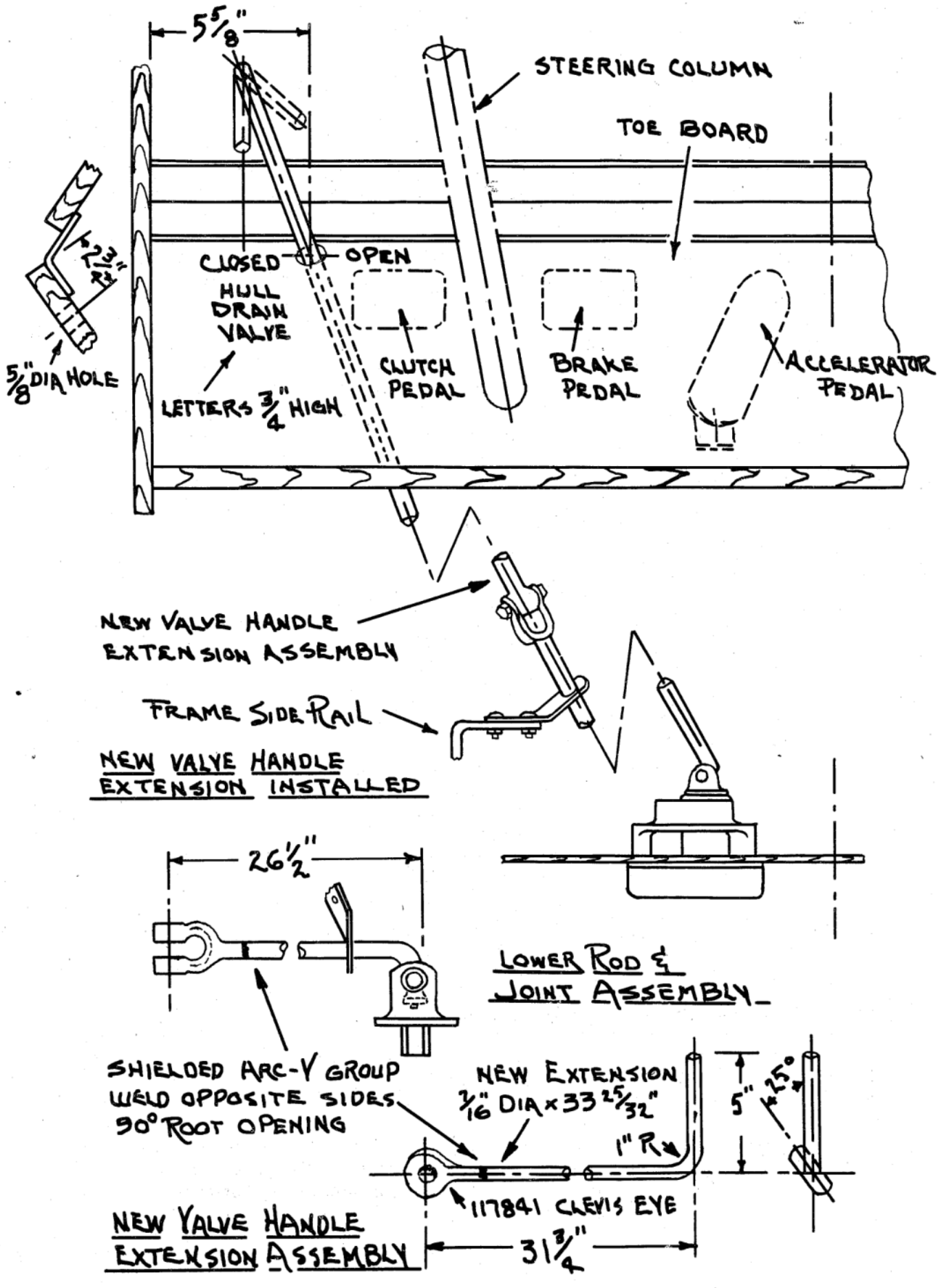
c. Issue of vehicle to driver and his assistant.

d. Assignment of mechanic to specific vehicles, so that each mechanic will be responsible for the maintenance of his 4 or 5 vehicles.

e. Make up Preventative Maintenance Schedule, by vehicle organization number, as suggested in paragraph 67.

f. (1) Unpacked crates, be sure to police up all nails and steel straps, as they will damage tires and brake hoses if left lying around DUKW parking area.

(2) Check and stow all equipment in correct places. Make list of shortages.


5 5/8"
STEERING COLUMN
TOE BOARD
2 3/4" R
CLOSED
OPEN
HULL DRAIN VALVE
5/8" DIA HOLE
LETTERS 3/4" HIGH
CLUTCH PEDAL
BRAKE PEDAL
ACCELERATOR PEDAL
NEW VALVE HANDLE EXTENSION ASSEMBLY
FRAME SIDE RAIL
NEW VALVE HANDLE EXTENSION INSTALLED
26 1/2"
LOWER ROD & JOINT ASSEMBLY
SHIELDED ARC-V GROUP WELD OPPOSITE SIDES 90° ROOT OPENING
NEW EXTENSION 3/16" DIA x 33 25/32"
1" R
5"
25°
117841 CLEVIS EYE
NEW VALVE HANDLE EXTENSION ASSEMBLY
31 3/4"

g. Install windshield.

h. Inspect hull, chassis and associated parts for leaks and damage.

i. Wire brush, clean and repaint all rust spots.

j. Install three hull bottom plugs and two (three if were removed) drive shaft housing plugs.

k. Remove four hull drain valve emergency plugs and install in rack inside engine hatch. These plugs are *not* to be used as long as hull drain valve are in working condition.

l. Remove all wire lashings, tape and cloth from winch cables and hook.

m. Unwind winch cable and clean off grease. Then give cable a coat of rust preventive thin film (or Navy Tectyl 506) rewind it and secure hook to winch cable guide.

n. Remove valve cores from tire valve stems, stow them in spare parts container inside engine hatch. (DUKWs with central tire control are shipped with valve cores temporarily in place.)

o. Scrape paint from black out and black out marker lights, but leave reflectors painted.

p. Fill grease gun and oil can.

q. Oil pintle hook parts until they work freely.

r. Remove, grease and replace gas tank hull drain plug. Drain any water from gas tank.

s. Check that exhaust manifold heat control valve is in "off" position.

t. Remove and clean fuel pump filter and drain main fuel filter.

u. Remove tape from generator, air cleaner, etc. in engine compartment.

v. Remove tapes over both bilge pump discharge holes, etc.

w. Close cab heating doors at lower front sides of cab.

x. Drain any water from air tank.

y. Check on tightness of coupling bolts on drive shafts between transmission and transfer case. Tighten if necessary.

z. Check that exhaust recirculation ducts are in closed position. These two ducks can be reached at each end of the air intake aisleway by removing the square plate with four Phillips screws on the inner side of the coaming.

aa. Clean bilges, remove all wood splinters, paper, rags, etc.

bb. Clean dashboard instruction plates and instruments as necessary.

cc. Weld extension bolt on flush drain plug in air compressor base.

dd. Secure organizational spare parts in accordance with SNL G-501.

ee. Perform monthly (1000 mile) maintenance check. While wheels are removed, treat brake parts as outlined in next paragraph below.

54. *Protection From Corrosion*: (Applies to all DUKWs.) Steam clean the vehicle thoroughly inside and out, remove any loose paint, prime and touch-up paint job, and then coat thoroughly with Rust Preventative Thin Film or Navy Tectyl 506. This is the one and only way to keep ahead of rusting difficulties. It should help insure a longer life for the light sheetmetal hull. It is not advisable to use this treatment in the bow compartment, in the engine space, or in the stowage space below the rear deck (those parts of a new DUKW that are painted white.) It is particularly important to include with this treatment all parts of the brake mechanism except the surfaces of the linings and the braking surface of the drums. Pins, springs, cylinders, backing plates, shoes, etc., etc., should be treated. In treating the wheel cylinders, they should be sprayed when they are in the retracted position. After rust preventive has dried, the wheel cylinders should be expanded to the normal "on" position and the exposed parts under the lip of each cap should be coated with a mixture 1/3 white lead and 2/3 water pump waterproof grease.

This mixture can also be put around the threaded portions where the stem comes out on each wheel cylinder cap. By careful treatment of the hull and also the brake parts as outlined, many hours of maintenance will be saved, the DUKW's life will be lengthened and the brakes will be more dependable.

55. *Winch Drag Brake Adjustment and Protection*: Disassemble and mask surface of band and braking surface. Paint thoroughly with Rust Preventive Thin Film or Navy Tectyl 506. Cover threads below adjusting nuts with mixture 1/3 white lead, 2/3 water pump grease. When the winch power take off in the driver's compartment is in neutral, and the winch jaw clutch on the rear deck is in the disengaged position, the winch shaft should rotate freely in the "forward" direction, but should be noticeably stiff in reverse. Make the test in the rear hatchway. With clean hands and clean shaft, it should be relatively easy to rotate the shaft forward with one hand. In the reverse direction it should be *just possible* with *one hand*, but still reasonably easy with *two* hands. Don't set the drag brake too tight or it will overheat and be damaged when paying out cable. Spray nuts and spring with rust preventive after an adjustment is completed. Check adjustment weekly, and always before using "A" frame.

56. *Protection of Propeller Shaft and Three Winch Drive Shaft Steady Bearings*: Using mixture of 1/3 white lead and 2/3 water pump grease, pack around outside of above bearings without disassembling, to exclude bilge water and spray which otherwise may get into and damage bearings. Make this part of regular weekly check.

57. *Naming and Numbering DUKWs*: Name as selected by driver and number and other markings shall be neatly painted on each side as directed.

58. *Air Outlet Shutters*: (Applies to all DUKWs.) Refer to pages 42, 43 and 44 in TM 9-802, 1 September 1943; also Section III, TB ORD 5. These air outlet doors are installed for only one purpose, that of preventing the escape of engine-discharged hot air at such times as this air is needed to heat the rest of the hull and the pump system to prevent dangerous formation of ice. Occasionally the shutters may also be used when the DUKW is being sealed for long overseas shipment or storage in an exposed area. At all other times the outlet shutters must be *hooked fully open*. The shutters are *not* intended to close temporarily during passage through heavy surf. The exhaust air keeps out most of the water and any that may get in at that point will not cause trouble. On the other hand, if the shutters are closed or partly closed, engine cooling will not be satisfactory and serious damage may result, not to mention discomfort to crew. The right procedure is to open the shutters wide and then turn the catch at each end of each shutter and allow the catches to come down over the pin at the end of each shutter, after which it is physically impossible for the shutter to shut by itself.

59. *Stowage of Oil Can in Driver's Compartment*: (Applies to DUKWs 001 to 4201) As oil must be applied to many points at frequent intervals, the relocating of oil can from engine compartment to driver's compartment is recommended. Remove the oil can and bracket from engine compartment, then mount bracket and can in driver's compartment on dash, just to the right of the lower corner of map compartment.

60. *Stowage of Grease Gun in Driver's Compartment*: (Applies to DUKWs 001 to 4201) To facilitate frequent lubrication of important pressure fittings, grease gun should be stored in driver's compartment. Using a suitable bracket, mount it on underside of gunner's seat.

61. *Stowage of Jack in Engine Compartment*: (Applies to DUKWs manufactured in 1943.) Early vehicles had no special location for the jack. On later vehicles the jack

was to be clamped in a bracket fitted to right frame side rail below air intake grating, where it was frequently rendered inoperative by water damage. The jack should be secured in the left front corner of engine compartment, using clamp from frame side rail on a ½x1x6 inch block, or using canvas or metal strop where clamp is not available. Clean, lubricate and paint jack to make operative before storing in engine space.

62. *Cargo Floor Beam Reinforcement*: (Applies to DUKWs 001 to 4650.) The three transverse cargo floor angle (channel) supports in chassis below No. 6450 may become bent as a result of dropping heavy cargo on the floor. These supports should be reinforced by adding ⅛x1 inch angle iron or similar leg-struts from frame rails. Weld the reinforcements in place. If metal reinforcements are not available the supports can be reinforced by using 1½ inch square hardwood legs.

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CHAPTER V

PREVENTIVE MAINTENANANCE AND OPERATIONAL SAFEGUARDS

63. *Assignment of Vehicles*: Each DUKW and its equipment must be assigned to a driver and assistant driver who will be held responsible for same. Driver and/or assistant will be on their DUKW whenever it is operated.

64. *Daily Preventive Maintenance*: Daily preventive maintenance duties are described in TM 9-802. The important items are covered by a dashboard instruction plate reproduced herewith. It is the duty of the driver (assistant driver if driver is not present) to accomplish these items.

MINIMUM DRIVER DAILY MAINTENANCE

Refer to TM 9-802 and Lubrication Order #505 for Details

BEFORE OPERATION—or on relieving another driver—
CHECK Fuel, oil & water—In engine, tire pump, & spare cans.
LUBRICATE V-strut—**CHECK** rudder, propeller, hull, tires, & equipment.
CHECK that all drain plugs & valves, seals & hatches are **tight.**

DURING OPERATION—at halt or traveling light—
CONSTANTLY CLEAN cargo space, bilges, and pump intakes.
LUBRICATE propeller stuffing box and V-strut. **CHECK** fan belt tension.
OIL all joints, pivots, bolts, hinges, clamps, wing nuts, shackles, pintle hook, switches, controls, etc., inside and outside of hull.

AFTER OPERATION—or before turning over to relief driver—
CLEAN & DRAIN bilges, pump intakes, and drive shaft hsgs. **OIL** pump chains.
REPLACE plugs. **CLOSE** drain valves. (Except in freezing weather).
CLEAN AND CHECK rudder, propeller, hull, seals, tires and fenders.
LUBRICATE V-strut, inter-axle shaft (3), front springs (6), drag link (2), tie rod (2) tire inflation hubs (6), bilge pumps (2), stuffing boxes (2).
OIL outside of front axle "U" joints. **CHECK** oil level in air cleaners.
REFILL fuel, oil, & water—In engine, tire pump & spare cans.
CHECK AND STOW tools & equipment. **CLOSE** hatches. Rig cab tarpaulin.

Daily Maintenance Plate

65. *Assignment of Mechanics*: To provide direct control of details of preventive maintenance and general operating conditions of each DUKW, it is recommended that a group of 5 DUKWs be assigned to each of the 10 best company mechanics. The driver and assistant driver of each of the 5 DUKWs in a given group will be under the direction of the assigned mechanic in all matters of mechanical nature. The assigned mechanic will then be directly responsible for mechanical condition and all scheduled preventive maintenance of his 5 DUKWs.

66. *Weekly Preventive Maintenance*: Weekly preventive maintenance duties are described in detail in TM 9-802. The important items are covered by a dashboard plate

reproduced herewith. It is the duty of the driver and assistant driver, with help from, and under the direction of, the assigned mechanic, to accomplish these items at the scheduled time.

MINIMUM DRIVER WEEKLY MAINTENANCE

Refer to TM 9–802 & Lubrication Order #505 for Details

DRAIN water from fuel tank & filter, & **CHECK** system for leaks.
CHECK fuel, oil, & water—In engine, tire pump, and spare cans.
CHECK oil level in transmission, main & prop. trans. cases, winch worm hsg.
OIL hand and foot throttle, choke, starter linkage & 2 cups on tire pump.
LUBRICATE controls for main & propeller transfer cases, brakes & clutch.
LUBRICATE V-strut & bilge pumps, **CHECK** drain valves & plugs all tight.
CHECK battery water & crankhouse & carb. Air cleaners—Clean radiator.

MAKE LAND TEST RUN. CHECK foot brakes & compass adjustment.
CHECK idling speed for 510 R.P.M. **CHECK** for loose manifold nuts.

MAKE WATER TEST RUN. CHECK for leaks. **CHECK** operation of pumps.
CHECK for 2350 minimum R.P.M. & not over 185° temperature at full throttle.

CLEAN & drain bilges, **LUBRICATE** 3 "U" joints through housing drains.
CHECK 4 breather tubes, 6 housing seals & inter-housing drain.
REPLACE plugs, **CLOSE** drain valves. **REMOVE ANY WATER** in pillow block, differentials and front axle "U" joints. **CHECK** lubricant levels.
LUBRICATE V-strut, inter-axle shaft (3), front springs (6), drag link (2), tie rod (2), tire inflation hubs (6), bilge pumps (2), stuffing boxes (2).
GREASE 3 winch points—**OIL** & **REWIND** cable. **OIL** pump drive chains.
CLEAN & paint rusted parts. **CLEAN** & **OIL** outside of front axle "U" joints.
CHECK & **STOW** tools & equipment. **CLOSE** hatches. **RIG** cab tarpaulin.

Weekly Maintenance Plate

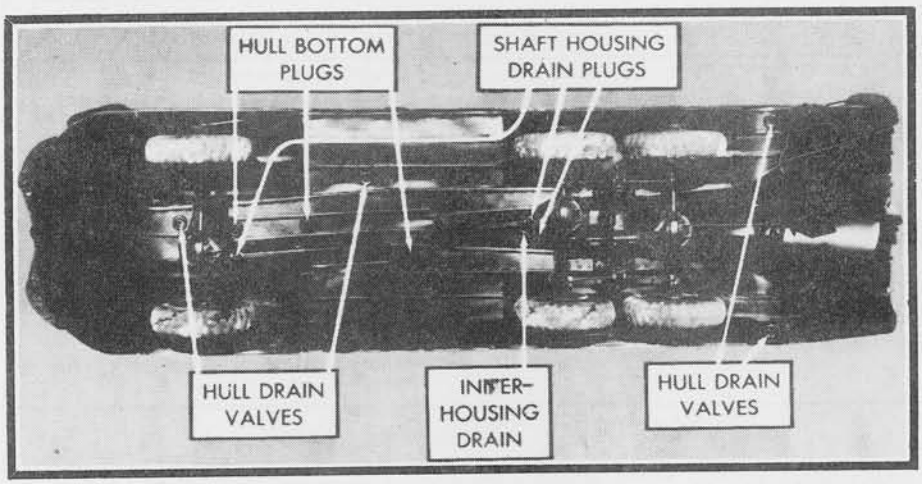
67. *Scheduled Maintenance and Numbering of DUKWs*: In order that maintenance facilities will not be overtaxed by necessity of servicing too many DUKWs at any given period, it is necessary to set up a schedule as shown on next page, for assigning specific times for accomplishment of weekly, monthly and semi-annual preventive maintenance. Details of all maintenance operation are given in TM 9-802 and Lubrication Order #505. To use schedule as shown, the DUKWs in each company should be numbered from 1 to 50.

SUGGESTED SCHEDULE FOR PREVENTIVE MAINTENANCE

	MON.	TUE.	WED.	THURS.	FRI.	SAT.	SUN.	MON.	TUE.	WED.	THURS.	FRI.	SAT.	SUN.	MON.	TUE.	WED.	THURS.	FRI.	SAT.	SUN.	MON.	TUE.	WED.	THURS.	FRI.	SAT.	SUN.	MON.	TUE.	WED.	THURS.	FRI.	SAT.	SUN.
6 MONTH PREVENTIVE MAINTENANCE (REPEAT EVERY 28 WEEKS)	1							3							5							7							8						
	2							4							6														9						
1 MONTH PREVENTIVE MAINTENANCE (REPEAT EVERY 4 WEEKS)			8	15	22	29	36	43		10	17	24	31	38	45		12	19	26	33	40	47		14	21	28	35	42	49		1	15			
			9	16	23	30	37	44		11	18	25	32	39	46		13	20	27	34	41	48							50		2	16			
WEEKLY PREVENTIVE MAINTENANCE	3	10	17	24	31	38	45	1	8	15	22	29	36	43	1	8	15	22	29	36	43	1	8	15	22	29	36	43	3	10	17			
	4	11	18	25	32	39	46	2	9	16	23	30	37	44	2	9	16	23	30	37	44	2	9	16	23	30	37	44	4	11	18			
	5	12	19	26	33	40	47	5	12	19	26	33	40	47	3	10	17	24	31	38	45	3	10	17	24	31	38	45	5	12	19			
	6	13	20	27	34	41	48	6	13	20	27	34	41	48	4	11	18	25	32	39	46	4	11	18	25	32	39	46	6	13	20			
	7	14	21	28	35	42	49	7	14	21	28	35	42	49	7	14	21	28	35	42	49	5	12	19	26	33	40	47	7	14	21			
							50							50							50	6	13	20	27	34	41	48						
AVAILABLE DUKW EACH DAY	43	41	41	41	41	41	42	43	41	41	41	41	41	42	43	41	41	41	41	41	42	43	42	42	42	42	42	42	41	43	41			

68. *Monthly and Semi-Annual Preventive Maintenance*: Monthly and semi-annual preventive maintenance will be accomplished by the maintenance personnel with the driver and assistant driver in attendance, ready to offer any necessary assistance. Time not needed for actual mechanical work will be devoted to cleaning and painting the vehicle.

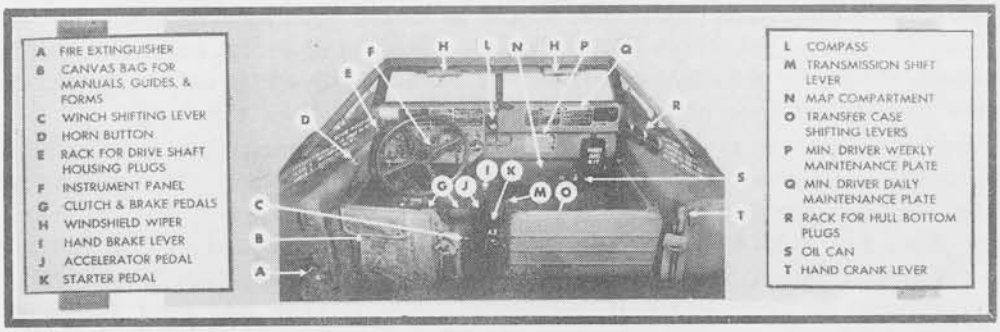
69. *Fire Caution*: The DUKW hull is a tight unit. Gasoline which leaks, or which may be spilled inside the hull, becomes a serious fire hazard. Any gasoline which has spilled or which has leaked into the hull must be cleaned up promptly and thoroughly. The hatches should be opened and the floor boards removed to allow all possible ventilation. Follow the advice given on the various warning and instruction plates. The fire extinguishers must be kept full and in good working condition. Smoking is never permitted on a DUKW when it is in the water.



70. *Clean Bilges*: It is of the utmost importance that bilges be kept clean. Any rubbish, dirt, or other foreign matter dropped in the vehicle eventually will get into the bottom of the hull unless it is cleaned up promptly. This material, if allowed to remain in the hull, is likely to get into pump intakes, drain valves, radiator core, and other key positions where it may cause damage serious enough to sink the DUKW. Sand is constantly carried aboard by personnel or with cargo. It must be cleaned out immediately to protect the pumps and to insure their satisfactory operation. When cleaning bilges, particularly when afloat, the hull should be checked for leaks. If any leaks are found their location should be noted so that maintenance crew may attend them at once.

71. *Drain Valves and Plugs*: All DUKWs are fitted with three (3) 3" diameter hull bottom plugs and three (3) 1½" diameter shaft housing drain plugs. In addition, all DUKWs whose manufacturers' number is above 2006, have four (4) hull drain valves. Before DUKWs are taken into the water, all bottom openings must be carefully checked to insure proper installation of plugs. At no time should the large bottom plugs be left out. They may be removed only temporarily for draining oil or cleaning center bilge. As a precaution, any plugs removed must be placed in racks in windshield base (see paragraph 42 and accompanying drawings) to remind the driver to install them before operating the vehicle. The three (3) 1½" diameter shaft housing drain plugs must be removed and replaced for weekly lubrication of "U" joints. They must also be removed to drain

housings after operation or immediately on leaving water when the temperature is below freezing. In chassis which have a manufacturers' number above 3620, the upper rear housing drains automatically through the flexible tube to the lower housing. Also in all vehicles, when the center bilge is dry, forward housing will empty itself out of its rear end into the hull when the vehicle is climbing up out of water. On leaving the water, the four (4) hull drain valves should be opened to drain the hull. (See paragraph 42.) As soon as the hull is drained the four valves should be closed. All four (4) valves should be kept in open position when the vehicle is being stored or shipped. In the event of valve failure, the hole in the drain valves is tapped to permit emergency use of the small screw plugs, which are located in the rack on the left side of the engine space. The defective valve should be repaired or replaced as soon as possible.



Driver's Compartment—Note plug racks "E" and "R"

72. *Over-Heating*: The cooling system of a DUKW *differs fundamentally* from that of a truck. The motion of the DUKW does not force air through the radiator, as is the case with a truck. All the cooling in a DUKW is accomplished by the engine fan. To secure adequate engine cooling in hot weather, all parts of the cooling system must be properly maintained. Proper functioning of the cooling system eliminates the necessity of opening the auxiliary air intake or box hatch. Both of these, when open, admit salt water which damages many parts of the engine, exhaust, and electrical system. To insure maintenance of cool engines, personnel should:

a. Maintain proper fan belt adjustment.
b. Keep radiator filled.
c. Keep surge tank half filled where no anti-freeze is used.
d. Keep air intake passages clear. Carry no cargo, equipment, or personnel on intake grating. Keep space below grating clear. Stow tarpaulin bows in bow compartment and not below intake grating.
e. Keep air outlets clear and outlet shutters latched fully open.

73. *Fan belt Adjustment*: Fan belt adjustment must be checked daily. Most overheating, and also fan belt wear, is caused by slipping of a fan belt that is too loose. A belt that is too tight will wear out water pump and generator bearings. The correct tension can be judged by turning the fan when the engine is stopped. Using one finger on the uppermost blade, it should be just comfortably possible (10 pounds pressure) to turn the top blade toward the right side of the DUKW. If it is difficult to move the fan, the belt is too tight. If the fan turns easily check that belt and pulleys are clean of oil and grease, and then tighten as necessary.

74. *Turning Off Engine*: Before turning off the ignition the engine should be allowed to idle slowly for 30 to 40 seconds. This action will overcome the tendency of the motor to continue to run, and will prevent damage to the early type of exhaust manifold from sudden cooling.

75. *Valve Adjustment*: The correct setting for exhaust valve rocker arm clearance is .016". Intake valves should be .012" as originally.

76. *Governor Adjustment*: No-load maximum speed with engine at approximately 180° temperature should be 2750—2900 RPM. Set carburetor stop screw to give 510 RPM idle speed.

77. *Front Spring Breakage*: This trouble has largely been the result of excessive tightening of rear bracket pin. The nut on this pin should be pulled tight and then backed off ½ or ¾ turns in which position it should be locked with a cotter pin.

78. *Keep Decks and Coamings Water-Tight*: All leaks in decks, coamings, particularly rear corners, should be promptly repaired. Winch cable guide hole covers in rear coaming and below windshield be kept in place and tight, except when winching.

79. *Remove Water from Fuel System*: Rough water operation, particularly when heavily loaded, will result in some water getting in fuel system. The following steps should be taken to eliminate trouble:

a. Keep fuel tank cap and its gasket in good condition, and so that it fits tightly when in place. Replace cap if necessary.
b. Weekly, or more often if necessary, after DUKW has been standing, drain enough from tank to eliminate water. Grease hull drain plug before replacing.
c. Weekly, or more often if necessary, drain filter, by removing base plug. Be certain to catch fuel in container. Do not allow any fuel to drain into hull bottom. Monthly, clean filter by disassembling .
d. Weekly, clean fuel pump. Be certain to catch any fuel that is spilled with suitable rags or container. Do not allow any fuel to get into hull bottom.
e. Monthly, clean out carburetor float chamber.
f. Always prime system by operating hand extension on fuel pump for about one minute after above cleaning operations. Also prime after running out of fuel, and after vehicle has been idle for over four days.
g. After above six items have been completed, carefully check entire fuel system to make sure there are no leaks—before starting engine.

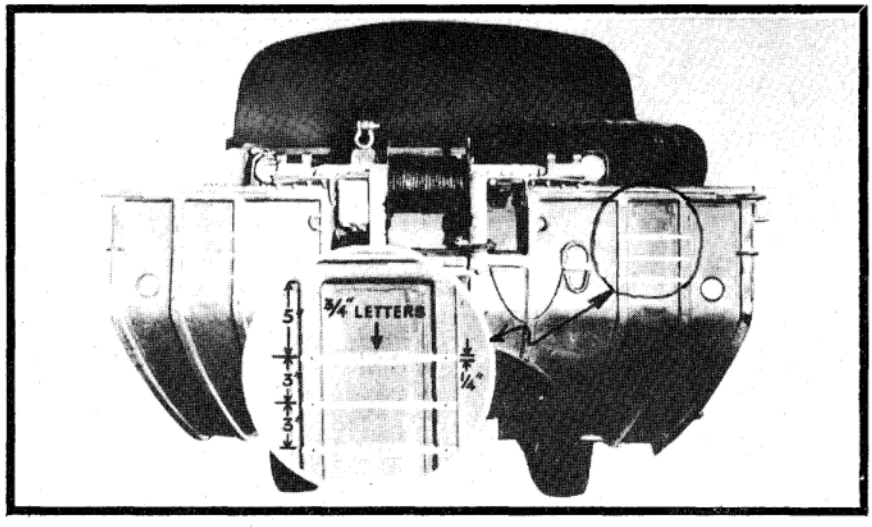
80. *Propeller Damage*: If propeller or shaft is damaged this results in excessive vibration. Operation of propeller in this condition is certain to result in additional damage to shaft, bearings, V-strut, hull, fuel tank or steering gear.

81. *Lubrication of "U" Joints Through Housing Drain Plugs*: All DUKWs with chassis numbers above 3325 have pointers below aisleway (visible from driver's seat) which enables the driver to stop in the right position so "U" point lubrication fittings will be accessable through drain plugs. The markings for rear "U" joints painted on forward *edge* of emergency brake drum, 1 mark for each joint (Unless they happen to be positioned so they can both be lubricated at one position). The mark for front "U" joint is pointed on a knuckle of the inside front "U" joint. These marks should be repaired clearly if obliterated, and should be added on old DUKWs not so marked.

82. *Preparation for Storage or Shipment*: It is very important that all parts particularly subject to salt water damage be thoroughly serviced before periods of infection. These parts would include brakes, winch drag brake, wheel bearings, pillow block (on

front rear axle) differentials, front axle "U" joints. It is desirable that DUKWs be loaded *dry* after servicing, when they will be on shipboard for a long time; where they must be loaded wet, if space permits, servicing should be done after loading.

83. *Maintenance During Advance Operations*: During an operation in which DUKWs are employed, the DUKW maintenance unit should establish itself at a suitable point as soon as possible. The best point is at the DUKW Assembly and Bivouac Area (see paragraph). If conditions ashore do not permit this, then it should be established on board an LST or other ramp landing craft. The maintenance personnel should have with them all the tools which their table of equipment authorizes, and all spare parts considered necessary to keep their DUKWs running for the duration of the operation. One DUKW from each company can be assigned to the maintenance section, and fitted up with work bench and parts and tool cabinets. By this means, a highly mobile repair shop will be available for minor emergency repairs at any desired point afloat or ashore.



Details of Load Markings

84. *Fueling During Advance Operations*: Before permanent shore fuel tanks are installed, the most efficient method of refueling DUKWs during an operation is by five gallon jerricans. When a DUKW refuels in this manner empty cans must be returned to the source of supply. When possible, operating DUKWs should refuel at the "cushion" at DUKW Control Point (See paragraph 133). Non-operating DUKWs can refuel at the DUKW Assembly and Bivouac Area. When gasoline is not available on shore, DUKWs can be refuelled on the tank deck of an LST, or at shipside by lowering cans to them. (See paragraph 200).

85. *Rudder Cable Wear*: At time maintenance, rudder cable should be cleaned carefully and inspected closely at all sheaves and spool while steering is turned from full left to full right. If broken strands or rust are found, cable must be replaced. After inspections, lubricate 6 rudder cable sheaves, and cable in way of sheaves and steering column spool. At point where cables are attached to tiller level, wires must be in grooves of thimbles. To prevent wire coming out of thimbles, nearest wire rope clamp must be secured within ¼" of ends of thimbles.

86. *Care of Life Presevers*: The life ring should be hung on hook on front face of forward cargo bulkhead. It should have 50 feet of clothes line attached to it, and neatly coiled, with coil hanging over life ring. This line serves to pull life preserver and person to whom it may be thrown, back to the DUKW. The three (3) jacket type life preservers must be kept out in the air and dried whenever possible to prevent their getting water-logged and rotten. Tie them to the cab top bow on each side above the aisleway when not in use. Do not stow them in the bilge where they get little ventilation and will quickly become water-logged and rotten.

87. *Spare Parts*: When spare parts are not available for deadline vehicles consideration should be given to removing parts off a DUKW or other vehicle that may be beyond repair. Frequently it will be found that parts from captured enemy equipment may be used.

Load Markings (See paragraph 157).

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CHAPTER VI
LAND OPERATIONS

88. *General*: When on land, the DUKW has the uses and characteristics of a conventional 2½-ton, 6x6 truck, and is operated in the same manner. It has six driving wheels propelled by a six cylinder engine through the transmission, transfer case, and shafts. Instead of dual wheels on the rear and intermediate axles, the DUKW is equipped with single wheels. All six wheels are mounted with 11.00/18-10 ply desert type tires.

89. *Road Operations.* a. *Starting*: When starting the vehicle from a dead stop, the selection of the proper gear combination together with the proper operation of the clutch is most important. The following table gives the correct gear combination under various conditions:

DUKW Load	*Terrain*	*Gear*	*Range*	*Front Wheels*
Light load or empty.	Level road	2	High	Out
Light load or empty.	Up grade or in hole	1	High	Out
Heavy	Level road	1	High	Out
Heavy	Level, but off the road	2	Low	In
Heavy	Up grade or in hole	1	Low	In
Empty or loaded.	Wheels stuck in sand or mud	1	Low	In

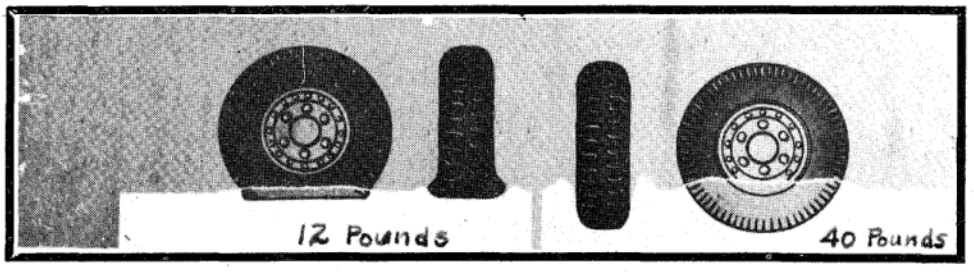
b. *Speeds*: Maximum speeds for each gear are indicated on the caution plate in the driver's compartment. Operators must keep below the maximum speed for each gear. They must also shift to a lower gear before the engine goes below 1200 revolutions per minute.

c. *Stopping*: The driver should learn to slow down well in advance of coming to a halt by releasing pressure on the accelerator and leaving the clutch engaged. The brakes should then be applied firmly but *gradually*. The clutch should not be disengaged until the DUKW has almost stopped.

90. *Operation On Hills.* a. *Uphill*: Before starting uphill the gear which will bring the DUKW to the top should be engaged. If the engine stalls on a steep hill, the driver will apply the foot brake and set the hand brake, shift into neutral and start the engine. Then, if necessary, he will shift into reverse and back down the hill. The driver will never step on the starter when the vehicle is rolling backward and the gears are engaged, even if the clutch pedal is down.

b. *Downhill*: The driver will use the same gear in driving down a hill that would be used in driving up the same hill. On grades over 30% the lowest gear should be used. Whatever gear is used, the speed will be kept down to or below the maximum speed shown on the dash plate for the gear being used. Apply brakes at intervals, only as needed. Coasting downhill with the clutch depressed or with the transmission in neutral is dangerous. Drivers will not attempt to change gears after starting downhill.

91. *Convoy Operations.* a. Safe Distances in Column: Under normal road and weather conditions, the distance in yards between vehicles in a motor convoy will be twice the driving speed. For example, at 25 miles per hour, there should be a distance of 50 yards between vehicles. Under actual or simulated battle conditions, no vehicle will be within 75 yards of any other vehicle.



At 12 pounds tire travels over sand—at 40 pounds it sinks in

b. *Blackout Lamps*: In convoy driving at night, under blackout conditions, the blackout marker lamps are of great assistance in estimating the distance between vehicles.

(1) The two rear lamps are divided into four parts each making eight parts in all. When the vehicle ahead is less than 60 feet away eight lights are visible; between 60 and 180 feet, four lights are visible; between 180 and 800 feet, two lights are visible; beyond 800 feet no lights are visible.

(2) The two front marker lamps are visible as four up to 60 feet; from 60 to 800 feet they appear as two; beyond 800 feet they are invisible.

c. *Rear End Collisions*: Dangerous leaks in the bow and broken winches result from rear end collisions. Such collisions are entirely due to careless driving. They can be avoided altogether if drivers will observe the following rules:

(1) When driving in convoy, do not come any closer than the proper convoy distance.

(2) *Before* starting up a hill, engage the gear which will take the DUKW to the top.

(3) When applying the brakes, apply them *gradually.*

(4) When about to slow down, stop or reverse, give a signal which will be clearly seen and understood by the driver in the vehicle behind.

(5) Always be on the lookout for signals from the vehicle in front. When a signal is seen, act at once, and pass on the signal to vehicle behind.

92. *Sand Operation*: a. *General*: Due to the suitability of its tires, the DUKW has exceptional ability to operate in difficult sand conditions.

b. *Front Wheel Drive*: For all soft sand operation the front wheel drive must be engaged.

c. *Tire Pressure*: Wherever soft sand is encountered, correct tire pressure must be used, in accordance with instructions on the dashboard. If tires have been deflated for sand operations, they must be inflated to 40 lbs pressure before the DUKW is parked for any length of time.

d. *Avoid Spinning Wheels*: With tires properly deflated, travel over the sand with full power. Do not "dig in." If progress stops, disengage the clutch immediately, then back out and make another try in a better place.

e. *Grades and Turning*: Difficult sand grades, up or down, should be negotiated straight and square. Keep rolling fast over sharp ridges, to avoid being straddled on the crest. The front wheels must be kept *dead straight ahead* to get maximum traction while going through a bad patch of soft sand.

f. *Follow the Leader*: Once the best available path has been picked by the leading DUKW, those behind should follow in the same tracks.

93. *Difficult Terrain*: a. *General*: Tree stumps, sharp rocks, etc. must be avoided. Soft deep mud and swamps should always be avoided, since no wheeled vehicle can operate in them.

b. *Wire*: In operations where wire may be encountered, the front brake shut-off cock must be closed. It is located on the right frame side rail below the middle of the driver's compartment. This is not necessary on vehicles which have been equipped with wireproof front brake hose protectors. Around dumps, the driver will be particularly careful of the steel bands which are used as cargo binders.

c. *Shapnel*: After bombings, naval bombardments, etc., the ground is littered with shrapnel fragments. These are very harmful to tires and will be avoided whenever possible.

94. *Goggles*: When roads are dusty, DUKW drivers can operate more efficiently if they are provided with dust proof goggles.

95. *Removal or Installation of Wheel and Axle Shaft*: To facilitate the changing of tires and the removal of axle shafts, the following procedure will be followed:

a. *Removal of Wheel and Tire.*

(1) Close individual valves at side of gunner's seat.
(2) Remove wheelhouse cover.
(3) Remove cover over hub unit to valve stem hose.
(4) Disconnect hose from valve stem and insert core in valve stem.
(5) Back off 3 hub unit mounting set screws, pull off hub unit and hang it on side of hull.
(6) Stamp end of wheel mounting stud next to valve stem with a numeral "6".
(7) Remove wheel and tire.

b. *Installation of Wheel and Tire.*

A fixed relation must be maintained between valve stem, wheel mounting stud, and the 3 special extended hub unit mounting bolts in axle flange.

If axle flange has not been removed, and if wheel mounting stud next to valve was stamped "6" before removal of wheel, proceed as follows:

(1) Mount wheel with valve next to #6 stud, and tighten wheel nuts.
(2) Replace hub unit and tighten 3 mounting set screws.
(3) Remove valve core from valve stem and immediately connect hose (from hub unit) to valve stem, hand tight. *Do not use pliers.*
(4) Replace cover over hub unit to valve stem hose.

(5) Replace wheelhouse cover.

(6) Open individual valves at side of gunner's seat.

c. *Installation of Axle Shaft & flange.*

In order to maintain the correct relation between 5 axle flange cap screws, 3 special extended hub unit mounting bolts, wheel mounting studs, and valve stem, *positions of certain of these should be marked before disassembly as follows*:

Before removal of wheel and tire, wheel mounting stud next to valve stem should be stamped "6".

Before removal of any axle flange fastenings, positions of the 3 special extended hub unit mounting bolts should be located by prick punching hub (not axle flange.)

d. *If shaft has been removed before marking or if marks have been obliterated,* proceed as follows:

(1) Before installing axle shaft and flange locate #1 wheel mounting stud in following manner: Select the 2 diametrically opposite wheel studs and the 2 diametrically opposite tapped holes in hub all of which are in line with each other and calling either of these wheel studs #1, #6 wheel stud will then be the 1st stud counter clockwise and if not marked should be stamped "6".

(2) Identify axle flange tapped holes in hub as 1 to 8 clockwise, #1 being nearest #1 wheel mounting stud. Mark hub with prick punch adjacent to tapped holes 1, 3 and 6 so that punch marks will be visible after axle shaft and flange have been installed.

(3) Install axle shaft and flange. Assemble the 3 special extended hub unit mounting bolts in punch marked positions (1, 3, 6) in hub, install regular cap screws in remaining five tapped holes.

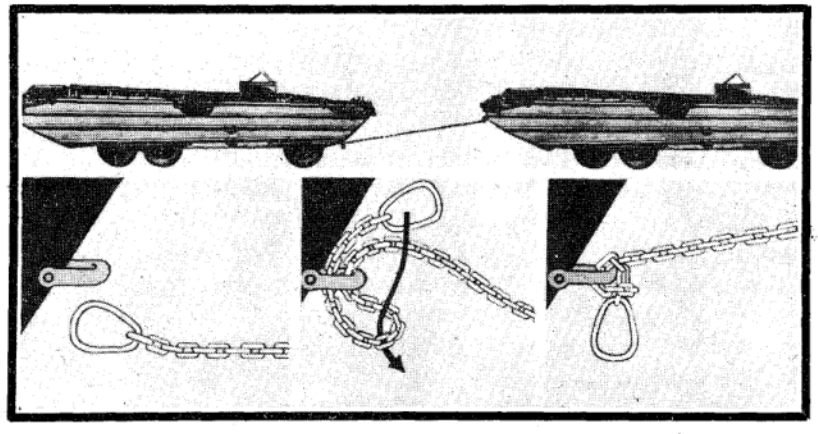
CHAPTER VII

WINCHING OPERATIONS

96. *General*: a. A thorough knowledge of winching techniques, circumstances in which the winch may be used, and methods of rigging are very important. The winch, because of its great power, can be of assistance under many conditions. Its main uses are to enable a DUKW to extract itself when stuck, to assist another vehicle when it is stuck, to refloat a beached landing craft, and for lifting, loading and unloading in conjunction with an "A" frame.

b. The winch on the DUKW is basically the same as that on a regular 6x6 truck except that on the DUKW it is mounted at the stern. It can be used for pulling either forward or backward. When winching forward, the cable is led through the winch guides in the rear coaming and at the base of the windshield, and then through the bow fairlead. When winching astern, the cable leads directly from the drum.

Land Towing: Do *not* use the winch cable for land towing. Instead, use the tow chain from the stern pintle hook to one of the lower bow shackles on the other vehicle. See fig. below. Never secure to above deck bow cable fairlead. It is only a cast iron guide and is easily broken by attaching to it when towing.



Land Towing With Chain—Showing details of Securing Thru Bow Shackles

97. *Details of The Winch*: a. The winch is equipped with 150 feet of half inch galvanized cable (breaking strength approximately 18000 lbs.) The cable is protected by a shear pin which will shear when the load on the cable exceeds 10,000 lbs. The shear pin is located below the rear deck at the coupling where the winch drive shaft goes through the stern of the DUKW. Spare shear pins are in a rack close by. Each DUKW is supplied with snatch block, tow chain and 75 ft. auxiliary cable.

b. *Power Take-Off Lever*: The winch is operated by a power take-off lever on the left side of the transmission. It can be placed in high, low and reverse gears with two

neutral positions in between. The hinged locking plate attached to the cab floor must be down when the winch is not in use, to lock the lever in the neutral position between reverse and low.

c. *Sliding Jaw Clutch*: The sliding jaw clutch on the rear deck is used to engage and disengage the winch drum. When in the disengaged position (handle moved toward the left side of the DUKW) the winch drum will rotate freely on its shaft.

d. *The Drum Flange Lock*: The drum flange lock is mounted on the sliding jaw clutch handle mechanism. It can be made to engage one of several holes in the winch drum flange when the sliding jaw clutch is in released position. It thus prevents the cable from unwinding while the vehicle is operated, the jaw clutch being normally left in the disengaged position.

98. *Operating Cycle*: a. *Signals*: It is most important that at all times when the winch is in use, a signal man will direct the winch operator with a clear system of hand signals. He will stand in such a position that his signals can be seen by the operator, who will watch him all the time, and take directions from him only.

b. *To Hook Up*: To hook up the cable, the sliding jaw clutch lever must be in the disengaged position and the drum flange lock released. Pull out as much cable by hand as is needed for the desired hook up. A minimum of at least five turns must be left on the drum, or the end may pull out.

c. *To Wind In*: Engage the sliding jaw clutch. Then operate the winch by shifting the power take-off lever in the cab, using the clutch in the same way as when driving. High speed should be used to take up slack in a loose cable or for extremely light loads, and low speed should be used for heavy pulling. Before starting to wind in the cable, the cable already on the drum must be tightly and evenly wound. The assistant driver should watch the cable closely while it is being wound in, and guide it with the hand crank bar so that it winds evenly and does not kink or jam.

d. *Engine Operating Speed*: When using the winch, the maximum engine speed should be 1000 RPM or about 1/3 throttle. The winch mechanism and bearings will be damaged if higher speeds are used.

e. *To Stop*: To stop the winch, the driver should depress the clutch pedal and shift the power take-off lever to neutral.

f. *To Pay Out Cable*: Whenever the cable is under load, the winch power take-off must be shifted into reverse to pay out cable. However, if the cable is slack and if there is more than ten feet to be paid out, the cable should be pulled out by hand, by releasing winch jaw clutch. The paying out of cable must be stopped when at least five turns remain on the drum, otherwise the cable load will fall directly on the end attachment, and it will pull out.

g. *When not in use*: After the winch has been in use, the cable must be cleaned and well coated to prevent rust, and must be wound up evenly on the drum. The best protection for the cable is Rust Preventive Thin Film. The hook at the end of the cable is secured to one of the winch guides. The cable must not be passed around the winch guides.

99. *Rigging Methods*: a. *General*: When winching, use an adequate rig upon the first attempt. This will eliminate failures and save time and equipment.

b. *Winching Point*: The term "Winching Point" is applied to any fixed object to which the winch cable or rigging is attached during winching operations. The winching point should be as nearly as possible in line with the direction in which the stuck vehicle is to be moved. Winching points will include the following:

(1) *Other Vehicles*: The most practical winching point is one or more vehicles. They can be moved to exactly the right position.

(2) *Trees*: If no suitable vehicle is at hand, a well rooted tree is the next best choice. Winching point should be as close to the roots as possible.

(3) *Anchor*: Where no trees are available, the DUKW anchor can be used for moderate pulls. It is most effective in soft sand where it will dig itself down when a pull is applied to it. In hard ground it should be buried in a manner similar to that described below for the deadman. The anchor is not strong enough to make more than a single rig effective. (See sub paragraph c (1) below.)

(4) *Deadman*: A deadman can be used when no vehicle or tree is available and when the anchor will not be effective. It should be a heavy log at least 10 feet long, buried in a trench 4 feet deep. A shallower trench leads off at right angles to the deadman trench, in the direction of the pull. This is for the tow chain, which is wrapped twice around the center of the deadman.

c. *Cable Hook-ups*: The effective power of the winch can be varied by a variety of cable hook-ups, involving the use of one or more snatch blocks, and sometimes, one or more auxiliary cables. The power of any hook-up will be greatest when the cable is paid out to the bottom layer of the drum. The following methods could be used:

(1) *Single Rig*: The simplest hook-up is a direct cable led forward or backward. It provides a maximum 10,000 lbs. pull. Auxiliary cable extends reach by 75 feet.

(2) *Double Rig*: When a single rig is not sufficient, the pulling power of the winch can be doubled by leading the cable through a snatch block which is secured by tow chain to the winching point. The end of the cable is brought back and hooked to the DUKW. For longer reach, the auxiliary cable can be hooked between the snatch block and the winching point.

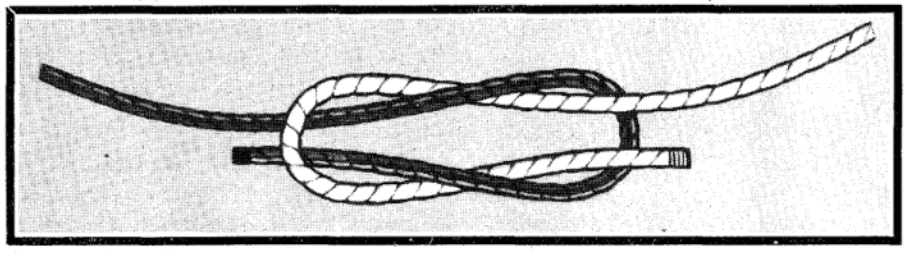
(3) *Triple Rig*: To pull out a badly stuck DUKW, the cable can be tripled by leading it through two snatch blocks. This will provide up to 30,000 lbs. effective pull. The first snatch block is at the winching point, or on the end of the auxiliary cable if that is needed for reach. The second snatch block is hooked on lower bow shackle of DUKW that is stuck (or in stern pintle—using pear shaped link for rearward pull). The cable is lead through the first snatch block, back through the second, and then secured to the winching point.

100. *Winching Operations.* a. *Winching on DUKW*: The most frequent use of the winch is to enable a DUKW to pull itself out when it has become stuck. A suitable winching point and rigging method should be selected. Do not engage the wheels until the winch cable becomes tight. When it is tight, assist the winch by engaging the wheels (low low for forward travel or low reverse for reverse travel).

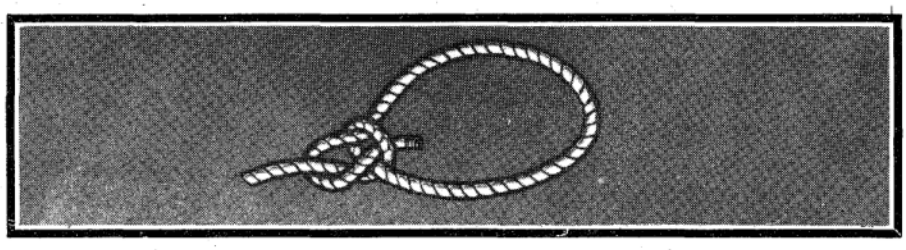
b. *Winching Another Vehicle*: To assist another vehicle that is stuck, it is better to use the winch on the assisting vehicle. Apply hand and foot brakes before attempting to winch. If the winch merely pulls the assisting vehicle toward the stuck vehicle, it will be necessary to secure the assisting vehicle to a tree or to another vehicle. If none is available, in soft ground or sand the assisting DUKW can disengage the winch, and engage its wheels for a few moments. This will dig the wheels of the assisting DUKW into the ground and help anchor it.

CHAPTER VIII
KNOTS AND FENDERS

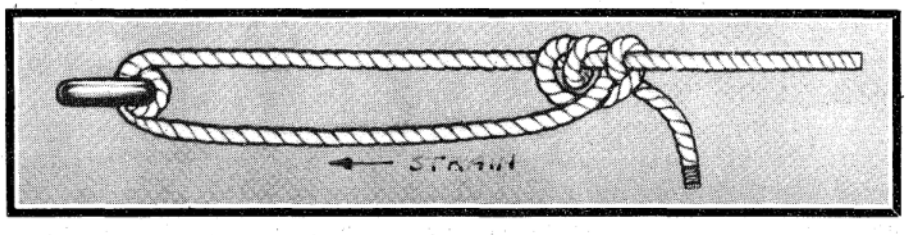
101. *General*: Knots, wire splicing and fenders are used constantly in DUKW operations. Not infrequently the safety of the DUKW and its crew will depend on ability to make a dependable knot quickly. DUKW crews must learn the following knots, and must practice tying them frequently. They should also learn to tie them with their eyes closed, for they will often have to use them at night.



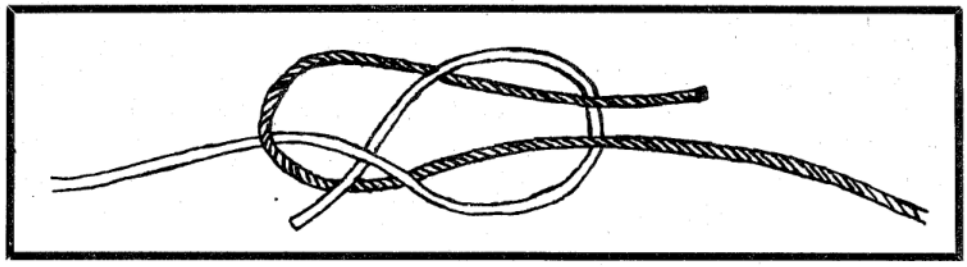
102. *Square Knot*: For square knot see figure above. This knot is suitable for joining two ropes of approximately the same size, or for joining the two ends of a lashing line. If a square knot is pulled very hard it will be difficult to untie.



103. *Bowline*: For bowline see figure above. It will make a loop at the end of a rope which will not pull tight on itself. The bowline can be easily untied, even after a heavy strain, but the rope must be slack while untying.

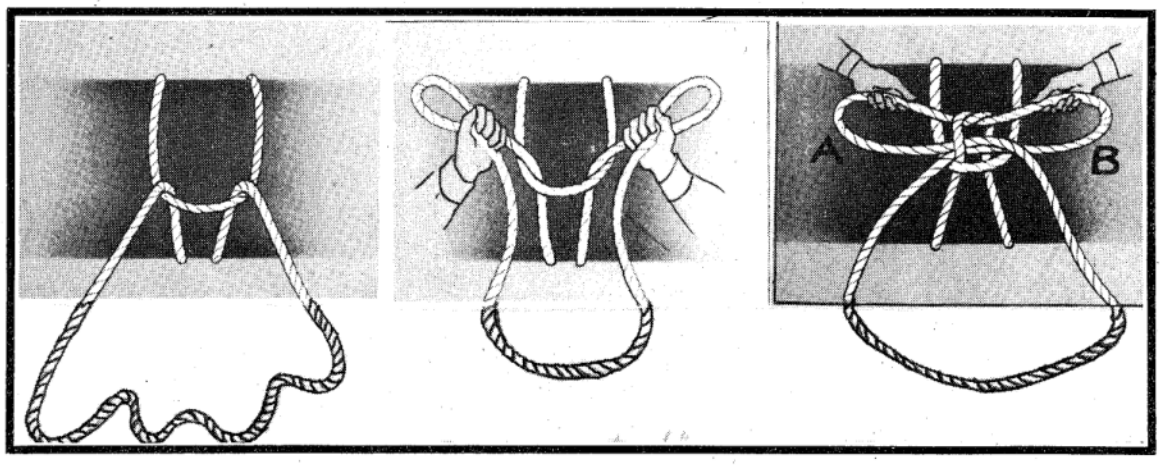


104. *Rolling Hitch*: The rolling hitch, see figure above, is used to make fast a rope to itself or to another rope that is already tight. It is handy in making a spring line fast to a guest warp (see paragraph 141). It is also used to make fast the ends of the hand ropes on the DUKW tarpaulin and the securing of the ends of fender lashings (see paragraph 109). It should be noted that the two turns should be on the side from which the strain comes.



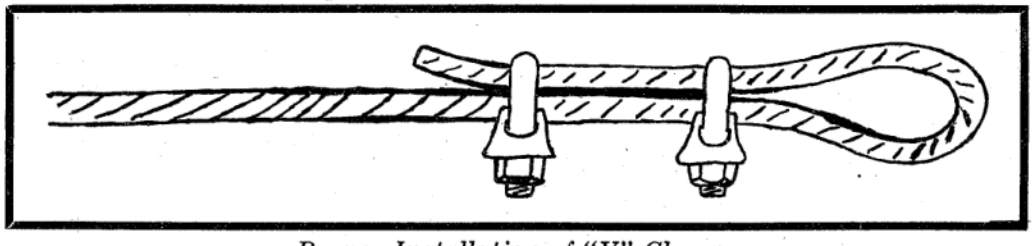
Sheet Bend

105. *Sheet Bend*: The sheet bend, see figure above, is used to join the ends of two ropes which will be subjected to considerable strain. If used to join ropes of different sizes, the bight should be made in the larger rope, and an extra turn made in the smaller rope.



Sling Knot—Used to Shorten a Sling

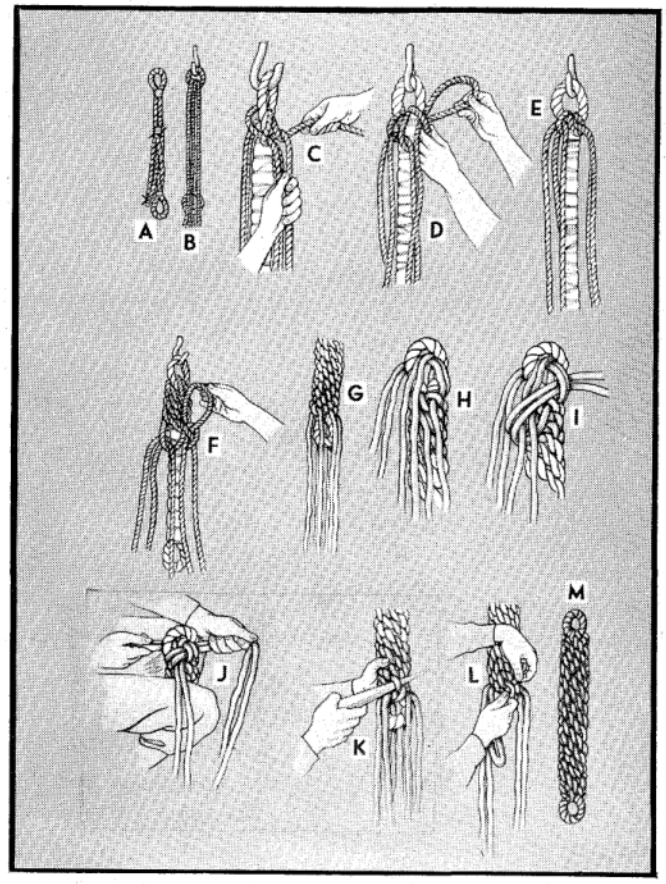
106. *Sling Knot*: The sling knot is used to shorten a continuous sling that is around a package to be lifted. A short bight of the excess sling lengths is held in each hand and the double ropes forming those 2 short bights are tied in an overhand knot (like the first half of a square knot). The hook for lifting the package is then hooked through the two ends of the short bights as marked A and B in figure above.



Proper Installation of "V" Clamps

107. *Wire Splicing*: In making wire cable slings, guy wires for "A" frames etc., "U" clamps are used. Two clamps are necessary for any splice. For proper installation of "U" clamps, see figure above. Note that saddles are on long part of wire, with "U" bolts over short end.

108. *Fenders*: Fenders, sometimes called bumpers, are rope cushions made to protect the sides of the DUKW. Mooring alongside ships in rough water, fender wear will be rapid, so it is important that DUKW companies familiarize themselves with details of making fenders as shown in figure below. Two men working together can make and install two fenders in two hours. One entire fender can be made from 48 feet of 1" diameter rope plus rags, canvas or scrap rope for padding out the core. First cut off 8 feet, and make the 40" over-all core by splicing an 8" eye in each end of the piece. Do not



cut off the ends after splicing. They will help pad the core. Next cut off two pieces each 20 feet long and unlay them, producing 6 pieces of 20 feet. These should be hung evenly through the upper eye of the core, and it is from these that the fender body is woven. Three 8 foot lengths of ⅜" diameter rope will provide the three fender lashing ropes.

a. The first step, shown in figure "A" is to make the core which should be 40" long overall, including eyes. The center part of the core to be made of two pieces of line each of which is doubled having 6" eyes placed opposite each other. These eyes should be lashed securely to each other at several points. The center of core should be made larger with additional ropes wrapped with canvas or rags all securely bound in place with twine or marline. The diameter of the core should be about 5".

b. Figure "B" shows the next step which is to hang the core at the highest convenient working height. Then lead six lines through the upper eye, with the center of the line resting in the eye. These lines should be ⅜ to½ inch rope, each one measuring about 20 feet. The 3 strands of the 1" rope on the DUKWs, used individually, are ideal for fender making.

c. For purpose of description number the ropes 1 to 12, starting with the front left rope and going in a counter clockwise direction. In the figure above, to clarify the drawing, only 3 ropes giving 6 ends are used instead of 6 ropes giving twelve ends. However, the procedure is the same. Rope numbers 1 and 12, 2 and 11, 3 and 10 etc. are the front and back of the same ropes respectively. Bring #12 around the left side of the core and under #1, leaving a small loop. Now lead #1 under #12 and extend #1 to the right. Hold #12 in left hand. Carry #2 over the front of #1. Head #1 over the front of #2 toward the left and into the left hand. This completes figure C.

d. Continue this same procedure by bringing #3 over the front of #2. Then bring #2 over the front of #3 toward the left and into the left hand. Bring #4 over the front of #3. Bring #3 over the front of #4 toward the left and into your left hand. Bring #5 over the front of #4. Bring #4 over the front of #5 toward the left and into your left hand. Continue process around to #11. Lead #11 around in back of core and through the small loop under #12 as shown in figure D. (This loop was made when #12 was brought around the left side of core and under #1 as the first step in paragraph c.)

e. Figure "E" shows the completion of the first row. Each of the six ends (in making DUKW fenders it will be twelve ends) has been tucked over and all pulled up evenly and tightly.

f. Figure "F" shows the fender after 4 full rows have been completed and the 5th row is having its final tuck preparatory to tightening. After each round all ends hanging down must be untangled and kept clear.

g. Continue the above procedure until the lower eye is reached as shown in Figure "G".

h. Now take the fender down and turn bottom end up. Hold it between the knees, then take two sets of four ropes and criss-cross them through the eye as shown in figure "H". (In this case the ropes are in pairs.)

i. Complete the crown by leading the remaining set of four ropes as shown in figure 1. This last set of ropes does not go through the eye.
1. This last set of ropes does not go through the eye.

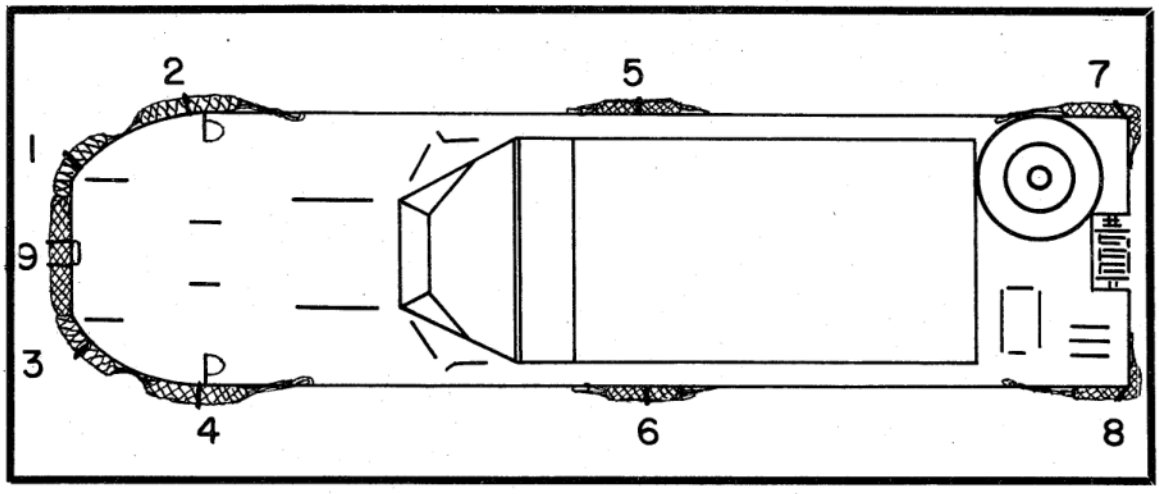
j. Figure "J" shows you how to pull the crown down tightly. Always pulling on two sets of ropes at at time.

k. Hang up fender in original position. Using a marline spike or fid as shown in figure K, tuck back the strands in a manner similar to splicing.

l. Each rope should be tucked under one strand, over the next and under the next, against the lay of the fender.

m. Figure "M" shows complete fender after loose ends have been pulled tight and then cut off.

109. *Installation of Fenders*: It is very important that the fenders are correctly installed on the DUKW, otherwise they will not protect the vulnerable points. For maximum protection, each DUKW should be equipped with nine fenders. For purpose of description, the fenders are numbered 1 to 9 in figure below.

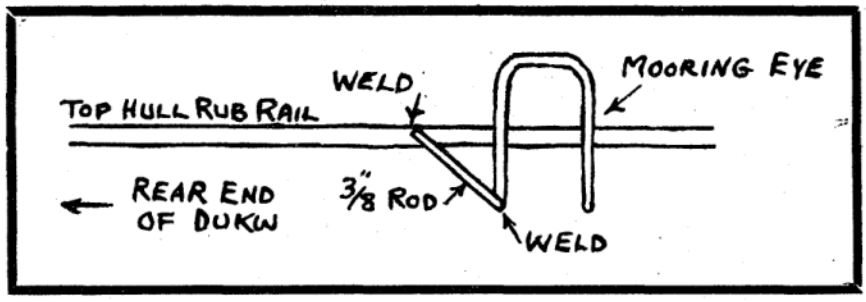


a. In all cases, lashing lines must be passed back and forth through lashing eyes as many times as the length of the line will permit. With the end of the line, make a rolling hitch around all the turns. (See paragraph 104). It will be found that 18 inches is needed to make the rolling hitch.

b. All the fenders are identical, with a lashing line at each end and one in the middle, except for #1 and #3, which have lines at only end. Lay #1 on the ground and join it to #2 at the end which has no lashing line. Make the join by overlapping the loops and lashing them together so that there is a space of ten inches between fenders. Hold up the pair of fenders so that fender #2 is centered under its lashing eye on the deck of the DUKW. Take the line at the end of #2 and lead it through the forward lifting eye, then back through the loop of the fender and lash it as described in paragraph a. Then take the line at the end of #1, and lead it through the small eye alongside the bow towing shackle. Pull the line as tight as possible before completing the lashing. Then take the middle line of fender #2 and lead it through the eye at the edge of the deck above it and then bring it down, over the outside of the fender, through the eye below. Complete the lashing as usual, taking as many turns as possible. Lash the middle of fender #1 in the same manner. (Note: In some older DUKWs the middle lashing eyes for fenders #1 and #3 are in the wrong position. Eyes should be welded to the hull in line with the middle of fenders #1 and #3.) Install fenders #3 and #4 in the same manner as #1 and #2.

c. Hold up fender #5 so that it is centered between the upper and lower fender eyes, which are located about midway along the side of the DUKW. Make the rear end of the fender fast to the lashing eye which is located further aft, and make the front end fast to the mooring eye. It is important that the lashing line is passed around the *forward* end of the mooring eye, or better still, a four inch length of $\frac{3}{8}$" rod can be welded from the bottom of the rear end of the mooring eye, to the hull rub rail, at a 45° angle to it. This will form a suitable lashing eye. (See figure below.)

If the aft end of the mooring eye is used as a lashing eye, the mooring hook will very soon cut through the lashing. Lash the middle of the fender, using the two lashing eyes Install fender #6 in the same manner. If fender eyes as described for fenders 5 and 6 are not installed on old DUKWs, they should be added. Locate them by measuring from mooring eye. Upper and lower eyes should be 28" aft of mooring eye and rear eye should be 56" aft of mooring eye.



d. In the case of fender #7 and #8 *about ¾ of the fender must be along the sides* of the DUKW. Hold the fender up in that position and then lash the forward end to the lifting eye. The rear end of the fender can then be pounded until it rounds the corner of the DUKW, and is made fast to the lashing eye on the stern, pulling the line as tight as possible. Then lash the middle of the fender in the usual manner.

e. An additional fender (#9) in the center of the bow is extremely useful. The top center lashing eyes for #1 and 3 can be used to lash the ends. The middle lashing can be passed around in back of the bow fairlead, then outside the fender and down to the lashing eyes alongside the bow towing shackle.

f. After several water operations, it will be found that when the fenders have dried, the lashing lines have stretched and slackened. It is necessary to take up all slack The checking of fenders and lashings is a part of Daily Driver Maintenance. It is very important to repair them, turn them, and replace them as often as necessary.

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CHAPTER IX
WATER OPERATION

110. *General*: The amphibian truck is as much a seagoing craft as a land truck. While drivers may be familiar with land operation of a 6x6 truck, boat handling will be an entirely new experience for most of them. Instructions applicable to water operations, therefore, should be studied carefully. If there is a DUKW Control Point on the beach, he will give instructions and advice on the correct techniques to be used. (See Chapter XII.)

111. *Preparing to Enter the Water from Shore*: a. *Conditions.* The principal considerations are: (1) how *steep* is the beach (can the DUKW get back out), (2) how soft is the sand (can it be crossed and at what tire pressure) and (3) how rough is the ground (can be *seen* above water, and must be negotiated below water). Obstacles under water will be more difficult to negotiate than if they were on dry land. Avoid mud, swamps, marshes, quicksand, stumps, wreckage, large sharp rocks and boulders.

b. *Tire Deflation. A very soft* sandy beach will require tire deflation to a *minimum* of 12 pounds, soft sand 20 pounds, while reefs of coral or sharp rocks require tire inflation to 30 pounds. For overloads all recommended pressures should be increased 1 pound for each 1,000 pounds over the 5,000 pound pay load.

c. *Hatches.* All hatch covers must be clamped tightly. Early model vehicles were equipped with auxiliary air intakes. Make sure this intake is also tightly clamped. However, air exhaust grill covers must be left *open,* except in sub-freezing weather.

d. *Hull drain valves, housing drain plugs and bottom plugs.* Before entering water, be sure that bilges are reasonably dry and that all 4 drain valves are closed and all plugs are tight. See paragraph 71 for details.

e. *Tarpaulins.* For surf over 5 feet high, rig the cargo tarpaulins securely. Tarpaulins must also be used when long hauls are to be made or when the hauls will be made in rough water.

f. *Surf.* Unless water is smooth, the bow surf plate must be set up. If the cargo comes up to or above the coamings, the tarpaulin may be lashed directly over the cargo and coamings without the use of tarpaulin bows.

112. *Entering the Water*: a. When operating in water, all men aboard will wear life jackets. When moving outside the cargo compartment, personnel should always maintain a secure hold with at least one hand.

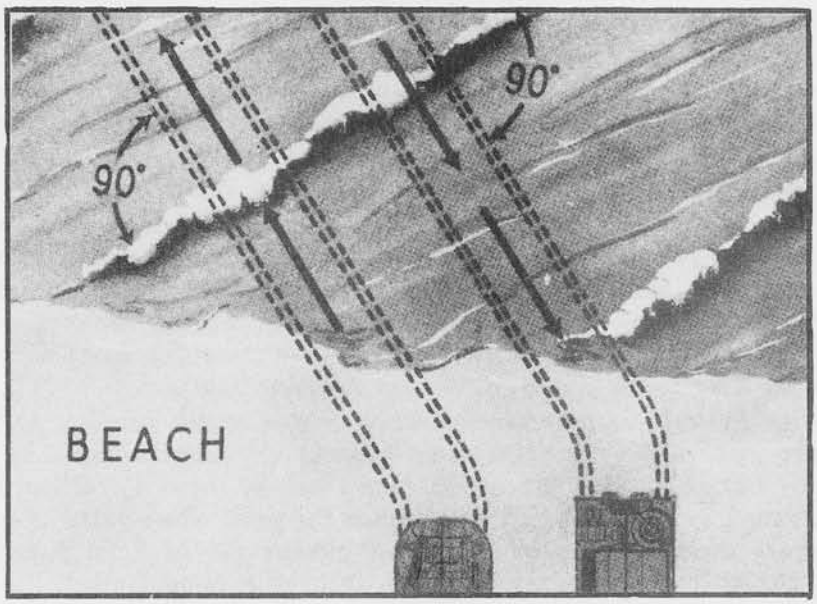
b. Set the bilge pump manifold open to the center or main compartment. Close other manifold valves, and close the manifold drain on DUKWs that are fitted with these. See dash instruction plate for pump system details.

c. Survey the beach and select the most desirable approach. This will vary with the location, but a hard, sandy, moderate grade beach is the best. Proceed with transmission in second gear, front wheels engaged and transfer case in low range.

d. Unless there is a heavy surf or strong current, *wait until fully afloat before engaging water propeller.* This practice will considerably decrease the chances of damaging the propeller. If the propeller is damaged, stop the propeller immediately before hull is punctured and return to shore, using wheels only. Operational beaches are usually littered close to the edge of the water with wreckage, spilled cargo, floating fuel cans, and

occasionally with barbed wire, stakes, coral, stumps, boulders and so forth. These should be avoided as much as possible. When engaging the propeller after floating, first give the brake pedal a touch to stop the wheels spinning.

e. If there is a heavy surf or strong current, the water propeller should be engaged before reaching the edge of the water. *The DUKW must be momentarily stopped* to accomplish this. Then proceed with *full throttle.* Face the bow at right angles to the surf as in figure below, except when there is a strong current parallel to the shore. In that case, point the bow sufficiently (generally about 15°) upcurrent of the normal course, to allow for the fact that the bow floats first and will be swung off.



Enter and leave the water at right angles to the waves.

f. When entering the water down steep banks or ramps, proceed *slowly* and do not engage propeller until afloat. Also set stern pintle hook in horizontial position so that it will not strike obstructions.

113. *In the Water*: a. *Driving Wheels*: The wheels will not be disengaged until the DUKW is clear of breakers and over all outlying reefs. Only approximately ½ mile per hour speed is lost by having the wheels and propeller engaged at the same time, and the danger of getting stuck is considerably decreased. When in deep water, stop the wheels by shifting the transfer case into neutral. *Do not disengage the front wheel drive.*

b. *Leaks*: As soon as the vehicle enters the water, look down through the air-intake grills. If there is excessive leaking, indicated by an abnormal quantity of water in the bilge, return to land as quickly as possible.

c. *Bilge Pumps*: There are three bilge pumps: (1) the rear pump which will discharge approximately 200 gallons of water per minute; (2) the forward pump, which will discharge approximately 50 gallons per minute; (3) the hand bilge pump, which will discharge approximately 25 gallons per minute.

(1) *Rear Pump*: The rear pump operates automatically whenever the propeller is driven ahead, but it does not begin to pump until the water is about 5 inches deep in the center compartment.

(2) *Forward Pump*: The forward pump, below the driver's seat, removes water from the left and the right rear compartments, from the center compartment and in old DUKWs, from the bow compartment. It is not practical to pump from more than one place at a time. It is dangerous for the pump to run *without* having one pump valve open. DUKWs that have 5 rods coming up through the floor immediately in front of the driver's seat have four manifold valves and a manifold drain. The center rod of the five is the manifold drain. Whenever afloat it is important that this manifold drain be in the closed position (control pushed down). If this control inadvertantly remains up, it will interfere with the pumping of the various compartments. Chassis numbers above 4202 have only 3 controls, these coming out through the front face of the driver's seat. On all DUKWs the different valves should be opened alternately, leaving an individual valve open as long as water continues to come out of the discharge. However, when no bilge water appears to be coming out it is advisable to operate the different valves in rotation, each valve for a minimum of about two minutes. The discharge should be watched. If an abnormal amount of water is being discharged from any one compartment, that section should be inspected for leaks and drain valves should be checked to see that they are shut tightly.

(3) *Hand Pump*: In emergencies, when engine is not running or power pumps are inoperative, the hand pump, buckets and helmets should be used for bailing purposes. If it is possible, cargo may be thrown overboard, particularly at the low side of the DUKW or near the point where water is coming in. Also move cargo as necessary to permit proper use of hand pump, particularly when it is necessary to pump from *rear* compartments.

d. *Steering*: Water steering requires more turning of the wheel than land driving. In water operations there is a conside able lag at both the start and at the finish of a wheel turn. The driver must anticipate turns, particularly in rough water. Swing the wheel ahead of time if possible. In the water, it is the *stern* that responds to the steering wheel, *not the bow*. In addition, the stern momentarily swings *toward* an object as the DUKW is steered *away* from that object. Rudder response will be less at reduced speed. But even at a very low speed, rudder control will be better if occasional short spurts are given, causing the propeller to drive sufficient water against the rudder to produce the desired turn.

e. *Speed*: At 2500 engine revolutions per minute smooth water speed without payload should be 6.5 miles per hour. This speed will be reduced about 0.1 miles per hour for each 1000 pounds of load carried, giving 6.0 miles per hour maximum speed with 5000 pounds of load and 5.7 miles per hour maximum with 8000 pounds of load. In addition, water speed will be reduced about 0.1 miles per hour for each foot of wave height encountered. Thus a DUKW with 7000 pounds load in 3 feet waves should make 5.5 land miles per hour (losing 0.2 for overload and 0.3 for wave height). Performance figures are given on dashboard plates. These figures are all based on *land* miles and must be multiplied by 7/8 to reduce them to nautical miles as used on most charts. Note that nautical miles may be multiplied by 1-1/7 to convert them into land miles.

f. *Endurance*: For runs where capacity of gasoline supply is not a factor, full throttle, with transmission in second gear, should be used. The propeller holds the engine down to reasonable operating speed of abou 2500 revolutions per minute. The maximum water range of the DUKW is 28 *nautical* miles. This is equal to 32 *land* miles. On extremely long runs when gasoline must be conserved, engine speed should be dropped to 2100 to 2200 revolutions per minute in second gear or to full throttle in third gear. The engine will have a tendency to run hot in third gear. Temperature can be brought down by periodically running the engine in second gear for several minutes.

g. *Manifold Glow*: At night in the water exhaust manifold glows cherry red and can be seen through floor boards. This is normal, and no sign of trouble.

h. *Refueling*: Refueling on the water is difficult. The DUKW should be maneuvered so that the gas fill is away from the waves, and rags should be kept handy to block out water as necessary.

i. *Reversing*: It is impossible to stop the DUKW quickly in water. Reversing is the only means of stopping. To do this, shift transmission into reverse, and also shift the propeller transfer case to overdrive (reverse) position. *Use full throttle* when reversing and engage all wheels in high range to get maximum effect. When traveling light, reversing is greatly improved by shifting the crew and any movable weights to the rear to keep the propeller tunnel under water.

j. *Precautions*: Keep clear of lines, moorings, anchor cables, nets and bouys, particularly on the windward or up-current side. Also keep loose lines clear of the propeller, particularly when towing. If the DUKW fouls a line or gets too close to one, disengage the propeller and wheels (if engaged) at once, use the boat hook to clear the lines and drift away. If a line becomes fouled in the propeller, try momentarily reversing and then going ahead again. This procedure repeated several times may throw the lines clear without causing damage. In no case *force* the propeller to turn when it is being held by a fouled line.

k. *Distress Signal*: While a DUKW is at sea, the driver may find himself in need of assistance. This may be on account of a mechanical breakdown or a fouled or damaged propeller. Whatever the cause, he may wish to summon another DUKW to tow him ashore or render other services. In such a case, during the day, he should lash a life jacket to one end of the boathook and hold the boathook up in a vertical position. At night, if the tactical situation permits, he can use his flashlight or headlight and flash the usual "SOS" signal in Morse Code (. . . - - - . . .). Upon seeing the distress signal, it is the duty of the nearest DUKW to come to the assistance.

l. *Towing*: In towing another DUKW, the towing DUKW will use its winch cable, which will be hooked in the towed DUKW's bow shackle. *Never use bow fairlead.* This is cast iron and will break easily. Unless conditions are very smooth, when a shorter cable can be used, the cable should be paid out until there are only five turns left on the winch drum. The towing DUKW must proceed very slowly until the cable is taut. Once taut, the cable should be kept that way to insure a steady pull.

m. *Anchoring at Sea*: There are normally two occasions during water operations when it is advisable to anchor. One is when the engine will not run and there is a possibility of the DUKW drifting into danger or away from the desired destination, before another vessel can come to its assistance. The other is when the engine will still run, but the position or desired course is not known, owing to darkness, fog, smoke, etc.

(1) The first step in anchoring is to ascertain the depth of water, if it is not already known. If the driver takes a sounding he will know how much anchor

line will be required. A suitable sounding line can be improvised by attaching the tow chain to the end of the heaving line.

(2) If the DUKW is not heavily loaded, and the sea is smooth or moderate, it can be anchored by the stern. Use the one-inch rope on the DUKW; tie it with bowline to the anchor, shackle, and tie the other end with a bowline around the winch drum, *before dropping the anchor overboard.* If a sounding has shown a depth of more than 30 feet of water, both 50-foot lengths of rope should be used. They should be joined with a sheet bend (see paragraph 105). If there is a depth of more than 75 feet of water, the winch auxiliary cable (75 feet long) can be used also by tying the rope to it with a bowline through the eye.

(3) If the sea is moderate but the DUKW heavily loaded, and in all cases when the sea is rough, the DUKW must be anchored by the bow. Attach the rope by a bowline to the bow lifting eye, leading it through the bow fairlead, and bring it back, outside of everything, to the stern deck. Make fast to the anchor as described before, and drop the anchor.

n. *Emergency Steering*: If the rudder cable or rudder shear pin breaks, the DUKW can still be steered with the tiller inside the stern compartment.

o. *Water Propeller Failure*: If the propeller fails, it must be immediately disengaged. With all wheels in high transfer range, third speed transmission and full-throttle about two miles an hour can be made under favorable conditions.

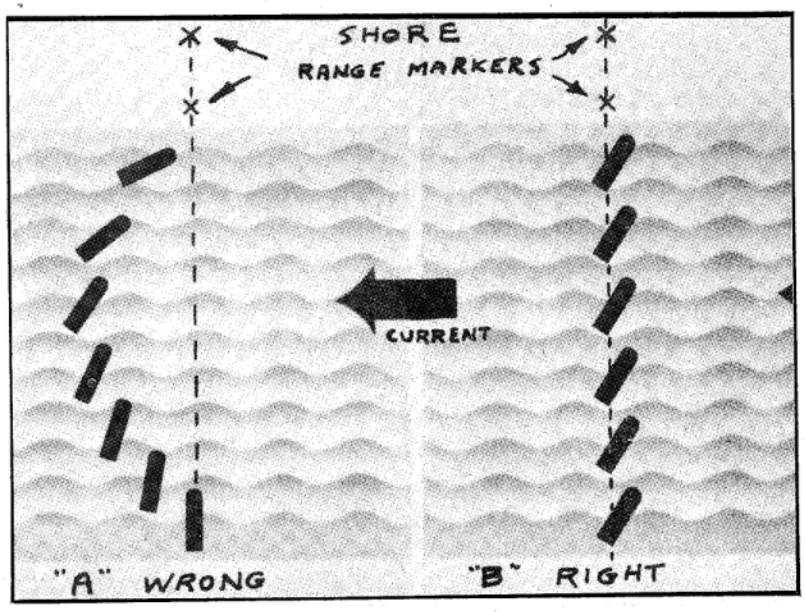
p. *Man Overboard*: Should a man fall overboard, the driver must immediately turn the wheel hard toward the side from which the man has fallen, to swing the stern and propeller away from him. Throw the life ring to him at once. At night, slow down and listen carefully in order to locate the man by his shouts. Great care must be taken not to run the man down. As a general preventive measure, personnel must not be permitted to walk outside the cargo space on the side decks.

r. *Current*:

(1) In water operations, the driver will often find that he must make frequent changes in his course in order to reach his destination. While the bow of the DUKW is headed towards the destination, the DUKW itself is being carried sideways by the current. In order to compensate for this, and thereby travel the shortest distance from point of departure to destination, he must steer the DUKW at an angle to his destination. To find what this angle must be, he should make use of ranges.

(2) When the DUKWs are operating in waters where there is considerable current, it is one of the duties of the DUKW Control Point to arrange for the setting up of range markers. One marker should be near the beach and the other farther away and higher. If range markers are not available, the DUKW driver must use natural ranges, by lining up his water entry point with a hill or tree or other prominent point behind it. If the ranges are kept in line, regardless of the direction in which the DUKW is headed, the driver will be traveling the shortest possible distance to his destination. (See figure).

(3) In heading from beach to ship the assistant driver can turn around and check to see that the ranges are being kept in line, and advise the driver accordingly. Or the ship may act as the marker ahead and the water entry point as the marker astern, with the DUKW kept on a straight line between them.



In "A" above the DUKW was headed for the shore point without allowing for current and keeping on the range.

114. *Preparing to Land*: a. *General*: The same careful planning and skill must be used in bringing the DUKW out of the water as is used when entering. The landing point should be reconnoitered, if possible. When in doubt, prepare for the most difficult landing conditions.

b. *Landing Spot*: Pick the most favorable available spot for landing. The principal considerations are: (1) how steep is the beach (can the DUKW get back out), (2) how soft is the sand (can it be crossed, and at what tire pressure) and (3) how rough is the ground (it can be *seen* above water, and must be *estimated* below water). Obstacles under water will be more difficult to negotiate than if they were on dry land. Avoid steep beaches, mud, swamps, marshes, quicksand, stumps, wreckage, large sharp rocks, and boulders. Set tire pressure (if equipped with central control) to best suited conditions. When DUKWs and landing craft are using the same beach, a small section should be marked off for the exclusive use of DUKWs so they will not be handicapped by having to operate over the big underwater holes dug out by the landing craft propellers.

c. *Approach*: Engage all driving wheels while still outside the line of surf. When landing conditions are unknown, wheels should be engaged at least 300 yards outside the breakers.

d. *Surf*: In rough weather, set up the rear surf shield. If the surf looks heavy, rig the tarpaulin. Before entering the breakers get in a position that will allow you to approach the desired landing point with the waves directly astern. While going through the breakers, *use full throttle,* and steer agressively to counteract any tendency for the waves to turn the DUKW off this safe course.

115. *Lading*: a. Landings on unfamiliar beaches should be made at *full throttle* with the transmission in second and the transfer case in low range, except for steep beaches (see paragraph *b* below) or for coral (see Chapter X). Come in at right angles with the

waves (paragraph 112). If the waves are at an angle to the shore, square around slowly after getting out of the surf and drive straight up the beach. Continue at *full throttle* until well ashore. On a rocky or coral beach drive *very slowly.* (See Chapter X).

b. *When the beach is steep or rocky, shift the transmission to first speed and the propeller to overdrive (reverse) position before reaching shallow water or surf.*

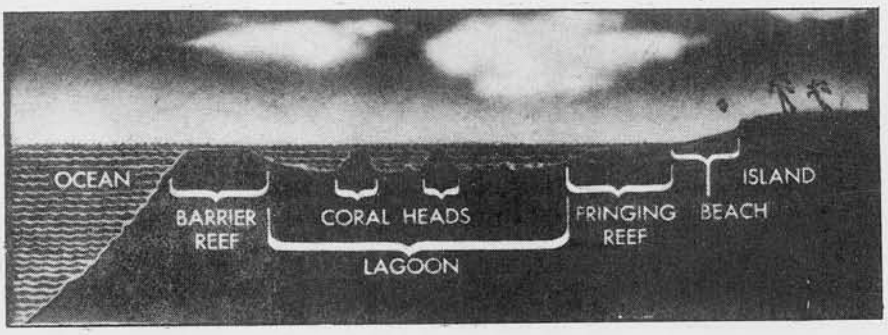
c. On a rough beach, on coral, and wherever wreckage may be in the water, it is very important to *disengage the propeller at the first possible moment.* This can be done as soon as some traction can be obtained from the wheels. This will greatly reduce the chances of propeller damage.

d. On beaches that are clear of obstacles, or in heavy surf or in strong current, the propeller should be disengaged as the DUKW leaves the edge of the water. It is not necessary to disengage the clutch or slow down. The propeller will disengage easily and quietly as soon as it lifts clear of the water,, since it is no longer under load.

e. In sand or mud, if progress stops because the wheels spin, disengage the clutch *immediately. Never allow the wheels to dig in.* If stopped in water, back up until well clear, using the propeller and all wheels at full throttle. Then try a better spot. If stopped practically clear of a bad surf, winch ahead. When stuck in rough water, rig tarpaulins immediately and keep pumps going.

f. As soon as possible after leaving water, open the 4 hull drain valves on vehicles so equipped. As soon as all water is drained out, close the valves. In below freezing weather, also drain axle housings immediately after leaving the water. For this condition note that in DUKW equipped with inter-housing drain, upper rear housing automatically drains through tube into lower rear housing. Also that in all vehicles when center bilge is dry, front housing will empty itself out of its rear end, into hull. Thus only lower rear housing drain plug would have to be temporarily removed.

CHAPTER X
OPERATIONS ON CORAL



Typical Coral Formation.

116. *General*: There are three basic types of coral formations.

a. *Barrier Reef*. The barrier reef is usually 1 or 2 miles off shore. It may run for many miles without a break, maintaining approximately the same distance from the shore. It is generally about 300 feet in width. The barrier reef acts as a breakwater and forms, between the reef and the shore, a smooth lagoon which is deep in most places. Seen from offshore, the barrier reef with its heavy surf is formidable in appearance, but actually is less harmful than other coral formations since the action of this surf keeps the coral comparatively smooth. Before crossing a barrier reef, select a point which is free from large cracks (called fissures), boulders, and loose rock. Use 30 pound tire pressure, and go slowly.

b. *Coral Head*: The coral head is usually an isolated, circular, drumlike patch up to 100 feet in diameter, frequently appearing inside lagoons. Since the water surrounding coral heads usually is smooth their presence will not be betrayed by surf. Coral heads may be detected by the change in color of water from a deep blue to light brown. Coral heads should be avoided whenever possible. Their surface is made up of rounded heads upon which the belly of the DUKW may easily become stuck.

c. *Fringing Reef*: The fringing reef extends out from the shore in the form of a flat ledge a few inches below the surface of the water. Its surface is composed of many sharp coral points, which can seriously damage tires unless they are inflated to 30 pounds air pressure and in addition low speed is maintained.

117. *Tire Pressure*: For all coral operations tires should be inflated to 30 pounds.

118. *Good Lookout*: It is important when approaching coral infested water to maintain a good lookout. During the day time the assistant driver should go forward and stand on the bow deck. He can steady himself with a short line made fast to the davit eye. In this manner he can see the coral much better than the driver, and can direct him to the right, left, slow down, etc., by hand signals. The water in coral areas is very clear and operators soon become expert in judging the depth of water and the character of coral reef.

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119. *Pick Your Landing Point*: Select the most desirable landing point. It is important that large coral heads and fissures on the edges of reefs be avoided. No attempts should be made to land on a reef with an abrupt edge since the front wheels of the DUKW will not take hold. Avoid holes in the surface of the reef. When crossing a lagoon, isolated coral head clusters should be avoided by passing to either side.

120. *Drive Slowly*: Upon approaching a landing where coral or rock is suspected, set tires at 30 pounds, *place transmission in low range, first gear, and place propeller drive in overdrive (reverse) position.* This provides maximum propeller drive with low wheel speeds necessary to protect tires. Drive slowly, and if temporarily stuck *do not spin wheels* as this will damage tires. Wait for a sea to lift the DUKW and then apply power. Coral will cut like a knife unless these instructions are followed. Approaching slowly, the operator is less apt to damage the hull and chassis should he strike a coral head, and he is not as likely to get his DUKW jammed between two coral heads or in a fissure.

121. *Propeller*: The driver should disengage the propeller as soon as possible after the wheels have taken hold and should not wait until the DUKW has reached the beach. This is of greatest importance on DUKWs not with propeller guards.

122. *Night Driving*: Driving in darkness requires great caution. If possible, landing spots should be selected during the day, and marked by range lights at night. The lights should be carefully placed so that when the operator is running the range, that is, keeping the two lights in line, they will lead him to the most desirable point on the beach.

123. *Inspection For Damage*: After every rough landing over coral, inspection should be made of DUKW for damage. Coral may cut tires and do other serious damage without the crew having become aware of it. Particular attention should be given to the front springs, brake hose, tie rods, differential housings, breather tubes, shaft housing seals, inter-housing drain, tires, propeller and propeller shaft, and propeller guard on DUKWs fitted with same.

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CHAPTER XI
PILOTING

124. *General*: A good working knowledge of the fundamentals of piloting is essential in the efficient water operation of DUKWs. Piloting is the technique of making use of visual observation, ranges, compass, charts and soundings in order to get from place to place while afloat.

125. *Currents*: In almost all water operations some current will be encountered. This current may be caused by tidal movement or by the proximity of a river. The speed and direction of the current must be allowed for when mooring, landing or when holding a course between two points. The easiest way to traverse the shortest distance between two points is by the use of ranges. (See Chapter IX, paragraph 113r).

126. *Under Water Obstructions*: The most difficult conditions under which DUKWs operate is that of driving on land covered by water. It is important therefore, to operate in deep water as far as possible until the landing point is reached. The location and depth of water over shoals, reefs bars and wrecks must be determined, and identified by reference to fixed points on shore, to buoys, or other markers in the water.

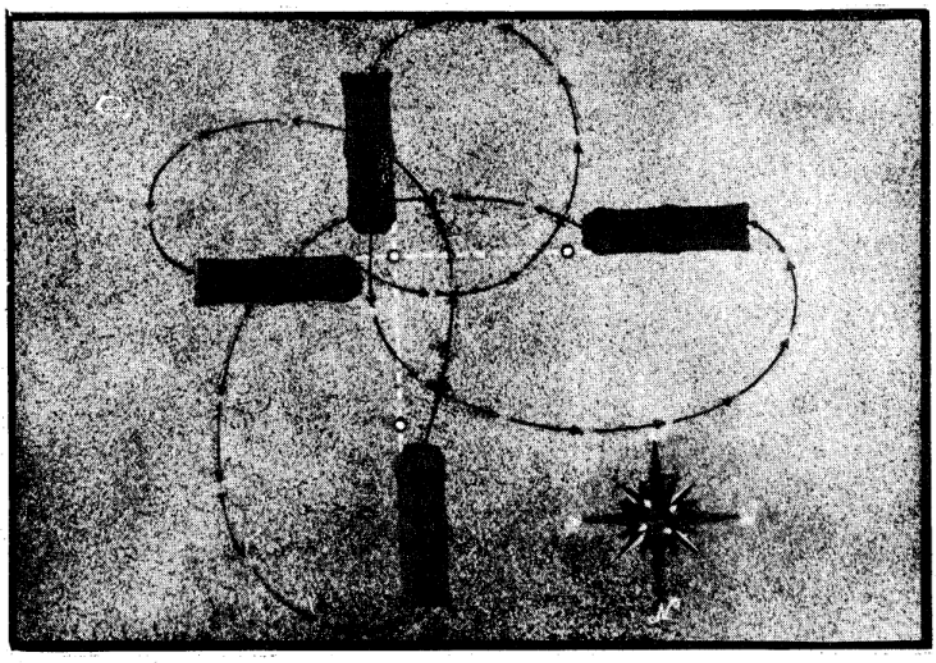
127. *Soundings*: Where charts are not available and where the tactical situation permits, reconnaissance of *underwater* conditions should be made. By travelling slowly in the water, depths up to eight feet can be measured by using the boat hook. It is also possible by this means to ascertain the consistency of the bottom, and be guided accordingly. Soft mud or extremely soft sand should be avoided.

128. *Tide*: The depth of water along the seacoast in almost all parts of the world varies according to a predictable 12 hour cycle which is called tide. There is normally a high tide twice each day. The difference between the depth of water at high tide and at low tide is the range of the tide. It is important to know the tidal range, also the times of high and low tide. Shoals and reefs which may safely be crossed at high tide may be dangerous at low tide.

129. *The Magnetic Compass*: a. In order to become oriented to the various key points indicated on chart or map, the magnetic compass is used. This compass, as installed in the DUKW, will be helpful only if kept in adjustment. The great amount of steel and the number of electrical parts close to the compass make frequent adjusting and checking necessary.

b. *Adjustment.* In adjusting the compass, it is necessary to mark out accurate North-South and East-West lines on a level portion of the beach. It is sufficient to have three stakes driven into the ground, a center stake and a north stake and a west stake, each about 40 feet away in the indicated direction from the center stake. (See figure.) The position of these stakes will be determined by using a pocket compass at least ten feet away from any metal objects. It is not satisfactory to use the DUKW compass, as it has built-in magnets and may give an erroneous heading even when the compass is removed from vehicle. After marking out the directions accurately, the DUKW should be placed along the North-South line heading directly north. The North-South compass magnet should be adjusted until the compass reads North. Next head the DUKW East, and

adjust East-West magnet until compass points East. Next head South. Compass should read South but if it does not, again use the North-South adjusting magnet and bring the compass *half-way* from its heading to South. Next head West. The compass should read West, but if it does not, adjust East-West magnet to bring the compass *half-way* from its heading to West. Repeat the above procedure in sequence of North, East, South and West headings, to make final adjustment. Then make a third check, this time without further adjusting the magnets, but carefully recording on deviation card the error in the compass at each of the four points checked. When the DUKW is lined up on the ranges, if the



Procedure for lining up directional stakes when adjusting the compass.

desired compass point on the DUKW Compass is *left* of the lubber line the error is *Easterly* and should be minus figure, and when the compass is *right* of the lubber line, the error is *Westerly* and should be a plus figure . For DUKWs equipped with Pioneer or Sherrill compasses, the adjustment is similar to above, but somewhat more complicated, and should be accomplished by following instructions of manufacturer, which are furnished with each unit.

130. *To Steer A Compass Course*: In some operations, the DUKW driver will be given a certain course to steer. To get his DUKW on this course, he will steer in such a direction that he can read the course he was given, on the side of the compass facing him. There is a small line, known as a lubber line on the side of the compass facing him. This will act as a marker. The compass card is divided into 360 degrees, but since the cards on small compasses are not large enough to show each degree, they are marked in tens of degrees. On the Hull compasses, they are not only marked in tens of degrees, they are numbered in the same system. For example, a driver given a course of 250 degrees to steer will steer his DUKW so that the 25th mark (one mark after 24, which is numbered) is opposite the lubber line.

131. *Right Of Way*: a. When landing, or going into the water, the DUKW afloat (landing) has right of way and the DUKW ashore (going onto the water) must keep out of the way.

b. When 2 DUKWs, or a DUKW and a boat, are meeting head on, each should turn slightly to its own right as needed to pass at a safe distance.

c. When 2 DUKWs, or a DUKW and a boat, are converging, the one that is being approached from its right side must keep out of the way of the other.

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CHAPTER XII

DUKW CONTROL

132. *Assault Phase*: a. During the initial assault, DUKW Companies operate as separate units attached to elements of the assault force for the service thereof.

b. They will be combat loaded with troops, Shore Party equipment, guns and ammunition in accordance with prearranged schedul

c. In the assault, DUKWs with guns or other heavy equipment will be landed and immediately unloaded by "A" frames. DUKWs will then tow guns to their initial positions.

(1) Upon the landing of the normal prime movers, DUKWs are *automatically* released to DUKW Battalion Headquarters, and accordingly will report to DUKW Beach Control Point.

(2) DUKWs reporting to DUKW Beach Control Point from artillery firing positions will bring either a messenger or a sketch of the gun location to facilitate location thereof by the normal prime movers.

133. *Supply Phase*: a. Upon reporting to DUKW Beach Control Point, the assualt phase is ended for the DUKW, and thereafter all DUKW operations are coordinated and supervised by DUKW Battalion Headquarters, which will set up a Command Post in a suitable area.

b. No DUKW can be dispatched on a mission unless it is cleared through the DUKW Command Post.

c. *DUKW Command Post* duties are as follows:

(1) To establish liaison with higher authority and to act upon orders received from them.

(2) To obtain from higher authority the following information:
  (a) Locations and descriptions of ships to be unloaded.
  (b) Type of cargo to be handled from various ships by DUKWs.
  (c) Overlay showing dump locations.
  (d) Time unloading operations will begin.
  (e) Type and condition of road markings for both day and night operations.
  (f) System of ship lighting during hours of darkness.

(3) To be responsible for overall recommendations affecting DUKW operations arising from weather and other conditions.

(3) To be responsible for overall recommendations affecting DUKW operations higher authority can have accurate information on present and future DUKW availability.

(5) To establish control points at the following places:
  (a) At the beach.
  (b) On ships.
  (c) At the dumps.
  (d) At the DUKW assembly area, and to maintain close contact by radio, telephone or runner with these points.

d. *DUKW Beach Control Point* will be set up on that portion of the beach chosen for the entrance of DUKWs into the water, preferably at a separate point from the landing craft. The DUKW Beach Officer's duties will be:

(1) To make arrangements for the proper marking of the DUKW beach, and to set up front and rear range markers if they will aid DUKW operators in keeping a straight water course to and from the beach.

(2) To make arrangements for the laying and maintenance of beach matting as necessary.

(3) To check on the seaworthiness of DUKWs before entering the water, i.e. bilge plugs installed, hull drain valves closed, hatches closed and dogged down, all equipment on board, etc.

(4) To dispatch DUKWs to the ships at such a rate that there are never more than two DUKWs waiting for their loads at each hatch. If operational DUKWs are held ashore pending dispatch, they will form a "cushion" in a suitable area close to the Beach Control Point. Here crews can refuel their DUKWs, receive rations when necessary, and can perform their "During Operations Maintenance" under the supervision of a senior non-com.

(5) To insure that DUKW operators can identify the ship which they are to unload and know the recommended route to it.

e. *Ship Control Point* will be set up on every ship discharging into DUKWs. The first DUKW to be dispatched to a ship will take with it a DUKW officer, DUKW rigging assistants and DUKW mooring equipment. Their duties will be:

(1) To assist in rigging the ship in accordance with the approved DUKW mooring system.

(2) To be responsible for DUKW mooring equipment and to keep constant check on its condition.

(3) To decide on the manner of loading and amount of load given to the DUKWs.

(4) To establish close liaison with the TQM and the master of the ship, and recommend to them any actions which may accelerate the unloading, such as the making of a lee, and the shifting of anchorage when it will shorten the ship-to-shore distance.

(5) To supervise the coming alongside and mooring of the DUKWs.

(6) To inform DUKW Command Post continuously concerning details of the off-loading.

(7) In discharging DUKWs from LSTs or other ramp vessels while afloat, to stand at the head of the ramp and insure that all DUKWs enter the water in accorance with the approved technique. (Paragraph 193.)

f. *Dump Control Points* will be set up at each dump where DUKWs are being unloaded, or a DUKW officer can circulate between the dumps. His duties will be:

(1) To expedite the turn-around of DUKWs, and to work closely with dump officers in the use of fast unloading methods such as hog troughs and "A" frames.

(2) To inform the DUKW Command Post continuously concerning details of unloading. If DUKWs are being delayed considerably, thus slowing down ship unloading time, he should recommend to higher authority through DUKW Command Post that transfer points be set up. A transfer point should be close to the beach and should have means for the rapid transfer of loads from DUKWs into land trucks. (See paragraphs 164, 165.)

g. *DUKW Assembly and Bivouac Area* will be set up in an area considered safe from enemy aerial and ground attack. This area is primarily intended for non-operating DUKWs and their crews. The DUKW Officer's duties will be:

(1) To be responsible for the presence in the assembly area of all non-operating DUKWs and their crews.
(2) To supervise, with the cooperation of DUKW maintenance Officers, all DUKW maintenance, except "During Operations" duties.
(3) To make arrangements for food, latrines and billets for DUKW personnel.
(4) To inform the DUKW Command Post on the status of all DUKWs in the assembly area.
(5) To require the highest standards of passive air defense by dispersal and camouflage of vehicles and personnel.
(6) To require the highest standards of security against enemy attack.

134. *Small Operations*: In operations involving only a company of DUKWs or less, the duties of DUKW Command Post can be combined with those of DUKW Beach Control Point and can be conducted at the latter point.

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CHAPTER XIII

OPERATIONAL ESTIMATES

135. *To Estimate the Number of DUKWs Needed at Each Unloading Shipside Position*:

a. Calculation:

1. Estimate the average time needed for a loaded DUKW to reach the beachhead dump, be unloaded, and return to the ship. This may be determined by a trial run, if necessary.
2. Divide this figure by the average loading time of the DUKWs at shipside.

b. Example:

1. Time needed to make a round trip — 60 minutes.
2. Divide by the average loading time at shipside — (5 minutes).
3. Result: 12 DUKWs needed for each position.

136. *To Estimate the Number of Hours Needed to Unload a Ship*: The number of DUKWs used in figuring estimates of this nature must not exceed the number that are available, nor can it exceed the number that can be kept working efficiently at ship's side.

a. Calculation:

1. Take the total number of DUKWs to be used in unloading a ship.
2. Multiply it by the number of round trips from dump to ship a DUKW can make per hour and
3. Multiply that figure by the average payload, then
4. Divide the result into the number of tons of freight to be unloaded.

b. Example:

1. Number of DUKWs to be used 37
2. Number of round trips a DUKW can make per hour 1
3. Average payload per DUKW 2.5
   Tons per hour 92.5
4. Tons of freight to be unloaded 9000
5. Answer: 9000. ÷ 92.5 = 97 hours operating time to unload.

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CHAPTER XIV

ROUND THE CLOCK OPERATIONS

137. *General*: When unloading or other operations in which the DUKW Company is engaged cannot be completed in one 12 hour working day, the personnel of the company will be organized into two shifts and the work to be done divided between them. Each shift will set up with an administration, a control, a maintenance and an operations unit so that each shift may operate independently of the other.

138. *Maintenance*: Regardless of the length of operations, maintenance must be conducted as described in Chapter V. Scheduled preventive maintenance operations, however, should never with-hold from operations more than 18 percent of operating DUKWs at one time. The maintenance unit must have sufficient personnel on duty during all shifts to take care of emergency repairs. The weekly preventive maintenance will be done either night or day by the driver and assistant driver, since their vehicle will not be available for operation during that period. Daily preventive maintenance will be performed by the driver and assistant driver as indicated on the dashboard instruction plate.

139. *Operations*: If there is sufficient personnel available from the DUKW Company to have driver and assistant on a DUKW at the same time, the driver must be given assistance from an outside source. This assistance is most necessary when mooring and cargo handling at shipside. Three systems by which this assistance can be rendered are described below:

a. Personnel from Port Companies or other service troops can act as crews, one for each DUKW. They will at no times, however, be permitted to operate the DUKW.

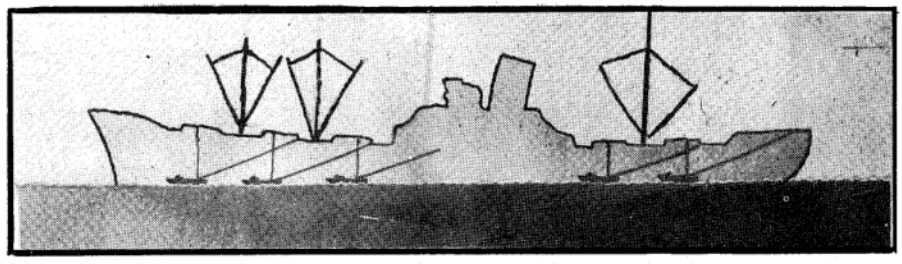
b. Inasmuch as the greatest need for the DUKW crew man is during the water operation, if there are not enough extra men to assign to each operating DUKW, a pool may be formed at the DUKW control point on the beach where a crew man can be picked up by each DUKW as it enters the water. On the return trip to shore he can dismount at the same point and be at the disposal of the next DUKW headed for the ship.

c. When it is not possible to get sufficient men for system *a* or *b* as outlined above, the minimum requirement is for a loading crew to be assigned at each loading position at shipside. These crews will perform the duties of securing the mooring hook and placing and securing the load in each DUKW in turn as it comes alongside, transfering from one DUKW to the next. It should be noted however, that this system is not practical except when the sea is smooth.

CHAPTER XV

MOORING AT SHIPSIDE

140. *General*: It is of particular importance that all ships discharging into DUKWs accurately follow out the details set forth in this section. The unloading operation involves a continuous sequence of mooring alongside by the DUKWs. In view of their small cargo space accurate and rapid positioning under booms is necessary.



Mooring Rig, Showing Spring Line and Messenger Lines

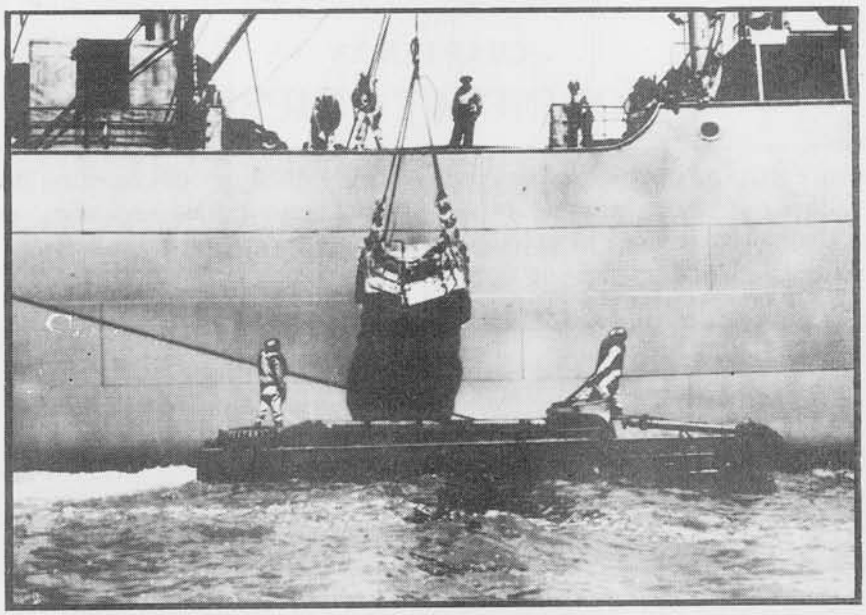
141. *Spring Line Mooring*: The DUKW will be moored at shipside by a single spring line 3½ to 4½ inches in circumference and about 100 feet long. This spring line will be secured on the deck of the ship. The forward end of the line carries a mooring hook which is engaged in the DUKW mooring eye. A messenger line of the same size as the spring line will be fastened to the spring line 4 feet back of the mooring hook and will lead to the deck of the ship directly above the mooring position. If necessary, the spring line will be parceled to prevent chafe at the ship's deck. Where the ship is rigged with a guest warp, it may be convenient to attach the individual spring lines to the guest warp rather than to lead them to the deck of the ship. When working with the guest warp, the individual spring lines can be considerably shorter. About 50 feet length will be sufficient. The messenger lines will also be rigged.

142. *Mooring Hooks*:

143. *Fender Protection*: If a ship has a guard rail or rough guards over hull outlets, rope or mat fenders should be rigged by the ship to protect the DUKWs. A floating log fender is very practical. If a ship has reasonably smooth sides, the DUKW's fenders should give sufficient protection.

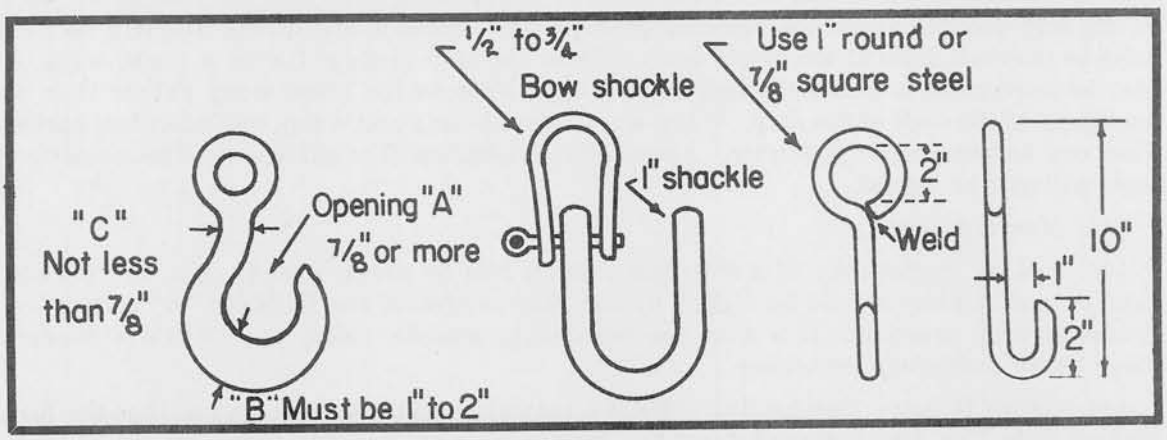
144. *Cargo Booms*: For loading DUKWs, cargo booms must be rigged so that the load centers only five feet outboard from the ship's side when hanging from outboard booms. Booms over the #1 hatch should rigged as far *aft* from bow flare as possible. Booms over the #5 hatch should be rigged as far *forward* from stern flare as possible. All booms should be rigged to keep DUKWs clear of dangerous hull obstructions, and to provide all possible space between adjacent berths. Double rigged hatches should be worked from opposite sides except when rough water necessitates operation from the lee side only. Spring lines must be adjusted so load comes down directly over the center of DUKW cargo space.

145. *Approaching Mooring Positions:*



Properly Moored With Stern Spring Line

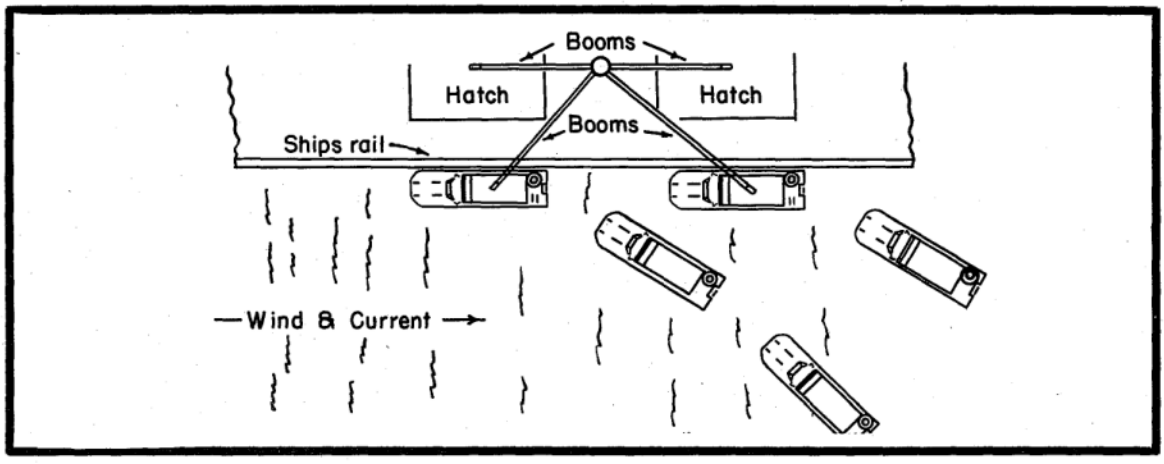
146. *Mooring:* When a DUKW approaches a ship to receive or deliver a load, it should take up a position not more than a hundred feet from the position where the DUKW expects to moor. Immediately upon receiving a signal to moor, the DUKW will approach



Alternate types of mooring hooks that may be used. To facilitate night operation, hooks should be painted with phosphorescent paint, or white paint.

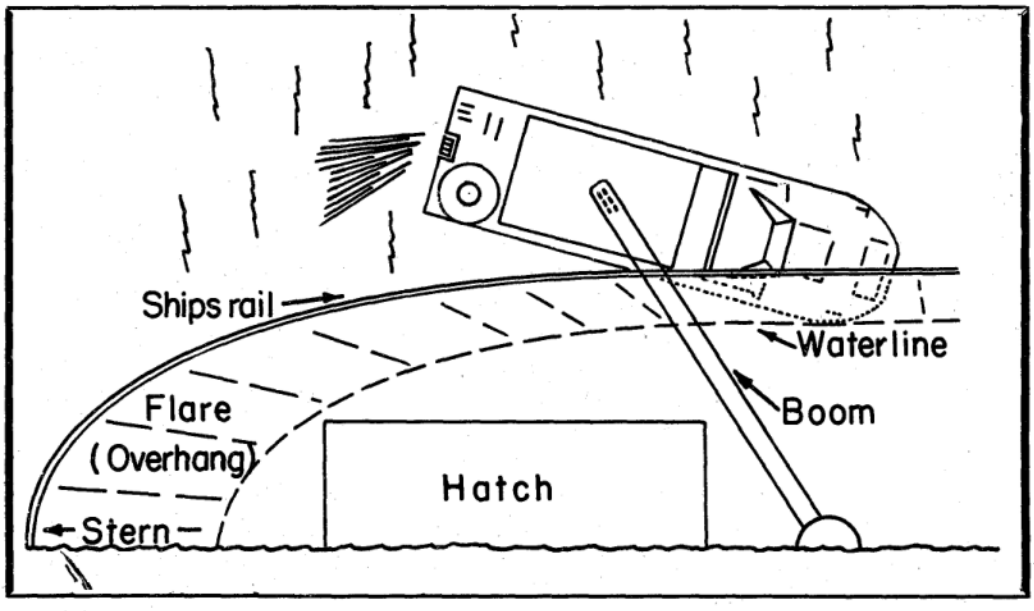
the mooring position at approximately a 45° angle from astern. See figure. As it approaches the mooring hook, the DUKW will be slowed down and turned parallel to the ship about one to three feet away from the ship's side. The assistant driver will reach the mooring hook from the aisleway and quickly hook it into the DUKW's mooring eye, with the point of the hook towards him.

147. *Holding Alongside*: When mooring near the bow of the ship, or in a very strong current, careful adjustment of the rudder is necessary to hold the DUKW close to the



Proper Approach to Mooring Position from Astern

ship's side. In such cases, the rudder must not be turned all the way from the ship, or the bow of the DUKW will be forced outwards by the current and waves. The steering wheel should be set so that the DUKW stays close and then lashed with a short length of line when necessary.



When There is Considerable Flare, Stern Must Be Swung Out to Receive Cargo.

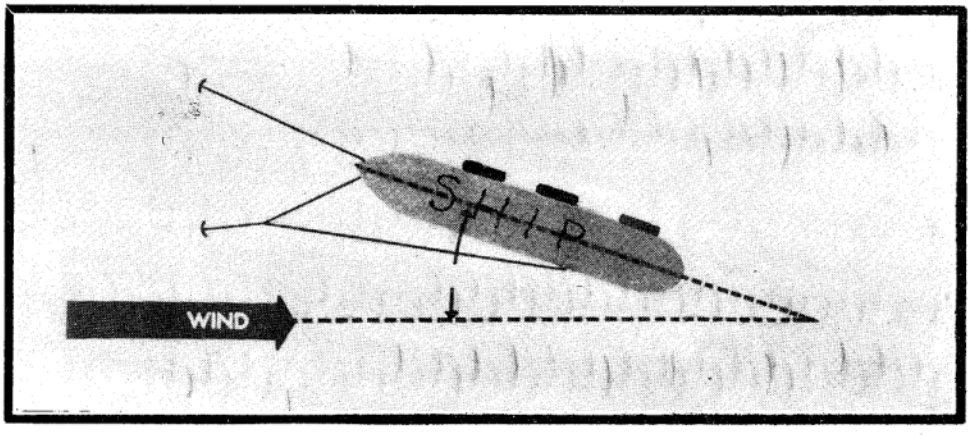
148. *Positioning Under Flare*: When there is considerable flare abreast the #1 and #5 hatches it will be necessary to steer the DUKW during loading, swinging the stern *out* to get under the load and to keep out from under the overhang (See figure.) In cases of extreme flare at #5 hatch particularly in rough water, it may be advantageous to lead

this spring line forward, engaging the hook in the inside bow lifting eye and using little or no power after picking up the hook. Under these conditions an additional stern line may be helpful but it will need constant attention due to its unfavorable angle.

149. *Double Mooring*: In smooth water such as exists in harbors, DUKWs can be moored in pairs. This system is particularly helpful where there is considerable flare, as abreast #1 and #5 hatches. The procedure is as follows:

a. Before coming alongside, two DUKWs tie up by lashing together their mooring eyes. They then maneuver like a twin motored boat and the inside DUKW secures the mooring hook to his mooring eye in the approved system.

b. When the DUKWs are moored the outside DUKW can shut off his motor and the inside DUKW turns the rudder and sets the hand throttle as usual. The crews of both DUKWs assist in the handling of the cargo.



c. When they are both loaded, they move away from shipside before separating.

d. It must be noted that this system is not practical in rough water.

150. *Making a Lee*: In extremely rough weather, the ship will do all possible to provide approximately a 20° lee (See figure).

151. *Working With Other Craft*: Where DUKWs and other types of craft are working on the same ship, it is desirable to divide the work by hatches, so that a hatch rigged for DUKWs will be available when DUKWs come for a load. In this connection it should be noted that LCM and LCVP can moor satisfactorily on gear rigged for DUKWs, but DUKWs can not operate effectively using mooring methods normally employed for LCM and LCVP. This is because the DUKW only pumps when propeller is being driven ahead and also because the DUKW has a weak reverse making it difficult to hold in position with the boat technique.

152. *Moor Against Current*: When the current or tide runs by the ship from stern to bow, due to the ship being aground or moored to a dock, the mooring rig will be reversed so that *DUKWs will come in head to the current.* In all cases, spring lines must be rigged to lead *aft from the DUKWs.*

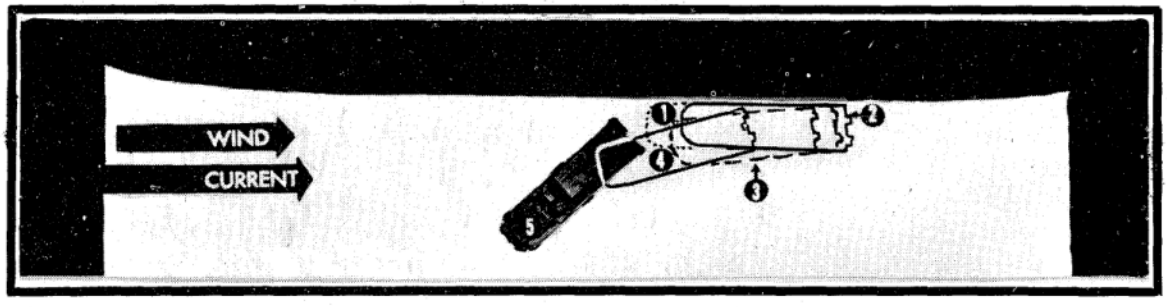
153. *Surf Plate and Rear Closure*: Whenever the DUKW is going to moor, the bow surf plate will be folded back. When the plate is set up it extends beyond the bow and bow fenders, and may be damaged. In addition, rear closure should be folded down before mooring.

154. *When Engine Stops*: If the engine stops and cannot be started while the DUKW is moored, the DUKW should cast off immediately, even if this necessitates cutting the

spring line with a knife or an axe. After drifting clear of the ship, the signal for assistance should be displayed and the DUKW should await tow. If no tow is in sight, the DUKW should anchor.

155. *The Procedure for Leaving a Mooring is as Follows*:

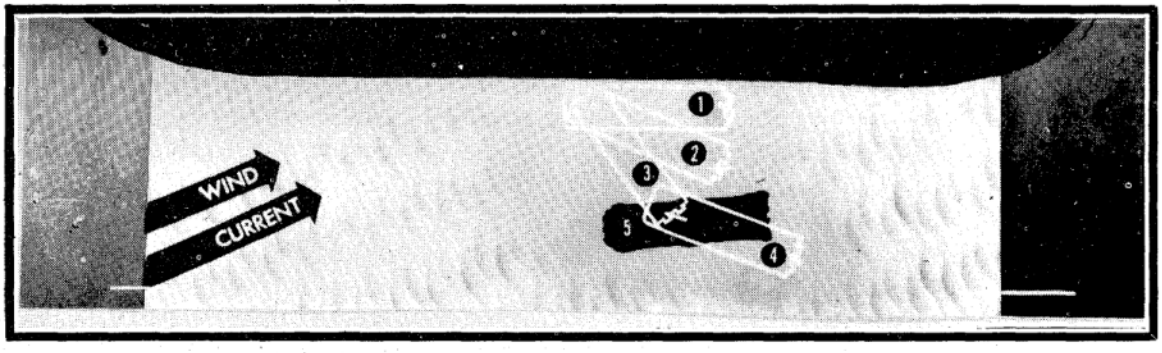
a. *Favorable Conditions*: Under favorable conditions, the clutch should be disengaged and the spring line unhooked as soon as it is slack. The bow should be pushed off (from the aisleway) and when the bow has swung away from the ship the clutch should be engaged to drive the DUKW ahead. Do not swing away sharply or the stern will hit the ship and pull the DUKW back alongside. See figure below.



Leaving Shipside Under Favorable Conditions.

(1) Moored alongside. (2) Drop back sufficiently to permit unhooking. (3) Push off by hand from aisleway before starting ahead. (4) Drive ahead, turning away gradually so stern does *not* swing against ship as this would tend to pull you on alongside again. (5) All clear—take desired course.

b. *Unfavorable Conditions*: If tide or other conditions make it impossible to leave the ship's side in the above manner, the steering wheel should be turned toward the ship before the DUKW is unhooked and the propeller should be driven ahead to swing the stern well clear. Then the DUKW should be unhooked and backed away with the propeller in reverse and the wheels in high transfer. When well clear, the DUKW should be turned away and driven ahead with the wheels disengaged. (See figure.)



Leaving Shipside under Unfavorable Conditions.

(1) Moored alongside. (2) Driving ahead, wheel turned *toward* ship forcing stern cut. (3) When this position is reached, unhook mooring line and back away. (4) When this position is reached turn DUKW *away* from ship and drive ahead. (5) All clear—take desired course.

CHAPTER XVI

LOADING CARGO AT SHIPSIDE

156. *Payload*: Payload weight must be governed by operating conditions. In determining payload, *all* personnel, personal gear, spare gasoline, oil, water, parts, dunnage, nets, pallets, and all items that are not part of a standard DUKW must be counted as part of the payload. The above persons and items usually weigh from 500 to 1500 pounds; 1000 pounds should be considered as average. Total payload should center about two feet forward of center of the cargo space and should normally not exceed 5000 pounds. However, under combat emergency and when conditions are such as indicated below under FAVORABLE Conditions or IDEAL Conditions, the payload may be between 5000 and 10,000 pounds. *More than* 10,000 *pounds, however, must never be carried.*

a. *Difficult Conditions*: Operating under DIFFICULT CONDITIONS, payload should not be over 5000 pounds. The term DIFFICULT will apply to all operations involving use of untried landing sites unless reconnaissance has definitely indicated conditions to be FAVORABLE. It also applies to surf at shore over three feet, wind over 15 miles per hour (white caps) and when the wave height at shipside is over three feet. In addition it applies to operations involving coral, very soft sand, steep landing, mud, steep hills, and land distance to dump over six miles.

b. *Favorable Conditions*: Operating under FAVORABLE Conditions, and combat emergency, payload may total 7500 pounds. The term FAVORABLE will apply to operations involving use of reconnoitered landings where reasonably smooth and firm terrain is available, where surf at shore is less than three feet, wind is less than 15 miles per hour (no white cap) and waves at the shipside are less than three feet. The route should be well marked. The landings on shore shall be definitely negotiable in low range second. The land distance to dump must be less than six miles, with moderate hills.

c. *Ideal Conditions*: Operating under IDEAL Conditions, and combat emergency, payload may total 10,000 pounds. The term IDEAL will apply to daylight operations over smooth, firm and gradually sloping landing, negotiable at a minimum of 30# tire pressure. Surf at shore must be less than two feet, the wind less than 10 miles per hour and waves at shipside less than one foot. Landing route to dump must be reasonably level and smooth and less than three miles long, and water trip less than one mile long.

157. *Load Markings*: To facilitate control of loading, there are three guiding lines on each side of the stern of most DUKWs which indicate the water lines resulting from loads recommended in paragraph 156. The lowest lines marked "Rated" are for DIFFICULT conditions, middle lines for FAVORABLE conditions and upper lines, marked "Danger", for IDEAL conditions. *Never* carry a load that puts the "Danger" lines below the water. DUKWs that do not carry these load markings should be so marked with non-lustrous yellow paint stripes one-quarter inch wide on the right side of the stern. The top lines marked "Danger" shall be painted five inches from the under side of the deck guard rail. The middle lines shall be three inches below the top lines. The bottom lines marked "Rated" should be three inches below the middle lines. The lines measured from the top of one line to the top of the next line.

158. *Dunnage*: Before receiving a load, if it is of a type that places considerable concentrated weight on a small portion of a cargo floor, dunnage must be used to protect the floor. In some cases, dunnage is used to protect the cargo, particularly when more than one layer is carried. Dunnage must also be used to block around cargo that might shift during water or land transit. Use dimensional timbers, pallets, nets, steel matting from air strips, boughs or whatever similar material is available. Use of dunnage must be more extensive in rough water as motion of DUKW and ship make cargo loads land more heavily in cargo compartment and increase the tendency for the cargo to shift.

First pallet crosswise—forward end of cargo space; Second pallet crosswise—close behind first; Third pallet fore and aft on top of first and second.

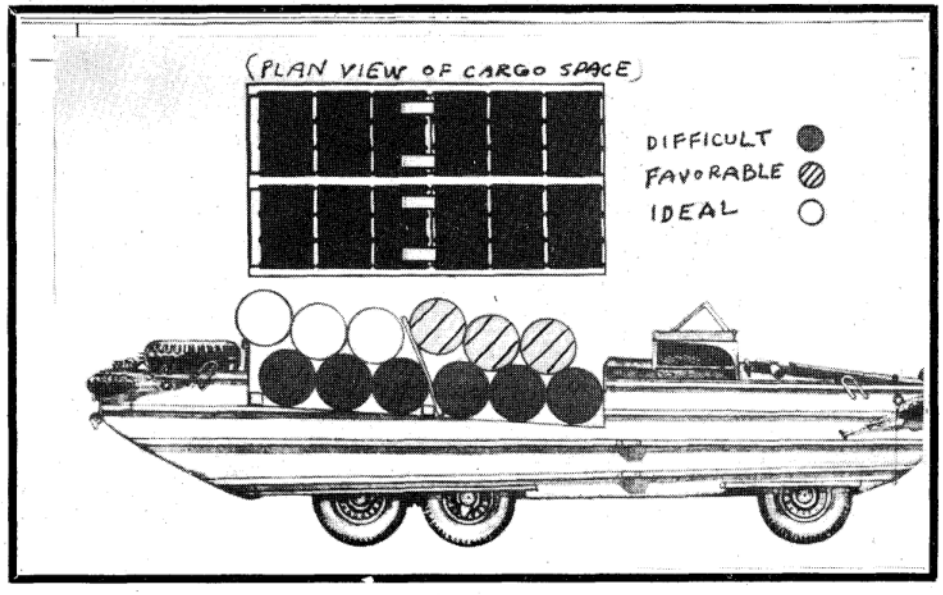
159. *Positioning of Cargo*: Normally, cargo weight should center approximately two feet forward of the middle of the cargo space. It should be lowered directly over the center of the cargo space. (See figure paragraph 141.) When cargo is of a type that completely fills the cargo space, it may not be possible to place the cargo forward of center, however. it is almost always possible to pile cargo higher at the forward end, also to place the heaviest objects at the forward end. Heavy cargoes must be placed forward of the center, otherwise the DUKW may ship water over the stern and be swamped. In addition, if too much weight is in the stern the water speed is reduced and, when on land, mobility and tire life are both reduced. Lateral position of cargo should be centered so DUKW will remain level.

160. *Normal Ship's Side Loading Procedures are Outlined Below*:

a. *Pre-palletized cargo*: The proper sized pallet for use with DUKW is 44" x 72". Weights should be as close under a top limit of 3000 pounds as possible. Three pallets can be stored crosswise in cargo space, providing a very seaworthy load. Tarpaulin can be placed directly over cargo space (without bows) in rough weather. Where width of pallets exceeds 44", pallets must be placed as in figure below, the third pallet being carried only when weight of pallets permit three under existing operating conditions and where the first two pallets are of a type that will not be damaged by stacking.

b. *Fuel Drums*: Fifty-five-gallon fuel drums weigh approximately 400 pounds each. Six or eight small pieces of dunnage are required in loading these drums. The drums should be handled by a cluster of six sets of chime hooks. (See paragraph 174.)

The first six drums should be set crosswise on their sides in the forward end of the cargo space. Immediately after unhooking, the drums should be rolled against forward cargo bulkhead, and small pieces of dunnage should be placed behind the rear drums to prevent them from rolling toward the rear part of the cargo space. The second cluster of six drums will be placed in the rear half of the cargo space. They should be rolled against the forward drums and blocked. This completes the load for DIFFICULT conditions. (See figure above). Under FAVORABLE conditions an additional cluster of six drums will be placed top of the drums at the forward end of the DUKW cargo space. It is extremely



Positioning of 55 *gallon drums under various conditions.*

important that suitable dunnage be wedged behind these drums to prevent them from rolling backward, particularly when climbing up on the beach or up a steep rise in the land operation. If the drums roll back they will smash the rear coaming and will be lost over the stern. Under IDEAL conditions, a fourth cluster of six drums may be placed at the rear end of the cargo space. To prevent them from rolling, they should be placed up against the rear coaming.

c. *Net Loads*: DUKWs will normally carry one, two or three net loads, depending on net load weights, and on operating conditions. If one net load only is to be carried, it should be placed in forward part of cargo space. If two net loads are to be carried, the first load should be placed in rear of the cargo space and the second in forward end. Any overhanging cargo should be allowed to overhang in forward end. When three net loads are to be carried, the first load should be placed in forward end, the second in rear, and third on top of first at the forward end. The third net will have to be carefully lashed so none of its contents will be lost.

d. *Projectiles*: 155 millimeter projectiles and other similar ammunition are normally loaded with clusters of from six to 12 hooks through lifting eyes in the nose of the projectiles. When loaded in this manner, considerable small broken dunnage or nets should be used to prevent the projectiles from rolling in transit. A heavy pallet having sides

approximately 24" high may be used in place of the cluster of hooks. If the pallets can be retained in the DUKW, only enough dunnage will be necessary to keep the projectiles from damaging each other.

e. *Boxed Ordnance Parts*: Dunnage is necessary for boxed Ordnance parts only as explained below. The boxes normally will be loaded singly or in groups. Rope slings will be used. Where enough slings are available, they should stay on the boxes during transit to dump for use in unloading. If there are not enough slings, 2 x 4s or similar size dunnage must be used in the DUKW to hold the boxes clear of the cargo floor to permit ship-side removal and dump application of slings. The heaviest boxes should be in the forward end of cargo space, and all boxes should be lashed or blocked so that they will not shift.

f. *Loose Pallet Loads*: Pallets are used for loose cargo that would be crushed in nets. Dunnage is not necessary. Where loads are heavy and enough pallets are on hand to permit it pallet loads may be carried intact. The first pallet will be placed at the forward end, crosswise if length will permit. One or two additional pallet loads should be placed behind the first one until the cargo space is full or the desired load is aboard. When pallet loads are sufficiently secure, and conditions permit, a second layer may be carried. Again the loading starts at forward end. Where pallet loads are light and where there is a shortage of pallets, the pallets should be loaded into the DUKW cargo space, and empty pallets sent up to the ship.

g. *Bombs*: DUKW's are well suited for handling bombs. Considerable valuable information can be found on this subject by referring to OS-939, Volume II, Bomb Handling. Additional details for handling various types of bombs are as follows: (Also see paragraph 176 for unloading details).

(1) 100 pound bombs, weight 145 pounds, packed in crates. No dunnage is necessary. They should be stowed lengthwise in cargo space, three rows each and eight abreast. For DIFFICULT conditions, the first row at forward end should be two deep, totaling 32 pounds and weighing 4650 pounds. For FAVORABLE conditions, first row should be three deep and second row two deep totaling 48 bombs, weighing 7000 pounds. For IDEAL conditions, first and second rows should be three deep, third row two deep, totaling 64 bombs and weighing 9300 pounds.

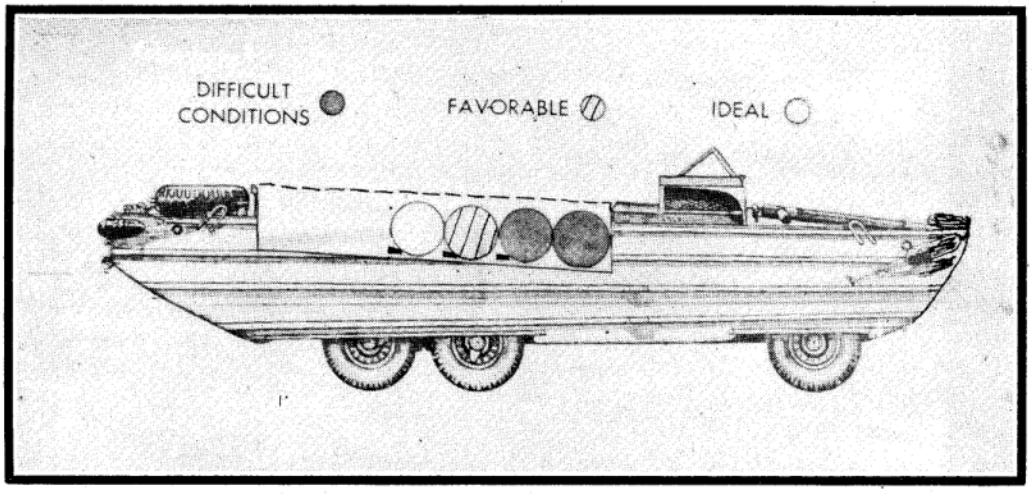
(2) 250 pound bombs, weight 250 pounds each. No dunnage is necessary. They should be stowed lengthwise in cargo space, four rows, each having five bombs, for DIFFICULT conditions, giving a total of 20 bombs and weighing 5000 pounds. For FAVORABLE conditions, there should be a second layer of four bombs on both first and second rows, giving a total of 28 bombs and 7000 pounds. For IDEAL conditions, each row should have a second layer of four bombs giving a total of 36 bombs and weighing 9000 pounds. Tail assemblies for these and all larger bombs are handled separately.

(3) 500 pound bombs, weight 528 pounds. Dunnage should be used to protect the floors and prevent the first layer from rolling. The bombs should be stowed lengthwise. For DIFFICULT conditions, load two rows of four bombs each at forward end of cargo space totaling eight and weighing 4225 pounds. For FAVORABLE conditions, an extra three bombs may be placed on top of the first and second rows, giving a total of 14, and weighing 7400 pounds. For IDEAL conditions, load four extra bombs lengthwise on floor at rear end of cargo space, total 18 bombs, 9500 pounds.

(4) 1000 pound bombs, weight 1000 pounds. Dunnage should be used to protect cargo floor and to wedge the bombs in place. For DIFFICULT conditions, load three

abreast lengthwise at forward end of cargo space. Then load two more on top of the first three. Total five, weight 5000 pounds. For FAVORABLE conditions, load three abreast lengthwise at forward end of cargo space and four abreast crosswise at aft end of cargo space. Total seven, weight 7000 pounds. For IDEAL conditions, add two on top of first three lengthwise at forward end. Total nine, weight 9000 pounds.

(5) 2000 pound bombs, weighing 2093 pounds. Place bombs crosswise. Use heavy dunnage to protect the floor and to wedge bombs securely, particularly to prevent their rolling back when the DUKW climbs out at the water's edge.



Positioning of 2000 pound bombs under various conditions.

(6) 4000 pound bombs, weighing 4152 pounds. Heavy dunnage must be used to protect cargo floor, and sufficient blocking must be made to cradle the bombs securely during transit. Under DIFFICULT conditions, one bomb will be placed diagonally in the cargo space, with its nose in the right forward corner, and the tail end of bomb against left coaming. Block heavily to prevent the bomb rolling or shifting. (See figure below).

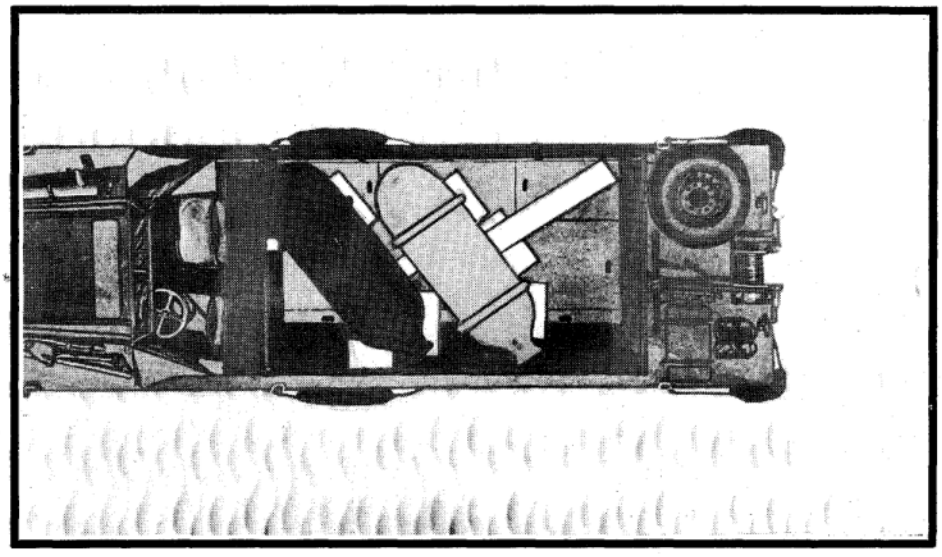
161. *Cargo Handling Duties of the Assistant Driver*: a. After hooking in the mooring hook, the assistant driver should stand on the stern, ready to guide the draft load from ship to proper position in the DUKW. The driver will assist from the *forward* end.

b. After unhooking the first load, the driver or the assistant driver will hook on any empty nets, pallets, slings, etc. from the previous trip so they can be lifted aboard ship for subsequent use.

c. After the DUKW has pulled away from the ship with a full load, the assistant driver will attend to securing the load, blocking and lashing any cargo that might shift, and shifting weights where possible to trim the DUKW level for its trip to shore.

d. On approaching the dump, nets should be arranged to expedite unloading. Slings should be adjusted and shortened as necessary and temporary lashing cleared away. These preparations will greatly expedite unloading at the dump.

e. On the DUKWs return trip to the ship, the assistant driver will utilize every opportunity to clean up bilge and cargo space, and to put through "During Operation" maintenance. Pallets, nets and slings should be moved clear of space where first load will be received from the ship.



Positioning of 4000 pound bombs under difficult and ideal conditions.

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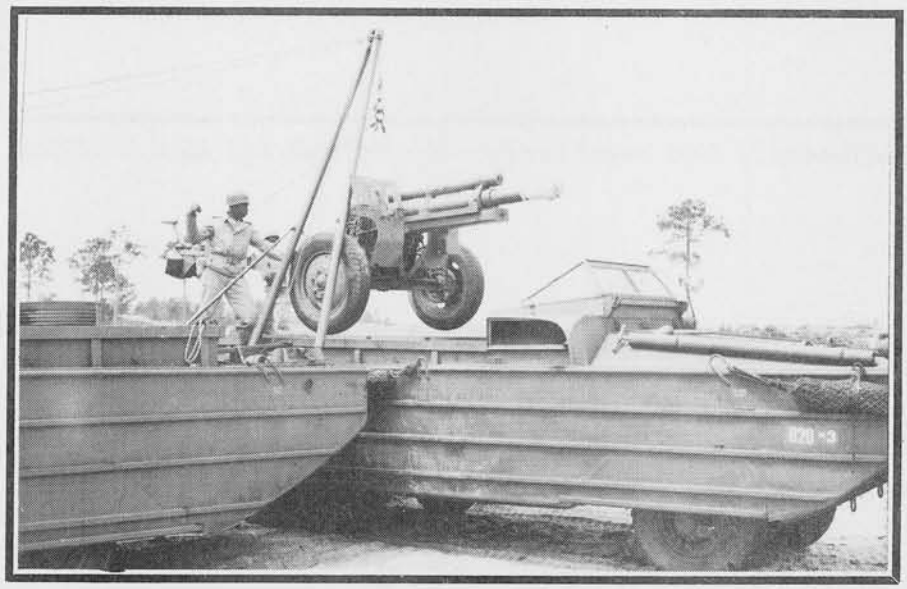
CHAPTER XVII

UNLOADING CARGO FROM DUKWs

162. *General*: To accomplish expeditious unloading, it is important to use the best available method. This will vary with each situation; DUKW company officers and non-commissioned officers must be prepared to offer advise and suggestions to Dump officers, which would expedite unloading. Thus DUKW turnaround time would be shortened, and ships unloaded faster. The most effective unloading methods are outlined below.

163. *Crane*: The crane will handle all cargo carried by the DUKW, it is a fast unloading aid, and saves man power.

164. *"A" Frame*: a. The "A" frames that may be attached to any DUKW will perform practically the same function as a crane. However, they are slower and should not be used unless cranes are not available.



Unloading a 105MM Howitzer with "A" Frame

b. The maximum capacity of an "A" frame is 5000 lbs. To lift this load, 1000 lbs. of cargo or personnel must be placed on the forward deck as ballast. Approximately 3500 lbs. is the maximum load that can be lifted with an "A" frame without ballast.

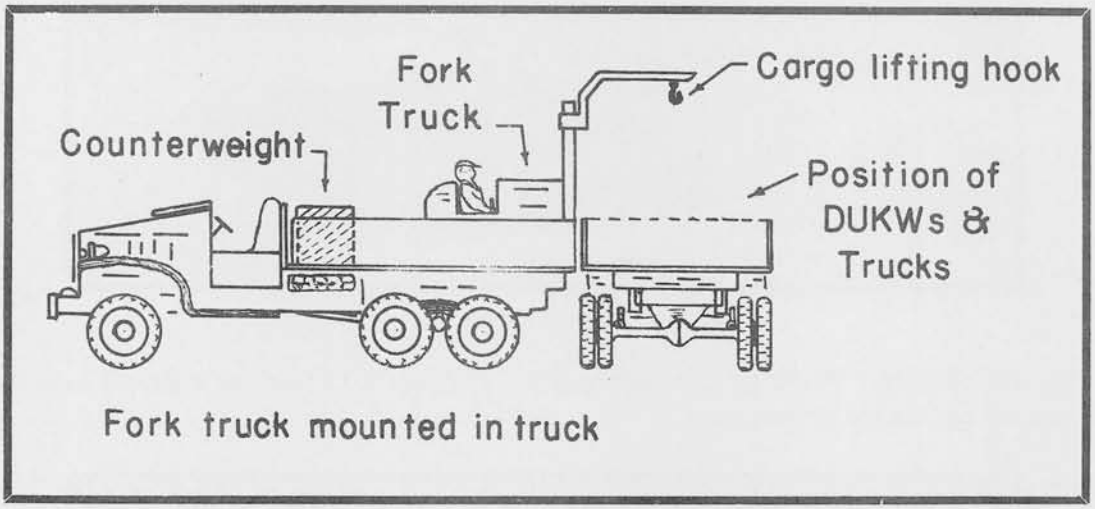
c. The "A" frame can handle cargo nets if chime hooks or spider bridles are used, hooked in down low on the sides of the net.

d. The winch drag brake must be kept in proper adjustment or the load being carried may drop without warning. (See paragraph 55.)

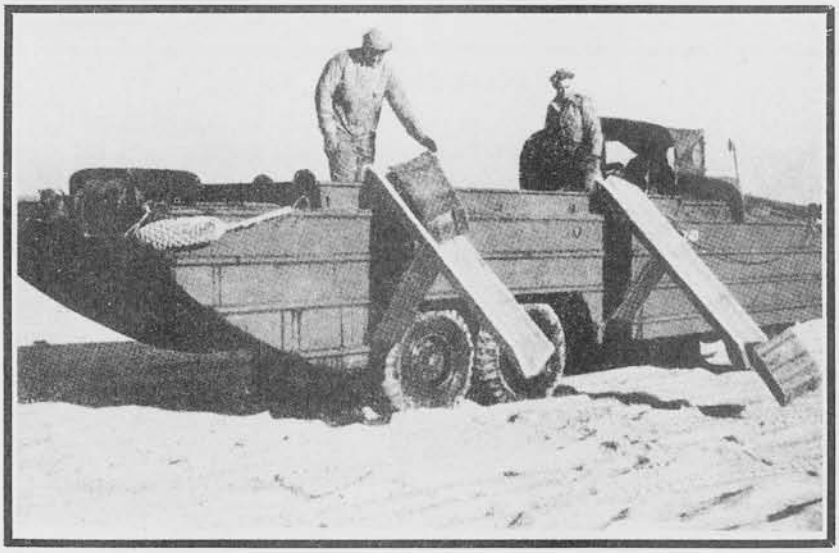
165. *Fork Truck Mounted in Truck*: This highly mobile, fast and self-contained unloading rig consists of a fork truck bolted to the bed of a 6 x 6 land truck. The fork truck faces the rear of the truck. At the front end of the cargo floor a 750 lb. counterweight

is installed. The finger lift of the fork truck is removed and replaced by an overhead five foot arm with a hook for lifting cargo slings at its outer end. (See figure below).

166. *Hog Trough*: Where there are small packages to be hand unloaded, Hog Troughs will be very useful. They can be made very easily by forming a "V" shaped trough out of two 2" x 12" planks, six feet long. The upper end is fitted with ¼" x 1½" strap hooks



to secure over the DUKW coaming. There is a three foot leg to support extended portion of the trough at a 45° angle, with the lower end about a foot clear of the ground. The three foot leg is braced against the lowest hull rub rail. The DUKW can be driven along slowly as packages are slid to the ground, giving dispersion and eliminating necessity of handling at base of trough. With two hog troughs, four men can unload 6000 pounds of cargo in less than two minutes.

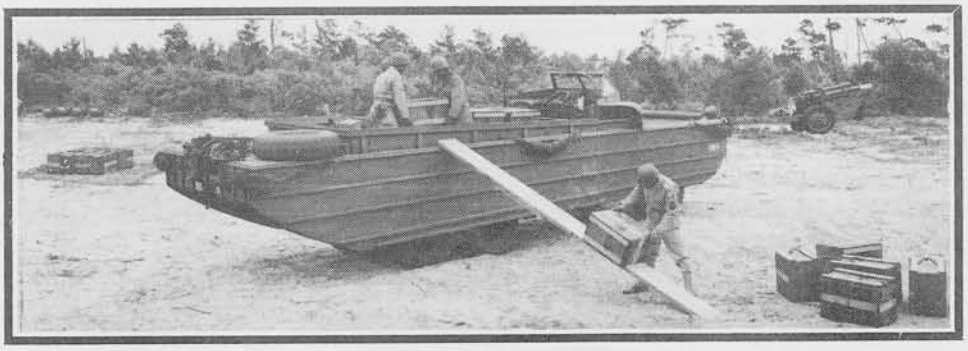


Unloading with "Hog Troughs"

167. *Barrel Skids*: Barrel skids made of two 4" x 4"s 10 feet long and secured 14" between inner edges, provide a useful method for hand unloading 55 gallon drums. The skid should be placed against the side of the cargo space and the drums slid edgewise over the coaming and down the skid.

Barrel Skids

168. *Plank Skids*: Plank skids measuring 2 x 12inches x 12 feet are a simple expedient for unloading square packages.



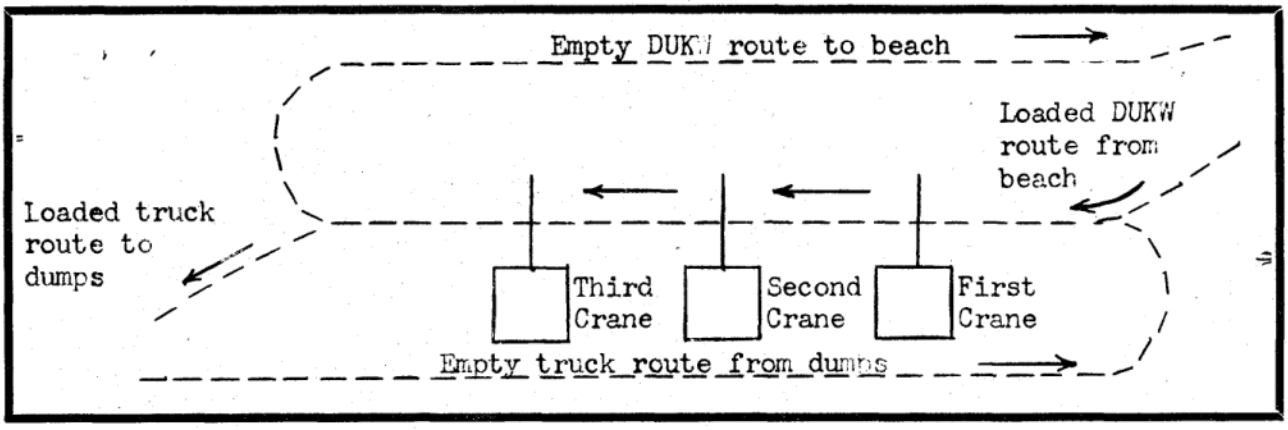
Plank Skids

169. *Roller Runways*: Roller runways can be used in a manner similar to plank skids.

Hand Unloading Platform

170. *Hand Unloading*: Where enough men are available, very rapid unloading can be accomplished without any equipment by forming the men in one or two circles. A convenient working height can be obtained against the side of the DUKW by piling packages in the form of a platform.

171. *Normal Unloading Procedures*: a. *DUKW Transfer Point*: If the distance from beach to dump is greater than two miles, cargo should be transferred from DUKW to land truck at a transfer point close to the beach. If such DUKW is bringing in three drafts of cargo, three transfer rigs (cranes, "A" frames, or other lifting devices) should be installed at about sixty foot intervals. When a DUKW drives in, it stops at the first crane and has its top (or rear) draft picked up. It then proceeds on to the second transfer rig, a truck following in its path to receive its loads. Thus, DUKWs and trucks alternate through the transfer point.



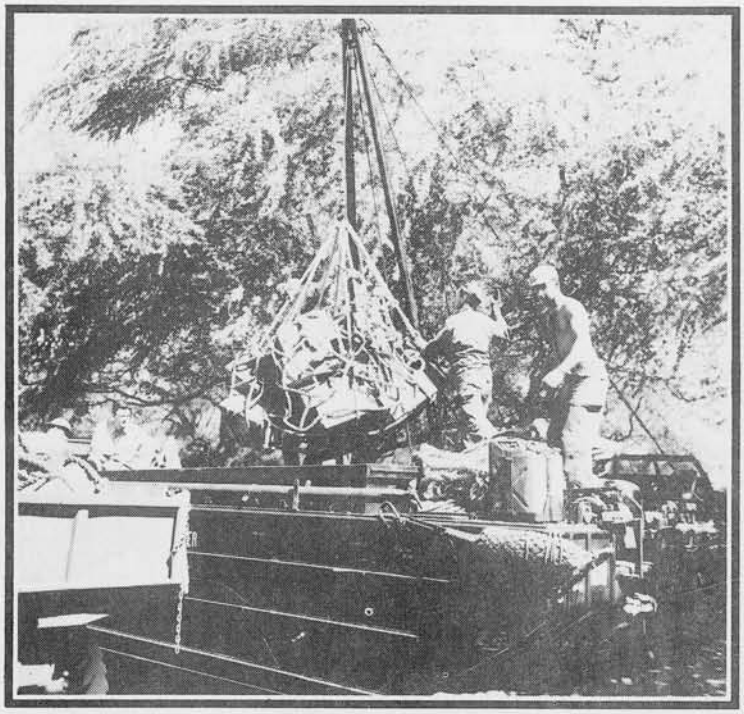
Transfer Point for Three Cranes, "A" Frames or Truck Mounted Fork Trucks

b. *Mixed Loads*: Where possible, mixed loads that involve going to more than one dump should be avoided. Also, loads that involve handling with several types of equipment in any one dump should be avoided.

c. *Return of Nets, etc*: Empty nets, slings, etc., must be returned to ships at the same rate as they come ashore loaded. Thus, if a DUKW receives three netloads of cargo from a ship, it must pick up three empty nets at the dump or transfer point, otherwise a shortage of nets on the ship may develop.

d. *Stopping Points*: Much time spent in backing and maneuvering will be saved at dumps and transfer points if the exact stopping points for DUKWs and other vehicles are clearly marked. The markers can be white tapes or painted stakes. By this means, cranes, "A" frames, etc. will be in exactly the right position to handle cargo in or out of vehicles.

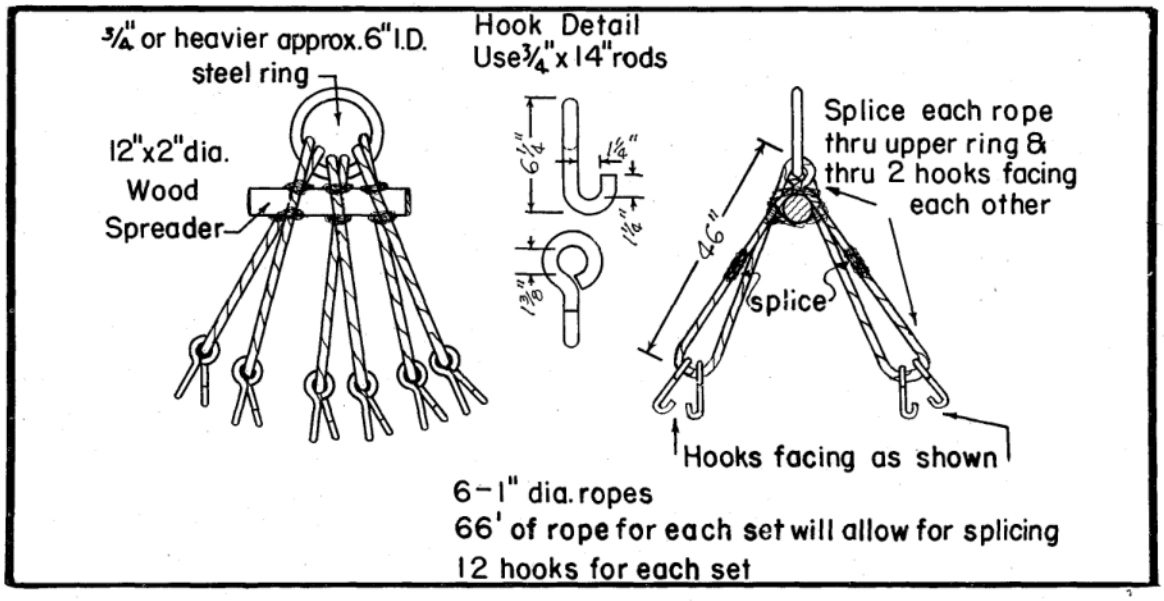
172. *Unloading Palletized Cargo*: Palletized loads should generally be unloaded intact and not opened until time of actual use. They may be unloaded with a crane, fork truck mounted on a truck, or "A" frame. Use doubled tow chain for bridle if pallet wires wont meet lifting hook. For hand unloading, the straps on the pallets must be broken and the cargo discharged preferably with hog troughs, otherwise with plank skids, roller runways or hand unloading, with platform if helpful.



Using Chime Hooks to Lift Net Load of Ammunition

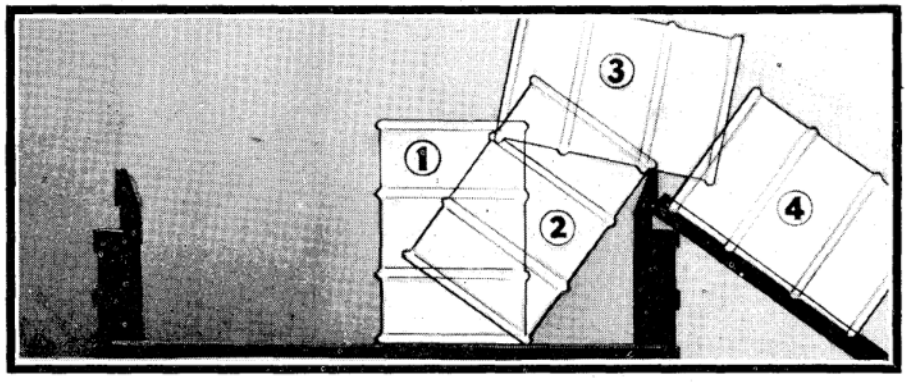
173. *Unloading Nets*: When discharging nets from a DUKW with "A" frames, or short cranes, it may be found that the height or drift of this equipment will be too short. Six Chime hooks or a six spider bridle with hooks that can engage the mesh of the nets will be found valuable for discharging such nets. (See paragraph 174).

Six Drum Chime Hooks



174. *Unloading 55 Gallon Drums*: The quickest way to unload 55 gallon drums is by the use of chime hooks in conjunction with cranes, fork truck mounted on a truck, or "A" frames. For details of chime hooks see figures below and on next page.

If mechanical equipment is not available, barrel skids will provide a useful method for the hand unloading of these drums. (See paragraph 167). The skid should be placed against the side of the cargo space and the drums slid edgewise over the coaming and down the skid to the ground where they can be rolled into storage piles. Drums on the bottom of



Unloading 55 Gallon Drums Onto Barrel Skids

the cargo space must be placed on end about two feet from coaming, then leaned against the coaming and with two men lifting the low end, slide the drum up over the coaming and down the skid. (See figure below). Work close to rear end where cargo space is least deep.

175. *Unloading Projectiles*: Projectiles are best unloaded with crane or "A" frame if carried in pallets. Crane or "A" frame with cluster of 12 chime hooks is best where pallets are not used. Hog troughs are best for hand unloading.

176. *Unloading Bombs*: The best methods for bomb unloading depend upon the bombs being carried. The methods are outlined below:

(a) 100 lb. bombs should be hand unloaded with hog trough, or with "A" frame, or crane when in pallets.

(b) 250 lb. bombs should be hand unloaded with hog trough, or with "A" frame or crane when in pallets, or cluster of six hooks or bridles.

(c) 500 lb. bombs should be unloaded with "A" frame or crane, with bridles or slings, to pick up four bombs at a time, or with suitable pallets. The bombs can also be rolled up on skids over the side of the cargo space and dropped onto soft ground *if mechanical aids are not available.*

(d) 1000 lb. bombs should be unloaded with "A" frames or cranes, with bridle or slings to handle two bombs at a time. In an emergency where mechanical aids are not available, bombs may be rolled up on skids over the side and dumped onto soft ground.

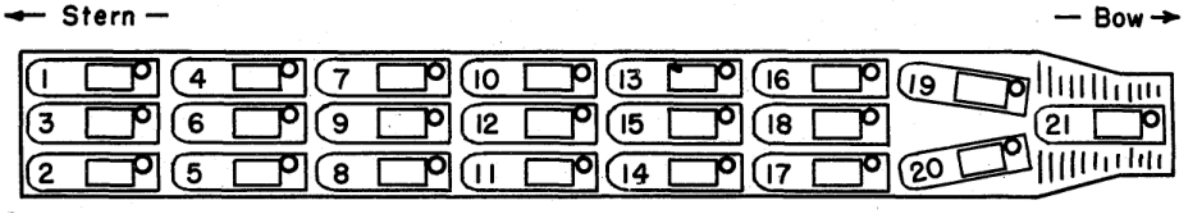
(e) 2000 and 4000 pound bombs. Unloading will be accomplished with "A" frame or crane fitted with suitable bridle or slings. (See figure below).

Bridle on 2000 Pound Bomb

CHAPTER XVIII

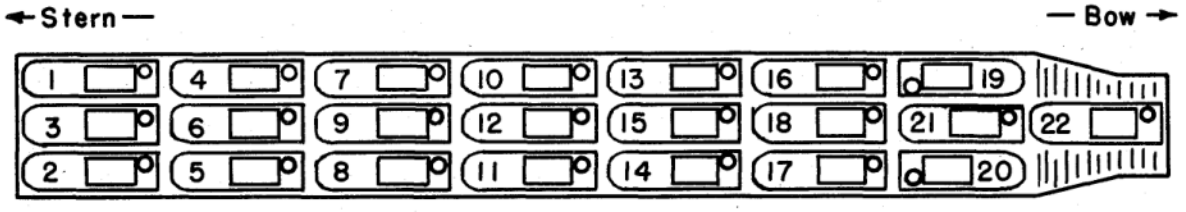
OPERATIONS WITH LSTs

177. *Initial Loading*: DUKWs should be driven aboard frontwards, the only exception being as mentioned in paragraph 178 below. Where possible, particularly when loading for a long trip, the *loading should be made from dry land.* This is necessary to prevent serious corrosion of brake mechanisms and other parts while the DUKW is stationary for a long period. DUKWs can also be driven up the ramp to the top deck on LSTs so fitted. The guides for the ramp to the upper deck should always be hung up out of the way when operating from the tank deck. In the normal unloading, the DUKWs leave the LST *stern* first.



21 DUKWs Loaded Frontwards, Showing Order of Loading

178. *Backing on Board*: If the loading plan places three DUKWs abreast immediately inside of the ramp opening (See Figure below) the last DUKW on each side should be *backed* on board to make it possible to get in and out of the corners near the ramp opening. DUKWs can be backed aboard easily on land, but afloat it requires smooth water and a skillful driver. It is most important that the center part of the ramp be clear of obstructions so that propeller guards will not be damaged on DUKWs so fitted, either when *backing on board* or *going off frontwards.* Also the pintle hook on the DUKW must be turned on its side to provide maximum clearance. The bolt thru the emergency ramp cable fitting at centerline of LST ramp, should be ground off as near to flush as possible. In all cases go on or off the ramp slowly, and when going off frontward, don't engage the propeller until *after* clearing the ramp.



Maximum of 22 DUKWs on Tank Deck, Showing Direction and Order of Loading

179. *Lashing*: The three bow shackles, and the stern pintle hook, plus the two fender eyes on each rear deck corner, are the most suitable lashing points. The two lifting eyes and one mooring eye on each side are strong for fore and aft lashings, but not good for side pulls. Do not use bow fairlead or either bow or stern davit eyes. Park the DUKWs in low range reverse and set hand brake.

180. *Tire Pressure*: Tires should be inflated to 40 pounds and individual valves shut (on DUKWs equipped with central tire control). Inspection should be made daily for leaking tires, and repairs effected when necessary. Individual valves should be opened to equalize tires (*after* inspection) and when necessary, tires inflated to maintain 40 pounds pressure.

181. *Maintenance*: (Also refer to Chapter V)

a. Gasoline tanks should be filled *before* loading.
b. After loading, bilges, including three drive shaft housings, should be drained, bilges cleaned and all plugs replaced and valves closed.
c. Run engine about 10 minutes every second day.
d. Operate propeller and winch drive shaft, briefly each time engine is run.
e. Perform "Weekly" maintenance as outlined on "Minimum Drivers Weekly Maintenance", paragraph 66. (Exclude land and water test runs). Do *not* drain any part of the fuel system, or replace any gasoline except when directed by company officers. At such times, LST deck fans must be running, and extreme care must be used to see that no gasoline is spilled.

182. *LST Marking*: During the unloading operations, much valuable time can be lost by the DUKWs going to the wrong LST. For that reason it is extremely helpful to have distinctive markings for each ship. Drivers must be thoroughly familiar with markings.

183. *Ramp Curbing Corner Guards*: The outboard corner of the ramp curb (see sketches on page 91) is very dangerous and can easily cut a hole in the bow of a DUKW when landing. It is extremely important that this corner be guarded. The simplest field expedient is to use one-third of a salvaged tire, fitting it over the corner, and wiring it securely thru small holes drilled in ramp curb, preferably with additional canvas or rope padding underneath the tire. A triangular shaped rope matting would also be helpful. A suitable type of removable curved steel guard to be used in conjunction with a tire is the best protection. (See sketch page 92).

184. *Ramp Obstructions*: Any obstructions that extend above the ramp cleats, or any appendages on ramp curbs, should be removed, and surface ground smooth to protect DUKW hull and tires. Inner face of ramp curb, and passageway into tank deck, should be kept clear of any obstructions. The bolt thru the emergency ramp cable, fitted to ramp center, should be ground off as nearly flush as possible.

185. *Distance from Shore*: Due to the slow speed of the DUKWs, it is imperative that the LSTs take station as near the shore as tactical situation will permit. By staying far off shore, danger in many cases will be increased, as the unloading period will be drawn out many times the period that would be necessary if a berth nearer shore were used. When strong currents must be negotiated there is a resultant loss in the DUKW's speed, placing more emphasis on nearness to shore, also suggesting initial unloading at a point up-stream from desired landing point. (See DUKW speed, paragraph 7e).

186. *Ramp Angle*: (See sketch next page). It is most important that the DUKW wheels or bow do not hit against the extreme lip of the ramp. To prevent this, the minimum sub-

mersion should be approximately four feet. In rough water, or when the LST is light forward, relatively steep ramp angles will be necessary to insure this submergence. On the other hand, a flat ramp angle makes landing and launching easier. Therefore, in smooth water, and when it is possible to ballast the LST forward tanks, the 48 inches depth over the lip of the ramp can be obtained with the ramp considerably above the bottom stop position.

187. *Ramp Cables, Shores and Doors*: Regardless of whether shores are employed or whether the ramp is set so it is down against the lower stop, it is important that either the hoisting cables or auxiliary cables (preferably covered with pipe) be kept tight to prevent the DUKW straddling one side of the ramp. It is also important that the doors be kept as close in to the sides of the ramp as possible to prevent a DUKW getting off the edge of the ramp *under* the support cables. Keep the DUKW wheel house covers securely in place and in good condition, as they help prevent wheel houses catching on the ramp cables.

188. *Keep Ramp Opening Clear of Personnel*: The curious crowd which normally collects in the ramp opening, tends to confuse the DUKW driver and frequently causes him to stop prematurely, perhaps in a dangerous position. The officer in charge of directing the landing (or launching) should stand clearly in the center. The rest of the opening should be kept absolutely clear.

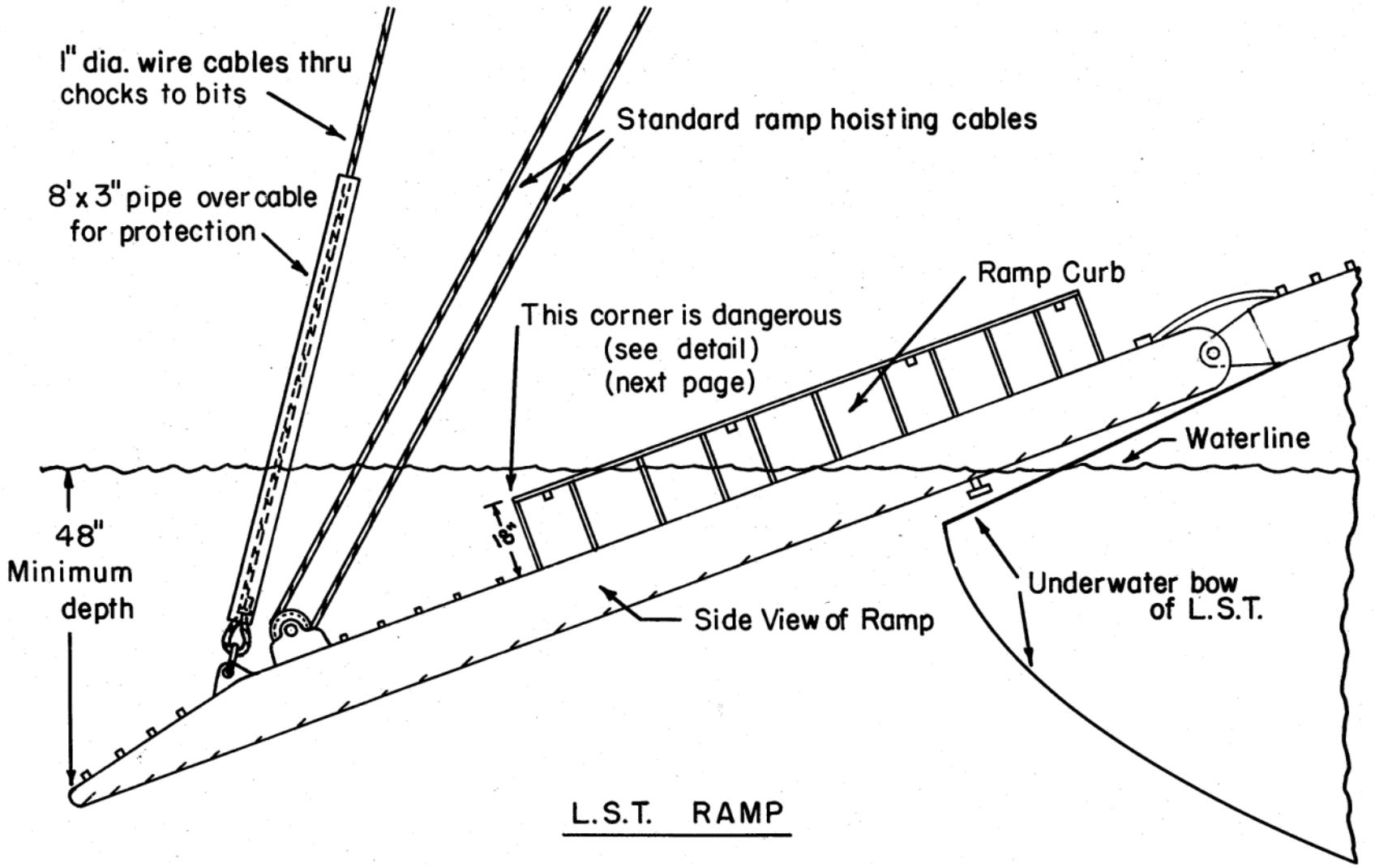
189. *Handling of Ship During DUKW Operations*: Due to the slow reverse speed of the DUKWs it is imperative that the LST have no headway when DUKWs are launching or landing. Where a strong current might take the ship out of position, operations could continue with the LST maintaining sternway up to two and one-half to three knots. In all cases, whether anchored or not, the LST engines should be used as much as possible to prevent yawing, and to eliminate cross currents or cross seas over the ramp.

190. *DUKW Loading*: The *total* payload should center approximately two feet forward of the center of the cargo space. It should not be more than 5000 pounds where conditions are unknown or where conditions are known to be difficult. Under combat emergency, where conditions are favorable, 7500 pounds may be carried. For ship launching operations, total payload should never exceed 7500 pounds. (See paragraph 156).

191. *Control*: No DUKWs will be launched from or land on the LST without clearance from the ship's officers. The actual direction of the DUKW at time of launching or landing will be by an officer of the DUKW Company, who will be stationed at the head of the ramp on the tank deck.

192. *Pre-Launching Check*:

a. Tire pressures correct for expected landing conditions.
b. Supply of gasoline, oil and water, including spare supply.
c. Weight of payload not excessive for conditions as they exist.
d. That load is properly placed and secured.
e. Inside the hull clean and dry, *all plugs in place and drain valves closed.*
f. All DUKW standard equipment and tools are on board and in place.
g. Hull is free from leaks. *Hold for repairs when necessary.*
h. Cab top removed, windshield down, bow surf plate folded down on deck.
i. Bow hatch, engine hatch, auxiliary air intake, rear hatch and two winch cable fairleads in coaming all tightly shut.

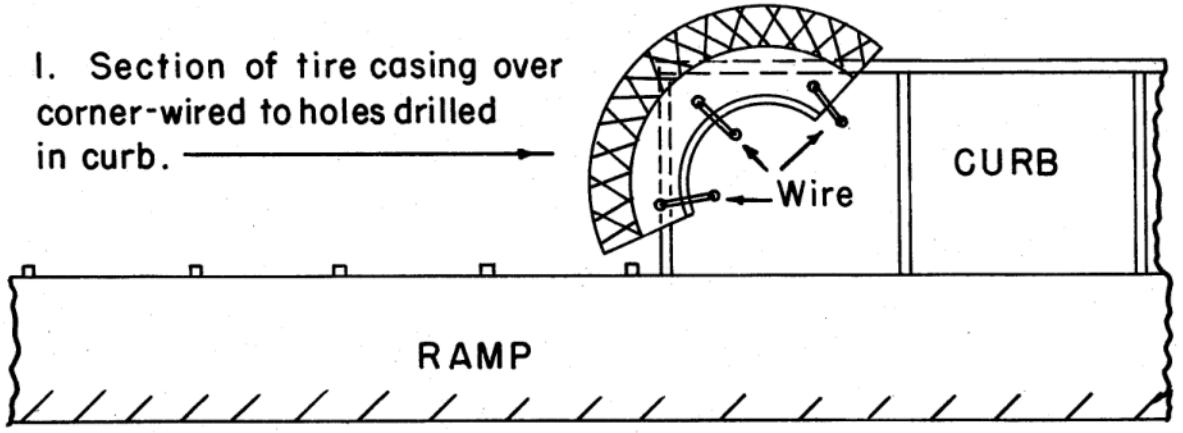

1" dia. wire cables thru chocks to bits
Standard ramp hoisting cables
8' x 3" pipe over cable for protection
Ramp Curb
This corner is dangerous (see detail) (next page)
Waterline
18"
48" Minimum depth
Side View of Ramp
Underwater bow of L.S.T.

L.S.T. RAMP

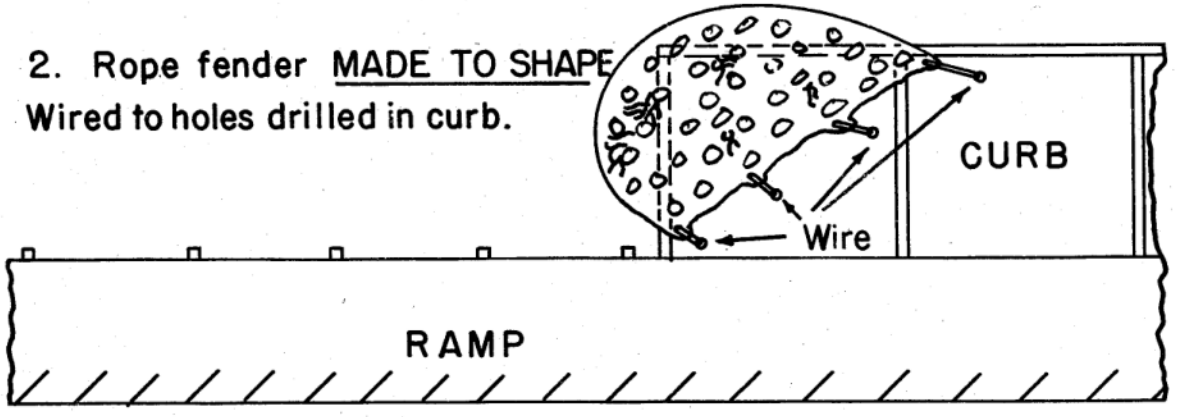
DETAILS OF

L.S.T. Ramp Curb Corner Protection, for use with DUKWs.
Guards and bumpers must be removed to seal Ramp.

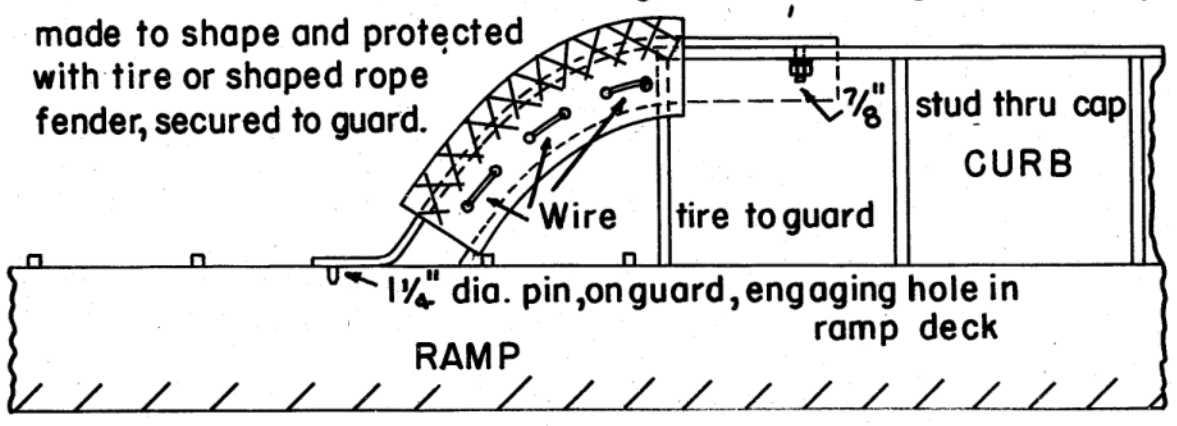
1. Section of tire casing over corner-wired to holes drilled in curb.



2. Rope fender MADE TO SHAPE Wired to holes drilled in curb.



3. Removable Guard of 5"x½" angle or similar angle or channel, made to shape and protected with tire or shaped rope fender, secured to guard.



j. Rear closure set up—except in case of 105mm Howitzer or special loads that prevent its being set up, in which case cargo tarp must be rigged tightly around rear coaming to keep out water when backing down the ramp.

k. When loaded, cargo tarp must always be rigged over at least the rear half of cargo space. In rough weather cargo tarp must completely cover cargo space.

l. Engine well warmed up—cooling passages all clear.

m. *Driver understands his instructions and objectives.*

193. *Launching*: At the actual launching, the following details should be carefully followed:

a. Personnel in DUKWs temporarily crowd forward to lighten the stern while descending the ramp.

b. Front wheels engaged and transfer case in low range.

c. Transmission in reverse. (First speed for forward launching).

d. Propeller drive in reverse (overdrive) position. For *forward* launching propeller should *not* be engaged until stern of DUKW clears the ramp.

e. Bilge pump manifold right rear valve open. All others shut.

f. Set pintle hook crosswise—necessary only for forward launching.

g. Release emergency brake.

h. Do not depress clutch after starting down ramp. Engine is the best possible control of your speed. To guard against inadvertantly depressing clutch, place left foot *on floor alongside the pedal.*

194. *DUKW Speed*: A Dukw in first-class operating condition will make 6.5 *land miles* per hour traveling light and in smooth water. From this you should deduct one-tenth of a mile for each 1000 lbs. of load carried, also one-tenth of a mile for each foot of wave height, and probably three-tenths for possible mechanical deficiencies (slow governor, lame engine, bent propeller, etc.) These figures should help in laying out a course to the shore or to control boats.

195. *DUKW Preparation for Landing on LST*: When approaching the LST preparatory to landing, the driver should check the following:

a. Bilge pumped as dry as possible.

b. Rear closure up. When loaded, tarpaulin rigged tightly over at least rear half of cargo space.

c. Tire pressure 25 pounds.

d. If loaded, that load is properly placed and secured.

e. Keep about 50 yards in front of LST ramp, and be alert to receive signal to land.

196. *DUKW Landing on LST*:

a. Lower bow surf plate and windshield when you get signal to land.

b. Engage transfer case in low range.

c. *Check that front wheel drive is fully engaged.*

d. Shift transmission to first speed.

e. Shift propeller control to reverse (overdrive) position.

f. Approach the ramp *keeping directly in line.* If the LST is swinging, allow for the swing—lead it by heading enough towards the side to which it is swinging, so that the DUKW will be directly in front when the ramp is reached. Step on the gas when

a turn is to be made. Turn the steering wheel in time, also straighten out ahead of time or the DUKW will swing too far. If the DUKW strikes the cables, slip the clutch until the DUKW bounces back sufficiently to enable the bow to get on the ramp. Do not reverse unless so directed by the officer controlling the landing from the tank deck of the LST.

g. When on the ramp, steer down the center and do not stop unless directed, until on the down grade inside.

197. *After Landing on the LST*:

a. Move DUKW to position as directed.

b. Deliver any messages from shore. Make known any special need so materials can be secured without delay.

c. Drain hull and close valves.

d. Get necessary fuel, water or oil. Do not fuel on tank deck without permission.

e. *If landing was rough, inspect carefully for damage and make any necessary repairs.* Rags, wooden wedges or plugs and seam compound will serve when it is out of the question to weld. A tarp can be securely lashed over a fairly large hole to permit safely reaching better repair facilities.

198. *Speed Up DUKW Operating Cycles*: With the exception of driving slowly down the steep part of the ramp, all phases of DUKW operations should be accomplished without delays. Some 75 to 300 DUKW round trips will be needed to unload the LST. Each round trip has a number of key points from which wasted time can be eliminated. When one DUKW is going down the ramp, the next should be moved quickly to the top of the ramp so it is ready to follow at a 10 to 15 second interval. When one DUKW is landing the next DUKW should be brought in close so that as soon as the landing DUKW is in a safe place, the next will reach the ramp. If a rendezvous circle is used, it should be kept small and close. Where there is current, the circle can be dispensed with and the DUKWs can stay in position driving slowly ahead, watching for their turn to land. The importance of saving a minute here and there on each DUKW trip is vital.

199. *Landing Alongside*: On LSTs carrying pontoons it is important that DUKWs be kept away from the dangerous areas from which the DUKWs might get forced under the pontoons. Thus if the LST is anchored by the stern or is making sternway, landings should not be made at the stern, as it is easy to be forced under the pontoons, which may then do serious damage to the personnel and equipment. However, landings at either side of the bow would be perfectly safe, provided the doors are kept in close to the ramp. On the other hand, if lying to a bow anchor, or mooring ahead, the stern would be the safer position to land.

200. *Fueling*: The first trip to shore should be started with a full gasoline tank and two full five gallon gasoline cans on rear deck. The maximum fuel consumption should be under seven gallons per hour, the normal average approximately half that figure. When on shore, if the tactical situation permits, gasoline should be put in the tank from the extra five gallon cans or from any other available source. In order to save time and bottle-necking a supply of filled five gallon cans should be available on shore, also on the LST. It is not advisable to pour in the gasoline on the tank deck of the LST unless it is absolutely necessary. Then it is important that ventilation fans are running and that every precaution is taken to avoid spilling fuel. Each time a DUKW lands on the LST, it should leave any empty five gallon cans and pick up in exchange cans that have been pre-

viously filled. It is advisable that the five gallon cans be filled on the weather deck of the LST. When sea conditions will permit, fueling can also be accomplished by a hose overside to the most sheltered landing place alongside the LST.

201. *Handling Ammunition*: When ammunition is carried on the tank deck under the DUKWs, after the DUKWs have gone overboard for their initial trip to shore, the dunnage should be removed from one side to the center line, leaving enough dunnage so that the DUKWs returning to load can drive in, in column, using the side from which the dunnage has not been removed. Ammunition should then be loaded on the DUKWs. This can be expedited by having a pile stacked in advance next to each position where a DUKW will be parked. The greatest emphasis must be laid on loading the last DUKW aboard as it must be the first to leave. The number of men in the loading crews should be graduated down for successive DUKWs, the largest crew loading the last DUKW aboard, and the smallest crew loading the first DUKW aboard. Assuming six DUKWs arrive for a load of ammunition and the first DUKW boards the LST at 0900, the DUKWs should enter not over thirty seconds apart, placing the sixth DUKW on board at 0902:30. Assuming five minutes to load the sixth DUKW, it then leaves at 0907:30. Assuming the DUKWs leave at thirty second intervals, there will have been six, seven, eight, nine and ten minutes for loading DUKWs five, four, three, two and one respectively. In an ideal operation, if the round trip, including loading and unloading can be made in an hour, and if the LST carried 24 DUKWs, a group of six would be loaded by the LST once every 15 minutes. There would be 24 trips leaving each hour and assuming three and one-half tons average load, that would be 84 tons per hour. The ideal set-up would have six DUKWs loading on the LST, six loaded DUKWs half way to the shore destination, six DUKWs unloading at destination and six empty DUKWs half way back to the LST.

202. *Miscellaneous Cargo*: Jeeps or M-29-Cs can be loaded by being driven up over the stern of a DUKW on temporary ramps 12 feet long. Ten foot ramp must be used in the DUKW cargo compartment and DUKWs rear deck and rear coaming must be amply protected with dunnage. A DUKW with an "A" frame could be used on the top deck to lower heavy loads through the main hatch on to vehicles on the tank deck. However, this should only be done where there is no other expedient available, as it is slow and ties up one otherwise needed vehicle. Two LST ammunition davits can be used, one at each forward corner of the main hatch.

203. *LSD Operations*: The details of operating with LSTs are generally applicable to LSD operations. An important exception is that where the tactical launching will be made by flooding, the DUKWs should be put aboard facing the stern, so they can swim out driving frontwards. Note that the tank deck of the LSD can accomodate 47 DUKWs.

204. *LSV Operations*: The details of operating with LSTs are generally applicable to LSV operations. A four inch extra heavy pipe tripod eight feet high should be welded on the LSV ramps to protect each outer sheave. This tripod should be heavily wrapped with rope to provide a cushion. A removable section of five inches by one-half inch angle should bridge the cut out section of the ramp curb on each side. Twenty-nine DUKWs can be loaded on the vehicle deck of LSVs up to LSV #3, and 31 on the later ships, all facing the bow. Additional DUKWs can be carried on the main deck and launched by the main derrick.

205. *LSM Operations*: The extreme corner of ramp curb on each side should be burned off on an 18" radius, recapped and then protected with sections of tire which can be permanently wired in place. The LSM can carry 9 DUKWs all driven aboard frontwards. The details of operating with LSTs are generally applicable to LSM operations.

CHAPTER XIX

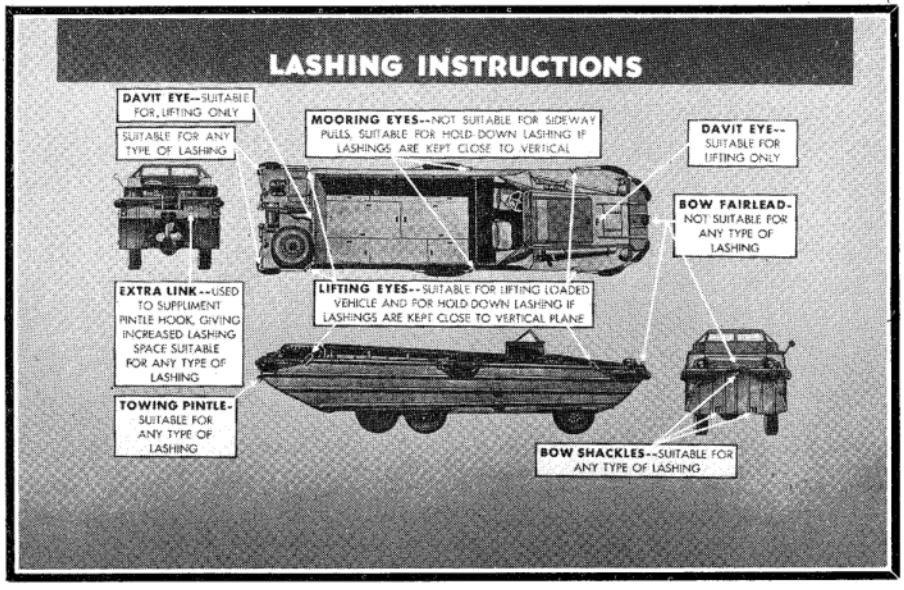
COMBAT SHIPMENT on APAs or AKAs

206. *Davit Eyes*: (See figure below). All DUKWs are fitted with davit eyes having same spacing as LSVP, and can be carried on any davits that can accomodate LCVP. Davit eyes spaced 22 feet five inches are designed to carry fully loaded DUKWs.

207. *Sling Lifting Eyes*: (See figure on next page). In addition to davit eyes, all DUKWs have four eyes for use with 16 foot (or greater) equal length four legged lifting bridle of not less than five-eighths inch diameter plough steel wire. These eyes are also designed to lift a fully loaded DUKW. DUKWs can be carried on deck or in any suitable hold, where ten ton booms are available.

208. *Weights and Load*: A DUKW with all standard equipment but *without payload* will weigh not more than 15,000 pounds. Load on after davit fall will not exceed 7750 pounds and load on forward davit fall will not exceed 7250 pounds. *Payload which must not exceed 7500 pounds for any ship launching operations,* will impose approximately two-thirds of its weight on after davit fall, and approximately one-third on forward fall.

209. *To Enlarge Davit Eyes*: If DUKW davit eyes are not large enough to receive davit hooks, shackles can be fitted in the davit eyes. These shackles, if used, should be made to stand upright, unsupported, by wrapping marline or rope yarns around between the deck and the shackles. This will greatly facilitate hooking and unhooking. In many instances, it will be helpful to slide the anchor five or six inches toward the stern to get it clear of the rear davit eye. When this is done, the anchor lashing straps should not be removed but merely loosened, so that the anchor cannot fall off the rear deck. In some



cases, where the davit hook will not fit in the davit eye, removal of the three-eighths inch thick caution plate on the deck will provide sufficient additional room so that the hook will fit.

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210. *Chocking Blocks and Gripes*: When carrying the DUKWs in davits swung outboard, *chocking blocks,* should be fitted against the full height of *DUKW's* side. The block face must be at least six inches wide and be padded to protect the paint. The blocking should be arranged so that it will not press against the light metal shields which cover the wheels. Griping should be from the center forward shackle and after towing pintle hock. Gripes leading completely around the DUKW hull should be avoided as should gripes leading to davit eyes. The cast iron fairlead in the bow is not strong enough to use for lashing.

211. *Securing on Deck*: If the DUKWs are carried on deck or in the hold, carry their weight on tires inflated to 40 pounds. Lash the DUKWs down from their bow shackles and stern pintle hook or two eyes on rear corners. Lashing may be rigged from the four lifting eyes or the two mooring eyes, but should be kept close to vertical plane of side to avoid lateral pull. Do not use bow fairlead or two davit eyes. Leave the DUKW in low range reverse with the hand brake set.

212. *Maintenance*: For maintenance, refer to Chapter V.

213. *Launching Checks*: For pre-launching checks, refer to paragraph 192.

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CHAPTER XX

OPERATIONS WITH 105MM HOWITZER

214. *Non-Combat Wheels*: For transportation in a DUKW, it is desirable that a 105 Howitzer be fitted with the non-combat wheels and tires. This permits Howitzer wheels to rest on cargo floor, using standard DUKW-105 Howitzer wheel chocks as described in paragraph 216. Overall height is approximately nine feet when on land.

Non-combat Wheeled 105 Howitzer in DUKW

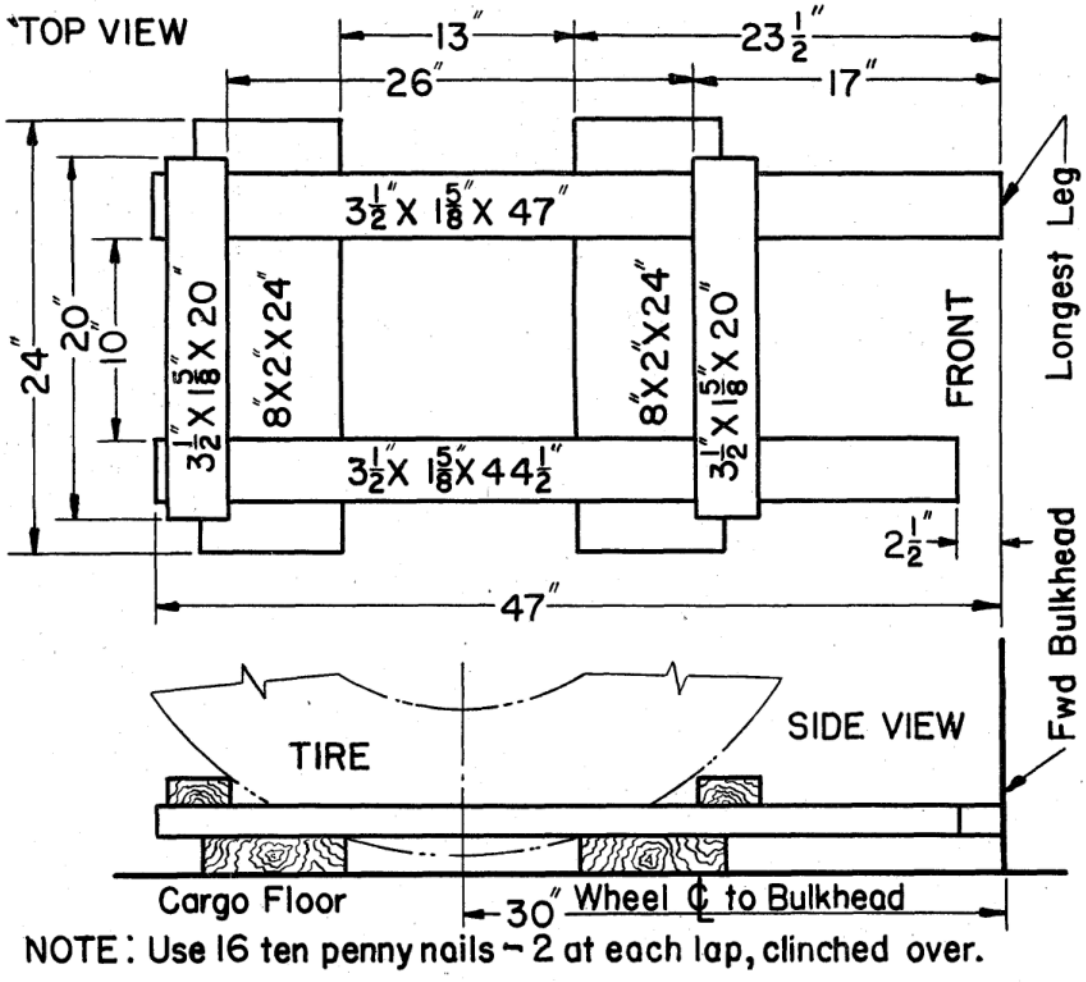
215. *Combat Wheels*: A combat-wheeled 105 Howitzer may be carried, but has the disadvantages of increasing overall height by at least 10 inches, which diminishes the amount of cargo that can be placed on the tank deck of LST below the loaded DUKWs. In addition the DUKW coaming must be hammered out in way of both Howitzer hubs which are

Combat Wheeled 105 Howitzer in DUKW

four inches wider than the space between coamings. The standard DUKW-105 Howitzer wheel chocks must be placed upside down on 6 inch blocks to raise the wheels ten inches above the normal position *on* the cargo floor. The overall height thus becomes at least nine feet, ten inches when on land.

216. *Wheel Chocks*: Two standard DUKW-105 Howitzer wheel chocks are needed for each DUKW. They may be used for any wheeled load, serving to distribute the tire load and thereby protecting the cargo floor. At the same time they help chock the load in place.

217. *Position of Wheel Chocks*: a. *With non-combat-wheeled Howitzer.* Place one wheel chock right side up in each forward corner of cargo space. Longest leg should touch forward cargo bulkhead, and main cross members should touch hull sides. Gun tires will then rest in position shown in side view sketch above.

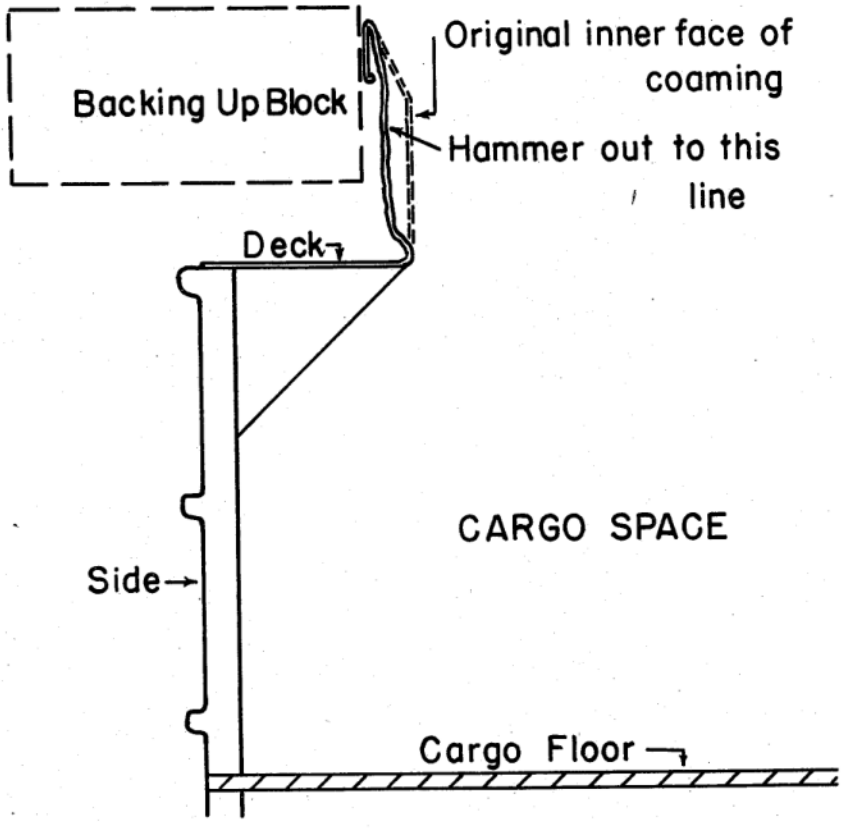


Wheel Chocks for 105 Howitzer

b. *With combat-wheeled Howitzer*, wheel chocks must each be placed upside down on six inch by ten inch by 4 foot, or equivalent blocks. The longest leg must still be against forward bulkhead, and the main cross members against the side coaming below deck extension.

218. *Coaming Alteration for Combat Wheeled 105 Howitzer*: The Howitzer axle should center 30 inches behind forward bulkhead. To provide for lowest reasonable position of wheels in cargo space, as outlined in foregoing paragraph, the inner bevel of the coaming must be flattened out to provide about two inches more clearance on each side. This can be accomplished easily by holding a block (such as six inches by ten inches by four feet wheel rest) endwise against the outside of the coaming, and then hammering with the back of the axe over a length of about 12 inches (centering 30 inches behind forward bulkhead).

SECTIONAL VIEW



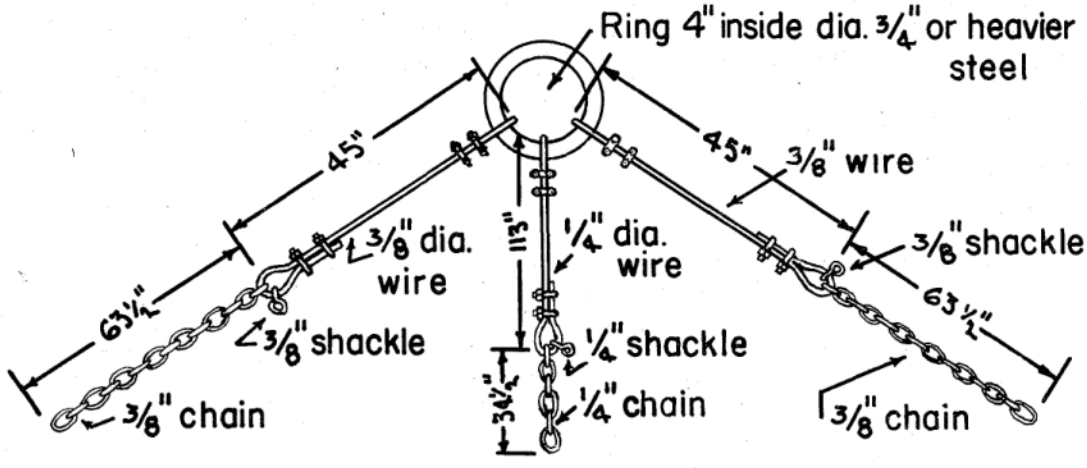
Details of Coaming Alteration.

219. *Trail Rest*: A folded cargo net or camouflage net should be placed on center of rear deck, against rear coaming. Thickness should be sufficient to keep trails about two inches above rear coaming.

220. *Rear Closure*: Canvas type should be attached to coaming but rolled down on rear deck. Plywood type should be removed and placed on cargo floor.

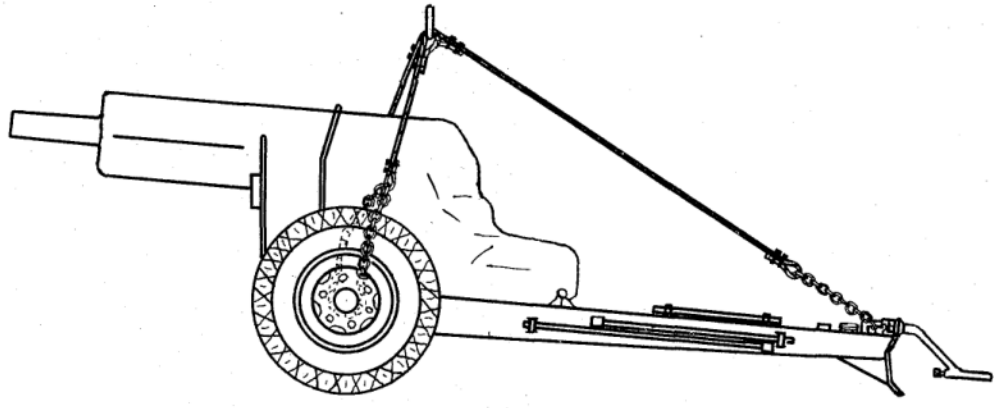
221. *Loading*: To place the Howitzer in the DUKW, and to remove it, another DUKW with an "A" frame, or a suitable crane is necessary. In emergency, the Howitzer could be removed by backing up to suitable steep bank or loading platform, then pulling gun out over ramps and dunnage in cargo space and on rear deck.

222. *Howitzer Slings*:



When placing clamps on wire, the saddle should be on the long part of the wire, the "U" bolt over the short end. (See paragraph 107.) Nuts should always be checked for tightness before using sling.

223. *Rigging Sling*: The sling should be rigged on this Howitzer as below:



Side chains lead outside tire, thru hole near top of wheel, inside wheel, under axle between brake and wheel, then up inside tire to shackle into cable. Rear chain leads thru lunette stem as in sketch above.

224. *Number of Howitzer Slings*: There *must* be a sling with each "A" frame, or preferably a sling with each Howitzer.

225. *Telescope Mounts*: The sling as described and rigged in paragraph 222, will clear telescope mount. It is advisable to tip the left hand telescope mount all the way forward and inboard. The sling is short to allow the Howitzer to be lifted clear with the 12 foot, five inch standard "A" frames.

226. *Winch Drag Brake Test*: Before attempting to load or unload a Howitzer (or any heavy load) with the "A" frame, the winch drag brake should be tested and adjusted if necessary. When the winch power take off in the driver's compartment is in neutral, and the winch jaw clutch on the rear deck is in the disengaged position, the winch shaft should rotate freely in the "forward" direction, but should be noticeably stiff in reverse. Make the test in the rear hatchway. With clean hands and clean shaft, it should be relatively easy to rotate the shaft forward with one hand. In the reverse direction it should be *just possible* with *one hand*, but still reasonably easy with *two* hands. Don't set the drag brake too tight or it will overheat and be damaged. Whenever any long amount of cable is to be paid out, release jaw clutch and pull out by hand, to save wear on drag brake.

227. *Lashing Howitzer in DUKW*: (See figure on next page) When the Howitzer has settled firmly in wheel chocks, set brakes tightly. Next secure a one inch diameter rope 50 feet long (two in each DUKW) with a bowline to the left mooring eye. Lead the rope thru under lunette stern (where rear leg of Howitzer sling is attached), another forward thru right mooring eye. Lead the rope back under lunette stern, and set tight by lashing around all three parts, using a rolling hitch. Next lock the lunette in the bow position and hook in the winch cable, and set it just tight. Then be sure winch jaw clutch is *locked* in *engaged* position, and winch power take off level (in driver's compartment) is locked in *neutral*.

228. *Additional Loads*: (See paragraph 156) The weight of the Howitzer will be between 4400 and 4900 pounds. That represents a complete load for "Difficult" conditions. However, to make the load effective, it is desirable to carry the gun crew and a small amount of ammunition, on the assumption that conditions will be "Favorable." In any case, it is most important not to let any unnecessary material be added to load, as it will jeopardize the chances of getting the Howitzer ashore.

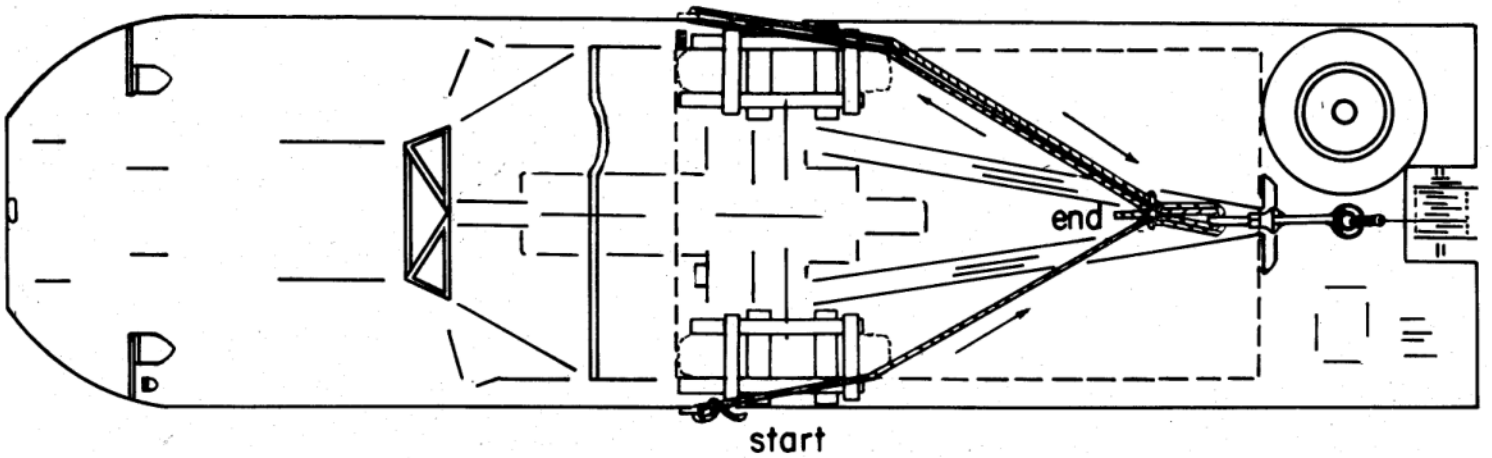
229. *Position of Ammunition*: To save weight and space, the rounds should be removed from crates and cloverleaves, and be carried in their sealed individual cartons. These should be placed equally *below* the four corners of the cargo space, in which position they are afforded the maximum protection.

230. *Position of Personnel*: Gun shields should be fully set up, and all personnel except driver and assistant should remain as low as possible in cargo space close behind gun.

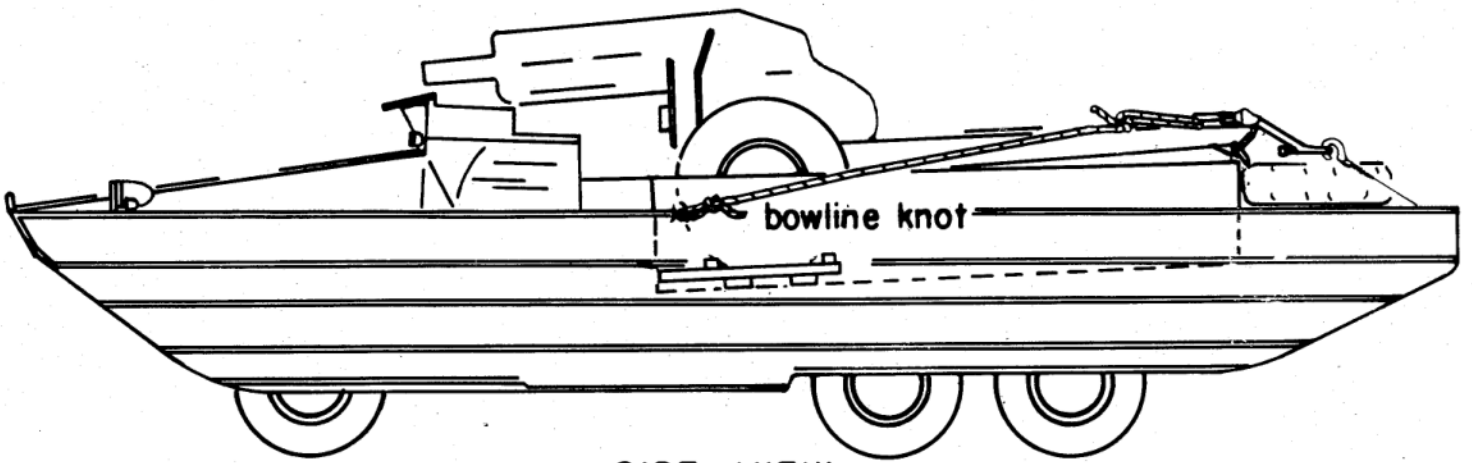
231. *Use of Tarpaulin*: The tarp should be rigged over the trail and tightly across rear coaming. The rear bow should not be used, but the second and third bows (counting the rear bow as #1) should be in place. The tarp must always be over these two bows before backing down the LST ramp. The remaining space forward should be tightly covered if rough water, high surf or rough coral is to be encountered.

232. *Unloading Procedure*: Pick the first reasonably level spot that will provide room for the operation, where there is reasonable cover and where the unloading will not block the roadway. Remove all lashings from the Howitzer and check sling carefully. Depending on the height of the "A" frame and the actual weight of the Howitzer, from one to six men

LASHING 105 HOWITZER IN DUKW



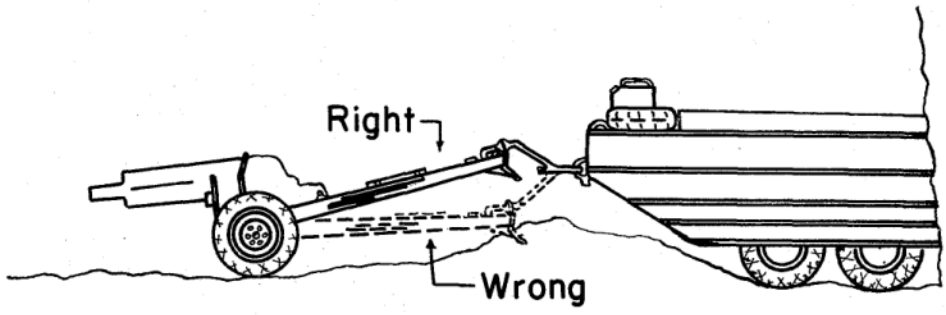
TOP VIEW



SIDE VIEW

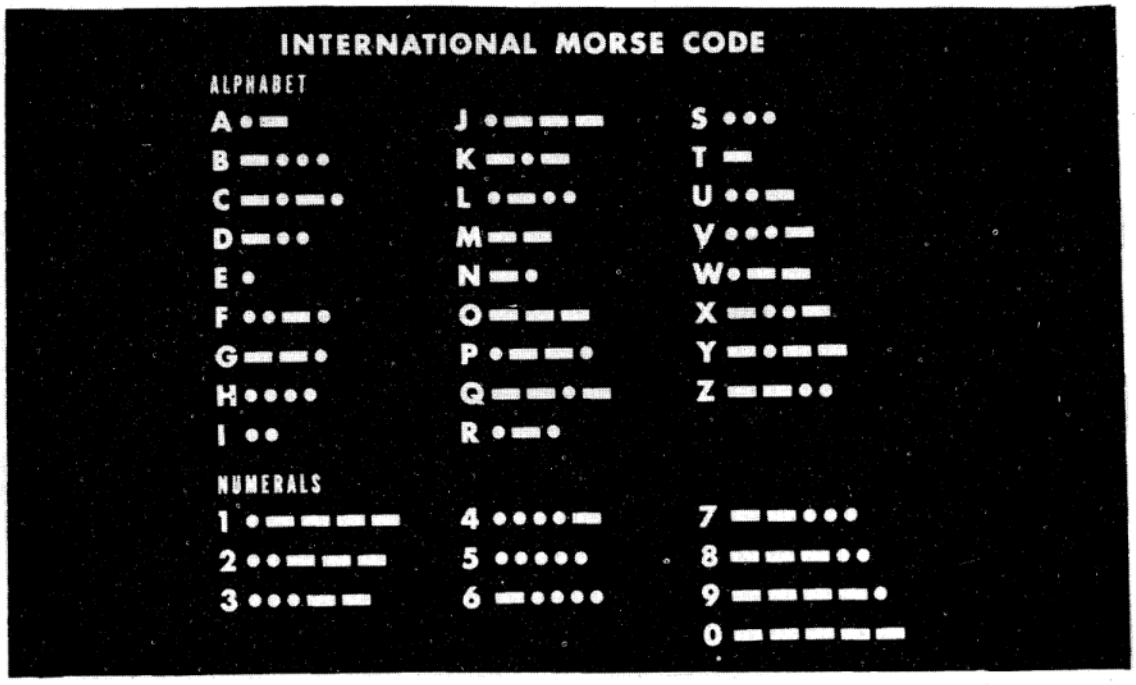
will be needed for temporary ballast on bow of "A" frame DUKW. If necessary, *all* personnel except the drivers of the "A" frame DUKW and the DUKW being unloaded can get on bow of "A" frame DUKW. As soon as the DUKW is clear the unloaded DUKW should pull forward. Remove sling. Release the Howitzer brakes. If ground is soft, rig lashing rope on axle, so DUKW can *tow* Howitzer clear of "A" frame so next DUKW can get under without delay. If ground is firm and level, gun crew can roll Howitzer clear—then turn it around.

233. *Position of Travel Lock and Lunette*: Throughout the loading into the DUKW, transporting and unloading, the Howitzer should be locked in traveling position. The lunette should be in the down position, which position should be used when limbering to the DUKW. When the Howitzer is trailed with the lunette incorrectly placed in the high position, the trail spade is apt to catch in high spots. (See figure below).



Positioning Lunette.

234. *Firing the 105 Howitzer from a DUKW*: By utilizing Harness T-1, described in T.B. 9x-67, it is possible to fire the 105 Howitzer from a DUKW, either afloat or on land. The full traverse and elevation of the Howitzer can be utilized. Firing afloat will only be effective with the use of a highly trained gun crew, and under extremely favorable conditions or from sheltered waters.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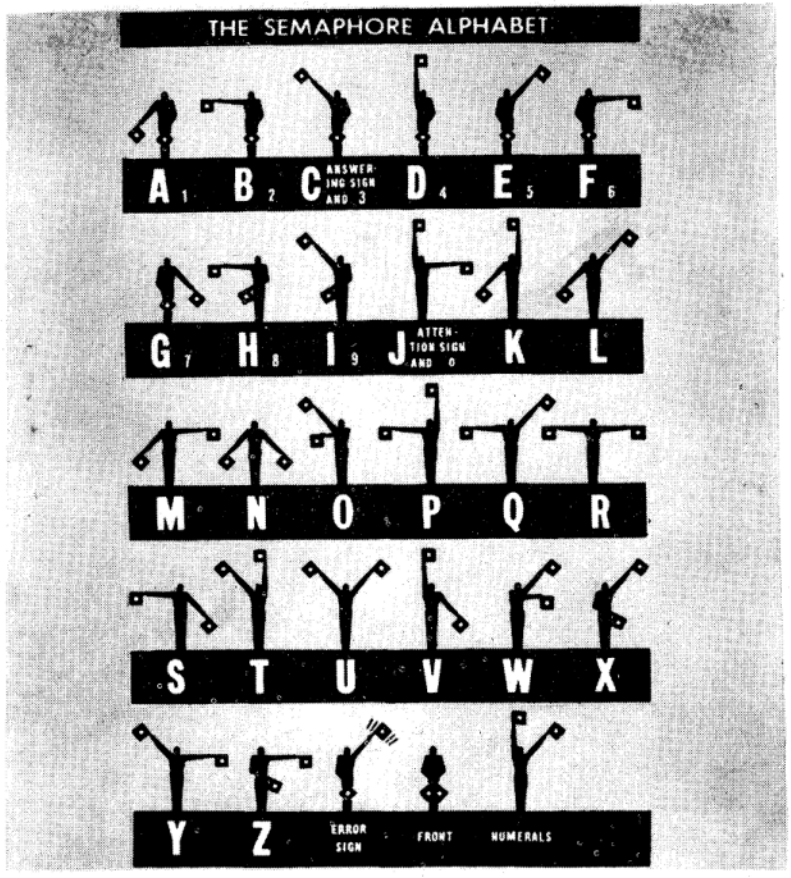
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Y Z ERROR SIGN FRONT NUMERALS

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APPENDIX "B"

The following references apply to DUKW operation as listed:

TM 9–802—Operating and Maintenance
Current edition dated 1 September 1943
New edition expected with late 1944 date

TM 9–1802A—Ordnance Maintenance—covers power plant
Current edition dated 15 July 1943

TM 9–1802B—Ordnance Maintenance—covers power train
Current edition dated 23 November 1943

TM 9–1802C—Ordnance Maintenance—covers hull and water drive
Current edition dated 21 December 1943

TB–ORD–5—Emergency Field Maintenance
Dated 31 December 1943
New TB expected with late 1944 date

SNL G–501—Standard Nomenclature—parts list
Current edition dated 1 July 1944

FM 55–150—Transportation Corps Field Manual
Current edition dated October 1943
New edition expected with late 1944 date

Lubrication Order 505
Current edition dated November 1943
New edition expected with late 1944 date

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APPENDIX "C"

Check List of Special Equipment to be Carried in DUKWs

5 gal. cans (2 gas on rear deck and 1 oil and water inside) 4 in each DUKW

Flexible extension spout for above cans.....1 in each DUKW

12 foot by 12 foot cargo nets.....2 in each DUKW

Mooring lines (100 feet of 4 inch circ. rope with hook and 40 foot 4 inch circ. messenger).....1 ih each DUKW

Semaphore flags (pair).....1 in each DUKW

TM 9–802 (Latest available).....

SOP for POA—October 15, 44.....

Lube. Order #505 (Latest available).....

"A" frames complete.....1 in every 4th DUKW

Howitzer slings..... 1 in each "A" Frame DUKW

Chime hooks (set for 6 drums).....1 in each "A" Frame DUKW

Barrel skids.....1 in every 4th DUKW

Hog troughs .....1 in every 4th DUKW

Stretcher rocks to go on coaming (set of 4).....1 in every 5th DUKW

Radios (SCR-510).....7 per Company

DUKW lifting slings.....1 in every 10th DUKW

Howitzer wheel chocks.....As required by mission.

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AMC PAMPHLET AMCP 706-350

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ENGINEERING DESIGN HANDBOOK

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AMC PAMPHLET
No. 706-350

11 January 1971

ENGINEERING DESIGN HANDBOOK
WHEELED AMPHIBIANS

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LIST OF SYMBOLS

Notes: The same symbol in many instances is used to represent more than one parameter. This is caused by the complex nature of amphibian design requiring many engineering disciplines. The symbols have been chosen to preserve familiar notations found in literature concerning each discipline.

Dimensional units are assigned to each symbol. Dimensionless quantities are indicated by "nd". In some equations, it may be necessary to convert the dimensional units in order to make the formula dimensionally correct; e.g., ft to in. or ft-lb/sec to hp.

A = jet area, ft^2; projected frontal area, ft^2; propeller disc area, ft^2; regular wave amplitude, ft

A_E = expanded bladed area of a propeller, ft^2

A_{comp} = planform area of machinery compartment, ft^2

A_{cool} = planform area of radiator and ducting, ft^2

A_e = effective aspect ratio, nd

A_{eng} = planform area of machinery in machinery compartment, ft^2

A_H = projected frontal area of faired hull, ft^2

A_o = operational availability, nd

A_p = average availability of parts, nd

A_w = projected frontal area of wheels, ft^2

AR = aspect ratio, nd

$ARC(K)$ = Amphibious Research Craft (Hydrokeel)

a = distance or lever arm, ft; acceleration, ft/sec^2

B = maximum molded breadth at the waterline, ft; web material ultimate tensile strength, psi; center of buoyancy; beam, ft

BAR = blade area ratio, i.e., ratio of the actual area of propeller blades to area $\pi D^2/4$, nd

$BARC$ = Barge-Amphibious-Resupply-Cargo (on early designation of LARC LX)

BHP = brake horsepower, hp

BM = vertical distance from center of buoyancy to the metacenter, ft (subscript t denotes transverse metacenter, ℓ denotes longitudinal metacenter)

BOA = overall breadth, ft

BTF = propeller blade thickness fraction ($= t/D$), nd

b = distance or lever arm, ft; span of the foil, ft; undeflected tire width, in.; deceleration, ft/sec^2

b_f = breadth of outstanding flange of a balanced stiffener, in.

CAB = captured air bubble

CL = centerline

C_B = block coefficient, nd

C_D = drag coefficient, nd

C_{D_A} = aerodynamic drag coefficient, nd

C_{D_H} = drag coefficient of faired hull, nd

C_{D_w} = drag coefficient of wheel and wheel wells, nd

C_F = frictional resistance coefficient, nd

C_{f_s} = free surface coefficient, nd

C_{L_T} = transverse inertia coefficient, nd

$C_{L_{o_a}}$ = slope of lift coefficient curve for shroud in free stream flow, nd

C_{L_a} = slope of the lift coefficient curve for a shroud enclosing a thrusting propeller, nd

C_R = residuary resistance coefficient, nd

C_T = load coefficient, nd; total resistance coefficient, nd

C_{T_p} = propeller thrust coefficient, nd

$\overline{CI}$ = average cone index of soil, psi

c = coefficient of (soil) cohesion, psi; cord of rudder, ft; shroud length parallel to propeller centerline, ft

D = deep water depth, ft; distance or lever arm, ft; drag force, lb; propeller diameter, ft; undeflected tire diameter, in.

D_{avg} = average vehicle depth, ft

D_1 = slipstream diameter, ft

DHP = delivered horsepower, i.e., the

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power actually delivered to the wheels or propeller, hp

$DTMB$ = David Taylor Model Basin

d = depth of stiffener or corrugation; depth of water, ft; distance or lever arm, ft; inside diameter of propeller shroud, ft; tire depth, in.

d_r = rim diameter, in.

E = modulus of elasticity, psi; system energy due to wave action, ft-lb

E_θ = work required to heel vehicle through an angle of θ degrees, ft-lb

EAR = expanded area ratio of a propeller ($= A_E/A$), nd

EHP = effective horsepower, i.e., resistance $\times$ speed $\div$ 550, hp

F = force, lb; steel temper—as fabricated

F_A = vertical force applied to aft wheels, lb

F_c = stress at failure from axial loading, psi

F_F = vertical force applied at forward wheels, lb

F_N = Froude number, nd

F_u = stress at failure from compressive loading, psi

F_x = force component in a given direction x, lb

F_y = tensile yield stress, psi

f = propeller material constant

f_b = compressive stress from bending load, psi

f_c = compressive stress from axial load, psi

f_d = compressive stress from loads normal to plating, psi

G = average gradient to cone index of sand versus depth, psi/in.; center of gravity

GM = metacentric height, ft

GVW = gross vehicle weight, lb (same as Δ)

GZ = righting arm, ft

g = acceleration constant = 32.2 ft/sec^2

H = draft forward or aft, ft; steel temper—strain hardened; SHP at maximum continuous rating, hp

H_b = height of breaking wave, ft

H_m = mean draft, ft

H_o = deep water wave height, ft

HP_A = power required by auxiliary systems, hp

h = head of water, ft

h_A = atmospheric pressure in feet of water, ft

h_H = depth of immersion of the screw axis, ft

h_v = vapor pressure, ft of water

I = moment of inertia, in.^{4} at ft^4

I_f = moment of inertia with respect to flange, in.^{4}

I_o = mass moment of inertia, ft-lb-sec^2

I_w = moment of inertia with respect to web, in.^{4}

i = moment of inertia of free surface, in.^{4} and ft^4

J = speed coefficient, nd

K = general symbol for constant; baseline (also B_L); rake of propeller blade, in./ft; soil consistency parameter; modulus of deformation

K_T = thrust coefficient, nd

K_Q = torque coefficient, nd

KB = vertical distance from the baseline to the center of buoyancy, ft

KG = vertical distance from the baseline to the center of gravity, ft

KG_v = virtual center of gravity above baseline, ft

k = radius of gyration, ft; ratio of operating hours to total hours, nd

L = length, ft; lift force, lb

L_D = wave length, ft

L_M = length of model ship, ft

L_o = deep water wave length, ft

L_S = length of full size ship, ft

LOA = overall length, ft

$LARC$ = Lighter-Amphibious-Resupply-Cargo

$LCSR$ = Land-Craft-Swimmer-Reconnaissance

$LCVP(T)$ = Landing-Craft-Vehicle-Personnel (test)

LLL = Land Locomotion Laboratory,

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LIST OF SYMBOLS (Continued)

U. S. Army-Tank Automotive Command
LVK = Landing Vehicle Hydrokeel type
$LVPT$ = Landing-Vehicle-Personnel Tracked
LVW = Landing Vehicle Wheeled
LWL = length at waterline, ft
LCB = distance of the center of buoyancy forward of the transom, ft; longitudinal center of buoyancy
LCG = distance of center of gravity forward of the transom, ft
ℓ = moment arm of rudder stock, ft; wheelbase, ft
M = metacenter; moment about ship's CG, ft-lb; mass of vehicle, slugs
M_B = bending moment, ft-lb
M_{B_x} = bending moment at x section, ft-lb
$M_{c/4}$ = moment about quarter chord point, ft-lb
Me' = inverse of Eklund mobility factor, nd
M_i = initial turning moment, ft-lb
M_r = moment about rudder stock, ft-lb
MDT = mean downtime, hr
$MTBF$ = mean-time-between-failures, hr
$MT/1$ = moment to trim one inch by the stern, ft-lb
$MTTR$ = mean-time-to-repair, hr
MWR = mean width ratio of propeller blades, nd
m = mass, slug
$\dot{m}$ = mass rate of flow, slug/sec
N = rotational speed, rpm
$NACA$ = National Advisory Committee on Aeronautics
$NDCC$ = nondirectional cross country
NPL = National Physics Laboratory, England
$NUGP$ = nominal unit ground pressure, psi
n = rotational speed, rps; soil sinkage characteristic exponent
O = steel temper—annealed
P = power, hp; grounding force, lb; delivered power, ft-lb/sec
P_o = pressure at a given depth; psi or lb/ft^2; reference pressure pressure, psi; power, hp; grounding force, lb; delivered power, ft-lb/sec
P_m = dynamic pressure, psi
P_r = pitch, at given nd radius r, ft
p = local pressure, lb/ft^2
p_{av} = ATAC average ground pressure, psi
Q = torque, ft-lb; intersection of the grounding force vector with amphibian centerline
QK = height along centerline from Q to the baseline, ft
q = length of shear plane, in.; dynamic head ($=\frac{1}{2}\rho V^2$), lb/ft^2; dynamic pressure of the undisturbed fluid, lb/ft^2
R = propeller radius, ft; radius of turn, ft; reliability, nd; revolutions at maximum continuous rating, rpm
R_{aero} = aerodynamic drag, lb
R_{AW}^* = average added resistance, lb
Re = Reynolds number, nd
R_F = frictional resistance, lb
R_R = residuary resistance, lb
R_T = total resistance, lb
R_W = added resistance in regular waves, lb
R_y = grade resistance, lb
RPM_{max} = revolutions at maximum continuous rating, rpm
r = undeflected tire radius, in.; fraction of total radius divided by R, nd
S = rudder or foil area, ft^2; wetted surface area, ft^2; shear strength, psi
SHP = shaft horsepower, hp
SHP_{max} = shaft horsepower at maximum continuous rating, hp
s = fillet size, in.
s' = slip ratio, nd
T = deep water wave period, sec; natural roll period, sec; propeller thrust, lb; transverse distance or arm, ft; transverse shear strength, psi; steel temper—thermally treated; trim, in.
T_o = turning moment, ft-lb
t = blade thickness, in.; plate or web thickness, in.; thrust deduction, nd; mission time, hr
t_f = flange thickness, in.

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LIST OF SYMBOLS (Continued)

t_w = web thickness, in.
U = wind speed, ft/sec; reference velocity, ft/sec
U_{cr} = critical speed, ft/sec
U_{x_1}, U_{x_2} = final and initial velocities of the body in the x direction, ft/sec
u = local velocity, ft/sec
V = forward speed, ft/sec
V_a = propeller speed of advance, ft/sec; initial or upstream velocity, ft/sec
V_{comp} = volume of machinery compartment, ft^3
V_{cool} = volume of radiator and ducting, ft^3
V_d = design speed, mph or ft/sec
V_{eng} = volume of machinery, ft^3
V_j = jet velocity, ft/sec
V_j' = ratio of jet velocity to the advance speed, nd
V_K = vehicle speed, nautical miles per hour (knots)
V_o = initial speed, ft/sec
V_s = ship speed, ft/sec
V_1 = final or downstream velocity, ft/sec
VCI = average rating cone index of field soils for a minimum of 50 passes, psi
v = mean flow velocity over rudder, ft/sec
v_1 = mean slipstream velocity, ft/sec
W = weight of shifted item, lb; average load on one tire, lb; width of blades at one-quarter radius, in.; width of top of corrugation, in.; steel temper—solution heat treated
W_A = hull structure weight, lb
W_B = machinery weight, lb
W_C = drive train weight, lb
W_D = marine propulsor weight, lb
W_E = running gear and suspension weight, lb
W_F = miscellaneous system weight, lb
W_L = load weight—including fuel, crew, and payload, lb
W_M = weight margin, lb
W_T = vehicle weight, lb
$W_{fusion\ line}$ = shear strength at web fusion lines, lb
W_{shear} = web shear strength, lb
$W_{tension}$ = web tensile strength, lb
W_1 = maximum rated load on tire at designed inflation pressure, lb
WCB = West Coast Branch, Amphibian Vehicle Division, Development Center, Marine Corps Development and Education Command
WL = waterline
$W'L'$ = heeled or inclined waterline
w = length between steering pivots, ft; material constant; wake fraction, nd; width of bottom of corrugation, in.
w_i = weight of the ith component, lb
w_x = weight of vehicle in section x, lb
X = distance from base plane to the center of gravity, ft
x = displacement in any direction, ft
x_i = distance from base plane to the center of gravity for the ith component, ft
$\ddot{x}$ = horizontal acceleration, ft/sec^2
y = neutral axis above reference axis, in.
$\ddot{y}$ = vertical acceleration, ft/sec^2
Z = number of propeller blades
z = vertical displacement, ft; sinkage, in.

GREEK LETTERS

a = effective inflow angle, deg; rudder angle of attack, deg
Δ = displacement, lb; gross weight, lb
Δ_v = virtual displacement, lb
$\Delta \cdot GZ$ = righting moment, ft-lb
Δt = duration of impact, sec
∇ = displaced volume, ft^3
δ = rudder helm angle, deg
ϵ = strain, in./in.
η_B = propeller efficiency in nonuniform wake, nd
η_i = ideal efficiency, nd
η_o = open water propeller efficiency, nd
η_p = propulsive efficiency, nd
η_r = relative rotative efficiency, nd
η_T = transmission efficiency—between engine and propulsor, nd

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LIST OF SYMBOLS (Concluded)

θ = heel angle, deg
θ_M = maximum roll angle, deg
θ_r = propeller pitch angle at nd radius r, deg
λ = wave length, ft; linear scale ratio, nd
μ = viscosity of fluid, slug/ft-sec
ν = kinematic viscosity ($= \mu/\rho$), ft^2/sec
ρ = mass density, $slug/ft^3$
ρ_s = mass density of water displaced by hull, $slug/ft^3$
ρ_l = mass density of liquid with free surface, $slug/ft^3$
ρg = weight density of fluid, lb/ft^3
σ = cavitation number, nd; normal stress on the soil, psi; tensile or compressive stress, psi
σ_{cr} = critical cavitation number, nd
σ_s = shear stress in weld, psi
σ_y = tensile or compressive yield stress, psi
$\sigma_1, \sigma_2, \sigma_3$ = principal tensile or compressive stress, psi
τ = shear stress, psi
φ = angle of friction, deg; angle of grade with the horizontal, deg
$\Phi^+_{\xi\xi}$ = wave spectral density ordinate, ft^2-sec
ψ_n = nozzle wake fraction
Ω = sweep angle of one-quarter chord line, deg
ω = wave frequency, rad/sec
ω_n = natural frequency of the system, rad/sec
ω_r = angular rudder rate, deg/sec
ω_2, ω_1 = final and initial angular velocities, rad/sec

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and the technical needs of the Armed Forces.

This handbook has been prepared as an aid to engineers designing wheeled amphibians. Fundamental design information not readily attainable elsewhere is presented along with requirements and problem areas that are unique to the wheeled amphibian. Part One introduces the principal elements of the wheeled amphibian, design requirements, and a history of amphibian development. The actual design process is described in Part Two in which the amphibian evolves from concept design through preliminary design and finally to detail design. Part Three deals with evaluation and testing of wheeled amphibians as an important link in the design process. Probable developments in future high-speed wheeled amphibian design are described in Part Four.

The material presented in this handbook is composed of data and design information gathered from many sources; however, treatment is limited to one of condensation and summary because of the vast scope of the subject. References appear at the end of each chapter for guidance in acquiring complete information on any topic.

When reference is made to Military Specifications, regulations, or other official directives, it is done so to reveal the existence of these documents. In this respect, the user should obtain the current editions for applications.

This handbook was prepared by Hydronautics, Incorporated, under subcontract to the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command for the Engineering Design Handbook Series. Technical supervision and guidance were given by an ad hoc working group under the co-chairmanship of Frank X. Stora and John F. Sargent, Mobility Equipment Research and Development Center, Ft. Belvoir, Virginia.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer
Letterkenny Army Depot
ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

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b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer with proper justification to:

Commanding Officer
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ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

c. Government agencies other than DOD having need for the Handbooks may submit their request directly to:

Commanding Officer
Letterkenny Army Depot
ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

or

Commanding General
U. S. Army Materiel Command
ATTN: AMCAM-ABS
Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and universities) must forward their requests to:

Commanding General
U. S. Army Materiel Command
ATTN: AMCRD-TV
Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence
ATTN: Foreign Liaison Office
Department of the Army
Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a *valid justification*.

Comments and suggestions on this handbook are welcome and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, N. C. 27706.

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PART ONE BACKGROUND INFORMATION

CHAPTER 1 INTRODUCTION

1-1 PURPOSE OF THE HANDBOOK

The necessity for an item such as the wheeled amphibian arose from unprecedented demands of WW II to move large amounts of equipment and supplies from ships to storage facilities, or users ashore where no ports existed. Since its inception, the wheeled amphibian has played an important and ever increasing role in the United States Army.

Unfortunately, the evolution of wheeled amphibian design has not been thoroughly documented. There exists no concise, generally accepted explanation of wheeled amphibian design; furthermore, much of the design data and technology in this area is scattered, and in some cases exists only in the memories of the men who were involved in developing these vehicles. This situation could retard the future technological advancement of the wheeled amphibian since much that has been learned may either be forgotten or lost as one generation of designers is replaced by another. In general, without good documentation, cataloging, and information availability; progress is slowed, efforts are duplicated, and money is wasted.

The purpose of this handbook, then, is to present that information from past and current design experience which is most useful for designers of future amphibians.

1-2 DEFINITION

An amphibian is a unique craft designed to be equally well suited for self-propelled operation both in the water and on land. This handbook is concerned only with amphibians which use rubber-tired wheels as the propulsors for land operation.

The fact that an amphibian must inherently possess both land and water capabilities indicates that design compromises must be made since the requirements for a good boat differ from those for a good land vehicle. In most cases, land performance must be sacrificed to achieve seaworthiness and waterborne performance must be sacrificed to achieve reasonable cross-country mobility. Note, however, in Southeast Asia the LARC V was often used extensively in land operations since its cross-country mobility in sand and clay greatly exceeds that of a truck.

The wheeled amphibian is designed to be used exclusively in a logistic-over-the-shore (LOTS) role. Current amphibians have been used on secondary missions such as passenger ferry boat, river patrol boat, and minesweeper. Its primary function is to transfer cargo and, in some cases, personnel from ships anchored off-shore to dispersed locations, or direct to material users, located several miles inland from the beach.

1-3 PRINCIPAL ELEMENTS OF THE WHEELED AMPHIBIAN

The wheeled amphibian is a complex item. A discussion of the principal elements or features follows.

1-3.1 HULL

The hull of a wheeled amphibian is the enclosure which contains the crew compartment, cargo compartment, engine compartment, and numerous other vehicle components. The amphibian hull differs fundamentally from the body of other military automotive assemblies in that it must satisfy certain marine design criteria. Specifically, it must exhibit the required stability and buoyancy characteristics as well as have a configuration that will result in an acceptable speed-power relationship for waterborne operations. In summary, the purpose of the amphibian hull is twofold—it serves as a boat hull and as a truck body.

1-3.2 PROPULSION SYSTEM

The propulsion system is that system of components which converts energy from a fuel source into a form usable by the amphibian and

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transmits this energy to those devices which develop the thrust or tractive effort required for propulsion. This system may be considered to include the three major subsystems defined in the paragraphs which follow.

1-3.2.1 Power Plant

The power plant is that part of the propulsion system which converts the energy of the fuel source into mechanical energy. It includes not only the engine but also the fuel, lubrication, cooling, exhaust, hydraulic, and electrical systems. The engine types most commonly used are internal combustion types, i.e., gasoline, Diesel, and gas turbine. A detailed discussion of the various types of power plants appears in Chapter 7.

1-3.2.2 Power Train

The power train is that system of components which transmits the useful energy produced at the output shaft of the power plant to the ultimate point of application, i.e., the propulsors. The wheeled amphibian normally has two sets of propulsors—wheels for land operation, and a marine propulsive device, usually a screw propeller, for waterborne operation. This means that the wheeled amphibian has two power paths. In most cases, the power path is common for either mode of operation up to a transfer case. At this point, there are separate drive shaft take-offs for the wheels and the propeller. The major components of the power train are clutches, transmissions, transfer cases, drive shafts, differentials, axles, and brakes. On the other hand, power transmission may possibly be effected by electrical, hydraulic, or pneumatic systems with quite different components.

1-3.2.3 Propulsors

The propulsors are those devices to which the power train delivers the mechanical power developed by the power plant. For overland operations, the propulsors are the wheels which apply the required tractive effort to the ground. The waterborne propulsor is usually a device which develops thrust by acceleration of water in the direction opposite to the desired direction of vehicle motion. The most successful types are the waterjet, the paddle wheel, and the screw propeller. Variations of these three basic types have been theoretically or experimentally considered. All standardized U. S. wheeled amphibians to date have used screw propellers.

1-3.3 SUSPENSION SYSTEM

The suspension system is that series of mechanical components between the vehicle frame or hull and the ground. The function of this system is to provide a flexible support for the assembly, which has good stability and control characteristics and which will allow the required overland speed to be attained. Though there are many types of suspension systems, the one that will receive the most attention in this handbook will be the "rigid" type in which the wheel assemblies are the only element in the system.

The suspension system is functionally useful only in the land mode. However, it must be considered in the waterborne mode since the wheels and the wheel wells are a major source of resistance and greatly influence the waterborne performance capability of the vehicle.

1-3.4 STEERING SYSTEM

The steering system is that assembly of components and linkages which enables the operator to control the direction of the vehicle. For land operation, steering systems are normally designed to provide for two-wheel steering or selective two-wheel, four-wheel, and oblique steering. For waterborne operations, steering can be accomplished by rudders or trainable thrust devices, by training the wheels (as for land operation), or by combinations of these methods.

1-3.5 AUXILIARY SYSTEMS

Auxiliary systems are those systems which cannot be included in any of the previous major categories because they are not related to any one of these categories, or because they are support systems related to several of them. Of those auxiliary systems discussed in Chapter 7, the electrical and hydraulic systems are the most important.

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1-3.5.1 Electrical System

The electrical system of an amphibian performs the same type of functions and services as the electrical system of any military automotive vehicle. In general, electrical power must be supplied to communications equipment, interior and exterior lighting systems, engine starting and ignition systems, heaters, pumps, fans, etc. While the standard Army automotive vehicle electrical system is a 24-V DC single-wire system incorporating a generating, distribution, and storage system; the more costly two-wire marine wiring system is desired for amphibians due to its waterborne operating environment.

1-3.5.2 Hydraulic System

A hydraulic power system is commonly used on amphibious vehicles to perform a host of auxiliary powering functions. The most common uses of hydraulic systems are to provide power to the steering system, the cargo winch, the ramp cylinders, the cargo and bilge pumps, and the cooling fan motors.

1-3.6 PAYLOAD

The wheeled amphibian is primarily a logistic vehicle; its payload is cargo. This cargo may be small vehicles, personnel, or containerized, palletized, and loose general cargo. The primary aim of logistic amphibian design is to produce a vehicle which can effectively and efficiently deliver a required amount of cargo.

1-3.7 FUEL

The required fuel load (subject to operating range) is of the same order of importance as the payload carrying ability. Usually, for a given amphibian, the total weight of cargo and fuel that can be carried is a constant. Thus, the more fuel that is required to perform the mission(s), the less will be the weight of cargo which can be carried. In some cases, the fuel consumption characteristics of a power plant will be the primary consideration for its selection or rejection.

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CHAPTER 2 FACTORS AFFECTING THE DESIGN OF WHEELED AMPHIBIANS

SECTION I MILITARY REQUIREMENTS

2-1 THE MILITARY MISSION AND ENVIRONMENT

The use of amphibians for logistic support was initiated during WW II due to the lack of suitable port facilities and because unfriendly areas were not directly accessible to large ocean-going vessels. The LARC V, the LARC XV, and the LARC LX are the newest post-war, wheeled, logistic amphibians and they follow the initial concept of the DUKW which was begun in 1942.

The development of true amphibians is motivated by the advances in weaponry which have prohibited the establishment of large beachheads. Thus, the present concept calls for the amphibians to move up and over the beach to dispersed materiel dumps located a moderate distance inshore from the beach. Amphibians are used to transport materiel from ships located up to 10 miles off-shore to destinations as far as 5 miles inland. General wartime planning figures indicate that approximately 80 percent of all cargo entering a theater of operations will be delivered through dispersed beach terminals, and 20 percent will move through established terminal facilities.

To satisfy dispersion requirements, the average beach terminal will work only two ships at a time. As a general rule, these ships will be anchored several miles off-shore, and amphibians will transport cargo over the beach to multiple transfer points or directly to users. These locations will be as close to the beach as practicable, while avoiding the establishment of congested materiel depots which are lucrative targets for the enemy.

Each of the two-ship discharge sites will support a division tonnage requirement of 1,440 short tons per day. Normally, five of the discharge sites will be dispersed a minimum of 5 miles apart, under terminal command control, to support a force of five divisions (7,200 short tons per day). These sites will be operated by two terminal service companies (each having a 720 short tons per day receiving rate), one light amphibian company (1,080 short tons per day delivery rate), and one heavy amphibian platoon (360 short tons per day delivery rate), all under terminal battalion control. Other small craft (barges, picket boats, etc.) will be assigned as required.

The lighterage assignments given are based on an average situation in which approximately 25 percent of all cargo moving over the beach will be vehicular or heavy equipment. Containerized, palletized, and loose general cargo comprise the remaining 75 percent. The tonnage capabilities of the amphibian units are specifically tailored to this 75-25 ratio of the 1,440-ton division requirement. The heavy amphibian delivers the outsized items (comprising the 25 percent) and the light company handles the remainder (comprising the 75 percent).

Thus, any improvement in the characteristics of the amphibian which results in increased speed, mobility, or payload will provide quicker, more efficient supply to the forces ashore.

This handbook is intended for use by designers who are relatively inexperienced in the design of wheeled amphibians. Therefore, it is of the utmost importance that the severity of the military environment be appreciated. Military vehicles must be inherently more rugged and reliable than commercial equipment.

Commercial vehicles are not designed to meet the rigors and widely divergent demands of the military environment. In fact, the development of the commercial automotive vehicle is attributable, to a great extent, to safe smooth roads with good traction. Such roads are virtually nonexistent in many combat zones.

The military vehicle must be capable of operating with satisfactory mobility over terrain which ranges from deep mud, sand, and steep rocky topography to paved highways. It must be reliable in arctic climates as well as in tropical regions.

A wheeled amphibian must not only be reliable under the above stated conditions. It

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must also be seaworthy in Sea State 3, survive the loads imposed by plunging surf, and operate in a highly corrosive environment when waterborne. Since it is a military vehicle, it may be called upon to effect landings under enemy fire.

Perhaps the most important characteristic of the military environment is the lack of highly skilled operators for wheeled amphibians. In most cases, the military operator is young and inexperienced; and in combat, it is only natural to worry more about one's safety than the proper operation of complicated and sophisticated controls. Other characteristics of the military environment are excessive dirt, subjection to explosive impact, and perhaps long periods of operation with little or no maintenance.

The major features of the military environment are listed:

a. High shock and vibration produced by off-road operations over rough terrain, air drop operations, high explosive blast, and ballistic impact

b. Extreme temperature ranges, extending from arctic to tropical

c. Operations under conditions of extreme dust

d. Operations in deep mud

e. Operations in ice and snow

f. Amphibious operations through heavy seas and plunging surf

g. Operations under conditions conducive to corrosion and fungus growth. Corrosion is a particular problem for the wheeled amphibian operating in the marine environment.

h. Operations involving long steep grades and side slopes

i. Extended operations under conditions of low speed and high load

j. Operator abuse in the form of overload, misuse, improper maintenance and neglect

A more detailed description of the military environment may be obtained from Refs. 1 and 16.

2-2 ESTABLISHMENT OF MILITARY REQUIREMENTS

2-2.1 GENERAL

The generation of military requirements for Army materiel in the form of Qualitative Materiel Development Objectives (QMDO), Qualitative Materiel Requirements (QMR), or Small Development Requirements (SDR), is provided by the U. S. Army Combat Developments Command (CDC).

These QMDO's, QMR's, and SDR's are established as a result of needs created by combat development studies for the determination of Army doctrine (how the Army of the future is to be organized and equipped, and how it is to fight).

New requirements documents are prepared by CDC and also in draft form by any agency or command of the Army. A QMDO may be initiated at any stage in the research and development cycle and may result from a combat development study, operational experience, development experience, technological breakthroughs, etc. QMR's and SDR's may be processed directly if the development is known to be feasible. However, if feasibility is uncertain, the usual procedure is to prepare a QMDO to provide the necessary data. Then a QMR, with its associated military characteristics, is formulated.

Detailed procedural information regarding the life cycle of Army materiel is provided in Ref. 2.

2-2.2 QUALITATIVE MATERIEL DEVELOPMENT OBJECTIVES (QMDO)

A QMDO is a Department of the Army (DA) approved statement of military need for the development of new materiel, the feasibility of which cannot be determined sufficiently to permit the establishment of a qualitative military requirement. The QMDO normally originates from requirements generated by combat development studies conducted by CDC. The QMDO as previously defined, pertains to items of materiel which are not sufficiently within the state-of-the-art to permit immediate development and, therefore, require further research. In general, these items are three to eight years away from the firm establishment of their military characteristics. The QMDO states in general terms the objective, the operational and organizational concepts for employment, and a description and full justification for the item.

The Army Materiel Command (AMC) Director of Research, Development and Engineering is responsible for processing all new materiel

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objective documents and for insuring that adequate QMDO plans are prepared. After the draft QMDO is reviewed by other interested agencies, it is revised and submitted by CDC to DA for approval and staffing. Upon DA approval, the QMDO is published in the Combat Development Objectives Guide (CDOG) which contains all approved DA operational objectives, organizational objectives, QMDO's, QMR's and SDR's. Within the DA staff, the Chief of Research and Development will assign responsibility to a development agency whose purpose will be to prepare a QMDO plan which will insure that appropriate research and development is conducted in support of the QMDO. Upon approval of the QMDO plan by the DA Chief of Research and Development, the AMC will assign prime, attendant, or sole responsibility for the QMDO to one or more of its commands or laboratories to perform the necessary work.

2-2.3 QUALITATIVE MATERIEL REQUIREMENTS (QMR)

After research and exploratory development have progressed to the point where the AMC feels it is possible to translate the knowledge and data acquired by the laboratories—in support of the QMDO—into a feasible system, it will recommend that the CDC prepare and issue a QMR. The QMR is directed toward the attainment of new or substantially improved materiel which will significantly advance the Army's ability to accomplish its mission.

Unlike the QMDO, the QMR is much more specific in describing the requirement. It states major materiel needs in terms of military characteristics and priorities, and relates the materiel to the operational and organizational context in which it will be used. The QMR is prepared as soon as possible after the need is established and probable feasibility is determined. The CDC staffs the QMR within its own organization for organizational, operational, and doctrinal concepts; with the AMC it assures that the proposed requirements are within the state-of-the-art. It also checks with the Chief of Personnel Operations for personnel implications, and checks with the United States Continental Army Command for training and training device implications. The QMR is then forwarded by the CDC to the DA for approval. Concurrently, the AMC would normally prepare and forward a Technical Development Plan (TDP) to the Office of the Chief of Research and Development (OCRD) defining the approach for achieving the QMR. The TDP should contain a history of the project, a detailed plan for its development, a test program, maintenance and reliability concepts and goals, firm scheduling and funding plan, a quality assurance plan, a configuration management plan, a new equipment training plan, and perhaps a procurement plan.

The new QMR will not be approved in the DA unless the TDP indicates that the following prerequisites have been fulfilled:

a. Primarily engineering rather than experimental effort is required.

b. "Building block" components and technology are sufficiently in hand.

c. A thorough trade-off analysis has been made.

d. The best technical approach has been selected.

e. The mission and performance envelopes are defined and optimized for technical feasibility and cost effectiveness.

f. The cost effectiveness of the proposed item has been determined to be favorable in relation to the cost effectiveness of competing items (on a DOD-wide basis).

g. Cost and schedule estimates are credible and acceptable for full scale development.

Upon DA approval, the QMR will be published in the CDOG.

2-2.4 SMALL DEVELOPMENT REQUIREMENTS (SDR)

An SDR states an Army need for the development of equipment which can be developed in a relatively short time, and does not warrant the major effort required in developing a QMR. An SDR is normally considered to be an appropriate requuirements document if:

a. The development item is of proven feasibility,

b. Time required for development is 2 years or less, and

c. Research, development, test, and evaluation costs will not exceed $2.5 million, and the projected investment of "Procurement

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of Equipment and Missiles, Army" funds (PEMA funds) will not exceed $10 million.

SDR's are staffed and approved by Headquarters, DA, in a manner similar to that prescribed for QMR's. Recommendations for establishing SDR's contain a brief description, purpose, priority, justification of need, and cost of development. Projects initiated as a result of SDR's are handled in the same manner as they are for QMR's.

SECTION II ENGINEERING REQUIREMENTS

2-3 THE MISSION OF ARMY WHEELED AMPHIBIANS

Amphibians are a unique class of vehicles capable of extended operations over both land and sea. Unfortunately, some of the criteria for good water performance conflict with criteria for good land performance. As a result, any amphibian design must be a compromise, a hybrid vehicle which is not likely to exhibit either optimum land or water performance. Hence, for efficient utilization, amphibious vehicles should be used where their special characteristics are clearly indicated, i.e., for missions which require both land and water operation.

The primary functions of Army amphibians may be divided into two categories—(1) tactical, and (2) logistical support. Tactical uses include direct support of assault and combat operations, including transport of personnel, supplies, light artillery, ammunition, missiles, etc., across beachheads and rivers. The seaworthiness and surfing ability of amphibians can be used to achieve strategic and tactical advantage by operating at places and in weather considered impossible for landings by conventional landing craft. Logistic uses involve supply and resupply of general cargo, from deep water shipping anchored offshore, directly across beaches to inland transfer points. Amphibians are not limited to these functions. Their versatility renders them capable of many diverse operations, as determined by circumstances and the operator's imagination.

Tracked amphibians are generally less vulnerable to enemy fire than wheeled amphibians. On the other hand, wheeled amphibians are capable of higher speeds both in water and over hard, smooth soil and roads. Hence, tracked amphibians are generally better suited to tactical support, whereas wheeled amphibians are preferred for logistical support. Since this handbook is directed to the design of wheeled amphibians, greater emphasis is placed on requirements for cargo transport.

2-4 OPERATIONAL REQUIREMENTS AND LIMITATIONS

2-4.1 GENERAL

The operational requirements for an amphibian define its intended mission or use. They range from basic requirements—such as payload, capacity, and roll stability—to special requirements such as cold weather starting and air drop capabilities. Proper selection of the requirements demands careful consideration of the limitations involved. The requirements must never be specified arbitrarily since this procedure leads to mutually prohibitive requirements that preclude the development of a satisfactory vehicle. For example, if payload is specified, the gross vehicle weight should not be arbitrarily stipulated.

Amphibians are subject to limitations imposed by nature and by the state of technology. The laws of nature cannot be opposed. However, natural laws which impose restrictions on present amphibians may possibly be circumvented in future designs if the problem is attacked with initiative and imagination. Any such development would, of course, be classified as a major breakthrough. There has been no such breakthrough in amphibian design since the development of the first WW II DUKW. Limitations imposed by the state of technology will continue to be surmounted with future development and technological progress. For example, advances in engine design will result in lighter, more efficient power plants so that future amphibians may have greater range and speed capabilities with no increase in weight.

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Operational requirements and limitations for amphibians will continually change with changes in mission and use, and advances in vehicle technology. The designer should be aware of the process and underlying principles used to determine the amphibian requirements. In many instances the designer must initiate changes in the requirements in order to alleviate conflicts within the requirements or to bring the requirements in line with the limitations imposed by the current state of technology. The requirements should be written to allow for reasonable, low risk advances in technology so that the designer is induced to incorporate these advances in developing a new amphibian. In this manner, progress is assured in the evolution of amphibian vehicles. On the other hand, unreasonable requirements will result in wasted effort and in some cases the requirement may be met, but the added capability does not justify the necessary expense.

The paragraphs which follow are presented in order to identify some of the basic areas in which requirements are specified, the nature of requirements, and the underlying principles and philosophy involved in their determination.

2-4.2 WATERBORNE PERFORMANCE

A typical mission for a wheeled amphibian is the transfer of supplies from a ship stationed offshore to an inland depot. Waterborne performance requirements are specified so that the proposed amphibian will be able to receive cargo at the ship's side and carry it to the beach quickly, efficiently, and safely.

2-4.2.1 Speed and Power

Minimum speed and power requirements for a logistic amphibian may be based upon considerations for safe operation through surf. Speed and power are, of course, closely related. It is desirable to have adequate speed so that the amphibian can match the speed of waves advancing toward the beach. It must have sufficient power to pass through these same waves on the return trip. Particular minimum values are not generally specified, but are left to the discretion of the designer. It is more likely that design speed will be selected on a basis of optimization studies of the entire logistic problem rather than on a safety requirement basis.

The type of power plant may be either specified or specifically limited for such reasons as maintenance and safety. For example, gas turbines may not be allowed because personnel in the field are not experienced in the special maintenance procedures for these engines. Gasoline engines may be prohibited because of the fire hazard.

A minimum allowable speed may be specified for amphibians that will perform tactical missions. The reasons for high speed in this case are obvious.

A requirement which is often specified is a minimum range or endurance for continuous operation. The speed and power of the design are indirectly affected by this type of requirement and others which apply to the various aspects of performance.

2-4.2.2 Maneuverability

Maneuverability requirements are likely to be in qualitative terms, viz., able to maneuver alongside a ship in Sea State 3, safely negotiate 10-ft plunging surf, etc. These requirements imply rather than specify a degree of maneuverability. This approach is understandable in view of the difficulty in applying meaningful quantitative measures to such a broad concept as maneuverability.

Specific maneuvering characteristics may also be stipulated. Minimum bollard pull, maximum allowable turning diameter (tactical diameter), and maximum allowable heel during a turn are common specifications. The difficulty with these characteristics is that they are only qualitatively associated with good maneuverability. Furthermore, safety and the ability to pass through surf probably depend as much on operator skill as on vehicle characteristics.

2-4.2.3 Seakeeping

Seakeeping requirements, like those for maneuverability, are apt to be qualitative in nature. The same requirement may be applicable to maneuverability and seakeeping, i.e., the ability to negotiate a 10-ft plunging surf implies a certain degree of seakeeping ability as well as maneuverability.

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Other requirements which relate to seakeeping are more specific. Reserve buoyancy, statical stability, and range of stability are all good indicators of relative seakeeping ability and minimum criteria may be specified, based on experience with successful amphibious operations and general practice. Self-bailing cargo decks or automatic bailing of cargo wells and watertight hatches are additional requirements that enhance seakeeping ability.

2-4.3 OVERLAND MOBILITY AND PERFORMANCE

Overland performance requirements are prescribed to assure that the amphibian will be able to negotiate any reasonable terrain between the water and the inland depot. Increased off-road mobility is generally the strongest motivation for these requirements, and safety is not as demanding a consideration here as in the case of waterborne performances.

2-4.3.1 Soft-soil Mobility

A requirement that simply states that a vehicle must be able to negotiate mud and sand or some other soft soil is too general to be of practical use to the designer because there are so many different types and grades of soil. A better requirement would specify one or more types of soil and a particular minimum index for each. A soil index is a quantitative measure of some physical property of the soil which can be empirically related to the vehicle trafficability. Several soil indexes are tabulated in Table 7-44. It should be noted that the indexes do not take into account all of the soil properties which affect mobility and are, therefore, only approximate guides.

Minimum soft soil mobility requirements that are given in terms of mobility (soil) indexes should be based on experience with operational amphibians and the proposed mission of the new design, i.e., the types and grades of soil most likely to be encountered.

2-4.3.2 Rough Ground and Obstacle Performance

Rough ground performance requirements are usually specified in terms of a minimum acceptable speed over some standard, reproducible, hard ground profile. Obstacle performance is specified by the ability to pass over a ditch, bump, or vertical wall of particular size and geometry. Speed is not of particular importance here. These ground profiles and obstacles are not necessarily representative of the conditions that an amphibian will face in the field. However, such requirements are easily confirmed by proof tests, and performance capability over these simple courses is indicative of the relative mobility of the amphibian over rough terrain.

2-4.3.3 Slope Performance

Slope performance requirements for military vehicles have traditionally been specified as the ability to negotiate a 60-percent grade and 30-percent side slope of smooth dry concrete. (The tangent of the angle between the ground and the horizontal plane is expressed as a percentage. Thus, a 100-percent grade corresponds to a 45 deg angle.) These performance requirements, like those for obstacles, do not represent conditions that the amphibian will meet in the field, but they do set a standard which is easy to confirm by prototype testing.

Side slope requirements are used mainly to specify the degree of stability that a vehicle must possess. Grade requirements present a good test of overall vehicle toughness. The specifications are usually written to include the capability of the brakes to hold the vehicle on the grade, and the ability to climb and descend the grade in both forward and reverse gear. Grade tests put large loads and stresses on the power train, the engine and its cooling system, and the suspension system.

2-4.3.4 Maneuverability

A minimum turning diameter is generally specified as the requirement on maneuverability. Other requirements which may be made include the maximum safe speed at which a specified turn may be negotiated, four-wheel steering, and crab steering.

2-4.3.5 Dimensional Requirements

Limitations on overall vehicle length, width, and height are generally based on transportability criteria and are discussed in par. 2-5.

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Brake angle, angles of departure and approach, and bottom clearance may be specified. However, these characteristics are mainly associated with obstacle clearance and may be superfluous if the requirements for obstacle performance are comprehensive.

2-4.3.6 Improved Road Performance

The requirement for improved road performance is simply a specification for maximum sustained speed. This requirement was compromised for recent amphibian designs because it conflicted with the requirements for waterborne performance which were considered more important. Rigid suspension system design rather than power was the limiting factor for these vehicles. A reasonable speed for overland travel in convoys is 30 to 35 mph.

2-4.4 RIVER BANK PERFORMANCE

To this date, there probably have been no requirements written specifically for river bank performance of amphibians. To some degree, requirements for soft soil mobility and obstacle performance provide for this special capability. This is an area that is in need of research and development. It is likely that more comprehensive riverine requirements may be developed for future amphibian designs.

2-4.5 PERFORMANCE WHEN ENTERING AND LEAVING LANDING (LST) AND DOCK-TYPE (LSD) SHIPS

Capability for entering and leaving particular classes of ships is often specified. Such a requirement should be based on the intended use of the amphibian and, particularly, its proposed method of deployment.

2-4.6 CARGO-CARRYING AND HANDLING REQUIREMENTS

The flexibility and usefulness of a logistic amphibian are greatly enhanced if it is capable of self-loading and unloading of cargo. Thus, requirements may be written to this end prescribing that loading ramps and/or winches be incorporated in the design.

2-5 TRANSPORTABILITY REQUIREMENTS AND LIMITATIONS

2-5.1 GENERAL

The design of wheeled amphibians is governed by various restrictions which limit and control their size, weight, and shape. Among these restrictions are those imposed by the need for unrestricted transportability in any or all of the transportation modes—rail, air, road, and ship. The transportability requirements are usually specified in the military characteristics for each developmental vehicle.

The policy of the Department of Defense with regard to transportability of items of materiel, as set forth in AR 705-8, Ref. 3, states that transportability must be a major consideration when establishing the priority of design characteristics for a new item of materiel or equipment, to readily permit transport by available means. Special or unique arrangements of schedules, right-of-way, clearances, or other operating conditions, will be undertaken only in exceptional cases and after first obtaining approval from the appropriate transportation agency, including the following designated by the Department of Defense:

a. Dept. of the Army: DCSLOG, Director of Transportation, U. S. Army, Washington, D. C. 20315

b. Dept. of the Navy: Naval Supply Systems Command Headquarters, Washington, D. C.

c. Dept. of the Air Force: Headquarters, Air Research and Development Command, Washington, D. C.

d. U. S. Marine Corps: Commandant, Marine Corps, Washington, D. C.

The designer must consider the limitations of the particular modes of transportation specified or selected for the vehicle to determine the maximum allowable dimensions and weight for an amphibian. The sources which are at the disposal of the designer to determine these limitations are:

a. The Highway Weight and Size Limitations established by the Federal Aid Highway Act of 1956.

b. The highway regulations of the individual States of the United States.

c. The physical limitations of highways in foreign countries.

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d. The Outline Diagram of Approved Limited Clearance of the Association of American Railroads

e. Weight limitations of individual carriers, available in the current issue of the Railway Line Clearance publication for individual railroads of the United States, Canada, Mexico, and other nations

f. Diagram of the Bern International Rail Interchange Agreement with weight limitations applicable to the railroads of individual countries for all items that may require transportation by rail in foreign countries

g. Loading and storage limitations of ocean vessels, and Army and Navy cargo handling procedures which are applicable

h. Regulations of the Department of Transportation (U. S. Coast Guard), the U. S. Army Mobility Equipment Command, and the U. S. Navy, covering water transportation

For convenience some of the main restrictions are presented in the paragraphs which follow. For more complete information refer to Refs. 1 through 9.

2-5.2 UNRESTRICTED HIGHWAY TRANSPORTABILITY

Ref. 1 prescribes maximum dimensions and weights for pneumatic-tired, highway, and off-the-road type vehicles for unrestricted highway operations. Oversize and/or overweight vehicles, as defined by the state roads commission of a particular state through which the vehicle is to be moved, are subject to certain procedures which usually involve the procurement of a permit with payment of a fee and with movement restricted to certain highways at specific times of the day.

2-5.2.1 Width

The maximum overall width of wheeled vehicles for unrestricted highway movement is 96 in.

2-5.2.2 Height

The maximum overall height of wheeled vehicles designed for unrestricted highway operation in the continental United States is 12.5 ft. The maximum allowable overall height for overseas highway operations is 11 ft.

2-5.2.3 Length

The maximum overall length of a wheeled vehicle comprised of a single, nonarticulated unit (in most cases wheeled amphibians will fall into this category) shall not exceed 35 ft. For wheeled vehicles comprised of an articulated double unit, such as a tractor-trailer, the overall length should not exceed 50 ft.

2-5.2.4 Axle Loading

An axle load is defined as the total load transmitted to the road by all wheels whose centers are included between two parallel transverse vertical planes 40 in. apart, extending across the full width of the vehicle. For the continental United States and overseas, the maximum axle load (subject to gross weight limitations) is 16,000 lb for axles spaced between 3½ ft and 7½ ft. For vehicles, designed for highway operation in the continental United States, and with axles spaced more than 7½ ft from the nearest adjacent axle, the maximum permissible load is 18,000 lb; for vehicles designed for overseas operations, it is 16,000 lb.

2-5.2.5 Gross Weight

The maximum permissible gross weight for a wheeled vehicle designed for highway operations (subject to axle load limitations) is 36,000 lb for vehicles having a distance of 10 ft or less between the extreme front and rear axles, and increases 850 lb for each foot of axle spacing over 10 ft to a maximum of 60,000 lb. This maximum gross weight exceeds the statutory limits of some states in the U.S.A. and special permits are required.

2-5.3 RAIL TRANSPORTABILITY

The requirements for transportability by railroad are set by certain clearances determined by bridges, tunnels, platforms, power transmission poles, and various wayside structures that may be encountered. Required clearances have been compiled and used to produce the clearance outline diagrams in Ref. 1. These diagrams set the maximum allowable cross section of a vehicle as loaded upon a railway car for shipping. In cases where vehicles of larger cross section are to be transported,

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they must be reducible in size by suitable disassembly to meet the diagram limits.

2-5.4 AIR TRANSPORTABILITY

When designing military vehicles for airlift, consideration must be given to the size, weight, and location of the vehicle's center of gravity; the size, location and configuration of the aircraft loading apertures; the size and configuration of cargo compartments (including limiting features that may prevent the full use of available space); the strength of the aircraft floor and loading ramp; the location, capacity, and type of tie-down fittings used; the allowances for loading controls and auxiliary equipment; and the air transportability requirements specified in MIL-A-8421A (USAF), Ref. 4. Each vehicle should be designed to be transportable in a maximum number of aircraft types to permit maximum use of available aircraft and to alleviate the possible shortage of a particular type. When designing vehicles for aerial delivery (airdrop), vertical and horizontal clearances in aircraft must be considered; in addition, the designer must make allowances for the weight and space taken up by the aerial delivery equipment and for the motions of the "package" as it leaves the aircraft. Additional data and guidance can be found in Refs. 5, 6, 14, and 15.

2-6 CLIMATIC ENVIRONMENT CRITERIA

Amphibians are frequently subjected to harsh corrosion environment resulting from frequent operation in and out of salt water. This and other environmental requirements are discussed in Ref. 7.

2-7 ELECTRICAL SYSTEM SPECIAL REGULATIONS

The Department of the Army has established a 24-V DC system as a design standard, as specified in AR 705-19, Ref. 8.

General design considerations—such as generating systems, voltage control, wiring harness, weatherproofing, suppression of radio interference, etc.—are discussed briefly in Ref. 1 and detailed treatment of some of the above factors may be found in Ref. 9.

2-8 SPECIAL REGULATIONS FOR FUELS, LUBRICANTS, AND HYDRAULIC FLUIDS

Specifications for fuels, lubricants, and hydraulic fluids are given in par. 3-2.5 of Ref. 1, and Ref. 13.

2-9 MAINTENANCE REQUIREMENTS

2-9.1 GENERAL CONSIDERATIONS

The design of a wheeled amphibian must provide an available and reliable tool for the Army. These two objectives are a function of the design as well as the maintenance performed after the vehicle is built.

Reliability can be designed into the vehicle and thus reduce maintenance. Maintenance that is relatively easy to perform because of accessibility or other criteria discussed in the paragraphs which follow will make the vehicle available and more reliable. Thus availability, reliability, and maintainability are all interrelated.

2-9.2 MAINTAINABILITY CRITERIA

Maintainability is a characteristic of good design. A vehicle is maintainable if the specified maintenance can be carried out routinely so that the vehicle continues to meet stipulated performance requirements. The definition of maintainability must be related to some measurable quantities which will significantly influence the designer's layout or machinery arrangement, or choice of components. These quantities are realistic descriptors: mean-time-to-repair (MTTR); mean-time-between-maintenance (MTBM); and mean downtime (MDT). This type of approach to maintainability is described in Ref. 10.

To design maintainability into a wheeled amphibian, the designer should hypothesize possible failures and determine procedures for repair. This process will immediately present the major factors involved, including:

a. Possible cause of failure
b. Access
c. Tools
d. Repair parts
e. Fasteners

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f. Specialists required for a complex repair.

Some of the specific criteria which are directly applicable to the maintainability of wheeled amphibians are given in par. 3-3.1 of Ref. 1.

2-9.3 RELIABILITY CRITERIA

Wheeled amphibians will tend to become more complex and sophisticated. The more complex a system becomes, the greater the tendency to failures. A complex system will not necessarily be an unreliable one, but complexity does imply that the designer's work must reflect a greater than usual concern for component reliability.

Reliability is defined as the probability that materiel or equipment will perform its designated function for a prescribed period of time under stated conditions. The criteria listed under maintainability will also apply because of their relationship to reliability. Reliability is often expressed quantitatively as mean-time-between-failures (MTBF). The three questions raised by this term are:

1. What is a failure?
2. What causes a failure?
3. How is MTBF increased?

A failure may be defined as a deficiency which prevents a component or subassembly from performing its intended function under specified conditions.

The failure of a wheeled amphibian may be due to defective components, weak components and defective subassemblies or equipment, or environmental conditions such as rough seas, extremely steep slopes, etc., beyond the capabilities of the vehicle. No system can ever be assumed to be 100 percent reliable. The cost to design a wheeled amphibian which approached 100 percent reliability would be prohibitive.

The approach to improved reliability is:

a. Design for increased MTBF's

b. Subject the product under development or any developed component to prototype testing

c. Use component parts which have a record of reliability

To increase MTBF, there are two simultaneous approaches which are directly related to the design process. These are:

a. Design for ruggedness, i.e., use high safety factors and low working stresses, install oversized or overpowered drives and propulsion systems, etc.

b. Design with expendable parts which can be routinely replaced.

One of the tools available for achieving increased reliability is prototype testing which can provide knowledge of problem components before the vehicle is delivered to the operator. It will also provide the designer with an evaluation of his work and suggest areas for improvement. The ease of maintenance, or lack of it, will become obvious during tests. Testing can also provide information on which to base estimates of future MTBF's, especially if a detailed log of the vehicle's history is maintained. This log, if carried through the life of the vehicle, will be valuable in providing performance data to the designer.

Reliability components are selected from service experience. Performance data will be available for parts which have been used extensively, or tested by the Army or the manufacturer. Use of such components improves reliability because their known behavior can be designed into the system under consideration.

2-9.4 USE OF STANDARD MILITARY COMPONENTS

The major benefits to be gained from standardization are in the following areas—improved reliability, improved maintainability, reduced maintenance cost, reduced procurement cost, and reduced procurement time. However, standardization is not intended to hinder design improvement. Design improvements should take precedence over standardization whenever the improvement outweighs the advantages of standardization.

The contribution of standardization to improved reliability includes:

a. Use of standard items which are produced in large quantities insures a greater level of uniformity and refinement.

b. Use of standard items avoids long storage periods. Because of low demand, nonstandard items usually spend long periods in storage and are thus exposed to component deterioration.

c. Standardization promotes item familiarity, thereby minimizing the chances of misapplication, faulty handling, or faulty installation.

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Standardization contributes to improved maintainability and reduced maintenance costs in the following ways:

a. Increased reliability reduces the frequency and extent of maintenance, thus reducing maintenance costs.

b. Maintenance downtime will be reduced since standard items will be more readily available and repairs will be more quickly effected.

c. Because of volume production, standard items will usually be less expensive than nonstandard items.

d. Costs associated with the logistic aspects of maintenance will be reduced since standardization allows greater interchangeability.

Standardization reduces the time and cost of system procurement because the development costs of nonstandard items are avoided. Even in cases where the nonstandard item is less expensive, this saving may be offset by the cost of introducing a new item into the supply system.

To summarize, the designer should attempt to use standard military components in his design for the following reasons:

a. Use of off-the-shelf items is cheaper than paying for the development of new items.

b. Components are readily available and have short delivery times.

c. Components have known properties and have more predictable reliability.

d. Use of known components will facilitate and speed maintenance because the components are familiar to personnel and the tools are available.

e. Use of known components will allow interchangeability between vehicles.

f. Components are part of an existing logistical support system.

Pertinent information concerning standard items which will help the designer are:

a. *Federal Cataloging Handbook*, H6-1.

b. *Numerical Index of Descriptive Patterns*, and other specifications and standards in accordance with MIL-STD-143.

c. *Army Repair Parts List.*

d. *Federal Supply Catalog* and AR 750-1.

2-10 HUMAN FACTORS

Human factors affect a wide variety of engineering requirements. Amphibians cannot operate without guidance and control by man. Hence, the designer must give due consideration to the physiological and psychological limitations of the human being. The operator and crew must be reasonably comfortable, have sufficient space in which to perform their functions, and have controls that are easily accessible and operable. More important, however, are the requirements for safe operation that include limits of human tolerance to vibration, noise, and shock.

Refs. 10, 11, and 12 discuss, in detail, the various aspects of human factor engineering which must be considered in developing satisfactory requirements.

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CHAPTER 3 PAST AND PRESENTLY OPERATIONAL WHEELED AMPHIBIANS

SECTION I BRIEF HISTORY OF WHEELED AMPHIBIAN DEVELOPMENT

3-1 GENERAL REQUIREMENTS WHICH LED TO THE DEVELOPMENT OF RECENT AMPHIBIANS

Although the concept was not new, amphibians first came into prominence during WW II. In both the European and Pacific Theaters, the problem was the execution of assault and supply missions on unfriendly and (especially in the Pacific Theater) undeveloped shores. This led to the development of various amphibians. The need for logistic support under assault conditions led to the development of the type amphibian with which this handbook is concerned—the logistic support wheeled amphibian. The DUKW, the first operationally successful, mass-produced wheeled amphibian, grew out of the necessity to move unprecedented tonnages of supplies and equipment from ship to shore storage dumps over undeveloped beaches. The DUKW served a primary role in U.S. Army amphibious assault logistic operations throughout the war and for some time thereafter.

After WW II, developments in military equipment dictated that amphibians with a greater cargo delivery rate were required. This requirement stems from the great increase in fire power and mobility of the Armed Forces. Study of amphibian speeds and sizes required to provide the increased capability led to the realization that a "family" of amphibians was needed for flexibility in meeting various logistic problem demands.

A brief history of wheeled amphibian development follows, starting with the amphibious jeep and proceeding to the present.

3-2 THE AMPHIBIOUS JEEP

During the Autumn of 1941 the 1/4-ton, 4 X 4 general purpose truck was converted into an amphibian, the "amphibious jeep", for use in carrying personnel. The chassis, power plant, transmission, differential, and wheel components of the parent vehicle were used in a lightweight, welded hull. A propeller mounted in a tunnel, the necessary power take-off, a marine rudder, bilge pump, capstan, and other marine appurtenances were added to complete the conversion.

Over 12 thousand units were produced after limited field tests indicated the amphibious jeep had maximum speed of 65 mph on land and 6 mph in water. Insufficient testing of early production models, inadequate inspection and supervision of production, failure to provide for a continuing development program, failure to provide adequate training, and, particularly, failure to consult the using services before production began resulted in early rejection of the project as a technical and tactical failure. However, many lessons were learned from this unfortunate experience that were applied most profitably in the development of the DUKW.

3-3 THE DUKW

The DUKW was the first operationally effective wheeled logistic amphibian, although it was not used exclusively for supply functions. The basic development effort for this vehicle consisted of using the operationally proven GMC 6 X 6 truck and wrapping a watertight hull around it. This was an expedient approach, chosen because war time pressures did not permit extensive development and design time (spring of 1942).

The chassis of the GMC, CCKW 2½-ton, 6 X 6 truck was the basic structure and was enveloped in a welded steel barge type hull. The CCKW transmission, with five speeds forward and one reverse speed, was retained. The truck suspension system was retained, except that water seals were added. A marine power train—including screw propeller, shafting, power take-off, and a rudder—completed the major modifications. These changes gave the original 2½-ton truck the desired amphibious characteristics.

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Following the initial introduction and production, certain design modifications were made to the DUKW to improve its waterborne capability. These included the following:

a. Originally, the cab was placed over the engine (forward) in the interest of operator visibility and maximum cargo space. Subsequently, the cab was moved just aft of the engine. This change increased the forward deck length, increasing operator protection and providing better engine accessibility. At the same time, the cargo compartment was widened in order to maintain available cargo space.

b. Water speed was increased from 5 mph to 6.5 mph. This was a result of modifications to the propeller, propeller location, engine carburetion, engine HP requirements, hull shape (adding 18 in. to the stern of the vehicle), and of providing covers for the front wheel housings.

The capability and adequacy of the DUKW, which was the result of a hasty but intensive design effort, is attested to by the fact that the DUKW did not become obsolete until nearly two decades after its introduction. The DUKW's were capable of transporting 5,000-lb payloads through plunging surf in excess of 10 ft and could attain land speeds up to 50 mph. The characteristics of the DUKW are given in Table 3-1 and Figure 3-1.

3-4 THE SUPERDUCK XM147

In the early 1950's, an improved version of the WW II DUKW was conceived, and was

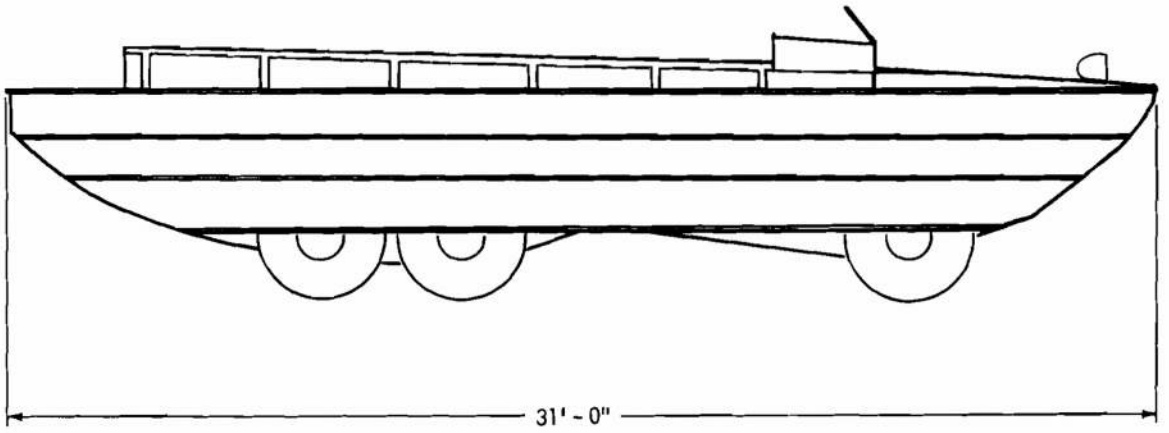

Figure 3-1. DUKW General Arrangement Sketch

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named the SUPERDUCK. The first prototype produced was designated the XM147. It was tested in the surf off Monterey, California, in 1954. After brief testing, it was realized that certain major deficiencies existed which needed correction. This resulted in the development of a revised vehicle named the XM147E1 SUPERDUCK. This version included, as a major improvement over the DUKW and XM147, a prototype commercial torque converter and transmission. The XM147E1 employed a new power train, raised bow with surf plate, 10-ply desert-type nylon tires, and an attempt at improved marine steering. This vehicle was tested alongside the DUKW for comparison. The XM147E1 demonstrated superior land mobility, but was inferior to the DUKW in surf operations. Tests were prematurely concluded when the XM147E1 was swamped in heavy surf and severely damaged.

Another improved version of the SUPERDUCK, the XM147E2 was then developed. This amphibian employed an integral watertight hull and was provided in two modes, one with steerable propeller and one with rudders. During the tests, it was determined that this vehicle demonstrated inadequate engine cooling in the land mode of operation. It was also found that the transmission lacked adequate cooling and that the transfer cases were unsatisfactory for sustained marine services.

This led to the final revised version of the SUPERDUCK designated XM147E3, incorporating over 80 recommended changes based on test results of the XM147E2. This vehicle was tested in surf at Monterey, California, until it was swamped. A decision was then made to discontinue further consideration of the vehicle. The XM147E3 SUPERDUCK demonstrated only marginal improvement over the DUKW in most areas and needed major power train modifications in order to correct its deficiencies. The characteristics of the SUPERDUCK XM147E3 are given in Table 3-2 and Figure 3-2.

3-5 THE GULL XM148

During the period of SUPERDUCK evaluation, another experimental vehicle was introduced, designated the XM148 GULL. Its physical dimensions were approximately 15 percent greater than those of the DUKW. The GULL employed a molded bow, rather than the barge-type bows used on previous vehicles. Another innovation was the use of a glass-reinforced plastic hull. The GULL also had greatly increased power over all the previous wheeled amphibians, and featured unskirted wheel wells and an enclosed cab like the XM147. Vehicle characteristics are given in Table 3-3 and Fig. 3-3.

The vehicle prototype, as built, was considerably over the design weight. This overweight caused many components to fail which, otherwise, may have been satisfactorily designed. The GULL carried a very large winch with an inadequate foundation. Finally, the vehicle was plagued by failures in the glass fiber reinforced plastic hull. The state of the art in molding plastic hulls was in its infancy when the GULL was built. These problems, especially the weight problem, caused the project to end prematurely so that the GULL concept was never fully evaluated.

3-6 THE DRAKE XM157

The XM157 DRAKE was initially conceived as a 5-ton 6 X 6 vehicle similar to the XM147 SUPERDUCK. However, experience gained from the XM147 and XM148 prototypes led to changing the concept to an 8-ton, 8 X 8 amphibian having substantially increased marine capability.

The DRAKE used many components common to the SUPERDUCK and, in addition, had several unique features. It employed two independent power plant and drive train assemblies, each driving one forward and one rear axle. The power train consisted of a torque converter in series with six-speed gearing, a combination two-speed land-drive transfer case, and a two-speed marine propulsion power take-off. Dual trainable, retractable propellers driven through universal joints provided the marine propulsion and steering. Aluminum construction was used for both frame and hull. An air bellows suspension with independently sprung axle allowed partial retraction of the wheels and axles during waterborne operation.

Tests demonstrated that the DRAKE was superior in land mobility to the XM147 and DUKW. Its air suspension system provided good

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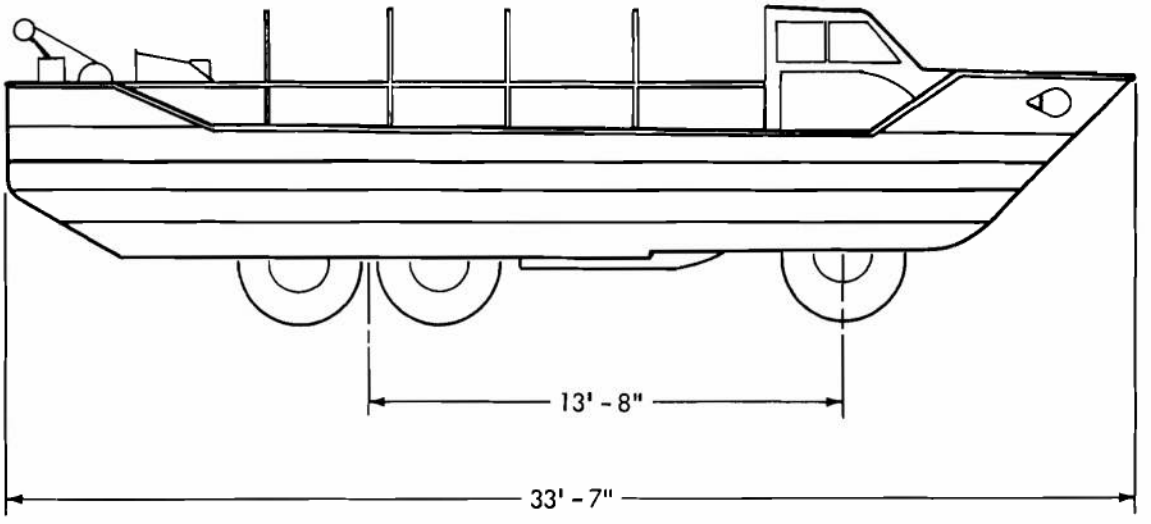

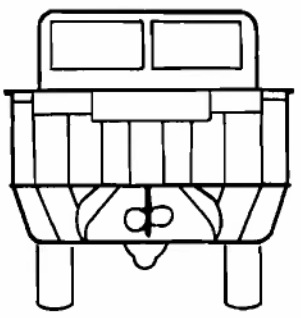

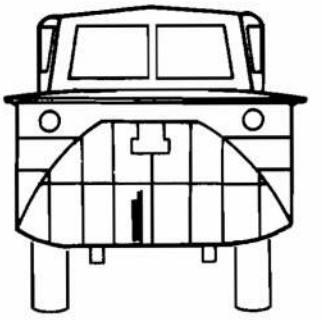

Figure 3-2. SUPERDUCK General Arrangement Sketch

lateral stability, and control was facilitated by power steering. The central tire inflation system also contributed to this mobility. In the waterborne mode, it demonstrated maneuverability superior to that of previous amphibians. However, there was a marked directional instability in the waterborne mode. It also proved capable of higher waterborne speeds than the previous amphibians. Vehicle characteristics are given in Table 3-4 and Fig. 3-4.

The greatest deficiency in the DRAKE design was that some bearings were underdesigned resulting in numerous breakdowns in the differential. The vehicle was also poorly designed from a maintenance standpoint. To service the engine, it was necessary to remove the cab. Since there was no major improvement in performance over the SUPERDUCK, the concept was abandoned.

3-7 THE PRESENT FAMILY OF OPERATIONAL LOGISTIC WHEELED AMPHIBIANS

The present family of amphibians consists of 3 vehicles—the LARC LX, the LARC V, and the LARC XV, which are capable of handling 60

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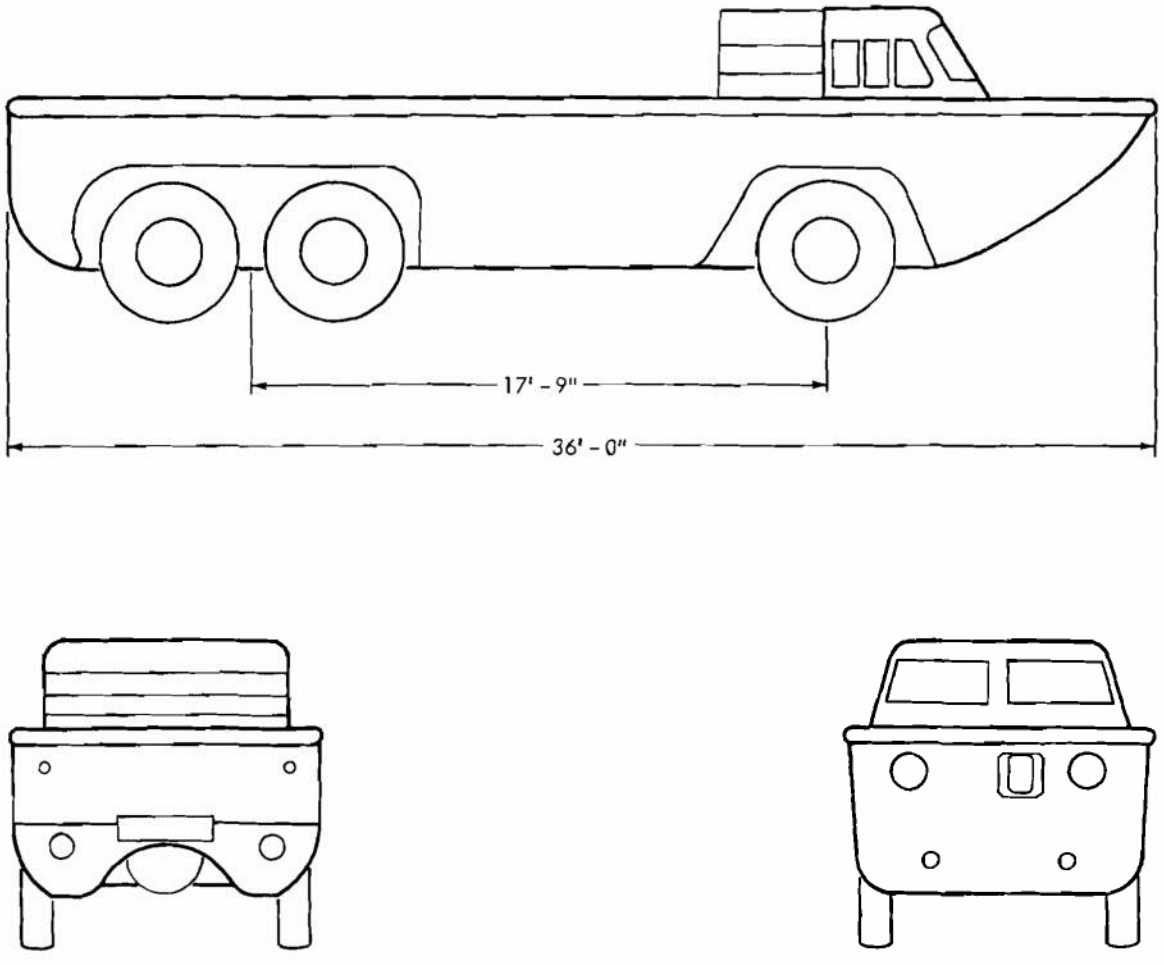

Figure 3-3. GULL XM148 General Arrangement Sketch

tons, 5 tons, and 15 tons of payload, respectively. It is fitting to refer to these three amphibians as a family since they complement one another in fulfilling the overall logistic requirements for amphibious operations. There exists a concept of usage for these amphibians and each one fulfills a part. The LARC V will transport nonmobile general cargo and has maximum roadability. The LARC XV will transport nonmobile general cargo (it can carry three loaded CONEX containers), lighter types of mobile equipment, and has good roadability. The LARC LX will carry all the heavy mobile and nonmobile equipment and has limited roadability. The LARC V and LARC XV will transport 75 percent of all the dry cargo, general cargo, special cargo, ammunition, and other Class IV wheeled and tracked vehicles, which are used by the military services. The LARC LX will transport the remaining 25 percent. A description of each vehicle follows.

3-7.1 THE LARC LX

The first of the family to be developed was the LARC LX. In fact, the LARC LX concept was initiated quite some time before the other LARC's. Development of this amphibian was initiated in 1951 and was carried forward during the same period of time as the SUPERDUCK development.

The LARC LX was developed to meet requirements for an amphibious vehicle of large size to transport heavy and bulky equipment from ship to shore and across unimproved beaches. The LARC LX is a Diesel-powered,

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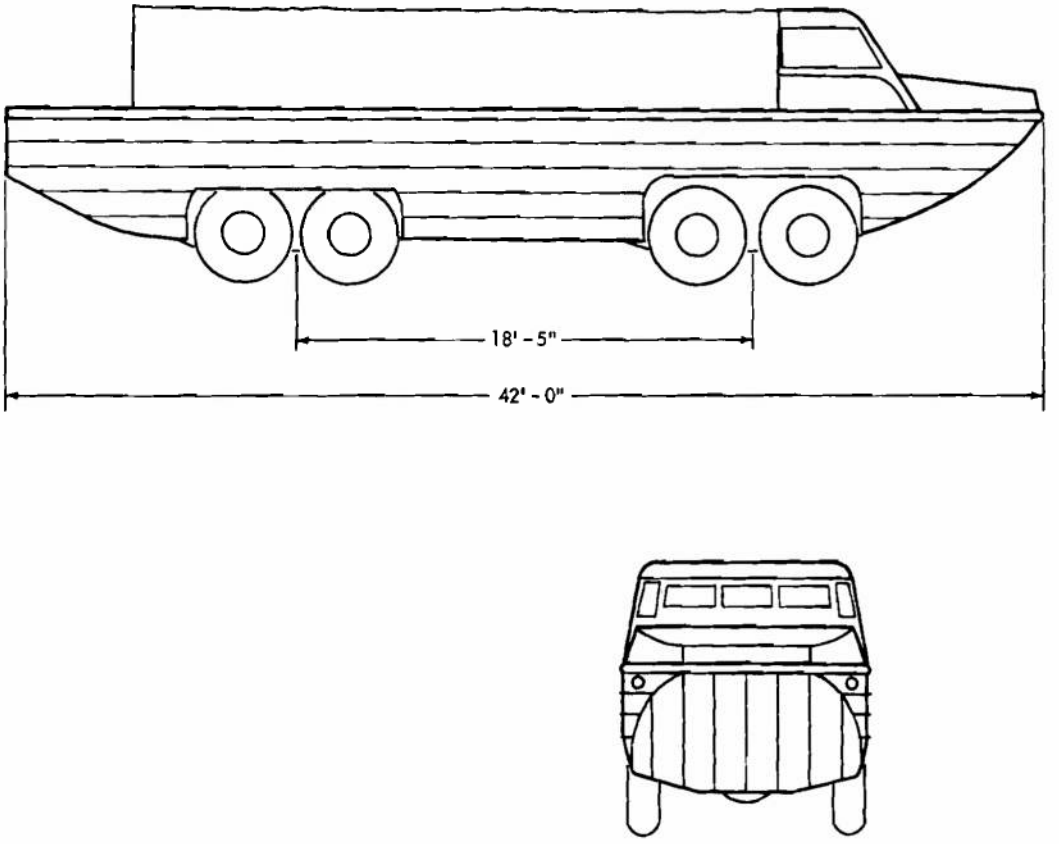

Figure 3-4. DRAKE XM157 General Arrangement Sketch

rubber-tired, amphibious lighter, with a bow loading ramp, center cargo compartment, closed stern, and wing machinery spaces. The basic structure is of welded steel. Four 6-cylinder GM Detroit Diesel engines are used for the propulsion power plant.

For marine propulsion, the two engines on the port side are connected end to end by a fluid coupling and shaft joined to a gathering box. The box is connected via a right angle drive to the reverse and reduction marine gear. Power is then transmitted from the marine gear, through shafting, to a propeller. The starboard installation is identical.

The land drive is so arranged that each of the four wheels is independently driven from one of the Diesel engines. A torque converter and transmission are mounted at one end of each engine. Each transmission is coupled to a miter box by a spheriflex coupling. The miter box effects the necessary right angle drive to the wheel column. The wheel column in turn transmits the power through a coupling and a final drive unit to a set of planetary gears in the wheel hub. Braking is accomplished by restraining the drive shafts, using air brakes attached at the miter box.

Wheel steering is accomplished by the use of tiller arms splined to the top of each wheel column, and attached to two hydraulic rams which provide the steering power. Marine steering is accomplished by the use of a wire rope loop which is attached to the starboard front wheel steering arm and to the quadrant which controls the two welded steel rudders. The characteristics of the LARC LX are given in Table 3-5 and Fig. 3-5.

3-7.2 THE LARC V

The LARC V was the first true production replacement for the WW II DUKW. Unlike the DUKW which, for the sake of expediency, was designed more or less as a floatable truck, the

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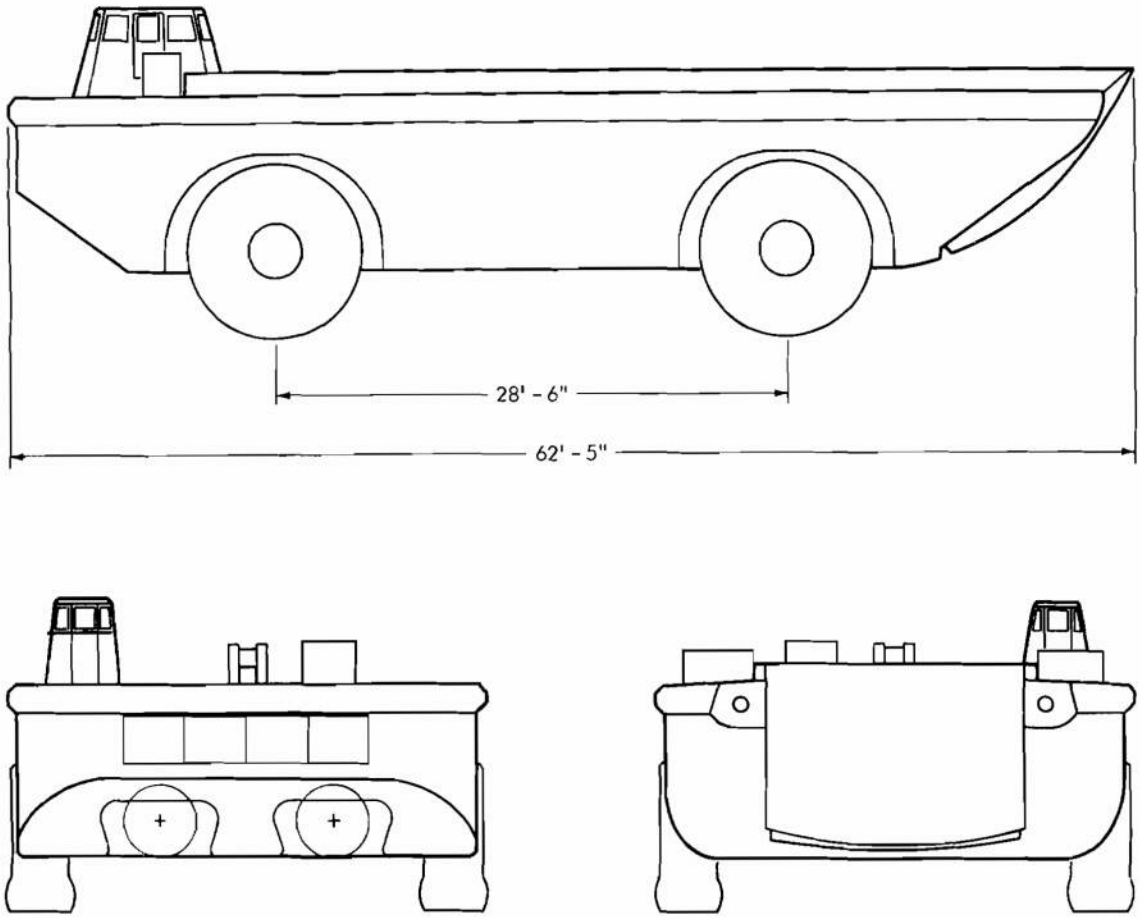

Figure 3-5. LARC LX General Arrangement Sketch

LARC V was designed from the ground up as a true amphibian. Its mission is to transport nonmobile general cargo from ship to shore, over undeveloped beaches and roads. The LARC V has been in service and classified Standard A since 1960 and has been in troop unit service since 1963.

The production model of the LARC V is a wheeled amphibian powered by a 300-horsepower, four-cycle, 8-cylinder, Cummins Diesel engine providing land propulsion through 2 or 4 driven, rubber-tired wheels, and waterborne propulsion through a single propeller. The width was increased by 1.0 ft during development to satisfy stability requirements. The engine, which is located in the stern of the amphibian (over the propeller tunnel), drives forward to a centrally located transfer differential transmission, where power is divided for driving the wheels and/or the propeller. The amphibian is equipped with 18 X 25 in., 12-ply, off-road type, low-pressure, tubeless tires, which also serve as the suspension system. Land-mode steering is provided using the bow wheels. Marine steering is provided through cables attached to the land steering linkage. The rudder and the front wheels operate together. The single propeller operates in a tunnel and is fitted with a Kort nozzle. The designed speed is 10 mph in water and 30 mph over land under full load conditions. The hull is constructed of aluminum.

The effectiveness of the LARC V, due to its increase in both cargo capacity and water speed, can best be expressed by comparison with other amphibians. Based on evaluation tests, the LARC V is the equivalent of 2.4 DUKW's or 1.6 SUPERDUCK's. The LARC V has demonstrated

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superiority to the SUPERDUCK in land mobility, maintainability, and design simplification; it is also a lighter vehicle. The vehicle characteristics are given in Table 3-6 and Fig. 3-6.

3-7.3 THE LARC XV

Since the LARC LX was developed to fulfill requirements for transport of bulky, heavy cargo, and the LARC V for transport of small general cargo; the LARC XV was developed to meet requirements for a medium self-propelled lighter. The mission of the LARC XV is to transport nonmobile general cargo and lighter types of mobile equipment from ship to shore, over the beach, and over the roads. The LARC XV is designed for expedient unloading using a fork lift truck for unloading nonmobile cargo, and using a ramp for mobile cargo.

The LARC XV is powered by two 4-cycle, 8-cylinder, V-type Diesel engines, the same as are used in the LARC V. The vehicle is driven on land through four large, low-pressure tires which also serve as the suspension system. As with the LARC V, the beam was increased, during development, by 2.0 ft for stability. In water, it is propelled by a single 4-bladed propeller. Steering is hydraulic; 2-wheel, 4-wheel, and oblique steering are possible. Marine steering is accomplished by a 3-bladed box rudder which is actuated by the same hydraulic system which provides for land-mode steering. Wheels and rudder turn together. The LARC XV hull is constructed of aluminum.

A unique feature of the LARC XV is that it is

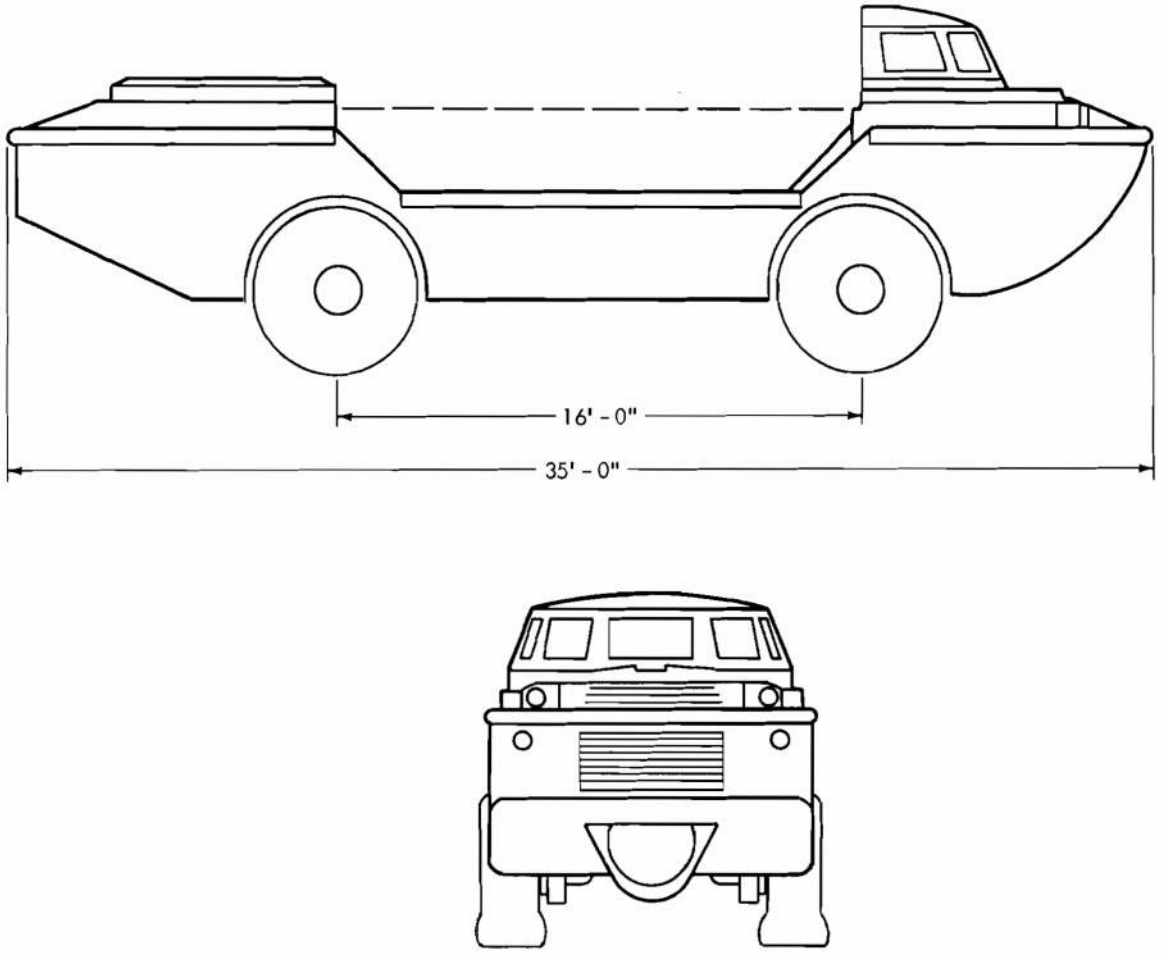

Figure 3-6. LARC V General Arrangement Sketch

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a two-way vehicle. In the waterborne mode, it is operated in the direction which places the boat-shaped bow forward and the cab aft, thus providing good operator protection. In the land mode, it is operated in the opposite direction, with the cab forward and the bow to the rear, thus providing good visibility for the operator. LARC XV characteristics are given in Table 3-7 and Fig. 3-7.

Fig. 3-8 shows the LARC family of amphibians and Fig. 3-9 shows the DUKW, SUPERDUCK, and prototype LARC V.

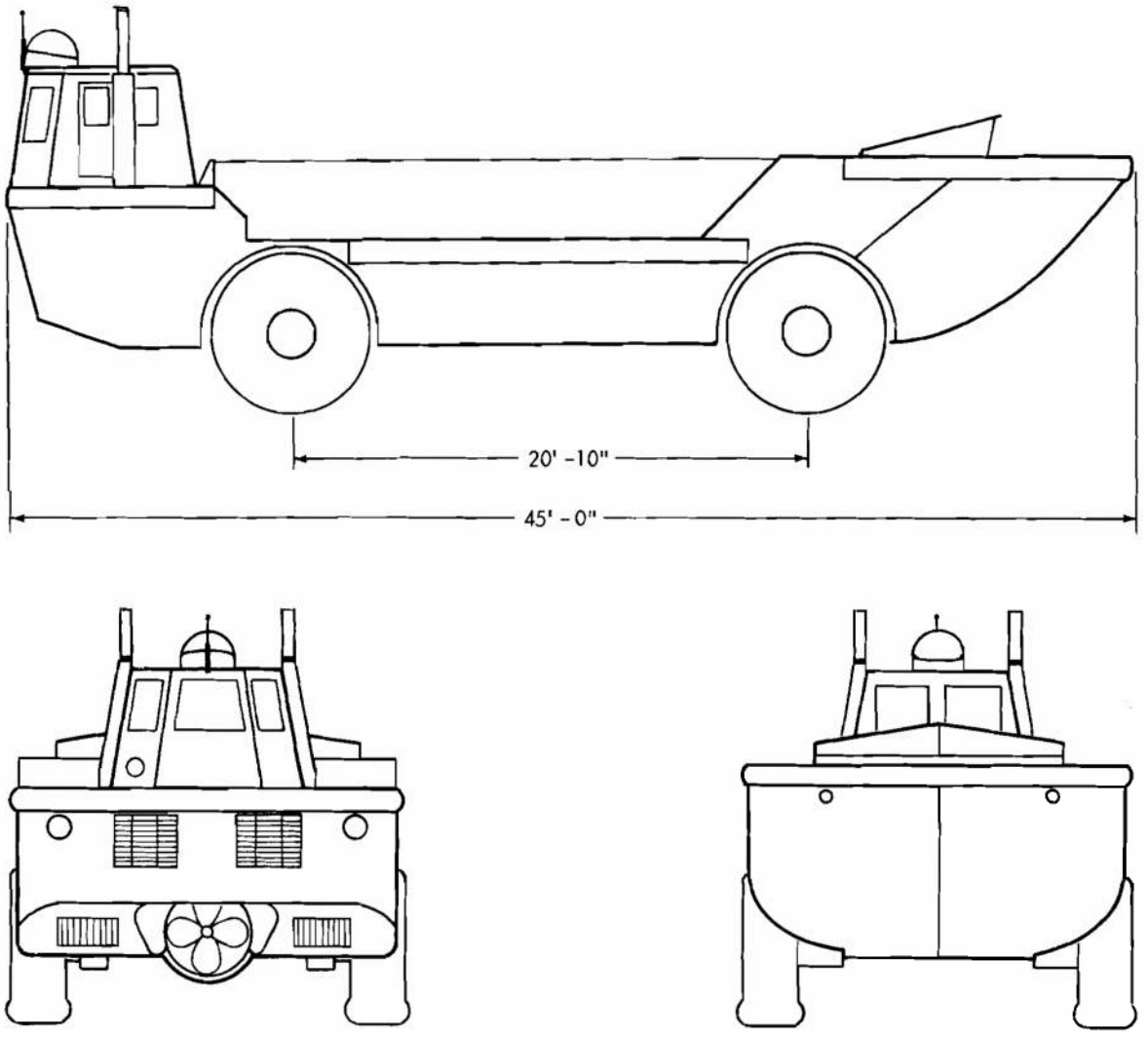

Figure 3-7. LARC XV General Arrangement Sketch

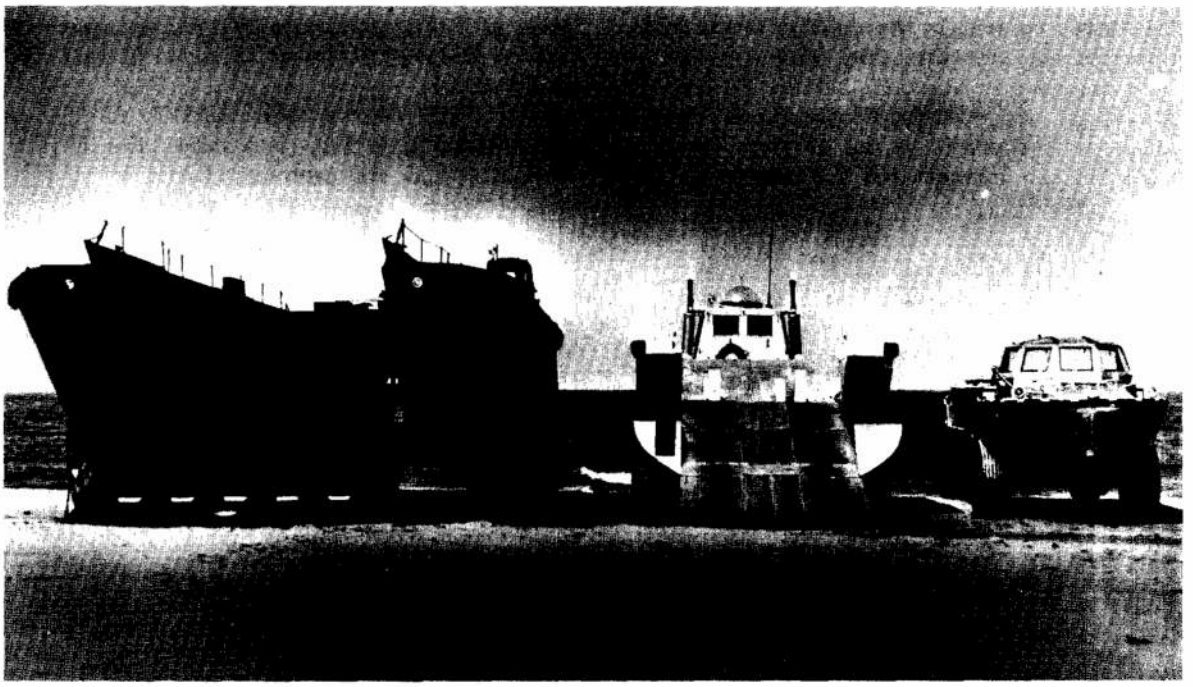

Figure 3-8. LARC Amphibians: LARC LX, LARC XV, and LARC V

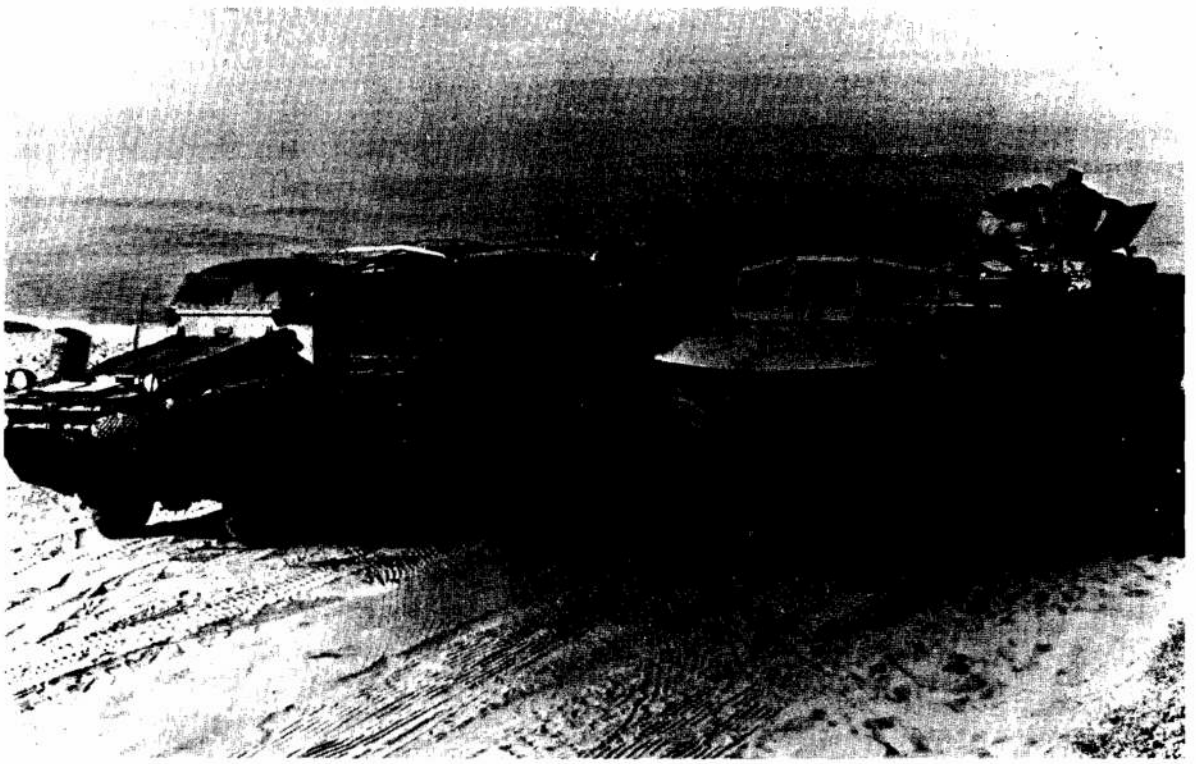

Figure 3-9. WW II DUKW, SUPERDUCK, and Prototype of the LARC V

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SECTION II TABULATION OF VEHICLE CHARACTERISTICS

3-8 VEHICLE CHARACTERISTICS OF PAST AND PRESENTLY OPERATIONAL WHEELED AMPHIBIANS

TABLE 3-1 DUKW—VEHICLE CHARACTERISTICS

Manufacturer	General Motors Corp.
Width, ft-in.	8-2 7/8
Length, ft-in.	31-0
Height, ft-in.	9-2½
Min Ground Clearance, in.	11¼
Freeboard, in.	24 fwd; 16 aft
Draft, ft-in.	3-6 fwd; 4-3 aft
Wheelbase, ft-in.	13-8
Track Width, ft-in.	5-3-5/8
Angle of Approach, deg	38
Angle of Departure, deg	25
Break Angle, deg	15
Land Speed, mph	50
Water Speed, mph	6.2
Land Range, mi	240
Water Range, mi	35 at 6 mph
Turn Radius (Land), ft	35
Turn Radius (Water), ft	20
Cargo Capacity	5,175 lb or 25 troops
Cargo Space (L×W×H), ft-in.	12-4 × 6-10 × 2-4
Total Weight, lb	20,055
Grade Ability, %	60
Surf Ability, ft	10
Engine Data	GMC Model 270
	6-cyl gasoline engine
	93 BHP at 2750 rpm
Fuel Type	Gasoline 72-80 octane
Marine Propulsor	3-bladed propeller; D = 25 in.; P = 14 in.
Suspension System	Truck type; leaf springs; 6 × 6
Brake System	Hydraulic
Tire Size	11 × 18 in. 10-ply
Land Steering	2-wheel, mechanical
Marine Steering	Rudder
Crew Size	2
Hull Material	Steel
Central Tire Inflation System	

TABLE 3-2 SUPERDUCK (XM147E3)—VEHICLE CHARACTERISTICS

Manufacturer	General Motors Corp.
Width, ft-in.	9-3/8
Length, ft-in.	33-7
Height, ft-in.	9-4
Min Ground Clearance, in.	13
Freeboard, in.	35 fwd; 28 aft
Wheelbase, ft-in.	13-8
Track Width, ft-in.	5-11¾
Angle of Approach, deg	40
Angle of Departure, deg	22
Land Speed, mph	48
Water Speed, mph	7
Turn Radius (Land), ft	35
Turn Radius (Water), ft	25
Cargo Capacity, lb	8,000
Cargo Space (LXWXH), ft-in.	15-2 X 7-4 X 2-10
Total Weight, lb	27,780
Grade Ability, %	60 at 1.64 mph
Surf Ability, ft	10
Engine Data	GMC 302-55; 6-cyl gasoline engine, 155 hp
Fuel Type	Gasoline
Fuel Capacity, gal	108
Marine Propulsor	3-bladed propeller; D = 31 in., P = 25 in.
Suspension System	Truck Type, Leaf Spring; 6 X 6
Brake System	Air over hydraulic, disc type
Tire Size	12.5 X 20 in.; 12-ply
Land Steering	Recirculating ball type, 2-wheel, power-assisted
Marine Steering	Single Rudder
Electrical System	24-V DC
Crew Size	2
Hull Material	Welded Steel

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TABLE 3-3 GULL (XM148)–VEHICLE CHARACTERISTICS

Manufacturer	ACF Brill
Width, ft-in.	5-9
Length, ft-in.	36-0
Height, ft-in.	9-10½
Min Ground Clearance, in.	20-5/8
Wheelbase, ft-in.	17-9
Angle of Approach, deg	30
Angle of Departure, deg	30
Land Speed, mph	63
Water Speed, mph	8
Land Range, mi	360
Water Range, mi	66
Cargo Capacity, lb	10,000
Cargo Space (LXW), ft-in.	16-5 X 8-4
Engine Data	Hall-Scott Model 485; 6-cyl; 300 BHP
Fuel Type	Gasoline
Fuel Capacity, gal	140
Suspension System	6 X 6
Land Steering	2-wheel
Hull Material	Glass-reinforced plastic

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TABLE 3-4 DRAKE (XM157)–VEHICLE CHARACTERISTICS

Manufacturer	General Motors Corp.
Width, ft-in.	42-0
Length, ft-in.	10-0
Height, ft-in.	10-10
Min Ground Clearance, in.	18
Freeboard, in.	28
Wheelbase, ft-in.	18-5
Angle of Approach, deg	34
Angle of Departure, deg	23
Land Speed, mph	44
Water Speed, mph	9
Land Range, mi	396
Turn Radius (Land), ft	49
Turn Radius (Water), ft	22
Cargo Capacity, lb	16,000
Cargo Space (LXWXH), ft-in.	23-0 X 8-11 X 3-3
Total weight, lb	49,200
Grade Ability, %	60
Engine Data	(2) GMC, Model 302, 155 hp
Fuel Type	Gasoline
Fuel Capacity, gal	240
Marine Propulsor	(2) Steerable propellers; D = 31 in.; P = 24 in.
Suspension System	Air bellows type; 8 X 8; partial retraction
Brake System	1 (i.e., no redundancy)
Tire Size	14.75 X 20 in.; 10-ply
Land Steering	4-wheel (front)
Marine Steering	Directed thrust (trainable propeller)
Hull Material	Welded aluminum
Central Tire Inflation System	

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TABLE 3-5 LARC LX—VEHICLE CHARACTERISTICS

Manufacturer/Designer	Treadway/Pacific Car and Foundry
Width, ft-in.	26-11
Length, ft-in.	62-5
Height, ft-in.	19-7 reducible to 14-7 for shipping
Min Ground Clearance, in.	30
Freeboard, ft-in.	5-0 fwd; 4-6 aft
Draft, ft-in.	8-2 fwd; 8-8 aft
Wheelbase, ft-in.	28-6
Track Width, ft-in.	23-2
Angle of Approach, deg	28
Angle of Departure, deg	28
Break Angle, deg	13½
Land Speed, mph	17 (loaded); 20.5 (empty)
Water Speed, mph	7 (Loaded); 7.5 (empty)
Land Range, mi	300 at 10 mph
Water Range, mi	150
Turn Radius (Land), ft	75
Cargo Capacity, lb	120,000
Cargo Space (LXWXH), ft-in.	41-11 X 14 X (6-2 fwd; 4-6 aft)
Total Weight, lb	319,000
Grade Ability, %	60
Side Slope, %	25
Surf Ability, ft	14
Engine Data	(4) GM Series 6-71 Diesel; rated at 165 BHP at 2100 rpm; separate drive for each wheel
Fuel Type	Marine Diesel
Fuel Capacity, gal	600
Marine Propulsor	(2) 3-bladed propellers; D = 48 in., P = 29 to 32 in.
Suspension System	Rigid, 4 X 4
Brake System	Air type, B. F. Goodrich Model H-500-1
Tire Size	36 X 41 in., 48-ply rating
Land Steering	Hydraulic selective 2-wheel, 4-wheel, or oblique
Marine Steering	Twin rudders
Electrical System	24-V DC single-wire
Hydraulic System, gal	300
Crew Size	4-5
Hull Material	Welded steel
Unit Cost	$390,000 (6/68)

TABLE 3-6 LARC V—VEHICLE CHARACTERISTICS

Manufacturer/Designer	Consolidated Diesel Electric Corporation/Ingersoll-Kalamazoo Div. of Borg-Warner
Width, ft-in.	10-0
Length, ft-in.	35-0
Height, ft-in.	10-2
Min Ground Clearance, in.	16
Freeboard, in.	10
Draft, ft-in.	4-3
Wheelbase, ft-in.	16-0
Track Width, ft-in.	8-5
Angle of Approach, deg	20.7
Angle of Departure, deg	27
Break Angle, deg	15
Land Speed, mph	28
Water Speed, mph	8.6
Land Range, mi	200
Water Range, mi	25
Turn Radius (Land), ft	36.5
Turn Radius (Water), ft	77 clockwise, 59 counter-clockwise
Cargo Capacity	10,000 lb or 20 troops
Cargo Space (LXWXH), ft-in.	16-0 X 8-8 X 2-6
Total Weight, lb	30, 950
Grade Ability, %	60 at 2.41 mph
Side Slope, %	20
Surf Ability, ft	10
Engine Data	(1) Cummins 8-cyl, 4-cycle Diesel engine; 300 BHP at 3000 rpm
Fuel Type	Marine Diesel
Fuel Capacity, gal	144
Marine Propulsor	(1) 3-bladed shrouded propeller; D = 30 in., P = 30 in.
Suspension System	Rigid, 4 X 4
Brake System	Hydroretarder and hydraulic disc on transmission shaft
Tire Size	18 X 25 in; 12-ply
Land Steering	Power assist—2-wheel
Marine Steering	Single rudder and front wheels
Electrical System	24-V DC single-wire
Hydraulic System, gal	19
Crew Size	2
Hull Material	Welded aluminum
Bollard Pull, lb	3,260
Unit Cost	$44,200 (6/68)

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TABLE 3-7 LARC XV–VEHICLE CHARACTERISTICS

Manufacturer/Designer	Freuhauf, Inc./Ingersoll-Kalamazoo Div. of Borg-Warner
Width, ft-in.	14-6
Length, ft-in.	45-0
Height, ft-in.	13-8
Min Ground Clearance, in.	16½ (to propeller shroud)
Freeboard, in.	15
Draft, ft-in.	5-1
Wheelbase, ft-in.	20-10½
Track Width, ft-in.	12-6
Angle of Approach, deg	22½
Angle of Departure, deg	30½
Break Angle, deg	13½
Land Speed, mph	29.9
Water Speed, mph	9.5
Land Range, mi	200
Water Range, mi	120
Turn Radius (Land), ft	55
Turn Radius (Water), ft	77
Cargo Capacity	30,000 lb or 53 troops
Cargo Space (L×W×H), ft-in.	24-0 × 13-6 × 3-3
Total Weight, lb	75,200
Grade Ability, %	40 at 1 mph
Side Slope, %	25
Surf Ability, ft	12
Engine Data	(2) Cummins V-8 Diesel engine; 4-cycle; 300 BHP at 3,000 rpm
Fuel Type	Marine Diesel
Fuel Capacity, gal	360
Marine Propulsor	(1) 4-bladed propeller with modified Kort nozzle; P = 36 in., D = 34 in.
Brake System	(4) Hydraulic disc
Tire Size	24 × 29 in.; 16-ply rating
Land Steering	Selective 2-wheel, 4-wheel, or oblique; hydraulic power
Marine Steering	3-blade box rudder and wheels
Electrical System	24-V DC single-wire
Hydraulic System, gal	25; 1,900 psi closed center
Crew Size	2
Hull Material	Welded aluminum
Bollard Pull, lb	7,700
Unit Cost	$165,000 (6/68)

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PART TWO DESIGN OF WHEELED AMPHIBIANS

CHAPTER 4 INTRODUCTION TO THE DESIGN PROCESS

4-1 PHASES OF THE DESIGN PROCESS

The design of a wheeled amphibian may be considered to take place in four phases. In the course of these phases the design progresses from general considerations, such as size and power, to specific considerations including the design, selection and arrangement of components and, finally, testing and evaluation. The four phases of the design process are:

1. Conceptual Design. During this phase the basic characteristics of the candidate amphibian are developed. This design work is done in support of system studies and used to develop realistic and specific requirements.

2. Preliminary Design. During this phase the characteristics developed in the conceptual design are checked and modified until the requirements are satisfied. This is done by designing, selecting, and arranging the major components and systems of the amphibian. This includes the necessary major hardware trade-offs to produce a cost-effective vehicle.

3. Detail or Final Design. During this phase the preliminary design is developed into a set of final plans from which the amphibian can be built. This involves the design, selection, and arrangement of all components and systems in the amphibian.

4. Testing and Evaluation. During this phase prototype vehicles are subjected to the tests necessary to show that the design satisfies the requirements. Testing and evaluation provide feedback on the validity of the design procedures used, and define the defects and problems that must be overcome for the amphibian to meet the requirements. Later in the life cycle, testing is carried out as part of product improvement programs.

These four phases of the design process are known by a variety of names. In general there is no sharp break between the different design phases; rather, they tend to overlap. This is especially true for the conceptual and preliminary design phases.

It is important to realize that, in general, the successive design phases of a wheeled amphibian will not be carried out by the same group. In the past the conceptual and preliminary designs have been conducted by designers working directly for the U.S. Army. The final design and some testing have been carried out by the contractor who builds the prototype vehicle. The remainder of the testing is conducted by the U.S. Army Test and Evaluation Command (USATECOM). This division of the design process introduces problems in control and information flow in the design. These areas are covered in pars. 4-2 and 4-3. However, design could also be obtained under the "Total Package Procurement" concept. In addition, design and other phases in a weapon system's life cycle could be a function of a Department of Defense or Department of Army Project Manager, or an AMC Product Manager. Project/Product Management of an equipment at any period during its life cycle vests one individual with ultimate responsibility for all aspects of the item he manages. The Project/Product Manager cuts across all functional lines engineering, logistics, programming and procurement—thereby greatly improving the vertical and horizontal coordination between these activities. The concept of project/product management is presented in Refs. 1 through 4.

4-2 CONTROL OF THE DESIGN PROCESS

In order to produce a successful wheeled amphibian in a reasonable time, the design process must be under the direction of a central authority. The person or persons who act as this authority must have the technical ability and authority to direct and control the design development. They must also be responsible for the design satisfying the requirements. Experience in the design of many different items has shown that when the responsibility for the satisfactory performance of the end product is clearly defined, the chances of success early in

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the project are greatly increased. This problem and, in particular, the need to establish responsibility through quantitative testable end requirements are covered in detail in Ref. 5.

As indicated in par. 4-1, the entire design process will probably not be carried out by one group. As a result, those with the ultimate authority and responsibility must plan for the necessary supervision, schedules, information, and coordination. In particular, time can be saved if there is the proper coordination among the final design, prototype construction, and testing. This includes the formulation of test teams, approval of regulatory bodies, the development of engineering test programs, and the correction of problems uncovered in tests.

4-3 INFORMATION FLOW IN THE DESIGN PROCESS

The design of a wheeled amphibian is, by its nature, an iterative procedure. Assumptions are made, then checked by calculations and layouts, and then modified as necessary. These iterations are repeated until a satisfactory design has been developed. The actual iteration cycles used are presented in Chapters 5 and 6.

Because of its iterative nature, the success of the design process depends on the timely flow of information. The more the design work is speeded up by concurrent work on different parts of the design, the more critical the problem becomes. The information flow in a design is both vertical from phase to phase and horizontal within a given phase.

If different design phases are carried out by different groups of designers, vertical information flow becomes important. In addition to the usual information transferred between phases—such as requirements, plans, and calculations—other information is useful. This includes the assumptions made, the important technical decisions, the reasons for these decisions, and, if appropriate, a brief description of the design philosophy.

Horizontal information flow becomes more important as the number of designers working on a design increases and is thus most important during final or detail design. This information is used to coordinate concurrent work on different parts of the design. The need for coordination among designers working such components as the hull, running gear, and drive train is obvious.

4-4 ORGANIZATION OF DESIGN CHAPTERS

The next four chapters of this handbook—organized by phases of the design process—present wheeled amphibian design procedures, techniques, and data. Chapter 5 covers conceptual design; Chapter 6 covers preliminary design; Chapter 7, detail design; and Chapter 8, testing and evaluation. Each of these chapters presents the procedures, techniques, and data appropriate to the particular design phase. There is some repetition of topics between chapters since the same topics must be considered in more than one phase of the design.

In effect, Chapters 5 through 8 form an interrelated group and should be considered as such. In order to understand the proper use of some of the general design procedures and data presented in Chapters 5 and 6, it will be necessary to review the basic concepts presented in Chapter 7. This is especially the case with respect to waterborne resistance, propulsion, and stability.

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CHAPTER 5 PARAMETRIC AND CONCEPTUAL DESIGN STUDIES

5-1 OBJECTIVE

The basic objective of conceptual design studies of wheeled amphibians is to define basic technical and performance characteristics for use in evaluation studies and for input to following design phases. Parametric design studies involve the development of a number of conceptual designs in which the inputs are varied systematically to determine design interrelationships, trade-offs, and optimum characteristics. These studies must be carried out rapidly and in sufficient detail to identify the gross characteristics of the craft, and to establish feasibility and technical problems areas.

5-1.1 BASIC PURPOSE

A parametric design study or a conceptual design may be carried out for a number of reasons, including the following:

a. Trade-off and Optimization Studies. In the early stages of the design process it is necessary to choose an optimum combination of characteristics from the many possible alternatives. Included in these alternatives are variables such as dimensions; hull material; and selection of engine, propulsor, and drive train. These selections are made from trade-off studies which involve the development of conceptual designs based on the possible alternatives. The choice is then made among the possibilities on the basis of a selection criterion which is often in the form of a cost-effectiveness ratio. Ref. 1 presents a detailed discussion of the use of conceptual designs in this type of optimization study. The information and data developed in such studies form the inputs to the preliminary design phase.

b. Requirement Development. The military or performance characteristics for a wheeled amphibian will be given in a requirement or specification such as a QMR (Qualitative Materiel Requirement) or SDR (Small Development Requirement). The initial form of this type of requirement comprises the input to the start of the conceptual design phase. In their final form these requirements must be free of impossible conflicts and lead to a practical vehicle if a great deal of time and effort is not to be wasted. The recommended approach to achieve this goal is the development of conceptual designs which include all of the requirements. This procedure will confirm that it is feasible to meet the requirements and facilitate a realistic estimate of the scope of effort required.

c. Background or Input Data. System analysis studies on military systems may be conducted by or for elements of the United States Government that make use of wheeled amphibians. The amphibian designer will be asked to provide technical data on the selection of wheeled amphibians for use in these systems. In many cases these systems will be intended for a future date and it will be necessary to develop information on vehicles that can be designed and produced by that date. To provide the required data for the system analysis, conceptual designs based on the expected technology must be developed. It may be expected that large scale system studies would be used to identify the need for new wheeled amphibian designs and define their performance requirements.

d. Technological Projections. The technological projection is intended to determine the probable affects of technological advances on the characteristics of wheeled amphibians. A simple example of this might be the determination of the effect on the characteristics of a 5-ton payload amphibian if the design were based on the use of a new engine with advanced characteristics. This type question is best answered with a conceptual design which makes use of the proposed technological advance. The technological projection study may provide impetus for the development of new components or designs based on new components if it indicates large gains in effectiveness are possible.

Depending on the purpose, a large number of conceptual designs may be necessary to develop the needed information and the conceptual design procedure must be such that it can be carried out rapidly with minimum effort. In many cases the conceptual design procedures are programmed for a computer.

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5-1.2 RELATION TO DESIGN CYCLES

The parametric studies or conceptual design form the first phase of the design development process and serve the purposes described in par. 5-1.1. In a design which will continue into the preliminary and detail phases, the conceptual design phase must provide information on expected technical characteristics, performance, and any basic trade-off studies performed. The conceptual design phase should also identify critical problem areas which will require modification during the following design phases. In this connection it is important to note that design assumptions made during the conceptual design should be conservative in nature. It has been shown repeatedly that a design that is marginal in meeting performance objectives at this early phase will not meet them in the later phases.

5-1.3 DESIGN CRITERIA

Many factors must be considered in the selection and design of the amphibian configuration and its systems, subsystems, and components. The relative importance of each factor will depend on the particular requirements and goals, i.e., criteria, that have been prescribed for a given concept. Factors to be considered include, but are not limited to, simplicity, durability, vulnerability, weight, arrangements, safety (human factors), maintainability, reliability, availability, effectiveness, and cost. These factors are not independent. For example, ease-of-maintenance, reliability, and economy are all associated with simplicity.

Criteria are most useful in trade-off studies or evaluation when the factors can be compared on a quantitative basis, i.e., a numeric value may be assigned to the variables. In many cases it is impossible to find a quantitative measure so that comparison must be made on a strictly qualitative basis. The paragraphs which follow define the various factors which are used as design criteria and indicate where quantitative evaluations may be made.

5-1.3.1 Simplicity

Simplicity of design leads to reliability and economy, and eases the problems of operation and maintenance. The desire for improved performance is always at odds with simplicity because these improvements inevitably arise from increased sophistication and complexity. The trade-off between simplicity and performance is quite difficult because simplicity is generally a qualitative factor. However, every effort should be made to limit complexity to a minimum consistent with the attainment of desired performance and cost objectives.

5-1.3.2 Durability

Durability is associated with the ability of the amphibian (and its components) to operate under adverse conditions over an extended period of time and yet remain free from material failures, i.e., its life expectancy. Unfortunately, this attribute usually evolves from additional material weight.

The most useful quantitative measure of durability is the statistical mean-time-between-failures (MTBF). The MTBF of a component is found by testing statistical samples of the component. The "confidence" level ascribed to the value of MTBF is a function of the number of sample components which are tested to failure. The greater the number of samples, the higher the level of confidence. Experience with similar components can be used to predict the MTBF in lieu of tests in which case the confidence level depends on the degree of experience with similar components and their similarity to the new component.

5-1.3.3 Vulnerability

Components which are susceptible to damage should be afforded any protection which does not unduly compromise normal operation. For example, sensitive electronic equipment may be specially mounted to isolate it from vibration damage. Trade-offs must be studied in some cases, e.g., housing the propeller in a tunnel certainly decreases its vulnerability, but the question arises as to what extent are propulsive efficiency and maneuvering characteristics degraded by this arrangement.

5-1.3.4 Weight

An amphibian is heavier than either a truck or boat with comparable payload capacity. The

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wheeled amphibian must carry wheels and suspension systems not found on boats; a hull and waterborne propulsion system are not necessary on trucks. As a result, weight is a critical factor in the selection of every component. Of course, quantitative comparisons are easily made with respect to weight.

5-1.3.5 Arrangements

The multiplicity of systems on an amphibian require that careful consideration be given to arrangement of components and systems.

Qualitative considerations include: placement of components with easy access for maintenance; location of operator's station to afford a good field of view; location of cargo deck (and ramp) for easy loading; and keeping all parts of the electrical system out of the bilges where they would be subjected to corrosive salt water environment.

Quantitative considerations are the amphibian stability and trim which are functions of the weight and center of gravity of all the components taken collectively. Strict limitations are always set on the stability of an amphibian.

5-1.3.6 Safety (Human Factors)

There are many aspects of the amphibian design which must take into consideration the safety and comfort of the operators and support personnel. The main hazards are capsizing in surf and the physiological effects of intensive accelerations, vibrations, and noise. For example, the vibration criteria for Army land vehicles is that the allowable energy level absorbed by personnel be limited to 6 watts. Other human factors are discussed in Refs. 2 and 3.

5-1.3.7 Maintainability

The environment in which the amphibian operates decreases the life expectancy of components and increases maintenance and replacement of parts. Surf operations, in particular, with frequent groundings on beaches and coral reefs give rise to short life expectancies for unprotected propellers. The replacement of a screw on an amphibian is ordinarily quite routine. However, the LARC XV was designed with the bearing and support struts aft of the propeller so that the shaft must be uncoupled and drawn from the stuffing box to make the propeller change. Any item under consideration for future amphibian designs should be rated according to its ease-of-maintenance and its contribution to the total amphibian maintenance requirement.

A quantitative measure of maintainability is the mean-time-to-repair (MTTR), another statistical concept.

5-1.3.8 Reliability

Reliability is the probability that an item will successfully perform its intended function for a specified time interval (mission time) under stated conditions. Logistic amphibians are normally required to operate for two 10-hr mission periods, each 24-hr day, without a failure that will interrupt the mission.

Reliability is a function of durability and mission length. The reliability R of an item with an exponential distribution of failures is given by:

$$R = e^{-t/m} \qquad (5\text{-}1)$$

where

t = mission time, hr
m = MTBF, hr

Thus, the reliability of an amphibian having 150-hr MTBF and 10-hr mission time is:

$$R = e^{-10/150} = 0.936 \text{ or } 94\%$$

Conversely, the expected number of failures is six per one hundred missions.

The reliability of an amphibian is a complex function of the reliability of each component and system. Refs. 4 and 5 give detailed discussion of multi-component reliability.

Eq. 5-1 is based on the simplifying assumption that the failure rate has an exponential distribution so that the probability of failure in a time interval of duration Δt is unique, i.e., dependent on the length of the interval only; independent of the starting time of the interval. This is a poor assumption for many items that show signs of wearing out as revealed by sharp increases in the probability of failure with increasing time. For example,

rubber tires have a much greater probability of blow-out after the tread has worn down to the cords. Periodic replacement of such items is necessary to maintain the desired level of reliability.

5-1.3.9 Availability

Availability (operational) is the probability that a system or item when used under stated conditions and in an actual supply environment shall operate satisfactorily at any given time. Availability (operational) A_o is a function of durability, maintainability, and the procurement time of unavailable parts:

$$A_o = \frac{m}{m + m_d} \qquad (5\text{-}2)$$

where

m = MTBF, hr
m_d = mean downtime (MDT) including supply downtime, administrative downtime, and mean-time-to-repair; but preventive maintenance downtime is zero; hr

MDT is given by:

$$m_d = k\left[m_r + (1 - A_p)m_s\right], \text{ hr} \qquad (5\text{-}3)$$

where

k = ratio of normal operating hours to total hours, nd
m_r = MTTR, hr
A_p = average parts availability, nd
$1-A_p$ = average parts unavailability, nd
m_s = mean procurement time for repair parts, hr

For example, the availability of an amphibian having 150-hr MTBF required to operate 20 hr each 24-hr day; and assuming MTTR = 3 hr, A_p = 0.85, and m_s = 20 days or 480 hr:

$$A_o = \frac{150}{150 + \frac{20}{24}[3 + (0.15)480]} = 0.71 \text{ or } 71\%$$

In this example, the main factor limiting the availability is the supply delay time, $k(1\text{-}A_p)m_s$.

5-1.3.10 Effectiveness

The effectiveness of a logistic amphibian is associated with its productivity. The effectiveness is measured in terms of transported cargo in ton-miles. This is the product of payload, speed, and time in operation. The speed should be the average speed for a complete cycle including time for loading and unloading. Effectiveness may also include the corrections for reliability and availability.

5-1.3.11 Economy

Cost is probably the most important criterion in the design of an amphibian and also the most difficult to assess. For any given item or system having comparable capabilities, the economic analysis consists of the comparative costs of development, production, operation, and maintenance amortized over the life of the vehicle. If the capabilities of the system are not comparable, it may be difficult if not impossible to fix a basis for economic comparison. If one system does not meet the required functional criteria, it is totally unacceptable regardless of how economical it might be; this would be a false economy. Amphibians with different capabilities can be compared on the basis of a cost-effectiveness ratio, the cost divided by the effectiveness in dollars per ton-mile of payload transported.

5-2 CONCEPTUAL DESIGN PROCEDURES

Before starting on any phase of the design process the designer must have a clear understanding of the input information, the required output, and the procedures or steps which lead from the input to the output. All phases of the design of a wheeled amphibian are similar in that the procedure involves an iterative series of calculations, drawings, and decisions which should result in a satisfactory solution. The design phases are distinguished from one another by the degree of detail involved in the design calculations, drawings, and decisions. The conceptual phase is the most general.

5-2.1 TYPICAL DESIGN INPUTS AND OUTPUTS

The inputs to the conceptual design phase can be considered as functional inputs, goals, and

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constraints. These should be given in the form of military or performance requirements such as a preliminary QMR or SDR. The functional inputs specifically define the productive requirements of a wheeled amphibian. Basically this involves a definition of payload, speed, and range. Information should be provided on the weight; volume; deck area; center of gravity and character of the payload; and the performance requirement in terms of waterborne and land speed, slope and grade climbing ability, soft-soil mobility, surfing ability, and range or endurance.

The design goals in the conceptual phase are general statements of desired characteristics which are to be considered in designing to meet the functional inputs. These goals, for example, involve the objective of obtaining the vehicle of minimum size, weight, and cost; and maximum reliability and maintainability that will satisfy the functional requirements.

The design constraints are limitations which have, for some reason, been placed on the technical characteristics of the design. These might include such things as limitations on the beam, weight, clearances, engine, and materials. These constraints are almost always imposed because of considerations of transportability, mobility, or compatibility with other equipment. It must be realized that when constraints of this nature are imposed on the design, it may not be possible to meet all of the functional requirements. Thus, one of the important results of the conceptual design phase is the identification of the conflicts between the design constraints and the functional requirements.

The outputs of the conceptual design of a wheeled amphibian include a summary of the expected design characteristics and performance, simple arrangement sketches, and all supporting data and calculations.

5-2.2 BASIC DESIGN ITERATION CYCLE

The basic design iteration cycle involves the systematic variation of the design characteristics until the functional requirements and constraints are satisfied. The variation of the design characteristics in the iteration is based on the following fundamental conditions which must exist for a wheeled amphibian: (1) weight must equal buoyancy, (2) the volume and area of all the components must be equal to or less than the available volume in the hull, (3) the center of gravity and buoyancy must lie on the same vertical line, and (4) the waterborne and side slope stability must be satisfactory.

The basic steps in the conceptual design process and the iteration loops are shown in the flow chart presented in Fig. 5-1. With the input data available, the first step will be to estimate the length, breadth, and depth of the hull and select the hull form type. These first estimates are based on experience with past designs with similar payloads. The second step will be to estimate the gross vehicle weight and center of gravity location. These estimates may be based on the payload-gross weight ratios of previous wheeled amphibians. These initial steps serve to establish an initial condition from which the design iteration can proceed.

The first step in the iteration cycle is the selection of the running gear arrangement and components, based on the estimate of dimensions, weight, and centers. This selection includes the number of wheels, their location, wheelbase, and tire size. The mobility requirements in the functional inputs will provide the criteria for the land gear arrangement. The next step in the cycle will be to estimate the power required to meet the performance inputs. In general, the power required to meet the waterborne speed will govern. In some cases a particular engine will be specified so that an estimate of the expected performance will be required.

With the information available at this stage, a calculation of the gross vehicle weight and center of gravity can be made. This calculation must be checked against the gross vehicle weight and center of gravity assumed in the selection of land gear and power required. If the two do not agree within a few percent, the design loop must be repeated until agreement is reached.

After the completion of the inner iteration loop, a calculation of the waterborne stability and trim can follow. This calculation is of great importance since the stability and trim criteria must be satisfied. In general, the stability and trim calculated initially will not agree with the criteria. As a result, some modifications in the dimensions and arrangements will be necessary. At this point the volume and area required by all components should be checked against the available volume and area in the hull. A simple

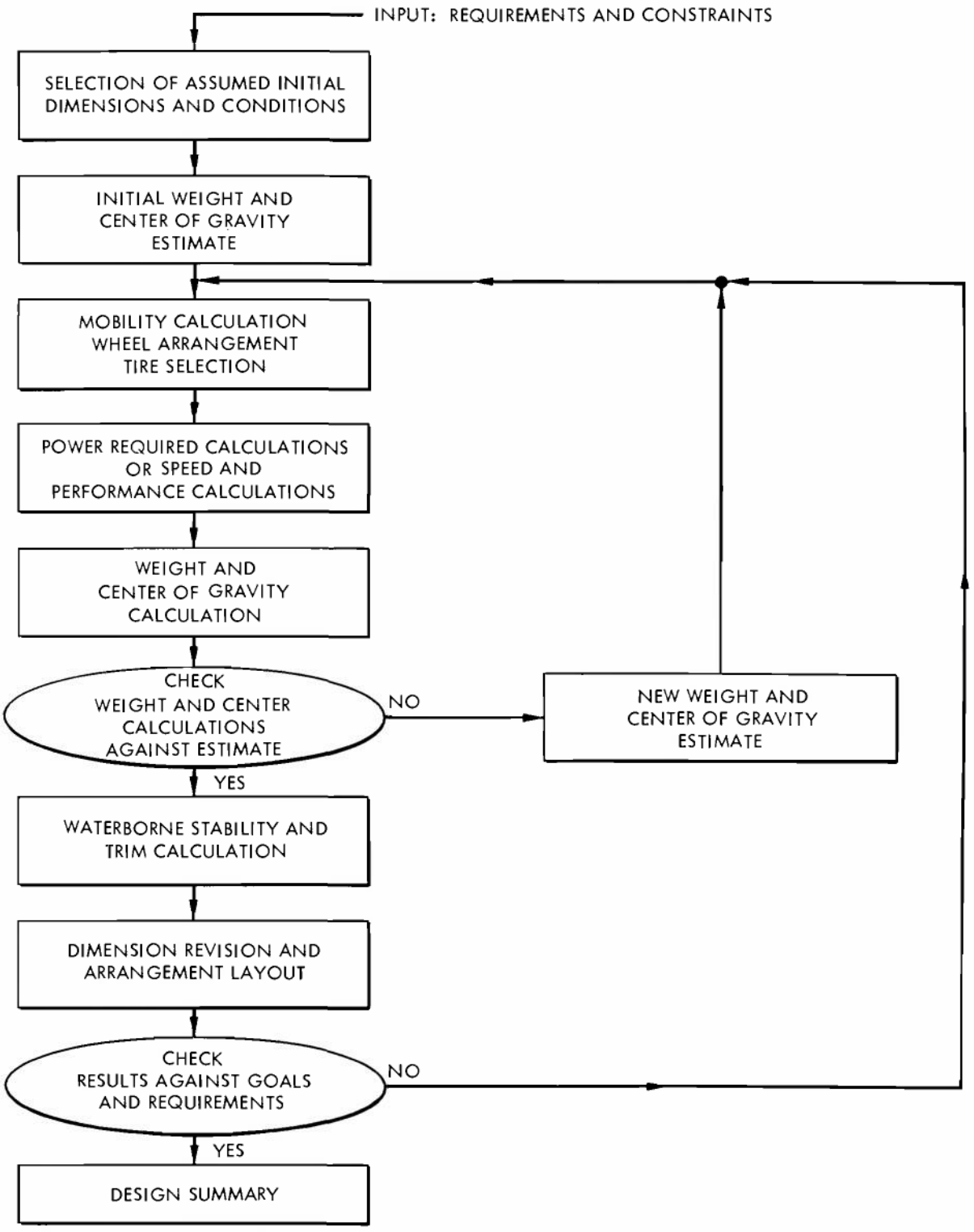

Figure 5-1. Conceptual Design Flow Chart for Wheeled Amphibians

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arrangement sketch can be made for this purpose. If it is necessary to revise the dimensions or arrangements, the iteration must be repeated from the beginning point. Of course with each time through the cycle, the information from preceding cycles is available to aid in making the required calculations, selections, and decisions. In this way, the process is made to converge to a design which satisfies the functional inputs, goals, and constraints. When this point is reached, a design summary is prepared.

The remaining paragraphs of this chapter present some of the data and calculation procedures needed to carry out the steps in the conceptual design procedure discussed.

5-3 SIZE AND ARRANGEMENTS

In general, the data and calculation procedures used in the conceptual design procedure are developed from experience with past successful designs in order to develop the conceptual design output in the shortest time with a minimum of manpower. For example, during preparation of the conceptual design, hull structural plans will normally not be developed to the state that a weight estimate can be prepared by direct calculation. Instead, the hull weight estimate will be made from known relationships among size, shape, and weight variations developed from data on past designs. As a result, conceptual design data must be updated each time information on a new design becomes available. Further, as the state-of-the-art with respect to vehicle components advances, the conceptual design data must be updated. This applies to such items as engines, transmission systems, running gear, and controls.

The designer must be careful that the use of data from past vehicles, in the designing of new vehicles, does not inhibit his use of new concepts and developments. In order to take advantage of such advances, it may be necessary to carry out some steps of the conceptual design in much greater detail than normally required. For example, when studying the effect of Fiberglas hull construction on vehicle characteristics, data on the weights of existing steel and aluminum hulls would not be of much use. It would be necessary to lay out a typical Fiberglas structure in sufficient detail to calculate a realistic weight. However, it should not be necessary to develop special data on items such as engines, drive trains, and running gear.

5-3.1 DESIGN INTERRELATIONSHIPS

Before undertaking a conceptual design, the designer must have a thorough understanding of the basic interactions between the performance and design characteristics. This knowledge is required for making the selections and compromises to produce a rapid convergence of the iterative parts of the design cycle. A summary of these interactions is presented in Ref. 6 for high water speed, planing hull amphibians. These interactions have been modified to apply to conventional wheeled amphibians and are presented in Figs. 5-2 through 5-7.

Fig. 5-2 presents the interactions between design characteristics and performance in terms of primary or secondary influence of a given design characteristic on the indicated performance characteristic. Fig. 5-3 presents a more specific indication of the interrelation of hull design characteristics and performance. This figure is arranged to indicate the effects of a change in a hull design feature on a given performance characteristic. Of course, various hull design features are not independent of one another. Fig. 5-4 presents the interrelationships among hull design features in terms of primary or secondary influences.

The running gear will affect both land and waterborne performance. Fig. 5-5 shows the effect of an increase or change in running gear characteristics on performance. Fig. 5-6 presents the interrelationships among running gear features in terms of primary or secondary influences. The final figure dealing with design interrelations is Fig. 5-7 which indicates the primary and secondary influences of mechanical features.

5-3.2 AREA, VOLUME, AND ARRANGEMENT RELATIONSHIPS

During conduct of the conceptual design it is necessary to determine the area and volume required for the major components and to

INDEPENDENT / DEPENDENT	WATER FEATURES					LAND FEATURES				CARGO FEATURES		
	GROSS VEHICLE WEIGHT	HULL		MARINE POWER SYSTEM	MARINE PROPULSION SYSTEM	RUNNING GEAR		LAND POWER SYSTEM	LAND STEERING SYSTEM	AREA	WET DECK	RAMP
		SIZE	FORM			SIZE	CONFIGURATION					
LOAD CAPABILITY	1	1	2	2		2	2	2		1	2	1
WATER PERFORMANCE	1	1	1	1	1	2	2				1	2
SURF & BEACHING PERFORMANCE	1	2	2		1	1	1		2		1	2
OFF-ROAD PERFORMANCE	1	2	2			1	1	2	2		2	2
ON-ROAD PERFORMANCE	2	1				2	2	2	2			
TRANSPORTABILITY	1	1				2						

1 - PRIMARY INFLUENCE
2 - SECONDARY INFLUENCE

Figure 5-2. Design Characteristic and Performance Interaction

arrange these in a logical fashion. These major components are the payload, machinery, running gear, crew, and marine propulsor.

The payload or cargo that a wheeled amphibian can carry is determined by its weight, vertical center of gravity, and the required deck area. In many cases both the cargo weight and its area will be given as input to the conceptual design. In the event that only the weight of cargo is given, Fig. 5-8 can be used to estimate the area required. This figure presents the design weight of payload per square foot of cargo deck area for the production wheeled amphibians. Data are also given on the unit weight of actual cargo carried by the LARC V and LARC LX in Southeast Asia in late 1967 and early 1968. In general, the cargoes have been lighter than the vehicles were designed to carry, i.e., load limitations are deck area rather than weight. Data are also presented in Fig. 5-8 on the loadings of CONEX and A.S.A. standard 8 X 8 X 20 ft commercial containers.

In general, the block volume and planform area of typical machinery items such as engines, transmissions, and transfer cases are readily available from manufacturers' data. Typically the power per cubic foot of block volume (block volume defined as overall length X overall width X overall height) of current production Diesel engines range from 4 to 8 BHP per cubic foot and 8 to 10 BHP per cubic foot for current production gas turbine engines. The power per square foot of planform area (planform area defined as overall length X overall width) of current production Diesel engines ranges from 14 to 20 BHP per square foot and 30 to 50 BHP per square foot for current production gas turbines.

During the conceptual design it is necessary to estimate the area and volume of the machinery space. This requires data such as that in Table 5-1 which presents the ratios of block machinery volume and planform area, and the machinery compartment volumes and areas for several wheeled amphibians. Data are also presented in Table 5-1 on the area and volume of the radiator compartments for the wheeled amphibians with liquid-cooled engines.

In a wheeled amphibian the crew is stationed in a cab which provides protection from the

HULL DESIGN VERSUS PERFORMANCE + = BETTER		LENGTH	BEAM (OVERALL)	GROSS VEHICLE WEIGHT	LONGITUDINAL CG FORWARD OF STERN	BOW SHAPE, FULLNESS	STERN SHAPE, FULLNESS	FREE BOARD	VCG, HEIGHT
RESISTANCE	WATER PERFORMANCE	+	-	-		-	-		
SEA KINDLINESS		+	-	+		-			
STABILITY		+	+	-		+	+	+	-
SURF ABILITY AND BEACHING		+	+	+		+	+	+	-
SOFT SOIL MOBILITY	LAND PERFORMANCE			-					
GROUND CLEARANCE									
APPROACH ANGLE		-			+	-			
BREAK ANGLE		-							
DEPARTURE ANGLE		-			-		-		
RIDE		+	+	+					
ROADABILITY		-	-	-					
SIDE SLOPE STABILITY			+	-					-
LONGITUDINAL STABILITY		+							
AGILITY		-	-	-		-	-		
LOAD PERFORMANCE		+	+	+			+	-	-
TRANSPORTABILITY		-	-	-				-	

Figure 5-3. Interrelation of Hull Design and Performance

INDEPENDENT / DEPENDENT	LENGTH	BEAM	APPROACH & DEPARTURE ANGLE	GROSS VEHICLE WEIGHT *	LCG	BOW SHAPE	STERN SHAPE	FREE BOARD	VCG	RUNNING GEAR	WATERBORNE STABILITY	RAMP
LENGTH		1		1		2	2			2	1	2
BEAM	1			1		2	2		1	1	1	2
APPROACH & DEPARTURE ANGLE						1	1			2		
GROSS VEHICLE WEIGHT *	1	1	2			2	2	1	2	1	1	2
LCG	2									1		
BOW SHAPE	2	2	2		2			2		2	2	1
STERN SHAPE	2	2			2			2		2	2	1
FREE BOARD	2	2	2	2					2			2
VCG	2	1	2	2		2	2	2		2	1	
RUNNING GEAR	1	1	2	1	1	2	2				2	
WATERBORNE STABILITY	1	1		1		2	2		1	2		
RAMP	2	2		2		1	1	2				

* AS AFFECTED BY HULL DESIGN ONLY
1 - PRIMARY INFLUENCE
2 - SECONDARY INFLUENCE

Figure 5-4. Interrelation of Hull Features

elements when in the water, in surf, and on land. Table 5-2 presents the planform area and volume of the cabs on several amphibians as a function of the number of seats in the cab. It should be noted that the LARC XV has different forward directions on land and water and, as a result, the cab is arranged for the driver to face in either direction, as required.

Information on the area, volume, and arrangement of the running gear and marine propulsor is given in pars. 5-5.3 and 5-5.4.

The arrangement of the major items in the hull is governed by considerations of center of gravity location, access, maintenance, and visibility. The longitudinal location of the center of gravity of the loaded amphibian should be such that it floats with no trim or a little trim by the stern. The running gear should be located so that the loading on the wheels is equal. The vertical center of gravity should be as low as possible consistent with other requirements such as freeboard.

INDEPENDENT / DEPENDENT (+ = BETTER)		LAND PERFORMANCE										WATER PERFORMANCE				
		SOFT SOIL MOBILITY	GROUND CLEARANCE	APPROACH ANGLE	BREAK ANGLE	DEPARTURE ANGLE	RIDE	ROADABILITY	SIDE SLOPE	GRADE	AGILITY	SURF AND BEACHING	SPEED	SEA KINDLINESS	STATIC STABILITY	LOAD PERFORMANCE
NUMBER OF TIRES (SINGLES)		+	-		+		+	+	+	+	+		+		+	
TIRE	DIAMETER	+	+	+	+	+	+		-			+	-		-	-
	SECTION WIDTH	+					+		-			+	-		-	
SUSPENSION DEPTH		+					+		-	-					-	-
STEERING MODE	ACKERMANN							+			+					
	ARTICULATED FRAME	+													+	
WHEEL DRIVE	DIRECT	+														
	FRICTION						-								+	+
GROSS VEHICLE WEIGHT *		-									-	-	-		-	-

*AS AFFECTED BY RUNNING GEAR DESIGN

Figure 5-5. Running Gear Changes vs Performance

INDEPENDENT / DEPENDENT	GROSS VEHICLE WEIGHT *	NUMBER OF TIRES	TIRE DIAMETER	TIRE SECTION WIDTH	WHEEL DRIVE ARRANGEMENT	STEERING MODE	SUSPENSION DEPTH	HULL
GROSS VEHICLE WEIGHT *		2	2	2	2	1	1	
NUMBER OF TIRES	1		1	1	2	2	2	1
TIRE DIAMETER	1	1		1	2	1	2	1
TIRE SECTION WIDTH	1	1	1			2		1
WHEEL DRIVE ARRANGEMENT	2	1	2			1	1	2
STEERING MODE	2	2	1					1
SUSPENSION DEPTH		2	2	2	1	2		
HULL		1	1	1	2	1		

* AS AFFECTED BY RUNNING GEAR DESIGN
1 - PRIMARY
2 - SECONDARY

Figure 5-6. Running Gear Features

INDEPENDENT / DEPENDENT	GROSS VEHICLE WEIGHT	HULL SIZE	HULL FORM	RUNNING GEAR SIZE	RUNNING GEAR CONFIGURATION	POWER SYSTEM, MARINE	POWER SYSTEM, LAND	WATER PROPULSION CONFIGURATION	LAND STEERING CONFIGURATION
GROSS VEHICLE WEIGHT		1		1	2	2	2	2	2
HULL SIZE	1			1	2	2		2	2
HULL FORM				1	1	2		2	2
RUNNING GEAR SIZE	1	1	2		1			2	1
RUNNING GEAR CONFIGURATION	2	2	1	1			2		2
POWER SYSTEM, MARINE	1	1	1	2				1	
POWER SYSTEM, LAND	1			2	2				2
WATER PROPULSION CONFIGURATION	2	2	2	2	2	1			
LAND STEERING CONFIGURATION			2	1	1		2		

1 - PRIMARY INFLUENCE
2 - SECONDARY INFLUENCE

Figure 5-7. Interrelation of Mechanical Features

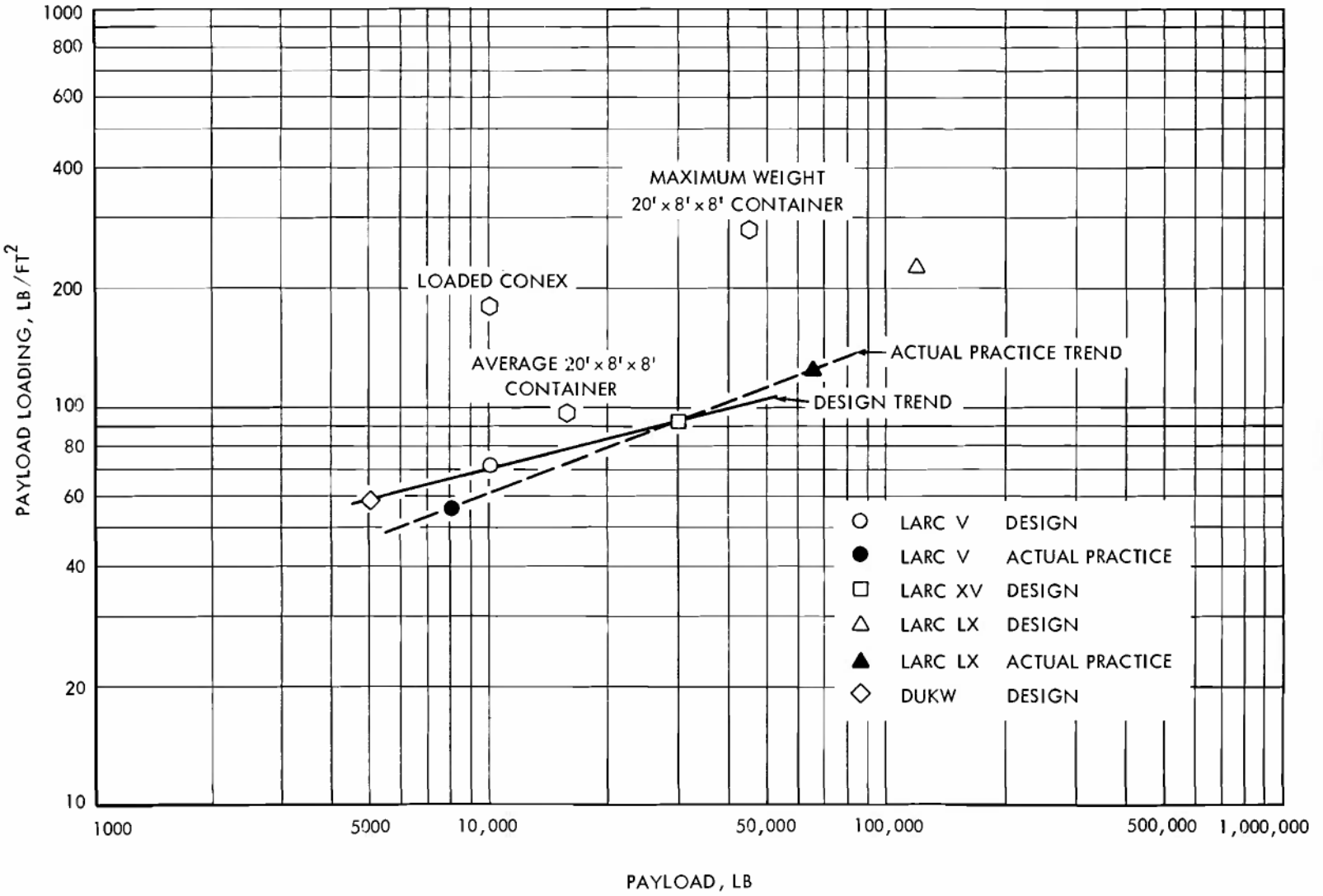

Figure 5-8. Wheeled Amphibian Cargo Loading

TABLE 5-1 ENGINE COMPARTMENT VOLUMES AND AREAS

Vehicle	*Engine Type*	*Max BHP*	*Cooling*	$\frac{A_{eng}}{A_{comp}}$	$\frac{V_{eng}}{V_{comp}}$	$\frac{A_{cool}}{BHP}$, ft²/BHP	$\frac{V_{cool}}{BHP}$, ft³/BHP
LARC V	Diesel	300	Liquid	0.33	0.264	0.058	0.172
LARC XV	Twin Diesel	600	Liquid	0.308	0.204	0.060	0.248
LARC LX	Four Diesels	660	Liquid	0.224	0.128	0.127	0.508
LVH-X2	Gas Turbine	1100	Air	0.47	0.260	—	—

A_{eng} = planform area of machinery in compartment, ft²

A_{comp} = planform area of compartment, ft²

V_{eng} = block volume of machinery in compartment, ft³

V_{comp} = volume of compartment, ft³

A_{cool} = planform area of radiator and ducting, ft²

V_{cool} = volume of radiator and ducting, ft³

TABLE 5-2 CREW CAB DATA FOR WHEELED AMPHIBIANS

Vehicle	*Seats in Cab*	*Cab Area, Seat*, ft²	*Cab Vol, Seat*, ft³
LARC V	3	11.3	62.7
LARC XV	4	14.9	70.8
LARC LX	1	28.0	140.0
LVH-X2	2	16.8	95.0

The usefulness of an amphibian is strongly affected by the ease with which it can be maintained and repaired. Good maintainability is assured by providing sufficient access and working space around those items which require maintenance. This implies that hatches should be located over major components such as engines and transmissions. In general, locating the cab over major components will reduce access to such components and complicate the running of control systems. The cab should be located so that the driver's visibility is not obstructed by the cargo or the amphibian structure. The number of components located under hatches on which cargo will be loaded should be minimized. Such hatches are often damaged and leak.

5-3.3 DIMENSION AND COEFFICIENT RELATIONSHIPS

The hull dimensions are a function of the volume, area, and arrangement requirements of the major components, as covered in par. 5-3.2, as well as the required buoyancy, stability, and trim. Any one of these items could have the effect of fixing a minimum value for one of the principal hull dimensions which include the

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overall length, the waterline length, the overall breadth, the waterline breadth, the hull depth at various locations, and the draft to the hull bottom at various locations.

5-3.3.1 Buoyancy

When an amphibian is floating in the static equilibrium, Archimedes' Law requires that its weight be equal to the weight of the displaced fluid, i.e., buoyancy. The weight of the displaced fluid is directly proportional to the volume of the amphibian below the free surface, which, in turn is related to the dimensions. During the conceptual design phase, the dimensions needed to obtain the required buoyancy are estimated without preparing detailed drawings of the hull.

In general, the buoyancy for different types of amphibian hulls can be estimated by using the "block coefficient" which is representative of the particular hull type. The block coefficient C_B is defined by:

$$C_B = \frac{GVW}{LBH_m \rho g}, \text{ nd} \qquad (5\text{-}4)$$

where

GVW = gross vehicle weight, lb
ρg = density of fluid, lb/ft^3
L = overall or waterline length, ft
B = overall or waterline breadth, ft
H_m = mean draft, ft

The value of the block coefficient used must be consistent with the choice of overall or waterline dimensions. In general, it is preferable to use the waterline dimensions if available since this avoids problems with adjustments for overhangs and bumpers. Table 5-3 contains information on the dimensions and block coefficients of existing wheeled amphibians. These data can be used for estimates of reasonable block coefficients for new designs. It should be noted that the block coefficient of the DUKW is lower than the LARC's despite its scow-type hull form. This is the result of the proportionately larger wheel wells and tunnels required by the 6 X 6 arrangement of the running gear and the sprung suspension.

In order to estimate the hull depth at different locations, it is necessary to determine the required freeboard as well as mean draft. The freeboard requirements are a function of the range of stability and reserve buoyancy criteria which are presented in par. 7-1.6.2. At this stage in the conceptual design there will be insufficient information to calculate the range of stability and reserve buoyancy to check an assumed freeboard. Accordingly, it is necessary to base an estimate of the freeboard on data from past designs, as given in Table 5-4.

It should be noted that the distribution of freeboard is a function of the arrangement of the cargo deck. Two arrangements of cargo decks have been used for wheeled amphibians, viz., the "wet deck" and the cargo compartment arrangements. In the wet deck type, the cargo is carried on a watertight deck located above the load water line. Water on deck from surf or waves will run overboard without entering the bilges. The LARC V and LARC XV have this type of arrangement.

In the cargo compartment arrangement, the cargo is carried on a deck below the waterline and is protected by high freeboard and coamings. Water which enters the cargo compartment from surf and waves flows into the bilge and must be pumped out. The LARC LX and the DUKW are arranged in this manner.

The wet deck arrangement has the advantage of being much safer in surf or high seas, and unloading can take place without the necessity for lifting the cargo over the high sides and coamings. This arrangement has the disadvantage of placing the center of gravity of the cargo relatively high, which requires an increase in hull dimensions for stability. Conversely, the cargo compartment arrangement provides for a reduced height of the cargo center of gravity, thus reducing the hull dimensions. It has the disadvantage of the possibility of swamping in high surf or waves and relatively greater difficulty in unloading.

From Table 5-4 it may be noted that the freeboard forward is greater than the freeboard aft. This is the result of trim and not due to greater hull depth forward. In general, when estimating the freeboard forward and aft for the purpose of establishing the hull depth, it is proper to use the mean of the bow and stern freeboard ratios. It is desirable for the forward and aft freeboard to be about the same, with the forward freeboard slightly greater, so that large trim angles do not develop at large heel angles.

TABLE 5-3 CHARACTERISTICS OF PRODUCTION WHEELED AMPHIBIANS

Vehicle	Gross Vehicle weight, lb	Payload, lb	Payload / GVW, nd	Length Overall	Length Waterline	Beam Overall	Beam Waterline	Mean Hull Draft	BHP	Speed, mph	Hull Depth		
											Forward	Midships	Aft
LARC V	31000	10,000	0.323	35'-0"	32'-0"	10'-0"	9'-8"	2'-3"	300	8.5	5'-10¾"	3'-1¼"	5'-5"
LARC XV	75200	30,000	0.396	45'-0"	39'-6"	14'-6"	14'-0"	2'-8½"	400	9.7	7'-0"	3'-10"	6'-0"
LARC LX	314000	120,000	0.382	68'-4"	58'-9"	26'-11"	25'-4"	5'-1"	660	7.0	3'-6" Side 9'-9"	4'-3" 9'-9"	3'-7¼"
DUKW	20,000	5,000	0.25	31'-0"	29'-0"	8'-4"	8'-0"	2'-6"	90	6.5	3'-9"		4'-0"

Vehicle	Running Gear Arrangement	Tire Size, in.	Block Coef. Based on Overall Dim., nd	Block Coef. Based on Waterline Dim., nd	C_{I_T} * Based on Overall Dim., nd	C_{I_T} * Based on Waterline Dim., nd
LARC V	4 x 4	18.00 x 25	0.610	0.690	0.051	0.055
LARC XV	4 x 4	24.00 x 29	0.658	0.776	0.0528	0.067
LARC LX	4 x 4	36.00 x 41	0.573	0.649	0.0495	0.063
DUKW	6 x 6	11.00 x 18	0.480	0.557	0.070	0.075

* C_{I_T} = Transverse Inertia Coefficient

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TABLE 5-4 FREEBOARD RATIOS, WHEELED AMPHIBIANS
(Full Load Condition)

Vehicle	*Freeboard Midships / Mean Hull Draft*		*Freeboard Forward / Freeboard Midships*	*Freeboard Aft / Freeboard Midships*
LARC V	0.39		3.42	2.58
LARC XV	0.46		3.73	2.66
LARC LX	0.935		1.05	0.95
	To Deck	*To Coaming*		
DUKW	0.61	1.00	1.21	0.79

5-3.3.2 Waterborne Stability—Intact

For a wheeled amphibian to operate safely in the water, its geometry and arrangement must be such that, when heeled, the couple produced by the buoyant force acting up and the weight acting down will tend to right the amphibian. The criteria for acceptable values of this restoring moment under different conditions, and procedures for calculating the moment, are covered in detail in pars. 7-1.6.2 and 7-1.6.3. During the conceptual design study, the time and information may not be available to perform detailed calculations and check all of the stability criteria. Therefore, the most important criteria must be selected and calculation procedures developed to check these criteria. The criterion usually considered is the initial stability expressed in terms of the *GM* or metacentric height. The concept of *GM* is covered in all textbooks on naval architecture and in pars. 7-1.6.2 and 7-1.6.3. The *GM* value is determined from the relation:

$$GM = KB + BM - KG \qquad (5\text{-}5)$$

where
- KB = vertical distance from the hull bottom to the center of buoyancy, ft
- BM = vertical distance from the center of buoyancy to the metacenter, ft
- KG = vertical distance from the hull bottom to the center of gravity, ft

For wheeled amphibians a good estimate of *KB* is given by:

$$KB = 0.50\, H_m, \text{ ft} \qquad (5\text{-}6)$$

where
- H_m = mean draft of hull, ft

The *BM* is calculated from the equation

$$BM = \frac{I}{\nabla}, \text{ ft} \qquad (5\text{-}7)$$

where
- I = transverse moment of inertia of the waterplane area about its centerline, ft^4
- ∇ = displaced volume of the amphibian, ft^3

Since the exact shape of the waterplane will not be known during the conceptual design, *I* may be estimated from

$$I = C_{I_T} B^3 L, \text{ ft}^4 \qquad (5\text{-}8)$$

where
- C_{I_T} = transverse inertia coefficient, nd
- B = overall or waterline beam, ft
- L = overall or waterline length, ft

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Table 5-3 presents values of the transverse inertia coefficient C_{I_T} for several wheeled amphibians based on both the waterline and overall dimensions. In Table 5-3 it should be noted that the value of C_{I_T} is largest for the DUKW. This is due to the aft wheel well being completely under the free surface at the full load condition.

The vertical height KG of the center of gravity is obtained from the weight and center estimate. From this value of KG and the calculations in Eqs. 5-6, 5-7, and 5-8 the intact waterborne stability can be determined from Eq. 5-5.

5-3.3.3 Trim

Trim is defined as the difference in the drafts measured forward and aft. To float in static equilibrium, the center of buoyancy must be on the same vertical line as the center of gravity. In general, any nonsymmetrical weights can be balanced so that the center of gravity is on the longitudinal centerline. Equilibrium is thus satisfied if the longitudinal center of buoyancy and gravity, measured from the same reference point, are equal. During the conceptual design studies, values of trim will be calculated for various loading conditions.

The trim T can be calculated from the following approximate equation:

$$T = \frac{\Delta(LCB - LCG)}{MT1}, \text{ in.} \qquad (5\text{-}9)$$

where

Δ = gross vehicle weight (GVW), lb
LCG = distance of center of gravity forward of the transom, ft
LCB = distance of the center of buoyancy at zero trim forward to transom, ft
$MT1$ = moment to alter trim one inch, ft-lb/in.

A positive trim calculated from Eq. 5-9 is defined as trim by the stern, i.e., draft aft is greater than draft forward.

An estimate of the value of LCB can be obtained from the data on existing wheeled amphibians given in Table 5-5.

It should be noted that the amphibian actually trims about the longitudinal center of flotation LCF, the longitudinal location of the center of area of the waterplane. The draft H at any point can be calculated from

$$H = H_m + \frac{T_d}{12\,LWL}, \text{ ft} \qquad (5\text{-}10)$$

where

H_m = mean draft, ft
T = trim, in.
d = distance from LCF to point that the draft is calculated, ft
LWL = load waterline length, ft

Note: If the point in question is forward of the LCF, d is (−) and if the point is aft of the LCF, d is (+).

Procedures for estimating the value of $MT1$ are presented in par. 7-1.6.4.

5-4 WEIGHTS AND CENTERS

The key step in the conceptual design process is the estimate of the vehicle weight and location of center of gravity. A realistic estimate of these items is of great importance because of their controlling effect on concept feasibility and the estimated performance of the amphibian. An unrealistic weight and center estimate will greatly increase the work required during the preliminary and detail design phases.

5-4.1 WEIGHT EQUATION AND WEIGHT GROUPS

It has been found from long experience in ship and boat design that the best way to make realistic weight and center estimates is to establish a weight equation that relates the sum of a number of weight groups to the gross

TABLE 5-5 LOCATION OF ZERO TRIM *LCB* AND *LCF* FOR WHEELED AMPHIBIANS

Vehicle	*LCB/LWL*	*LCF/LWL*
LARC V	0.495	0.485
LARC XV	0.498	0.482
LARC LX	0.490	0.498

NOTE: *LCB* and *LCF* are measured from the aft end of the load waterline.

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vehicle weight. Such a weight equation for wheeled amphibians is given by

$$\text{Gross Vehicle Weight} = GVW = W_A + W_B + W_C + W_D + W_E + W_F + W_M + W_L \quad (5\text{-}11)$$

where the subscripts refer to the major weight groups that, combined, equal the gross vehicle weight. A description of these weight groups is given in Table 5-6.

A detailed breakdown of the items included in each of the eight major groups listed in Table 5-6 is given in par. 6-6.1.

5-4.2 WEIGHT DATA

In order for the weight equation, Eq. 5-11, to be useful in the conceptual design, methods must be developed to estimate the total weight of each major weight group. This has been accomplished by taking "as built" weight data from existing wheeled amphibians, and separating the data into the major weight groups. These data were then related to vehicle characteristics and parameters which are known during the conceptual design stage. The resulting data are described in the paragraphs which follow.

5-4.2.1 Group A—Hull Structure

The hull weight was found to be most closely related to the parameter

$$\text{Hull Size Parameter} = \frac{LOA(BOA + D_{avg})}{100} \quad (5\text{-}12)$$

where

LOA = length overall, ft
BOA = breadth overall, ft
D_{avg} = average depth, ft

The average depth is defined as the projected vertical profile area of the hull and cab divided by the overall length. The weights of Group A for several wheeled amphibians are plotted against this parameter in Fig. 5-9. It should be noted that the LARC LX is steel while the rest of the amphibians included in Fig. 5-9 are aluminum.

TABLE 5-6 WHEELED AMPHIBIAN WEIGHT GROUPS

Major Group	*Description*
A	Hull Structure
B	Machinery
C	Drive Train
D	Marine Propulsor
E	Running Gear and Suspension
F	Miscellaneous Systems
M	Margin
L	Loads, including fuel, crew, and payload

5-4.2.2 Group B—Machinery

The weight of engines varies with the type, power, date of development, and intended use. Weight data on a number of engines that could be used in a wheeled amphibian are presented in Fig. 5-10. In addition to the engine proper, other items included in Group B are listed in par. 6-6.1. For wheeled amphibians these items amount to between 1.5 and 3.0 lb/BHP for liquid-cooled internal combustion engines, and between 0.5 and 1.0 lb/BHP for air-cooled internal combustion and gas turbine engines.

5-4.2.3 Group C—Drive Train

The weight of the drive trains of several wheeled amphibians is presented in Fig. 5-11 as a function of brake horsepower. With the exception of one point, these data all apply to mechanical drive trains. The exception, which is marked, applies to the estimated weight of a hydraulic drive train proposed for the Mobile Floating Assault Bridge-Ferry in 1961.

5-4.2.4 Group D—Marine Propulsor

The weight of the items in weight Group D totals between 2.0 lb/BHP (around 300 BHP) to about 1.5 lb/BHP (around 600 BHP) for existing amphibians. These weights apply to systems using propellers in tunnels with Kort nozzles. Values in this weight group will depend greatly on the propeller diameter, rpm, length of

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shafting, and type of propulsor. The use of a right angle drive system on a conventional wheeled amphibian would increase the weight of Group D to about 3.0 lb/BHP. The use of waterjets would result in a Group D weight of about 3.5 lb/BHP, including the weight of water in the pump and ducting. Of course, the weights of the right angle drive and waterjet propulsor will also depend greatly on the detail characteristics of the system.

5-4.2.5 Group E—Running Gear and Suspension System

The weights of the running gear and suspension systems of several wheeled amphibians are presented in Fig. 5-12 as a function of gross vehicle weight. The LARC series of amphibians does not have sprung suspensions but depends instead on the flexibility of the tires for spring action. The

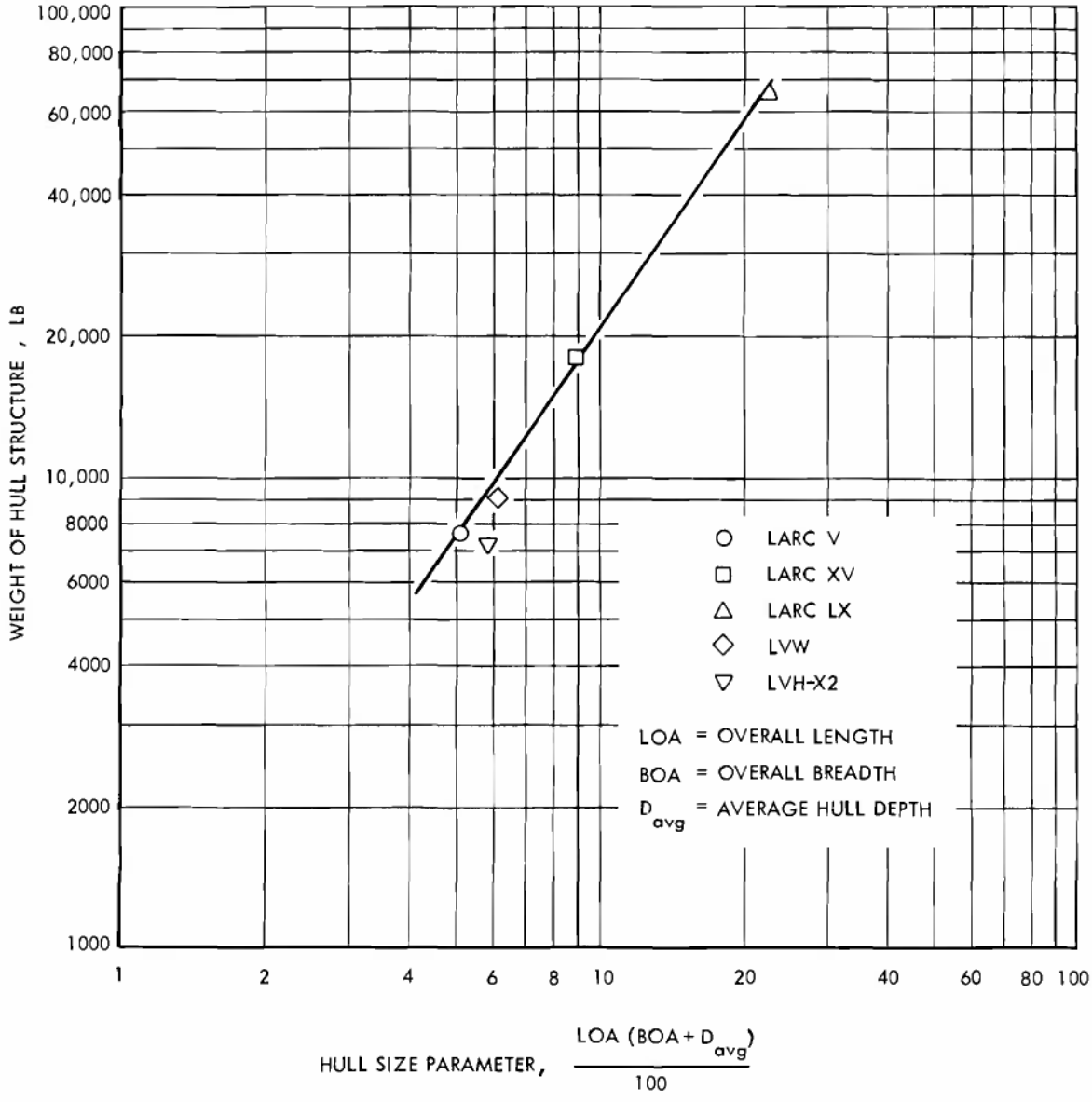

Figure 5-9. Weight Group A—Hull Structure

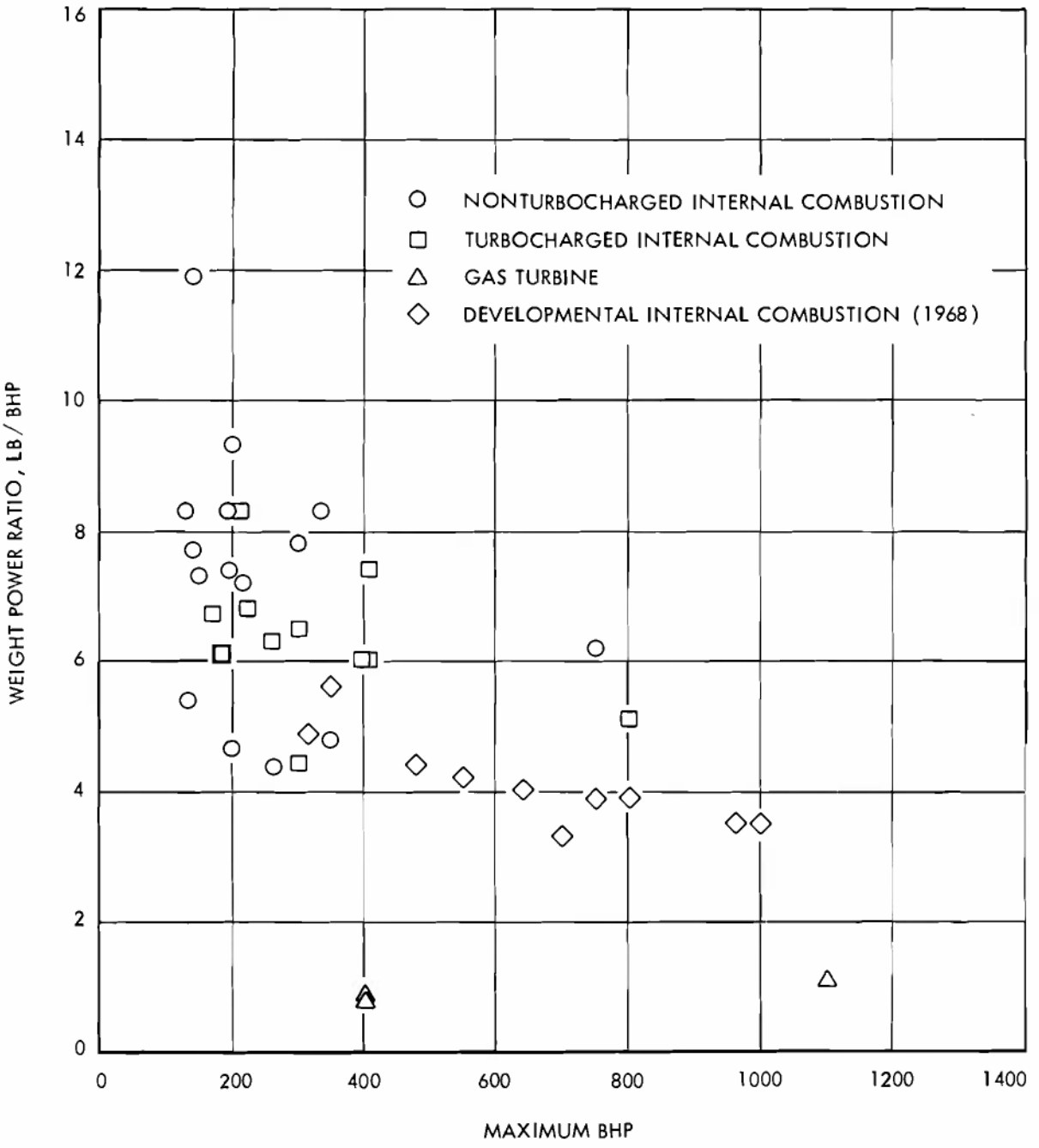

Figure 5-10. Specific Engine Weights for Multi-fuel or Diesel Engines

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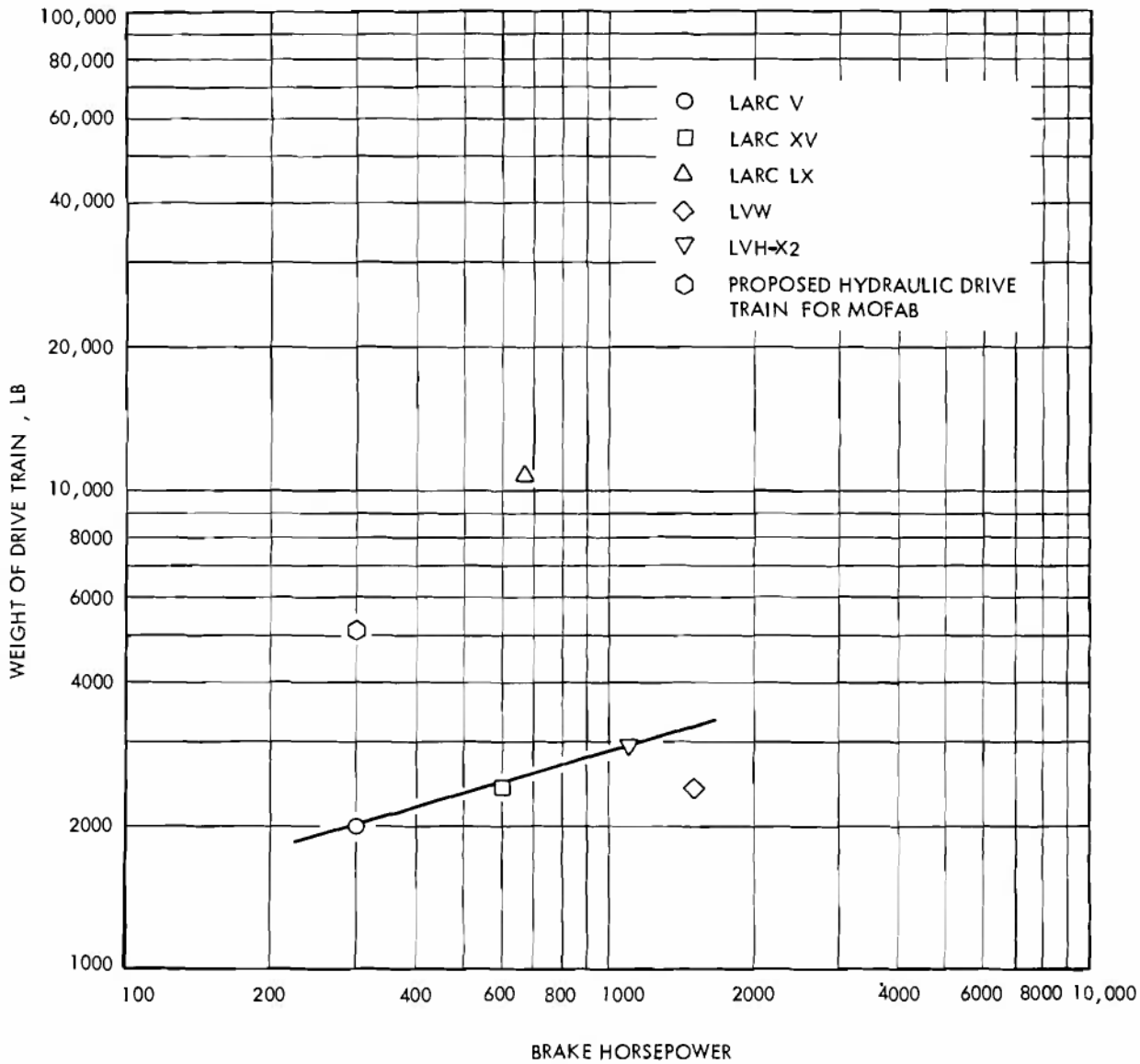

Figure 5-11. Weight Group C—Drive Train

LVW and LVH-X2 have wheel retraction systems built with very lightweight components.

5-4.2.6 Group F—Miscellaneous Systems

The weights of the miscellaneous systems are presented in Fig. 5-13 as a function of the vehicle empty weight. The LVW is equipped with a very complex hydraulic system which results in a high weight for Group F relative to the other wheeled amphibian data shown in Fig. 5-13.

5-4.2.7 Group M—Margins

The subject of weight margins is covered in par. 5-4.4.

5-4.2.8 Group L—Loads

The loads a wheeled amphibian is to carry are determined by the input requirements and machinery type. As a result loads can be calculated directly during the conceptual design studies.

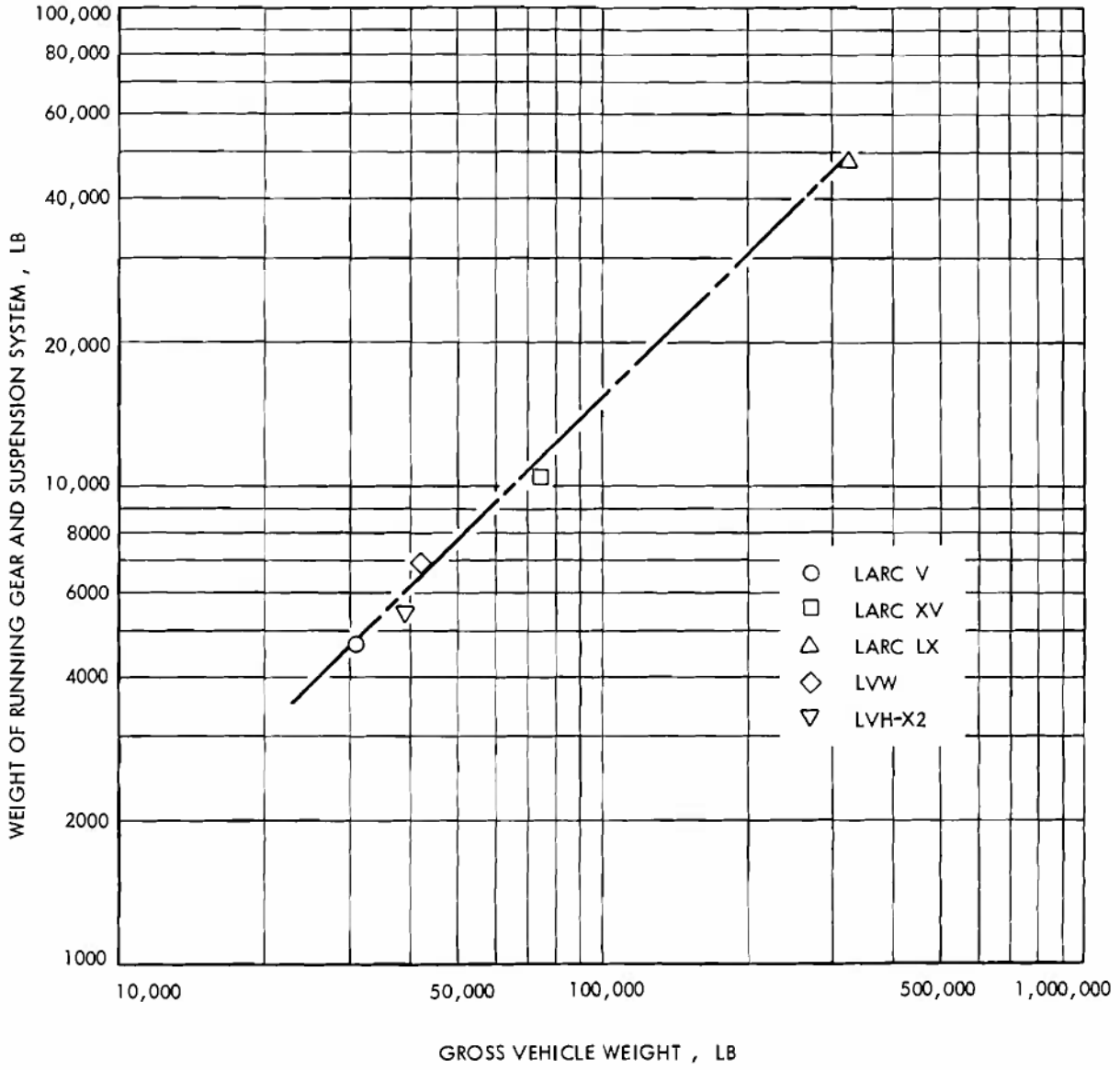

Figure 5-12. Weight Group E—Running Gear and Suspension System

5-4.3 CENTER OF GRAVITY LOCATIONS

In addition to an estimate of the gross vehicle weight, the longitudinal and vertical coordinates of the center of gravity must be determined so that the stability and trim may be calculated. This is best accomplished by estimating the center of gravity of each of the major weight groups and combining them to obtain the center of gravity of the complete amphibian.

From a simple arrangement sketch prepared during the conceptual design study, it is possible to make a good estimate of the longitudinal and vertical centers of Groups B—Machinery, C—Drive Train, D—Marine Propulsor, E—Running Gear and Suspension, and L—Loads. Data are presented in Figs. 5-14 and 5-15 on the center of gravity locations for Groups A—Hull and F—Miscellaneous Systems. In the calculation of the vertical center of gravity of the cargo, loaded CONEX containers have been assumed to have a CG height of 40 in. above the cargo deck.

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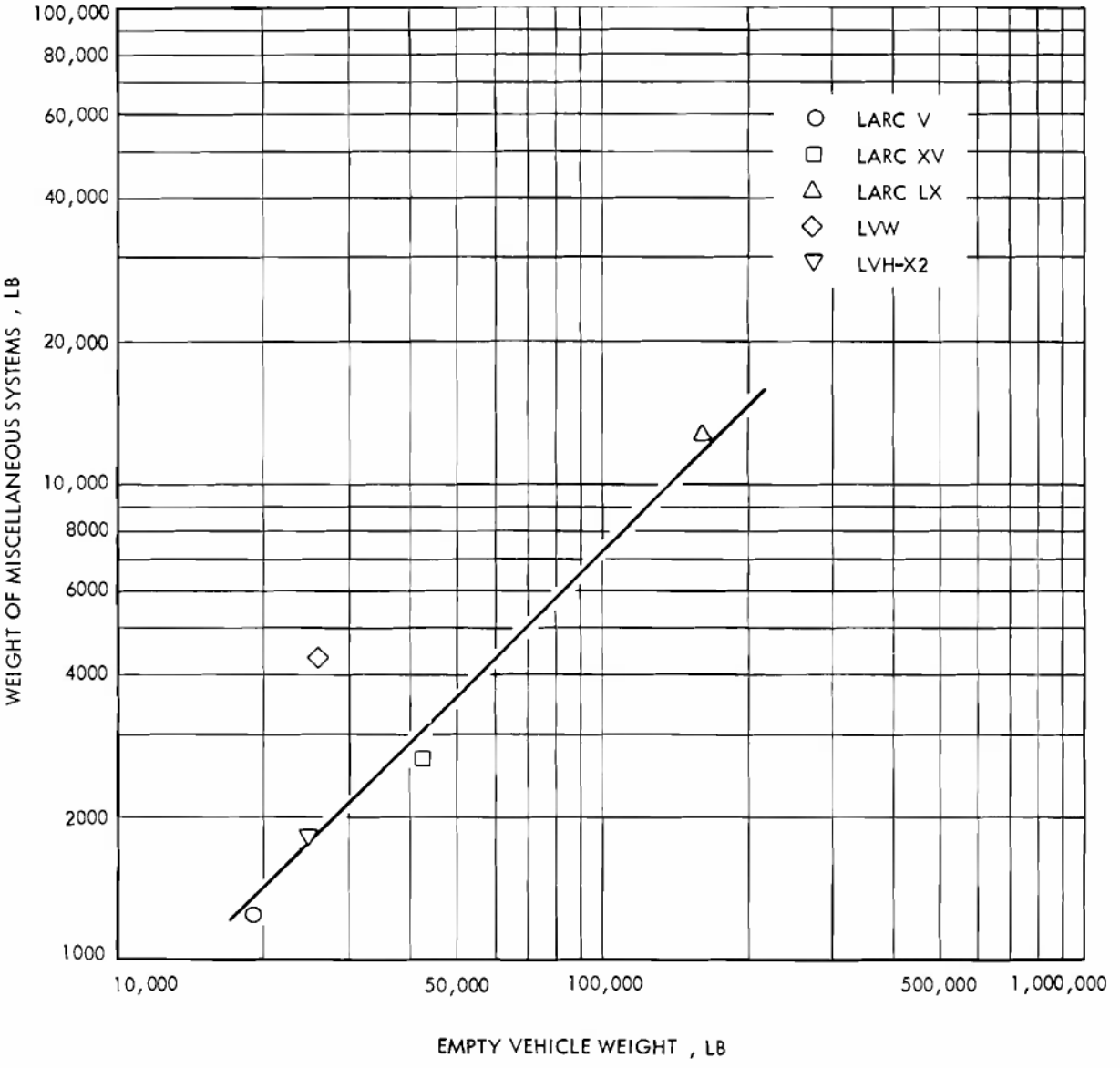
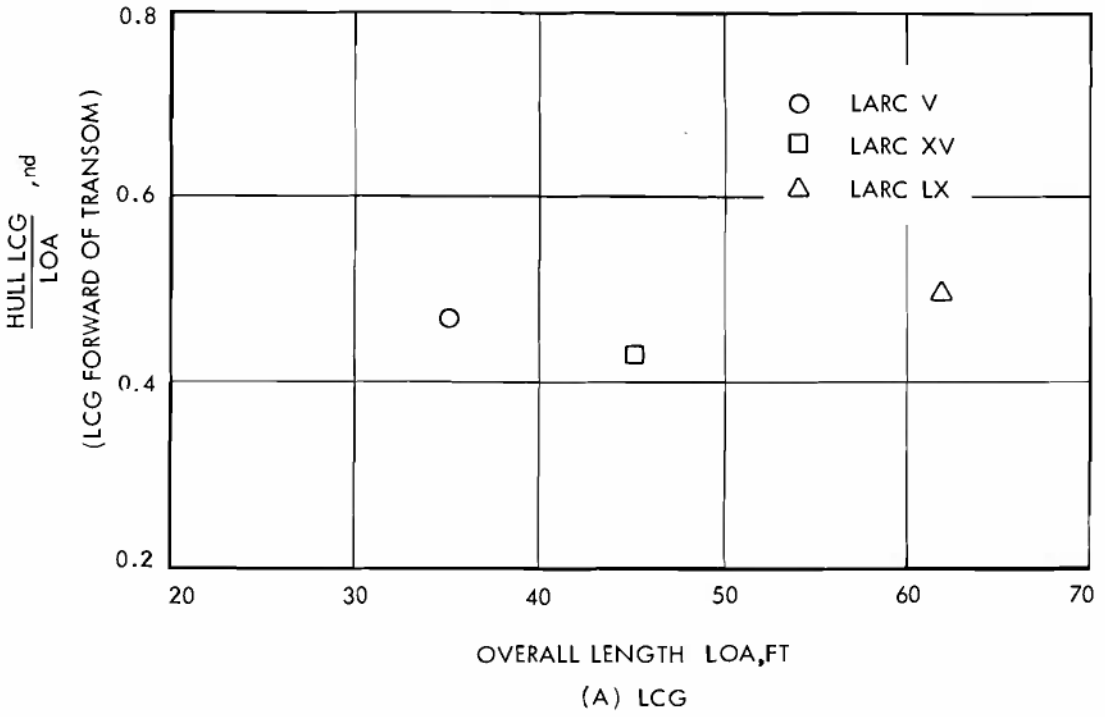


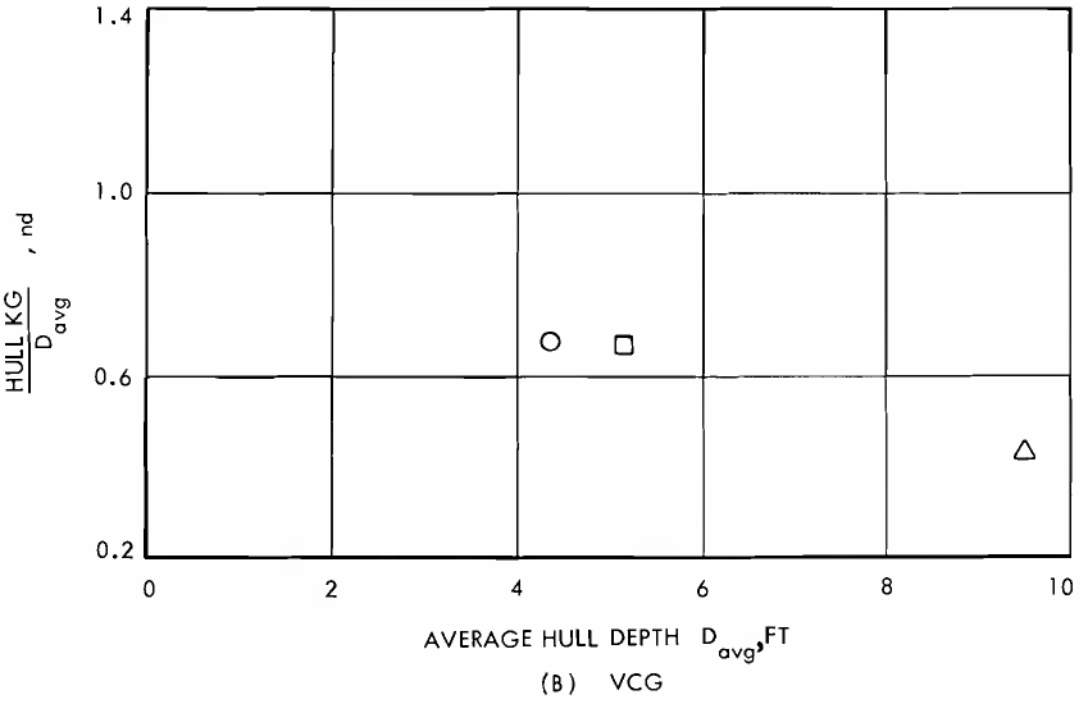
Figure 5-13. Weight Group F—Miscellaneous Systems

5-4.4 MARGINS

Margins are generally added to estimated empty vehicle weight and empty vehicle vertical center of gravity to account for items that are overlooked or underestimated. For a conventional wheeled amphibian on which the conceptual design estimates are based on reliable "as built" data from similar vehicles, these margins can be small. Values on the order of 3 to 5 percent on the empty weight and vertical center of gravity would be reasonable. In the event that components are to be used for which "as built" weight (of identical or similar items) are not available, a larger margin should be added to the appropriate weight groups. In this case the margin should be on the order of 5 to 10 percent of estimated weight of the component. It should be noted that conceptual designs in which weight estimates are based on past designs have some small built-in margin due to advancing technology. This tends to support

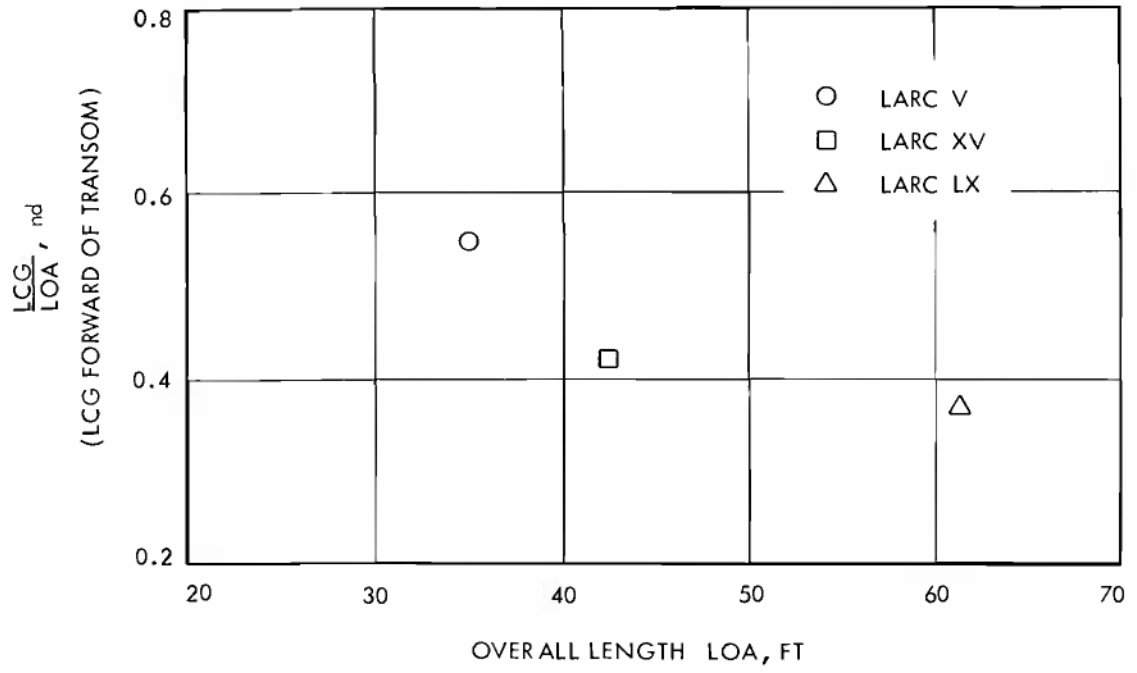


(A) LCG

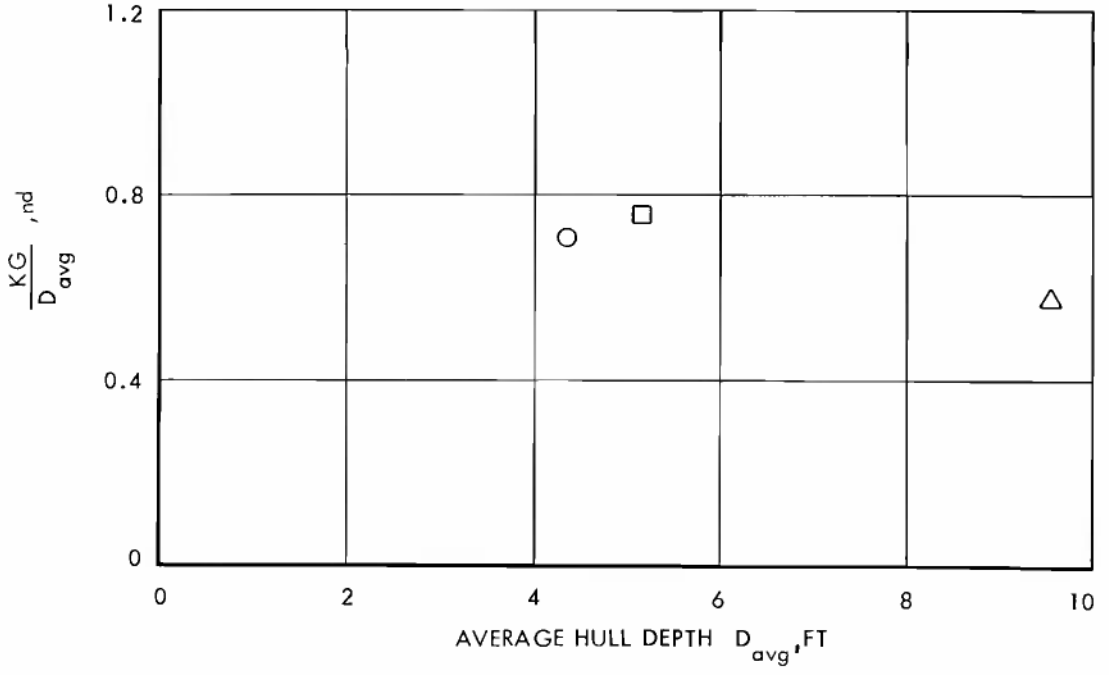


(B) VCG

Figure 5-14. Weight Group A—CG Locations



(A) LCG



(B) VCG

Figure 5-15. Weight Group F—CG Locations

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the use of small margins during the conceptual designs.

The use of a large or small margin depends to some extent on the design policy and goals. If initial cost is most important, a large margin should be used and if performance is more important, a low margin should be used in association with minimum weight. Design policies or goals of this type should be clearly defined so that in the preliminary and detail design phases, for example, lightweight components are used in spite of higher cost when performance is controlling.

5-5 PERFORMANCE AND POWERING

During the conceptual design phase an estimate of the power required or performance will be made, using the estimated vehicle weight and characteristics. At this stage in the design there is not enough information or time to conduct model tests and detailed propulsor calculations to arrive at an estimate of performance or power required. Accordingly, data from previous designs must be used.

5-5.1 BASIC CONCEPTS

In a true wheeled amphibian the power required to obtain the necessary water speed will almost always be greater than that needed to meet any of the land performance requirements. As a result, during the conceptual design the power required is selected on the basis of waterborne performance unless some very unusual land performance requirement is given. However, the land performance, and especially off-road mobility, affects the geometry of the hull and the size and arrangement of the running gear. This in turn affects the power required to meet the waterborne performance. Thus, consideration during conceptual design must also be given to those aspects of land performance involving mobility.

5-5.2 HULL AND APPENDAGE RESISTANCE

The first step in determining the power required is to estimate the resistance of the amphibian at the design speed and condition. The fundamental principles involved in wheeled amphibian resistance and data on past designs are presented in pars. 7-4.1 through 7-4.1.3. This material should be reviewed and understood before any attempt is made to calculate resistance for a conceptual design.

The procedure available for the calculation of resistance is the selection of the appropriate drag coefficient from Figs. 7-55 and 7-56. The drag coefficient for the faired hull shape can be obtained from Fig. 7-55, and the drag coefficient for the wheels and wheel wells can be obtained from Fig. 7-56. In this way it is possible to account for combinations of hull forms and running gear sizes, and arrangements that have not been tested. The resistance is then given by

$$R_T = \tfrac{1}{2}\rho V^2 \left(C_{D_H} A_H + C_{D_w} A_w\right), \text{ lb} \qquad (5\text{-}13)$$

where

R_T = total resistance, lb
ρ = mass density of water, slug/ft^3
V = forward speed, ft/sec
C_{D_H} = drag coefficient of faired hull, nd
A_H = projected frontal area of faired hull, ft^2
C_{D_w} = drag coefficient of wheels and wheel wells, nd
A_w = exposed frontal area of wheels, ft^2

In the event that the design speed point is not in calm water, the procedures and data presented in par. 7-4.1.2.4 may be used to estimate the added resistance.

5-5.3 PROPULSOR AND POWER REQUIRED

The brake horsepower required by a wheeled amphibian is defined by

$$BHP = \frac{DHP}{\eta_T} + HP_A, \text{ hp} \qquad (5\text{-}14)$$

where

BHP = brake horsepower of the engine, hp
DHP = delivered horsepower to the propulsor, hp
η_T = transmission efficiency between engine and propulsor, nd
HP_A = horsepower required by auxiliary systems, hp

The fundamental principles involved in the calculation of the delivered horsepower to the propulsor are presented in pars. 7-7 through 7-7.6.4. These paragraphs should be reviewed before an estimate of DHP is made for a

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coneeptual design. In the event that the amphibian is propelled with a serew propeller, the procedure whieh follows may bc used to obtain a preliminary estimate of the required delivered horsepower.

In order to make a preliminary estimate of *DHP*, the power required by the propulsor to achieve the desired design speed, the dcsigner must obtain appropriate values of:

a. Drag R_T and effective horsepower *EHP* at the design speed V_D

b. Thrust deduction t and wake fraetion w

e. Relative rotative efficiency η_r and the propeller diameter D

Fig. 5-16 is a nomograph which may be used to make a quick estimate of propeller opcn water efficieney η_o which is needed to find the necessary delivered horsepower *DHP*. This nomograph is based on the assumption that the propeller efficiency is 80 percent of the ideal efficieney η_i predicted by simple momentum theory (see par. 7-7.4.1). The 80-percent assumption reprcsents thc state-of-the-art in marine screw propeller design for carefully designed "optimum" propellers. Thus, the efficiency found from the nomograph will almost always be on the high, i.e., optimistic, side. It is suggested that the nomograph value be decreased by 3 or 4 percentage points to obtain a more realistic valuc of propeller efficiency for amphibians. Use of the nomograph will bc illustrated by the following example problem using data for a model LARC V from Table 7-35.

Example

Given:

V_D	= 9 mph	η_r	= 0.955
D	= 2.5 ft	*EHP*	= 70 hp
$(1-t)$	= 0.647	R_T	= 2901 lb
$(1-w)$	= 0.748		

Eq. 7-82:

$$V_a = V_D\ (1 - w)1.47 =$$
$$9(0.748)1.47 = 9.9\ \text{ft/sec}$$

Eq. 7-83:

$$T = R_T/(1 - t) = \frac{2901}{0.647} = 4500\ \text{lb}$$

A line is drawn between the values of V_a and D on the appropriate seales. A second line is drawn between point "A" and the value of T on the thrust seale. The value of η_o = 0.38 is read (eompared to 0.33 from model tests). If this value is reduced by 0.04, as previously suggested to arrive at a more realistic value, the rcquired horsepower may be calculated (Eqs. 7-54 and 7-96)

$$DHP = \frac{EHP\,(1 - w)}{\eta_o \eta_r (1 - t)} = \frac{70(0.748)}{0.34(0.955)0.647} = 250\ \text{hp}$$

In the event that a propulsor other than a screw propeller is selected, an estimate of thc *DHP* may be developed from the information in pars. 7-7 through 7-7.6.4.

The transmission effieiency depends on the type of transmission, the arrangement of the drive train, and the numbcr of gcar reductions if the system is meehanical. For existing wheelcd amphibians, the approximate transmission effieiency of the marine drive ranges between 90 and 95 pereent. This assumes that any torquc eonverters in the drive train are mechanically loeked during waterborne operation.

Auxiliary system requiremcnts include the power which must be supplied by the engine to run electrical, hydraulic, and cooling systems. Under normal waterborne operating conditions, this load varies between 7 and 15 hp for thc LARC amphibians, assuming the bilge pumps are not operating. In waterborne operation the eooling loads are low on the LARC amphibian since they are all fitted with sea water coolers which have no fan load. If an air-cooled internal combustion engine is installed, thc cooling load may be as high as 10 to 12 percent of the gross enginc brake horscpower.

5-5.4 LAND PERFORMANCE

To develop arrangement sketches and waterborne performance estimates during the eonceptual design phase, information on the size and arrangement of the running gear and suspension systems must be developed. These items are a function of the land performanee and, in particular, the mobility required. A number of measures of mobility now in usc are discussed in par. 7-8 with the values which apply to wheeled amphibians. The calculation of thesc mobility measures is too tedious to carry out

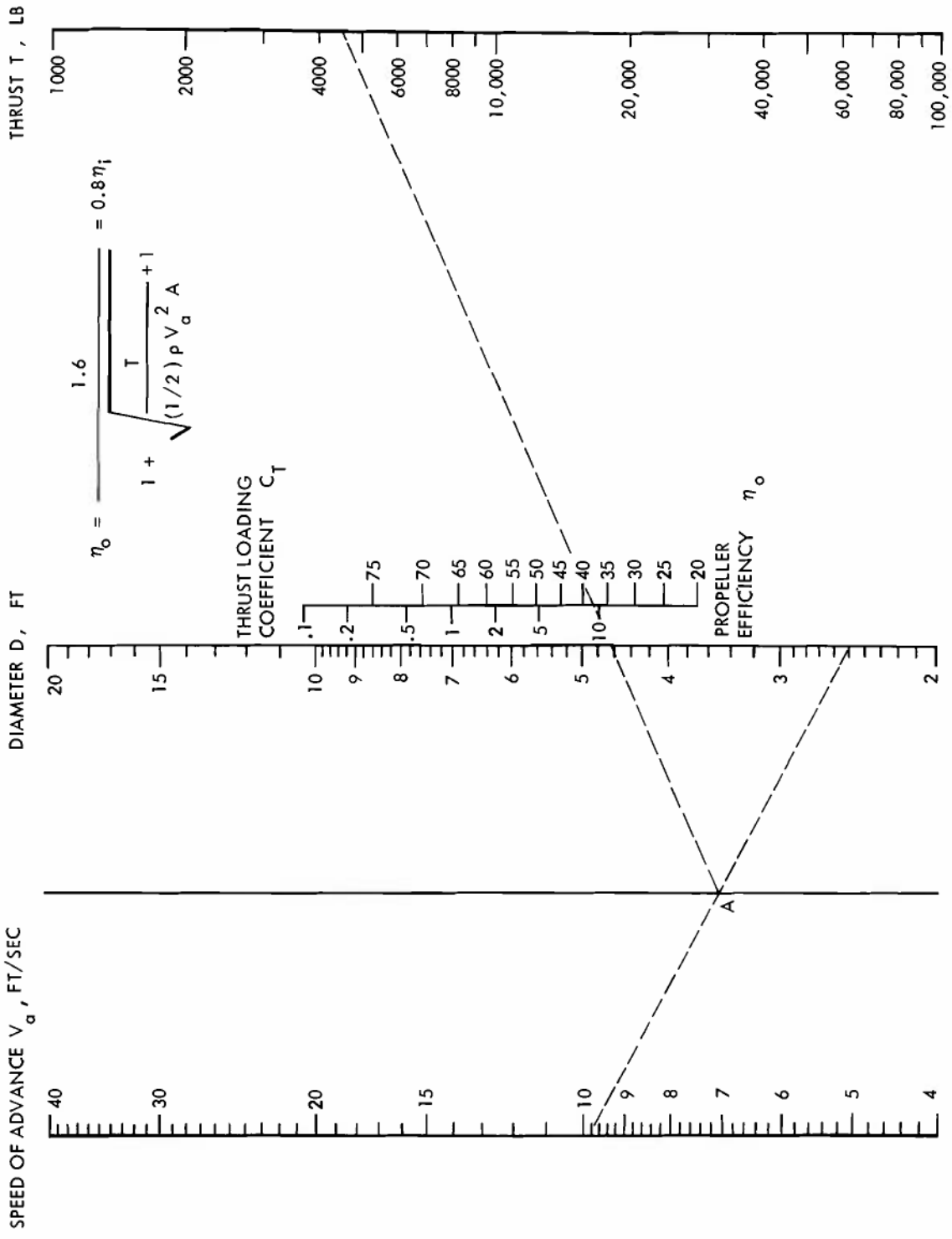

Figure 5-16. Nomograph for Estimating Propeller Efficiency η_o

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during the conceptual design iteration process. However, all of these measures are functions which improve as ground pressures are reduced. As a result, it is reasonable to use some measure of ground pressure during the conceptual design to make a preliminary estimate of required tire size. The nominal unit ground pressure and ATAC ground pressure for several wheeled amphibians are presented in Table 5-7.

The ability to cross obstacles is a function of the vehicle geometry and power. Among the most important geometric characteristics for this purpose are the approach, break and departure angles, and the ground clearance. The values of these quantities which have been used on several wheeled amphibians are also given in Table 5-7.

5-6 EXAMPLE CALCULATIONS

In order to illustrate some of the conceptual design procedures and the use of some of the data presented in pars. 5-3 through 5-5.4, an example of a conceptual design calculation is presented. The input conditions were chosen for the purpose of illustration only and do not necessarily reflect current requirements or hardware.

Input:
- Conventional Wheeled Amphibian
- 10-mph full load in calm water
- 10-ton payload *VCG* = 40 in. (Wet Deck)
- Area 265 ft^2, Ramp for unloading
- Endurance = 8 hr at full power
- Mobility, *NUGP* 10 - 11 psi target for concept design
- Engine - New class of vehicle gas turbine - 1.5 lb/*BHP* 30 *BHP*/ft^2, and 8 *BHP*/ft^3
- Fuel Rate = 0.40 lb/*BHP*-hr

1. Initial Assumptions
   a. Conventional aluminum hull structure

TABLE 5-7 WHEELED AMPHIBIAN LAND MOBILITY

Vehicle	*Approach Angle, deg*	*Break Angle, deg*	*Departure Angle, deg*	*Ground Clearance, in.*		*Nominal Unit* Ground Pressure NUGP,psi*	*ATAC** Ground Pressure p_{av}, psi*
				Hull	*Prop*		
DUKW	35	17	28	17	—	13.1	18.8
LARC V	27	15	20.7	24	16	14.1	20.1
LARC XV	30.5	13.5	22.5	29¼	16½	15.0	21.4
LARC LX	28	14	29	28	—	36.0	51.5
LVW	25	13.5	25	28	—	20.6	29.4
LVH X2	50	15	28	30	—	18.3	26.1

* $NUGP = \frac{W}{rb}$

** $p_{av} = \frac{W}{0.7\,rb}$

where

W = average load per tire, lb
r = undeflected tire radius, in.
b = tire width, in. (see par. 7-8.4.4)

b. Unsprung suspension, 4 X 4 arrangement of running gear
c. Propulsion—propeller in tunnel
d. Mechanical transmission and drive train

2. Initial Dimensions—
LOA = 40 ft
BOA = 12 ft (overall)

Estimate	Payload/GVW = 0.35
Estimate	GVW = 57,000 lb = Δ
LCB Loaded	18 ft fwd transom

3. Preliminary Tire Size—
Loaded per wheel = 14,250 lb
Tire 27 X 33 in., $NUGP$ = 10.9 psi
Tire Diameter = 87.5 in., width = 30 in.

4. Assume $LWL \approx 36$ ft (at WL),
B = 11.5 ft (at WL),
C_B = 0.70

$$\text{Mean draft } H_m = \frac{GVW}{(LWL)B\,C_B\,\rho g}$$

$$= \frac{57{,}000}{36(11.5)0.70(64.4)} = 3.05 \text{ ft}$$

Speed-length ratio,

$$\frac{V_K}{\sqrt{L}} = \frac{10}{\sqrt{36}}\left(\frac{5{,}280}{6{,}080}\right) = 1.45$$

Note: V_K is speed in knots.

$C_{D_H} = 0.47$, $C_{D_w} = 0.40$
(from Figs. 7-55 and 7-56)

5. Hull Area = Beam X Draft
= 11.5 X 3.05 = 35 ft^2 = A_H

6. Appendage Area = Radius X Width

$$= \frac{43 \times 30}{144}(4) = 35.8 \text{ ft}^2 = A_w$$

V = 10 mph = 14.7 ft/sec

$$R_T = \tfrac{1}{2}\rho V^2 (C_{D_H} A_H + C_{D_w} A_w)$$

$$= 0.99\,(14.7)^2\,[(0.47\,(35) + 0.40\,(35.8)]$$

$$= 6{,}550 \text{ lb}$$

$$EHP = R_T V/550 = \frac{6{,}550 \times 14.7}{550} = 175 \text{ hp}$$

7. Single Propeller in Kort Nozzle
Propeller Diameter 3.0 ft
$1-t$ = 1.08;
$1-w$ = 1.16;
η_r = 0.93(from Table 7-35)

$$T = \frac{R_T}{1-t} = \frac{6{,}550}{1.08} = 6{,}060 \text{ lb}$$

η_o = 50 percent (from Fig. 5-16)

η_o for amphibian $\approx$ 46 percent

$$DHP = \frac{EHP\,(1-w)}{\eta_o \eta_r\,(1-t)}$$

$$= \frac{175(1.16)}{(0.46)0.90(1.08)} = 440 \text{ hp}$$

8. Assume η_T = 0.95 and Auxiliary Loads = 10 BHP

$$\therefore BHP = \frac{DHP}{\eta_T} + HP_A = \frac{440}{0.95} + 10 = 475 \text{ hp}$$

9. Hull Depth

D 'midship = Freeboard + Draft
Freeboard = 0.40 X H_m = 0.4(3.05) (Table 5-4)
= 1.2 ft

D 'midship = 1.2 + 3.05 = 4.25 ft
Freeboard Fore and Aft = 3.0 (midship freeboard)
= 3.0(1.2) (Table 5-4)

= 3.6 ft
Depth Fore and Aft = 6.65 ft

10. Length of Cargo Deck

$$= \frac{\text{Area}}{\text{Beam}} = \frac{265}{12} = 22 \text{ ft}$$

11. A simple sketch of the vehicle profile should now be made for use in making LCG and KG estimates for the weight groups.

12. Weight Estimate
a. Group A—Hull
LOA = 40 ft, BOA = 12 ft, D_{avg} = 5.3 ft

$$\frac{LOA(BOA + D_{avg})}{100} = \frac{40(12 + 5.3)}{100} = 6.9$$

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W_A = 12,000 lb (from Fig. 5-9)
KG = 3.40 ft
LCG = 18.8 ft fwd transom (from Fig. 5-14)

b. Group B—Machinery
Specific Weight = 2.25 lb/*BHP*
W_B = 2.25(475) = 1,070 lb
KG = 3.5 ft
LCG = 31 ft fwd transom

c. Group C—Drive Train
W_C = 2,300 lb (from Fig. 5-11)
KG = 2.0 ft
LCG = 18.0 ft

d. Group D—Marine Propulsor
Specific Weight = 1.75 lb/hp
W_D = 1.75(475) = 830 lb
KG = 1.0 ft
LCG = 5.5 ft

e. Group E—Running Gear and Suspension
To obtain a lower *NUGP* than on existing amphibians, this design has proportionately larger tires. As a result, the weight of Group E will be proportionately larger. For the LARC V and LARC XV the tires amount to about 6 percent of the gross vehicle weight. A weight estimate for the preliminary tires for this design indicates a weight of about 9 percent of the current estimate of gross vehicle weight. Therefore, to account for the larger tires and rims the weight of Group E indicated in Fig. 5-12 should be increased by 4 percent of the gross vehicle weight.

$\therefore W_E$ = 8,500 + 0.04(57,000) = 10,800 lb
KG = 0.0 ft
LCG = 18.0 ft

f. Group F—Miscellaneous Systems
Fig. 5-13 indicates the weight of Group F will be about 7.5 percent of the empty weight.

$$\text{Empty weight} \approx \frac{W_A + W_B + W_C + W_D + W_E}{1.0 - (0.0075 + 0.03)^*}$$

$$\approx \frac{12{,}000 + 1070 + 2300 + 830 + 10{,}800}{0.895} = \frac{27{,}000}{0.895}$$

$$\approx 30{,}200 \text{ lb}$$

**Note:* the denominator accounts for W_F and W_M in the empty weight.

$\therefore W_F$ = 30,200 (0.075) = 2,260 lb
KG = 4.0 ft
LCG = 22.0 ft (Fig. 5-15)

g. Group M—Margins
For this design use a margin of 3 percent of the empty weight.
W_M = 30,200 − (27,000 + 2,260)
= 940 lb
KG = 0.25 ft (added to computed KG) Margin

h. Group L—Loads
(1) Payload = 20,000 lb
KG = 7.6 ft (40 in. above cargo deck)
LCG = 18 ft
(2) Crew = 500 lb
KG = 7.0 ft
LCG = 35 ft
(3) Fuel
Rate = 0.4(475) = 190 lb/hr
Endur. = 8 hr
T. Pipe Factor = 0.97 (for fuel in tank below suction inlet)
Weight = 190(8)/0.97 = 1,570 lb
KG = 2.5 ft
LCG = 14 ft

Referring to the Weight and Center Summary following, the calculated weight is about 4000 lb less than the current estimate of 57,000 lb. At this point the iteration should be repeated starting with a new estimate of waterline length, beam, and calculated draft using an estimated gross vehicle weight of between 51,000 and 52,000 lb

For the purposes of this example it is assumed that the iteration has converged with the following characteristics:

LOA = 40 ft
BOA = 12 ft
LWL = 38 ft
B = 11.5 ft
BHP = 450 hp
H_m = 2.56 ft
Δ = 51,000 lb
LCG = 18.4 ft
KG = 3.9 ft

At this point a check of the waterborne stability and trim should be made.

Stability Estimate
$KB = 0.50H_m$
$KB = 0.50(2.56) = 1.28$ ft

WEIGHT AND CENTER SUMMARY

Group	*Weight, lb*	*KG, ft*	*Vertical Mom., ft-lb*	*LCG, ft*	*Horizontal Mom., ft-lb*
A	12,000	3.4	40,800	18.8	225,600
B	1,070	3.5	3,750	31.0	33,170
C	2,300	2.0	4,600	18.0	41,400
D	830	1.0	830	5.5	4,560
E	10,800	0.0	0	18.0	194,400
F	2,260	4.0	9,040	22.0	49,700
Subtotal	29,260	2.02*	59,020	18.7*	548,830
M	940	0.25	—	0.0	—
Empty Vehicle	30,200	2.27	68,500*	18.7	565,000*
Payload	20,000	7.6	152,000	18.0	360.000
Crew	500	7.0	3,500	35.0	17,500
Fuel	1,570	2.5	3,920	14.0	22,000
Gross Vehicle	52,270	4.35*	227,920	18.4*	964,500

* Computed from relation between weights and moments, e.g., 59,020/29,260 = 2.02 (see Eq. 6-1).

$\nabla = \Delta/(\rho g) = 51{,}000/64.4 = 790 \text{ ft}^3$

$I = C_{I_T} B^3 (LWL)$

$C_{I_T} = 0.060$ (Table 5-3)

$I = 0.060(11.5)^3 38.0$

$= 3{,}460 \text{ ft}^4$

$BM = \frac{I}{\nabla} = \frac{3{,}460}{790} = 4.38 \text{ ft}$

$GM = KB + BM - KG$ (Eq. 5-5)

$= 1.28 + 4.38 - 3.9$

$= 1.76 \text{ ft}$

Based on the data in par. 7-1.6.2 this is about the minimum acceptable value of *GM*.

Trim Estimate

$LCB = 0.495 LWL$ (Table 5-5)

$LCB = 18.8 \text{ ft}$

$GM_\ell \approx BM_\ell = \frac{11.5(38)^3}{12(790)}$ (Eq. 7-28)

$\approx 66 \text{ ft}$

$MT1 = \frac{\Delta GM_\ell}{12LWL}$ (Eq. 7-29)

$= \frac{51{,}000(66)}{12(38)}$

$= 7{,}380 \text{ ft-lb}$

$\text{Trim} = \Delta (LCB - LCG)/MT1$ (Eq. 5-9)

$= \frac{51{,}000(18.8 - 18.4)}{7{,}380}$

$= 2.8 \text{ in. by stern}$

This is a reasonable trim for a wheeled amphibian.

At this point a three view sketch of the wheeled amphibian should be prepared and used to check the feasibility of the assumed arrangement. A sketch of the type is shown in Fig. 5-17. The iteration loop can now be repeated as required.

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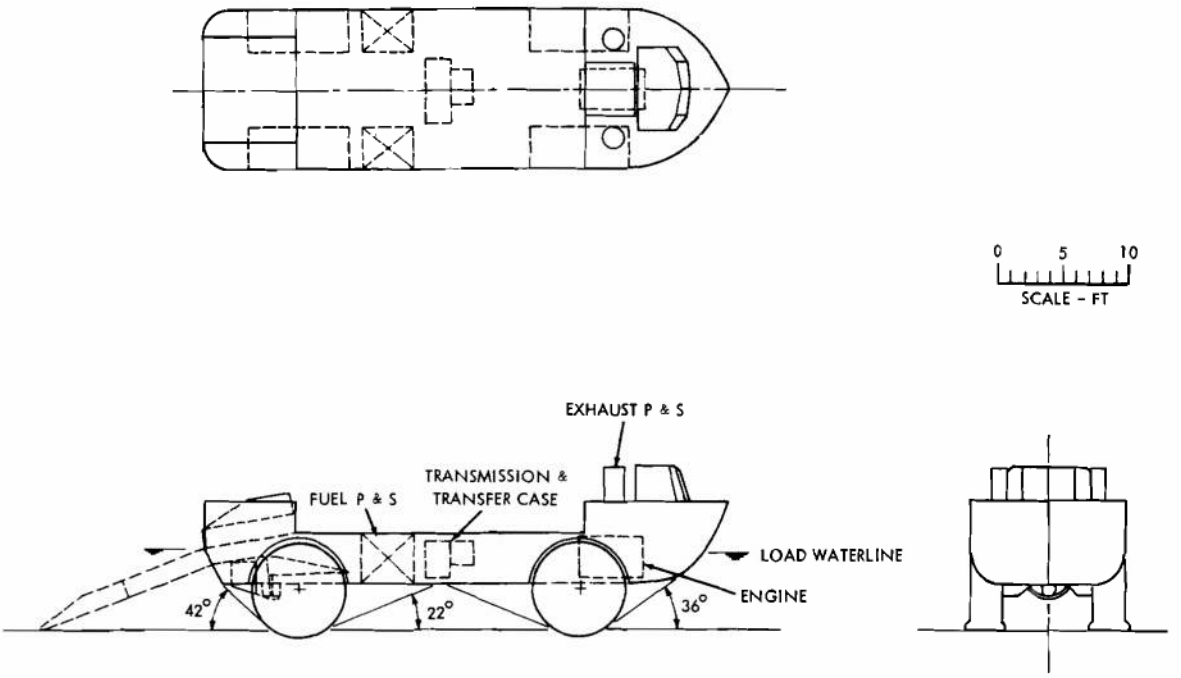

Figure 5-17. Concept Design Sketch

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CHAPTER 6 PRELIMINARY DESIGN

6-1 OBJECTIVE

6-1.1 BASIC PURPOSE

The basic purpose of the preliminary design phase in the development of a wheeled amphibian is to confirm the characteristics developed in the conceptual design and define the major components. This must be carried out to the extent that enough information is made available to complete the final design and working plans.

In addition to leading directly to a final design, the preliminary design may have several other purposes—similar to those presented in par. 5-1.1 for the conceptual design—including trade-off or optimization studies, large scale system analysis or effectiveness studies, "what if" studies, and the development of specifications for procurement. The preliminary design phase is used for these purposes only when the conceptual design phase cannot be expected to yield information in sufficient detail or with a high enough confidence level. This will generally occur when the design specifications or requirements call for a radical increase in performance or a radical change from past practice.

6-1.2 RELATION TO THE DESIGN CYCLE

The preliminary design phase serves as a transition between the conceptual and final design phases. In the preliminary design the major components are designed or selected and arranged. This procedure confirms that the characteristics and performance developed in the conceptual design can be achieved with practical hardware. The preliminary design phase, therefore, must demonstrate the final technical feasibility of the design and identify technical problem areas as well as requirements for the development of special components. If, during the preliminary design phases, the feasibility is shown to be marginal or many technical problems appear; the design cannot continue to the final phase without considerable risk of failure. At the completion of the preliminary design phase, the amphibian should be sufficiently well defined so that the final design and plans can be developed with routine design procedures.

6-2 PROCEDURE

The preliminary design of a wheeled amphibian is an iterative process. Assumptions and estimates made early in the design phase are later checked and, if found in error, revised until the cycle converges. In this respect the preliminary design phase is similar to the conceptual design phase. However, the assumptions and estimates made during the early part of the preliminary design are based on the conceptual design and as a result should be much better than their counterparts made during the conceptual design. This should reduce the number of times the iteration cycle must be repeated.

6-2.1 TYPICAL INPUTS AND OUTPUTS

The inputs to the preliminary design phase consist of the results of the conceptual design phase (i.e., parametric studies, trade-off studies, and estimated vehicle characteristics), the final requirements or specifications (e.g., a QMR or SDR), and any other goals or constraints on the design. It is expected that, by this stage in the design development, interactions between the conceptual design and the preliminary requirements will have eliminated impractical and conflicting final requirements.

The outputs of a formal preliminary design phase include a design summary, preliminary plans, the design calculations, and a design history. The design summary should include a tabulation of the design characteristics and a description of any special features included in the design. Typical plans or drawings that should be developed during preliminary design are listed in Table 6-1. The design calculations and design history present the background data, design methods, and decisions made during the preliminary design. This information will be of great value during the detailed design and in the development of future designs.

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TABLE 6-1 TYPICAL PRELIMINARY DESIGN PLANS

Plan	*Comments*
General Arrangement Plans, Profiles, and Sections	These drawings will show the location and arrangements of all major components in the amphibian
Hull Lines	See par. 6-4.6
Structural Arrangements	These drawings should show the arrangement and scantlings typical of basic structure.
Schematic System Layouts	These drawings should show the layout of the control (including steering), hydraulic, electrical, cooling, and any other systems which have primary importance to the amphibian.
Arrangements or Layouts of Specially Designed Components	These drawings should show the preliminary arrangement or layout of any components that must be specially designed.

6-2.2 PRELIMINARY DESIGN ITERATION CYCLE

The iteration cycles for preliminary and conceptual design processes are similar (par. 5-2.2) in that both involve the systematic variation of characteristics until the requirements are satisfied.

The steps in the preliminary design iteration cycle are given in Fig. 6-1 in the form of a flow chart. This flow chart is somewhat of an idealization in that it indicates that the various steps directly follow one another. In general, the press of time and efficient use of manpower will require that several of the steps be conducted concurrently. This implies that effective communications must exist among the members of the design team so that all of the parts "fit" at the end of the cycle.

At the end of the cycle a check will be made against the requirements, goals, and the assumptions on which the preliminary design was based. If these are not satisfied, the iteration cycle must be repeated. Use is made of the data generated in previous cycles to make the process converge. Due to time considerations, it will probably not be possible to conduct more than one set of model tests in spite of the need for several passes through the iteration cycle. However, with the correct choice of test conditions and use of scaling laws, acceptable estimates can still be made (see par. 7-4).

The remaining paragraphs of this chapter cover the topics indicated on the flow chart in Fig. 6-1 as they apply to the preliminary design phase. In some cases the discussions present the general ideas as they apply to preliminary design with the technical details left to referenced paragraphs in Chapter 7. When all of the requirements, goals, and assumptions are satisfied, the design summary and history are prepared.

6-3 PROPULSION SYSTEM DEVELOPMENT

For the purpose of preliminary design, the items considered in the propulsion system include engines, drive train, running gear, and the marine propulsor. For practical purposes, both the technical and economic feasibility of an amphibian design depend on the availability of these components or the ability to design and produce them. As a result, during the preliminary design, suitable candidate components must be selected or a preliminary design for them prepared. The decision to use an existing component or to design a special one depends on considerations of performance, economics, reliability, and maintainability.

6-3.1 CANDIDATE ENGINES

Within the size and speed range that may be expected for future Army wheeled amphibians, there is little chance that the development of a

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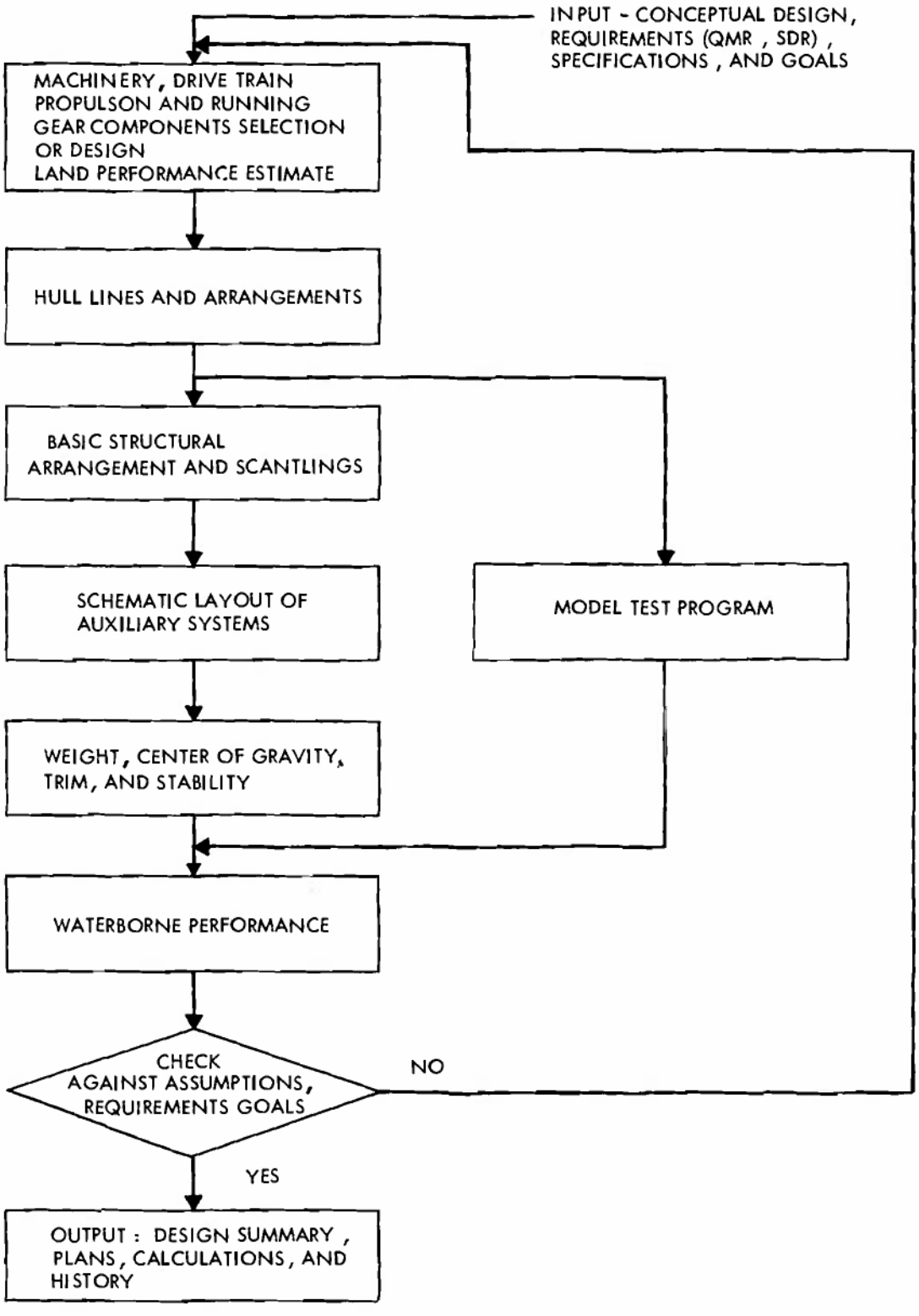

Figure 6-1. Preliminary Design Flow Chart for Wheeled Amphibians

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special engine could be justified. Accordingly, some available military or modified commercial engine must be used. This should not be a serious limitation since there is a reasonable variety of possible engines available, unless a water speed in excess of 15 mph is required.

The choice of the actual engine will have a substantial effect on the characteristics, cost, reliability, and maintainability of the amphibian. It is advisable to consider in detail, during the preliminary design, as many engines as possible that come near to meeting the performance requirements. This group of candidate engines should be selected on the basis of power output, size, and weight. The target values for these criteria are obtained from the conceptual design, or previous design cycles through the preliminary design iteration. The group of candidate engines is then narrowed down to a final selection on the basis of the other important criteria such as safety, cost, reliability, and maintenance.

6-3.2 WATER PROPULSOR

Within the context of the preliminary design of the propulsion system, the water propulsor must be defined in terms of type, power and torque required, rpm, and size. The data and procedures needed to generate this information are presented in pars. 6-7.1 and 7-7 through 7-7.6.

In general, the overall water propulsion system will be custom designed to suit the particular amphibian. The components of the system may be off-the-shelf or custom designed. The propeller in a tunnel is the simplest water propulsor in terms of its components. The propeller itself may be a stock item or custom designed, depending on the performance required. The shafts and struts will be arranged to suit the installation.

A waterjet marine propulsor is next in complexity to the simple propeller in a tunnel. A number of complete waterjet units are available as stock commercial items. In the event those available are not suitable, a custom waterjet system could be designed which makes use of an available commercial pump. In this case it would be necessary to design the inlet, exhaust nozzle, and controls. Further, the pump case must be made of lightweight material (aluminum) instead of the cast iron or steel ordinarily used in commercial practice.

A right angle drive marine propulsor will be the most complex type that is likely to be used on a wheeled amphibian. Only a few units are commercially available at this time (1968) that would be suitable for a wheeled amphibian. Even these units would have to be modified to provide a satisfactory retraction system for an amphibian. Although a right angle drive system is mechanically complex, one can be custom designed if justified by the performance requirements. This was the case for the Mobile Floating Assault Bridge-Ferry.

6-3.3 LAND PROPULSION AND MOBILITY

In the preliminary design phase the arrangement of the running gear, the tire size, and torque and rpm requirements at the wheels must be fixed. These performance specifications will define the requirements for these items, and the design cycles through conceptual and preliminary design will provide guidance on arrangements and component selections. Design information and calculation procedures required to make these selections are presented in pars. 6-8, 7-4.2 through 7-4.3, and 7-8 through 7-8.4.

There is a wide variety of military and commercial components available for use in the running gear. Information on these items is contained in the commercial catalogs and other literature published by manufacturers. These components are generally not directly suitable for use on a wheeled amphibian because of the requirement that the running gear must withstand repeated immersion in salt water. Some changes in the materials and seals used in standard components may be required. This was done successfully for the planetary wheel ends used on the LARC series.

6-3.4 POWER TRAIN

The power train transmits power from the engine to the shafting of the marine propulsor to the wheel ends. The gear ratios and torque capabilities of the drive train depend on the engine characteristics, and requirements of the marine propulsor and running gear. These items must be defined before the preliminary design of the power train is undertaken. The same criteria

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and general performance requirements apply to the preliminary and final selection or design of power train components. These criteria and requirements are discussed in par. 5-1.3.

In the preliminary design phase the major decision that must be made with regard to the power train is whether to select an available military or modified commercial transmission or to design a special transmission. This decision depends on considerations of performance, size, weight, cost, reliability, and maintenance. These factors, as they apply to this discussion and the power train in general, are covered in par. 7-6.3. In the past, wheeled amphibians such as the LVW have been equipped with custom designed transmissions, whereas the LVH-X2 and the Mobile Floating Assault Bridge-Ferry have been fitted with modified commercial transmissions.

6-3.5 MAINTAINABILITY AND RELIABILITY CONSIDERATIONS

The success of a wheeled amphibian, when placed in the hands of its users, largely depends on its ability to be operated reliably and be easily maintained. This should be uppermost in the mind of the designer when the preliminary selection or design of components in the propulsion system is undertaken. The requirements on the operating life, conditions, and maintenance goals of the amphibian will be given in the QMR or other performance specification. This information must be used in evaluating existing components for possible use or in establishing design factors and goals for custom designed components. It should be noted that maintainability considerations strongly favor the use of components that are already in the U. S. Army supply system. The subject of maintainability and reliability as applied to the design of Army materiel is covered in Ref. 1, and the designer should be familiar with this AMC Pamphlet before working on the preliminary design phase of the propulsion system.

A note of caution is in order here concerning the use of standard components. The virtues ascribed to the use of standard military components in par. 2-9.4 must not lead the designer to the conclusion that their use is a panacea for all the problems in amphibian design. In the preliminary and conceptual design phases, it is more important to consider new "experimental" items and components than to doggedly cling to old "standard" items. In this way, progress in the evolution of improved amphibians is assured. It is important to remember that so-called "standard items" in our current inventory of amphibians were "experimental items" only a short time ago.

The function of a development cycle is to bring a feasible concept to an optimum or "standard" production stage. In many cases the maintainability and reliability of a standard component may be just as undefined as that of an experimental component because of the unusual amphibian environment. Thus, the final analysis of which is best can only be made after testing has occurred. In any case, the idea of using standard military components simply because they have known properties and predictable reliability is a nonprogressive, nonproductive, and often uneconomic approach.

6-4 INITIAL HULL LINES AND ARRANGEMENTS

For the initial drawings, the lines and arrangements are considered together since the hull form is designed around the machinery, working, and cargo spaces.

6-4.1 ENGINEERING APPROACH

For low water speed amphibians the general approach will be to position all of the components and working spaces with minimum clearances, and then design a minimum volume hull form around the package. This will result in the smallest practical vehicle, which is generally one of the objectives. All designs will have compartments or areas that have extra volume over and above that apparently required. These spaces, frequently at the ends of the vessel, are necessary to meet the buoyancy, stability, resistance, or other hull design requirements. As the design is progressively checked, there will always be conditions which require changes in the dimensions. A certain amount of adjustment will normally be required to arrive at a compact arrangement.

6-4.2 DIMENSION LIMITS AND GOALS

The primary dimension limits and goals should be established during the conceptual

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design phase as discussed in par. 5-3. The remainder must be determined during the preliminary design. The limits will be firmly established at the start of the preliminary design process. Many limits determined earlier during the conceptual design stage will have to be checked. The sources of some of the limits are listed in Table 6-2.

6-4.3 COMPONENT SIZES AND WEIGHTS

For each of the potential mechanical or structural components considered, a drawing should be obtained or produced showing the size of the unit and the envelopes of spaces around the unit required for operation, maintenance, and removal. These envelopes should include the space required for tools, to withdraw parts, or to make adjustments.

Accurate weights of the complete units are necessary in order to make satisfactory weight estimates.

6-4.3.1 Sources of Information

The two primary sources of information on component sizes and weights are the component manufacturer and the component user. The manufacturer is trying to sell his products and presents the best possible information and the user has, in general, the history of operation and maintenance for each component.

6-4.3.2 Typical Sizes

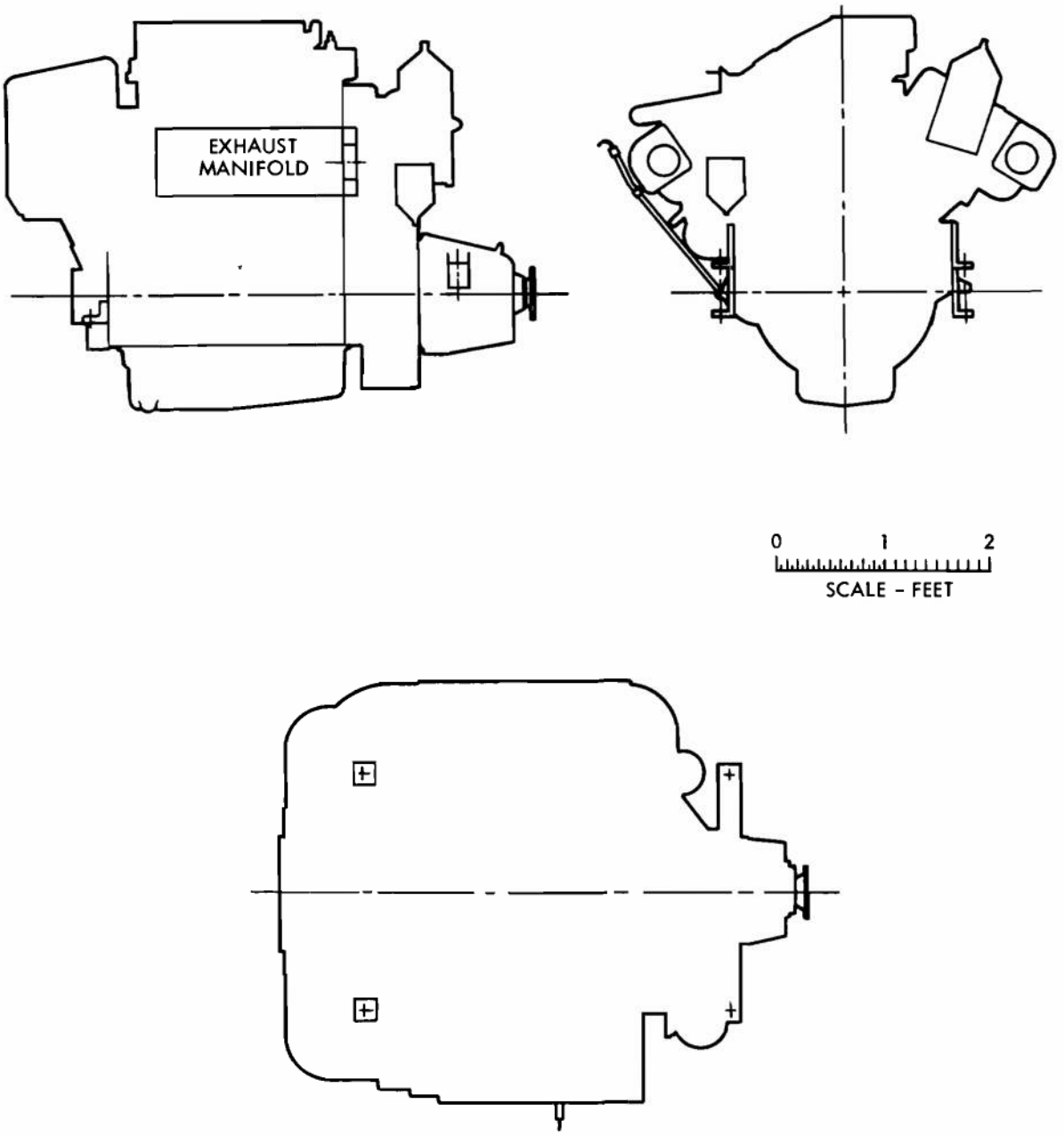
Figs. 6-2, 6-3, and 6-4 are typical drawings of a Diesel engine with the maintenance and removal envelopes drawn. Scale drawings of the components are normally furnished by the manufacturer. The clearance envelopes must be developed by the designer.

6-4.4 BLOCK ARRANGEMENT

The block arrangement is the initial interior arrangement drawing. It uses the envelopes for each component (from par. 6-4.3.2) including the structural scantlings to build up a minimum volume interior arrangement. It is normally matched with the exterior components which have been previously arranged in the conceptual stage. Clearances for construction and maintenance personnel are added where necessary and the minimum size of the hull with respect to the arrangement is complete.

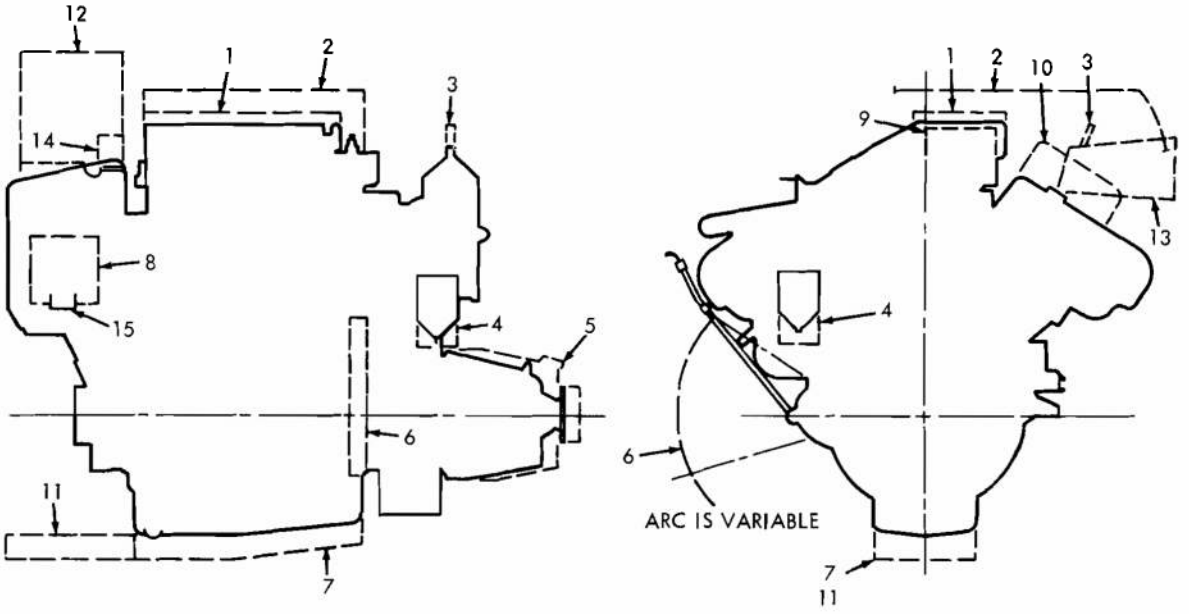
TABLE 6-2 SOURCES OF DIMENSION LIMITS

Dimension	*Limit*	*Source*
Length	Transportability	pars. 2-4.3.6, 2-5; QMR, SDR
Breadth	Transportability and Stability	pars. 2-4.3.6, 2-5, 7-1.6.2; QMR, SDR
Height	Transportability	par. 2-5
Freeboard	Range of Stability and Seaworthiness	par. 7-1.6.2
Wheelbase	Mobility and Maneuverability	par. 2-4.3; QMR, SDR
Ground Clearance and Clearance Angles	Mobility	par. 2-4.3; QMR, SDR
Turning Circle	Mobility and Maneuverability	par. 2-4.3; QMR, SDR; (wheels must be removable)
Machinery Operating Angle	Lubrication	Manufacturers' Data
Driver's Station	Visibility and Protection	par. 7-2



NOTE: SCALE DRAWINGS ARE NORMALLY AVAILABLE FROM THE ENGINE MANUFACTURER. THE ENGINE OUTLINE MAY BE TRACED FROM A SCALE DRAWING AND USED AS A TEMPLATE IN LAYING OUT THE ARRANGEMENT. MANY ACCESSORIES CAN BE MOUNTED EITHER IN OTHER POSITIONS ON THE ENGINE OR ELSEWHERE IN THE MACHINERY SPACE.

Figure 6-2. Typical Marine Engine Outline



GHOST LINES SHOW SPACE REQUIRED TO REMOVE:

1 AIR SILENCER

2 BLOWER (CAN BE REMOVED FROM EITHER SIDE)

3 LUBE OIL FILTER (CENTER STUD TYPE)

4 FUEL FILTER

5 REVERSE GEAR

6 STARTER (ARC OF WRENCH)

7 OIL PAN (DROPPED ONLY, CAN'T BE REMOVED WITHOUT ADDITIONAL CLEARANCE OR REMOVAL OF LUBRICATION OIL PICKUP TUBE)

8 HEAT EXCHANGER CORE

9 GOVERNOR

10 CYLINDER HEAD COVER (ONLY ONE SIDE SHOWN)

GHOST LINES FOR SPACE:

11 FOR LUBRICATING OIL DRAIN CATCH PAN

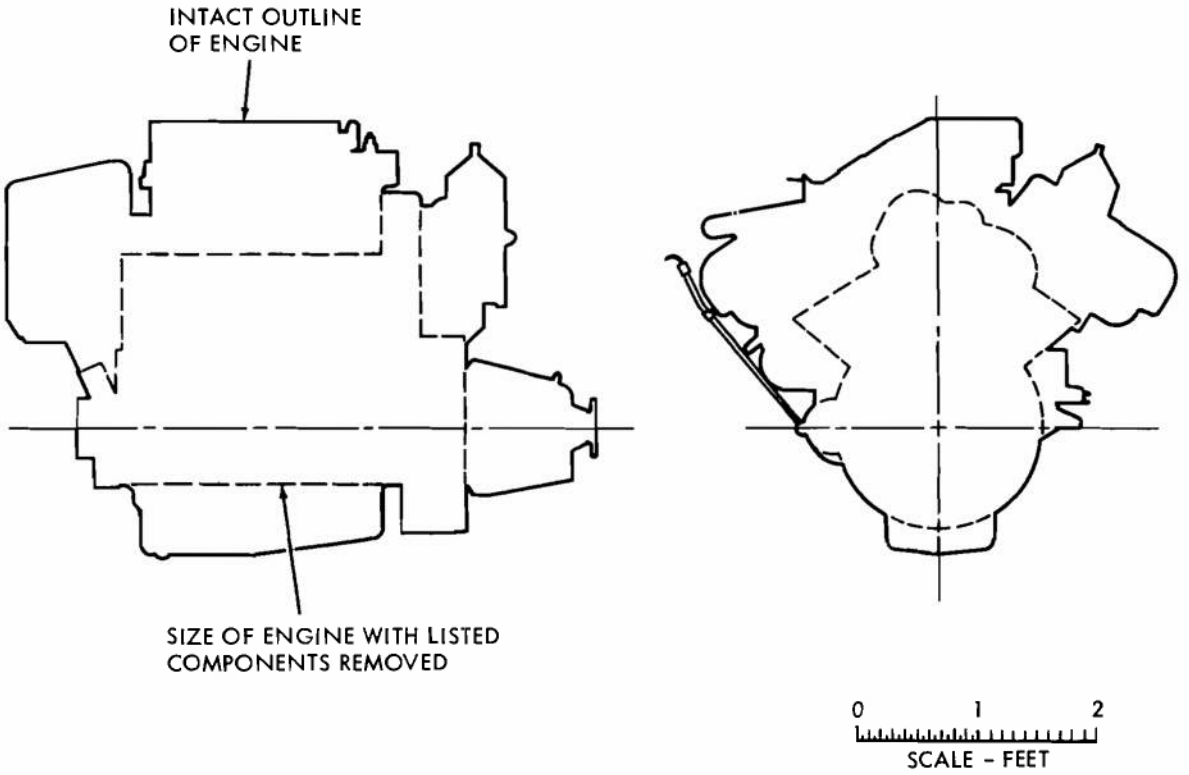
12 FOR HEADROOM FOR WATER LEVEL INSPECTION

13 TO ADD LUBRICATION OIL

14 TO ADD COOLING WATER

15 TO OPEN PETCOCK

Figure 6-3. Typical Envelope of Space Required for Maintenance and In Situ Repairs



LIST OF MAJOR COMPONENTS REMOVED

AIR SILENCER
BLOWER
CYLINDER HEADS AND COVERS
EXHAUST MANIFOLDS
EXPANSION TANK AND PIPING
FUEL FILTER
GENERATOR
LUBRICATING OIL FILTER AND PICKUP TUBE
OIL LEVEL GAGE
OIL PAN
REVERSE GEAR

NOTE: IF ACCESS IS RESTRICTED THE ENGINE MAY BE PARTIALLY DISMANTLED PRIOR TO REMOVAL. AN OUTLINE SIMILAR TO THIS MAY BE USED AS A TEMPLATE BY THE ARRANGEMENT DESIGNER.

Figure 6-4. Typical Stripped Engine Outline

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6-4.5 HULL LINES

6-4.5.1 Purpose of Hull Lines

The hull lines drawings serve a number of purposes in the overall scheme of amphibious vehicle design. Fig. 7-1 is an example of an amphibious vehicle lines drawing, and par. 7-1.1.1 includes an explanation of the lines drawing.

The lines drawing graphically describes the shape of the outer hull surface. The hull lines provide the boundaries along the hull length to check space and clearances of various components. From the lines drawing, the builder obtains information on size and shape of plates and frames required to construct the hull. The form calculations relating to vehicle displacement, center of buoyancy, trim, and stability are calculated using the lines drawing.

There are two stages of lines drawings—preliminary and final. The final lines drawing is a product of the final stages of the design cycle, wherein the lines drawing is refined by adding additional stations, waterlines, and buttock lines. The curved surfaces may be made developable during the final design stages if the designer so chooses. The final lines drawing requirements and procedures are given in par. 7-1.1.2.

6-4.5.2 Preliminary Lines Drawing

Preliminary lines drawing is an output of the preliminary design cycle. The design cycle, as explained in par. 6-2, is an iterative process with various vehicle dimensions and characteristics changing with each iteration. In the preliminary stages, the lines drawing may undergo many successive modifications.

Before the preliminary lines drawing can be developed, there are a number of preliminary characteristics which must be known or estimated. These include:

a. Displacement

b. Longitudinal Center of Buoyancy (LCB) location

c. Principal dimensions (length overall, waterline length, beam, draft, hull depth forward, aft, and 'midships, and the approach, beam, and departure angles)

d. Block arrangements

e. Running gear size and characteristics

f. Marine propulsor type and size

g. Hull material and construction procedures

This information is obtained from the requirements, the conceptual design phase, and previous preliminary design work.

6-4.5.3 Lines Development

The following steps may be used in the development of the preliminary hull lines:

a. Select a drawing scale and lay out a grid. For a preliminary design, the drawing need not be larger than 18 to 20 in. long.

b. Draw the vehicle centerline profile on the profile plan. The wheels should also be shown at this time.

c. Draw the projection of the deck at side in the half breadth plan.

d. Draw the stations on the body plan. The shapes of the stations are determined by the requirements of the block arrangements plan, the wheels and marine propulsor, buoyancy, and longitudinal center of buoyancy location. The requirements are checked by comparisons and calculations. Reference should be made to pars. 7-1 through 7-1.6.5 for other criteria and calculation procedures.

e. Draw the waterlines and buttock lines in the half breadth and profile plans.

f. Fair the lines in all three views and make certain that all the intersection points are consistent. This process is described in par. 7-1.1.1.

In the event that the required buoyancy or longitudinal center of buoyancy (LCB) cannot be obtained with reasonable station shapes within the assumed dimensions, the dimensions must be changed. It is best to make small changes in buoyancy by changing the draft. Small changes in the LCB can be made by changing the trim. There are practical limits to such changes and major changes in the buoyancy or LCB will require that all of the principal dimensions be adjusted.

6-5 DEVELOPMENT OF BASIC STRUCTURAL DESIGN

The basic structure, as defined herein, includes the general structural configuration, materials selection, and the major scantlings. It excludes local bracing, doublers, special fittings, small foundations, final joint design, and details.

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6-5.1 FORCES

The determination of the forces which the vehicle must sustain are discussed in par. 7-3.1. For this phase it is necessary to determine critical forces for the selection of the shell and framing scantlings for all materials under consideration. Smaller amphibians, in almost all cases, will be designed from local loading considerations.

6-5.2 MATERIALS

There are currently only three practical materials for the construction of amphibians, viz., steel, Fiberglas, and aluminum. It is anticipated that the high performance required of wheeled amphibians will usually result in the selection of aluminum for the hulls of future vehicles. Aluminum is discussed in detail in par. 7-3.2. Since rivets tend to leak after aluminum has been heavily stressed, only all-welded construction is recommended for the hull. Hot forming of high strength aluminum without losing material strength is difficult. Therefore, it is preferable to use developable surfaces unless a sufficient number of units will be made so that the cost of special dies is not prohibitive.

6-5.3 STRUCTURAL CONFIGURATION

The structural configuration of a wheeled amphibian must be compatible with:

a. Vehicle design objective and goals
b. Hull material
c. Vehicle configuration
d. Machinery arrangement
e. Anticipated production methods and quantity

Par. 7-3 discusses these and other items in more detail.

In general, the hull of a wheeled amphibian takes all of the loads applied to the vehicle without the aid of a separate frame such as used in a truck. In order to make the most efficient use of the hull material, the structural configuration should be of the stressed skin type. In this configuration the shell plating or skin takes the overall bending and torsional loads. The stability of the skin under these loads is maintained by the direct framing. The local loads are distributed by the skin to the direct framing which further distributes the loads to the indirect framing. For most conventional type wheeled amphibians it may be expected that the local loads will determine the scantlings of the skin, direct framing, and indirect framing.

6-5.4 DESIGN OF BASIC HULL STRUCTURE

The design objective is normally to define a minimum cost structure to meet a given weight allowance and mission requirements. Pars. 7-3.3 through 7-3.4 present details of structural design procedures. In the preliminary design phase it is possible to use structural data from past successful designs for first estimates of structural arrangements (i.e., frame spacing, proportions, and scantlings). Data of this type are presented in Tables 6-3 through 6-5 and Figs. 6-5 through 6-7. These data may also serve as a useful check on the final structural design to confirm that it is reasonable.

6-6 WEIGHT AND CENTER OF GRAVITY

In the conceptual design phase, weights and centers of gravity are generally estimated using previous design experience tempered with engineering judgment and a minimum of calculations. The required horsepower and running gear are dependent on the weight of the vehicle. These two items are a significant part of the weight of the vehicle so that errors in weight estimates tend to lead to large errors in the overall design. It is necessary, therefore, in the preliminary design phase to carefully estimate the weight by groups.

6-6.1 SYSTEMATIC WEIGHT ESTIMATE

In order to use past designs to the best advantage, it is necessary to use a standardized weight breakdown. If the weight classification is logical and used by the industry, the information developed by different organizations can be used by all designers. Since this type of breakdown is not available, Table 6-6 presents a recommended system. This list was developed from the U. S. Navy's weight classification system for boats (Ref. 4).

Figs. 5-9 to 5-13 present weights of previous amphibians in the recommended weight classification system. A further advantage of a systematic weight classification system is that it serves as a reminder of all of the components

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TABLE 6-3 TYPICAL ALUMINUM BOAT SCANTLINGS (Ref. 2)

Note: The Table is arranged for longitudinally framed vessels. "Transverse" and "Longitudinal" can be interchanged for a transversally framed vessel.

	Length Range, ft			
Frame Spacing	*24-30*	*30-40*	*45-55*	*60-70*
Bottom transverse	30	36	48	30-48
Side transverse	30	36	48	30-48
Deck transverse	12	12	12	12
Bottom longitudinal	12	10-12	12-18	9-12
Side longitudinal	12	10-12	12-18	9-12
Bulkhead vertical	12	12	12	12
Transom vertical	12	12	12	12
Transom horizontal	24	24	30	30
Fenders 1/2 pipe***	2	3	4	5
Plating	*24-30*	*30-40*	*45-55*	*60-70*
Bottom forward 0.8	0.140 −0.160	0.190	1/4	5/16
Bottom aft 0.2	0.140 −0.160	0.190	5/16	3/8
Side	0.130 −0.160	0.160	3/16	1/4
Deck	0.125	0.125	3/16	3/16
Transom	0.130 −0.160	0.160	1/4	5/16
Cabin*	0.125	0.125	0.125	0.125
Keel	1/2 X 3	3/8 X 5	3/8 X 6	1/3 X 7
Stem	1/2 X 3	3/8 X 5	3/8 X 6	1/2 X 7
Chine**	1/2 dia bar	5/8 dia bar	3/4 dia bar	1 dia bar
Bulkhead	0.125	3/16	3/16 - 1/4	3/16 - 1/4
Framing	*24-30*	*30-40*	*45-55*	*60-70*
All sections are flat bars unless noted.				
Transverse side	3 X 1/4	3 X 5/16	4 X 3/8	6 X 2 X 1/4 flg
Transverse bottom	5 X 1/4	5 X 5/16	6 X 3/8	6 X 2 X 1/4 flg
Transverse deck	1-1/2 X 1/4	2 X 1/4	3 X 1/4	3 X 1/4
Transverse floors	1/4 plate	1/4 plate	1/4 X 2 flg	1/4 X 2 flg
Longitudinal side	2 X 1/4	3 X 1/4	4 X 1/4	3 X 1 X 1/4 flg
Longitudinal bottom	2 X 1/4	3 X 1/4	4 X 1/4	3 X 1 X 1/4 flg
Engine fdn vertical	1/4 plate	1/4 plate	1/4 plate	3/8 plate
Engine fdn horizontal	1/4 plate	1/4 plate	3/8 plate	5/8 plate
Bulkhead stiffeners	2 X 3/16	3 X 3/16	3 X 1/4	3 X 1 X 1/4 flg
Transom vertical	2 X 1/4	3 X 1/4	4 X 1/4	3 X 1 X 1/4 flg
Transom horizontal	5 X 1/4	5 X 5/16	6 X 3/8	6 X 3 X 1/4 flg

Note: All dimensions are in inches.

* *Interlocking extrusions can be substituted here.*
** *Special extrusions would be recommended if production warranted.*
*** *Extrusions or formed plate may be more desirable.*
flg = flange
fdn = foundation

TABLE 6-4 SCANTLINGS FOR RECENT ARMY AMPHIBIANS

Configuration - Longitudinal bulkheads connecting to the inboard sides of the wheel wells. Plate and "T" stiffeners used throughout.

Item	*LARC V*	*LARC XV*
Bottom		
Plate-thickness, in.	3/16	0.190
Alloy	5086-H32	5086-H32
Stiffener-spacing, in.	30 (max)	30 (max)
-scantlings, in.	3 X 3 X 1/4 Tee	5 X 4 X 3/8 Tee
-alloy	5083-H112	5083-H112
Indirect framing	Longitudinal Bulkheads	Longitudinal Bulkheads
-spacing, in.	67	104
Remarks -	Approx. 30 in. transverse frames	Transverse frame spacing selected to suit arrangement
Deck	Forward and Aft / Cargo	
Plate-thickness, in.	3/16 / 0.250	0.250
Type	/ Diamond pattern B	Diamond pattern B
Alloy	/ 6061-T6	6061-T6
Stiffener-spacing, in.	30(max) / 30(max)	30 (max)
-scantlings, in.	3 X 3 X 1/4 Tee	3 X 3 X 5/16 Tee 4 X 3 X 5/16 Angle
-alloy	5083-H112	5083-H112
Indirect framing	Longitudinal Bulkheads	Longitudinal Bulkheads
Spacing, in.	67	104
Spacing to braces, in.		84 Extra longitudinals used to support tires of gun carriage and vehicles: They are also 3 X 3 X 5/16 Tee
Sides		
Plate-thickness, in.	3/16	0.190
Alloy	5086-H32	5086-H32
Stiffeners-spacing, in.	30 (max)	30 (max)
-scantlings, in.	3 X 3 X 1/4 Tee	3 X 3 X5/16 Tee
-alloy	5083-H112	5083-H112
Indirect framing	Deck and bottom	Deck and bottom
Spacing, in.	36	45
Longitudinal Bulkheads (nonwatertight)	33-1/2 in off centerline	52 in.off centerline
Plate-thickness, in.	3/16	0.250
Alloy	5086-H32	5086-H32
Stiffener-spacing, in.	30 (max)	30 (max)
-scantlings, in.	3 X 3 X 1/4 Tee	3 X 3 X 5/16 Tee
-alloy	5083-H112	5083-H112
Indirect framing	Deck and bottom	Deck and bottom
Spacing, in.	36 (max)	45 (max)
Transverse bulkheads and floors (nonwatertight)		
Plate - thickness, in.	3/16	1/4 3/8 in way of wheels
Alloy	5086-H32	5086-H32
Stiffener-spacing, in.	12-3/4	No stiffeners
-scantling, in.	1-3/4 X 2 X 3/16 channel welded toes to plate	
Alloy	5083-H112	
Indirect framing	Deck and bottom	Deck and bottom
Spacing, in.	36	45
Stem, in.	3/4 X 5-1/2 flat bar	
Welding	Continuous and intermittent	Continuous and intermittent
Torsional rigidity	Partial bulkheads and floors	Partial bulkheads, floors and braces between longitudinal bulkhead frames and transverse deck frames

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TABLE 6-5 STEEL BEAM PROPORTIONS (Ref. 3)

These beam proportions are recommended for steel merchant ships.

Component	*Minimum depth of beam, in./ft of beam length*	*Minimum thickness of web, in.*
Panting frames (reduce shell plating deflections from heavy seas)	0.6	
Deck girders	0.7	0.01/in. of beam depth + 0.16
Deck girder in water or fuel tanks (to allow for dynamic effects)	1.0	0.01/in. of beam depth + 0.12
Watertight bulkhead girders or web frames	1.0 plus 1/4 depth of slots for stiffeners	0.01/in. of beam depth + 0.12
Web frames	1.5	0.01/in. of beam depth + 0.14
Hold stringers	1.5	
Deep tanks, girders, and webs (to allow for dynamic effects)	1.75	

whose weight must be included so that none are inadvertently omitted.

Experience has shown that weight estimates based on the sum of estimated component weights will tend to be low. Ref. 5 reports on the weight growths of some recent off-road vehicles. Fig. 6-8 is from that reference with data on the LARC V and LARC XV added. It shows conclusively that weight growth will occur and, as a result, a margin should be added in the preliminary design weight estimate to account for this. There are two basic types of margins of interest—the construction margin and the growth margin. The construction margin is intended to account for the difference between the estimated weight and the actual weight of the amphibian. The growth margin is intended to account for increases in weight due to new equipment added to the vehicle later in its life cycle. Of these two, the construction margin is of more importance to an amphibian design.

Both types of margins take the form of a percentage of the estimated empty weight of the amphibian. The size of the margin must be determined by the judgment of the designer and his confidence in the weight estimating data. The trends indicated by the data in Fig. 6-8 indicate that a preliminary design construction margin on the order of 5 to 10 percent of the estimated empty weight would be suitable for a wheeled amphibian.

6-6.2 CENTER OF GRAVITY ESTIMATE

The center of gravity of n components is easily calculated using the following formula

$$X = \frac{\sum_{i=1}^{n} x_i W_i}{\sum_{i=1}^{n} W_i} \qquad (6\text{-}1)$$

where

X = distance from base plane to the center of gravity, ft

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x_i = distance from base plane to the center of gravity of the ith component, ft

w_i = weight of the ith component, lb

This formula is used in the longitudinal, transverse, and vertical directions to completely determine the position of the center of gravity. Recommended base planes are at the stern for the longitudinal direction, at the hull bottom for vertical direction, and at the hull center plane for the transverse direction with forward, up, and starboard being the positive directions, respectively. The transverse center is needed only if part of the arrangement is unsymmetrical. In the arrangement, some allowance is desirable for shifting heavy components fore and aft in the final design in order to adjust the trim. The longitudinal center is used for trim estimates, and the vertical center is used for the stability calculations. Typical longitudinal center of gravity (LCG) and vertical center of gravity (VCG) values from previous designs are listed in Table 5-5 and Figs. 5-14 and 5-15.

Margins for the center of gravity are normally applied only in the vertical direction. For a design, it is usually a fixed distance which is added to the VCG. If an error in trim in one direction would be serious to the design, a margin on the LCG should be added. Normally, errors in either the fore or aft direction are equally bad and a margin is not used. For boats, the U. S. Coast Guard sometimes uses a 6-in. forward margin so that if the estimates are accurate, the boats trim down by the stern.

6-7 WATERBORNE PERFORMANCE

6-7.1 SPEED AND POWER

It is possible that no specific type of propulsor would be selected in the conceptual design stages. In this case, the preliminary design procedures should be expanded to include candidate propulsor types so that a rational selection may be made among them in this stage of the design. The discussion which follows applies to a conventional screw propulsor. However, the design process is essentially similar for any other suitable propulsor, e.g., waterjet.

The principal variables concerning the propulsor design must be selected or at least narrowed down within reasonable limits in the preliminary design stage. Propeller diameter, design rotative speed, blade-area ratio, number of blades, and pitch can be selected from design charts (par. 7-7.5.2) using a preliminary estimate of design speed, resistance, wake fraction, and thrust deduction. In the process, the propeller efficiency and, hence, required horsepower will be calculated. The rotative speed and required horsepower are used in the selection of a suitable power plant and any necessary marine drive reduction units.

The problem may, of course, be worked inversely, i.e., the candidate power plant(s) characteristics may be used to select the optimum propeller and, thus, arrive at a realistic design speed.

The effect of any alternative propulsion systems or design features (e.g., controllable pitch) on the speed and power and on the overall design concept should also be evaluated. If a Kort nozzle propulsor is to be used, the geometry of the shroud must be delineated. The off-design and/or static thrust of each candidate propulsor should be estimated if such performance is deemed important in the selection of a suitable design.

6-7.2 STATICAL STABILITY AND TRIM

The stability and trim of the amphibian are of primary importance and must be checked at every stage of the design. The weights and arrangements are constantly changing in the evolutionary design process. Generally, the gross vehicle weight and vertical center of gravity will tend to rise throughout the design stages. Consequently, subsequent increases in the length and/or beam may be required to insure adequate displacement and stability. Similarly, changes in the arrangements may be necessitated by undesirable trends in the static trim as the design evolves.

Other changes in the design—such as tire size and alterations in the propeller tunnel—will, of course, also affect the displacement, stability, and trim of the amphibian and must be taken into account.

6-7.3 SEAKEEPING AND MANEUVERABILITY

The surf zone always presents the greatest test to an amphibian with respect to seakeeping ability. Thus, the main requirement concerning seakeeping that an amphibian design must

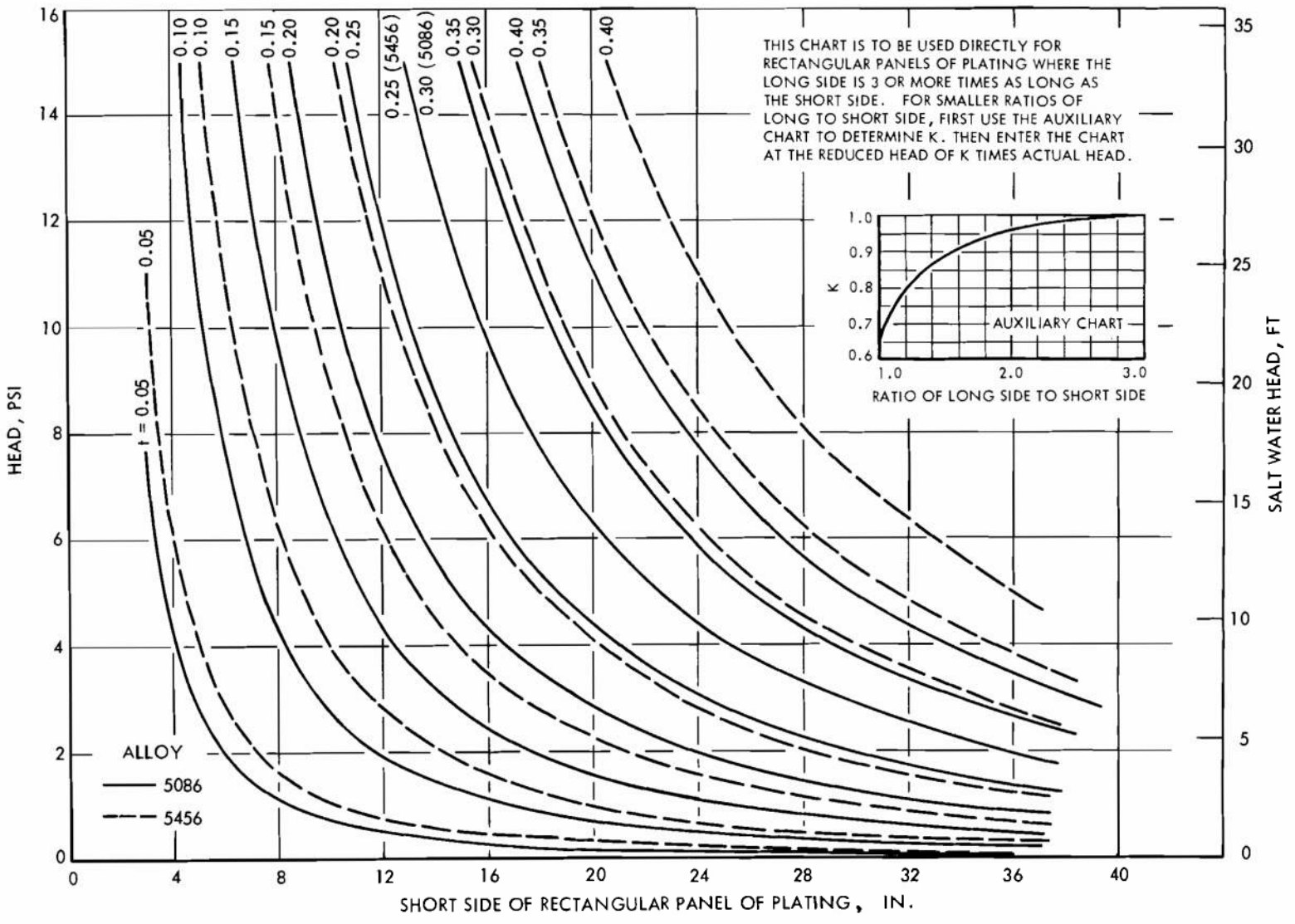

Figure 6-5. Minimum Thickness of Aluminum Shell Plating With No Permanent Set

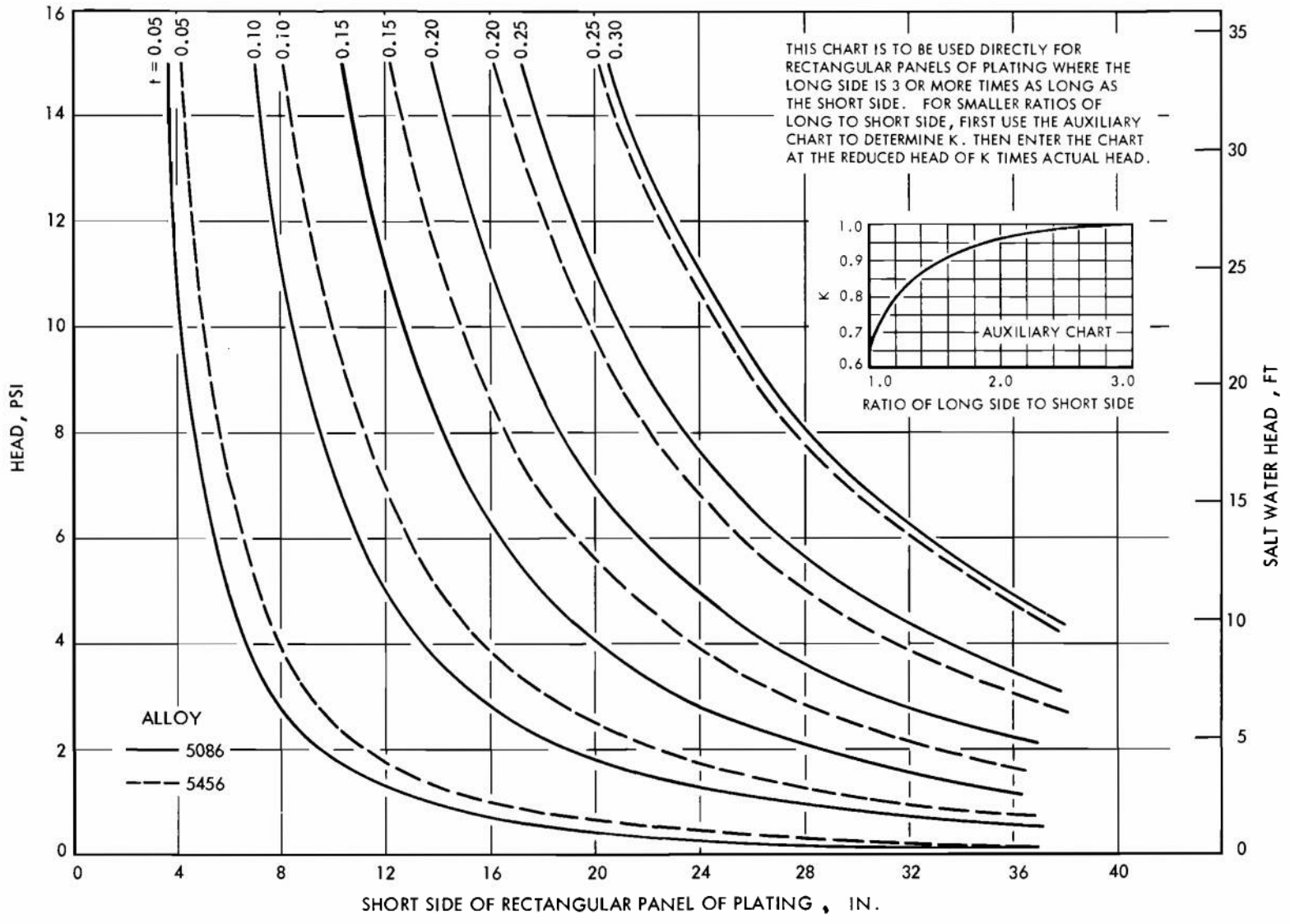

Figure 6-6. Minimum Thickness of Aluminum Shell Plating With Slight Permanent Set < t/2

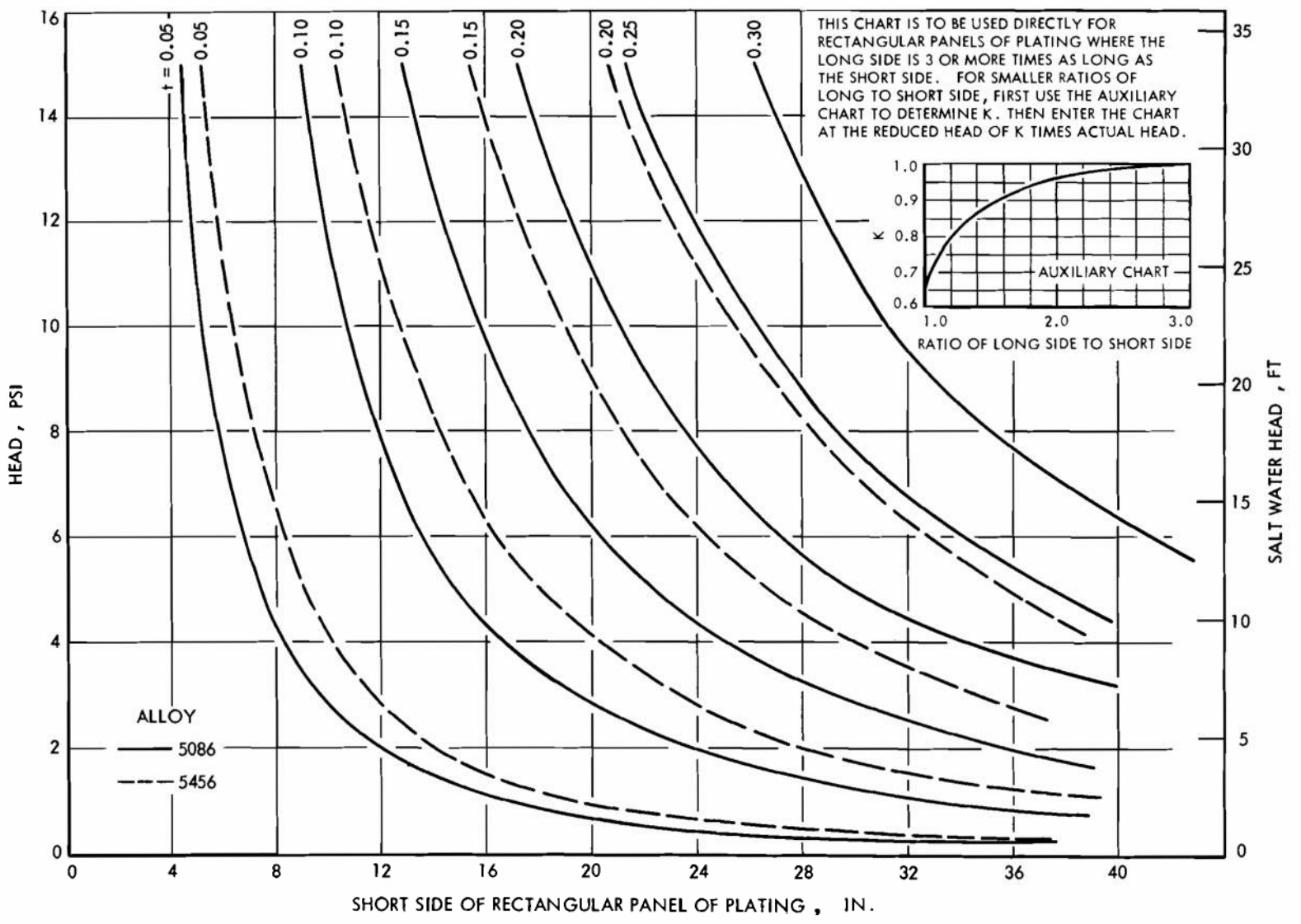

Figure 6-7. Minimum Thickness of Aluminum Shell Plating With Permanent Set > t/2

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TABLE 6-6 RECOMMENDED WEIGHT CLASSIFICATION FOR WHEELED LOGISTIC AMPHIBIANS

Major Groups	*Description of Included Items*
A	Hull Structure
B	Machinery
C	Main Drive Train
D	Marine Drive Train
E	Running Gear and Suspension System
F	Miscellaneous Systems
-	Margin
-	Loads

The total of the major groups is equal to the gross vehicle weight (GVW). The total without the cargo and crew is the curb weight.

Hull Structures

A-01	Shell plating—includes:	
	Sides	
	Bottom	
	Transom	
	Headlogs	
	Rub rail (if integral)	
A-02	Framing—includes:	
	Keel and keelsons	Chines
	Gunwale	Stringers
	Stiffeners	Breast hooks
	Web frames	Girders
	Gussets	Brackets
A-03	Flats—includes:	
	Framing	
	Plating	
A-04	Main Deck—includes:	
	Deck beams	
	Toe rail	
	Gussets	
	Plating	
A-05	Cab—includes:	
	Framing	
	Beams	
	Plating	
	Brackets	
	Hatch framing	
	Door framing	
	Windshields	
A-06	Foundations for Main Propelling Machinery—includes:	
	Foundations for shaft logs	
	Propeller struts	
	Foundations for main engines	
	Foundations for inboard/outboard drives	
	Foundations for machinery auxiliaries	
A-07	Foundations for Other Equipment—includes:	
	Foundations for winches	
	Doublers for cleats, chocks, and other deck fittings	

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TABLE 6-6 (Continued)

Hull Structures	*(Cont'd)*
A-08	Bulkheads—includes: Stiffeners Plating
A-09	Ballast and Buoyancy—includes: Solid ballast Locked-in-place liquid ballast Permanent flotation material (not including buoyancy tanks)
A-10	Doors, Hatches, Manholes, and Scuttles—includes: Doors, hatches, manholes, and scuttles Ramps Companionways Operating gears for above
A-11	Masts and Spars—includes: Booms Masts Staffs Sockets and foundations
A-12	Fastenings—includes: Mechanical fasteners Welding Adhesives
Machinery	
B-01	Machinery—includes: Main engines (complete with all attached accessories except transmission)
B-02	Main Engine Exhaust System—includes: Piping Smokepipe (outer and inner casing) Lagging (insulation) Mufflers Insulation (sound) Fluids in system
B-03	Main Engine Coolant System (When not Attached to Main Engines) —includes: Piping Hoses Clamps Heat exchangers Keel coolers Coolant wells and gratings Expansion tanks Fluids in system Fans Fan drives Radiators
Main Drive Train	
C-01	Main Drive Train—includes: Transmissions Differentials

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TABLE 6-6 (Continued)

Main Drive Train	*(Cont'd)*
C-01	Torque converters Shafting Couplings Fasteners Fluids in system Universals Clutches Hydraulic retarders Transfer cases Keys
Marine Drive Train	
D-01	Marine Drive Train—includes: Shafting Couplings Fasteners Bearings Stuffing boxes Shaft logs Fairwaters Propellers or other propulsors Kort nozzles Struts On-board-water (waterjets)
Running Gear and Suspension System	
E-01	Running Gear and Suspension System—includes: Tires Tubes Wheels Wheel ends Wheel covers Springs Shock absorbers Fasteners Hydraulic steering cylinders Mechanical steering linkages Service brakes Fluids in system Bearings (for axles if separate) Axle boots Clamps Torsion bars Keys Trailing and leading arms King pin assemblies Seals (in system) Parking brakes Wheel retraction system (complete) Control arms Ball knuckles

TABLE 6-6 (Continued)

In general, Group E includes all components of the land gear and suspension system that are connected outboard of the universal joint (if any) at the end of the fixed shafting or differential. Items such as hydraulic steering pumps, or variable tire inflation systems, are, in general, secured to the hull structure and are included in Group F—Miscellaneous.

Miscellaneous

F-01	Control System—includes: Control panels Remote controls
F-02	Fuel Oil System—includes: Piping Valves Pumps (if not part of engine) Strainers Manifolds Tanks (except built-in tanks) Filters Filling connections
F-03	Spare Parts—includes: Spare propellers Spare shafts, keys, nuts Spare bearings Spare engine parts On board tools Spare parts for electronics
F-04	Auxiliaries—Equipment powered by, but not attached to, main propulsion engine and not properly grouped with another distinct group—includes: Hydraulic pump Generators Vacuum pumps Air compressors Central tire inflation systems
F-05	Electric Power Generation and Cable—includes: Generators (independently driven) (including normal operating liquids) Piping Exhaust Foundation fastenings Batteries Battery cable and clamps Battery box Voltage regulators Resistors Panels Cable Wireways Supports and drip pans Switchboards Muffler

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TABLE 6-6 (Continued)

Miscellaneous	*(Cont'd)*
F-06	Lighting System—Distribution and Fixtures—includes: Switch gear Cable Supports Wireways Fastenings Lighting fixtures
F-07	Navigational Systems and Equipment—includes: Compasses Repeaters Binnacles Running, signal, and anchor lights Searchlights Blinkers Flags Megaphones Horns
F-08	Interior Communication System—includes: Telephones
F-09	Countermeasure and Protective Systems (except electronics)—includes degaussing system and equipment
F-10	Electronic Systems—includes: Radios Radar Cable Wireways Supports Motor-generator sets Antennas Switch gear
F-11	Ventilation and Heating—includes: Ducting Heaters Cowls and louvers Blowers and fans Brackets
F-12	Piping Systems—includes: Fresh water system Plumbing fixtures Tanks (when not built-in) Hangers Chemical fire system (not portable) Bilge drainage system Pumps Pipe insulating materials
F-13	Steering Gear System—includes: Rudders Stuffing tubes Rudder carrier Steering gear

TABLE 6-6 (Continued)

F-13	(cont'd) Distant controls Sheaves Wire rope or rod Steering wheel Sprocket and chains Brackets
F-14	Winches, Capstans, and Anchor; and Cargo Handling Systems—includes: Winches Windlasses Capstans Anchors Chain or rope, and Grapnel and lines All cargo handling

Does not include fixed items for use with these systems such as bitts, chocks, davits.

F-15	Hull Fittings—includes warping and towing fittings, and hand rails: Tow posts Tow bridles Davits Chocks (closed or open) Cleats Bitts Fairleads Blocking and brackets Grab rails Hand rails Life rails (wire rope or pipe) Guard rails (wire rope or pipe) Stanchions and sockets
F-16	Boats, Boat Handling, and Stowage—includes: Boats complete (dinghies, etc.) Boat chocks Boat lashings Boats, rubber life (complete) Stowage for life rafts (wood or metal) Boat falls (lines and blocks) Lifting pads (for hoisting) Boat davits

Lifting slings for the vehicle are not included as part of the light condition unless they are normally carried on board the vehicle. These are treated as a load when determining the hoisting condition.

F-17	Rigging and Canvas—includes: Standing rigging Running rigging (for winches) Wire rope and fittings (for mast) Manila rope Mooring lines Heaving lines Lashings

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TABLE 6-6 (Continued)

F-17	(cont'd)
	Blocks
	Deck tackle
	Awnings
	Weather cloths
	Canvas covers
	Cushions
F-18	Ladders and Gratings—includes:
	Ladder rungs
	Steps
	Portable ladders
	All gratings
F-19	Joiner Work—includes:
	Bulkheads, minor and divisional
	Partitions
	Wire mesh
	Doors in the above items
	Tanks and supports when separate from hull structure and not part part of the system
F-20	Painting—includes:
	Paint
	Preservatives
	Cement
	Other coatings
F-21	Insulation—includes:
	Insulating materials
	Sound proofing
	Sheathing
Does not include pipe lagging which is included with the pipe in piping systems.	
F-22	Stowages and Lockers—Lockers and Fittings—includes:
	Hardware
	Shelving
	Bins
	Stanchions (portable)
	Gratings
	Battens
	Work benches (in machinery spaces)
	Stowage racks (in machinery spaces)
	Stowage bins (in machinery spaces)
	Life jackets
	Lockers not properly grouped elsewhere
F-23	Furniture—includes all furniture, built-in or otherwise, such as:
	Chart table
	Desks
	Seats
	Chairs and stools
	Litter supports
	Plotting boards

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TABLE 6-6 (Concluded)

F-24	Equipment—includes: Signal searchlights (portable) Hand lanterns Medical chests First aid boxes Fire extinguishers (portable) Rope or other fenders (portable) Litters Ring buoys Cleaning gear Fire and bilge pump (portable) Hoses Damage control gear Books Boat hooks Deck gear Buckets Life jackets Mess gear Stoves Hot plates Other on equipment materiel
F-25	Armament—includes: Guns Small arms and fire control equipment Ready service boxes Small arms locker Pyrotechnics locker
Margins	Margins—includes: Growth Construction Conceptual design Preliminary design Detailed design
Loads	Ammunition—includes: Small arms cartridges Pyrotechnics Complement—includes: Men and effects (Passengers are included with cargo) Stores—includes: Dry provisions General stores Medical stores Machinery stores and lubricating oil Potable Water—includes: Drinking water Cargo—includes: All cargo (dry, bulk, or liquids) Passengers and effects Litter patients Fuel—includes: Diesel oil Gasoline

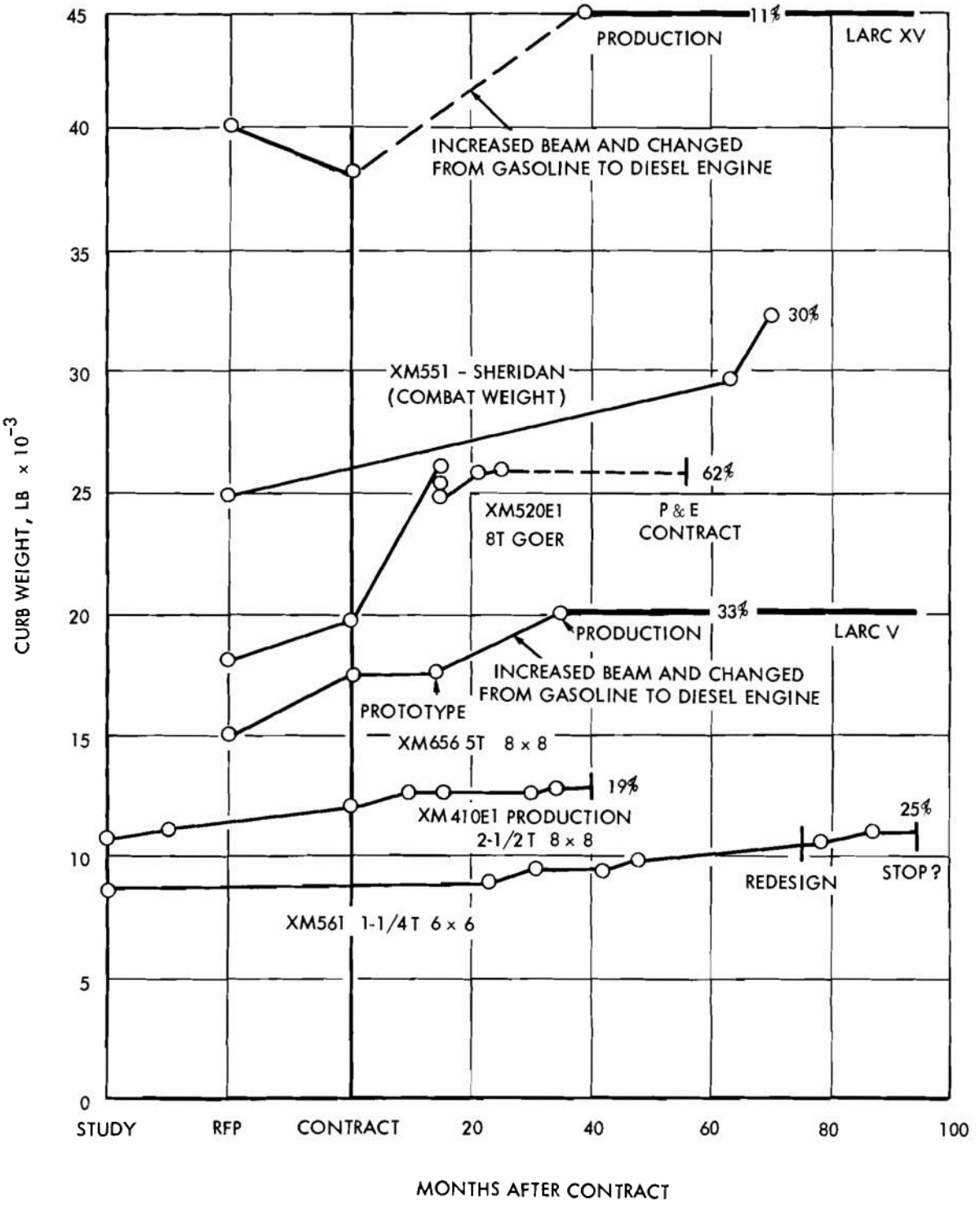

Figure 6-8. Weight Growth of Recent Experimental Off-road Vehicles and the LARC V and LARC XV (Ref. 5)

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satisfy is the ability to safely pass through surf whose severity is usually specified in terms of breaker height from crest to trough. Unfortunately, there are no formulas available with which the designer can predict, quantitatively, surfing ability. Model testing does not offer much help in this respect, although qualitative comparisons of different designs might be made on the basis of model tests in waves. In the past, the only reliable information on surfing ability has come from full scale testing and operational experience. Thus, the designer must rely heavily on past practice and experience with existing amphibians.

There are many characteristics which are directly related to the performance of an amphibian in surf. The range of stability indicates to what degree the amphibian can roll and yet return to an upright position. The static stability as determined by the metacentric height GM is a measure of the resistance of the amphibian to roll and is often given as a design requirement (unlike surfing ability, static stability is readily calculated; see par. 7-1.5.2). Maneuverability, especially in terms of quick and positive response to the helm, is related to the ability of this amphibian to operate in surf without broaching. Reserve buoyancy and provisions for automatic bailing of bilges and cargo wells are factors which affect the resistance of the amphibian to swamping. The speed of an amphibian may affect its ability in surf with respect to the ability to outrun waves (see par. 7-4.3.1).

A simple scaling law can be used as a general rule-of-thumb concerning surfing ability in the preliminary design stages. The maximum safe wave heights for similar amphibians are roughly proportional to their relative size. Length could be used as a measure of size, but for this purpose, the cube root of displaced volume, $\nabla^{1/3}$, is a better parameter. On this basis, an amphibian with twice the gross weight of another should be able to negotiate surf that is statistically 26 percent higher. As a rough estimate, the ratio of significant wave height $h_{1/3}$ (average of the 1/3 highest waves) in plunging surf to the cube root of volume can be taken as

$$\frac{h_{1/3}}{\nabla^{1/3}} \approx 1.2.$$

This corresponds to a wave height of 8 ft for the DUKW, which is considered as the safe limit for this amphibian. A SUPERDUCK was broached and turned over in plunging surf reported to be about 12 ft high at Monterey, California. A LARC V safely negotiated the same surf ($h_{1/3}/\nabla^{1/3} \approx 1.5$).

Another factor which should be considered for surfing ability is reliability. If the propulsion system or steering system should fail for any reason while the amphibian is in the surf zone, it is likely that the amphibian will broach, swamp, founder, and capsize. Similar consequences might follow a bilge pump breakdown. Self-bailing cargo wells are desirable for this reason.

The requirement for maneuverability is usually expressed in terms of a minimum tactical diameter, although minimum acceptable performance in some other maneuver may also be specified. The factors which determine maneuverability are discussed in par. 7-9.1. Simple model tests can be performed during the preliminary design stages in order to determine, qualitatively, the degree of directional stability of any candidate amphibian design. Scale effects may preclude accurate prediction of tactical diameter. The relative merits of different steering system configurations can be deduced from model tests, however. As with surfing ability, there are no convenient theoretical methods available to predict the maneuverability of proposed amphibian designs. The designer must rely on past practice, experience, or model tests. A simple scaling principle, however, can be applied to tactical diameter, i.e., the ratio of tactical diameter to length is roughly constant for similar amphibians. Of course, one must be careful in assessing similarity. For example, two amphibians of the same design could have grossly different turning ability, where one was directionally unstable and the other was made stable by virtue of an additional skeg or keelson, etc. A reasonable value of the ratio of tactical diameter to length (LOA) for amphibians with satisfactory maneuverability is 3.0. The subject of waterborne maneuverability is covered in more detail in pars. 7-9 through 7-9.4.

6-8 LAND PERFORMANCE

The land performance of wheeled vehicles is discussed at length in Refs. 6, 7 and pars. 7-8 through 7-8.5.2. The paragraphs which follow are included for general background.

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6-8.1 SPEED AND TRACTIVE EFFORT

The maximum speed of an amphibian on land is a function of available power, rolling resistance, wind resistance, grade resistance, the suspension system, roughness of the terrain, and the type of soil. The gross tractive effort is the maximum propelling force that can be developed by the tires on a given type of surface. The limiting factor(s) determining the maximum speed is different for various environments. For example, over rough terrain and obstacles the speed is reduced for operator comfort and to avoid damage due to shock loads. On paved roads, power, especially on grades, may be the limiting factor. The natural frequency of the rigid suspension system is the limiting factor for the LARC V. In weak soils and sand, the gross tractive effort is limited by the strength of the soil and, at the same time, the rolling resistance of the tires is increased due to sinkage.

Rolling resistance is a function of the amphibian weight, tire design, speed, and the soil or other surface. Grade resistance is directly proportional to the weight and the slope of the grade. Wind resistance is a function of the frontal area and shape of the amphibian and its velocity, but is a small part of the total resistance at speeds below 35 mph. Where gross tractive effort is the limiting factor, the total resistance is just equal to the gross tractive effort at the maximum speed. This subject is covered in greater detail in par. 7-4.2.

6-8.2 SIDE SLOPE STABILITY

The side slope stability is a function of the vertical center of gravity and the suspension system design. With a rigid suspension system, the important parameters are the track width and the tire deflections. Fig. 6-9 illustrates the condition. The axial and radial tire deflections are caused by the increased loading on the downhill wheels. The radial deflection causes the amphibian to lean away from the slope so that the amphibian angle is greater than the slope angle. The axial deflection decreases the effective track width. Both effects are detrimental to the side slope stability. As the side slope increases the center of gravity moves toward a position over the center of pressure of the downhill tire. Once the center of gravity passes over this point, the amphibian will, of course, capsize laterally.

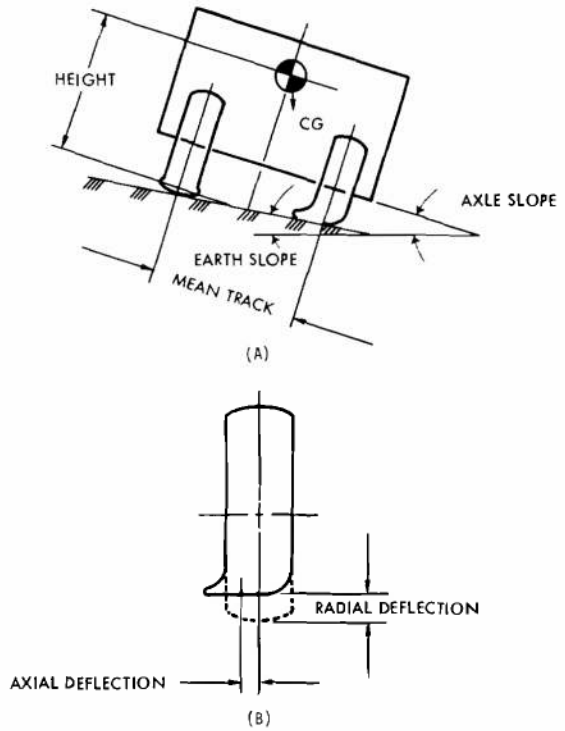

Figure 6-9. Side Slope Stability Definition Sketch

The limiting condition on side slopes is not necessarily the stability of the amphibian. For instance, the downhill tires on the LARC V would lose air and go flat on side slopes while the vehicle remained stable. This was caused by the axial deflection of the tire which pulled the sidewall away from rim, breaking the seal.

The side slope requirement is normally specified in the QMR.

6-8.3 APPROXIMATE MOBILITY INDEX

Mobility indexes provide a convenient quantitative measure of vehicle mobility. Some simple formulas for calculating the approximate mobility indexes, suitable for use in preliminary design, are given in Table 7-44. These indexes apply to soft soil and sand mobility.

6-9 MODEL TESTING

6-9.1 NECESSITY FOR MODEL TESTING

Model tests may be required at several stages of the design process in order to confirm

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engineering estimates of diverse design variables or to obtain more accurate values of these variables when the estimates are rough or based on incomplete data. Model tests are needed especially for new and unconventional designs for which there is no previous experience or quantitative data which can be used to make estimates. While there are a number of successful operational amphibians in existence, they are certainly not considered to be optimum configurations with respect to waterborne performance. In any case, there does not exist a store of amphibian design experience or systematic series test data comparable to that which is available to the merchant ship designer.

Model tests are conducted in a controlled environment so that the effect of a single design variable can be found independently and the test results can be confirmed by simply repeating the test. Unknown variables such as wind and tide do not obscure the results. As long as there are no predominant scale factors involved, confidence in properly conducted model tests should be at a high level.

In summary, the gains which can be obtained by model tests are associated with the data which can be used to make design decisions with a high confidence level. These data can be obtained at relatively low cost and in a short time.

6-9.2 TYPES OF MODEL TESTS

The various types of model tests are described briefly in the paragraphs which follow. Greater detail concerning test procedures and modeling laws are found in pars. 7-4.1 to 7-4.1.3 and 7-7.6 to 7-7.6.4.

6-9.2.1 Resistance

The model is towed in a model basin over a straight path at various constant speeds. The drag, as a function of speed and displacement, is measured by a simple force gage or dynamometer. The drag component of appendages is deduced by running tests with and without appendages mounted on the model.

6-9.2.2 Self-propulsion

The model is propelled by a model propulsor in a model basin at the desired speeds. The rotative speed and power absorbed by the propulsor at each velocity are measured with suitable instrumentation. The test measurements are used, in conjunction with resistance and propulsor tests, to define the interaction between the hull and propulsor in terms of wake fraction and thrust deduction.

6-9.2.3 Maneuverability

Free running and captive model tests may be conducted to determine different aspects of maneuverability.

6-9.2.3.1 Free Running

The simplest test that can be made with a free running model is rarely used because it only indicates whether the amphibian is directionally stable or not. A self-propelled model with rudder fixed amidships is set on a straight course and then a momentary side force is applied at the bow. If the model establishes some new straight line path it is directionally stable, by definition. If it is directionally unstable, it will go into a steady turn after the force is applied to the bow.

Steady turning diameters can be obtained with the free running model by setting the rudder at fixed angle increments. However, more information can be obtained if the rudder is remotely controlled. Definitive maneuvers can be simulated with a remotely controlled free running model. The turning maneuver is described in par. 7-9.1.1 and Fig. 7-98. The Dieudonne spiral maneuver is described in par. 7-9.1.2 and Fig. 7-99. The spiral maneuver serves mainly to determine qualitative stability characteristics. One other maneuver, the Kempf overshoot (or zig-zag), serves to determine control characteristics. This maneuver is described in Ref. 7.

Free running model tests must be run in large turning or maneuvering basins. The model trajectory is recorded so that quantities such as yaw rate, turning radius, and speed may be determined. Model trim and heel in turns may also be observed.

6-9.2.3.2 Captive Model

The model is restrained by the towing carriage through a dynamometer in captive model tests

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to obtain numerical values for the hydrodynamic coefficients in the equations of motion. With these coefficients, mathematical models, in conjunction with high-speed computers, are used to simulate the vehicle motions. This approach has the potential for obtaining more basic information on maneuverability than free running tests which only predict the motions but do not give insight into the controlling factors.

Three types of captive model tests are commonly performed: (1) steady state yaw, (2) planar motion mechanism, and (3) rotating arm. The first two are conducted in conventional towing tanks. The third must be run in a turning or maneuvering basin. The forces and moments on both the model and control surfaces are measured in these tests. A complete description of these tests, including how the results are used in the motion equations, is given in Ref. 8.

6-9.2.4 Seakeeping

Seakeeping tests are conducted in towing tanks equipped with wavemaking mechanisms. The model is generally towed into the waves (head seas) which may be either regular (constant length and height) or irregular, with long crests (waves coming from one direction only). If tests in quartering and/or short crested (waves coming from several directions) seas are desired, they must be performed in special seakeeping basins. The model may be free of pitch and heave or may be constrained in all six degrees of freedom. As with maneuvering tests, the free model tests are used to simulate the motions in waves and the captive model tests are used to measure forces and moments in order to derive the motion coefficients. These coefficients are used in the equations of motions from which the motions in arbitrary sea conditions can be calculated. These calculations require the use of a high-speed computer. This approach has the advantage that the motions in a wide range of sea conditions can be studied without the need to simulate each in a testing tank.

6-9.2.5 Propulsion

Propulsion tests are conducted to determine the propulsor performance coefficients (thrust, torque, and efficiency) over a wide range of operating conditions in open water. Tests may be performed either in a towing tank or a circulating water tunnel or channel. If cavitation effects are important, a water tunnel or channel with provisions for modeling cavitation number must be used. Thrust, torque, rotative speed, and advance speed are all measured. The data are usually reduced to the coefficient form as propeller characteristic curves. These tests are covered in detail in pars. 7-6 through 7-6.4.

6-9.3 SCHEDULE OF TESTS

Several factors should be considered when fixing a schedule for model tests:

a. Relation of model test to design process
b. Interrelation of tests
c. Lead time
d. Testing agency and facility

The model tests are arranged to provide data for decisions and estimates in the evolutionary design process. The test schedule should take into account the natural sequence of events in the design evolution. For example, the hull lines and gross vehicle weight must be known before a model test can be made to determine the resistance. This resistance, in turn, should be known before the propulsor characteristics are selected and propulsion tests are performed. Thus, the relation between tests such as resistance, propulsion, and self-propulsion tests must be considered.

The lead time for model tests includes time for model construction, facility availability, testing, and data reduction. These factors may depend greatly on the schedules and capabilities of the prospective test agencies and facilities, i.e, their work-load. The test schedule should be carefully considered when selecting a test facility because delays in obtaining test results will lead, indirectly, to increased costs in the design process.

Another very important factor which must be considered in selecting a suitable test facility is its size. Larger tank cross sections allow proportionally larger models to be tested without any increase in tank wall effects. The use of larger models is advantageous with respect to scale effects as explained in par. 7-4.1.1.3. In effect, the larger the model the more accurate the prediction of full scale performance will be.

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6-9.4 POSSIBLE LOCATIONS FOR MODEL TESTS

Table 6-7 is presented to give a comprehensive list of test facilities which might be considered for amphibian model tests. Governmental, institutional, and private facilities are included. A brief description of the facility and any special capability is included for convenience. More complete information including foreign facilities is tabulated in Ref. 9.

TABLE 6-7 MODEL TEST FACILITIES

Name and Location	Type of Facility	Dimensions of Basin or Test Section (Length x Width x Depth)	Speed, fps	Remarks
Aerojet-General Corp. Azusa, California	Ring Channel with Rotating Arm	Diameter = 110 ft Channel width = 20 ft Depth = 10 ft	1[illegible]	
California Institute of Technology Pasadena, California	Variable Pressure Water Tunnel	1[illegible] in. Diameter, Free Surface 20 in. wide 20 in. deep	100 to 25	Pressure from atmospheric to 1/15 atmospheric used for body studies.
Collins Marine Laboratory Collins Radio Co. Cedar Rapids, Iowa	Towing Tank	90 x [illegible] x [illegible] ft	22	Has plate surface agitator.
Davidson Laboratory Stevens Inst. of Tech. Hoboken, N. J.	Towing Tanks (2)	313 x 12 x [illegible] ft 103 x 9 x [illegible].5 ft	100 21	Both tanks have plunger type wavemakers for uniform regular or irregular waves.
	Seakeeping Basin	75 x 75 x [illegible].5 ft	[illegible]	Wavemaker can generate regular or irregular waves and models can be run at all angles to the waves.
	Rotating Arm	75 x 75 x [illegible].5 ft	150	The rotating arm is in the seakeeping basin above.
General Dynamics/Convair Hydrodynamics Laboratories, San Diego, Calif.	Towing Tank	320 x 12 x [illegible] ft	100	Mechanical paddle type wavemaker.
HYDRONAUTICS, Incorporated Laurel, Maryland	Towing Tank	308 x 24 x 13 ft	[illegible]	Plunger type wavemaker for uniform regular or irregular waves.
	Variable Pressure Water Channel	12 x 2 x [illegible]	[illegible]0	Pressure from atmospheric to 3 in. Hg. Used for bodies, foils and propellers.
Iowa Inst. of Hydraulic Research, Univ. of Iowa, Iowa City, Iowa	Towing Tank	300 x 10 x 10 ft	20	
	Water Tunnel	13.5 in dia. or [illegible] x [illegible] in. cross-section	8-35	Pressure from 3 to 30 psia. Used for pressure distribution on bodies and foils.
Lockheed Underwater Missile Facility Sunnyvale, California	Towing Tank	180 x 15 x 15 ft	50	Controlled pressure from 0.73 to 14.7 psia.

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TABLE 6-7 (CONTINUED)

Name and Location	Type of Facility	Dimensions of Basin or Test Section (Length x Width x Depth)	Speed, fps	Remarks
Massachusetts Inst. of Technology, Cambridge, Mass.	Towing Tank	108 x 8.6 x 40 ft	25	Hydraulic paddle wavemaker for uniform regular or irregular waves.
	Water Tunnel	24 in. diameter	34	Pressure from 0.8 to 14.7 psia. Used for propeller tests.
NASA Langley Field, Va.	Towing Tanks (2)	2800 x 24 x 12 ft	80	Flat plate wavemaker.
		2200 x 8 x 5 ft	200	High speed capability.
	Water Tunnel	2.5 in. diameter	43	Used for pressure measurements on foils and visual cavitation studies.
Naval Ship Research and Development Center (NSRDC-DTMB) Carderock, Maryland	Towing Tanks(4)	1886 x 51 x 22 ft	42	Pneumatic wavemaker.
		303 x 51 x 10 ft	42	Combined shallow water and turning basin.
		2968 x 21 x 10 ft	100	High speed basin.
		1?2 x 5.5 x 10 ft	10	Pneumatic wavemaker.
	Seakeeping Basin	360 x 240 x 20 ft,	24	Regular and irregular and short crested waves can be generated at any angle to the model.
	Water Channel	60 x 22 x 9 ft	17	
	Water Tunnels (2)	36 in. diameter	85	Pressure from 2 to 50 psia. Propellers and contra-rotating propellers.
		12 in. diameter	26	Pressure from 1 to 15 psia propellers.
	Rotating Arm Basin	260 x 260 x 21 ft	85	
Newport News Shipbuilding and Dry Dock Company Newport News, Virginia	Towing Tank	56 x 8 x 4 ft		
	Water Tunnel	7 x 2? in. cross-section	21	
Northwestern University Evanston, Ill.	Towing Tank	70 x 6 x — ft		Wavemaker
Ordnance Research Lab. Pennsylvania State College, Penn.	Water Tunnel	48 in. diameter	80	
St. Anthony Falls Hydraulic Laboratory, University of Minnesota Minnesota, Minn.	Towing Tank	250 x 9 x 6 ft	25	Hinged plate wavemaker
	Water Channels (3)	10 x 3 x 5 ft	5	Low speed channel
		50 x 1.5 x 1.0 ft	45	High speed channel
		40 x 2.5 x 3.33	10	
	Water Tunnel	6 in. diameter	8-54	Pressure from 1 to 14.7 psia

TABLE 6-7 (CONCLUDED)

Name and Location	Type of Facility	Dimensions of Basin or Test Section (Length x Width x Depth)	Speed, fps	Remarks
University of Calif. Berkeley, California	Towing Tank	200 x 8 x 6 ft	6	Hydraulic paddle wavemaker can produce uniform regular or irregular waves.
University of Michigan Ann Arbor, Michigan	Towing Tank	360 x 21 x 9.5 ft	20	Plunger type wavemaker for uniform regular waves.
U. S. Naval Acadamy Annapolis, Maryland	Towing Tank	86 x 6 x 4 ft	20	Pneumatic wavemaker.
Webb Institute Glen Cove, N. Y.	Towing Tank	73 x 10 x 5 ft	16	Plunger type wavemaker for uniform regular or irregular waves.

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CHAPTER 7 DETAILED DESIGN

SECTION I HULL DESIGN

7-1 HULL LINES

A fundamental part of the hull design process is the development of the hull shape or lines. This part deals with the drawing of the hull lines, some of the considerations involved in selecting the shape, and the calculations required for support of the drawing process.

7-1.1 GENERAL DESCRIPTION AND EXPLANATION

The hull shape of an amphibious vehicle is rather complex so that a systematic method of describing it must be employed. To accurately delineate the hull shape, three sets of planes are used to slice the craft along three orthogonal axes. The three sets of planes are the buttock, section, and waterline planes.

The *buttock planes* cut the hull along its length and are parallel to a vertical plane.

The *section planes* cut the hull into transverse vertical slices. The section planes are rotated 90 deg from the buttock planes.

The last of the orthogonal set of planes are the *waterline planes* which cut the craft into horizontal slices, parallel with the baseline plane.

The intersection of the hull surface with each section plane is described by an outline on the cutting plane.

The composite drawing of the outlines from each successive cut of the section planes is called the body plan. Similarly, the half-breadth and profile plans are composite drawings of the outlines obtained by intersection of the hull and waterline planes and buttock planes, respectively.

The three drawings—body, half-breadth, and profile plans—are collectively called the lines drawing or often just the "lines", Fig. 7-1 is a lines drawing of the LARC V, showing the three plans.

In addition to the body, profile (or sheer), the half-breadth plan, it is customary for the lines drawing to contain a table of offsets. The offsets are the dimensions to the outside of the shell plating. These dimensions are given at each station for the distance of the intersection of each buttock plane with the shell above the base line and the distance of the intersection of each waterline plane with the shell from the centerline. The dimensions in the table of offsets in Fig. 7-1 are given in inches and tenths of inches. It is customary in naval architecture to give the offsets in feet, inches, and eighths of an inch and to give offsets to the inside of shell plating. This type of offset table may be encountered in the lines drawing of some wheeled amphibians.

It is customary in a lines drawing of a wheeled amphibian to label the section, buttock, and waterline planes with a dimension which is the distance from an appropriate reference plane. The reference plane for the section planes may be established at the extreme forward point (or aft point) of the hull. The reference plane for the buttock planes is the centerline plane. The reference plane for the waterline planes is an arbitrary baseline plane. In general the baseline plane is established on the hull bottom or keel.

7-1.1.1 Lines Fairing Procedure

The basic steps in drawing a set of lines are given in par. 6-4.5.3. These steps apply to the final lines as well as the preliminary lines and need not be repeated. The major difference is that the final lines are done to a larger scale and contain more section, buttock, and waterline planes for improved accuracy.

For the reasons given in pars. 7-1.2 through 7-1.2.4, the waterborne performance of a wheeled amphibian will be improved if the hull lines are fair. A fair line is one which is smooth and continuous, i.e., without rapid changes in the radius of curvature. A line which is fair in three different orthogonal projections will be fair in all projections. This is one of the reasons that three orthogonal sets of planes are used to describe the hull shape.

In developing a fair set of lines, the key is to produce lines that are geometrically correct as

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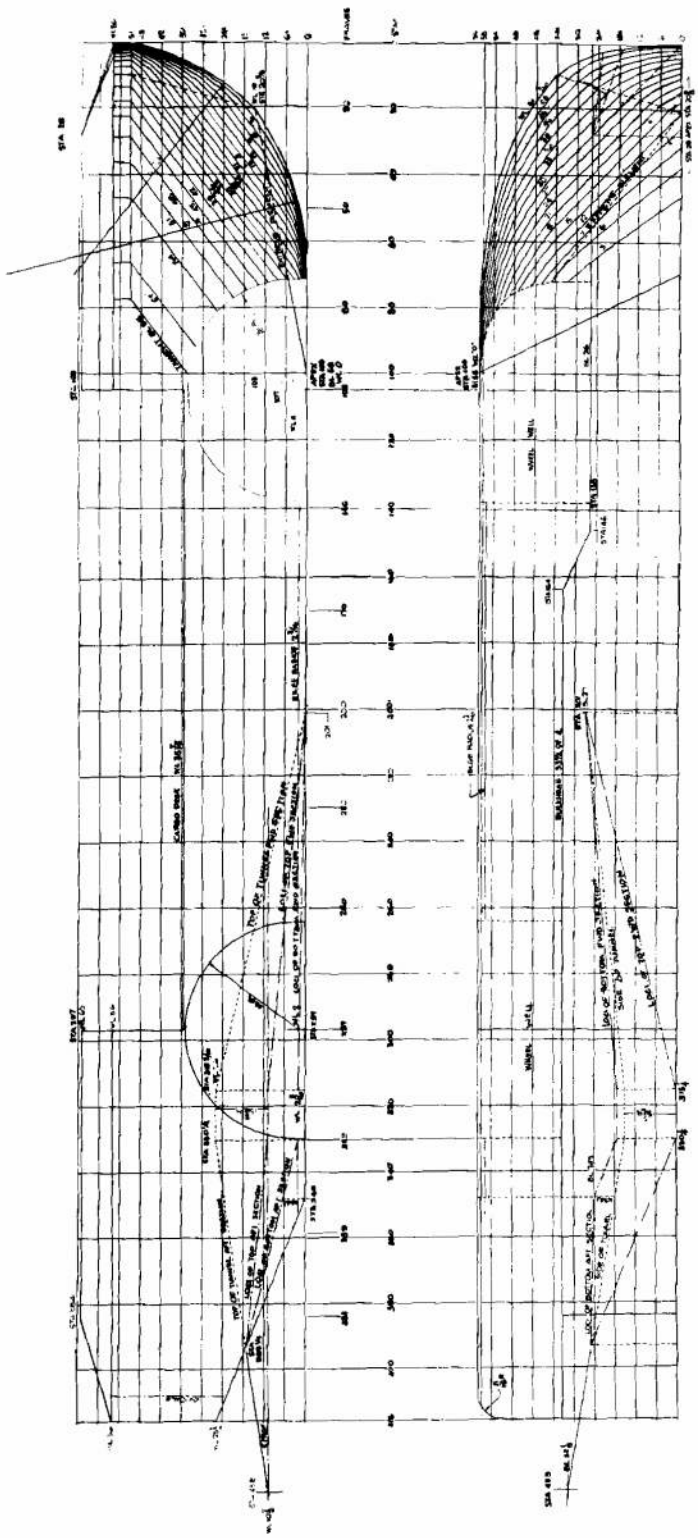
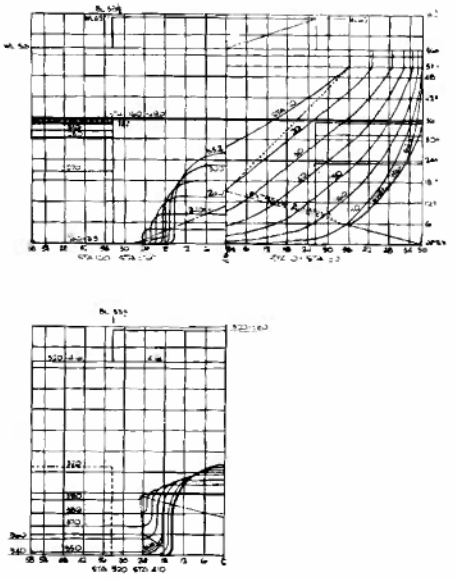


Figure 7-1. LARC V Lines Drawing (1 of 2)



BUTTOCK HEIGHTS AT STATIONS

STA	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
0	51.0																		
10	27.7	29.3	30.7	32.4	34.2	36.0	38.0	39.7	42.0	44.1	46.4	48.6	51.0						
20	15.6	18.0	20.3	22.5	25.0	27.2	29.6	32.0	34.3	36.5	39.0	41.2	43.6	46.4	49.5				
30	9.5	11.1	13.0	15.3	17.6	20.0	22.3	24.6	27.0	29.3	31.6	34.0	36.3	39.0	42.1	45.6	50.0		
40	5.2	5.7	6.7	8.3	10.3	12.5	15.0	17.3	19.6	22.0	24.3	26.6	29.1	31.7	35.0	38.5	42.6	48.0	
50	2.3	2.5	3.0	3.6	4.5	6.0	7.7	10.0	12.3	14.6	17.1	19.3	21.7	24.4	27.5	31.0	35.3	40.6	48.4
60	0.5	0.6	0.7	1.1	1.4	2.0	2.5	3.5	5.2	7.4	9.7	12.1	14.4	17.2	20.4	24.0	28.1	33.2	41.1
70	0.0	0.0	0.1	0.1	0.2	0.3	0.5	1.0	1.3	2.0	3.0	4.7	7.3	10.1	13.2	16.6	21.0	26.1	34.0
80																			26.2
90																			
100																			

HALF BREADTH AT WATERLINE

STA	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	56
0																			
10										4.2	9.6	14.4	19.5	23.7	28.1	32.0	36.0	36.0	36.0
20						3.2	6.6	10.5	14.5	18.3	22.2	26.0	30.0	33.7	37.3	40.4	43.3	43.3	43.3
30				4.3	8.4	12.3	16.1	20.1	24.0	27.6	31.5	35.4	39.0	41.7	44.3	46.5	48.5	48.5	48.5
40		3.2	9.7	14.1	18.0	21.7	25.5	29.4	33.2	37.0	40.1	42.7	45.3	47.4	49.3	51.0	52.3	52.3	52.3
50	5.4	15.1	19.5	23.4	27.3	31.2	35.0	38.4	41.5	44.2	46.4	48.3	50.1	51.4	52.6	53.7	54.7	54.7	54.7
60	19.1	25.1	28.7	32.6	36.4	39.6	42.4	45.0	47.2	49.1	50.6	52.1	53.2	54.2	55.0	55.6	56.4	56.4	56.4
70	29.7	34.3	37.6	40.6	43.4	45.7	48.0	49.6	51.3	52.5	53.5	54.4	55.2	55.7	56.4	57.0	57.5	57.5	57.5
80								53.1	54.2	55.0	55.5	56.0	56.5	57.1	57.4	57.6	58.0	58.0	58.0
90																			
100																			

SHOWN IN INCHES

Figure 7-1. LARC V Lines Drawing (2 of 2)

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well as fair. Geometrically correct means that all three views (the body, profile, and half-breadth planes) must represent the same hull surface. This requires that all intersection points among the three sets of orthogonal planes be consistent in all three views on the lines plan. For example, the distances from the centerline plane to the waterlines in the half-breadth plan measured at each section plane must be the same as the distances from the centerline plane to the sections in the body plan as measured at each waterline plane. Similar relationships must exist between the distances of the buttocks above the baseline plane in the profile plan and body plan, and between the distances of the intersections of waterlines and buttocks from the section planes in the half-breadth and profile plans.

It must be remembered that when a line is changed in any of the three views on the lines plan it must be corrected in the other views so that the geometric accuracy is maintained. Thus the development of a set of lines that is fair and geometrically accurate is an iterative procedure which requires many cycles. An easy way of rapidly checking the geometric accuracy between views is to mark a strip of paper with a tick mark at an intersection and at a reference plane in one view and then compare the marked distance on the paper strip with the distance from the reference plane to the intersection in another view. This takes less time and is more accurate than measuring the distances with a scale.

7-1.1.2 Developable Surfaces

7-1.1.2.1 Advantage of Developable Surfaces

If the hull is to be of metal, it is desirable that the final lines be developable. A developable surface is one which can be represented by the surface of a cone with a movable or fixed apex. A cylindrical surface is also developable. Plating for developable surfaces can be formed by relatively simple rolling techniques or cold bending in place over frames or jigs.

Accordingly, developable surfaces are used in metal hulls for simplicity of construction with resulting lower cost. Special shaping techniques necessary for more complex shapes are very costly, time-consuming, and require special equipment. Further, vehicles with developable surfaces can be repaired in shops which have minimal equipment.

7-1.1.2.2 Amphibian Hull Developable Surfaces

There are, essentially, only three surfaces on an amphibian hull which depart from the box-shape—the spoon-shaped bow which is the largest curved hull surface, the propulsor tunnel, and the corners.

The corners at the intersection of two flat plates can be simple circular arcs. The tunnel can be shaped as a combination of cylindrical and conical surfaces.

The bow of a wheeled amphibian can be made up of a combination of developable surfaces. The bow of the LARC V, illustrated in the profile and half-breadth plans of Fig. 7-1, is an example of this. The bow shape of the LARC V consists of four different developable surfaces—two cones, a flat, and a cylinder. The cones are located between the dotted lines (one is labeled EXTREME ELEMENT) and the centerline keel. The flat surface is located between the dotted lines, and buttock 39 in the profile plan. The cylindrical surface starts in the vicinity of buttock 39 and extends up to the sheer line (or deck at side).

In developing the bow surface, the designer is advised to begin with arbitrary elements similar to those in Fig. 7-1. Each of the surfaces—the two conical and one cylindrical—are developed independently. For example, when the two elements and other boundary for the flat are chosen, the three surfaces can be developed independently. Once the surfaces have been developed, body plans for the bow are obtained and compared with the body plan from the preliminary lines process. If the body plans do not agree, new elements and a new flat surface are chosen, the three surfaces developed again, and the resulting body plans compared. This is, quite obviously, a trial and error process.

7-1.1.2.3 Surface Development Procedures*

The first step is to draw the profile and half-breadth view of the bow and part of the parallel section through the cargo space. The waterline scale, which is the vertical scale in the profile plan, should be greater than the station and buttock scales. The purpose of this deliberate distortion of the profile plan serves to increase the curvature of the keel (and sheer line, in the case of vehicles with a boat-like sheer

* The major portion of this paragraph is reproduced from a paper by Kilgore, Ref. 1.

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line), thus making tangents easier to obtain. A similar distortion in the half-breadth plan may also be necessary.

A simple surface development scheme is described and three methods are outlined. The designer will find the first and third methods most often used for the amphibian bow development. The lines of a small boat are developed as an illustrative example.

The important properties of a developable surface are:

1. A developable surface may be depicted graphically by drawing the family of planes that are tangential to it.
2. Any tangential plane to the surface is also tangential to any curve lying in the surface and intersecting the line of tangency, or ruling.
3. Any plane found to be tangential to the surface at any point is unique.

These properties, as far as drawing is concerned, suggest the following constructional approaches:

1. Planes tangential to the surface should be found.
2. These planes are best found by using given curves already known to lie in the desired surface, such as chine, sheer, and profile centerline outline.
3. If any plane can be found to be tangential at a particular point, it is the unique plane tangential at that point and may be used with confidence.

The best means of illustration is a practical example. The example which follows gives the general procedure for the development of planes applicable to a lines drawing of a vessel with the following particulars:

Length (waterline) $LWL = 39.5$ ft
Displacement $\triangle = 15.57$ tons
Longitudinal center of buoyancy
$LCB = 0.53\ LWL$ abaft Station 0

A preliminary hull design drawing, meeting these requirements with straight line sections, is shown in Fig. 7-2. Sheet materials can hardly ever be applied to a hull of straight line sections, hence these sections must become suitably curved. The designer, with practice, will learn how to make allowances for this curvature in the preliminary design stage, so as to finally yield the required hull parameters.

The sides of the boat above the chine are not as easy to develop as the bottom below it. In Fig. 7-3 the hull drawing has been laid out,

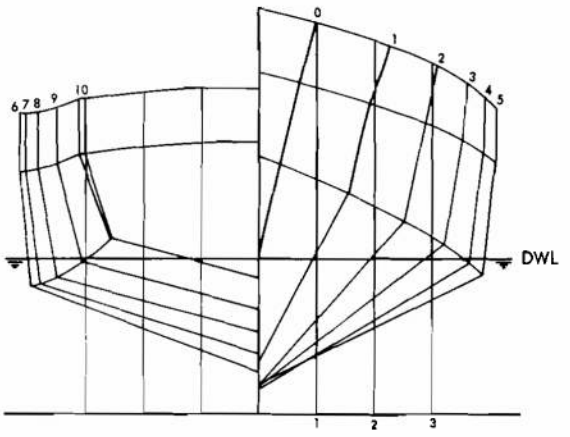

Figure 7-2. Preliminary Body Plan

foreshortened longitudinally, in half-breadth and profile. This is done because the main method of constructional drawing consists of locating various points by drawing tangents to curves at these points.

The side surface of the boat above the chine is obviously contained by two required curves, the sheer and chine lines, but some doubt exists at present whether a developable surface can be fitted to the straight stem line. As the sheer and chine lines are not simple curves, we cannot develop the surface by the simpler method that will be utilized on the bottom. The approach used is to draw a tangent to one curve and the plane generated is then swung until it comes into tangency with the other known curve. This is not difficult, as is shown by the following procedure:

1. Take a point P at the bow on the chine and, in both the half-breadth and profile, draw the tangents to the chine line passing through P.
2. From this tangent draw any line AB intersecting the sheer line in B at a reasonable intersection angle in profile and half-breadth view.
3. At suitable short intervals from this line, i.e., at C and E, draw the same lines parallel to AB in the profile and the half-breadth.
4. At the intersection of the lines through C and E, and the sheer line in the half-breadth plan are the points D and F.
5. Transfer these points to the profile giving curve BDF.
6. Define the point Q where the curve BDF cuts the sheer line.
7. Take the point P' at the midpoint of BQ.
8. Join P and P' giving the line of tangency

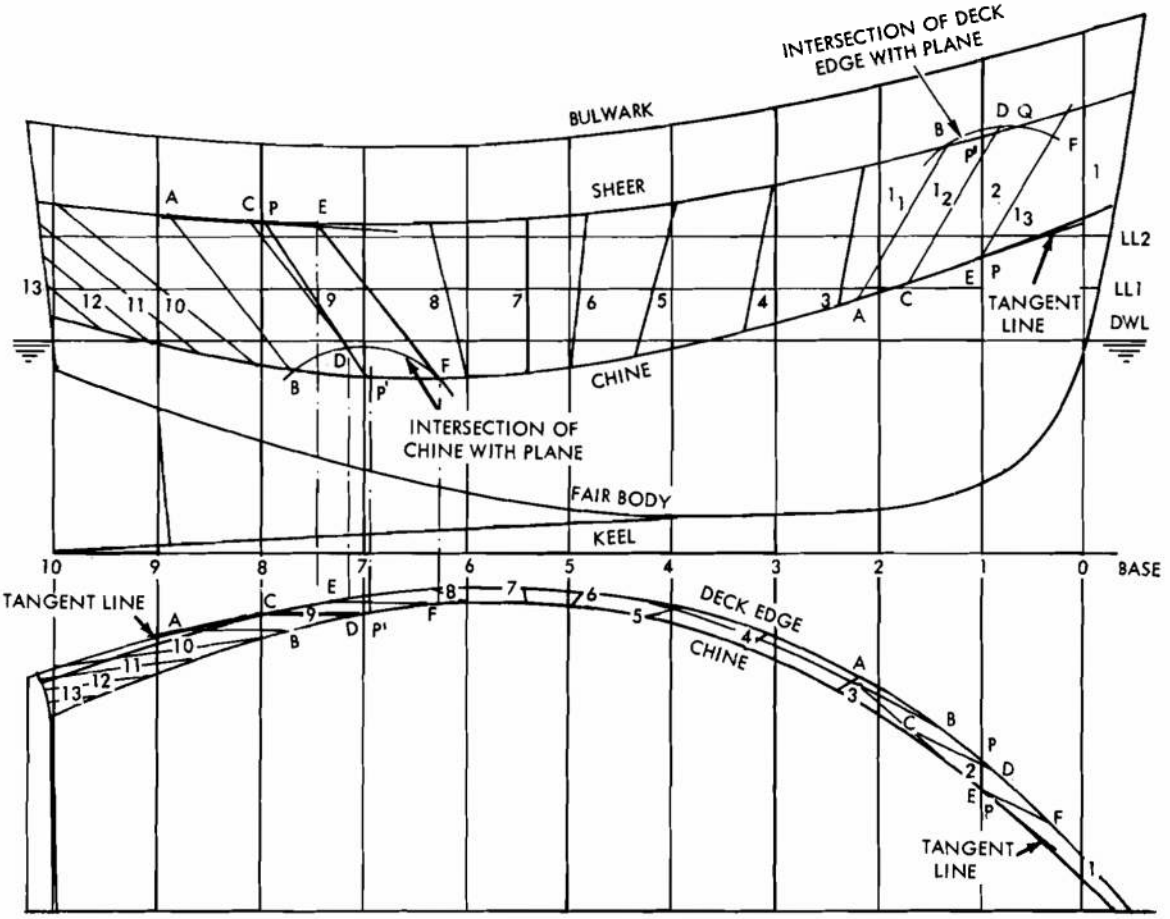

Figure 7-3. Development of Sides

(ruling) of the plane *PAB* with the side surface of the vessel.

An explanation of the above procedure follows: The line *ACE* is the tangent to the chine line at *P* in both views. Therefore, *PAB* gives a plane that is tangential to the chine and cuts the sheer line. If in profile this plane cuts the sheet line again at a second point adjacent to *B*, the plane must be almost tangential to the sheer line. To find this second point, we suppose the sheer line in the half-breadth to be the edge view of a cylinder. This cylinder cuts the plane *PAB* and because *AB*, *CD*, and *EF* lie in the plane *PAB*, the cylinder must cut the lines at the points *B*, *D*, and *F* and these lie, as already stated, on the sheer line in half-breadth. Therefore, the curve *BDF* in profile shows the intersection of the cylinder with plane *PAB* and coincides with the sheer line at *B* and the second point *Q*.

Now, if *PAB* is rotated about *PA*, it would become completely tangential to the sheer line approximately at the midpoint of *BC* at *P'* (osculating circle). The line *PP'* is, therefore, a line of tangency of a plane with the surface of the boat.

Another similar operation is illustrated farther aft. This time the initial tangent line is taken at the deck edge rather than on the chine. The sequence is the same as before: beginning at *P*, a tangent line to *A*; from *A*, on the tangent line, to *B* on the chine; parallel lines *CD* and *EF* to the chine in half-breadth plane. In profile, the lines are drawn initially from *C* and *E* parallel to *AB* without knowing where *D* and *F* occur on them. The locations of *D* and *F* in the profile view must be located by projecting them upwards from the lines in the half-breadth view. The curve *BDF* is the intersection of a cylindrical surface (of which the chine in this

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case is the edge view in half-breadth view. The curve *BDF* is the intersection of a cylindrical surface (of which the chine in this case is the edge view in half-breadth) with plane *PAB*. This curve intersects the chine at *B* and *F*, and therefore a slight rotation of *PAB* will bring it into tangency about midway between *B* and *F*, at *P'*. The line *PP'* is a line of tangency of a plane with the surface of the boat, shown as ruling number 9, Fig. 7-3.

The rest of the rulings on the side surface, shown in heavy lines and numbered 1 through 13, were obtained by the same procedure. The procedure will require approximately two hours. It should be noted that development of the planes was commenced in the half-breadth view. It could have been started in the profile view, letting the sheer or chine in that view represent the edge view of the cylinder, but then the cylinder would have intersected the plane almost perpendicularly, and the curve of intersection when projected on half-breadth would not be so well defined. With experience, the draftsman will initially select the view where the plane will be intersected at the most acute angle. Occasionally the two points of intersection of the plane with the given line will be too far apart, in which case it will be necessary to refine the accuracy by drawing a new plane closer to the point of tangency.

Development of the bottom is much simpler because the centerline curve lies entirely within a plane. Because of the foreshortening of the drawing, the resultant curvature of the lines makes points of tangency easier to find. The development of the surface near the bow is shown in Fig. 7-4. Ruling 2 is used as the example. The graphical construction follows:

1. In half-breadth draw tangent to chine line at *P* and project it forward to intersect with the centerline plane at *A*.

2. Transfer the point *P* to the profile and draw the tangent to the profile chine line through *P*.

3. Transfer point *A* from half-breadth to extended tangent line through *P* in profile giving the point *B*.

4. Through *B* draw tangent line to bow profile obtaining point *C*, giving the plane *PBC*.

The explanation of the above procedure follows: The intersection of the tangent with the centerline at *A* in the half-breadth must be in the same plane as the point *B* in profile. The line from *B* locates *C* and is tangent to the stem profile. Hence the tangential plane is complete in *PBC* because it is a plane tangential to two curves lying in a developable surface. Line *PC* is the unique line of tangency of *PBC* with the surface. Hence *PC* is ruling number 2. Rulings numbered 1, 3, and 4 are determined by the same method.

Beyond Station 4, a tangent to the chine will run off the drawing-board before it intersects the centerline, so that from this point a third method of development must be employed. The method used follows (Fig. 7-5):

1. Draw a line parallel with the centerline tangential to the chine line giving the point *P* in the half-breadth.

2. Transfer this point to the profile and draw the tangent to the chine line through *P*.

3. Still in profile, draw a line parallel to this tangent line to the chine, but tangential to the centerline outline giving the point *A*.

4. Join *PA* which is the ruling of the surface number 5.

This procedure is based on the theorem of parallel tangents already stated. Therefore, by the theorem, the tangent to the chine at a ruling of the surface through *P*, in the profile view, will be parallel to the centerline outline curve at the intersection of that ruling with the centerline outline.

Now referring to Fig. 7-2, note that bottom sections 8, 9, and 10 are parallel in the body plan. They are also parallel in all other views, and, therefore they define a cylindrical surface. Hence we do not have to develop the bottom abaft Station 8; this is already done.

To obtain the rulings 6 to 9, the following procedure is adopted:

1. Transfer the buttock lines 1, 2, and 3 to profile by using the height intersection from the body sections for sections 8, 9, and 10. Transfer the intersections of the buttocks and rulings 1, 2, 3, 4, and 5 in the half-breadth to the profile. Fit a spline to these points precisely, and draw the buttock lines in profile.

2. Draw parallel tangents to the buttocks and centerline profile line in profile; the points of tangency give the rulings.

3. Check that all points lie on straight lines in both views. This gives the points *BB'*, etc., and the rulings 6, 7, and 8.

This again is dependent on the parallel tangent theorem as buttocks and centerline

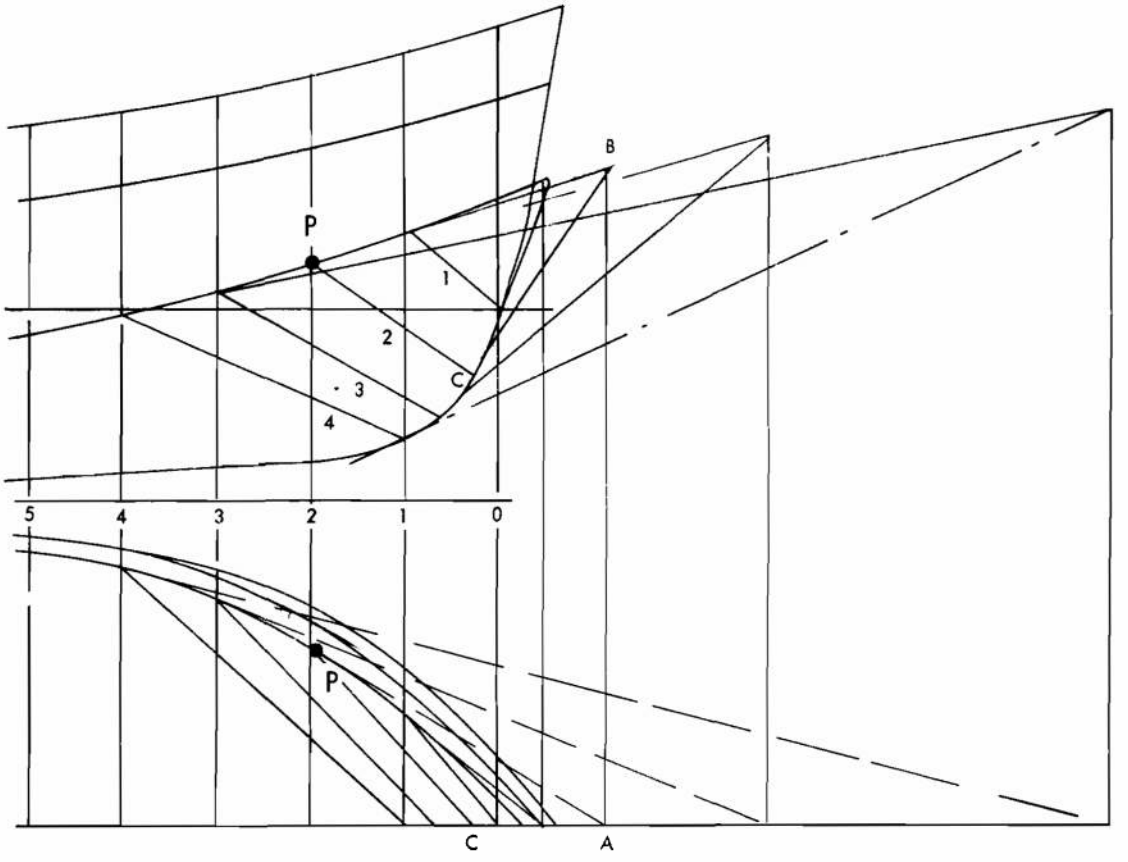

Figure 7-4. Development of Bottom by Intersecting Tangents

profile represent parallel planes. The gap between Station 8 and ruling number 5 is considerable, but the spline is held on at least three points at each side of the gap. It will fairly accurately describe the only fair line that can be drawn between these points. The balance of the bottom, abaft Station 8, of course, has already been found to consist of straight, parallel frames.

Developing the bottom should require a half hour. If it had been necessary, the same method could have been used on the bottom as on the sides, but faster and more accurate methods were available. The final lines are shown in the body plan, Fig. 7-6. This was obtained by transferring the new buttock lines on the stations from the profile and half-breadth shown in Fig. 7-5. The sections in the sides of the forward part of the boat are so nearly straight that the very slight curvature in them cannot be shown with the small scale on which these drawings were done. Almost any material, metal or otherwise, will have sufficient plasticity to accommodate slight deformation. The development of the bulwarks is not shown. In this case the top of the rail is drawn at a constant distance from the deck, and the bulwarks could be rapidly and accurately developed by the method of parallel tangents because over short distances the sheer and bulwark lines in profile can be considered straight lines.

The displacement, and the position of the longitudinal center of buoyancy have been altered, although not a great deal. If the exact specified particulars are desired, the designer should make provision in the preliminary plan for these predictable changes. The lines of chine, sheer, and outline are exactly the same as originally proposed.

7-1.2 WATERBORNE SPEED AND RESISTANCE CONSIDERATIONS

At the point in the design process that the

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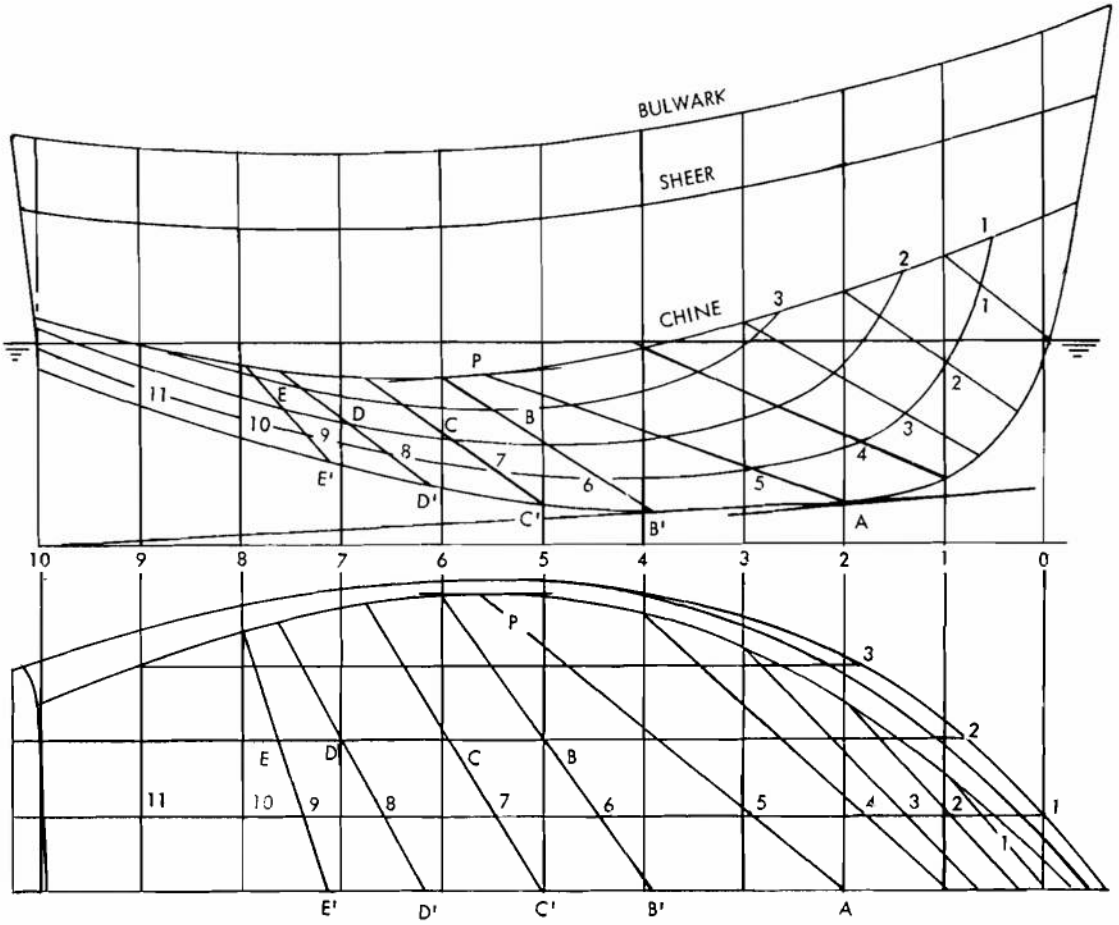

Figure 7-5. Use of Parallel Tangents

hull lines are drawn, the basic hull form requirements—such as dimensions, displacement, center of buoyancy, and general shape—will have been established. Within these constraints the details of the hull shape must be developed. The actual details of the shape depend on both hydrodynamic and hydrostatic considerations. The remainder of this paragraph on hull lines deals with the relationships between hydrodynamic and hydrostatic considerations and the details of the hull shape. It must be realized that many of these considerations conflict with one another so that compromises must be made on the basis of the designer's judgment and in light of the overall design objectives.

7-1.2.1 Hull Shape and Fairness

The basic area of the hull in which the designer has a range of shapes to choose from is at the bow. A review of Fig. 7-1, the figures in Chapter 3 showing conventional amphibian hulls, and the figures in Chapter 9 showing high-speed amphibian hulls indicates the variations possible. These can be divided into two basic types, i.e., the scow bow, as exemplified by the DUKW, and the faired or boat-type bow as exemplified by the LARC V. Par. 7-4.1.2.2 and Fig. 7-61 indicate the effect of bow form on the calm water resistance. It has been concluded from calm water model test data that the effect on calm water resistance is not large. It is expected that the bow shape will have a larger effect on rough water resistance and seakindliness. In these areas the faired bow should be superior to the scow shaped bow. However, there are no quantitative data available to evaluate the effects or suggest details of the shape. Experience with small boats indicates that for seakindliness, the bow should be given

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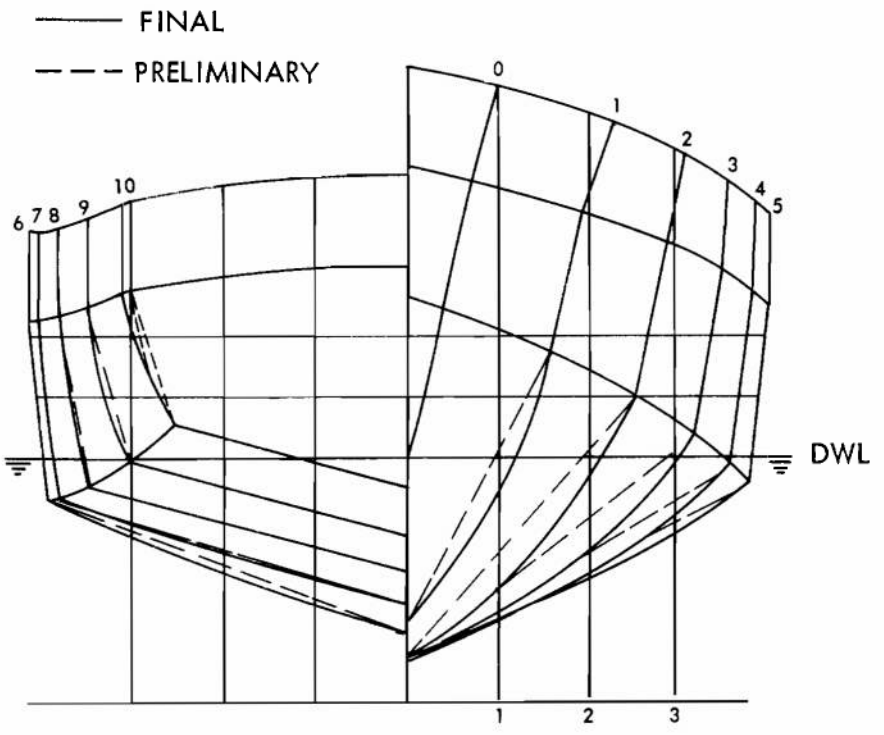

Figure 7-6. Final Body Plan

the maximum possible freeboard and flair and the minimum possible entrance angle. It is the opinion of one of the LARC V designers that the prototype LARC V, which had more flair and a smaller entrance angle than the production LARC V, shipped less water in head seas and was, generally, more seakindly.

The concept of a fair surface is presented in par. 7-1.1. By the absence of rapid changes in radius of curvature, the fair surface reduces the change of local flow separation or turbulence which results in the formation of eddies and increases the eddymaking component of the residuary resistance (see par. 7-4). Thus, it is desirable for the designer to provide a fair shape where possible.

7-1.2.2 Chines and Spray Strips

The requirements for internal volume and, in most cases, developable hull surfaces require that an amphibian hull be designed with chines. A chine can be defined as an intersection between two fair surfaces. Fig. 7-3 illustrates a typical chine on a small boat. Across a chine the hull is, of course, unfair and, as a result, flow across the chine may cause local eddymaking and increased resistance. Therefore, if possible, chines should be aligned parallel to the direction of the local flow. In many cases this will not be possible. In this event a sharp chine should be replaced with as large a radius as possible. The intersection of the hull side and bottom amidships in the LARC V lines shown in Fig. 7-1 is an example of such a condition. An exception to the idea of rounded chines occurs in the case of high-speed amphibians where a sharp chine will cause the flow to break away which reduces wetted surface.

A spray strip is often fitted to high-speed amphibians to "peel" the spray off the hull surface, reducing frictional drag. The spray strip can have a triangular or square cross section with sharp edges. A typical spray strip cross section and location are illustrated in Fig. 9-9. In practice the location of the spray strips is often determined by trial and error in model tests.

7-1.2.3 Wheels and Wheel Wells

As indicated in par. 7-4, the exposed wheels of a conventional amphibian are a major source

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of drag. This drag is basically a function of exposed frontal area so that little can be done to reduce it by altering hull shape. However, if possible, exposed projections on wheel rims and wheel ends should be faired or recessed into the hull. From considerations of resistance and stability, the wheel wells should be kept as small as possible. The minimum width is determined by clearance requirements for steering. Model tests of the LARC V hull arranged for 2- or 4-wheel steering with the same turning radius showed little difference in resistance. Radial clearance between the tire and wheel well is required to keep loose objects from being wedged between them. Experience with the LARC V indicates that it has been provided with about the minimum acceptable radial clearance.

7-1.2.4 Appendages

The major appendages on a wheeled amphibian are associated with the propulsion, steering, and suspension systems. The design of the appendages for the propulsion and steering systems are covered in pars. 7-7 and 7-9. The appendages involved with the suspension system can have a significant effect on the details of the hull shape. These appendages include items such as axles, wheel ends, and differential housings. In an amphibian with a rigid suspension, the only exposed item of this type will be the wheel ends and associated gear box. These should be recessed into the hull as far as possible or appropriately faired when exposed. In the case of an amphibian with a spring suspension system; exposed axles, differentials, or other appendages should be housed in hull recesses. This was done on the DUKW and found to significantly reduce the total resistance.

7-1.3 WATERBORNE PROPULSION CONSIDERATIONS

It is probable that any wheeled amphibian design propelled with a screw propeller will require a propeller tunnel. The function of the propeller tunnel is to provide inflow to a propeller that has been recessed into the hull for protection and to increase clearance on land. In conventional amphibians of the LARC series the propeller operates in the tunnel at all times; whereas in high-speed amphibians the propeller only operates in a tunnel during surf operations. In either case the highest possible propulsion efficiency is required, hence care is required in designing the tunnel.

From the standpoint of propulsion, the inlet section of the tunnel (i.e., from the forward end to the propeller) is most critical. For highest propulsive efficiency and minimum vibrations, it is desirable that the inflow to the propeller have a uniform velocity. It is important, therefore, that flow separation does not occur in the tunnel inlet section. In this respect the tunnel design problem is similar to that of diffuser, condenser scoop, water jet inlet, or air scoop design. Refs. 2 through 9 provide design information on this subject.

It is of value to consider experience with the LARC series tunnel designs since the propeller tunnel is not exactly analogous to the items covered in the references. Data on the LARC series tunnels are presented in Fig. 7-7. The most critical part of the tunnel inlet geometry is the inlet angle. If this angle is too large, flow separation will occur. The values of this angle in the LARC series ranged between 10.5 and 13.5 deg.

Ref. 10 indicates that for flush waterjet inlets the maximum angle should not exceed 15 deg. Every effort should be made in the tunnel design to keep the inlet angles below this value. If there is some compelling reason to increase the inlet angle, the design should be model tested to determine if separation exists and the form modified if necessary.

The LARC LX was the first of the series designed and was found to have significant propeller vibration. To solve this problem on the later LARC V and LARC XV designs, the sides of the inlet were opened transversely. This had the effect of increasing the tunnel volume and altering the tunnel inlet sectional area curve, as shown in Fig. 7-7. It is reported that the propeller induced vibrations of the LARC V and LARC XV are less than those of the LARC LX. Further information on tunnel design and the effects of propulsion requirements on hull shape is presented in par. 7-7.

7-1.4 WATERBORNE MANEUVERABILITY CONSIDERATIONS

The requirements for adequate maneuverability will have important effects on the hull shape in the area of the maneuvering device. The basic concepts and types of

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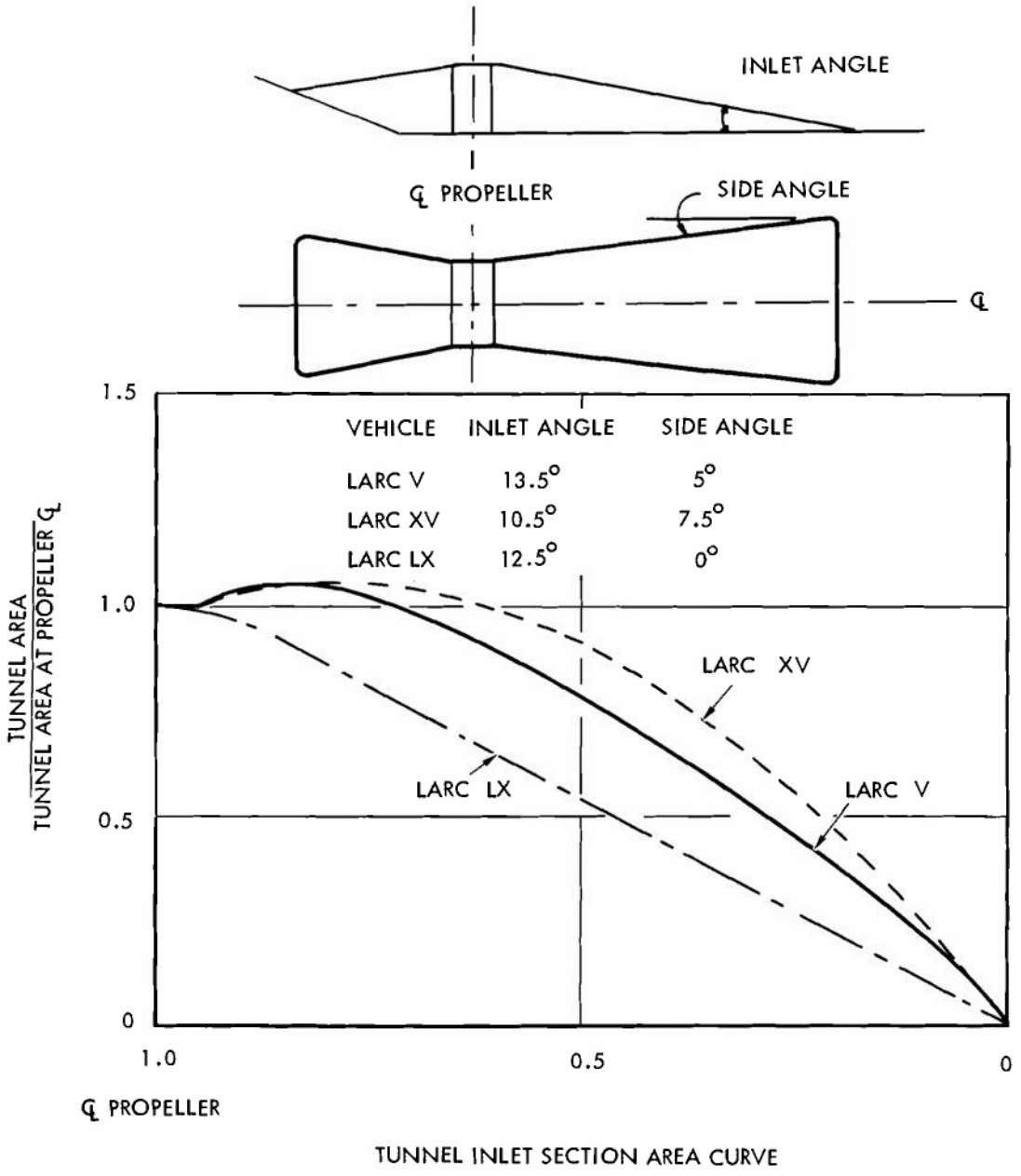

Figure 7-7. Wheeled Amphibian Tunnel Data

maneuvering devices are covered in detail in par. 7-9. In order to operate effectively; rudders, right angle propeller drives, and vertical axis propellers must have unrestricted inflow and outflow. In the case of a passive maneuvering device such as a rudder, adequate inflow is provided even at low speeds by placement in the propeller slipstream. Active maneuvering devices which rotate the propulsion thrust vector must be provided inflow according to the considerations covered in pars. 7-1.3 and 7-7.

Fig. 7-8 shows the interaction between rudder and tunnel. Outflow from the maneuvering device must be provided over the range of angles through which the slipstream is deflected. Any projection in the deflected slipstream may be

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expected to produce drag forces which will act against the turning forces. For this reason the sides of the propeller tunnel, aft of the propeller, are flared outward in all amphibian designs. The angle of the tunnel side with respect to the centerline ranges from 12 deg on the older LARC LX to 14 deg and 16 deg on the newer LARC V and LARC XV, respectively. The depth of the tunnel is rapidly reduced aft of the propeller on the LARC series by the cutaway of the hull required to produce an acceptable approach or departure angle.

The importance of opening up the propeller tunnel aft of the propeller is illustrated by the model tests of the LARC V reported in Ref. 11. A configuration was tested in which the tunnel sides were extended straight aft from the propeller by means of flaps. This had the effect of reducing the side force for maneuvers to 20 to 40 percent of that developed with diverging tunnel sides.

7-1.5 SEAKEEPING AND SURFING CONSIDERATIONS

To operate successfully in waves and surf, a wheeled amphibian must have adequate power, control or maneuverability, stability, and watertight integrity. These areas and their effect on hull shape are covered in pars. 7-1.4, 7-1.6, 7-4.1.2.4, 7-4.3.1, and 7-9.

7-1.6 BUOYANCY AND WATERBORNE STABILITY

Pars. 7-1.2 through 7-1.5 deal with the hydrodynamic considerations involved in the selection of the details of the hull shape. Of equal or greater importance in the development of the hull shape are the hydrostatic considerations of buoyancy and stability which are covered in the paragraphs which follow.

7-1.6.1 Buoyancy

Under conditions of equilibrium in calm water, the sum of the forces and moments acting on an amphibian are equal to zero. If no external forces are acting, this condition requires that the weight of the displaced fluid (buoyancy) be equal to the weight of the vehicle and that the center of buoyancy (the center of gravity of the displaced fluid) be located on a vertical line which passes through the center of gravity of the vehicle. For a given vehicle weight and center of gravity, the volume of the hull and all appendages must be such that these conditions are satisfied. This is accomplished by appropriately adjusting the hull shape.

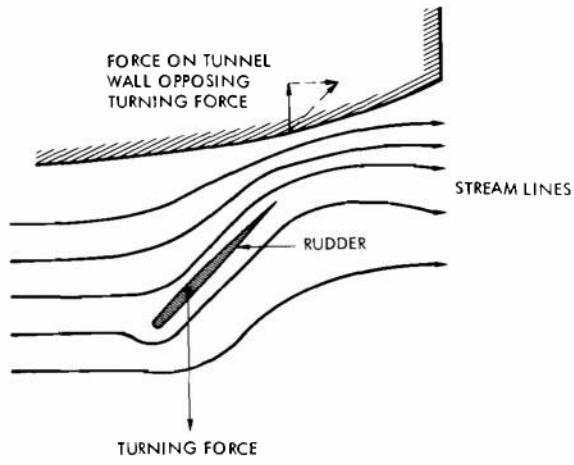

Figure 7-8. Interaction Between Rudder and Tunnel Walls

7-1.6.1.1 Calculation Procedures

In all studies of buoyancy and stability the basic requirement is the determination, by calculation, of the displaced volume and the center of this volume. The basic calculation procedure is one of integration. Linear dimensions from the lines drawing are integrated analytically, numerically, or mechanically to obtain areas which are integrated by the same procedures to obtain volume. In the event that the hull surface can be defined in terms of simple analytical expressions, the areas may be obtained by substituting the proper numerical limits into the expressions resulting from integrating the original analytical expressions. This is almost never possible because of the complex nature of the hull shape. As a result, it is necessary to use numerical or mechanical integration procedures.

Standard reference books on naval architecture such as Refs. 12, 13, and 14 present several numerical integration procedures. The one most commonly used is due to Simpson and is known as Simpson's rule. First the area under

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a curve of y, a function of x, is approximated by

$$\Phi = \int_o^{2h} y\,dx \approx \frac{h}{3}(y_0 + 4y_1 + y_2) \qquad (7\text{-}1)$$

where

Φ = area under the curve of y between $x = 0$, and $x = 2h$

h = 1/2 the distance between the limits of integration

$y_{0,1,2}$ = value of the function y at $x = 0$, h, and $2h$

Note: The units of Φ depend on the units of y and x. If x and y are both given in ft, then Φ is ft^2. If y is in ft^2 and x in ft, then Φ is ft^3.

Simpson's First Rule will give exactly the correct area if y may be expressed as a polynomial of x up to the third order (i.e., $y = a_0 + a_1x + a_2x^2 + a_3x^3$). It may be used to approximate the area under any curve if the interval h is made small enough so that a third degree polynomial can be made to closely approximate y over the interval 0 to $2h$. This is of special importance to buoyancy and stability calculations of an amphibian where discontinuities such as wheel wells may make the approximation of the local hull shape by a third degree polynomial poor. In these cases it is better to use a mechanical integrator or to pass a fair extension of the lines over the discontinuity and obtain the area under the faired curve. The area of the discontinuity can then be determined and subtracted from the area under the fair curve. An example of this procedure is given in Table 7-2.

The first moment of an area about the $x = 0$ axis is approximated by

$$M_x = \int_o^{2h} yx\,dx \approx \frac{h^2}{3}\left[(0)y_0 + (1)4y_1 + (2)y_2\right] \qquad (7\text{-}2)$$

The "longitudinal" center of the area is given by

$$\bar{x} = \frac{\int_o^{2h} yx\,dx}{\int_o^{2h} y\,dx} = \frac{M_x}{\Phi} \text{ (in units of } x) \qquad (7\text{-}3)$$

The first moment of an area about the $y = 0$ axis is approximated by

$$M_y = \int_o^{2h} \left(\frac{y^2}{2}\right)dx \approx \frac{h}{6}(y_0^2 + 4y_1^2 + y_2^2) \qquad (7\text{-}4)$$

The "vertical" center of the area is given by

$$\bar{y} = \frac{\int_o^{2h} \left(\frac{y^2}{2}\right)dx}{\int_o^{2h} y\,dx} = \frac{M_y}{\Phi} \text{ (in units of } y) \qquad (7\text{-}5)$$

These quantities are illustrated in Fig. 7-9.

Where the moment of an area is obtained using Simpson's Rule, caution must be observed with respect to the degree of approximation obtained with a third degree polynomial.

In most problems using Simpson's numerical integrations, more than three ordinates are used (i.e., y_0, y_1, and y_2) to break the curve into smaller intervals in order to achieve greater accuracy in the approximation. The technique to get the total area simply involves adding successive integrations of the type given in Eq. 7-1, thus:

$$\Phi = \int_o^{nh} y\,dx \approx \frac{h}{3}(y_0 + 4y_1 + 2y_2 + 4y_3 + 2y_4 + \ldots 2y_{n-2} + 4y_{n-1} + y_n) \qquad (7\text{-}6)$$

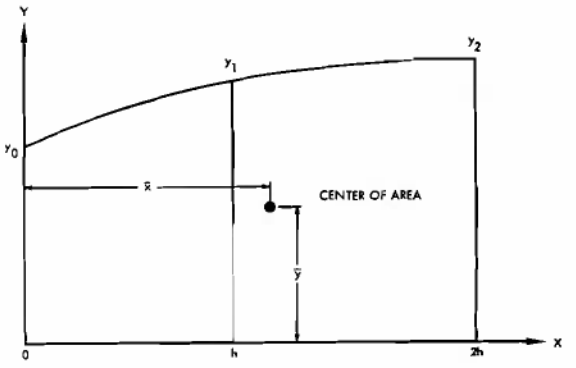

Figure 7-9. Definition Sketch for Area and Center of Area Using Simpson's Integration

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where

Φ = area under the curve of y between $x = 0$ and $x = nh$

n = number of equal intervals

h = length of the interval

y_i = value of y at $x = (i)h$

Note: There must be an odd number of ordinates so that n must be an even number.

Similarly,

$$M_x = \int_0^{nh} yx\,dx \approx \frac{h^2}{3}\left[(0)y_0 + (1)4y_1 + (2)2y_2 + (3)4y_3 + (4)2y_4 + \ldots (n-2)2y_{n-2} + (n-1)4y_{n-1} + (n)y_n\right] \quad (7\text{-}7)$$

and

$$M_y = \int_0^{nh} \left(\frac{y^2}{2}\right)dx \approx \frac{h}{6}\left(y_0^2 + 4y_1^2 + 2y_2^2 + 4y_3^2 + 2y_4^2 + \ldots 2y_{n-2}^2 + 4y_{n-1}^2 + y_n^2\right) \quad (7\text{-}8)$$

$\bar{x}$ and $\bar{y}$ are still given by Eqs. 7-3 and 7-5, respectively.

The area under a curve on a plane surface may be obtained mechanically using a polar planimeter. This is a simple instrument which measures an area on a plane surface by means of a mechanical polar integration. The theory, operation, and accuracy of polar planimeters are described in Ref. 15. The major advantage of using a planimeter instead of numerical methods for integration is in the possible time saving.

The procedure used to find the buoyancy and center of buoyancy of a hull's underwater volume with Simpson's integrations follows.

First, the sectional area up to the desired waterline is determined at each station, using Eq. 7-6. These areas are then used as the ordinates y_i in Eq. 7-6 with the station spacing = h, to find the displaced volume $\Phi = \nabla$. The buoyancy (force) is found by multiplying the volume by ρg where ρ is the mass density of the displaced fluid and g the gravitational acceleration. Values of ρg commonly used are 64.0 lb/ft^3 for sea water (sw) and 62.2 lb/ft^3 for fresh water (fw), with volume in cubic feet.

The longitudinal center of buoyancy *LCB* is calculated using Eqs. 7-3 and 7-7 in the same manner as for volume.

If it is desired to find the vertical center of buoyancy VCB first, the vertical center of area $\bar{y}$ at each station must be found using Eqs. 7-5 and 7-8. Then Eq. 7-8 is used again except that the terms $y_i^2/2$ are replaced by $y_i\bar{y}_i$ where y_i is the cross-sectional area at station i and $\bar{y}_i$ is the corresponding vertical center of area. The resulting volume moment is divided by the volume to find the vertical center of buoyancy.

An alternative procedure, also widely used, is quite similar. First the waterplane areas for several equally spaced waterline depths are found, and then these are integrated in the vertical direction to find the volume. *LCB* and *VCB* are found using analogous methods.

Finally, corrections are made to the displaced volume and center of buoyancy to account for wheel wells, wheels, and any appendages including shafts, struts, keels, skegs, rudders, propellers, and shrouds.

7-1.6.1.2 Curves of Form

The development of a hull shape that has the necessary buoyancy and center of buoyancy location is a trial and error process. A set of lines is drawn and then the buoyancy, center of buoyancy, and stability are calculated to determine if the equilibrium conditions are satisfied. If the resulting freeboard, draft, trim, or stability are unsatisfactory; the lines are modified and the calculations repeated.

To aid in this process, several sets of curves can be developed. The most useful of these are the Bonjean curves which are a graphical representation of the area of a hull station as a function of draft. As an example, Fig. 7-10 presents a set of Bonjean curves for a LARC V. These curves may be used to determine the buoyancy and longitudinal center of buoyancy location for a waterline at any trim angle.

As an example, in Fig. 7-10 the approximate full load waterline is indicated on the Bonjean curves. The resulting area below this waterline at each station is plotted in Fig. 7-11 as a sectional area curve. The area under this curve is the displaced volume of the hull. This volume, when multiplied by the density of water, is the hull buoyancy. The discontinuities in the sectional area curve are due to the wheel wells. It is important to note that to obtain the total

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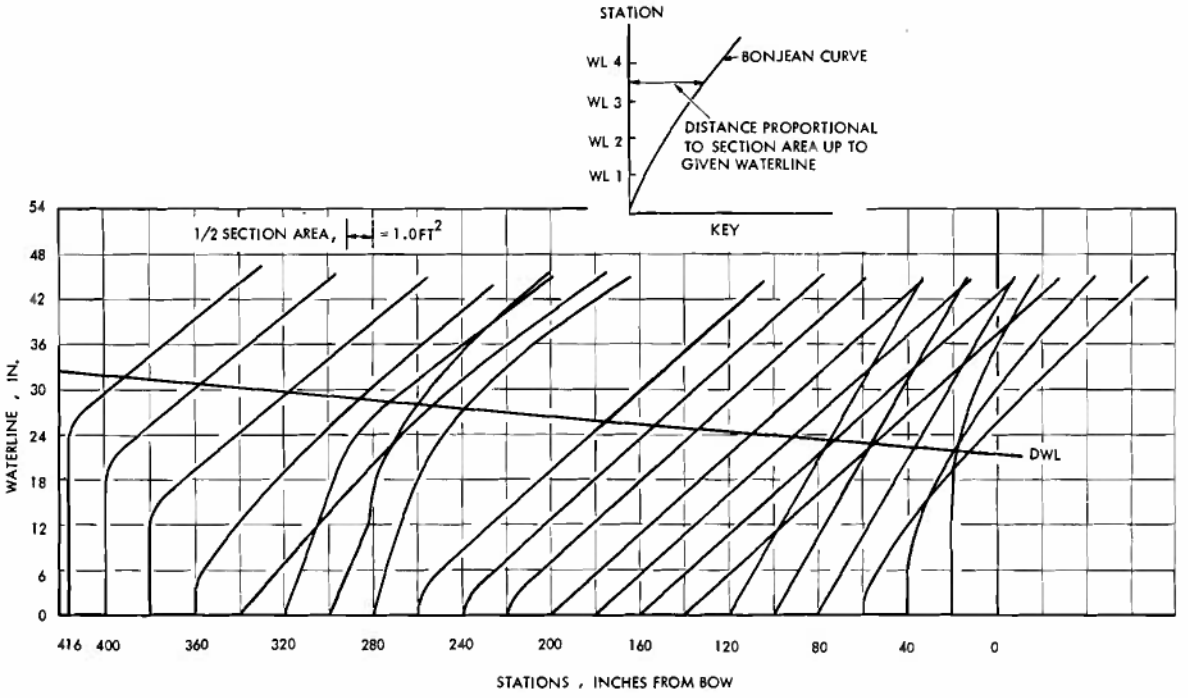

Figure 7-10. Bonjean Curves for LARC V

buoyancy of the amphibian, the displacement of the appendages and wheels must be added to that of the hull. For a LARC V, the wheels account for about 10 percent of the buoyancy.

In the design of a ship or a boat it is common to prepare other curves of form from the final lines. These curves include—as a function of draft—the displacement, wetted surface, vertical and longitudinal center of buoyancy, tons per inch immersion, moment to change trim, and transverse and longitudinal metacentric height. Many of these curves are not used directly in the design of an amphibian, hence, in general, a full set of curves of form is not prepared. Details of the method of calculation of these quantities are given in Refs. 12, 13, and 17.

7-1.6.2 Transverse Stability

A free body at rest and floating in still water is in equilibrium when the sum of all the forces and moments acting on the body are equal to zero. If the body is displaced slightly in any way, this state of equilibrium is (1) stable if the body returns to its original state; (2) neutral if it remains in the displaced position, and (3) unstable if it moves away from the original position. The transverse stability of an amphibian is generally associated with its response to roll, or heel, displacements. In the discussion which follows, stability is taken to mean transverse stability.

An amphibian can have more than one position of stable equilibrium, including one where the vehicle is capsized with the bottom up (if it will remain afloat in this condition). The normal position of stable equilibrium is upright or near upright. In the upright position, the centerline plane of the amphibian is perpendicular to the still water surface and the heel angle θ is defined as zero. It is possible that an amphibian has unstable equilibrium in the upright position due to the condition of cargo loading. In this case, the amphibian would list through a small angle until a position of stable equilibrium is reached.

7-1.6.2.1 Positive Stability

An amphibian has positive stability if the buoyant forces coupled with the weight forces act to return the amphibian to the upright position from a heeled position. The righting moment of a stable amphibian at some heel

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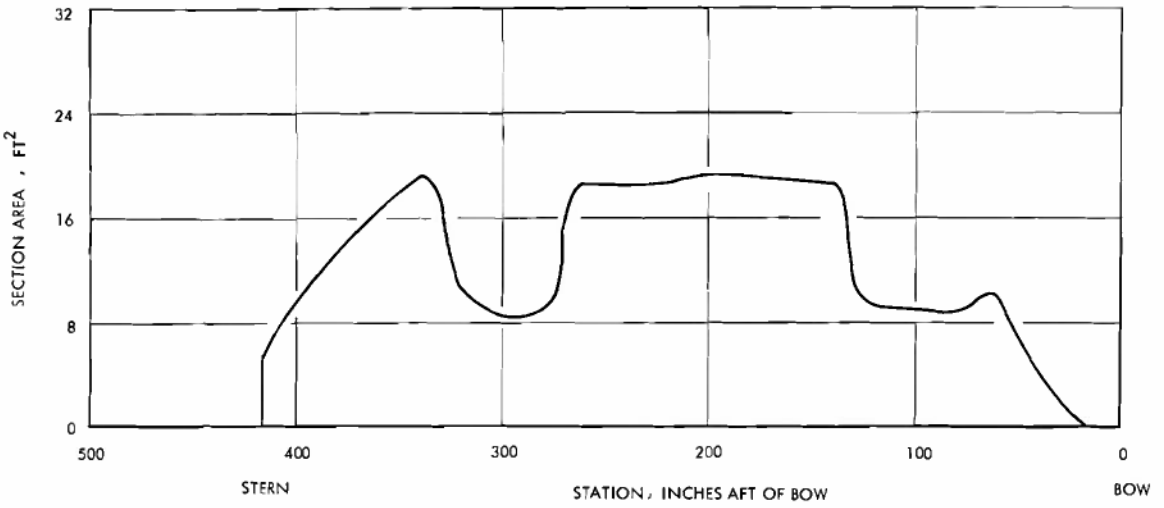


Figure 7-11. LARC V Hull Section Area Curve to Design Waterline

angle is shown in Fig. 7-12 and is equal to the displacement Δ times the righting arm GZ. The righting arm is a function of the heel angle θ and the shape of the hull. Fig. 7-13, a statical stability curve, shows a typical curve of righting arm GZ as a function of heel angle θ. GZ is normally zero at the upright position, increases to a maximum value with increasing heel, and then decreases through zero with further increase in heel.

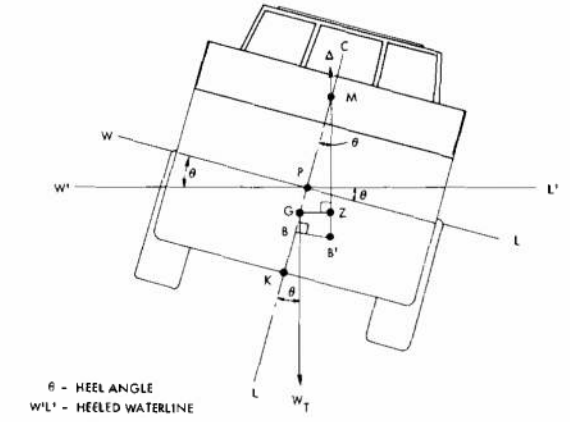
7-1.6.2.2 Range of Stability

The range of stability is defined as the range of heel angles to one side (port or starboard) over which the righting moment is positive, i.e., acts to return the amphibian to an upright position. This is indicated in Fig. 7-13 as the range over which GZ is positive. Experience indicates that an acceptable range of stability for a fully loaded amphibian with wheels lowered for landing on a beach is from 50 deg to 60 deg. The range of stability is important with respect to the amphibian's ability to operate in surf and heavy seas.

7-1.6.2.3 Dynamic Stability

Dynamic stability at any heel angle is defined as the work done to heel the amphibian to that angle. The dynamic stability can be calculated by integrating to find the area under the statical stability curve (see Fig. 7-13):

$$E_\theta = \frac{\Delta}{57.3} \int_o^\theta GZ d\theta, \text{ ft-lb} \qquad (7\text{-}9)$$



θ - HEEL ANGLE
W'L' - HEELED WATERLINE
WL - ORIGINAL WATERLINE
B' - HEELED CENTER OF BUOYANCY
B - ORIGINAL CENTER OF BUOYANCY
G - CENTER OF GRAVITY
K - BASELINE
CL - CENTERLINE
W_T - TOTAL WEIGHT, LB = Δ
Δ - DISPLACEMENT, LB = W_T
GZ - RIGHTING ARM
Δ x GZ - RIGHTING MOMENT = W_T x GZ
M - METACENTER
GM - METACENTRIC HEIGHT

THIS FIGURE APPLIES TO THE CASE OF SMALL HEEL ANGLES

Figure 7-12. Amphibian With Positive Stability

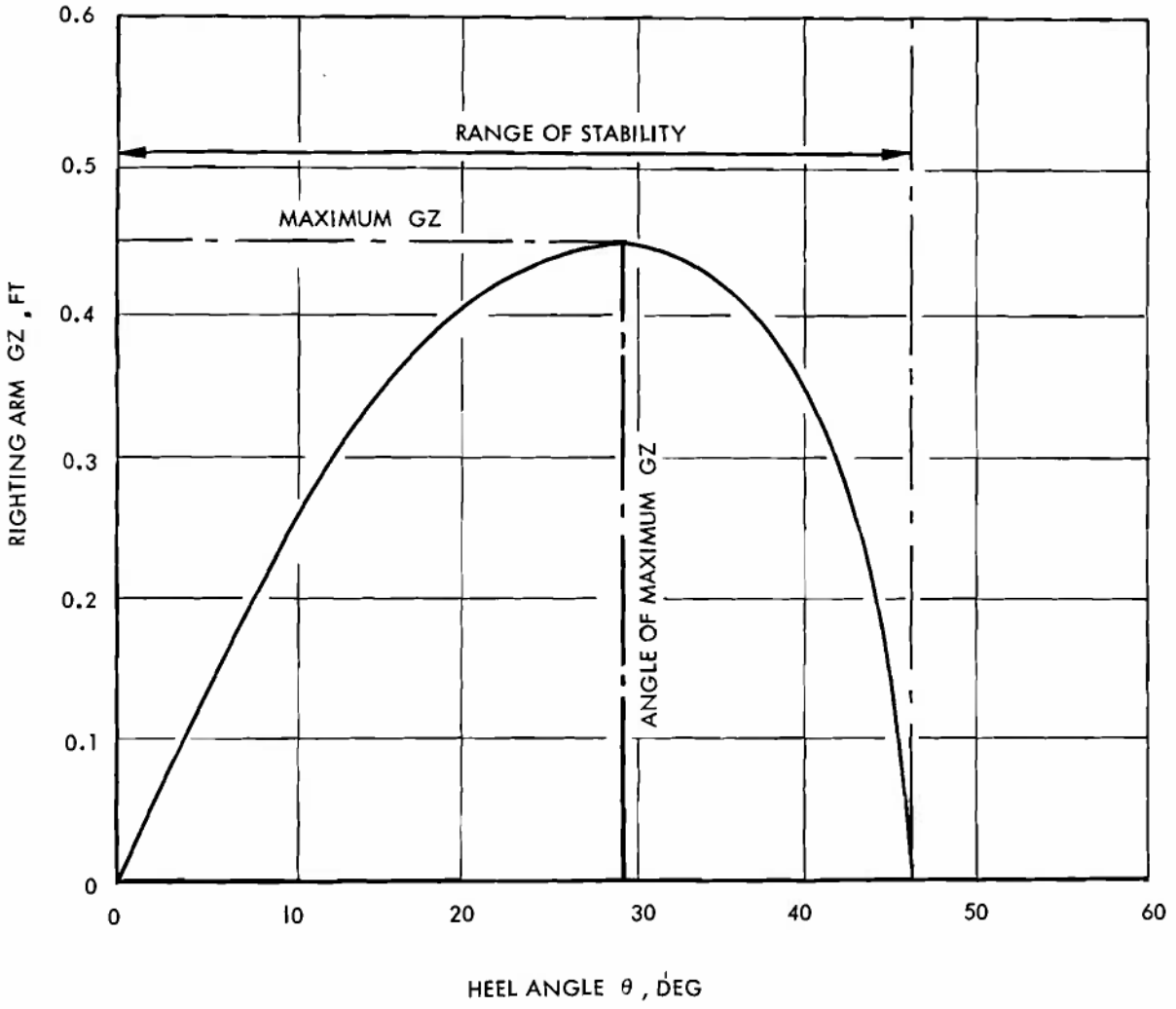


Figure 7-13. Statical Stability Curve

where

E_θ = the work to heel to θ, ft-lb
Δ = displacement, lb
GZ = righting arm, ft (a function of θ)
θ = heel angle, deg

Dynamic stability is rarely calculated for amphibian design, but may be used in investigations of motions in waves. A typical use of dynamic stability would be to calculate the heel that a ship would undergo to absorb the energy from the recoil of a large gun.

7-1.6.2.4 Cross Curves of Stability

The cross curves of stability are determined by calculating the buoyancy and center of buoyancy of the underwater volume at several waterlines for a constant heel angle. The righting arm is given by trigonometry:

$$GZ = CB \sin\theta - (KG - KB') \sin\theta, \text{ ft} \quad (7\text{-}10)$$

where

GZ = righting arm, ft
CB = transverse distance from centerline to center of buoyance B' (BB' in Fig. 7-12 for small heel angles), ft
KB' = perpendicular distance from B' to keel or baseline K (KB in Fig. 7-12 for small heel angles), ft

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KG = vertical distance to center of gravity from keel or baseline, ft
θ = heel angle, deg

The righting arm is plotted versus displacement for constant values of heel angles as in Fig. 7-14.

The cross curves of stability are useful for determining the statical stability curve at any desired displacement. Simpson's integration may be used to find the buoyancy and center of buoyancy. However, time may be saved by using simple mechanical methods such as Blom's Method or integrating planimeters. These methods are discussed in Refs. 12, 13, and 14.

7-1.6.2.5 Initial Stability

Initial stability is measured by the metacentric height GM, as in Fig. 7-12, for an infinitesimal heel angle $d\theta$. It may be defined as the slope of the statical stability curve at zero heel angle (Fig. 7-13):

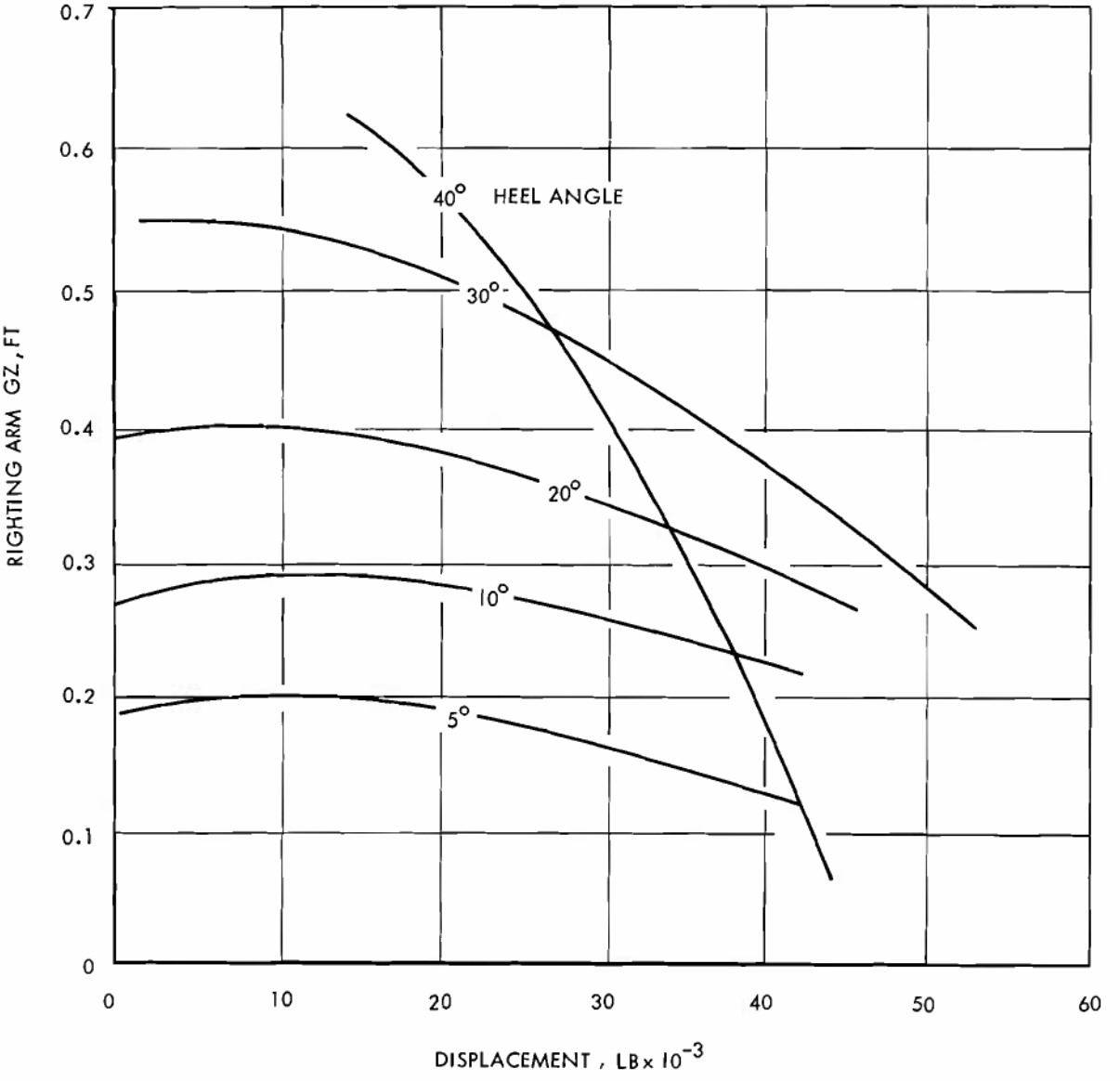

Figure 7-14. Cross Curves of Stability

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$$GM = \left.\frac{d(GZ)}{d\theta}\right|_{\theta \to 0}, \text{ ft} \qquad (7\text{-}11)$$

where θ is in radians.

M is the metacenter in Fig. 7-12. The metacentric height is positive when the metacenter lies above the center of gravity. Fig. 7-15 shows the righting arm curve for a vehicle with negative initial stability, i.e., the metacenter at zero heel angle lies below the center of gravity. This particular vehicle would be in stable equilibrium at a heel angle of 11 deg.

A criterion for initial stability, based on experience, is that the metacentric height is at least 0.18 times the beam.

7-1.6.2.6 Calculation of Initial Stability

The initial stability GM is found from simple geometry (Fig. 7-12):

$$GM_t = BM_t + KB - KG, \text{ ft} \qquad (7\text{-}12)$$

where

there are no free surface effects and the subscript t indicates the transverse metacenter

BM_t = vertical height of the transverse metacenter from the center of buoyancy, ft

KB = vertical center of buoyancy from keel or baseline, ft

KG = vertical center of gravity from keel or baseline, ft

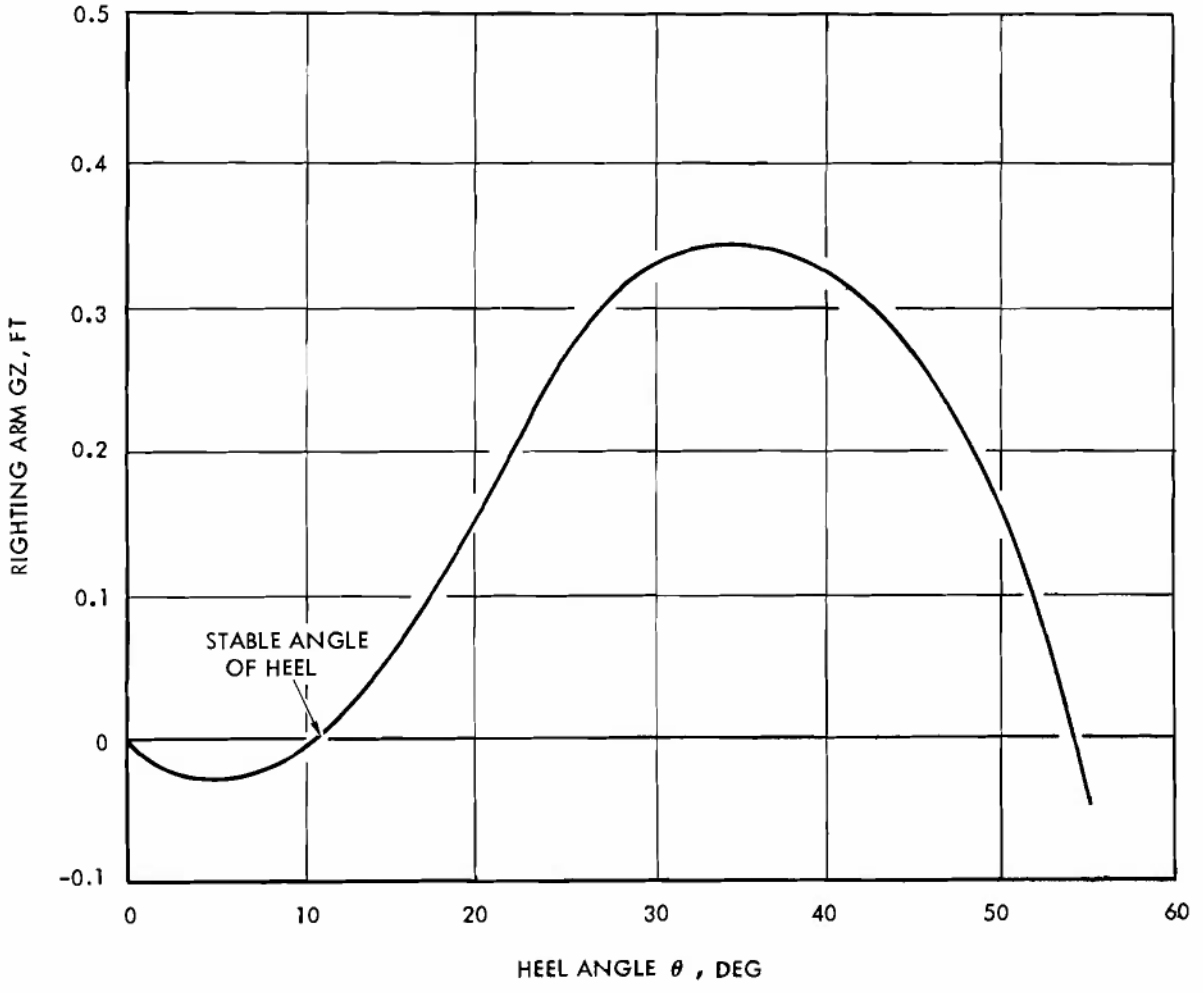

Figure 7-15. Statical Stability Curve, Initially Unstable Vehicle

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M_t = point M in Fig. 7-12

The only unknown at this time is BM_t.

Consider the transverse movement of the center of buoyancy from B to B' in Fig. 7-12 due to an incremental change $\Delta\theta$ in heel angle. The total underwater volume remains constant. However, a wedge of volume $L'PL$ extending from the bow to the stern has been immersed and a corresponding wedge WPW' has emerged. The area of wedge at any cross section is given by

$$\tfrac{1}{2}\, y(y \tan \Delta\theta),\ \text{ft}^2 \qquad (7\text{-}13)$$

where

y = the half-breadth of the amphibian at the waterline, ft

The distance between the centers of area of the immersed and emerged wedges is just 4/3 y, ft.

Integrating over the length of the amphibian, the moment of volume about the plane of symmetry is given by

$$2/3\ (\tan \Delta\theta) \int_o^L y^3\, dx,\ \text{ft}^4 \qquad (7\text{-}14)$$

Hence, the lateral shift in center of buoyancy CB is:

$$CB = 2/3 \left(\frac{\tan \Delta\theta}{\nabla}\right) \int_o^L y^3\, dx = \left(\frac{\tan \Delta\theta}{\nabla}\right) I_t,\ \text{ft} \qquad (7\text{-}15)$$

where

∇ = total underwater volume, ft^3

I_t = (transverse) moment of inertia of the waterline plane about its longitudinal centerline, ft^4

But,

$$BM_t = \frac{CB}{\tan \Delta\theta} = \frac{I_t}{\nabla},\ \text{ft} \qquad (7\text{-}16)$$

Finally,

$$GM_t = \frac{I_t}{\nabla} + KB - KG - \sum \left(\frac{i\rho_t}{\nabla \rho_s}\right) C_{f_s},\ \text{ft} \qquad (7\text{-}17)$$

where

$\sum \left(\frac{i\rho_t}{\nabla \rho_s}\right) C_{f_s}$ = sum of reductions in metacentric height due to free surface effects discussed in par. 7-1.6.3, ft

The importance of waterplane area inertia I_t and vertical center of gravity KG to transverse stability is apparent from this equation.

An example calculation of transverse stability is presented. Volume ∇, vertical center of buoyancy KB, and waterplane inertia I_t are found by using Simpson's integrations. The data presented are for the LARC V.

Full load displacement and vertical center of buoyancy calculation: Eqs. 7-3, 7-6, and 7-7 are used where:

x = waterline height from baseline, ft

y = ½ area of waterplane at x, ft^2

h = 0.25 ft

n = 10

Summation of the data is presented in Table 7-1.

Since ½ areas are used, Eq. 7-6 is doubled to find the total volume:

$$\nabla = \frac{2}{3}\, h\, \Sigma 1 = \frac{2}{3}\ (0.25)\ 2581.1 \quad \text{(read } \Sigma 1 \text{ from Table 7-1)}$$

$$= 430\ \text{ft}^3$$

or

$$\Delta = 430 \times 64.0 = 27{,}600\ \text{lb (sw*)}$$

* salt water

Eq. 7-7 must also be doubled to find the volume moment about the baseline:

$$M_x = \frac{2}{3}\, h^2\, \Sigma 2 = \frac{2}{3} (0.25)^2\ 13381 \quad \text{(read } \Sigma 2 \text{ from Table 7-1)}$$

$$= 557\ \text{ft}^4$$

Eq. 7-3 yields

$$KB = \frac{M_x}{\nabla} = \frac{557}{430} = 1.29\ \text{ft}$$

A correction for buoyancy of tires is now made:

TABLE 7-1 SIMPSON'S INTEGRATION FOR FULL LOAD DISPLACEMENT AND KB

1	*2*	*3*	*2 X 3*	*4*	*2 X 3 X 4*
Waterplane, in.	*1/2 Area, ft²*	*S.M.**	*Product*	*Step*	*Moment*
0 (Baseline)	0	1	0	0	0
3	69.8	4	279.2	1	279.2
6	79.4	2	158.8	2	317.6
9	85.4	4	341.6	3	1024.8
12	92.6	2	185.2	4	740.8
15	97.4	4	389.6	5	1948.0
18	103.7	2	207.4	6	1244.4
21	121.0	4	484.0	7	3188.0
24	106.8	2	213.6	8	1708.8
27	71.9	4	287.6	9	2588.4
30	34.1	1	34.1	10	341.0
			Σ1 = 2581.1		Σ2 = 13381.0

**S. M. = Simpson multiplier*

Tire size = 18 X 25

Approximate as torus r_{max} = 19 in., r_{min} = 7 in. (from tire manufacturer)

Volume per tire $= 2\pi^2 \, r_{min}^2 \, r_{max}$

$= 2\pi^2 \left(7^2\right) 19$

$= 18{,}350 \text{ in.}^3$

$= 10.6 \text{ ft}^3$

KB, fwd = 4 in.
KB, aft = 2 in.
} Added Moment $= 4\left(\frac{3}{12}\right)10.6 = 10.6 \text{ ft}^4$

Total volume $\nabla = (4)10.6 + 430 = 472 \text{ ft}^3$

$\Delta = 30{,}200$ lb (sw)

Total $M_x = 557 + 10.6 = 568 \text{ ft}^4$

Final $KB = \frac{568}{472} = 1.20$ ft

The waterplane inertia I_t must be calculated in steps due to the complex shape of the LARC V hull. A Simpson's integration is used for smoothly faired approximation of the waterplane area. Wheel well cutouts and the contribution of the tires are treated as corrections.

A form of integration similar to Eq. 7-8 is used for

$$I_t = \frac{2}{3}\int_o^L y^3 \, dx$$

where y is the half-breadth at the full load waterline, ft. The station spacing h = 20/12 ft. Summation of the data is presented in Table 7-2.

The transverse moment of inertia I_t is given by

$$I_t = \frac{2}{3}\left(\frac{h}{3}\right)\Sigma 3 = \frac{2}{9}\left(\frac{20}{12}\right)5571 \text{ (read } \Sigma 3 \text{ from Table 7-2)}$$

$= 2060 \text{ ft}^4$

Wheel well cutouts:

Forward, 32 in. wide X 52 in. long with center 41 in. from centerline

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TABLE 7-2 SIMPSON'S INTEGRATION FOR I_t AT FULL LOAD DISPLACEMENT

1	*2*	2^3	*3*	3×2^3
Station	*Half-breadth, ft*	$(HB)^3$	*S. M.**	*Product*
0	0.0	0.0	1	0.0
20	0.75	0.42	4	1.68
40	2.25	11.40	2	22.8
60	3.58	45.85	4	183.4
80	4.25	76.75	2	153.5
100	4.50	91.125	4	364.5
120	4.83	112.68	2	225.36
140	4.83	112.68	4	450.72
160	4.83	112.68	2	225.36
180	4.83	112.68	4	450.72
200	4.83	112.68	2	225.36
220	4.83	112.68	4	450.72
240	4.83	112.68	2	225.36
260	4.83	112.68	4	450.72
280	4.83	112.68	2	225.36
300	4.83	112.68	4	450.72
320	4.83	112.68	2	225.36
340	4.83	112.68	4	450.72
360	4.83	112.68	2	225.36
380	4.83	112.68	4	450.72
400	4.83	112.68	1	112.68
				$\Sigma 3 = 5571.12$

**S. M. = Simpson multiplier*

Aft, 24 in. wide × 38 in. long with center 46 in. from centerline

Tires:

Assume waterplane geometry to be 10 in. wide × 20 in. long rectangles 54 in. from centerline

$$I_{correction} = -\left[\frac{1}{12}\left(\frac{32}{12}\right)^3\left(\frac{52}{12}\right) + \left(\frac{32}{12}\right)\left(\frac{52}{12}\right)\left(\frac{41}{12}\right)^2\right] \text{(2), front wheel wells}$$
$$-\left[\frac{1}{12}\left(\frac{24}{12}\right)^3\left(\frac{38}{12}\right) + \left(\frac{24}{12}\right)\left(\frac{38}{12}\right)\left(\frac{46}{12}\right)^2\right] \text{(2), aft wheel wells}$$
$$+\left[\frac{1}{12}\left(\frac{10}{12}\right)^3\left(\frac{20}{12}\right) + \left(\frac{20}{12}\right)\left(\frac{10}{12}\right)\left(\frac{54}{12}\right)^2\right] \text{(4), tires}$$

$$= -284 - 190.6 + 112.8$$
$$= -361.8 \text{ ft}^4$$

$$I_{t_{final}} = I + I_{correction}$$
$$= 2{,}060 - 362$$
$$= 1{,}698 \text{ ft}^4$$

$$BM_t = I_t / \nabla = 1{,}698/472 = 3.60 \text{ ft}$$

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The weight and center of gravity of the LARC V are found using the weight summaries of the amphibian. The center of gravity and the weight of the cargo may be estimated.

By taking moments of the two about the baseline, the KG of the loaded amphibian may be calculated:

Item	Weight, lb	Arm, ft	Moment
Light weight	20,200	2.14	43,200
Cargo	10,000	4.62*	46,200
	ΣW=30,200		ΣM=89,400

* Note cargo center assumed 20 in. above deck.

$$KG = \frac{\Sigma M}{\Sigma W} = \frac{89,400}{30,200} = 2.96 \text{ ft}$$

Finally the initial stability, neglecting free surface corrections, may be calculated:

$$GM_t = BM_t + KB - KG$$

$$= 3.60 + 1.20 - 2.96$$

$$GM_t = 1.84 \text{ ft}$$

7-1.6.2.7 Heeling Forces

There are a number of forces which tend to heel an amphibian including those due to wind, waves, movement of personnel, shifting of cargo, propeller torque, and maneuvering. The discussion which follows will apply only to those forces which may be treated statically to predict equilibrium conditions.

The heeling moment caused by lateral movement of cargo, personnel or other items is given by:

$$\text{Heeling Moment} = Wa\cos\theta, \text{ ft-lb} \qquad (7\text{-}18)$$

where

W = weight of shifted item, lb
a = transverse movement of item's center of gravity, ft
θ = heel angle, deg

In case the cargo is loaded or removed, the heeling moment is given by Eq. 7-18 where a is the transverse distance between the cargo center of gravity and the amphibian's centerline.

The rudder or any other steering device produces turning moments from force components in the transverse direction. At the same time a heeling moment is produced:

$$\text{Heeling Moment} = \Sigma F_t a, \text{ ft-lb} \qquad (7\text{-}19)$$

where

ΣF_t = sum of the transverse components of the hydrodynamic forces, lb
a = vertical arm between the center of forces and the vehicle CG, ft

In a steady turn, the centrifugal force at the vehicle CG is equal to the centripetal force at the center of lateral hydrodynamic pressure. The heeling moment is equal to the centrifugal force times the vertical arm between the CG and the lateral center of pressure of the underwater body:

$$\text{Heeling Moment} = \left(\frac{mV^2}{R}\right)a, \text{ ft-lb} \qquad (7\text{-}20)$$

where

m = vehicle mass = Δ/g, slug
V = linear speed in turn, ft/sec
R = radius of turn, ft
a = vertical arm, ft

The center of pressure may be assumed as the center of the projected area of the profile below the waterline at rest.

A heeling moment is applied to the amphibian by the propeller. This moment is just equal to torque transmitted by the propeller shaft and acts in the direction opposite to the propeller rotation.

The heel angle resulting from any of these moments is determined from statical stability curves. In many cases, the heeling moment is a function of heel angle. For instance, the center of pressure on the underwater portion of the hull in a turn depends on the hydrodynamic flow over the hull, hence, on the radius of turn and on heel angle. The heeling moment may be resolved into a heeling arm by dividing by the amphibian's displacement. This heeling arm may then be plotted with the statical stability curve. The point at which the two curves cross is the equilibrium position, i.e., the heeling arm is equal to the righting arm as in Fig. 7-16.

7-1.6.2.8 Stability Criteria

No suitable theory for predicting the forces acting on an amphibian in surf is available at this time. In the past, criteria for adequate stability of amphibians have been limited to simple requirements on range of stability and initial stability based on experience. Some additional stability criteria, taken from Ref. 16, are presented here. The criteria were established as guidelines for U.S. Navy ships and may prove useful for future amphibian designs. These criteria may be used to assure that adequate reserve stability is provided when the amphibian is heeled over due to any of the types of forces presented in par. 7-1.6.2. See also Ref. 17.

The worst probable heeling condition should be calculated whether this be caused by poor location of the cargo, high-speed turns, or any other likely situation. The suggested criteria for adequate stability in this condition are (Fig. 7-16):

a. The steady heel angle does not exceed 15 deg

b. The righting arm at the steady heel angle does not exceed 60% of the maximum value of righting arm.

c. The reserve dynamic stability represented by the shaded area in the figure is not less than 40% of the total area under the righting arm curve.

The reserve stability indicated by these criteria is required to provide a margin against capsizing due to the possible concurrence of more than one of the conditions that have been discussed, including the effects of wind and wave actions. It should be noted that the amphibian is subject to capsize if the heeling arm should exceed the maximum righting arm or if the heel angle should exceed the range of stability.

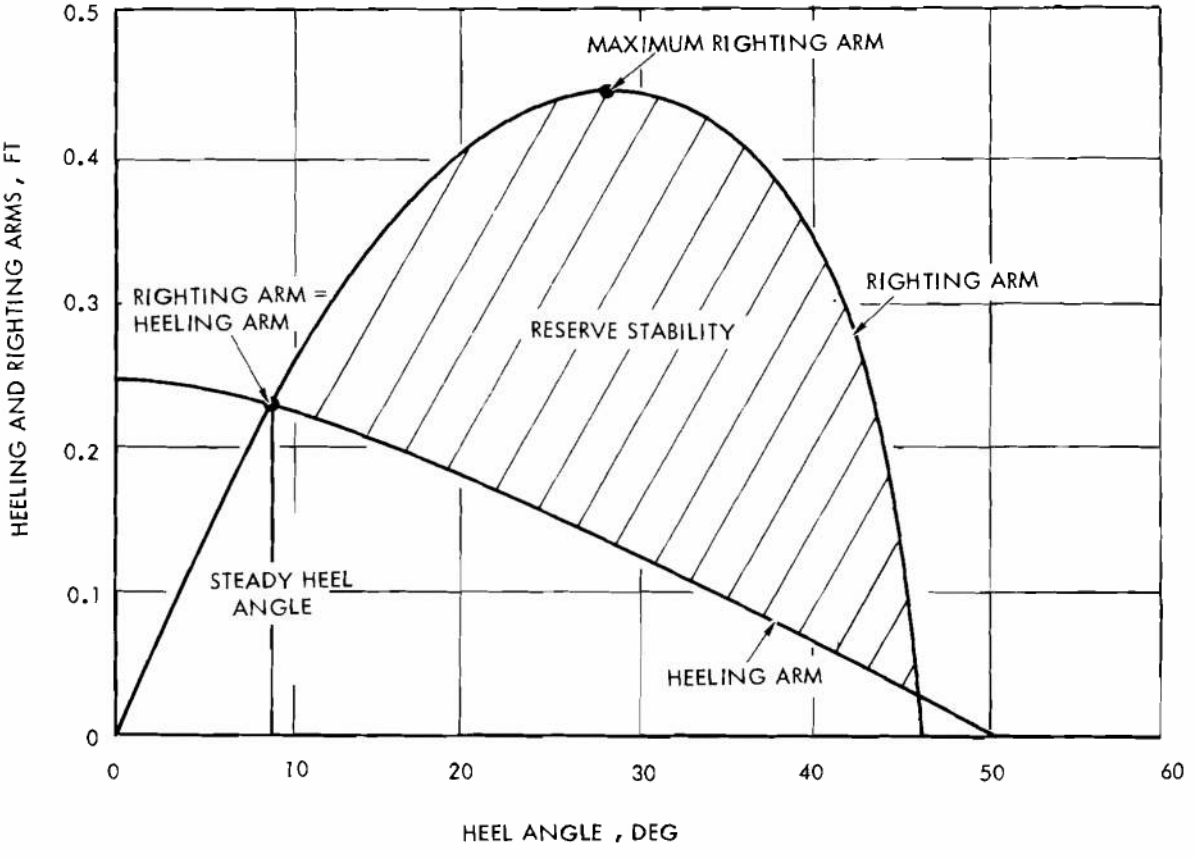

Figure 7-16. Stability Criteria

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7-1.6.2.9 Grounded Stability

Coming ashore through surf and waves, an amphibian may drive onto a shoal, reef, or ledge, thereby grounding. Grounding results in a virtual rise in the center of gravity and may seriously degrade its transverse stability. The virtual or effective center of gravity is given by:

$$KG_v = \frac{KG(\Delta) + QK(F)}{\Delta - F}, \text{ ft} \qquad (7\text{-}21)$$

where

KG = height of center of gravity above baseline, ft
Δ = amphibian displacement, lb
F = grounding force, lb
Q = intersection of the grounding force vector with the amphibian centerline plane
QK = height along centerline from Q to the baseline, ft

Subscript v denotes virtual or effective value.

The virtual displacement of the grounded amphibian is

$$\Delta_v = \Delta - F, \text{ lb} \qquad (7\text{-}22)$$

For a free floating amphibian at small heel angle (Fig. 7-11)

$$\text{Righting Arm } GZ = GM \sin\theta, \text{ ft} \qquad (7\text{-}23)$$

and

$$\text{Righting Moment} = GZ\,(\Delta), \text{ ft-lb} \qquad (7\text{-}24)$$

Similarly, for a grounded amphibian (Fig. 7-16)

$$\text{Righting Arm } G_vZ_v = G_vM' \sin\theta, \text{ ft} \qquad (7\text{-}25)$$

and

$$\text{Righting Moment} = G_vZ_v(\Delta_v), \text{ ft-lb} \qquad (7\text{-}26)$$

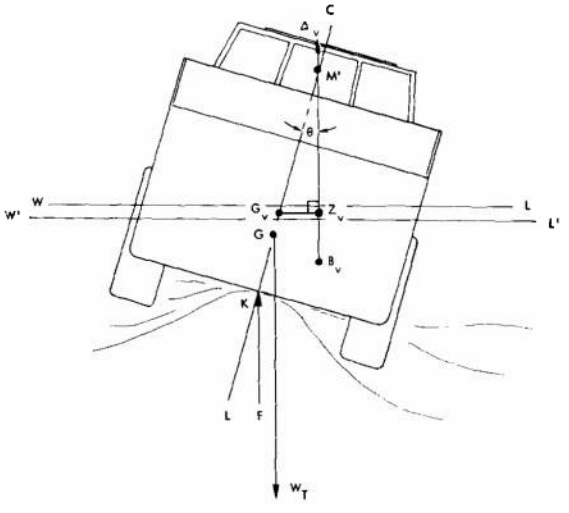
where M' is the metacenter of the grounded waterline as shown in Fig. 7-17.

In Fig. 7-17 the point Q is at the baseline so that $QK = 0$, as shown. In a more general case, Q will lie below the baseline and is a function of the heel angle θ. The amphibian is stable at some angle θ and the waterline $W'L'$ if the virtual center of gravity lies below the metacenter M', i.e., a positive righting moment exists.

A criterion which is suggested here for adequate stability in the grounded condition is that a positive righting moment be maintained for any waterline when the amphibian is grounded on a side slope slightly less than the requirement for side slope stability on land.

7-1.6.2.10 Damaged Stability

The stability of an amphibian which has incurred hull damage below the waterline is degraded due largely to the free surface effects. The subsequent flooding results in a virtual decrease of waterplane area and lowers the metacentric height. Recent amphibians do not have watertight compartmentation because of the added weight that would result from this safety feature. As a result, the entire hull is subject to flooding from damage at any point unless the bilge pumps are capable of pumping water at a rate equal to or higher than it enters



WL - HEELED, UNGROUNDED WATERLINE
W'L' - HEELED, GROUNDED WATERLINE
B_v - CENTER OF BUOYANCY, GROUNDED
G - CENTER OF GRAVITY
G_v - VIRTUAL CENTER OF GRAVITY
K - BASELINE
W_T - WEIGHT OF CRAFT = Δ
F - GROUNDING FORCE
Δ_v - VIRTUAL DISPLACEMENT TO W'L'
θ - HEEL ANGLE
M' - METACENTER FOR W'L' AND θ

Figure 7-17. Grounded Amphibian Stability

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the hull. Thus, it is only a matter of time before the damaged craft will sink. The question of damaged stability is, in this case, only of interest from a standpoint of how long the craft will remain upright for the crew to abandon ship. In any event, means of escape from a capsized amphibian must also be provided because of the possibility that an amphibian may turn over abruptly in heavy seas or surf. Treatment of damaged stability is fully discussed in Ref. 14.

7-1.6.3 Free Surface Effects

A liquid with a free, unrestrained surface such as fuel in the fuel tanks or water in the bilges of the amphibian will shift when the craft heels so that the center of gravity of the liquid moves, thus creating a heeling moment which opposes the righting moment due to waterplane inertia I_t. In effect, the waterplane inertia is decreased by the inertia of the free surface area in question corrected for the specific gravity of the liquid. Thus, the reduction in metacentric height BM due to a liquid free surface is given by

$$\text{Reduction in } BM = \frac{i\,\rho_t}{\nabla\,\rho_s}\;C_{f_s},\ \text{ft} \qquad (7\text{-}27)$$

where

i = moment of inertia of the free surface area about a longitudinal axis through the center of area of that surface, ft^4
∇ = displaced volume of the amphibian, ft^3
ρ_t = mass density of the liquid, slug/ft^3
ρ_s = mass density of water displaced by the hull, slug/ft^3
C_{f_s} = free surface coefficient, nd

The free surface coefficient C_{f_s} is applied to the moment of inertia when the liquid level is either very low or very high in a tank to take account of the reduction in breadth of the free surface when the tank is heeled slightly. Fig. 7-18 gives values of C_{f_s} for rectangular tanks. Generally, the worst case is calculated for the free surface reduction in metacentric height. In this case, the tank is half-full of liquid and C_{f_s} = 1.0.

For example, consider two fuel tanks, half-full of Diesel oil in the LARC V amphibian of the problem in par. 7-1.6.2.6.

Tank dimensions: (2) length ℓ = 2.5 ft
breadth b = 2.25 ft
Diesel oil: ρ_t = 1.675 slug/ft^3
salt water: ρ_s = 1.99 slug/ft^3
coefficient: C_{f_s} = 1.0
volume: ∇ = 472 ft^3

free surface area inertia, (each tank)

$$i = \ell b^{3/12}$$
$$= 2.5(2.25)^{3/12} = 2.59\ \text{ft}^4$$

$$\text{free surface reduction in } BM_t \text{ for both tanks} = 2\left(\frac{2.59}{472}\right)\left(\frac{1.675}{1.99}\right) = 0.01\ \text{ft}$$

The reduction in metacentric height from these fuel tanks is rather small. Larger effects may arise from water in the bilges, cargo well, or on a cargo deck. In these cases, the displaced volume and the amphibian's center of gravity must be corrected for the weight and center of the water acting as if it were added, solid cargo. The free surface effect is calculated as for the fuel tanks.

Free surface effects in tanks can be reduced by fitting liquid-tight longitudinal structures to reduce the effective breadth of the free surface area and, thus, the inertia i.

7-1.6.4 Longitudinal Stability and Trim

Longitudinal stability is not usually a problem. Longitudinal metacentric height GM_ℓ may be calculated in the same manner as transverse GM_t; the only differences being in the moment of inertia of the water plane and in the free surface corrections. Both I_ℓ and i_ℓ are taken about transverse axes.

The waterplane moment of inertia should be taken about the transverse axis through the longitudinal center of area of the waterplane. The axes of individual free surfaces, for corrections, should each be taken at its center of area.

$$GM_\ell = KB + BM_\ell - KG - \sum\left[\frac{i_\ell}{\nabla}\left(\frac{\rho_t}{\rho_s}\right)\right] C_{f_{s_\ell}},\ \text{ft} \qquad (7\text{-}28)$$

It is evident that KB and KG are the same in the longitudinal direction as in the transverse direction.

Continuing our example for the LARC V, the longitudinal moment of inertia I_ℓ can be approximated by taking the area inertia about

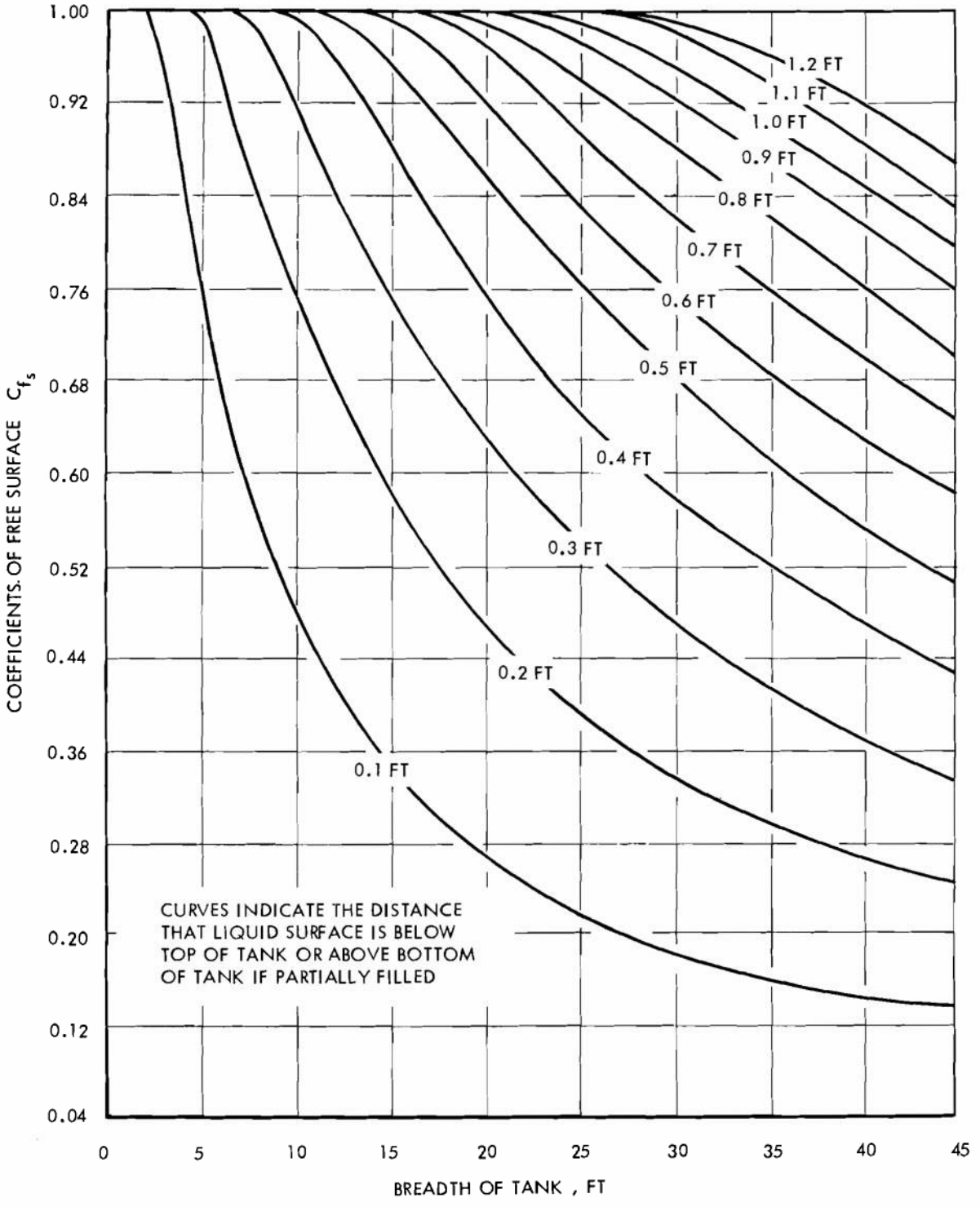

Figure 7-18. Coefficients of Free Surface for Rectangular Tanks When Inclined to 5° Heel

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the midpoint of a rectangle which approximates the hull shape.

L = 31 ft
B = 10 ft

$$I_{\ell} = \frac{L^3 B}{12} = \frac{(31)^3 10}{12}$$

$$= 24{,}800 \text{ ft}^4$$

$$\nabla = 472 \text{ ft}^3$$

$$BM_{\ell} = \frac{24{,}800}{472}$$

$$= 52.5 \text{ ft}$$

KB = 1.20 ft, KG = 2.96 ft } from par. 7-1.6.2.6

The free surface of the fuel tanks will have very little effect and can be assumed neglected.

Longitudinal Metacentric Height by Eq. 7-28 is

$$GM_{\ell} = 1.20 + 52.5 - 2.96$$

$$GM_{\ell} = 50.7 \text{ ft}$$

Thus, the longitudinal metacentric height is considerably greater than the transverse metacentric height.

Trim is defined as the difference between the drafts measured forward and aft. If the draft aft is the greater, the craft is trimmed by the stern; if the draft forward is the greater, the craft is trimmed by the bow.

For an amphibian, it is desirable that the rear wheels touch bottom first while approaching the shore. With the rear wheels on land, the craft will be less likely to be swung around by incoming waves. Trim by the stern should be designed into an amphibian, with due regard given to keeping the cargo deck above water.

The moment required to alter the trim by 1 in. is:

$$MT1 = \frac{\Delta GM_{\ell}}{12L}, \text{ ft-lb} \qquad (7\text{-}29)$$

where

Δ = displacement, lb
GM_{ℓ} = longitudinal metacentric height, ft
L = length between points where trim is measured, ft

The subscript ℓ indicates longitudinal direction.

Therefore, the moment required to change the trim of the LARC V by 1 in. is (where L = 23.3 ft)

$$MT1 = \frac{30{,}200(50.7)}{12(23.3)}$$

$$= 5{,}500 \text{ ft-lb}$$

A 175-lb man moving from the bow to the stern will change the trim less than 1 in.

At large angles of heel, trim may result from a change in longitudinal center of buoyancy. This problem can be avoided by designing the vehicle with sufficient freeboard at both bow and stern to provide surplus buoyancy at each end at large heel angles. Thus, the center of buoyancy when heeled does not tend to move longitudinally.

7-1.6.5 Freeboard

Freeboard is the distance measured vertically from the waterline to the deckline. Generally speaking, increased freeboard results in greater reserve buoyancy, greater range of stability, and less likelihood of waves breaking over the deck.

Ease of cargo handling may be of prime consideration to the amphibian designer. The highest reach of a fork-lift truck or the lack of good unloading facilities may dictate a low cargo deck. As a result, the freeboard amidships may be low. Raising the freeboard forward and aft will provide the necessary reserve buoyancy and range of stability without increasing the difficulty of unloading cargo. As long as the hull is watertight and any water on the cargo deck will drain freely, low freeboard amidships will cause no particular problem.

Removable sidewalls in way of the cargo deck may be used to raise the freeboard. As they are not particularly strong, their effectiveness in increasing reserve buoyancy and range of stability is not very great. However, the protection afforded the cargo may make such sidewalls desirable.

7-1.7 LAND OPERATION CONSIDERATIONS

The requirements for operation on land have some effects on the design of an amphibian's hull shape. These effects are basically limitations on principal dimensions, ground clearance, and the approach, break, and departure angles. These limitations are almost always identified during

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the preliminary design phase and, as a result, are covered in par. 6-4.2. The size and location of the wheels and wheel wells also affect the hull shape. The size and location of the wheels are determined by the limitations on dimensions, critical angles, and mobility considerations covered in par. 7-8. The size and shape of the wheel wells are determined by the tire size and clearances for steering. The equations relating turning radius to vehicle geometry and wheel angles are presented in par. 7-9.4.

7-2 GENERAL ARRANGEMENT

The detailed arrangement plans serve as a final check prior to manufacturing that the components will fit as planned and that there is sufficient clearance for installation and maintenance. The arrangement drawings should provide sufficient detail and instructions so that all components and systems will be properly installed.

7-2.1 CARGO

The primary mission of a logistic amphibian is to carry cargo. Each phase of the cargo-carrying operation must be considered for each anticipated mix of cargo. This includes:

a. Methods of loading and unloading each item
b. Interference of loading method from cargo previously loaded
c. Securing cargo in all types of weather
d. Trim and stability at all times during loading
e. Protection of crew and parts of the vehicle from swinging cargo
f. Jettisoning cargo
g. Fire in cargo
h. Crew access to machinery with cargo aboard
i. Efficiency of loading cargo, including practical clearances
j. Water drainage with cargo aboard
k. Protection of cargo from the environment
l. Crew escape routes if cargo shifts
m. Tie down considerations (no projections which can be damaged or cause damage)

7-2.2 MACHINERY

In the preliminary design phase the machinery and the associated components are arranged but the accessories, in general, are not considered in any detail. The detailed machinery arrangement should include all components, their location, and method of attachment. The following detail considerations are of importance:

a. Kits for special operating conditions
b. Maintenance procedures
c. Access
d. Air supply system
e. Exhaust system
f. Expansion
g. Spare parts
h. Fasteners
i. Vibration
j. Noise
k. Starting
l. Control
m. Fail-safe features
n. Cooling/heating
o. Clearances
p. Securing procedures
q. Ventilation

The quality of machinery maintenance is controlled to a large extent by the ease with which the work can be accomplished. A high degree of maintainability requires good access and sufficient clearance for each preventive maintenance action and repair which must be accomplished.

Gas turbines require special design consideration for both the intake and exhaust. Both require extra space because of the large air volume required, the removal of salt particles in the intake, and the necessary noise controls.

7-2.3 AUXILIARY SYSTEMS

Many of the auxiliary systems are neglected in the earlier phases and must be studied during final arrangement planning. Some of these systems will be fitted after the major components are installed and must be located accordingly. The design of each system is described in par. 7-10 and there are arrangement requirements associated with each system that are part of the design. Special arrangement precautions that are associated with many of these systems are:

a. Maintainability
b. Operation in environmental extremes
c. Fire fighting
d. Flooding
e. Emergency operation

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7-2.4 STRUCTURE

The direct and indirect framing causes many problems in the arrangement. The depth of this structure can be reduced only at the expense of added structural weight. For shapes such as angles, tees, or channels, holes may be cut in the webs with only a minimal loss in strength. The U. S. Navy practice for access and lightening holes in framing of steel ships abstracted from Ref. 18 is:

> Openings in strength members shall be well separated and not aligned in a transverse plane. Where openings, of necessity, are close together, they shall be combined to form a single opening. In general, holes in structure shall be circular. Where a circular opening is not practical, corners of openings in areas of stress (including shear stress) shall be rounded to radii of at least one-eighth (preferably one-fourth) of the clear dimension normal to the direction of the principal stress. If the size or location of an opening impairs the strength of an important structural member, it shall be reinforced.
>
> In general, framing which is six inches or more in depth, shall be lightened except where this would impair the strength such as framing over a stanchion or where the principal stress is parallel to the frame or where the frame is part of a watertight compartment.
>
> Except for special situations, lightening or access holes should be centered at the neutral axis of the combined cross section of the structural members and associated plating. The depth of the hole should not exceed 40 percent of the depth of the web and the length of the hole should be parallel to the member and not more than twice as long as it is deep. Holes shall be spaced so that the distances between edges of adjacent holes will not be less than 5/4 times the length of the holes.
>
> Drain holes and water courses should be provided to permit the free flow of liquids in the bilge and in other pockets to the bilge pumps. In compartments fitted with bilge pumps, the total area of drain holes through any frame or longitudinal shall be at least twice the area of the suction pipe.

Air holes in the framing should be provided to prevent the formation of gas pockets. For amphibians this is generally not a problem except in the case of the battery where hydrogen is generated as the battery is charged.

Each construction material has certain deficiencies which must be specially handled. The arrangement designer should determine from the structural designer what these are for each design. In welded aluminum, for example, the heat affected zone (HAZ) in way of the weld may have a much lower strength than the parent metal so that brackets and clips should not be indiscriminately specified in high stress areas. Likewise, holes for mechanical fasteners must be in areas of low stress.

7-2.5 BUOYANCY, TRIM, AND STABILITY

In order to achieve satisfactory performance in a seaway and survival in bad weather, it is necessary to have a proper relationship between the amount and distribution of weight and of buoyancy. In particular this includes:

a. Excess buoyancy of ends
b. Trim in all conditions of loading
c. Freeboard
d. List in all conditions of loading
e. Change of trim as fuel is burned
f. Initial stability for all conditions of loading and wheel positions (if retractable)
g. Range of stability for all conditions of loading and wheel positions (if retractable)

One problem in this regard peculiar to wheeled amphibians is the wheel wells when they are fitted with side covers. If the wells are not vented, they may catch air and be buoyant or fill with water and add weight when rolling. The trim, buoyancy, and stability calculations must be considered in the worst condition from the standpoint of safety. There are two ways to prevent this—(1) pump air into each wheel well so it is always air-filled, or (2) design wheel wells so they are inherently self-venting. Small vent pipes are not sufficient because they will fill with dirt and/or ice.

7-2.6 SAFETY

The safety of each system is the responsibility of the system designer. The design of the arrangement must consider the interrelationship of each system with the others and ensure that the total design will be safe to operate.

7-2.7 HUMAN FACTORS ENGINEERING

The human factors engineering for an

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amphibian must take into consideration that these vehicles are used to the limit of the ability of the man-machine system to function. They will be used in a war-time environment for missions for which they are not designed, by people who may have not been properly trained, and in an environment exceeding the original specification. From this point of view it is obviously necessary to design the vehicles so that standard operations can be accomplished with only average human ability.

Ref. 19 is a Human Engineering Laboratories Standard for use by the subordinate commands of the Army Materiel Command (AMC) in the area of human factors engineering, in accordance with Suppl. 1 to AR 602-1. It gives engineering design principles and detailed criteria for anthropometrics and the environment. Refs. 20-22 provide additional data on human response to vehicle vibration.

7-3 HULL STRUCTURE

Amphibians are subjected to a complex assortment of loads including both those associated with wheeled vehicles and with boats. Consequently the structural design cannot be based on past practice for either type of vehicle but must consider all of the forces which will be imposed in conjunction with the limited amount of previous experience available.

This paragraph includes information on:

a. Imposed forces
b. Materials
c. Structural configuration
d. Detail design
e. Hull weights

The primary emphasis is on delineating the problems and methods used for the structural design.

7-3.1 FORCES

The first step in the hull structural design is to estimate, with a satisfactory degree of accuracy, all of the forces which the hull must resist. There are instances where either the forces are so small that they can be neglected or they are so large that no attempt is made to produce a structure which will not be damaged. For example, the former might be a man walking on the cargo deck, and the latter might be the deck being hit by an armor-piercing round. These types of forces can be neglected but the effects of all others that may be critical must be considered.

The forces are divided into the following types:

a. Longitudinal. Vertical forces acting on the hull such that the hull acts as a beam.

b. Torsional. Forces acting perpendicular to the centerline of the hull which tend to twist it around a longitudinal axis.

c. Local. Forces acting on a section of the hull which do not produce a significant stress throughout a major portion of the hull.

For each of these types of forces the load can be applied at different rates which cause the structures to react differently. The different strain rates have been categorized as

a. Creep	10^{-8}—10^{-5} (in.)/(in.-sec)
b. Static	20^{-5}—10^{-1}
c. Rapid loading	10^{-1}—10^{1}
d. Impact	10^{1}—10^{4}
e. Hypervelocity impact	10^{4}—10^{7}

Some materials will elongate if subjected for a long period of time to a stress below their elastic limit, particularly at high temperatures. This is known as creep and is not important for amphibians. Some aluminum alloys creep at moderate temperatures but not the alloys that are to be used in the marine industry.

Static loads are easiest to handle as no dynamic motion is involved. Many "quick" engineering solutions involve approximations which reduce the answer to the static load condition.

Rapid loading requires only relatively simple factors to account for the dynamics of the loading, but fatigue must be carefully handled for a properly engineered structure.

At the speed of impact loadings (10^{-1} to 10^{-4} sec) materials react differently. The stress-strain curves, in particular, are altered and this change must be considered. The stress-strain relationship above the elastic limit may be increased as much as 50 percent for steel, and 0 to 1 percent for aluminum. Data for impact loadings are not yet available for all materials. Ref. 23 is a basic reference on this subject.

Hypervelocity impact loading can alter the material response severely and in ways that are

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not yet predictable. The amphibian structure is not involved with these phenomena.

7-3.1.1 Longitudinal Forces

7-3.1.1.1 Waterborne

The scantlings of longitudinal structural members for ship hulls are normally sized to resist the bending moment imposed on the hull in waves either in a hogging condition when the wave crest is amidships or for the sagging condition when the wave crests are at the ends of the ship. For ships less than about 100 ft in length, the local loads usually are the determining factors for the selection of longitudinal scantlings and not the bending moment. The bending moment stress must be considered, however, as it is at times superimposed on other stresses in the hull and it can be very significant for hulls that are shallow amidships.

The determination of the bending moment is particularly critical for large ships and there has been a substantial amount of research effort expended to improve the accuracy of the prediction techniques. For use on amphibian design, however, the treatment in Ref. 14 is sufficient.

To determine the static bending moment, the hull is considered at the various loading and trim conditions in still water. For the dynamic bending moment it is considered in a stationary wave with a length equal to the waterline length of the hull. For a "sagging" condition where the deck is in compression the wave trough is amidships, and for the "hogging" condition where the deck is in tension the wave crest is amidships. A trochoidal wave profile is normally used with the wave height selected from past experience. For amphibians a wave height of 1.1 times the square root of the waterline length can be used as a satisfactory approximation.

The bending moment calculation consists of:

a. Balancing the hull in the water, either smooth water or in the stationary wave. Bonjean curves are used to determine the buoyancy at selected stations along the hull (see par. 7-1).

b. Calculating the buoyancy along the length of the hull

c. Estimating the weight along the length of the hull

d. Calculating the bending moment along the length of the hull

If desired, the shear and the deflection from this loading can also be determined. Since a high degree of accuracy is not required, the calculation can be simplified by dividing the hull into a number of equal lengths and assuming the buoyancy and weight are constant for the length of each section.

Figs. 7-19 and 7-20 show the curves developed from such a calculation for the LARC V. The maximum bending moment is 34,350 lb-ft, 203 in. aft of the bow for the sagging condition using a wave 2.1 ft high. To estimate the bending moment for similar vessels of other sizes it can be assumed that (Ref. 14):

$$M_B \propto B(LWL)^2 H_m C_B \qquad (7\text{-}30)$$

where

M_B = bending moment, ft-lb
B = maximum molded breadth at the waterline, ft
LWL = length at the waterline, ft
H_m = mean draft, ft
C_B = block coefficient, nd

7-3.1.1.2 Landborne

Another longitudinal force that must be considered is the land mode. The static bending moment can be calculated in the same manner as for the afloat condition except that the forces supporting the vehicle are simply the loads from the wheels. The dynamic bending moment applied to the hull can be approximated by assuming:

a. A maximum acceleration of the center of gravity,

b. that this acceleration is the result of vertical motion of the wheels farthest away from the center of gravity, and

c. that a vehicle pivots around the remaining set of wheels.

The assumptions are shown in Fig. 7-21. Let

$\triangle W$ = weight of the vehicle, lb
F_F = applied vertical force at the forward wheels (up is positive), lb
F_A = applied vertical force at the aft wheels (up is positive), lb
a = distance from aft wheels to the longitudinal center of gravity, ft
b = distance from the forward wheels to the longitudinal center of gravity, ft

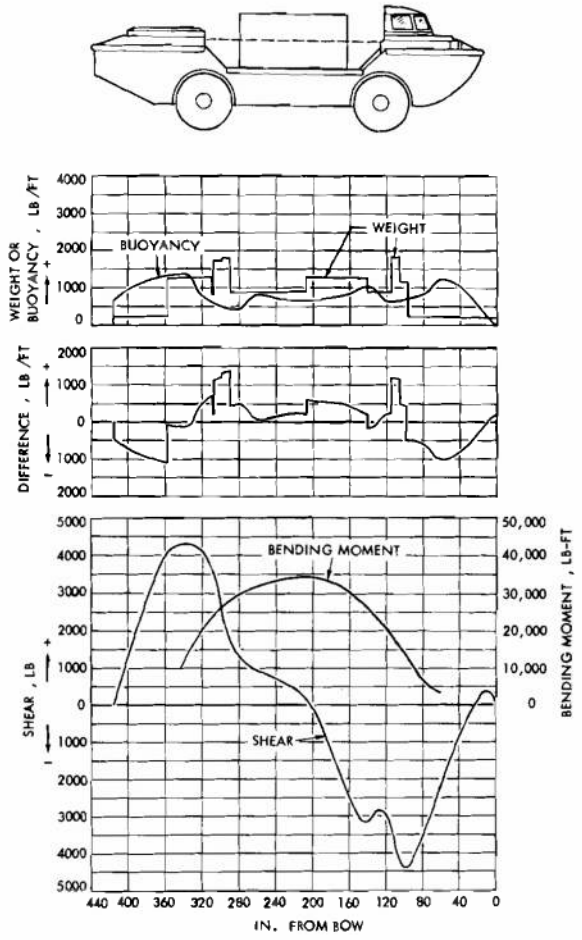

Figure 7-19. Bending Moment Curves for LARC V (Sagging)

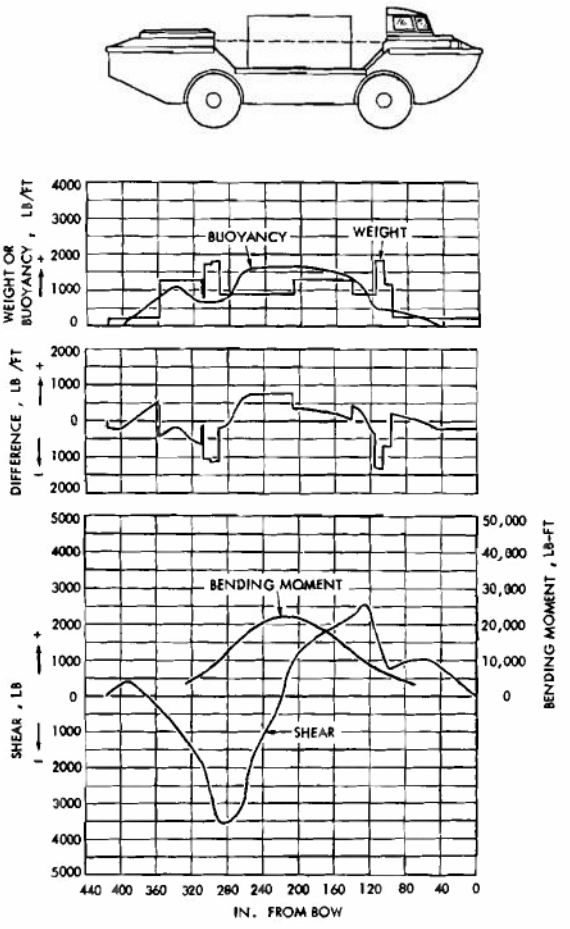

Figure 7-20. Bending Moment Curves for LARC V (Hogging)

ℓ = length of wheelbase, ft

w_x = weight of the vehicle in the x section, lb

x_n = distance to center of x section measured from bow, ft

$\ddot{y}$ = vertical acceleration at the center of gravity, in number of g's, i.e., ft/sec^2 divided by 32.2 ft/sec^2

k = radius of gyration about transverse horizontal axis through the center of gravity, ft

To calculate the bending moment:

1. Determine the weight curve using a number of sections. The weight is to be considered evenly distributed in each section. Fig. 7-22 shows a curve for the LARC V.

2. Plot the acceleration curve. The vehicle is assumed to pivot about the set of wheels nearest to the center of gravity, and the design maximum vertical acceleration at the center of gravity is used. The acceleration curve is a straight line since the amphibian is assumed to be a rigid body. Fig. 7-22 shows a plot for the LARC V.

3. Find F_F from

$$F_F = \frac{\Delta a}{\ell}\left\{\ddot{y}\left[\left(\frac{k}{a}\right)^2 + 1\right] + 1\right\}, \text{ lb} \quad (7\text{-}31)$$

4. Determine the bending moment curve for the desired section of the vehicle. This is generally taken at the 'midship section for half of the length. It should include the length of any midship well. The bending moment at section x is calculated using Eq. 7-32:

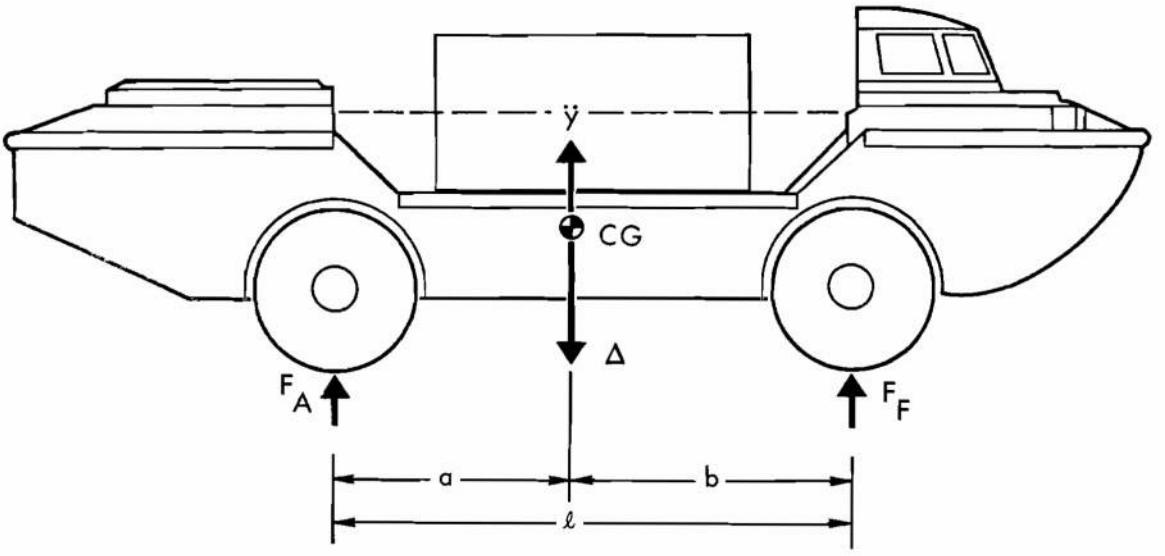

Figure 7-21. Forces for Maximum Bending Moment (Landborne)

$$M_{B_x} = F_F b_x - \sum_{i=1}^{x} w_i \ddot{y}_i \ell_i, \text{ ft-lb} \qquad (7\text{-}32)$$

where

M_{B_x} = bending moment at section x, ft-lb
b_x = arm between forward wheels and x, ft
w_i = weight of vehicle at i^{th} section, lb
$\ddot{y}_i$ = acceleration at i^{th} section, g's
ℓ_i = arm between i^{th} section and x, ft

A typical bending moment curve for the LARC V is shown in Fig. 7-22.

The bending moment applied to the hull when it is hoisted may be calculated in the same manner as for the land mode. Normally the accelerations are relatively small and the vehicles are handled without cargo aboard so that the forces are not critical. The proof test requirement for the lifting pads can be checked if there is any doubt about whether this may be a critical condition.

Another special loading condition that is sometimes critical for ships occurs during the launch when the bow is on the launching ways and the stern is afloat. There is a parallel for this in the amphibian cases when it is traversing the beach. Again, the forces should be no higher than when the vehicle is in the land mode.

7-3.1.2 Torsional Forces

7-3.1.2.1 Waterborne

Major torsional loads occur in the waterborne mode when running oblique to the waves where the bow on one side is supported on a wave crest and the stern of the other side is on the next crest. For ships, the torque is estimated by the following formula from Ref. 24 for full bodied vessels:

$$\text{Torque} = 0.22\, LWL\, B^3, \text{ ft-lb} \qquad (7\text{-}33)$$

LWL = waterline length, ft
B = beam, ft .

7-3.1.2.2 Landborne

For the land mode the maximum torque is imposed on the hull when wheels on opposite corners are lifted and the other two wheels are unloaded. This occurs simultaneously with an acceleration which increases the torque.

$$\text{Torque} \approx \frac{T}{4} \ddot{y}\, \Delta\, \frac{(\ell - b)}{\ell}, \text{ ft-lb} \qquad (7\text{-}34)$$

T = transverse distance from center of gravity to wheel, ft
$\ddot{y}$ = design acceleration at the center of gravity, g's

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Δ = total weight of vehicle and payload, lb
b = longitudinal distance from wheel to center of gravity, ft
ℓ = wheelbase, ft

The torque forces from the land mode are substantially greater than those from the water mode unless the beam is extreme. The design torque then would be the higher torque value using the above equation assuming the design value of the acceleration.

7-3.1.3 Local Forces

Local forces are considered to be those that are applied in a sufficiently small area that they do not produce a significant stress in the hull as a unit. For amphibians these loads are the critical ones for most of the structure. In some cases, however, the stresses from the local loads must be combined with other stresses to determine those that are critical.

These loads can be applied by the water, suspension system, vibration, motion of the vehicle, collision with extraneous objects, and by a variety of special modes of operation such as towing.

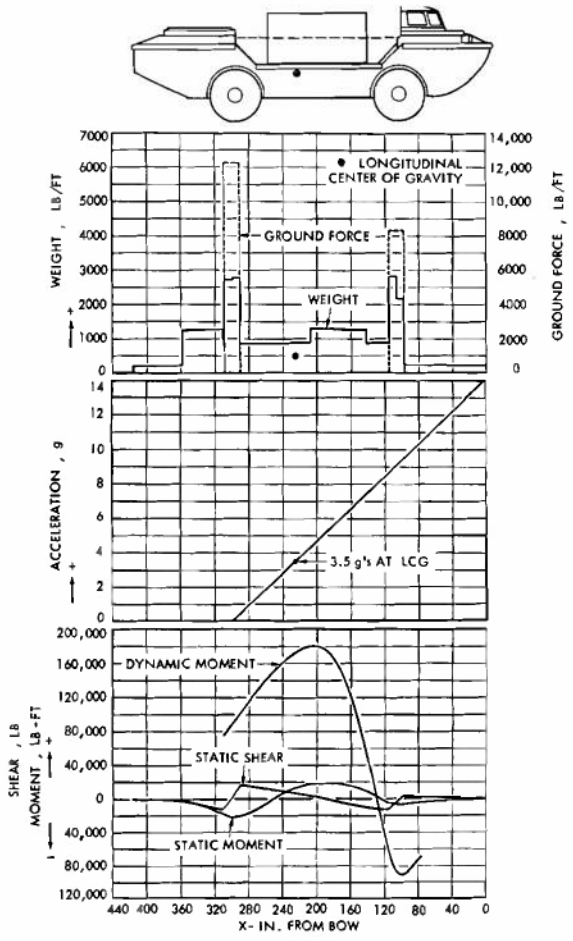

Figure 7-22. Bending Moment Curves for LARC V (Landborne)

7-3.1.3.1 Water Forces

The shell and its supporting structure will be loaded hydrostatically when afloat. For general use, the pressure is:

$$P_o = \rho g h, \text{ lb/ft}^2 \qquad (7\text{-}35)$$

where

P_o = pressure normal to the shell at the given depth h, lb/ft^2
ρg = 64 for salt water, lb/ft^3
ρg = 62.2 for fresh water, lb/ft^3
h = head of water, ft

The head of water will vary with the location of the hull, mission, and other characteristics. Normally for the smaller vehicles the smallest head should be to a point 4 ft above the shear line, as per Refs. 24 and 25. This minimum requirement is selected from experience on other vessels to provide loads for the normal conditions. There are other hydrodynamic loads that must be specifically considered, including wave slap on the vertical surfaces, slamming on the bottom, and breaking waves on the bow and stern.

7-3.1.3.2 Other Impact or Shock Forces

Most of the critical forces are generated from dynamic conditions. The previous paragraph discusses the local water loads when the vehicle is considered to be motionless. This paragraph covers the forces occurring when the amphibian collides with stationary objects and the local forces imposed from the suspension system in the land mode.

When alongside a ship or other essentially motionless object the amphibian will, at times, be pushed against the ship by the wave action. When the two are side by side, there is only a small impact because the water between them

acts as a cushion. However, there is a problem when the two are not parallel, as during the approach and departure of the amphibian from alongside a ship. The corners of the bow and particularly the quarters or corners of the transom are frequently damaged on both amphibians and landing craft. A solution to the bow damage problem is, where feasible, to round off the corners. The ideal shape is similar to that used for tugboats. If this is not feasible, then the structure in these areas must be designed to absorb the load.

The curve in Fig. 7-23 shows the relationship between the water surface velocity and the wave height for solitary waves of minimum stable length.

By use of the curve from Fig. 7-23 the maximum energy may be estimated from

$$E = \frac{V^2 \triangle}{2g}, \text{ ft-lb} \qquad (7\text{-}36)$$

where

E = approximate energy in the system due to wave action, ft-lb
V = speed of vehicle, ft/sec
$\triangle$ = displacement of vehicle, lb
g = 32.2 ft/sec^2

The preceding calculation neglects two phenomena. One is the virtual mass or assumed entrained water that acts with the vehicle to increase the energy level. The other is that the actual velocity for a floating object propelled by a wave is a function of the characteristics of the wave, hull form, and relative orientation of the body. For a heavily loaded boat shape such as an amphibian, the actual velocity will be less than the maximum surface water speed and this will reduce the maximum energy in the system.

Another local load that has led to extensive damage in the past has been loading cargo. This is particularly a problem in the higher sea states when receiving cargo from a ship. During that operation the amphibian is moving vertically with the waves, the ship is rolling, and the cargo is lowered using manual control. If the ship is rolling more than the operator can compensate, it can be assumed that the loading operation will be stopped. In general, cargo is lowered at a normal speed of about 25 ft/sec until it is near the amphibian and then it will be lowered slowly until it is down. The winchman, however,

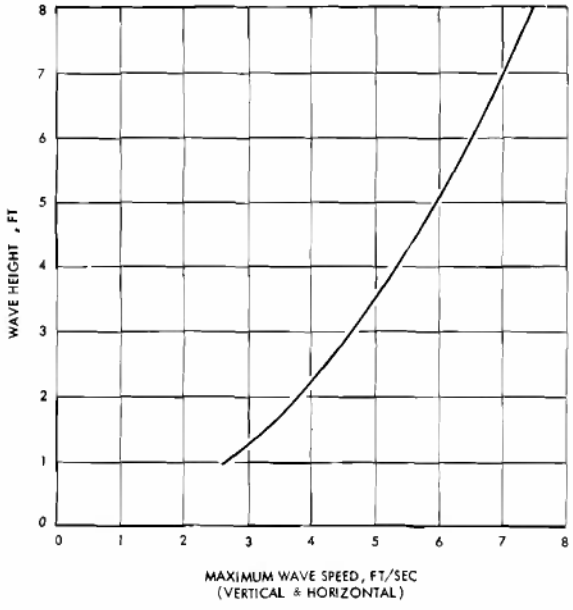

Figure 7-23. Wave Height and Maximum Speed for Solitary Deep Water Waves

usually cannot see over the side and he lowers on signal from the gangway man. Therefore, it is anticipated that on occasion the cargo will land with a relative motion of 25 ft/sec, plus the vertical speed from Fig. 7-23. In some instances the cargo may be dropped due to errors in judgment. Since a CONEX container may be loaded to a gross weight of 10,000 lb, it would, in general, be impractical to size the structure to withstand such a load.

Another typical type of force that cannot be countered in all cases is collision when operating on land. Since there is a great variety of sizes and shapes of objects that can be hit, it is generally not practical to calculate the possible loads unless there is a special hazard that will be encountered frequently for a particular design.

Another consideration of importance is the impact load to which the vehicle will be subjected through the suspension. Loads of this type come from shocks imparted to the wheels when they encounter obstacles, and shocks occurring when the vehicle is being transported.

Inputs with typical off-road obstacles are of such short duration that the most practical means of calculating them is using momentum equations. The momentum equations described the impact by relating linear impulse (force $\times$ $\triangle$ time) to changes of momentum (mass $\times$ velocity), where "$\triangle$ time" is the time duration over

which the force acts. These equations and the calculations used to determine the forces are described in Ref. 26.

7-3.1.3.3 Semi-static Forces

There are a number of local loads that can be considered essentially as static loads.

The lifting pads are subjected to loads as shown on Fig. 8-2. If the specifications do not indicate these loads, the pads should be designed for a dynamic load factor of 3. If the pads are not centered about the center of gravity of the vehicle, they will not be equally loaded. Normally amphibians are hoisted without cargo but they may be hoisted in a sinking condition with a large amount of entrained water.

There are two philosophies with regard to the cargo lashings. One is that the cargo will be secured so that it will not come loose, and the other is that the cargo will break loose and fall overboard when the roll exceeds some value (less than the range of stability). In either case it is likely that the lashing pads on the amphibian will be built to retain the cargo in any eventuality. Forces on the lashings are determined from vector analysis for maximum roll angle without acceleration and maximum horizontal acceleration from rolling at zero roll angle. The procedure which follows may be used to determine the acceleration.

The natural period of roll is estimated from

$$T \approx \frac{0.44B}{\sqrt{GM}}, \text{ sec} \qquad (7\text{-}37)$$

where

T = natural roll period, sec
B = beam, ft
GM = metacentric height, ft

If we assume sinusoidal motions, the maximum roll acceleration is

$$\ddot{x} = \frac{0.689\,\ell\theta_M}{T^2} \qquad (7\text{-}38)$$

where

ℓ = vertical arm from CG to point of interest, ft
θ_M = maximum roll angle to one side, deg
$\ddot{x}$ = maximum horizontal acceleration from rolling, ft/sec^2

and eliminating T^2 from the Eq. 7-38

$$\ddot{x} = \frac{3.55\,\ell\theta_M\,(GM)}{B^2} \qquad (7\text{-}39)$$

This equation may be used for $\theta_M < 15°$. At greater roll angles, the equation gives values that are too high. In general, it will be found that the static loads at the maximum roll angles are higher than the acceleration loads. These loads are not additive since they are out of phase. The wheel loads from wheeled cargo such as howitzers can also be significant for the design of the cargo deck. These loads can be determined using Ref. 27 (which lists the load per axle) and the design maximum vertical acceleration $\ddot{y}$:

$$\text{Max wheel load} = \frac{(\ddot{y} + 1)\text{ axle load}}{\text{Number of wheels on the axle}} \qquad (7\text{-}40)$$

Ref. 26 shows the assumed area and pressure distribution for typical tires.

Pad eyes, or equivalent, are normally fitted for towing fixtures which will permit the amphibian to be towed both on land and in the water. The fixtures for use while waterborne must be above the waterline and, preferably, on the deck. The loads to be transmitted are:

a. For towing cleats (waterborne) the strength of the strongest line that will fit. Nylon lines are normally used for mooring purposes.

b. For towing pads (land) the strength of the standard towline.

Both should have a factor of safety of 3 on the ultimate strength of the material (Ref. 28).

The suspension system is subject to impact loads which are the controlling factor in its design.

Some method of changing tires is required. Hard points for jacking near each wheel should be available and clearly marked for that purpose. Each of these points should be designed to support half the vehicle weight.

7-3.1.3.4 Vibration

Vibration of structural members in an amphibian can originate from the engine, propulsor, drive train, suspension system, or the action of waves in a seaway. Since the power is usually high relative to a conventional truck, it is possible to generate significant vibrations which

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can add to the stress in some of the members.

There are certain frequencies, such as the engine operating rpm or the blade rate of the propeller, that will occur throughout the life of the vehicle. It is possible to calculate with a good degree of accuracy most of the natural frequencies of the structure. The calculations are tedious and time-consuming so that usually they are neglected and the prototype vehicle is closely checked for vibrations. Undesirable vibrations are eliminated where possible or reduced by the addition of extra stiffeners. Where the suspension system of wheeled cargo is in synchronization, it can be eliminated with proper tie-downs.

7-3.2 MATERIALS

The selection of materials for the construction of the hull is a very important phase of the structural design, and can play an important part in the life-cycle cost, reliability, and maintainability of the vehicle.

Important considerations for the selection of materials include:

a. Availability of the necessary shapes in the time frame required

b. Cost of the basic material and cost to fabricate

c. Weight of the completed hull

d. Repairability in the field

e. Maintenance required, particularly in the sea water environment

f. Strength and size of framing (large frames reduce the mobility of maintenance personnel)

g. Familiarity of the constructing facility with the material

This list is not all-inclusive and there are many interrelationships among the items listed; they are, however, major items that must be considered prior to selection of a material.

The materials available at this time that could be considered are aluminum, steel, and Fiberglas. The specifications for these materials as used by the Navy are listed in Table 7-3.

7-3.2.1 Comparison Parameters

There are a number of parameters that can be used to compare materials without specific reference to a design. These are useful to eliminate potential construction materials prior to designing the structure. Absolute comparisons for any case require preparation of complete optimized designs in each material.

The base cost of the materials is shown in Table 7-4. A variety of special charges or discounts are applied to these costs but the relative final costs will be close to those shown.

Table 7-5 shows approximate relative costs of fabricated aluminum materials for commercial structures similar to the LARC V or LARC XV in quantities of 20 or more. These are only an indication of the trends with respect to aluminum because reliable information is not available from manufacturers equally experienced in using all materials.

The strength-weight ratio, i.e., tensile strength/density, is a gross indication of the relative weight of a structural material. Table 7-6 lists the comparisons of interest.

Ductility is important as an indication of resistance to cracking at stress concentrations. Table 7-7 lists elongation values, a measure of ductility.

The ability to absorb impact with water (as in slamming) or solid objects may be judged by the area under the stress-strain curve, which is an indication of the energy that can be absorbed. The distance along the strain axis depends on the design criteria. Table 7-8 lists the areas of interest.

These values do not consider weight, but are based on an equal volume. Table 7-9 lists the approximate values on an equal weight basis.

Deflection is another criterion for design in some instances. Table 7-10 lists the approximate relative deflections.

Perhaps the most important consideration for the material selection is the fatigue strength. This varies for each material, and for each material it varies primarily with the stress history. Time, environment, and other factors have a major effect in some instances, but not normally for use in amphibians.

The stress history is the order and magnitude of each stress which the structure sustains. From the available data, it appears that the order of the application of stresses is of secondary importance compared with the number and magnitude in the applied stress spectrum. It is at this particular point in the analysis that engineering estimates must start since data on fatigue strength for various applied stress spectra are not available. There is, however, a sufficient quantity of data for the unique case where the

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TABLE 7-3 MILITARY SPECIFICATION NUMBERS FOR HULL MATERIALS (Ref. 28)

Bars and shapes

Steel, medium	MIL-S-20166, Grade M
Steel, high tensile	MIL-S-20166, Grade HT
Steel, high yield strength (extruded)	MIL-S-22664
Steel, high yield strength (rolled)	MIL-S-22958
Steel, high yield strength (bars)	MIL-S-21952

Plates

Steel, medium	MIL-S-22698
Steel, high tensile (surface ships)	MIL-S-16113, Grade HT
Steel, high tensile (surface ships or submarines)	MIL-S-24094
Steel, high yield strength	MIL-S-16216
Steel, special treatment	MIL-S-20154

Tubing

Tubing, steel	MIL-T-16343, Type 1

Reinforcements such as doublers, reinforcing rings, and flat bar reinforcement of stiffeners, for members designated to be high tensile steel or high yield strength steel, shall be of the same material. Where approved the following may be used:

Iron castings, extra tough, MIL-I-22243.
Iron castings, gray, Fed. Spec. QQ-I-652 or ASTM Standards A48 to A278.
Malleable iron castings, Fed. Spec. QQ-I-666, or ASTM Standard A47 for minor installations.
Ductile iron, MIL-I-17166, for minor installations.
Marine boiler plate, Fed. Spec. QQ-S-691, Class B, for parts that require a large amount of working under repeated heatings, such as for flanging.
Steel castings, high yield strength, MIL-S-23008.
Steel forgings, high yield strength, MIL-S-23009.

Use	*Aluminum Alloy* *Spec.*	*Alloy*	*Condition Grade or Class*	*Remarks*
Castings	QQ-A-601	356	3M	Note 1
Castings	QQ-A-601	195	4M	Note 2
Castings	QQ-A-601	214	5M	Note 3
Plates	QQ-A-250/7	5086	H32	Note 4
Plates	QQ-A-250/9	5456	H321	Note 5
Plates	QQ-A-250/10	5454	H34	Note 6
Plates	QQ-A-250/11	6061	T6	Note 7
Shapes				
Extruded or rolled	QQ-A-200/5	5086	H111	Note 4
Extruded	QQ-A-200/7	5456	H111	Note 5
Extruded or rolled	QQ-A-200/6	5454	H111	Note 6
Rolled or drawn	QQ-A-225/8	6061	T6	Note 7
Extruded	QQ-A-200/8 or ASTM B221	6061	T6	Note 7

(cont'd)

TABLE 7-3 (Concluded)

Use	Aluminum Alloy Spec	Aluminum Alloy Alloy	Condition Grade or Class	Remarks
Tubing				
*Drawn or extruded	WW-T-700/5	5086	H32	Note 4
**Welded	QQ-A-250/7	5086	H32	Note 4
All sizes	WW-T-700/6	6061	T6	Note 7

*Drawn preferred. Consideration must be given to wider dimensional tolerances when extruded is used.

**Tubing manufactured from plate and having a longitudinal welded seam may be used for tubing sizes that are not available in drawn tubing.

Note 1 - For use with complex castings where castability, pressure tightness, strength, and resistance to corrosion are required. Will respond to heat treatment to improve strength. For applications requiring high casting quality and excellent fluidity.

Note 2 - High tensile, with less corrosion resistance than Class 1, 3, 5, 7, and 8. Heat treatment is required. For uses such as ammunition stowages, frames and sills for joiner doors, and ladder treads.

Note 3 - For use wherever good tensile strength and relatively high resistance to corrosion are required. Heat treatment is not required. For applications similar to Class 4 but requiring resistance to corrosion at a sacrifice of tensile properties.

Note 4 - Shall be used for applications where higher strength is not required.

Note 5 - Shall be used for applications where high strength is required and where higher cost is warranted.

Note 6 - For a structure subject to elevated temperatures over 150°F such as the upper portion of smokestacks.

Note 7 - This alloy shall be used for nonwelded structure only.

Fiberglas	MIL-P-17549
Polyester Resin	MIL-R-7575B
Polyester Resin	MIL-R-21607
Woven Roving	MIL-C-19663A
Mat	MIL-M-15617A

TABLE 7-4 BASE COST OF HULL MATERIALS

Material	¼ in. Plate		2 in. × 3 in. × ¼ in. Angle	
	$/lb	$/ft²	$/lb	$/ft²
Mild Steel	0.09	0.92	0.10	0.41
High Tensile Steel	0.24	2.45	0.25	1.03
Aluminum (5456-H32)	0.46	1.59	0.74	1.06
Fiberglas Cloth	0.37	0.64*	0.37	0.26*
Polyester Resin	0.49		0.49	

*Assuming 50% glass and 50% resin by weight (sp. gr. 1.15)

TABLE 7-5 RELATIVE FABRICATION COSTS PER POUND (WITH RESPECT TO ALUMINUM)

Material	*Relative Cost, %*
Mild Steel	30
High Tensile Steel	45
Fiberglas	49

TABLE 7-6 STRENGTH-WEIGHT RATIOS

Material	*Yield Strength,* lb/in.^{3}	*Ultimate Strength,* lb/in.^{3}
Steel	115	230
Fiberglas	(no yield)	240 - 520
Aluminum (5456-H24)	406	530

TABLE 7-7 TYPICAL MINIMUM ELONGATION

Material	*Elongation in 2 in., %*
Steel	24
Fiberglas	2.5
Aluminum (5456-H24)	9

TABLE 7-8 RELATIVE AREAS UNDER TYPICAL STRESS-STRAIN CURVES

Material	*Area to Yield Stress*	*Area to Ultimate Stress*
Steel	1	2½
Fiberglas	(no yield)	1
Aluminum (5083 welded)	4	3

TABLE 7-9 RELATIVE ENERGY ABSORBED FOR EQUAL WEIGHTS

Material	*Energy to Yield Stress*	*Energy to Ultimate Stress*
Steel	1	1
Fiberglas	(no yield)	1.8
Aluminum (5083 welded)	13	3.2

applied stress is constant. Fig. 7-24 shows the standard type of fatigue S-N curves for steel, aluminum, and Fiberglas. It is obvious from these curves that great care must be exercised in the estimate of the number of cycles selected for design.

The bottom structure is stressed primarily at each wave, and the cargo well deck will also be highly stressed at each wave when cargo is aboard. The sides may only be severely stressed when coming alongside. Consequently, the fatigue strength will vary depending on the location of the structure. Assuming 10 yr of active service with an average use underway of 20 hr per week and a stress cycle averaging 1 cps, then the number of cycles is 3.7×10^7 cycles.

By use of Fig. 7-24, Table 7-11 was developed to show the influence of fatigue stress at 3.7×10^7 cycles.

Table 7-12 lists the mechanical properties for various materials. The data are from the listed sources.

7-3.2.2 Steel

Steel is the basic construction material for practically all automotive vehicles and ships. Its use is limited in aerospace due to weight and in small boats because of excessive corrosion problems. The reasons for its extensive use include low material cost, low fabrication cost, high mechanical characteristics, excellent availability, and practically universal familiarity with construction and repair procedures.

Two basic types of steel for construction have been developed to include a consistently high grade of material to withstand the dynamic loading that is prevalent. The primary one is a

TABLE 7-10 RELATIVE DEFLECTIONS

Material	*Tensile Modulus of Elasticity*	*Equal Volume*	*Equal Weight*	
			Beam in Tension	*Beam in Bending*
Steel	29×10^6 psi	1	9	9
Fiberglas	1.4×10^6 psi	21	4½	2
Aluminum	10.3×10^6 psi	3	1	1

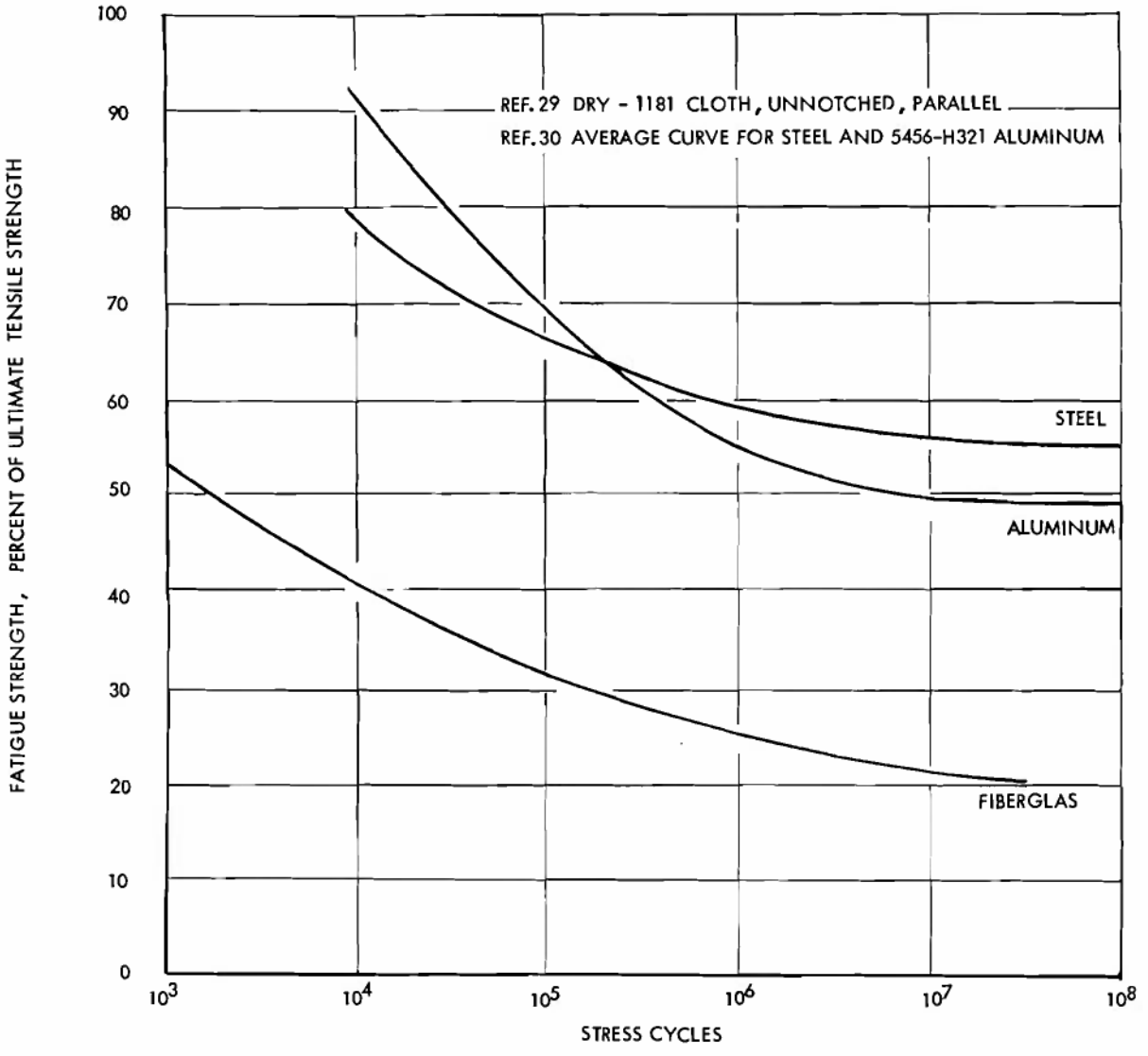

Figure 7-24. Fatigue Strength as a Function of Stress Cycles

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TABLE 7-11 RELATIVE FATIGUE STRESS/DENSITY

Material	3.7×10^7 *Cycle Fatigue Stress,* psi	*Relative Values of Fatigue Stress/Density*
Steel	37,000	1.3
Fiberglas	7,000	1.0
Aluminum (5456-H34)	21,000	1.9

low carbon killed or semi-killed steel manufactured with rigid controls. The Navy classifies this as medium steel, and it conforms to MIL-S-22698 for plates and MIL-S-20166, Grade M for bars and shapes.

The second type is a low-alloy, high tensile strength steel generally labeled HTS. These meet the following specifications: ASTM A-242, MIL-S-20166, Grade HT for bars and shapes, and MIL-S-16113, Grade HT or MIL-S-24094 for plates.

As a construction material for amphibians, steel has many advantages, including:

a. Excellent availability
b. Low cost, even for HTS
c. Properties are well known
d. Strength is high except at very low temperatures
e. Fireproof

The disadvantages are:

a. Corrosion in a marine environment
b. Heavy weight

Since, in general, only thin plates (10 and 12 gage for the LARC LX) are required for the shell to obtain adequate strength, corrosion must be minimized. There are coatings available that can practically eliminate the problem. These coatings have a long life and are expensive.

The problem of weight is not so easily solved. In fact, a steel hull will weigh about twice as much as a comparable aluminum hull. This one disadvantage essentially eliminates steel from serious consideration as a construction material except when the design penalty for added weight is low, such as in a swimming type vehicle, i.e., low water performance.

7-3.2.3 Fiberglas

Fibrous glass reinforced plastics, commonly called "Fiberglas" in this country, is a very successful material for boats. In the smaller boat sizes it dominates the industry. This material is relatively new and its technology is still moving forward at a fast pace. The design information of today (1969) may well be out of date in a few years.

Fiberglas is a combination of high tensile strength glass filaments in a plastic structure. The glass fibers carry the load and the plastic holds the fibers in position and distributes the forces in much the same way as steel reinforced concrete functions. The glass fibers are available in a wide range of sizes and configurations which vary from woven material to glass mat which is a layer of short fibers in a random pattern. There is also a variety of plastic resins available, primarily the polyesters and epoxies. The possible combinations of different configurations of glass fibers and resins are very useful in optimizing the use of the material for the particular structure needed. The cost of fabrication is low if there is a sufficient number of hulls made to reduce the cost of the molds per hull.

Other important characteristics are (1) repairability is good if the working temperature is above about 50° F, and maintenance is relatively low since it is an inert material that does not oxidize readily; (2) the weight of material required is higher than aluminum and lower than steel; (3) if the structure is designed to a deflection criterion, then a sandwich-type configuration can be used which will be light; and (4) many shops now specialize in Fiberglas construction, and there are personnel available that are well trained in using the material. In general, however, these special facilities are not in the companies that are likely to build amphibians.

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TABLE 7-12 MECHANICAL PROPERTIES OF CONSTRUCTION MATERIALS

Material	Steel		Fiberglas see note (1)	Aluminum 5456-H321 (2)		Tempered Plate Glass
	Mild	Hi Tensile		Parent	HAZ (3)	
Tensile Strength, ksi(7)						
Ultimate						
Minimum		70	9.8	46	42	25
Typical	67		33	51		30
Yield						
Minimum		50		33	26	
Typical	33			37		
Elongation						
Minimum	25(5)	18(6) 22(5)		12(5)		
Typical				16(5)		
Compression Strength, ksi						
Yield						
Minimum			4.2	32	25	25
Typical	67		15.8	30		30
Shear Strength, ksi						
Ultimate						
Minimum				27	25	
Typical	50		11			
Yield						
Minimum				19	15	
Bearing Strength, ksi						
Ultimate						
Minimum				84		
Yield						
Minimum				56		
Weight, lb/in.^{3}	0.283	0.283	0.059	0.096		0.091
Specific Gravity	7.84	7.84	1.64	2.66		2.53
Modulus of Elasticity, ksi						
Tension/Compression	30,000	30,000	2060/1900	10,300		10,000
Shear				3,850		
Poisson's ratio	0.26	0.26	.14/.65/.11 (4)	0.33		0.23
Coefficient of Expansion, °F^{-1}	0.65 x 10^{-5}	0.65 x 10^{-5}		1.33 x 10^{-5}		0.49 x 10^{-5}
Refs.	28	50	29	31		51

Notes:

1. 25-27 oz woven roving with polyester resin 1/4 in. thick, 51 percent glass by weight, immersed in water at room temperature for 30 days.
2. 1/4 in. thick sheet
3. HAZ - Heat affected zone
4. 0° to weave/45° to weave/ and 90° to weave
5. Percent in 2 in.
6. Percent in 8 in.
7. ksi - 1,000 lb/in.^{2}

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From Table 7-12 it can be seen that the strength of Fiberglas is high and the configuration can be varied throughout the structure to take full advantage of this strength. There are, however, four areas that must be carefully considered in Fiberglas design:

1. The peel strength of Fiberglas is low. This is particularly important where bulkheads or other structures are added perpendicular to the hull with bonding angles.
2. The laminate bearing strength is also low and results in local crushing from mechanical fasteners unless the bearing surface is enlarged over that available with normal size washers. Consequently, in an amphibian the problems of attaching the components of the machinery and drive trains must be specially considered for Fiberglas to be a successful construction material.
3. Besides these problems of attachment, the impact strength is low, as shown in Table 7-9.
4. The flexibility is high which can cause alignment problems.

7-3.2.4 Aluminum

Of the three potential construction materials available, aluminum construction will result in the lightest hulls. Aluminum has been successfully used for the LARC V and LARC XV vehicles. Although there are problems, it is probable that future amphibians of 5- to 15-ton size will be constructed of aluminum. For this reason the characteristics of aluminum are presented here in more detail.

Two types of wrought aluminum alloys are available for structural purposes—heat treatable and nonheat-treatable. The heat treatable alloys gain a major portion of their strength by a post fabrication heat treatment. If the structure is too large to fit in an oven, either the lower strength must be accepted in the way of welding and the other areas where heat is applied during manufacturing or mechanical fasteners and cold forming may be used. The nonheat-treatable alloys use a combination of alloying elements and cold work to achieve high strength.

The wrought alloys are designated using a four-digit system. The first digit indicates the alloy group, and these are defined in Ref. 31 and in other references. The "marine" alloys are in the 5000 series which has magnesium as the main alloying element. The ultimate tensile strength ranges from 63,000 psi to 31,000 psi varying with the alloy and the temper. The temper designation system is used for all forms of wrought and cast aluminum alloys except ingot and is based on the sequences of basic treatments used to produce the various tempers. The temper designation follows the alloy designation with the basic identifier consisting of one letter, and variations are indicated by a series of digits. Table 7-13 lists the basic temper designations.

Two special designations of interest are:

a. H311—Alloys with over 4 percent magnesium which are strain hardened less than the amount required for a controlled H31 temper.

b. H321—Alloys with over 4 percent magnesium which are strain-hardened less than the amount required for a controlled H32 temper.

Other properties of the 5000 series are:

a. Excellent corrosion resistance in the marine environment

b. Easily weldable and initial mechanical properties are not greatly affected by welding

c. Good formability

d. Good availability

The mechanical properties of the two higher strength most common alloys in the 5000 series are listed in Table 7-12.

Standard and maximum plate sizes for the more popular 5000 series alloys and for 6061-T6, the heat treatable alloy most commonly used in the marine structures, are listed in Table 7-14. Standard structural shapes are stocked at local warehouses throughout the country mainly in 25-ft lengths. Other sizes are frequently available locally to suit the special requirements of the area. Mill orders of extrusions can be supplied in any alloy with the length limited only by the available transportation. Aluminum is generally formed cold using the same equipment and techniques used for steel. Many members which would require hot forming in steel can be formed cold in aluminum.

Various aspects of cold forming aluminum can be found in Ref. 32. In addition, Table 7-15 and Figs. 7-25 to 7-32 are presented for use in designing bends in developable surfaces. The major difference between cold forming aluminum and steel is the greater spring-back of the aluminum. Where necessary, hot forming can

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TABLE 7-13 BASIC TEMPER DESIGNATIONS

Designation	*Description*
F	As fabricated
O	Annealed
H	Strain hardened (nonheat-treatable alloys)
W	Solution heat treated
T	Thermally treated (heat treatable alloys)

The first digit of the subdivisions are:

1 Strain hardened only

2 Strain hardened and partially annealed

3 Strain hardened and stabilized. A first digit of 3 is used only for the alloys with significant amounts of magnesium because they will gradually age-soften at room temperature unless they are stabilized.

The second digit indicates the degree of strain-hardening remaining after stabilization. Where

0	Annealed
1, 2, 3, 4, 5, 6, 7	Ultimate strength approximately equal to the annealed ultimate plus the number/8 of the difference between the ultimate strength of the annealed and of the 75 percent cold reduction condition
8	75 percent cold reduction

be used with aluminum where the temperatures are limited to about 400° F for a short period of time. This temperature must be carefully considered for each alloy. Unlike steel, there is little or no visual change in the appearance of aluminum at reasonable forming temperatures so that great care must be exercised. Cutting of aluminum in shipyards is normally done by sawing or shearing. Normal wood working portable tools with special blades are very useful. High-speed arc cutting is feasible and routers are often used for intricate shapes or where a number of identical pieces can be cut from one pattern.

Leaks almost always develop at riveted connections after the structure has been stressed; accordingly, riveting is impractical for fastening the shell. Rivets or other mechanical fasteners can be used where there are no requirements for a watertight joint.

Welding is now the primary means of fastening the structural sections together. Two main types of welding guns are in use. TIG, called "tig", for tungsten-arc, inert-gas shield; and MIG, called "mig", for metal-arc, inert-gas shield. The TIG system has a tungsten electrode which forms the arc, and a hand-held welding rod. A jet of inert gas, usually a mixture of

TABLE 7-14 ALUMINUM PLATE PRODUCTS – STANDARD AND MAXIMUM SIZES AVAILABLE (Ref. 52)

(All Dimensions in in.)

	Unit[1]	Standard Sizes				Maximum Sizes			
Thickness	Wt, lb/ft²	5052-H32	5086-H32	5456-H321	6061-T651	5052-H32	5086-H32	5456-H321	6061-T651
1/4	3.46	48 x 144	48 x 144 72 x 144	60 x 144	36 x 96 48 x 144 60 x 144 72 x 144	120 x 480	132 x 480	120 x 480	120 x 480
5/16	4.31	48 x 144	48 x 144 72 x 144		36 x 96 48 x 144	120 x 480	132 x 480	120 x 480	120 x 480
3/8	5.2	48 x 144	48 x 144 72 x 144	60 x 144	36 x 96 48 x 144 60 x 144	120 x 480	132 x 480	120 x 480	120 x 480
1/2	6.9	48 x 144	48 x 144	60 x 144	36 x 96 48 x 144	120 x 540	132 x 540	120 x 480	120 x 480
3/4	10.4	48 x 144	48 x 144	60 x 144	36 x 96 48 x 144	125 x 540	120 x 540	120 x 480	132 x 540
1	13.8	36 x 96		60 x 144	36 x 96 48 x 144	96 x 540	96 x 540	120 x 480	132 x 540

[1]Weights given above apply to 5052, 5086 and 5456. These must be multiplied by 1.02 to apply to 6061.

		C102 (Diamond) Pattern Tread Plate	
1/8	2.0	48 x 192; 60 x 192; 48 x 144	60 x 300
3/16	3.0	48 x 192; 60 x 192	72 x 360
1/4	3.9	48 x 192; 60 x 192	72 x 360
3/8	5.6	48 x 192	60 x 360
1/2	7.3	.....	60 x 360
		Abrasive Tread Plate	
1/8	1.7	48 x 144	48 x 144
3/16	2.6	48 x 144	48 x 144
1/4	3.4	48 x 144	48 x 144
3/8	5.1	.....	48 x 96

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TABLE 7-15 APPROXIMATE RADII FOR 90° COLD BEND SHEET AND PLATE

Al. Alloy and Temper	All Radii in In. (1)				
	1/8	3/16	1/4	3/8	1/2
5052-O	O	O-3/16	O-1/4	3/16-9/16	1/2-1
5052-H32	1/16-3/16	1/8-5/16	1/8-3/8	3/8-3/4	3/4 - 1-1/4
5052-H34	3/16-5/16	5/16-7/16	1/2-3/4	3/4 - 1-1/8	1-1/4 - 1-3/4
5083-O	O-1/8	O-3/16	1/8-1/4	3/8-9/16	1/2-1
5086-H32	1/8-1/4	5/16-3/8	3/8-5/8	3/4-15/16	1-1/4 - 1-1/2
5086-H34	3/16-5/16	3/8-9/16	1/2-3/4	15/16 - 1-5/16	1-1/2-2
5456-O	O-1/8	1/8-3/16	1/8-1/4	3/8-9/16	1/2-1
5456-H321	1/4-3/8	3/8-9/16	1/2-3/4	1-1/8 - 1-1/2	1-1/2-2
6061-O	O	O-3/16	O-1/4	3/16-3/4	1 2 - 1-1/4
6061-T6(2)	1/8-1/4	5/16-9/16	1/2-1	15/16 - 1-1/2	1-1/2 - 2-1/2

(1) Minimum permissible radius over which sheet or plate may be bent varies with nature of forming operation, type of forming equipment, and design and conditions of tools. Minimum working radius for a given material or hardest alloy and temper for a given radius can be ascertained only by actual trial under contemplated conditions of fabrication.

(2) Tread Plate may require bend radii up to as much as twice the values listed for plain sheet and plate.

helium and argon, is fed by the welding gun around the electrode. TIG, with respect to MIG, requires more skill and generally is slower and produces more distortion. It is no longer used extensively for marine structures except for repair work.

The MIG system employs a gun with the welding wire used as the electrode, driven at various constant speeds. It also includes use of a jet of inert gas for shielding. These guns may be either air- or water-cooled. Outlines of typical MIG guns are shown in Fig. 7-33.

In general the weld quality required will govern the cleanliness required for welding. It is essential to degrease the prepared edges if lubricants are used in the preparation of the edges. Also the oxide film must be removed with a stainless steel wire brush if a high quality weld is required. These brushes should be used only for this purpose. A new film forms immediately after the original oxide film is removed and grows in thickness until stability is reached. The growth rate and eventual thickness of film depend on the environment. For each project it is necessary to determine the maximum allowable time between cleaning the weld area and welding. For one amphibian where the aluminum was chemically cleaned, a maximum allowable time of 24 hr was established.

Only two electrodes, alloys 5556 and 5356, are widely used in marine applications. Many others are available for special purposes. Alloy 5556 provides the highest weld strength. It is the only material recommended for use with 5456 and provides the highest fillet strengths with 5086 and 5052. Alloy 5356 provides high weld strength and is used with 5086 or 5052 parent metal. These two electrodes are also used when attaching 6061 structural shapes to a 5000 series plate.

Welding procedures are essentially the same as those used for steel except that a higher order of cleanliness is required, which should include the work area in the vicinity. The work must be shielded from the wind so that the gas shield is not blown away from the weld puddle. Intermittent welding can be used with continuous welds at the ends. The Navy requires double continuous welds in most cases to reduce cracks from shock loads. Welding in any position is practical although a better weld will generally be made in the down-hand position. Particular care must be used to allow room for the large snout on the gun, as shown on Fig. 7-33.

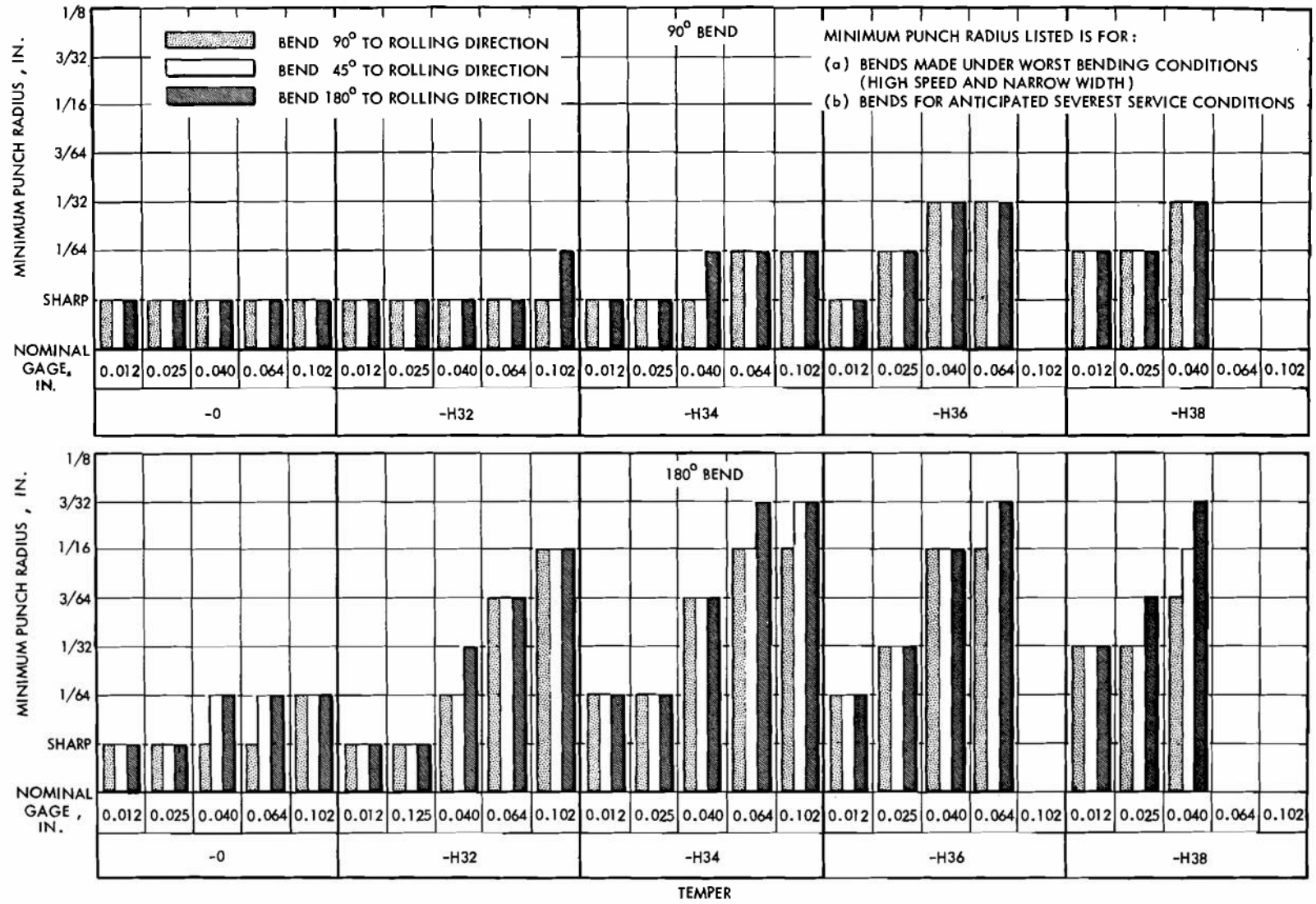

Figure 7-25. Bend Characteristics for Alloy 5457 Sheet

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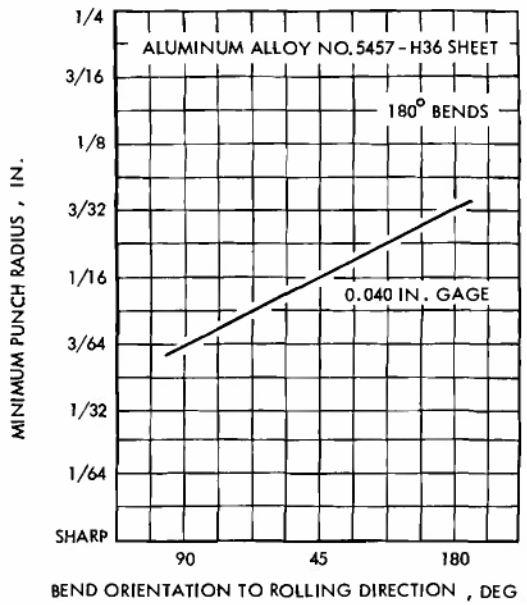


Figure 7-26. Effect of Bend Orientation on Bend Characteristics

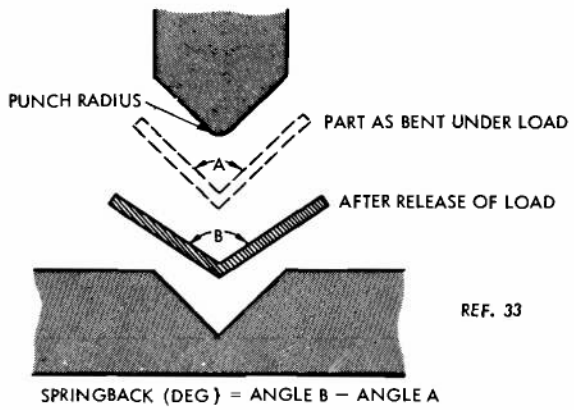


Figure 7-27. Springback Test Tooling

One of the advantages of aluminum with respect to steel is the high resistance to salt-water corrosion. This characteristic has been carefully investigated and proven by tests and in general practice. The marine alloys exhibit a self-limiting type of corrosion because the oxide formed is hard and tends to protect the metal underneath it. Stress corrosion is possible with the 5000 series. However, stress corrosion can be eliminated with proper combinations of alloying elements (magnesium limited to not more than 10 percent), temper, stress level, and the degree of cold work. For those situations where high stresses occur in material that has been extensively cold worked, the selection of the temper of the material used should be specially considered. The total cold-working that must be considered includes the original strain hardening done by the aluminum manufacturer and specified in the temper designation, and that done in cold-forming the plate or shape to fit by the vehicle manufacturer. The minimum bend radii for 90-deg cold bends given in Table 7-13 are, to a certain extent, limited by this consideration. Smaller radii should be hot formed. Service temperature should not exceed about 150°F without special consideration of the stress-corrosion problem. Where higher temperatures are unavoidable, such as in a stack enclosure, the 5454 alloy should be used.

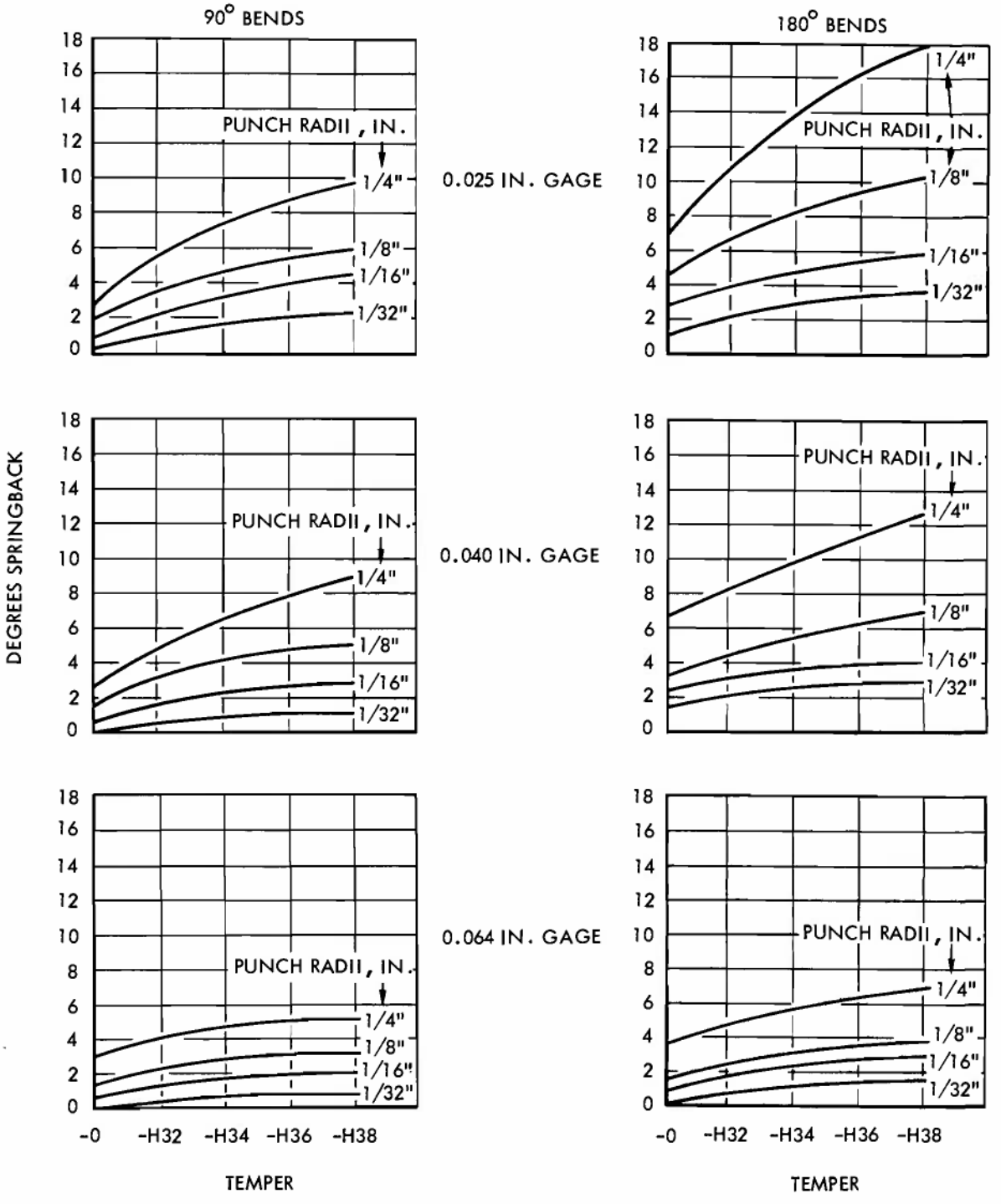
Galvanic corrosion resulting from the use of electrically connected dissimilar metals in an electrolyte such as salt water can be excessive in an aluminum hull. Table 7-16 lists the galvanic series where the more anodic metal is corroded. There are three general techniques for eliminating or reducing galvanic corrosion:

1. Alter the materials so they are the same or very close on the galvanic series. This may be done by placing a sacrificial anode in the vicinity. Magnesium alloys are frequently used for this purpose on aluminum hulls.

2. Eliminate the electrical path between the two electrodes, using any of a variety of caulking materials. The three most popular types are polysulfide, neoprene, or butyl-base materials which are available in either liquid or tape form. All electrical paths, including mechanical fasteners, must be eliminated and not allowed to reform during the life of the vehicle.

3. Isolate one or both materials from the electrolyte with a paint or other coating.

Crevice corrosion is a phenomenon that occurs in locations where the oxygen dissolved in sea water is depleted due to chemical action, and not replaced. Then if the passive film is broken in one spot a local galvanic cell is started and, since there is no oxygen, the passive film is not re-established. These conditions are prevalent where materials are joined by mechanical fasteners and the crevices are so small that there is no water flow. Crevice corrosion is generally not a problem for aluminum or copper alloys but it is for most of



ALL SPRINGBACK PLUS; OTHER RADII IN RELATIVE ORDER

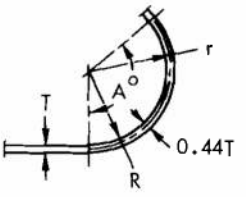
SPRINGBACK FOR BENDS AT 90°, 45°, AND 180° TO ROLLING DIRECTION SIMILAR

Figure 7-28. Springback of Alloy 5457 Sheet at Various Radii

FOR CALCULATIONS OF BEND ALLOWANCE WITH RADII GREATER THAN 1 IN. USE THE FOLLOWING FORMULA:

$0.017453\,rA$ = BEND ALLOWANCE

r = BEND RADIUS + 0.44 MATERIAL THICKNESS
A = NUMBER OF DEGREES IN BEND



CHANGE FRACTIONS OF DEGREES TO DECIMAL EQUIVALENT BEFORE SUBSTITUTING IN THE FORMULA

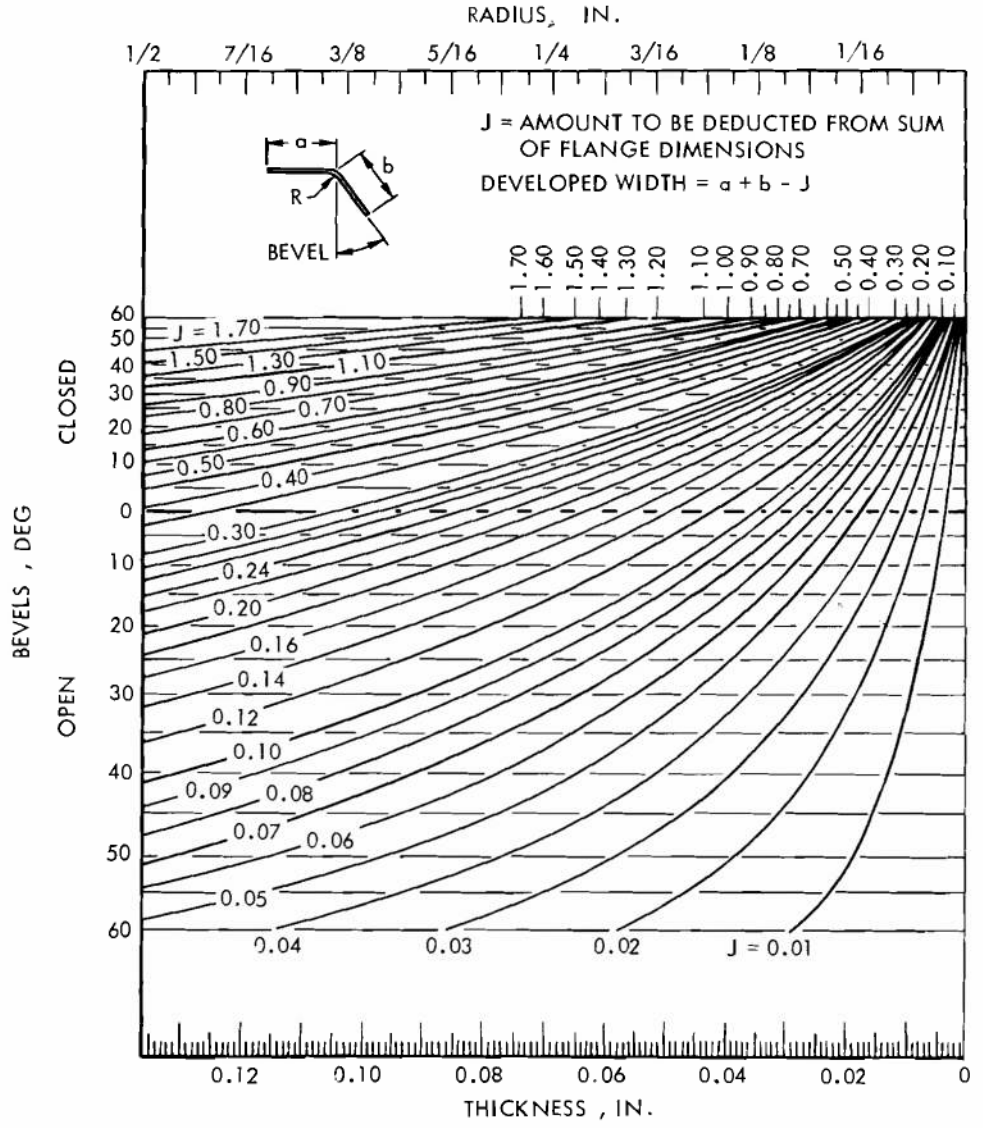


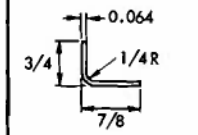
Figure 7-29. Developed Length Chart

BEND RADIUS R	MATERIAL THICKNESS T													
	0.016	0.020	0.025	0.032	0.040	0.051	0.064	0.072	0.081	0.091	0.125	0.156	0.188	
1/32	0.0342	0.0395	0.0459	0.0554										1/32
1/16	0.0481	0.0525	0.0589	0.0675	0.0790	0.0929	0.1099	0.1205						1/16
3/32	0.0611	0.0664	0.0728	0.0823	0.0920	0.1068	0.1238	0.1335	0.1461	0.1589				3/32
1/8	0.0750	0.0794	0.0858	0.0953	0.1059	0.1198	0.1368	0.1474	0.1591	0.1719				1/8
5/32	0.0880	0.0933	0.0997	0.1092	0.1189	0.1337	0.1507	0.1613	0.1730	0.1858	0.2295			5/32
3/16	0.1019	0.1072	0.1127	0.1222	0.1328	0.1467	0.1637	0.1743	0.1860	0.1988	0.2434	0.2829	0.3253	3/16
7/32	0.1149	0.1202	0.1266	0.1361	0.1467	0.1606	0.1776	0.1882	0.1999	0.2127	0.2564	0.2968	0.3383	7/32
1/4	0.1288	0.1341	0.1396	0.1491	0.1597	0.1736	0.1906	0.2012	0.2129	0.2257	0.2703	0.3098	0.3522	1/4
9/32	0.1418	0.1471	0.1535	0.1630	0.1736	0.1875	0.2045	0.2151	0.2268	0.2396	0.2833	0.3237	0.3661	9/32
5/16	0.1557	0.1610	0.1674	0.1760	0.1866	0.2014	0.2175	0.2281	0.2398	0.2526	0.2972	0.3367	0.3791	5/16
11/32	0.1687	0.1740	0.1804	0.1899	0.2005	0.2144	0.2314	0.2420	0.2537	0.2665	0.3102	0.3506	0.3930	11/32
3/8	0.1826	0.1879	0.1943	0.2029	0.2135	0.2283	0.2444	0.2550	0.2667	0.2795	0.3241	0.3636	0.4060	3/8
13/32	0.1956	0.2009	0.2073	0.2168	0.2274	0.2413	0.2583	0.2689	0.2806	0.2934	0.3371	0.3775	0.4199	13/32
7/16	0.2095	0.2148	0.2212	0.2307	0.2404	0.2552	0.2722	0.2819	0.2936	0.3064	0.3510	0.3914	0.4329	7/16
15/32	0.2234	0.2278	0.2342	0.2437	0.2543	0.2682	0.2852	0.2958	0.3075	0.3203	0.3640	0.4044	0.4468	15/32
1/2	0.2364	0.2417	0.2481	0.2576	0.2673	0.2821	0.2991	0.3088	0.3205	0.3333	0.3779	0.4183	0.4598	1/2
17/32		0.2547	0.2611	0.2706	0.2812	0.2951	0.3121	0.3227	0.3344	0.3472	0.3918	0.4313	0.4737	17/32
9/16			0.2750	0.2845	0.2942	0.3090	0.3260	0.3357	0.3483	0.3611	0.4048	0.4452	0.4867	9/16
19/32				0.2993	0.3090	0.3238	0.3408	0.3496	0.3613	0.3750	0.4187	0.4582	0.5006	19/32
5/8					0.3211	0.3359	0.3529	0.3626	0.3752	0.3880	0.4317	0.4721	0.5136	5/8
21/32						0.3498	0.3668	0.3765	0.3882	0.4019	0.4456	0.4851	0.5275	21/32
11/16							0.3798	0.3904	0.4021	0.4149	0.4586	0.4990	0.5405	11/16
23/32								0.4034	0.4151	0.4297	0.4725	0.5129	0.5544	23/32
3/4									0.4290	0.4418	0.4855	0.5259	0.5674	3/4
25/32										0.4557	0.4994	0.5389	0.5813	25/32
13/16											0.5124	0.5528	0.5952	13/16
27/32											0.5263	0.5658	0.6082	27/32
7/8											0.5393	0.5797	0.6221	7/8
29/32											0.5332	0.5936	0.6351	29/32
15/16												0.6066	0.6490	15/16
31/32												0.6205	0.6620	31/32
1												0.6335	0.6759	1

NOTE:
1. ALL DIMENSIONS IN IN.
2. BEND ALLOWANCES FOR RADII GREATER THAN 1 IN. SEE FIG. 7-29

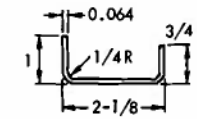
TO FIND DEVELOPED LENGTH MULTIPLY THE NUMBER OF BENDS BY THE APPLICABLE CHART VALUE AND SUBTRACT THE RESULT FROM THE SUM OF THE FLANGE DIMENSIONS.

EXAMPLE



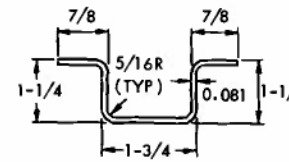
3/4 + 7/8 = 1-5/8

1.625 - 0.1906 = 1.434
DEVELOPED LENGTH



1 + 2-1/8 + 3/4 = 3-7/8

3.875 - 2(0.1906) = 3.4938
DEVELOPED LENGTH



7/8 + 1-1/4 + 1-3/4 + 1-1/4 + 7/8 = 6.000

6.000 - 4(0.2398) = DEVELOPED LENGTH

6.000 - 0.9592 = 5.041

Figure 7-30. Developed Length of 90° Bends

BEND RADIUS R	MATERIAL THICKNESS T																			
	0.016	0.019-0.020	0.025	0.028	0.031-0.032	0.038	0.040	0.050-0.051	0.063-0.064	0.072	0.078	0.081	0.091	0.094	0.109	0.125	0.156	0.188	0.250	
1/32	0.00067	0.00070	0.00074	0.00077	0.00079	0.00084														1/32
1/16	0.00121	0.00125	0.00129	0.00131	0.00135	0.00138	0.00140	0.00149	0.00159	0.00165										1/16
3/32	0.00176	0.00179	0.00183	0.00186	0.00188	0.00193	0.00195	0.00203	0.00213	0.00220	0.00224	0.00226	0.00234							3/32
1/8	0.00230	0.00234	0.00238	0.00240	0.00243	0.00247	0.00249	0.00258	0.00268	0.00274	0.00279	0.00281	0.00289	0.00291						1/8
5/32	0.00285	0.00288	0.00292	0.00295	0.00297	0.00302	0.00304	0.00312	0.00322	0.00328	0.00333	0.00335	0.00343	0.00346	0.00358	0.00370				5/32
3/16	0.00339	0.00342	0.00347	0.00349	0.00352	0.00356	0.00358	0.00367	0.00377	0.00383	0.00388	0.00390	0.00398	0.00400	0.00412	0.00424	0.00449	0.00473		3/16
7/32	0.00394	0.00397	0.00401	0.00403	0.00406	0.00411	0.00412	0.00421	0.00431	0.00437	0.00442	0.00444	0.00452	0.00454	0.00467	0.00479	0.00503	0.00528		7/32
1/4	0.00448	0.00451	0.00456	0.00458	0.00461	0.00465	0.00467	0.00476	0.00486	0.00492	0.00497	0.00499	0.00507	0.00509	0.00521	0.00533	0.00558	0.00582		1/4
9/32	0.00503	0.00506	0.00510	0.00512	0.00515	0.00519	0.00521	0.00530	0.00540	0.00546	0.00551	0.00553	0.00561	0.00563	0.00576	0.00588	0.00612	0.00636		9/32
5/16	0.00557	0.00561	0.00564	0.00567	0.00570	0.00574	0.00576	0.00584	0.00595	0.00601	0.00606	0.00608	0.00616	0.00618	0.00630	0.00642	0.00667	0.00691		5/16
11/32	0.00612	0.00615	0.00619	0.00621	0.00624	0.00628	0.00630	0.00639	0.00649	0.00655	0.00660	0.00662	0.00670	0.00672	0.00684	0.00697	0.00721	0.00745		11/32
3/8	0.00666	0.00669	0.00673	0.00676	0.00679	0.00683	0.00685	0.00693	0.00704	0.00710	0.00715	0.00717	0.00725	0.00727	0.00739	0.00751	0.00776	0.00800	0.00849	3/8
13/32	0.00721	0.00724	0.00728	0.00730	0.00733	0.00737	0.00739	0.00748	0.00758	0.00764	0.00769	0.00771	0.00779	0.00781	0.00793	0.00806	0.00830	0.00854	0.00903	13/32
7/16	0.00775	0.00778	0.00782	0.00785	0.00787	0.00792	0.00794	0.00802	0.00812	0.00819	0.00823	0.00826	0.00834	0.00836	0.00848	0.00860	0.00884	0.00909	0.00958	7/16
15/32	0.00829	0.00833	0.00837	0.00839	0.00842	0.00846	0.00848	0.00857	0.00867	0.00873	0.00878	0.00880	0.00888	0.00890	0.00902	0.00915	0.00939	0.00963	0.01012	15/32
1/2	0.00884	0.00887	0.00891	0.00894	0.00896	0.00901	0.00903	0.00911	0.00921	0.00928	0.00932	0.00935	0.00943	0.00945	0.00957	0.00969	0.00993	0.01018	0.01067	1/2
17/32	0.00938	0.00942	0.00946	0.00948	0.00951	0.00955	0.00957	0.00966	0.00976	0.00982	0.00987	0.00989	0.00997	0.00999	0.01011	0.01023	0.01048	0.01072	0.01121	17/32
9/16	0.00993	0.00996	0.01000	0.01002	0.01005	0.01010	0.01012	0.01020	0.01030	0.01037	0.01041	0.01043	0.01051	0.01054	0.01066	0.01078	0.01102	0.01127	0.01175	9/16
19/32	0.01047	0.01051	0.01055	0.01057	0.01058	0.01064	0.01065	0.01073	0.01083	0.01091	0.01096	0.01098	0.01105	0.01108	0.01120	0.01132	0.01157	0.01181	0.01230	19/32
5/8	0.01102	0.01105	0.01109	0.01112	0.01114	0.01119	0.01121	0.01129	0.01139	0.01146	0.01150	0.01152	0.01160	0.01163	0.01175	0.01187	0.01211	0.01236	0.01284	5/8
21/32	0.01156	0.01160	0.01164	0.01166	0.01170	0.01173	0.01175	0.01183	0.01193	0.01200	0.01205	0.01207	0.01214	0.01217	0.01229	0.01241	0.01266	0.01290	0.01339	21/32
11/16	0.01211	0.01214	0.01218	0.01220	0.01223	0.01228	0.01230	0.01238	0.01248	0.01254	0.01259	0.01261	0.01269	0.01271	0.01284	0.01296	0.01320	0.01345	0.01393	11/16
23/32	0.01265	0.01268	0.01273	0.01275	0.01276	0.01282	0.01283	0.01291	0.01301	0.01309	0.01314	0.01316	0.01322	0.01326	0.01338	0.01350	0.01374	0.01399	0.01448	23/32
3/4	0.01320	0.01323	0.01327	0.01329	0.01332	0.01337	0.01338	0.01347	0.01357	0.01363	0.01368	0.01370	0.01378	0.01380	0.01393	0.01405	0.01429	0.01454	0.01502	3/4
25/32	0.01374	0.01378	0.01381	0.01384	0.01386	0.01391	0.01392	0.01401	0.01411	0.01418	0.01423	0.01425	0.01432	0.01435	0.01448	0.01459	0.01484	0.01508	0.01557	25/32
13/16	0.01429	0.01432	0.01436	0.01438	0.01441	0.01445	0.01447	0.01456	0.01466	0.01472	0.01477	0.01479	0.01487	0.01489	0.01502	0.01514	0.01538	0.01562	0.01611	13/16
27/32	0.01483	0.01486	0.01490	0.01493	0.01494	0.01500	0.01501	0.01509	0.01519	0.01527	0.01532	0.01534	0.01540	0.01544	0.01556	0.01568	0.01593	0.01617	0.01666	27/32
7/8	0.01538	0.01541	0.01545	0.01547	0.01550	0.01554	0.01556	0.01565	0.01575	0.01581	0.01586	0.01588	0.01596	0.01598	0.01610	0.01623	0.01647	0.01671	0.01720	7/8
29/32	0.01592	0.01595	0.01599	0.01602	0.01604	0.01609	0.01611	0.01619	0.01629	0.01636	0.01641	0.01643	0.01650	0.01653	0.01665	0.01677	0.01701	0.01726	0.01775	29/32
15/16	0.01646	0.01650	0.01654	0.01656	0.01659	0.01663	0.01665	0.01674	0.01684	0.01690	0.01695	0.01697	0.01705	0.01707	0.01719	0.01732	0.01756	0.01780	0.01829	15/16
31/32	0.01701	0.01704	0.01708	0.01711	0.01712	0.01718	0.01720	0.01727	0.01737	0.01745	0.01749	0.01752	0.01758	0.01762	0.01774	0.01786	0.01810	0.01835	0.01884	31/32
1	0.01755	0.01759	0.01763	0.01765	0.01768	0.01772	0.01774	0.01783	0.01793	0.01799	0.01804	0.01806	0.01814	0.01816	0.01828	0.01841	0.01865	0.01889	0.01938	1

NOTE:
1. ALL DIMENSIONS IN IN.
2. BEND ALLOWANCES FOR RADII GREATER THAN 1 IN. SEE FIG. 7-29

VALUES IN THIS TABLE ARE DERIVED FROM THE EMPIRICAL FORMULA:

$(0.01743R + 0.0078T) \times$ NUMBER OF DEGREES IN THE BEND = BEND ALLOWANCE

WHERE R = BEND RADIUS
T = MATERIAL THICKNESS

MULTIPLY VALUES SHOWN IN THIS TABLE BY THE NUMBER OF DEGREES IN A BEND TO OBTAIN BEND ALLOWANCE

Figure 7-31. Bend Allowance Chart—1° Bend

BEND RADIUS R	MATERIAL THICKNESS T																				
	0.016	0.019-0.020	0.025	0.028	0.031-0.032	0.038	0.040	0.050-0.051	0.063-0.064	0.072	0.078	0.081	0.091	0.094	0.109	0.125	0.156	0.188	0.250		BEND RADIUS R
1/32	0.0603	0.0630	0.0666	0.0693	0.0711	0.0756														1/32	
1/16	0.1089	0.1125	0.1161	0.1179	0.1215	0.1242	0.1260	0.1341	0.1431	0.1485										1/16	
3/32	0.1584	0.1611	0.1647	0.1674	0.1692	0.1737	0.1755	0.1827	0.1917	0.1980	0.2016	0.2034	0.2106							3/32	
1/8	0.2070	0.2106	0.2142	0.2160	0.2187	0.2223	0.2241	0.2322	0.2412	0.2466	0.2511	0.2529	0.2601	0.2619						1/8	
5/32	0.2565	0.2592	0.2628	0.2655	0.2673	0.2718	0.2736	0.2808	0.2898	0.2952	0.2997	0.3015	0.3087	0.3114	0.3222	0.3330				5/32	
3/16	0.3051	0.3078	0.3123	0.3141	0.3168	0.3204	0.3222	0.3303	0.3393	0.3447	0.3492	0.3510	0.3582	0.3600	0.3708	0.3816	0.4041	0.4257		3/16	
7/32	0.3546	0.3573	0.3609	0.3627	0.3654	0.3699	0.3708	0.3789	0.3879	0.3933	0.3978	0.3996	0.4068	0.4086	0.4203	0.4311	0.4527	0.4752		7/32	
1/4	0.4032	0.4059	0.4104	0.4122	0.4149	0.4185	0.4203	0.4284	0.4374	0.4428	0.4473	0.4491	0.4563	0.4581	0.4689	0.4797	0.5022	0.5238		1/4	
9/32	0.4527	0.4554	0.4590	0.4608	0.4635	0.4671	0.4689	0.4770	0.4860	0.4914	0.4959	0.4977	0.5049	0.5067	0.5184	0.5292	0.5508	0.5724		9/32	
5/16	0.5013	0.5040	0.5076	0.5103	0.5130	0.5166	0.5184	0.5256	0.5355	0.5409	0.5454	0.5472	0.5544	0.5562	0.5670	0.5778	0.6003	0.6219		5/16	
11/32	0.5508	0.5535	0.5571	0.5589	0.5616	0.5652	0.5670	0.5751	0.5841	0.5895	0.5940	0.5958	0.6030	0.6048	0.6156	0.6273	0.6489	0.6705		11/32	
3/8	0.5994	0.6021	0.6057	0.6084	0.6111	0.6147	0.6165	0.6237	0.6336	0.6390	0.6435	0.6453	0.6525	0.6543	0.6651	0.6759	0.6984	0.7200	0.7641	3/8	
13/32	0.6489	0.6516	0.6552	0.6570	0.6597	0.6633	0.6651	0.6732	0.6822	0.6876	0.6921	0.6939	0.7011	0.7029	0.7137	0.7254	0.7470	0.7686	0.8127	13/32	
7/16	0.6975	0.7002	0.7038	0.7065	0.7083	0.7128	0.7146	0.7218	0.7308	0.7371	0.7407	0.7434	0.7506	0.7524	0.7632	0.7740	0.7956	0.8181	0.8622	7/16	
15/32	0.7461	0.7497	0.7533	0.7551	0.7578	0.7614	0.7632	0.7713	0.7803	0.7857	0.7902	0.7920	0.7992	0.8010	0.8118	0.8235	0.8451	0.8667	0.9108	15/32	
1/2	0.7956	0.7983	0.8019	0.8046	0.8064	0.8109	0.8127	0.8100	0.8289	0.8352	0.8388	0.8415	0.8487	0.8505	0.8613	0.8721	0.8937	0.9162	0.9603	1/2	
17/32	0.8442	0.8478	0.8514	0.8532	0.8559	0.8595	0.8613	0.8694	0.8784	0.8838	0.8883	0.8901	0.8973	0.8991	0.9099	0.9207	0.9432	0.9648	1.0089	17/32	
9/16	0.8937	0.8964	0.9000	0.9018	0.9045	0.9090	0.9108	0.9180	0.9270	0.9333	0.9369	0.9387	0.9459	0.9486	0.9594	0.9702	0.9918	1.0143	1.0575	9/16	
19/32	0.9423	0.9459	0.9495	0.9513	0.9522	0.9576	0.9585	0.9657	0.9747	0.9819	0.9864	0.9882	0.9945	0.9972	1.0080	1.0188	1.0413	1.0629	1.1070	19/32	
5/8	0.9918	0.9945	0.9981	1.0008	1.0026	1.0071	1.0089	1.0161	1.0251	1.0314	1.0350	1.0368	1.0440	1.0467	1.0575	1.0683	1.0899	1.1124	1.1560	5/8	
21/32	1.0404	1.0440	1.0476	1.0494	1.0530	1.0557	1.0575	1.0647	1.0737	1.0800	1.0845	1.0863	1.0926	1.0953	1.1061	1.1169	1.1394	1.1610	1.2051	21/32	
11/16	1.0899	1.0926	1.0962	1.0980	1.1007	1.1052	1.1070	1.1142	1.1232	1.1286	1.1331	1.1349	1.1421	1.1439	1.1556	1.1664	1.1880	1.2105	1.2537	11/16	
23/32	1.1385	1.1412	1.1457	1.1475	1.1484	1.1538	1.1547	1.1619	1.1709	1.1781	1.1826	1.1844	1.1898	1.1934	1.2042	1.2150	1.2366	1.2591	1.3032	23/32	
3/4	1.1880	1.1907	1.1943	1.1961	1.1988	1.2033	1.2042	1.2123	1.2213	1.2267	1.2312	1.2330	1.2402	1.2420	1.2537	1.2645	1.2861	1.3086	1.3518	3/4	
25/32	1.2366	1.2402	1.2429	1.2456	1.2474	1.2519	1.2528	1.2609	1.2699	1.2762	1.2807	1.2825	1.2888	1.2915	1.3032	1.3131	1.3356	1.3572	1.4013	25/32	
13/16	1.2861	1.2888	1.2924	1.2942	1.2969	1.3005	1.3023	1.3104	1.3194	1.3248	1.3293	1.3311	1.3383	1.3401	1.3518	1.3626	1.3842	1.4058	1.4499	13/16	
27/32	1.3347	1.3374	1.3410	1.3437	1.3446	1.3500	1.3509	1.3581	1.3671	1.3743	1.3788	1.3806	1.3860	1.3896	1.4004	1.4112	1.4337	1.4553	1.4994	27/32	
7/8	1.3842	1.3869	1.3905	1.3923	1.3950	1.3986	1.4004	1.4085	1.4175	1.4229	1.4274	1.4292	1.4364	1.4382	1.4490	1.4607	1.4823	1.5039	1.5480	7/8	
29/32	1.4328	1.4355	1.4391	1.4418	1.4436	1.4481	1.4499	1.4571	1.4661	1.4724	1.4769	1.4787	1.4850	1.4877	1.4985	1.5093	1.5309	1.5534	1.5975	29/32	
15/16	1.4814	1.4850	1.4886	1.4904	1.4931	1.4967	1.4985	1.5066	1.5156	1.5210	1.5255	1.5273	1.5345	1.5363	1.5471	1.5588	1.5804	1.6020	1.6461	15/16	
31/32	1.5309	1.5336	1.5372	1.5399	1.5408	1.5462	1.5462	1.5543	1.5633	1.5705	1.5741	1.5768	1.5822	1.5858	1.5966	1.6074	1.6290	1.6515	1.6956	31/32	
1	1.5795	1.5831	1.5867	1.5885	1.5912	1.5948	1.5966	1.6047	1.6137	1.6191	1.6236	1.6254	1.6326	1.6344	1.6452	1.6569	1.6785	1.7001	1.7442	1	

NOTE:
1. ALL DIMENSIONS IN IN.
2. BEND ALLOWANCES FOR RADII GREATER THAN 1 IN. SEE FIGURE 7-29

VALUES IN THIS TABLE ARE DERIVED FROM THE EMPIRICAL FORMULA:

$(0.0173R + 0.0078T)\ 90^{\circ}$ = BEND ALLOWANCE

R = BEND RADIUS
T = MATERIAL THICKNESS

Figure 7-32. Bend Allowance Chart—90° Bend

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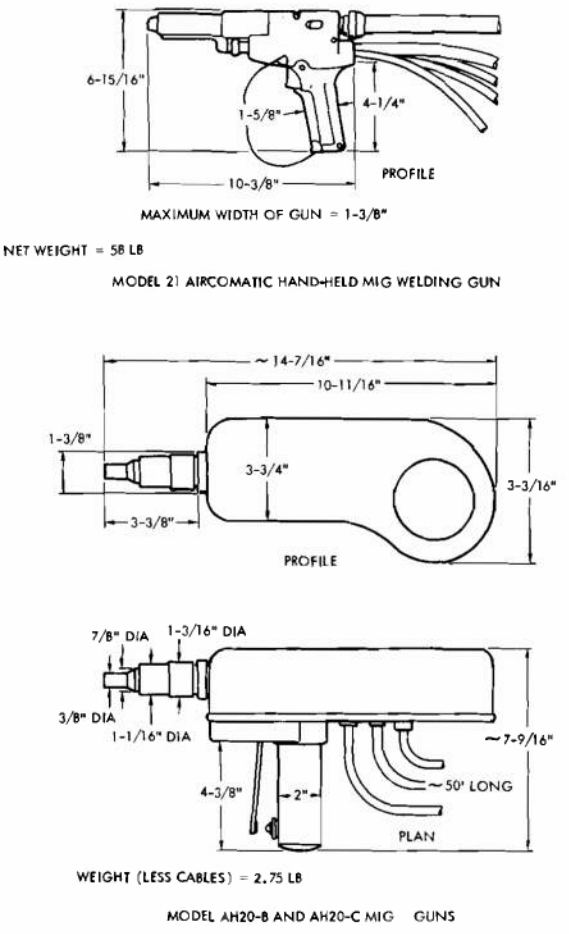

Figure 7-33. Typical MIG Hand-held Welding Guns

the stainless steel and nickel alloys. These alloys may be used for shafting, fasteners, or in the landborne running components.

Another type of reaction sometimes found on aluminum boats is exfoliation where the magnesium in the grain boundaries is attacked. This occurs primarily in the bilges when there is dirty bilge water present. Exfoliation can be controlled by special handling in the thermal part of the tempering process. This problem should be considered with the aluminum manufacturer's engineers since at this time (1969) they are still investigating this phenomenon.

Coatings for aluminum are applied using the same techniques used for steel. However, the paints used are frequently different. In particular, copper bearing antifouling paint can cause corrosion if improperly applied. An organic type of antifouling paint, such as tri-butyl-tin-oxide (TBTO), is frequently used with success and without corrosion. Aluminum amphibians are normally not left in the water for significant periods of time and therefore do not require antifouling protection. Present practice is to leave the entire vehicle unpainted both inside and out. After a period of exposure to the weather the aluminum oxide film forms on the exterior and leaves a dull gray finish which is quite satisfactory and requires no maintenance.

Table 7-12 lists the mechanical properties of the two aluminum alloys which are most frequently used for marine structures. Aluminum loses its strength without warning as it is heated. Tests show that 5052-H32 heated to 700° F for a long time will lose 90 percent of its yield strength and 47 percent at 400° F. It is important to consider in the arrangement the possible complications that could develop in a fire. For instance, the engine mounts might be safer if made from 5454 which retains its strength to a higher temperature.

Ref. 30 presents a wide variety of fatigue information which illustrates the characteristics of aluminum as a basic material and also some of the distinctive features which may appear in particular products such as extrusions, castings, and weldments. It does not, however, furnish the designers with all of the information needed for marine alloys. Fatigue tests are normally run using either axial or bending loads and with either smooth or notched specimens. The results of each variation of these tests are different so that the designer must interpret the tests for each design. The strength of a structure in a cyclic loading condition is primarily dependent on the stress level and the number of cycles. It is very important to properly estimate the number of cycles since the maximum strength in some cases will be reduced by 10,000 psi between 10^4 and 10^5 cycles. Fig. 7-34 is a modified Goodman diagram (maximum stress, minimum stress, and number of cycles) for axial stress applied to alloy 5456-0. This figure is from Ref. 34 which also contains a considerable amount of useful information on the fatigue of 5000 series aluminum. Some generalizations from Ref. 34 for 5000 series aluminum are:

a. Fatigue strength of sheet products is about 85 percent of that obtained from the rotating beam tests.

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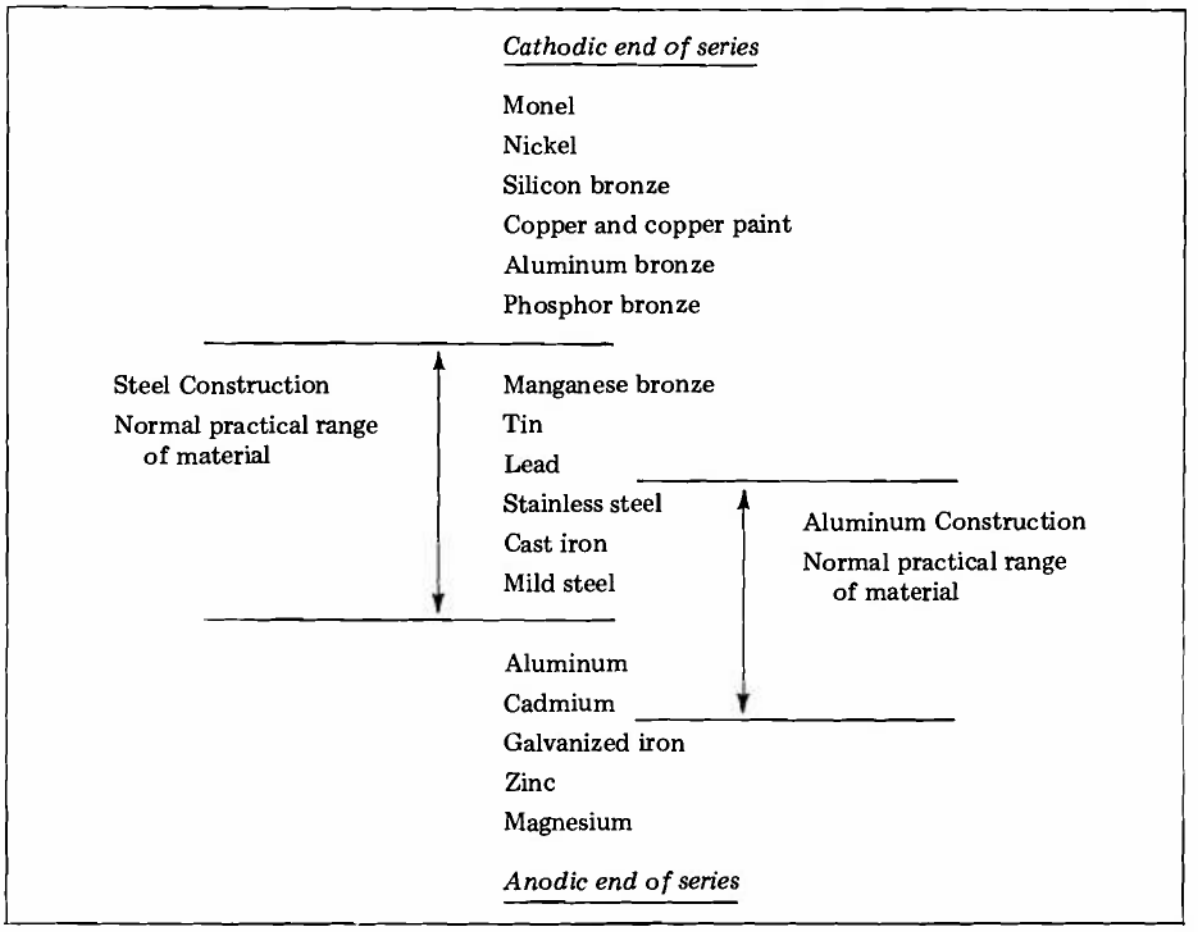
TABLE 7-16 GALVANIC SERIES



b. Fatigue strength for axial-stress (complete reversal of stress) is about 80 percent of that obtained from the rotating beam tests.

c. For low numbers of cycles the fatigue strengths are generally proportional to the static strength.

d. For lives greater than 10^6 cycles, the differences in fatigue strength between cycles and tempers become less; all fall within a reasonably narrow band.

e. Most of the alloys with 4 percent or more of magnesium in the annealed temper have fatigue strengths about equal to those of cold-worked material.

f. In general, the highest fatigue properties are developed by alloy 5456.

7-3.2.5 Glass

In the past some windshields have broken from the pressures of the waves in the surf and others have cracked from unequal expansion caused by the defroster. The 3/4 in. thick laminated safety glass, approximately 23 in. wide and 13 in. high, used on the LARC V has been satisfactory. During one series of tests the glass was broken while traversing a 12 ft surf.

Fully tempered glass should be used laminated to provide non shattering characteristics. The glazing can be neoprene with a rabbet depth at least one-half of the glass thickness. The mechanical properties of tempered plate glass are listed in Table 7-12.

Electrically heated glass such as "Electropane" by Libbey-Owens-Ford Glass Company has been successfully used for de-icing and de-fogging. Applications have included jet transport planes, Coast Guard Cutters, and land vehicles. It is available in sizes up to 48 in. by 60 in.

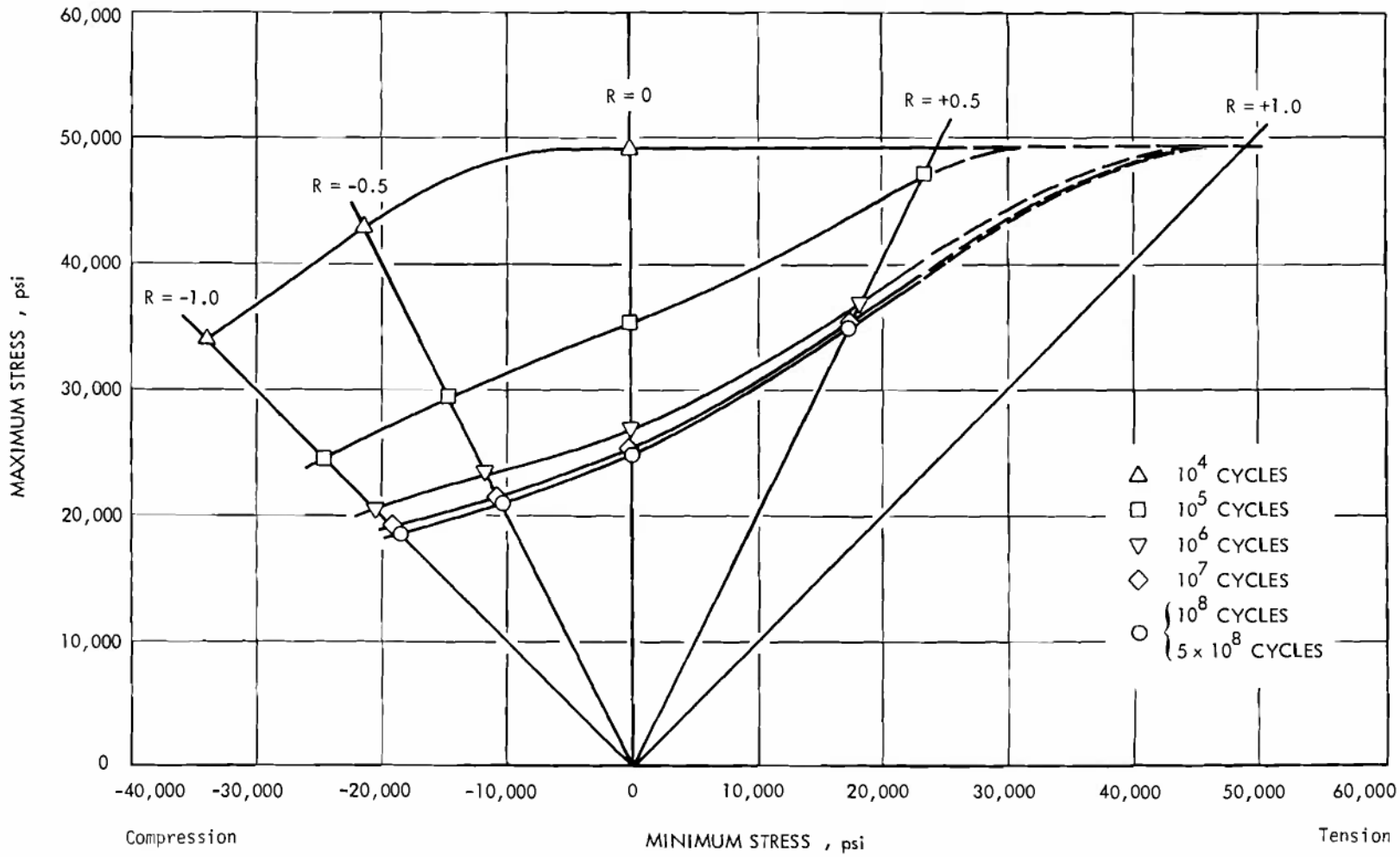


Figure 7-34. Modified Goodman Range-of-stress Diagram to Determine Typical Axial Stress Fatigue Strength for Aluminum Alloy 5456-0

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7-3.3 STRUCTURAL CONFIGURATION

The primary requirements for the structure of an amphibian are twofold—

1. Support the cargo, and all of the components of engine and power transmission systems.
2. Provide a buoyant platform.

These two equally important requirements must be satisfied with respect to the total mission of the vehicle. Other considerations include:

a. Cost
b. Weight
c. Maintainability
d. Repairability
e. Waterborne resistance
f. Safety
g. Availability
h. Reliability

The starting point of the structural configuration is in preliminary design where all of the variables are considered and the best overall system selected. This is described in par. 6-5.3 in detail. It is important in the detail design to keep in mind the compromises and goals established during the preliminary design so that they are not degraded. Likewise, it is important to keep informed of the progress of the design with respect to the items that influence the structure and to inform the other members of the design team of any structural goals that cannot be met.

The most important design step is to insure compatibility of the structural configuration with the design as a whole. An expensive lightweight machinery plant with an inexpensive, heavy structure is not well engineered. An arrangement where the structure is very complex and the various parts of the hull cannot be easily joined together is also not compatible. Thus, compatibility is the first step that should be made at the start of detail design. If it is not made first, it is difficult and expensive to retrace the step later on.

The second step is a review of the access, particularly for machinery maintenance, which is a part of the maintainability problem. Access is frequently neglected in the rush to complete a design. As the design develops, access tends to get worse, rarely better. Hence if the access to any area is poor, either the arrangement must be altered or special emphasis must be applied to improve it throughout the detail structural design.

The third step is to take each load and calculate the stresses or other failure criteria in the critical structure, starting with the most severe loads and working down. It is important to consider the manner in which the forces will be transmitted through each joint. The forces should be followed through the structure until they have spread out sufficiently to become negligible. At some point in this analysis the effect of combined stresses from two or more simultaneous loads should be considered. In general, the maximum loads from a number of sources will not occur simultaneously so that it is important to apply a practical series of forces when considering simultaneous loads so as not to unduly penalize the design.

The last step in the detail structural design is to recheck the final design of those joints or intersections that are highly loaded. Those joints that have structure intersecting from 3 or more directions are particularly important because of the residual welding stresses and the 3-dimensional stresses involved.

For many designs, extra weight of structure is considered to be compatible with the design if it is used so as to reduce engineering costs and the damage from local abuse loads. This philosophy is effectively used for work boats, trucks, and other types of "low" performance structures. For this type of design there is a low cost point between the high cost of excess material and the high labor cost of complex structures. Much of the design work outlined above can be abbreviated or neglected if the structure is purposely made extra heavy.

7-3.3.1 Shell Plating

In a stressed skin configuration that uses the skin to carry the major part of the stress, the shell is the most important part of the structure. In the LARC V it is over one-third of the total structural weight. With the partial exception of kayaks and other flexible skin craft, all boats and ships use the stressed skin principle because it is the lightest configuration that will provide both the buoyancy and the structural strength required.

The forces imposed on the shell plating are:

a. Tension, compression, or shear in the plane of the shell from the hull bending

b. Shear from torsion of the hull

c. Pressure perpendicular to the shell from the water or from liquids in tanks in the hull

d. Vibration

e. Impact loads from waves and from solid objects

f. Local loads

g. Forces applied from the framing

When it is considered that all of these can act simultaneously, the list appears somewhat complex. In general, however, the maximum forces from each of these is applied to different parts of the shell. The particular combinations that are normally critical are:

a. Items a and b for shear at the mid-depth of the sides of the hull

b. Items a and c for tension or compression in the hull bottom or deck in the mid-length of the hull

c. Items a, c, and g for tension or compression in the hull bottom or deck in the mid-length where the shell is used as one flange of the frame

d. Items e and f which cover such a large variety of conditions that they must be individually considered. In general, however, their influence covers only a small area. They may be the critical load for the area and may control the design.

Refs. 35 and 36 describe the six accepted theories of failure. The four theories which apply to ductile materials state that elastic failure occurs when:

1. Maximum Stress Theory; $\sigma \geq \sigma_y$
2. Maximum Strain Theory; $\epsilon \geq \sigma_y / E$
3. Maximum Shear Theory; $\tau \geq \sigma_y / 2$
4. Constant Energy of Distortion Theory; $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \geq 2\sigma_y^2$

where

σ = tensile or compressive stress, psi
σ_y = tensile or compressive yield stress, psi
ϵ = strain, in./in.
E = modulus of elasticity, psi
τ = shear stress, psi
$\sigma_{1,2,3}$ = principal tensile or compressive stresses, psi

Of these four theories the Constant Energy of Distortion Theory agrees best with experimental evidence but the Maximum Shear Theory leads to results which are nearly the same. The latter theory is simpler in application and is much more widely used as a basis for design. For the condition where the stress is uniaxial the Constant Energy of Distortion Theory reduces to the Maximum Stress Theory. For the design of the shell the stresses are rarely uniaxial and, therefore, the familiar Maximum Stress Theory is not adequate.

Table 7-17 lists the approximate relative allowable load for a condition where the principal stresses are all tensile and are in the ratio of 1, 2/3, and 1/3. For this particular condition, using the Maximum Stress Theory would introduce a 70 percent overload with respect to the more accurate Constant Energy of Distortion Theory. Fiberglas is an anisotropic material and must be specially considered.

Under critical loads, if the supporting structure does not fail, the shell will fail from either combined tension or compression (includes both column and bending loads), shear, or instability in compression. Shear loads are rarely critical in a stressed skin design although the torsion loads can cause trouble at the corners of large deck cut-outs such as hatches.

Consider the stresses from the hydrostatic pressure or other loads acting perpendicular to the plane of the plating. The normal boundaries of the plate form a panel which may be very small if the stiffeners are closely spaced or may cover the whole bottom of a vehicle if the framing is formed by the sides. The manner in which these panel boundaries hold the plating is a very important parameter. They may be flexible either in the plane of the panel, or perpendicular to the panel; they may be initially curved or straight; and they may hold the panel rigid at the edge or not restrict the rotation of the edge. Other major variables are the dimensions of the panel including the length L, width W, and thickness t; the type of loading including uniform, uniformly varying, or local; the characteristics of the material; and the allowable deflection. From this list it can be seen that there is a large number of possible combinations. For some, the stresses can be calculated from simple formulas; for others there are either experimental results or theory available; and for some there are no available solutions and the closest approximations to the conditions are used.

If the deflection is less than about one-half the plate thickness, the tension forces—from the

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TABLE 7-17 RELATIVE ALLOWABLE LOAD AT ELASTIC FAILURE FOR FOUR THEORIES OF FAILURE

Theory of Failure	*HTS Steel*	5456-H321 *Aluminum*
Maximum Stress	1.7	1.7
Maximum Strain	1.0	0.7
Maximum Shear	2.0	1.8
Constant Energy of Distortion	1.0	1.0

deforming plate pulling in the edges—are negligible and only the stresses from bending are important. For very large deflections where the stresses exceed the yield stress, plastic flow occurs and there is a permanent set in the plate after the load is removed. In general, if a small amount of permanent set is allowed, the loads can be much higher than otherwise. For instance Ref. 37 indicates that WW II aircraft were designed to allow a permanent set of 0.005 times the shorter panel side length. This is only about one-third the plate thickness for an average span-thickness ratio, and it may be less than the welding distortion.

Table 7-18 lists the major combinations of variables and references which show their solution. Figs. 7-35 and 7-36 show how plating reacts to pressure against the plate. Solutions for three dimensional plates, i.e., curved plates, are scarce. The side on which the pressure acts is very important. If the pressure is on the concave side, the reactions are similar to those of a pressure vessel. If on the convex side, and there is some rigidity of the panel edges in the plane of the panel, the initial resistance to deflection is high but there is a critical pressure where the panel is unstable and buckling occurs. This condition can lead to "oil-canning" when the panel pops back and forth through the unstable position. From these solutions the stress at various locations in the panel that may be critical can be determined. (Fig. 7-37 is referenced in Table 7-18.)

Next consider the stresses in the panel from tension or compression of the hull acting as a beam. In tension, the stress is spread equally throughout the plate and longitudinal stiffeners. For compression, however, there is a problem of instability. For this condition the plate and stiffener combination must be considered as a unit. With transverse framing, the panels are very long and the plating can buckle between frames. The major variables for the stress in a panel in edgewise compression are:

a. Thickness/span ratio
b. Span/width ratio
c. Hydrostatic loading
d. Material characteristics
e. Plate curvature (including manufacturing distortion)
f. Edge conditions

The solution for this problem considering all of the variables is not yet available except for a few special cases. For the amphibian the normal bending stresses are low if the hull depth is reasonable in the mid-length. DDS-1100-3 and 1100-4 of Ref. 28 describe the Navy's solutions.

7-3.3.2 Stiffeners

Stressed skin construction normally implies direct and indirect framing. The direct framing is the stiffeners which support the shell, and the indirect framing is that used primarily to support the direct framing. A secondary function of the stiffeners is to support and spread the load of machinery components that are inside of the hull. If these components are small, the stresses they introduce can be neglected. It should be noted that this nomenclature is not universal and the structural components are classified differently by each industry.

The forces imposed on the stiffeners include all of those imposed on, and shared with, the shell. The types of shell-stiffener configurations are:

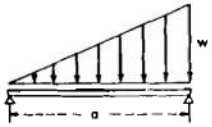
a. Monocoque (including sandwich)
b. Corrugated
c. Plate and stiffener (including flat bar, angle, tee, eye, channel, and inverted channel stiffeners).

7-3.3.2.1 Monocoque

Monocoque construction is a plate configuration without stiffeners. In isotropic material it is heavy except for shapes with significant curvature, light loads, or of small size. A lightweight monocoque configuration is

TABLE 7-18 FORMULAS FOR FLAT RECTANGULAR PLATES (Refs. 35 and 36)

Notation: W = total applied load, lb; M = bending moment, in.=lb; w = unit applied load, lb/in.^{2}; t = thickness of plate, in.; s = unit stress at surface of plate, lb/in.^{2}; y = vertical deflection of plate from original position, in.; θ = slope of plate measured from horizontal, rad; E = modulus of elasticity; m = reciprocal of ν, Poisson's ratio. q denotes any given point on the surface of plate; r denotes the distance of q from the center of a circular plate. Other dimensions and corresponding symbols are indicated on figures. Positive sign for s indicates tension at upper surface and equal compression at lower surface; negative sign indicates reverse condition. Positive sign for y indicates upward deflection, negative sign downward deflection. Subscripts r, t, a, b, f, and g used with s denote radial direction, tangential direction, direction of dimensions a, b, f, and g, respectively. All dimensions are in inches. Long side of rectangle is length (a) and the short side is length (b); aspect ratio α = b/a.

Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections (Max < t/2)	Formulas for use with coefficients listed at the end (ν = 0.3)
1	All edges supported. Uniform load over entire surface.	(At center) $s_a = -\frac{wb^2(0.225 + 0.382\alpha^2 - 0.320\alpha^3}{t^2}$ $s_b = -\frac{0.75\,wb^2}{t^2(1 + 1.61\alpha^3)}$ = Max s Max $y = -\frac{0.1422\,wb^4}{Et^3(1 + 2.21\alpha^3)}$ (Based on coefficients given by Timoshenko, ν = 0.3)	Max $s = s_b = \frac{\beta wb^2}{t^2}$, at center Max $y = \frac{\gamma wb^4}{Et^3}$, at center
2	All edges supported. Uniform load over small concentric circular area of radius r_o.	(At center) $s_b = -\frac{3W}{2\pi mt^2}\left[(m+1)\,\text{ln}\,\frac{b}{2r_o} + m(1+k)\right]$, where $k = \left(\frac{0.914}{1 + 1.6\alpha^5}\right) - 0.6$ Max $y = -\frac{0.203Wb^2(m^2 - 1)}{m^2Et^3(1 + 0.462\alpha^4)}$ (Approximate formulas based on coefficients given by Timoshenko).	Max $s = \frac{3W}{2\pi t^2}\left(1.3\,\text{ln}\,\frac{2b}{\pi r_o} + 1-\beta\right)$, at center Max $y = \frac{\gamma Wb^2}{Et^3}$, at center
3	All edges supported. Distributed load varying linearly along length. 	Max $s = \beta\frac{wb^2}{t^2}$ Max $y = \alpha\frac{wb^4}{Et^3}$, where β and α may be found from following table by interpolation:	

a/b	1	1.5	2.0	2.5	3.0	3.5	4.0
β	0.16	0.26	0.34	0.38	0.43	0.47	0.49
α	0.022	0.043	0.060	0.070	0.078	0.086	0.091

ν = 0.3

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TABLE 7-18 (Continued)

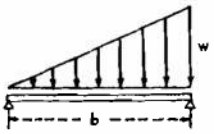
Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections ($s_{max} < t/2$)	Formulas for use with coefficients listed at the end ($\nu = 0.3$)
4	All edges supported. Diatributed load vsrying linearly slong bresdth.  	$s_{max} = \beta\frac{wb^2}{t^2}$ $\quad y_{max} = \alpha\frac{wb^4}{Et^3}$, where β and α may be found from following table by interpolation: s/b: 1	1.5	2.0	2.5	3.0	3.5	4.0 β: 0.16	0.26	0.32	0.35	0.37	0.38	0.38 α: 0.022	0.042	0.056	0.063	0.067	0.069	0.070 $\nu = 0.3$	
5	All edges fixed. Uniform load over entire surface.	(At centers of long edges) $s_b = \frac{0.5wb^2}{t^2(1 + 0.623\alpha^6)}$ = Max s (At centers of short edges) $s_a = \frac{0.25wb^2}{t^2}$ (At center) $s_b = -\frac{0.75wb^2}{t^2(3 + 4\alpha^4)}$ $\quad s_a = -\frac{0.054wb^2(1+2\alpha^2-\alpha^4)}{t^2}$ $y_{max} = -\frac{0.0284wb^4}{Et^3(1 + 1.056\alpha^5)}$ (Formuls for s_b $\nu = 0.3$. Other formulas due to Westergaarde, $\nu = 0$).	$s_{max} = s_b = \frac{\beta wb^2}{t^2}$, at center of long edges. $y_{max} = \frac{\gamma wb^4}{Et^3}$, at center
6	All edges fixed. Uniform load over small concentric circulsr srea of radius r_o.	(At center) $s_b = -\frac{3W}{2\pi mt^2}\left[(m+1)\ln\frac{b}{2r_o} + 5(1-\alpha)\right]$ $= s_{max} = \frac{\beta(m^2-1)Wb^2}{m^2Et^3}$, where β has values ss follows: (Approximate stress formuls by linear interpolation between stress in square plate snd in infinitely long strip.	Max edge stress $= \beta W/t^2$, at center of long edges. $y_{max} = \gamma Wb^2/Et^3$, at center.
7	Long edges fixed, short edges supported. Uniform load over entire surfsce.	(At centers of long edges) $s_a = \frac{wb^2}{2t^2(1+0.2\alpha^4)}$ $= s_{max}$ (At center) $s_b = -\frac{wb^2}{4t^2(1+0.4\alpha^4)}$ $s_a = -\frac{3wb^2(1+0.3\alpha^2)}{40t^2}$ ($\nu = 0$)	$s_{max} = s_b = \frac{\beta wb^2}{t^2}$, at center pf fixed edges. $y_{max} = \frac{\gamma wb^4}{Et^3}$, at center

TABLE 7-18 (Continued)

Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections (Max < t/2)	Formulas for use with coefficients listed at the end (ν = 0.3)
8	Short edges fixed, long edges supported. Uniform load over entire surface.	(At centers of short edges) $\sigma_a = \frac{0.75wb^2}{t^2(1 + 0.8\alpha^4)}$ = Max σ (At center) $\sigma_b = -\frac{0.75wb^2}{t^2(1 + 0.8\alpha^2 + 6\alpha^4)}$; $\sigma_a = \frac{0.09wb^2(1 + 3\alpha^2)}{t^2(1 + \alpha^4)}$	Max $s = s_a = \frac{\beta wb^2}{t^2}$, at center of fixed edges. Max $y = \frac{\gamma wb^4}{Et^3}$, at center
9	One long edge fixed, other free; short edges supported. Uniform load over entire surface.	(At center of fixed edge) $\sigma_b = \frac{3wb^2}{t^2(1 + 3.2\alpha^3)}$ = Max σ (At center of free edge) $\sigma_a = \frac{0.75wa^2}{t^2\left(1 + \frac{0.285}{\alpha^4}\right)}$ Max $y = -\frac{1.37wb^4}{Et^3(1 + 10\alpha^3)}$ (ν = 0.3)	
10	One long edge clamped. Other three edges supported. Uniform load over entire surface.	Max $\sigma = \beta \frac{wb^2}{t^2}$ Max $y = \alpha \frac{wb^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 2.5 3.0 3.5 4.0 β 0.50 0.66 0.73 0.74 0.74 0.75 0.75 α 0.030 0.046 0.054 0.056 0.057 0.058 0.058 (ν = 0.3)	
11	One short edge clamped. Other three edges supported. Uniform load over entire surface.	Max $\sigma = \beta \frac{wb^2}{t^2}$, Max $y = \alpha \frac{wb^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 2.5 3.0 3.5 4.0 β 0.50 0.67 0.73 0.74 0.75 0.75 0.75 α 0.030 0.071 0.101 0.122 0.132 0.137 0.139 (ν = 0.3)	
12	One short edge free. Other three edges supported. Uniform load over entire surface	Max $\sigma = \beta \frac{wb^2}{t^2}$, Max $y = \alpha \frac{wb^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 4.0 β 0.67 0.77 0.79 0.80 α 0.140 0.160 0.165 0.167 (ν = 0.3)	

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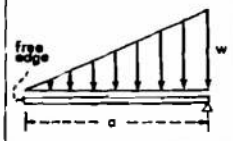
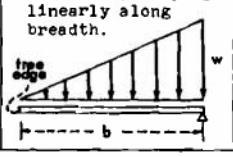
TABLE 7-18 (Continued)

Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections (Max < t/2)
13	One short edge free. Other three edges supported. Distributed load varying linearly along length. 	Max $s = \beta \frac{wb^2}{t^2}$, Max $y = \alpha \frac{wb^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 2.5 3.0 3.5 4.0 β 0.2 0.28 0.32 0.35 0.36 0.37 0.37 α 0.040 0.050 0.058 0.064 0.067 0.069 0.070 ($\nu = 0.3$)
14	One long edge free. Other three edges supported. Uniform load over entire surface.	Max $s = \beta \frac{wa^2}{t^2}$, Max $y = \alpha \frac{wa^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 β 0.67 0.45 0.36 α 0.140 0.106 0.080 ($\nu = 0.3$)
15	One long edge free. Other three edges supported. Distributed load, varying linearly along breadth. 	Max $s = \beta \frac{wa^2}{t^2}$, Max $y = \alpha \frac{wa^4}{Et^3}$, where β and α may be found from the following table by interpolation: a/b 1 1.5 2.0 β 0.2 0.16 0.11 α 0.040 0.033 0.026 ($\nu = 0.3$)

Coefficients β and γ for rectangular plates with small deflections - equations above.

Case No.	Coef.	a/b = 1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	∞
1	β	0.2874	0.3318	0.3756	0.4158	0.4518	0.4872	0.5172	0.5448	0.5688	0.5910	0.6102	0.7500
	γ	0.0443	0.0530	0.0616	0.0697	0.0770	0.0843	0.0906	0.0964	0.1017	0.1064	0.1106	0.1422
2	β	0.564	0.440	0.349	0.275	0.211	0.165	0.124	0.0950	0.072	0.0560	0.041	0.000
	γ	0.1265	0.1381	0.1478	0.1560	0.1621	0.1671	0.1714	0.1746	0.1769	0.1787	0.1803	0.1849
5	β	0.3078	0.3486	0.3834	0.4122	0.4356	0.4542	0.4680	0.4794	0.4872	0.4932	0.4974	
	γ	0.0138	0.0164	0.0188	0.0209	0.0226	0.0240	0.0251	0.0260	0.0267	0.0272	0.0277	
6	β	0.7542	0.8310	0.8940	0.9380	0.9624	0.9810	0.9906	0.9960	1.000	1.000	1.004	
	γ	0.0611	0.0666	0.0706	0.0735	0.0755	0.0768	0.0777	0.0782	0.0786	0.0787	0.0788	
7	β	0.420	0.444	0.462	0.474	0.486	0.498	0.500	0.501	0.502	0.503	0.504	0.498
	γ	0.0209	0.0228	0.0243	0.0255	0.0262	0.0270	0.0273	0.0276	0.0279	0.0282	0.0284	0.0284
8	β	0.420	0.474	0.522	0.564	0.600	0.630	0.654	0.6720	0.690	0.702	0.714	0.750
	γ	0.0209	0.0274	0.0340	0.0424	0.0502	0.0582	0.0658	0.0730	0.0799	0.0863	0.0987	0.1422

TABLE 7-18 (Continued)

Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections (Max < t/2)
16	Simply supported by 2 opposite edges rigid and the other 2 on elastic beams. (See Fig. 7-37) Uniform load over entire surface.	H is the ratio of the stiffness of the plate to the stiffness of the beams. $H = (1-\nu^2)\frac{E_{beam}\ I_{beam}}{E_{plate}\ I_{plate}}$

Values of C Used in Determining Bending Moment in the (f) direction at the Center from Equation

$M_f = C\frac{wf^2}{8}$; Poisson's Ratio $\nu = 0^*$

Values of g/f	Values of C								
	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = ∞
0.33	1.015	0.751	0.625	0.452	0.250	0.145	0.081	0.045	0.006
0.5	1.008	0.834	0.713	0.555	0.342	0.222	0.136	0.088	0.035
0.6	1.004	0.856	0.748	0.603	0.394	0.267	0.180	0.129	0.071
0.8	0.997	0.886	0.802	0.681	0.496	0.373	0.286	0.232	0.171
1.0	0.992	0.908	0.843	0.745	0.588	0.481	0.402	0.353	0.295
1.2	0.990	0.925	0.874	0.796	0.669	0.579	0.512	0.470	0.418
1.4	0.990	0.939	0.899	0.838	0.739	0.664	0.609	0.574	0.532
1.6	0.991	0.951	0.920	0.873	0.793	0.735	0.691	0.662	0.628
1.8	0.991	0.961	0.936	0.900	0.837	0.791	0.757	0.735	0.707

Values of C Used in Determining Bending Moment in the (g) direction at the Center from Equation

$M_g = C\frac{wf^2}{8}$; Poisson's Ratio $\nu = 0^*$

0.33	-0.125	-0.052	-0.038	0.001	0.039	0.100	0.085	0.091	0.101
0.5	-0.098	-0.045	-0.009	0.037	0.101	0.138	0.167	0.177	0.197
0.6	-0.092	-0.032	+0.005	0.054	0.126	0.169	0.198	0.217	0.236
0.8	-0.055	-0.009	+0.026	0.076	0.152	0.203	0.239	0.262	0.287
1.0	-0.035	-0.060	+0.037	0.082	0.155	0.207	0.243	0.268	0.295
1.2	-0.021	+0.012	+0.039	0.080	0.145	0.192	0.227	0.250	0.275
1.4	-0.012	+0.016	+0.038	0.073	0.129	0.170	0.199	0.219	0.242
1.6	-0.007	+0.016	+0.035	0.063	0.110	0.144	0.170	0.186	0.206
1.8	-0.003	+0.016	+0.031	0.053	0.091	0.120	0.140	0.154	0.171

* The values of the bending moment for any value of ν may be found by using Bending Moment with Poisson's Ratio Effect equal to the bending moment without Poisson's Ratio plus the product of the bending moment at the same location in a perpendicular plane times Poisson's ratio.

TABLE 7-18 (Continued)

Values of C Used in Determining Deflection at Center of Plate from Equation

$$y = C(1-\nu^2)\frac{wf^4}{Et^3}$$; Poisson's Ratio $\nu = 0.15$

Values of g/f	Values of C								
	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = ∞
0.33	0.1591	0.1214	0.0983	0.0714	0.0398	0.0234	0.0135	0.0079	0.0019
0.5	0.1579	0.1310	0.1122	0.0879	0.0549	0.0358	0.0233	0.0160	0.0079
0.6	0.1573	0.1345	0.1180	0.0956	0.0636	0.0439	0.0307	0.0228	0.0140
0.8	0.1563	0.1394	0.1264	0.1080	0.0796	0.0609	0.0476	0.0395	0.0301
1.0	0.1557	0.1428	0.1327	0.1179	0.0940	0.0776	0.0656	0.0581	0.0493
1.2	0.1554	0.1455	0.1314	0.1258	0.1064	0.0927	0.0825	0.0761	0.0684
1.4	0.1553	0.1476	0.1415	0.1322	0.1167	0.1057	0.0974	0.0921	0.0856
1.6	0.1554	0.1496	0.1446	0.1374	0.1253	0.1165	0.1098	0.1056	0.1004
1.8	0.1556	0.1509	0.1473	0.1416	0.1321	0.1252	0.1200	0.1165	0.1125
2.0	0.1557	0.1521	0.1493	0.1449	0.1375	0.1321	0.1280	0.1253	0.1222
3.0	0.1565	0.1557	0.1551	0.1543	0.1528	0.1517	0.1509	0.1503	0.1496

Values of C Used in Determining Maximum Bending Moment in Flexible Beam Support from Equation $M_{beam} = Cwf^2$; Poisson's Ratio $\nu = 0.15$

Values of g/f	Values of C								
	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = ∞
0.33	0	0.0033	0.0052	0.0076	0.0103	0.0117	0.0126	0.0131	0.0134
0.5	0	0.0040	0.0067	0.0103	0.0152	0.0180	0.0199	0.0210	0.0217
0.6	0	0.0055	0.0095	0.0150	0.0228	0.0276	0.0308	0.0328	0.0349
0.8	0	0.0057	0.0101	0.0164	0.0261	0.0325	0.0370	0.0398	0.0430
1.0	0	0.0058	0.0104	0.0172	0.0282	0.0357	0.0412	0.0446	0.0487
1.2	0	0.0059	0.0106	0.0177	0.0294	0.0376	0.0438	0.0477	0.0524
1.4	0	0.0059	0.0107	0.0179	0.0301	0.0388	0.0454	0.0496	0.0546
1.6	0	0.0060	0.0108	0.0181	0.0305	0.0395	0.0463	0.0507	0.0560
1.8	0	0.0060	0.0108	0.0182	0.0308	0.0399	0.0469	0.0514	0.0568
2.0	0	0.0060	0.0108	0.0182	0.0309	0.0402	0.0472	0.0518	0.0573
∞	0	0.0060	0.0109	0.0183	0.0311	0.0405	0.0477	0.0523	0.0579

Values of C Used in Determining Maximum Deflection of Flexible Beam Support from Equation $y_{beam} = C(1-\nu^2)\, wf^4/Et^3$; Poisson's Ratio $\nu = 1/4$

Values of g/f	Values of C								
	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = 10.0
0.33	0.146	0.1265	0.1013	0.0724	0.0390	0.0221	0.0118	0.0061	0.0049
0.5	0.170	0.1381	0.1162	0.0882	0.0512	0.0301	0.0165	0.0087	0.0070
0.6	0.172	0.1425	0.1220	0.0947	0.0567	0.0340	0.0189	0.0100	0.0081
0.8	0.174	0.1482	0.1296	0.1037	0.0648	0.0398	0.0225	0.0120	0.0098
1.0	0.175	0.1515	0.1341	0.1090	0.0693	0.0436	0.0249	0.0134	0.0109
1.2	0.175	0.1534	0.1366	0.1121	0.0728	0.0460	0.0265	0.0143	0.0117
1.4	0.176	0.1546	0.1382	0.1140	0.0747	0.0474	0.0274	0.0149	0.0121
1.6	0.176	0.1553	0.1391	0.1150	0.0757	0.0482	0.0280	0.0152	0.0124
1.8	0.176	0.1557	0.1396	0.1156	0.0763	0.0487	0.0283	0.0154	0.0125
2.0	0.176	0.1559	0.1399	0.1160	0.0767	0.0490	0.0285	0.0155	0.0126
3.0	0.189	0.1562	0.1403	0.1165	0.0772	0.0494	0.0287	0.0156	0.0127

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TABLE 7-18 (Continued)

Case No.	Manner of Loading	Formulas for Stress and Deflection for Small Deflections (Max < t/2)
17	Simply supported by 2 opposite edges rigid and the other 2 on elastic beams. Load P at center uniformly distributed over a circle of diameter $d_o = f/4$.	H is the same as for case 16. Poisson's ratio correction is the same as for Case 16.

Values of C Used in Determining Bending Moment in the (f) direction at the Center from Equation $M_f = CP$; Poisson's Ratio $\nu = 0$

Values of g/f	Values of C								
	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = ∞
0.33	0.686	0.521	0.421	0.305	0.171	0.101	0.060	0.037	0.010
0.5	0.468	0.396	0.348	0.284	0.200	0.148	0.119	0.100	0.080
0.6	0.398	0.350	0.314	0.268	0.202	0.161	0.133	0.117	0.098
0.8	0.318	0.292	0.274	0.246	0.204	0.176	0.158	0.145	0.132
1.0	0.274	0.260	0.249	0.232	0.207	0.189	0.176	0.168	0.159
1.2	0.248	0.242	0.236	0.225	0.209	0.198	0.190	0.184	0.177
1.4	0.235	0.230	0.225	0.220	0.210	0.204	0.198	0.195	0.199
1.6	0.225	0.223	0.221	0.217	0.211	0.207	0.204	0.202	0.200
1.8	0.220	0.218	0.217	0.215	0.211	0.208	0.207	0.205	0.204
2.0	0.217	0.216	0.215	0.214	0.211	0.210	0.209	0.208	0.207
3.0	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212

Values of C Used in Determining Bending Moment in the (q) direction at the Center from Equation $M_g = CP$; Poisson's Ratio $\nu = 0$

	Values of C								
0.33	-0.0185	0.0276	0.0553	0.0864	0.124	0.142	0.154	0.160	0.168
0.5	0.0307	0.0522	0.0687	0.0870	0.114	0.130	0.139	0.144	0.151
0.6	0.0543	0.0717	0.0840	0.101	0.124	0.138	0.147	0.163	0.160
0.8	0.0850	0.0963	0.104	0.117	0.135	0.144	0.152	0.158	0.164
1.0	0.103	0.111	0.116	0.123	0.135	0.143	0.149	0.153	0.159
1.2	0.114	0.118	0.121	0.126	0.134	0.140	0.144	0.147	0.150
1.4	0.120	0.123	0.125	0.128	0.133	0.137	0.140	0.142	0.144
1.6	0.123	0.126	0.127	0.129	0.132	0.135	0.136	0.138	0.139
1.8	0.127	0.127	0.129	0.130	0.132	0.134	0.135	0.135	0.136
2.0	0.129	0.130	0.130	0.131	0.132	0.133	0.134	0.135	0.135
3.0	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131

If d_o is less than $f/4$, a correction of $0.17P\ (1/4 - d_o/f)/(1/4 + 1/2\ d_o/f)$ must be added to both M_f and M_g.

TABLE 7-18 (Continued)

Values of C Used in Determining Maximum Deflection at Center of Plate from Equation

$$y = C(1 - \nu^2)\frac{Pf^2}{Et^3}$$; Poisson's ratio $\nu = 0.15$

	Values of C								
0.33	0.7593	0.5810	0.4718	0.3449	0.1957	0.1187	0.0718	0.0456	0.0174
0.5	0.5076	0.4250	0.3677	0.2932	0.1925	0.1340	0.0958	0.0736	0.0489
0.6	0.4264	0.3693	0.3280	0.2720	0.1910	0.1429	0.1098	0.0902	0.0689
0.8	0.3305	0.3004	0.2774	0.2446	0.1942	0.1610	0.1374	0.1230	0.1063
1.0	0.2789	0.2619	0.2485	0.2290	0.1975	0.1758	0.1600	0.1501	0.1385
1.2	0.2491	0.2391	0.2312	0.2195	0.2000	0.1863	0.1761	0.1696	0.1619
1.4	0.2312	0.2253	0.2206	0.2135	0.2016	0.1930	0.1866	0.1826	0.1776
1.6	0.2202	0.2167	0.2139	0.2096	0.2024	0.1972	0.1932	0.1907	0.1877
1.8	0.2135	0.2114	0.2097	0.2071	0.2028	0.1996	0.1972	0.1957	0.1938
2.0	0.2093	0.2081	0.2071	0.2055	0.2029	0.2010	0.1996	0.1887	0.1975
3.0	0.2031	0.2030	0.2030	0.2029	0.2028	0.2027	0.2027	0.2026	0.2026

Values of C Used in Determining Maximum Bending Moment in Flexible Beam Support from Equation $M_{beam} = C\,(Pf/4)$; Poisson's Ratio $\nu = 0.15$

	Values of C								
Values of g/f	H = 0	H = 0.05	H = 0.10	H = 0.20	H = 0.50	H = 1.0	H = 2.0	H = 4.0	H = ∞
0.33	0	0.105	0.169	0.247	0.328	0.372	0.399	0.413	0.423
0.5	0	0.072	0.122	0.185	0.271	0.320	0.352	0.371	0.383
0.6	0	0.060	0.103	0.161	0.242	0.292	0.325	0.345	0.368
0.8	0	0.043	0.076	0.122	0.193	0.240	0.273	0.293	0.316
1.0	0	0.032	0.057	0.094	0.153	0.193	0.223	0.241	0.263
1.2	0	0.024	0.044	0.073	0.120	0.154	0.179	0.195	0.213
1.4	0	0.019	0.033	0.057	0.094	0.121	0.142	0.155	0.170
1.6	0	0.015	0.026	0.044	0.074	0.095	0.111	0.121	0.134
1.8	0	0.011	0.020	0.034	0.057	0.074	0.087	0.095	0.104

Values of C Used in Determining Maximum Deflection of Flexible Beam Support

from Equation $y_{beam} = C(1-\nu^2)\frac{Pf^2}{Et^3}$; Poisson's Ratio $\nu = 0.15$

	Values of C								
0.33	0.7641	0.5805	0.4681	0.3375	0.1837	0.1044	0.0558	0.0291	0
0.5	0.5008	0.4104	0.3477	0.2664	0.1565	0.0928	0.0511	0.0269	0
0.6	0.4110	0.3454	0.2979	0.2336	0.1412	0.0857	0.0479	0.0254	0
0.8	0.2937	0.2541	0.2240	0.1810	0.1150	0.0715	0.0407	0.0219	0
1.0	0.2189	0.1923	0.1715	0.1409	0.0919	0.0582	0.0335	0.0182	0
1.2	0.1665	0.1475	0.1324	0.1098	0.0727	0.0465	0.0271	0.0150	0
1.4	0.1278	0.1137	0.1024	0.0855	0.0571	0.0368	0.0215	0.0117	0
1.6	0.0985	0.0879	0.0793	0.0664	0.0446	0.0288	0.0169	0.0092	0
1.8	0.0760	0.0679	0.0614	0.0515	0.0347	0.0235	0.0142	0.0082	0
2.0	0.0596	0.0534	0.0484	0.0408	0.0279	0.0194	0.0112	0.0066	0
3.0	0.0156	0.0140	0.0126	0.0106	0.0072	0.0047	0.0027	0.0015	0

TABLE 7-18 (Concluded)

For large deflections ($y \geq t/2$) of rectangular plates under uniform load use the following table: where, s_d = diaphragm stress, s_b = bending stress, s = total stress ($s = s_d + s_b$), and $\nu = 0.316$. All other terms are as defined at the head of this table.

a/b	Edges and point of Max s		wb^4/Et^4										
		Coef.	0	12.5	25	50	75	100	125	150	175	200	250
1	Held; not fixed	y/t	0	0.430	0.650	0.930	1.13	1.26	1.37	1.47	1.56	1.63	1.77
	At center of plate	$s_d b^2/Et^2$	0	0.70	1.60	3.00	4.00	5.00	6.10	7.00	7.95	8.60	10.20
		sb^2/Et^2	0	3.80	5.80	8.70	10.90	12.80	14.30	15.60	17.00	18.20	20.50
1	Held; riveted	y/t	0	0.406	0.600	0.840	1.00	1.13	1.23	1.31	1.40	1.46	1.58
	At center of plate	$s_d b^2/Et^2$	0	0.609	1.380	2.68	3.80	4.78	5.75	6.54	7.55	8.10	9.53
		sb^2/Et^2	0	3.19	5.18	7.77	9.72	11.34	12.80	14.10	15.40	16.40	18.40
1	Held and fixed	y/t	0	0.165	0.25	0.59	0.80	0.95	1.08	1.19	1.28	1.38	1.54
	At center of long edges	$s_d b^2/Et^2$	0	0.070	0.22	0.75	1.35	2.00	2.70	3.30	4.00	4.60	5.90
		sb^2/Et^2	0	3.80	6.90	14.70	21.0	26.50	31.50	36.20	40.70	45.00	53.50
	At center of plate	$s_d b^2/Et^2$	0	0.075	0.30	0.95	1.65	2.40	3.10	3.80	4.50	5.20	6.50
		sb^2/Et^2	0	1.80	3.50	6.60	9.20	11.60	13.0	14.50	15.80	17.10	19.40
1.5	Held; not fixed	y/t	0	0.625	0.879	1.18	1.37	1.53	1.68	1.77	1.88	1.96	2.12
	At center of plate	$s_d b^2/Et^2$	0	1.06	2.11	3.78	5.18	6.41	7.65	8.60	9.55	10.60	12.30
		sb^2/Et^2	0	4.48	6.81	9.92	12.25	14.22	16.0	17.50	18.90	20.30	22.80
2 to ∞	Held; not fixed	y/t	0	0.696	0.946	1.24	1.44	1.60	1.72	1.84	1.94	2.03	2.20
	At center of plate	$s_d b^2/Et^2$	0	1.29	2.40	4.15	5.61	6.91	8.10	9.21	10.10	10.90	13.20
		sb^2/Et^2	0	4.87	7.16	10.30	12.60	14.60	16.40	18.00	19.40	20.90	23.60
1.5 to ∞	Held and fixed	y/t	0	0.28	0.51	0.825	1.07	1.24	1.40	1.50	1.63	1.72	1.86
	At center of long edges	$s_d b^2/Et^2$	0	0.20	0.66	1.90	3.20	4.35	5.40	6.50	7.50	8.50	10.30
		sb^2/Et^2	0	5.75	11.12	20.30	27.8	35.0	41.0	47.0	52.50	57.60	67.00

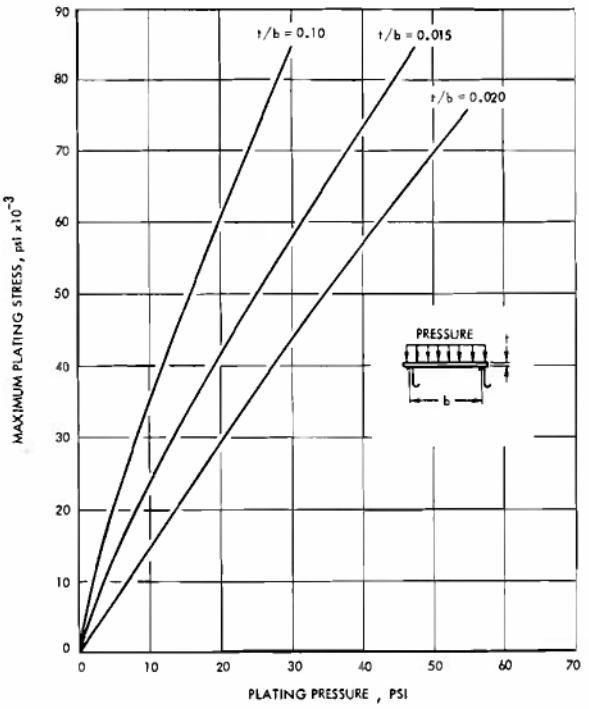

Figure 7-35. Plating Stress as a Function of Plating Pressure

sandwich construction where the inner and outer faces carry the tension and compression, and the lightweight core carries only the shear load. Sandwich-type construction is used with Fiberglas or metal for the face plates. The purpose of this arrangement is to increase the rigidity and strength of a thin plate with a minimum increase in weight. The problems anticipated for use in an amphibian include:

a. Leaks into the core

b. Difficulty of fastening to the faces and edges

c. Ability to absorb shear between the core and the faces

All of these can be solved and sandwich construction is used for boats and missiles. Core materials used are end-grain balsa-wood, paper or metal honeycomb, and a variety of types of plastic foam. Many of the larger Fiberglas work boats, such as trawlers, are now being built with a sandwich configuration.

The theoretical analysis of sandwich construction is a lengthy process and the theory is not yet complete. The analysis generally results in expressions which are very cumbersome and tedious to evaluate. Ref. 29 presents a few simplified examples of the design of sandwich panels. This type of construction is undergoing a high rate of development and the latest references should be consulted for design information.

7-3.3.2.2 Corrugations

Corrugations add stiffness and eliminate the need for stiffeners. They also leave a hydrodynamically rough surface and therefore, are rarely used for the exterior of boat or ship hulls. They may be used for bulkheads and other interior components and, for amphibians, they could be considered for use on the sides, deck, or interior structure. In general, the weight of corrugated structure is higher than the minimum possible with other configurations. It is also less expensive than conventional structural systems.

The simple methods of analysis which follow (Ref. 38) are sufficient to estimate the scantlings for a corrugated structure. For areas with high loadings, additional studies should be made to determine that the structural stability is sufficient for the use intended.

The equations which follow are for pressed corrugations. Sheets corrugated in this manner do not undergo any reduction in width. Horizontal parts remain as thick as they were in the original sheet, but the webs become thinner as they are formed by stretching. Another method of corrugation reduces the width of the finished sheet but retains a constant thickness throughout. These are formed by bending or rolling. The equations hold for these constant-thickness corrugations, except, that as the corrugations become nearly rectangular, the inertia of the web is underestimated, hence, the equations are conservative.

Height of neutral axis above reference line ($y = 0$)

$$\bar{y} = K_1 t\,(2 - K_3 - K_2 K_3)/2, \text{ in.} \qquad (7\text{-}41)$$

Moment of inertia

$$I = Lt^3\,(K_1^2\,A + 1)/12, \text{ in.}^4 \qquad (7\text{-}42)$$

where the symbols are defined in Fig. 7-38. When webs are curved, a straight line approximation is used for the webs and flanges.

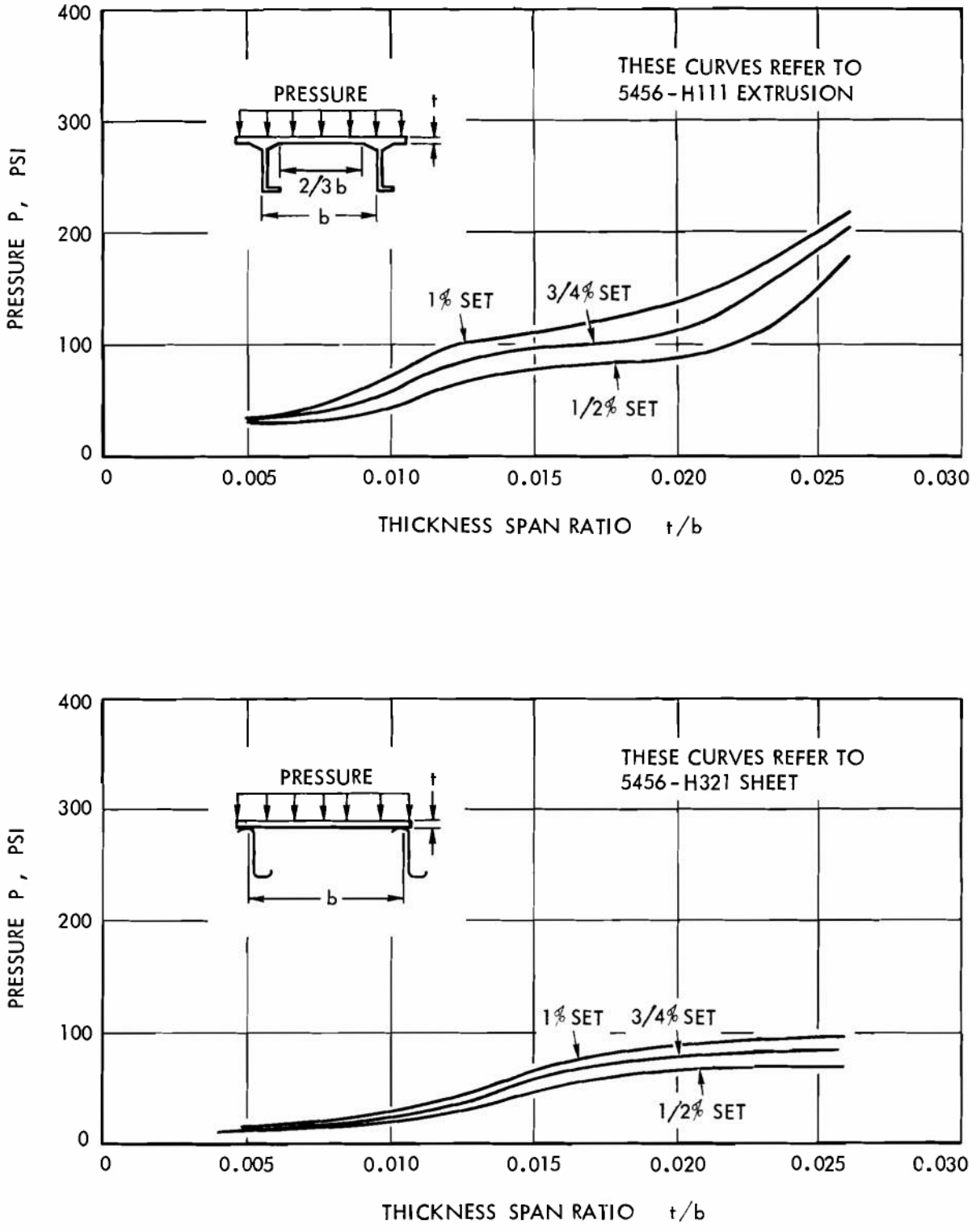

Figure 7-36. Bottom Plating Deformation Curves

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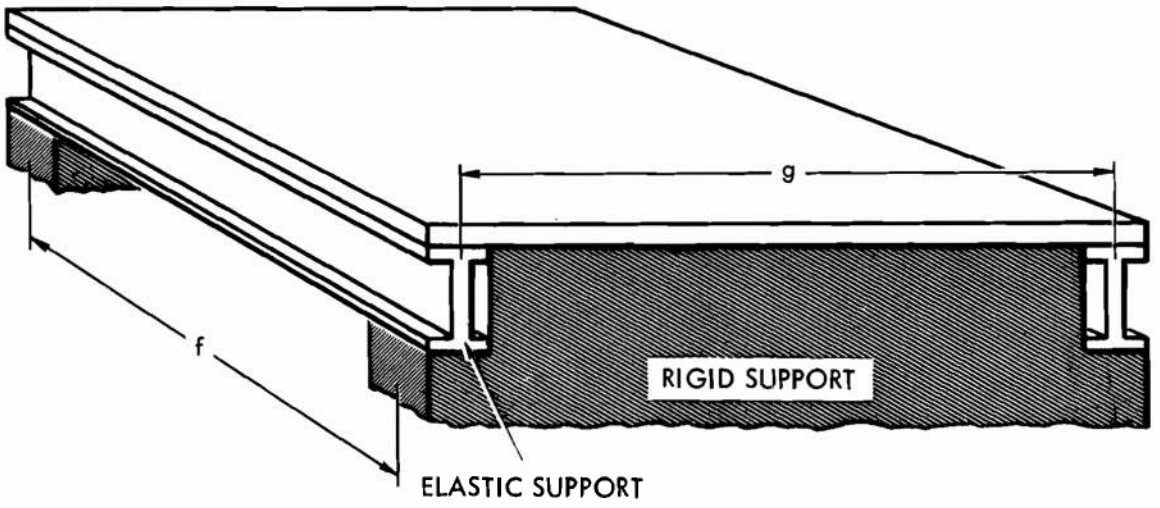


Figure 7-37. Rectangular Flat Plate With Two Edges on Elastic Support

7-3.3.2.3 Plate and Stiffeners

Almost all large stressed skin structures are built with plate and stiffener construction. In general the weight of the structure decreases as the spacing between stiffeners decreases so that monocoque is the heaviest configuration and sandwich, which represents a structure with the distance between stiffeners reduced to zero, is the lightest. The problems inherent with sandwich construction have limited the use of that configuration but it does have promising potential and can be used if the extra construction difficulty is worth the reduction in weight.

The general solution to designing a lightweight structure is to reduce the stiffener spacing and the skin thickness to the minimum practical with the stiffener depth as large as is necessary. The minimum distance or thicknesses are related to the problems of construction, repair, local or abuse loads, and cost. As the scantlings get lighter and the pieces smaller, the cost of handling each piece goes down but the number of pieces goes up so that the total cost is higher. Part of the project management is to determine the "value" of reducing the weight.

There are an unlimited number of potential stiffener shapes that might be used. The ones that are popular are listed in Table 7-19.

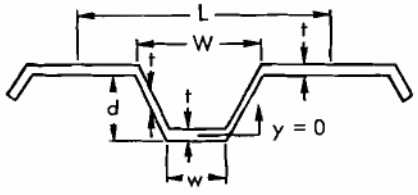
The flat bar stiffeners are used where the loading is low and where they are sufficiently strong in the minimum thickness plate used. In some cases where the shell is in sheets or plates, the thickness of the shell will be standardized even though the loads are variable. In the more lightly loaded areas, flat bar stiffeners will be used. They are vulnerable to damage from lateral abuse loads at the upper edge. They can be installed with a bulb on the upper edge to resist these loads.

If mechanical fasteners or spot welding are used, the stiffener must have a faying flange against the plate. In addition to this function, the faying flange reduces the effective distance between stiffeners so that fewer stiffeners may be required. In general when the stiffeners are either welded or extruded integral with the plate, the use of a faying flange will result in a higher weight.

The inverted angle is convenient to use since the orientation of the outstanding flange can be alternated and the backs can then be fastened together with less fitting problems.

The tee is widely used because it offers the lightest total weight with a balanced section. It is the shape most frequently extruded integrally with the plate. The extrusion procedure is, of course, limited to aluminum and the primary advantage is the reduction of welding and the accompanying distortion. Table 7-20 shows ALCOA's tentative limits of integrally stiffened extrusions.

Flanged plates are frequently used where deep stiffeners are required, primarily for indirect framing. On the assumption that the structural



PRESSED CORRUGATION
(MODEL USED TO DERIVE EQUATIONS)

A = PARAMETER DEPENDING ON K_2 AND K_3

d = DEPTH OF CORRUGATION , IN.

I = MOMENT OF INERTIA , $IN.^4$

K_1 = RATIO d/t

K_2 = RATIO w/W

K_3 = RATIO W/L

L = CORRUGATION PITCH LENGTH , IN.

t = THICKNESS OF SHEET , IN.

w = WIDTH OF BOTTOM OF CORRUGATION , IN.

W = WIDTH OF TOP OF CORRUGATION , IN.

$\bar{y}$ = HEIGHT OF NEUTRAL AXIS , IN.

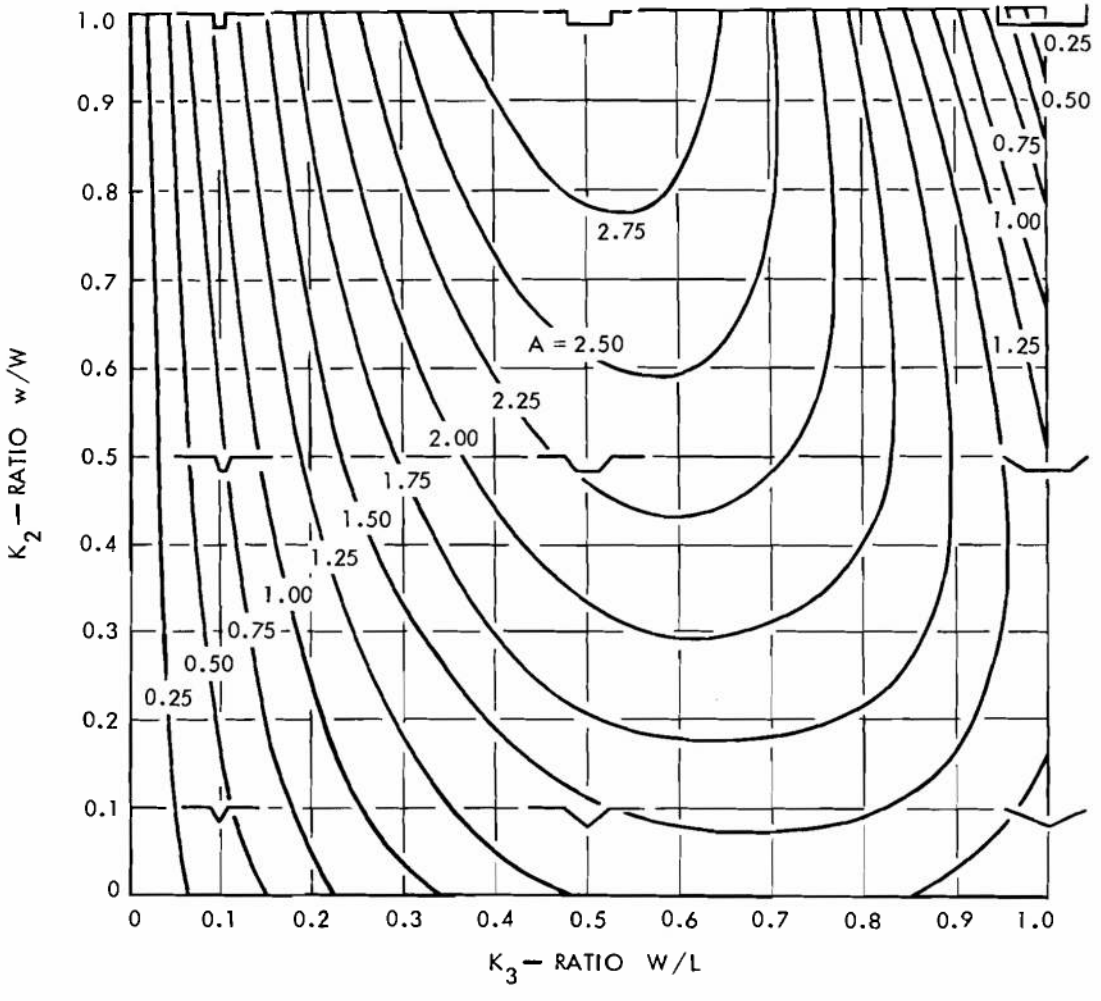
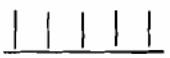
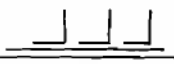
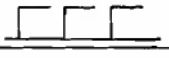
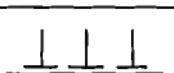
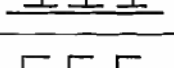
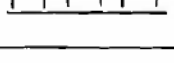
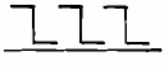


Figure 7-38. Nomenclature and Plot of Constant "A" for Corrugated Material

TABLE 7-19 STIFFENER SHAPES IN GENERAL USE

Shape	*Cross Section*	*Remarks*
Flat Bar		Simple but unstable at high loads.
Angle		Mechanical fasteners or spot welded construction.
Inverted Angle		Simple but unbalanced.
Inverted Tee		Most widely used. Balanced construction.
Tee		Mechanical fasteners or spot welded construction—spreads the load on the plate.
Channel		Mechanical fasteners or spot welded construction. Formed from sheet, extruded or rolled. Slightly unbalanced.
Inverted Channel		Used for aluminum offshore race boats. Interior cannot be maintained. Reduces effective distance between stiffeners.
Zee		Widely used in aircraft industry. Mechanical fasteners or spot welded.
I or H		Mechanical fasteners or spot welded. Balanced.
Flanged Plate		Versatile for materials with a short bend radius.

arrangement and the plating thickness have been selected, the adequacy of the stiffeners can be checked. Some or all of the shell will act as a flange for the stiffener. There is a phenomenon known as shear-lag which limits the stiffening effectiveness of plating attached to a stiffener. Because of the shear strain, the longitudinal tensile or compressive stress in wide beam flanges diminishes with the distance from the web. Ref. 36 presents the results of several investigators on the problem of shear lag. It depends not only on the method of loading and support, and the ratio of span to flange width, but also on the ratio of modulus of rigidity to the modulus of elasticity and on the ratio:

$$\frac{(3I_w + I_f)}{I_w + I_f}$$

where

I_w = moment of inertia about the neutral axis with respect to the web, in^4.

I_f = moment of inertia about the neutral axis with respect to the flanges, in^4.

The Navy (Ref. 28) uses a maximum effective breadth of plating for the calculation of section modulus of

$$2t\sqrt{E/\sigma_y}\text{ , in.}$$

where

t = plate thickness, in.

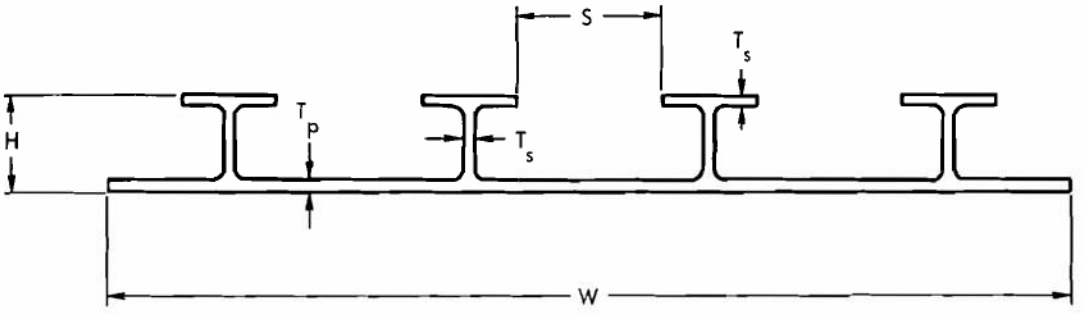
E = modulus of elasticity, psi

σ_y = yield strength, psi

The maximum effective breadth is given in Table 7-21 for the more common materials.

The section moduli and cross-sectional areas of the stiffener and plating combination can be calculated using the standard method (Ref. 36). For body-bound mechanical fasteners, the net section should be used for tension and the gross section for compression. By use of these calculated section characteristics and the loads, the stresses and stability can be calculated. Table 7-21 contains a variety of formulas that can be used for these calculations.

TABLE 7-20 LIMITS OF WIDE INTEGRALLY STIFFENED EXTRUSIONS



ALLOYS	MAXIMUM W	MINIMUM T_p	MINIMUM T_s	MAXIMUM H*	MINIMUM S
5083, 5086	21.000	0.156	0.125	2.0	2.0
	26.000	0.188	0.156	2.0	2.0
	32.000	0.250	0.188	2.0	2.0
	36.000	0.375	0.250	2.0	2.0
5456	21.000	0.156	0.125	2.0	2.0
	26.000	0.188	0.156	2.0	2.0
	32.000	0.250	0.188	2.0	2.0
	36.000	0.500	0.375	2.0	2.0
6061	23.375	0.094	0.078	2.0	2.0
	28.675	0.094	0.078	2.0	2.0
	34.313	0.094	0.078	2.0	2.0
	39.000	0.188	0.125	2.0	2.0

* THIS HEIGHT BASED ON MINIMUM THICKNESS
GREATER HEIGHTS ARE POSSIBLE WITH HEAVIER SECTIONS
ALL DIMENSIONS IN IN.

TABLE 7-21 COMBINED STIFFENER ON PLATE FORMULAS (REF. 28)

b_f - Breadth of outstanding flange of a balanced stiffener

d - Depth of stiffener

E - Modulus of elasticity

f_b - Compressive stress from bending load

f_c - Compressive stress from axial load

f_d - Compressive stress in plating from loads normal to plating

F_c - Stress at failure from axial loading

F_u - Stress at failure from compressive loading

F_y - Tensile yield stress

t - Plating thickness, in.

t_f - Flange thickness

t_w - Web thickness

(1) To calculate section modulus use a maximum effective breadth of plating equal to the stiffener spacing or

$$2t\sqrt{\frac{E}{F_y}}$$ whichever is less

Material	$2t\sqrt{\frac{E}{F_y}}$
Mild Steel	60 t
Hi Tensile Steel	51 t
Al 5456-H321 parent	35 t
Al 5456-H321 welded	40 t

TABLE 7-21 (Concluded)

(2) Combined bending and compression interaction formula

$$\frac{f_c}{F_c} + \frac{f_b}{F_y} \leq 1$$

(3) Breadth/thickness ratios for balanced flanges should be equal or less than

$$\sqrt{\frac{E}{F_y}}$$

Material	Max b/t
Mild Steel	30
Hi Tensile Steel	26
Al 5456-H321 parent	18
welded	20

(4) Maximum ratio of span L to flange width b_f, should equal or be less than

$$\frac{1.283\sqrt{E/F_y}}{\sqrt{1 + 0.333\,\frac{dt_w}{b_f t_f} - \frac{E}{7.8F_y}\left(\frac{t_f}{d}\right)^2}}$$

(5) Ratio of stress at failure to stress under specified conditions of loading for stiffened panels with compressive and normal loading is

$$\frac{1}{\left(\frac{f_c}{F_u} \times \frac{F_y}{F_c}\right) + \frac{f_d}{F_y}}$$

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7-3.3.3 Indirect Framing

The primary use of the indirect framing is to support the shell and direct framing. It includes athwartship and longitudinal bulkheads and girders. These members also may provide watertight compartments and machinery foundations. Included with this group, although not necessarily fitting the description, are stanchions. The indirect framing usually is required to carry the bending moment between adjacent side and deck or side and bottom. Transverse bulkheads do this with a shear load, and transverse girders act as a ring frame. Frequently brackets are fitted between deck and side, or bottom and side girders, to carry the bending moment.

The design of the shell and direct framing furnish the loads that must be carried by the indirect framing. The transverse girders should be analyzed as ring frames (Ref. 35); the longitudinal girders, as beams. The bulkheads can be considered to be short, deep plate girders although the loads are almost entirely shear. Access is a critical concern when designing indirect framing because of the depth of the structure involved. Ref. 40 presents formulas that can be used for the design. The analysis involved for the bulkheads, in particular, is difficult and careful consideration of past practice may be helpful.

7-3.3.4 Ramps

The structural design of ramps must consider three problem areas:

1. Deck loads
2. Ground support loads
3. Hinges

The deck or roadway is subject to dynamic loads from vehicles and from cargo. The critical loads are likely to result from the grousers on tracked vehicles or the wheels on loaded fork lift trucks. It is sometimes advantageous to place the stiffeners on top of the plate where they can serve a secondary function as tread bars for wheeled vehicles.

In the lowered position, the ramp is supported at the after end by the hinges and at the forward end by the ground. The ramp and the hinges must be constructed to resist the torsion that occurs when the ground is uneven and the ramp is supported only on one side at the forward end. Also the forward side must be able to resist the local loads when it is supported by a rock or other small hard object.

7-3.3.5 Miscellaneous

There are many miscellaneous fittings that apply a load over a small area. These include:

a. Cleats
b. Foundations
c. Lifting pads
d. Cargo tie-down fittings
e. Appendages

The manner in which the stress is dissipated must be carefully considered because large forces are involved and the results of a failure can be serious. For instance, consider the results of a lifting pad failure while the amphibian is being unloaded from a cargo ship and it is 40 ft above the bottom of the hold.

There are standard patterns of cleats available so that the cleat itself is not a design problem. The base of the cleat, however, must be fastened such that it can take the impact loads from the strongest rope that will fit on the cleat.

Foundations can add much extra, unplanned weight if they are not carefully designed. The propeller thrust must be carried by either the transmission or the engine foundation, depending upon the design. Vibration effects must be considered. Some previous vehicles have had trouble when the fixed ends of the hydraulic wheel steering cylinder were fastened to the wheel well plate without a special foundation plate. All places where a concentrated load is applied should be specially considered.

Lifting pads should be designed to meet the test specifications. Some of the common tests are shown in Fig. 8-2. The pads must fit the standard lifting gear and they must be able to take the side loads. It should be noted that the pads are convenient for other tasks besides lifting.

Cargo tie-downs must be designed to take standard fittings and at a wide range of pull angles. There have been problems in the past with water and dirt collecting in the tie-down recesses and freezing which has made them difficult to use.

The appendages including the rudder and the propeller are damaged occasionally, particularly in the land mode. It is important that they fail

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before the connection to the hull so that the watertight integrity of the hull is not broken even though some component is not working.

7-3.4 DETAIL DESIGN

During the preliminary design, the major decisions for the structural characteristics are made. These include, basically, the material, configuration, hull shape, and smoothness. Along with these selections is a series of goals which may or may not be promulgated as such. These include structural weight, position of the center of gravity, hull cost, safety level, and maintenance and repair levels. Additional goals which should be known during detail design are potential manufacturers, anticipated development programs, hull tests, approximate vehicle quantity, and production schedule.

As mentioned previously, communications between designers on a project must not deteriorate at this phase due to the rush to finish the design. The final structural design has a major impact on the total design. The probability of meeting, surpassing, or missing the goals must be made known to the project manager. The structural designer must appreciate the real mission of the user of the vehicle. This mission at times demands the maximum performance from the vehicle, regardless of the original mission for which the vehicle was designed. It is the responsibility of the designers to produce a design that is as safe as practical for this condition and not overlook some detail that will cause a catastrophic failure.

7-3.4.1 Factors of Safety

The rational process of design of each load resisting member may be considered in four steps which are:

1. Determine mode of failure.
2. Determine a relationship between the loads and the quantity which is most significant in the failure of the member.
3. By appropriate tests of the material used in the member, determine the maximum value of the quantity that is considered to cause structural damage.
4. By use of experimental observations and analyzing experience, judgment, and the basic design philosophy for the project; select a value of the quantity for use in Step 2 which will allow the member to fulfill its duty as required, in spite of human ignorance or error. Normally Step 2 is, in some way, an idealized situation of the actual service conditions of the member. In many cases the loads cannot be predicted accurately; the material is not completely uniform; the fabrication is not the best quality; the material will deteriorate in service; the relationship in Step 2 is only an approximation using simplifying assumptions; or many other conditions exist which reduce the level at which failure will occur. Step 4, then, is used to apply a reduction factor, to cover all of the conditions and considerations that cannot be expressed quantitatively in mathematical form, and applied in Step 2.

The most common reduction factor is the factor of safety which is the ratio of the load that would cause failure to the load that is imposed in service. It is not a ratio of stresses. For those situations where the load is proportional to the quantity that first causes structural damage, the factor of safety is the same as the ratio of stresses or other quantity of failure. Table 7-22 lists typical factors of safety and the values on which they are based. For steel structures the effects of corrosion should be countered by the addition of a uniform increase in the scantling, normally called a "corrosion allowance".

7-3.4.2 Fasteners

A chain of structural members is only as strong as the weakest member. Fasteners are one of the links in the chain and they must be designed with as much care as the members. The three main types of fasteners are:

1. Mechanical
2. Welding
3. Adhesive

7-3.4.2.1 Mechanical

Mechanical fasteners can be further subdivided into

a. Bolts
b. Rivets
c. Special purpose (primarily patented types)

Although the actual stress patterns in a bolt or riveted joint are complex, it is customary to make certain simplifying assumptions and apply certain factors of safety. The system (Ref. 40)

TABLE 7-22 TYPICAL FACTORS OF SAFETY

Type of Structure	Ref.	Factor of Safety	Strength Basis	Material	Remarks
Main Engine Foundation LARC V	47	2.0	Ultimate	Aluminum	Re-design after failure
LVPT Sheet and Plate Shapes	46	 1.46 1.28	 Yield Yield	Aluminum	Study
LVK-Structure	47	1.1 1.5	Yield Ultimate	Aluminum	Proposal
LVH-X2 Structure	48	1.15 1.5	Yield Ultimate	Aluminum	A carry-over factor of 1.1 used so that foundations fail before hull structure
Bridge-Ferry	49	Tension 1.25 Compression 1.43 Shear 1.54 Pina-flexure 1.11 Bearing 1.43	Minimum Yield	Aluminum	Specification Fatigue stress, in general use not more than 1/2 of yield
Planing craft	37	1.1	Yield	Aluminum	Excludes plating for which 0.005 permanent set is suggested
Bridges	40	2.2 1.85 1.35	Ultimate Yield Incipient buckling	Aluminum	ASCE Specifications Allowances of percent static loads for dynamic loads
Buildings		1.95 1.65	Ultimate Yield		Elevator support 100 Traveling crane supports 25
		1.35	Incipient Buckling		Light machinery supports 20 Reciprocating machinery supports 50
Hydrofoil Structure		1.0 1.5	Fatigue with a required life Ultimate	Aluminum	Shell designed for a (0.005 x span) permanent set
Deck		1.84	Compression Yield		Deflection criteria $EI/(span)^3 \geq 60$
Ships	50	1.22 1.18 1.45 1.22 1.15 1.08 1.24 1.24 1.14 1.14 1.52	Yield Yield Yield Yield-HAZ " " " " " " Yield-parent	Mild Steel HTS HY-80 5086-H32 5086-H111 5086-O 5456-H321 5456-H111 5456-H34 5454-H111 6061-T6	
Boats	29	 2 4 4 6 6 10	 Ultimate " " " " "	Fiberglas	Deflection limit = 1/200 span Static short term loads Static long term loads Variable or changing loads Repeated loads Fatigue or load reversal Impact loads-repeated
Minesweeper hull		4 2	Ultimate Ultimate	Fiberglas	Allows for unknowns in estimating underwater explosion pressures Panel buckling deflection limit = 1/150 span.

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which follows is used in the aerospace industry which depends heavily on mechanical fasteners. The assumptions normally made are:

a. The applied load is carried entirely by the fastener. Friction between the connected parts is ignored.

b. When the center of gravity of the fasteners is on the assumed line of action of the load, the fasteners are all loaded in proportion to their respective section areas.

c. Shear stress is uniformly distributed across the fastener section.

d. The bearing stress between plate and fastener is uniformly distributed over an area equal to the fastener diameter times the plate thickness.

e. The stress in a tension member is uniformly distributed over the net area.

f. The stress in a compression member is uniformly distributed over the gross area.

The possibilities of failure due to secondary causes, such as shearing or tearing out of a plate between fastener and edge of plate, or between adjacent fasteners, are minimized by using the following standards:

a. Edge distance from a fastener to a sheared edge shall not be less than 1 ¾ diameters, or to a rolled edge 1 ½ diameters.

b. The minimum fastener spacing is 3 diameters.

c. The maximum fastener pitch in the direction of stress shall be 7 diameters; at ends of a compression member 4 diameters or a distance equal to 1 ½ times the width of the member (for stiffeners).

d. For a zig-zag joint the net width of the part shall be obtained by deducting from the gross width the sum of the diameters of all the holes, and adding for each gage space $S^2/4g$, where S = longitudinal spacing of any two successive holes and g = spacing of the same two holes transverse to the direction of stress.

e. The shear and bearing stresses shall be calculated on the basis of the nominal fastener diameter; the tensile stresses on the hole diameter.

f. Special consideration must be given to long fasteners (grip length/diameter greater than 3).

g. For bolts in tension the factor of safety must be at least 1.5. The use of aluminum bolts in tension should be avoided.

h. Hole-filling fasteners (rivets) should not be combined with nonhole-filling fasteners (bolts). The shear and bearing failure loads must be separately calculated and the lower value used.

The SAE Standard J429 recognizes the 9 grades of bolts shown in Table 7-23. For combined loads of shear and tension the interaction formula is on Fig. 7-39. Clearances required to install bolts are shown on Fig. 7-40. Unit bearing strengths are given in Figs. 7-41 and 7-42. For the features and design procedures for special fasteners, the manufacturer should be consulted.

7-3.4.2.2 Welding

Welding is the primary method of attachment for the present fleets of amphibians. One of the primary reasons for using welding is that mechanical fasteners in aluminum usually leak after the joint has been severely stressed a few times. Largely all-welded ships have been the standard since World War II, and the proper procedure for welding steel is widely known. Butt welds, when properly back chipped to remove all oxidized and unfused metal, are as strong as the parent metal. For amphibians, all butt welds should be designed for full penetration and therefore full efficiency. Butt welds may be laid out to suit fabrication and need not be staggered or offset.

The efficiency of fillet-welded connections can be calculated but it is more convenient to use safe design loads. Table 7-24 lists the allowable design loads for various fillet sizes in mild steel. These loads are based on an allowable shear value of 13,600 psi on the throat of the fillet and are taken from Ref. 41. These are safe loads for design, the breaking loads are about 4 times the values tabulated. Intermittent fillet welds are generally sufficient but where a double continuous fillet weld is desired, such as for high impact loads, the fillet should be 0.707 times the thickness of the thinner plate. Table 7-25 from Ref. 41 lists the fatigue strengths of various types of joints for ASTM-A7 structural steel. Note the poor fatigue characteristics of the tee joints in the fillet weld, and the plug and slot welds. In general any joint that can be seen can be welded, but additional clearance will reduce the cost and increase the quality of the weld.

Welding aluminum successfully requires a higher quality of workmanship than for steel. There have been major advances in the knowledge, techniques, and equipment for

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TABLE 7-23 SAE BOLT GRADES

Grade	Bolt Size Dia, in.	Proof Load, psi	Tensile Strength, min, psi	Hardness	
				Brinell	Rockwell
0	All sizes	-	-	-	-
1	All sizes	-	55,000	207 max	95 B max
2	Up to 1/2 incl over 1/2 to 3/4 incl	55,000 52,000	69,000 64,000	241 max	100 B max
	Over 3/4 to 1-1/2 incl	28,000	55,000	207 max	-
3	Up to 1/2 incl Over 1/2 to 5/8 incl	85,000 80,000	110,000 100,000	207-269	95-104 B
5	Up to 3/4 incl Over 3/4 to 1 incl Over 1 to 1-1/2 incl	85,000 78,000 74,000	120,000 115,000 105,000	241-302 235-302 223-285	23-32 C 22-32 C 19-30 C
6	Up to 5/8 incl Over 5/8 to 3/4 incl	110,000 105,000	140,000 133,000	285-331 269-331	30-36 C 28-36 C
7	Up to 1-1/2 incl	105,000	133,000	269-321	28-34 C
8	Up to 1-1/2 incl	120,000	150,000	302-352	32-38 C

aluminum welding in the last few years and some manufacturers are apt to be using out-dated techniques. Several characteristics of aluminum affecting the welding process are:

a. Aluminum melts at about 1200° F and does not become "red-hot" or otherwise change color when heated. The oxides of aluminum melt at about 3600° F or some 2400° F higher than the parent metal.

b. Aluminum conducts heat 3 times faster than steel and the thermal expansion is approximately twice as great. Distortion from welding must be carefully controlled.

c. Cleaning the weld surface of oxide, grease, or other foreign material just prior to welding is necessary to produce good welds with low porosity. The lower melting temperature, lower specific gravity, and higher heat conduction are some of the reasons why this problem is much worse for aluminum than for steel.

To minimize distortion, it is necessary to use:

a. Minimum amount of weld material

b. Back up chill bars to absorb heat

c. Rigid jigs

d. A high speed, concentrated heat input welding process

e. Equalized welding on both sides of material

f. Proper welding sequence

g. Increased scantlings

As with all types of fabrication, some residual stress will be built into any redundant structure. For welded aluminum this problem is compounded by the large welding distortion. The major method of combating residual stress is proper weld sequence.

Ref. 42 is addressed to high quality welding for the construction of missiles. There are, however, two items of special interest in this reference:

a. Very high quality welds are practical when the material is tack welded to hold the alignment. The general practice has been to avoid tack welds, but they can be used if properly cleaned prior to production welding.

b. Fiberglas tape with adhesive backing can be used as a backup in lieu of metal backup bars, without weld contamination.

Ref. 43 is an extensive collection of information on welding aluminum. It covers all types of welding including:

a. Arc (MIG and TIG)

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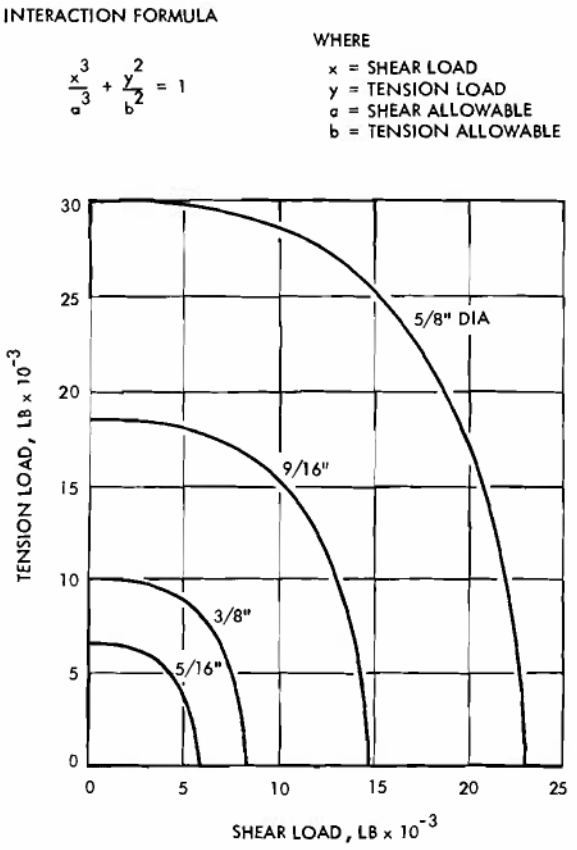


Figure 7-39. Combined Shear Load and Tension Load on Steel Bolts (With an Ultimate Tensile Strength of 125,000 psi)

b. Resistance (seam, spot, flash butt)
c. Gas
d. High frequency
e. Pressure
f. Ultrasonic
g. Electron beam
h. Laser

Strengths of butt joints are listed in Table 7-26.

The stress in a double fillet weld in longitudinal shear is:

$$\sigma_s = \frac{F}{1.414sL} \qquad (7\text{-}43)$$

where

σ_s = shear stress in weld, psi
F = total longitudinal force, lb
s = fillet size (length of fillet leg), in.
L = length of weld, in.

Fillet welds are loaded in transverse shear if the load is applied perpendicular to the axis of the weld. For equal leg length transverse fillet loading, the plane of maximum strength is not at the minimum throat depth but, theoretically, is at an angle of 22½ deg with the fillet leg for the maximum shear stress, and at an angle of 67½ deg for the maximum tensile stress. The stress will be the same in both of these planes so the weld will fail in shear since the ultimate shear strength is lower than the ultimate tensile strength. Table 7-27 lists filler alloy shear strengths. The stress values produced by the longitudinal shear loading are always higher than the shear stresses from an identical transverse loading. It is the practice of some designers in fillet weld design to assume the longitudinal shear loading regardless of the direction of the applied load. Fig. 7-43 shows the transverse shear strength of alloy 5356 and 5556. The failure is assumed to be in the fillet.

A common application of fillet welds is for fully connecting two members at right angles, using a double fillet weld. If it is desired to make this welded connection strong enough so that in severe loading failure would occur in the base metal of the web, then the three methods of failure in the weld area are:

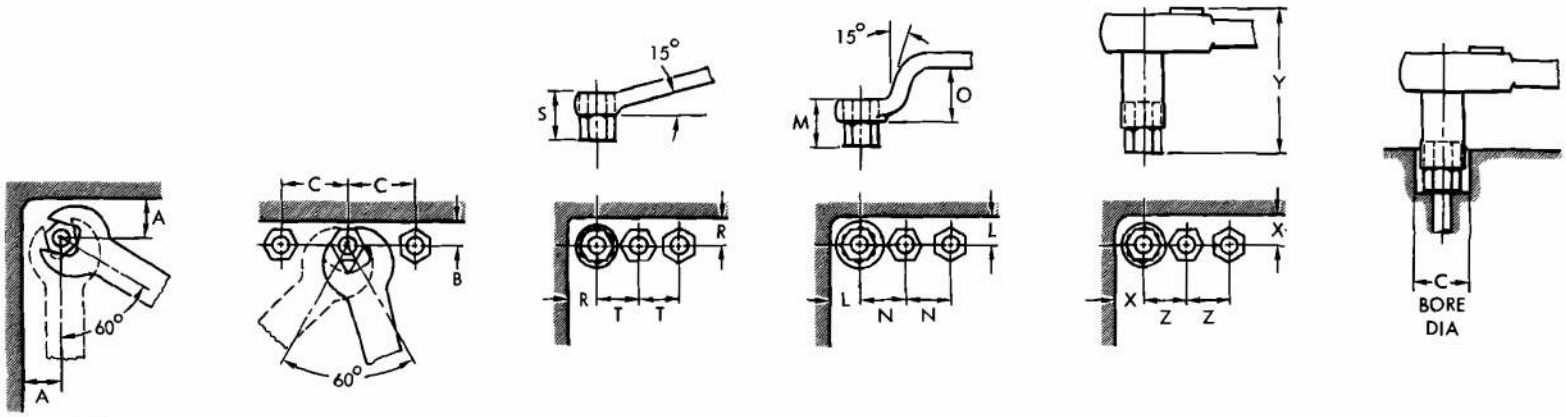
1. Failure in a plane through the fillets at or near the minimum throat depth
2. Failure in an irregular plane that roughly follows the fusion line of the fillet
3. Transverse tensile failure in web

Figure 7-44 illustrates these assumptions. The length of the irregular shear plane q, by measurement is about 1.1 times the length of the fillet leg.

The following items govern the fillet size and the strength of the weld metal:

a. The fillets must be sufficiently large to provide an adequate length of shear plane q adjacent to the fillets so that failure does not occur as base-metal shear adjacent to the fillets. It is general practice to assume the heat affected zone (HAZ) extends one inch into the parent metal from either the center of a butt joint or the heel of a fillet, regardless of the weld size.

b. After the minimum fillet size is determined by the length of shear plane q, a corresponding minimum fillet weld shear strength must be established so that fillet failure does not occur before base metal failure in the web.



(A) (B) (C) (D) (E) (F)

BOLT SIZE NOMINAL	BOLT HEAD OR NUT ACROSS FLATS	AN8505 STYLE OPEN END WRENCH (FIGURES A,B)			BOX WRENCH - 15° ANGLE (FIGURE C)			OFFSET BOX WRENCH (FIGURE D)				SOCKET WRENCH (FIGURE E)			MIN "C" BORE DIA BASED ON SOCKET END (FIG.F)
		CLEARANCE		MIN BOLT SPACING	CLEARANCE		MIN BOLT SPACING	CLEARANCE		MIN BOLT SPACING	OFFSET	CLEARANCE		MIN BOLT SPACING	
		CORNER MIN A	ROW MIN B	C	ROW & CORNER R	HEAD MIN S	T	ROW & CORNER L	HEAD MIN M	N	O	ROW & CORNER X	HEAD MIN Y	Z	
No. 8	0.344											13/32	1-15/16	19/32	5/8
No. 10	0.375	7/16	3/8	11/16	11/32	21/32	9/16					1/2	2- 3/4	23/32	11/16
1/4	0.438	1/2	15/32	13/16	3/8	3/4	5/8	13/32	25/32	21/32	13/16	1/2	2-13/16	3/4	3/4
5/16	0.500	1/2	1/2	27/32	13/32	27/32	11/16	7/16	27/32	3/4	7/8	1/2	2-27/32	25/32	7/8
3/8	0.563	5/8	9/16	1	15/32	31/32	25/32	1/2	31/32	27/32	15/16	1/2	2-15/16	27/32	15/16
7/16	0.625	5/8	19/32	1 - 1/32	1/2	1 - 1/16	27/32	17/32	1 - 1/32	15/16	1	1/2	2-31/32	7/8	1 - 1/16
1/2	0.750	23/32	23/32	1 - 3/16	17/32	1 - 1/8	1	5/8	1 - 7/32	1 - 3/32	1 - 1/16	19/32	3 - 3/32	1	1 - 3/16
9/16	0.875	3/4	11/16	1-11/32	21/32	1 - 3/8	1 - 5/32	11/16	1 - 5/16	1 - 7/32	1 - 3/16	25/32	4 - 1/16	1 - 9/32	1 - 3/8
5/8	1.000	27/32	3/4	1 - 1/2	25/32	1-19/32	1 - 3/8	13/16	1-17/32	1 - 3/8	1 - 5/16	13/16	4 - 5/32	1 - 3/8	1 - 5/8
3/4	1.125	15/16	27/32	1 - 3/4	31/32	1-25/32	1-19/32	1	1-21/32	1-21/32	1 - 3/8	7/8	4 - 3/8	1-19/32	1 - 3/4
7/8	1.313	1 - 1/8	1	2	1 - 1/16	1-31/32	1-27/32	1 - 1/32	1-25/32	1-25/32	1 - 3/8	1	4 - 5/8	1-13/16	2 - 1/16
1	1.500	1 - 7/32	1 - 1/32	2 - 3/16	1 - 3/32	2 - 3/32	1-31/32					1 - 3/32	4 - 7/8	2 - 1/16	2 - 1/4

Figure 7-40. Minimum Wrench Clearances

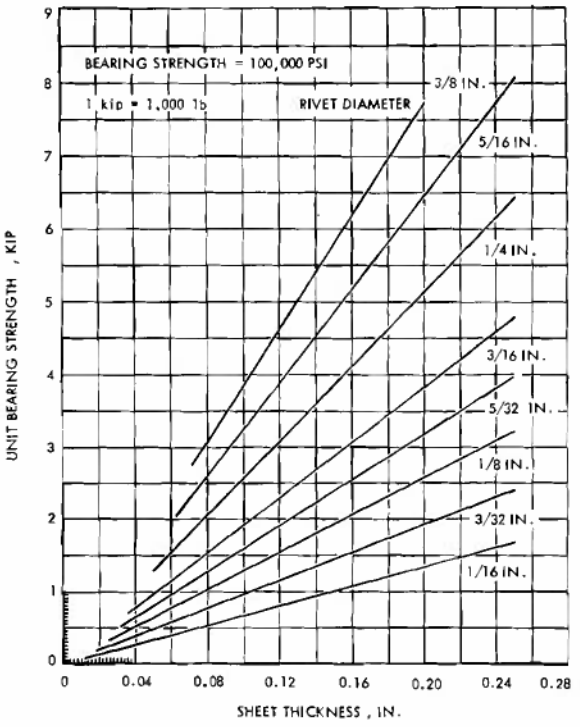


Figure 7-41. Unit Bearing Strength of Sheets on Rivets

c. If a weld metal weaker than the base metal is used, the fillet size must be increased accordingly.

d. There is little benefit in using an overly strong weld metal with the object of reducing fillet size. If this is done, the base metal shear strength through the irregular plane q at the fillet fusion line will not have sufficient strength.

In applying calculations to fulfill Item a, the given symbols for a one-inch-long segment of the structure are:

The unit length web tensile strength
$W_{tension} = tB$, lb (7-44)

The unit length shear strength
$W_{shear} = tS_1$, lb (7-45)

In shear at the weld fusion lines, the unit length shear strength (7-46)
$W_{fusion\ lines} = 2qS_2$, lb

where

For the Web Material

t = web thickness, in.

B = web material tensile ultimate strength, psi

S_1 = web material shear strength, psi

In the Weld Area

q = length of shear plane, in.

S_2 = weld material shear strength, psi

2 = number of fillets

When the welds are loaded in transverse shear, the web is in tension. To insure that failure will not occur in web shear at the fusion line, the web-shear strength on plane q near the fillets must at least equal the web tensile strength, thus:

$W_{tension} = W_{fusion\ line}$

$tB = 2qS_2$

with $S = S_1 = S_2$

$q = \frac{tB}{2S}$ but $q = 1.1s$, where s is the fillet size (7-47)

$1.1s = \frac{tB}{2S}$; $s = \frac{tB}{2.2S}$ = minimum fullet size, when the welds are loaded in transverse shear.

When the welds are loaded in longitudinal shear, the web is also in shear. In this case let $W_{shear} = W_{fusion\ line}$

$tS_1 = 2qS_2$

$q = \frac{tS_1}{2S_2} = \frac{t}{2}$, but $q = 1.1s$, so $1.1s = \frac{t}{2}$ (7-48)

$s = \frac{t}{2.2}$ = minimum fillet size when the welds are loaded in longitudinal shear.

The foregoing calculations show how the shear strength of the web base metal near the fillet can determine the minimum fillet size. After the minimum fillet size is determined, the minimum strength of the filler metal must be determined in fulfillment of Item b relative to fillet size and strength. For a one-inch-long segment of the structure, the fillet weld unit length shear strengths are:

Transverse shear strength $= 0.7071sT$, lb (7-49)

Longitudinal shear strength $= 0.7071sL$, lb (7-50)

and the fusion line unit length shear strength is:

$W_{fusion\ line} = 1.1sS$, lb (7-51)

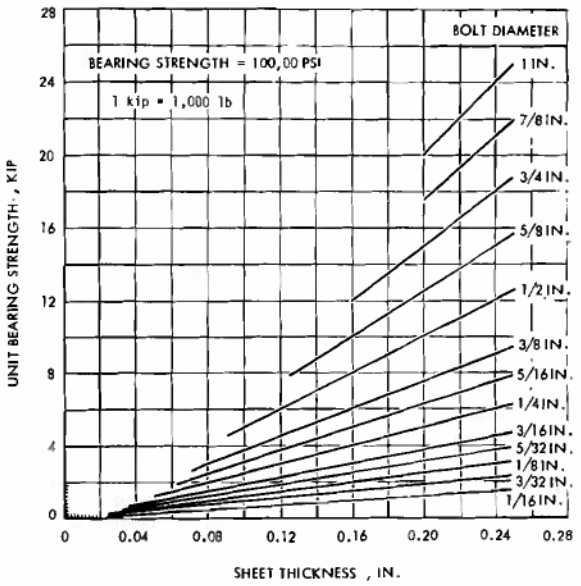


Figure 7-42. Unit Bearing Strength of Sheets on Bolts

where

In the Fillets

$0.7071s$ = weld failure path, in.
T = transverse shear strength, psi
L = longitudinal shear strength, psi

In Fusion Line Shear

q = $1.1s$ = fusion line failure path, in.
S = shear strength of base metal, psi

By equating the fillet weld shear strength to the fusion line shear strength, the minimum filler metal shear strength can be found, for the minimum size fillet.

Transverse

$$0.7071sT = 1.1sS$$

$$T = \frac{1.1S}{0.7071} \qquad (7\text{-}52)$$

$$T = 1.555S$$

Longitudinal

$$0.7071sL = 1.1sS$$

$$L = \frac{1.1S}{0.7071} \qquad (7\text{-}53)$$

$$L = 1.555S$$

TABLE 7-24 ALLOWABLE LOAD ON FILLETS (13,600 psi SHEAR ON THROAT)

Size, in.	*Allowable load per inch of length, lb*
3/16	1800
1/4	2400
5/16	3000
3/8	3600
7/16	4200
1/2	4800
5/8	6000
3/4	7200
7/8	8400
1	9600

If the minimum fillet size is used, the filler metal must have at least 1.555 times the base metal shear strength to avoid shear failure in the weld. Thus

$$\frac{T}{S} \text{ or } \frac{L}{S} = 1.555.$$

If this ratio is not met, the minimum fillet size must be increased by a ratio of

$$\frac{1.555}{T/S} \text{ or } \frac{1.555}{L/S},$$

which fulfills Item c of the precepts governing calculations for fillet size.

In accordance with Item d, a filler metal shear strength which meets the requirement of 1.555 times the base metal shear strength is adequate. There is no advantage in using stronger filler metal because the minimum fillet size is established by the base metal shear strength.

Joint accessibility is an important factor to consider. It is very easy to design a part which cannot be welded because part of the joint is not accessible to the welding tip. Typical MIG guns with dimensions are shown on Fig. 7-33. A full size template of the gun to be used is useful.

7-3.4.2.3 Adhesives

Ref. 44 discusses adhesive aluminum bonding, including:

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TABLE 7-25 FATIGUE STRENGTH OF STEEL WELDS, psi x 10^{-3}

ASTM-A7 Structural Steel

Type of Joint	0 to Tension		Reversed	
	Cycles 100,000	Cycles 2,000,000	Cycles 100,000	Cycles 2,000,000
Fatigue strengths of flat-plate specimens with and without butt welds, as-welded and with reinforcement removed flush, psi x 10^{-3}				
Plain plate (A-7 steel)	47.8	31.7	26.8	17.5
Transverse butt-welded joint (single V) as welded	34.9	23.2	22.4	14.9
Transverse butt-welded joint (a) single-V; (b) single-U - reinforcement off	37.5(a)	28.7(a)	27.4(b)	16.0(b)
Longitudinal butt-welded joint (single-V) — as welded	39.6	26.0	-	-
Longitudinal butt-welded joint (a) single-V; (b) double V - reinforcement off	47.1(a)	30.5(a)	21.0(b)	15.6(b)
Fatigue strengths of fillet welds of various arrangements in specimens designed for failure in the welds)				
Fillet-welded lap joints - 5/16 in. transverse welds. Failure in welds	30.3	18.5+	16.2	11.3
Fillet-welded lap joints - 5/16 in. longitudinal welds. Failure in welds	27.2	19.7	15.2	10.7
Fillet-welded lap joints - 5/16 in. transverse and longitudinal welds. Failure in welds.	28.3	20.5	13.1	8.9
Tee joints - 5/16 in. fillet welds. Failure in welds.	19.1	9.6	13.3	6.2
Moment connectors - 5/16 in. vertical fillet welds. Failure in welds	46.8	26.5	26.6	17.3
Fatigue strengths of rolled beams with lateral connection plates attached to the tension flanges				
Beams with welded attachments. Longitudinal welds	24.4	13.6	-	-
Beams with welded attachments. Transverse welds	19.2	12.2	-	-
Fatigue Strengths of Welded Beams and Girders				
Rolled beams, 12-in., 31.8 lb I, with continuously welded, partial length cover plates, 4 x 9/16 in. and 3/8 in. transverse fillet welds across square ends of cover plates	22.8	12.0	-	-
Rolled beams, 12-in., 31.8 lb I, with continuously welded, full-length cover plates 4 x 9/16-in. top plate and 6 x 3/8 in. bottom plate, 3/16-in. fillet welds	41.1	22.8	-	-
Built-up girders with continuous web-to-flange fillet welds and with middle stiffeners welded only to compression flange and upper half of web	46.7	17.6	-	-
Fatigue Strengths of Plug- and Slot-Welded Joints (Stresses given are those in welds)				
Plug welds - weld failure	23.1	12.6	11.3	6.5
Slot welds - transverse (balanced design for weld and plate failure)	20.0	10.2	10.0	5.3
Slot welds - longitudinal (balanced design for weld and plate failure)	27.9	11.1	16.1	6.1
Fatigue Strength of Plug-Welded Lap Joint Designed to Fail in Plate Material (Stresses given are those in Plate Material)				
Plug-welded lap joint - plate failure	26.3 24.1	10.1 11.7	14.2 14.1	5.3 6.6

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TABLE 7-26 TENSILE STRENGTH OF MIG AND TIG BUTT JOINTS

Alloy	5086	5456	6061-T6
Filler Alloy	5356	5556	5356
Average Ult Tensile, psi	39,000	46,000	30,000
Min Annealed Ult Tensile, psi	35,000	42,000	24,000
Average Yield, psi	19,000	23,000	17,000
Min Yield, psi	17,000	20,000	18,000
Free Bend Elongation, %	38	28	25
Tensile Elongation in 2 in., %	17	14	10

TABLE 7-27 SHEAR STRENGTH OF WELDED ALUMINUM ALLOY

Alloy	*5356*	*5556*
Typical Longitudinal Shear, psi	21,000	26,000
Min Longitudinal Shear, psi	17,000	19,500
Typical Transverse Shear, psi	34,000	41,000
Min Transverse Shear, psi (double fillet)	26,000	30,000

a. Applications
b. Surface preparation
c. Adhesive classifications
d. Design of an adhesive-bonded joint
e. Adhesive selection
f. Safety precautions

This method of fastening aluminum is advancing rapidly with new products and techniques being introduced frequently. Adhesive bonding is being used for the foils on hydrofoil craft, helicopter rotor blades, and other high performance components. Table 7-28 compares the properties of epoxy adhesives. It is recommended that the manufacturers of adhesives be consulted for the latest information before designing adhesive-bonded aluminum structures.

7-3.4.3 Miscellaneous Details

The following list includes many items previously covered. They are listed here to prevent their neglect in the vast amount of calculations and specifications:

a. Areas most frequently damaged include:

(1) Quarters where the sides and transom intersect

(2) Cargo deck area, including all adjacent vertical surfaces

(3) Cab accessories and the tires when the vehicle rolls when moored alongside a ship. The tires can be used effectively as fenders if they are adequately supported.

b. Adequate hand and foot holds must be provided. These may be used to secure gear if a line can be tied to them.

c. Drain plugs should be easily accessible so they can be replaced (with water in the bilge). Plugs with a "T" handle and a guide will prevent their loss and assist in securing in an emergency. The material used for the plug must be compatible with the hull material. An aluminum plug in an aluminum hull will seize.

d. Vibration will be present in any prototype. Addition of some extra panel stiffeners or braces should be anticipated to reduce the amplitude for any new design.

e. Piping penetrating the hull should have a

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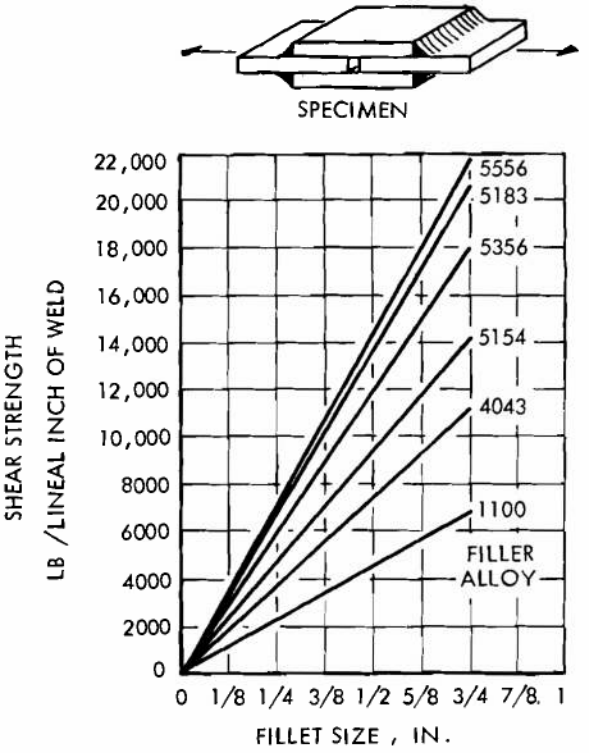

Figure 7-43. Typical Transverse Shear Strengths of Aluminum Fillet Welds

flexible section so that it will not vibrate with respect to the hull.

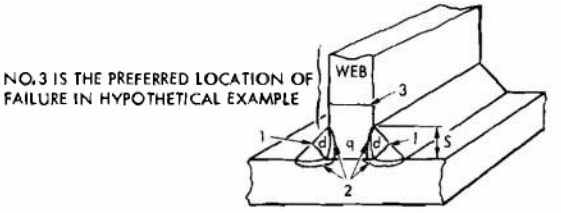

Figure 7-44. Three Possible Areas of Failure in a Double Fillet Weld

f. Good drainage is necessary for minimum maintenance.

g. Hatches for the removal of all machinery components should be provided. It is recommended that the cargo deck be solid. Hard points to attach lifting gear should be provided in the design stage. Foundation extensions which will allow sliding heavy pieces of machinery to a hatch may be useful.

h. Access inside the hull for maintenance or inspection is usually poor in some locations. Good maintenance will not be maintained with poor access. Likewise maintenance that must be conducted underneath the hull, while it is still dripping, is likely to be frequently overlooked.

i. Ventilation is usually deficient for maintenance work in the hull in hot weather.

Refs. 45 to 49 may be studied to determine past practice with regard to amphibian structural design.

SECTION II PROPULSION SYSTEM DESIGN

7-4 HORSEPOWER REQUIREMENTS

In the design of a propulsion system for a wheeled amphibian, the first step should be a determination of the required horsepower. In general the power requirements will be determined by the mission requirements or military characteristics defined in a QMR or SDR. It is the task of the amphibian designer to establish the minimum power required to satisfy the performance requirements given in the QMR. In some cases the amphibian designer may be faced with the converse problem in which the power plant is specified and the performance must be estimated. In either case the same basic data and design procedures apply.

Among military vehicles the amphibian is unusual in that it has performance requirements on or in three media, viz., water, land, and the interfaces between water and land. Performance in all of these media must be checked to determine which will determine the required power. The paragraphs of this section, which follow, present design theories and data for use in defining the power requirements.

7-4.1 WATERBORNE POWER REQUIREMENTS

In the LARC series of amphibians and the existing high speed amphibian prototypes, the power required is determined by the demands for waterborne performance. In future wheeled amphibians, with the current trend toward improved waterborne performance, this will almost certainly be the case. The waterborne

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TABLE 7-28 COMPARISON OF PROPERTIES FOR EPOXY ADHESIVES(1)

Type	*Tensile Shear Strength*,(2) psi	*T-Peel*(3) *Strength*, lb/in.
1. One-component (Heat cured)		
a. High-strength Flexible	4,000-7,000	12-160
b. High-strength Semirigid	4,500-5,500	2-6
2. Two component (Room-temperature-cured)	1,000-4,000	2-30

(1) All test specimens were chemically cleaned—chromic acid-sulfuric acid solution.

(2) Tensile-shear strength—Alclad 2024-T3 1/2 in. lap.

(3) Pull in lb/in. at a right angle to a base plate necessary to peel 0.009 in. thick 5052-H18 alloy from a rigid plate.

performance requirement is generally expressed in terms of a speed. In the case of current displacement hull amphibians (the LARC's), the required performance is expressed in terms of a top speed in calm, deep water. In the case of high speed amphibians, the required performance is expressed in terms of a sustained speed in a given sea state. Other waterborne performance criteria which may affect the power required include navigation in rough water, surfing ability, bollard pull, reversing, and maneuvering. The applicable performance requirement will be defined in the QMR.

The basic relationship between the power delivered to the propulsor and the amphibian's speed, resistance or drag, and propulsor efficiency is given by

$$DHP = \frac{EHP}{\eta_p} = \frac{R_T V}{550\,\eta_p} \qquad (7\text{-}54)$$

where

DHP = power delivered to the propulsors, hp
EHP = effective horsepower, hp
R_T = total resistance, lb
V = vehicle speed, ft/sec
η_p = propulsive efficiency, nd (par. 7-7.4.3.4)

To determine the delivered power it is necessary to obtain both the total resistance and the propulsive efficiency. Par. 7-7 deals with the selection and design of the propulsor and the calculation of the propulsive efficiency. The remainder of this section deals with the total resistance term of Eq. 7-54. For information on power requirements as determined by bollard pull, reversing, and maneuvering; reference should be made to pars. 7-7 and 7-9. Chapter 9 presents data on the resistance of high-speed amphibians.

7-4.1.1 Elements of Amphibian Waterborne Resistance

The waterborne resistance of an amphibian or marine vehicle can be considered as being made up of the following four main components:

1. The frictional resistance due to the motion of the hull through a viscous fluid
2. The eddymaking resistance due to the energy carried away in eddies shed from the hull, wheels, and appendages
3. The wavemaking resistance due to energy which must be supplied by the craft to the wave system created on the water surface
4. The aerodynamic resistance due to the passage of the above-water part of the craft through the air

Of these resistance components, Components 2 and 3 are of greatest importance to an amphibian and 4 is of little importance. It is common to consider Components 2 and 3 of the resistance together under the term "residuary resistance".

In general the flow conditions on the surface around an amphibian or other marine vehicle are much too complex to allow a theoretical calculation of resistance which is useful in design

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work. As a result, experimental data must be used. In order to make the greatest possible use of these data, the principles of dimensional analysis are employed. Dimensional analysis is based on the principle that every equation which expresses a physical relationship must be dimensionally homogeneous. The three basic dimensions in mechanics are mass, length, and time (M, L, and T) from which the dimensions of other quantities—such as acceleration, force, and pressure—can be derived. To apply dimensional analysis to a problem, it is only necessary to know the variables which govern the results. Dimensional solutions do not provide numerical answers themselves but provide the form of the answers. As a result, experimental data may be interpreted in a form most useful in obtaining an empirical solution. Refs. 4 and 53 present the theory and procedures of dimensional analysis in detail.

In applying dimensional analysis to the resistance of a waterborne vehicle, the following variables are assumed to govern the relationship between two geometrically similar bodies (geosims) of different size.

a. Speed V, ft/sec
b. Size of body, as represented by the linear dimension L, ft
c. Mass density of the fluid ρ, slug/ft^3
d. Viscosity of fluid μ, slug/ft-sec
e. Acceleration due to gravity g, ft/sec^2
f. Pressure per unit area in the fluid p, lb/ft^2

Dimensional analysis then indicates that the form of the relationship between the resistance R and the above variables is given by

$$R \propto (\rho V^2 L^2) f\left[\frac{\rho VL}{\mu}, \frac{gL}{V^2}, \frac{p}{\rho V^2}\right] \qquad (7\text{-}55)$$

where f is a symbol indicating "some function of". The kinematic viscosity ν (the ratio μ/ρ) and the wetted surface S or other area which is proportional to L^2 are commonly used in Eq. 7-55. This equation is then written in the form

$$\frac{R}{\frac{1}{2}(\rho V^2 S)} = f\left[\frac{VL}{\nu}, \frac{V^2}{gL}, \frac{p}{\rho V^2}\right] \qquad (7\text{-}56)$$

The ½ is introduced into the left hand side of Eq. 7-56 to make the pressure (ρV^2) numerically identical with the dynamic pressure in a fluid as defined by Bernoulli's equation. Experimental data must be used to determine the form of the relationship between resistance and the nondimensional parameters VL/ν, $V^2/(gL)$ and $p/(\rho V^2)$.

William Froude in England in 1868 first proposed the form of the relationship between the resistance and the above parameters. His basic concept is still in use. He assumed that the total resistance can be divided into two components, i.e., frictional resistance and residuary resistance. The frictional resistance is assumed to be a function of the parameter VL/ν only and the residuary resistance as a function only of $V^2/(gL)$. The parameter $p/(\rho V^2)$ is a form of the Cavitation Number discussed in par. 7-7.4.4.1 and is assumed not to affect the resistance components except at very high speeds on specialized craft.

7-4.1.1.1 Frictional Resistance

The frictional resistance due to the passage of the hull and appendages through a viscous fluid typically amounts to 50 to 80 percent of the total resistance for a conventional ship or boat form and considerably less for amphibians. Following the concepts presented in par. 7-4.1.1, a frictional resistance coefficient can be defined as

$$C_F = \frac{R_F}{\frac{1}{2}(\rho V^2 S)} \qquad (7\text{-}57)$$

where

C_F = frictional resistance coefficient, nd
R_F = frictional resistance, lb
S = surface area, ft^2

and other terms are as previously defined.

For geosims, C_F is only a function of the parameter VL/ν. This follows from the work of Osborne Reynolds, published in 1893, for which reason this parameter is known as the Reynolds number Re. For convenience in calculations of C_F and Reynolds number, Tables 7-29 and 7-30 from Ref. 14 which give the mass density and kinematic viscosity of fresh and salt water are included here.

For the purpose of making ship resistance estimates, considerable effort has been devoted to determining the relationship between the frictional resistance coefficient C_F and the Reynolds number Re. The development of several proposed relationships for smooth flat plates is covered in Ref. 14. Three of these relationships are given in Fig. 7-45. These

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TABLE 7-29 VALUES OF MASS DENSITY ρ FOR FRESH AND SALT WATER

Values as adopted by the ITTC meeting in London, 1963.
Salinity of salt water 3.5 percent.

Density of fresh water ρ, slug/ft^3	*Temp*, °F	*Density of salt water* ρ, slug/ft^3	*Density of fresh water* ρ, slug/ft^3	*Temp*, °F	*Density of salt water* ρ, slug/ft^3
1.9399	32	1.9947	1.9384	59	1.9905
1.9399	33	1.9946	1.9383	60	1.9903
1.9400	34	1.9946	1.9381	61	1.9901
1.9401	35	1.9945	1.9379	62	1.9898
1.9401	36	1.9944	1.9377	63	1.9895
1.9401	37	1.9943	1.9375	64	1.9893
1.9401	38	1.9942	1.9373	65	1.9890
1.9401	39	1.9941	1.9371	66	1.9888
1.9401	40	1.9940	1.9369	67	1.9885
1.9401	41	1.9939	1.9367	68	1.9882
1.9401	42	1.9937	1.9365	69	1.9879
1.9401	43	1.9936	1.9362	70	1.9876
1.9400	44	1.9934	1.9360	71	1.9873
1.9400	45	1.9933	1.9358	72	1.9870
1.9399	46	1.9931	1.9355	73	1.9867
1.9398	47	1.9930	1.9352	74	1.9864
1.9398	48	1.9928	1.9350	75	1.9861
1.9397	49	1.9926	1.9347	76	1.9858
1.9396	50	1.9924	1.9344	77	1.9854
1.9395	51	1.9923	1.9342	78	1.9851
1.9394	52	1.9921	1.9339	79	1.9848
1.9393	53	1.9919	1.9336	80	1.9844
1.9392	54	1.9917	1.9333	81	1.9841
1.9390	55	1.9914	1.9330	82	1.9837
1.9389	56	1.9912	1.9327	83	1.9834
1.9387	57	1.9910	1.9324	84	1.9830
1.9386	58	1.9908	1.9321	85	1.9827
			1.9317	86	1.9823

Note: For other salinities, interpolate linearly.

friction lines are based on turbulent flow.

In practice, the hull of a marine vehicle is neither flat nor smooth. As a result, in estimating the frictional resistance some increase is made in the values of C_F given in Fig. 7-45. For standard ship resistance estimates, it is customary to increase the value of C_F by 0.0004. The ATTC line +0.0004 roughness, or correlation allowance ΔC_F, is also shown in Fig. 7-45. In the event that it is necessary to make a resistance estimate for an amphibian form in which the effect of Reynolds number on C_F is important (see par. 7-4.1.1.3) it would be reasonable to use a roughness allowance of 0.0004.

7-4.1.1.2 Residuary Resistance

Those components of the total resistance due to eddymaking and wavemaking are commonly

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TABLE 7-30 VALUES OF KINEMATIC VISCOSITY ν FOR FRESH AND SALT WATER

Values adopted by the ITTC meeting in London, 1963.
Salinity of salt water, 3.5 percent.

Kinematic viscosity of fresh water ν, $\frac{ft^2}{sec}$	*Temp*, °F	*Kinematic viscosity of salt water* ν, $\frac{ft^2}{sec}$	*Kinematic viscosity of fresh water* ν, $\frac{ft^2}{sec}$	*Temp*, °F	*Kinematic viscosity of salt water* ν, $\frac{ft^2}{sec}$
1.9231×10^{-5}	32	1.9681×10^{-5}	1.2260×10^{-5}	59	1.2791×10^{-5}
1.8871	33	1.9323	1.2083	60	1.2615
1.8520	34	1.8974	1.1910	61	1.2443
1.8180	35	1.8637	1.1741	62	1.2275
1.7849	36	1.8309	1.1576	63	1.2111
1.7527	37	1.7991	1.1415	64	1.1951
1.7215	38	1.7682	1.1257	65	1.1794
1.6911	39	1.7382	1.1103	66	1.1640
1.6616	40	1.7091	1.0952	67	1.1489
1.6329	41	1.6807	1.0804	68	1.1342
1.6049	42	1.6532	1.0660	69	1.1198
1.5777	43	1.6263	1.0519	70	1.1057
1.5512	44	1.6002	1.0381	71	1.0918
1.5254	45	1.5748	1.0245	72	1.0783
1.5003	46	1.5501	1.0113	73	1.0650
1.4759	47	1.5259	0.9984	74	1.0520
1.4520	48	1.5024	0.9857	75	1.0392
1.4288	49	1.4796	0.9733	76	1.0267
1.4062	50	1.4572	0.9611	77	1.0145
1.3841	51	1.4354	0.9452	78	1.0025
1.3626	52	1.4142	0.9375	79	0.9907
1.3416	53	1.3935	0.9261	80	0.9791
1.3212	54	1.3732	0.9149	81	0.9678
1.3012	55	1.3535	0.9039	82	0.9567
1.2817	56	1.3343	0.8931	83	0.9457
1.2627	57	1.3154	0.8826	84	0.9350
1.2441	58	1.2970	0.8722	85	0.9245

Note: For other salinities, interpolate linearly.

known jointly as the residuary resistance. A residuary resistance coefficient can be defined as

$$C_R = \frac{R_R}{\frac{1}{2}(\rho V^2 S)} \qquad (7\text{-}58)$$

where

S = surface area, ft^2
C_R = residuary resistance coefficient, nd
R_R = residuary resistance, lb

It has been shown that for the purpose of engineering estimates C_R can be considered to be a function of the parameter $V^2/(gL)$ so that geosims operating at the same value of $V^2/(gL)$ have the same value of C_R. Since Froude first suggested this, the parameter $V^2/(gL)$ is known as the Froude number F_N. The Froude number often is given in references in the form $V/\sqrt{gL}$ which is also nondimensional. A common

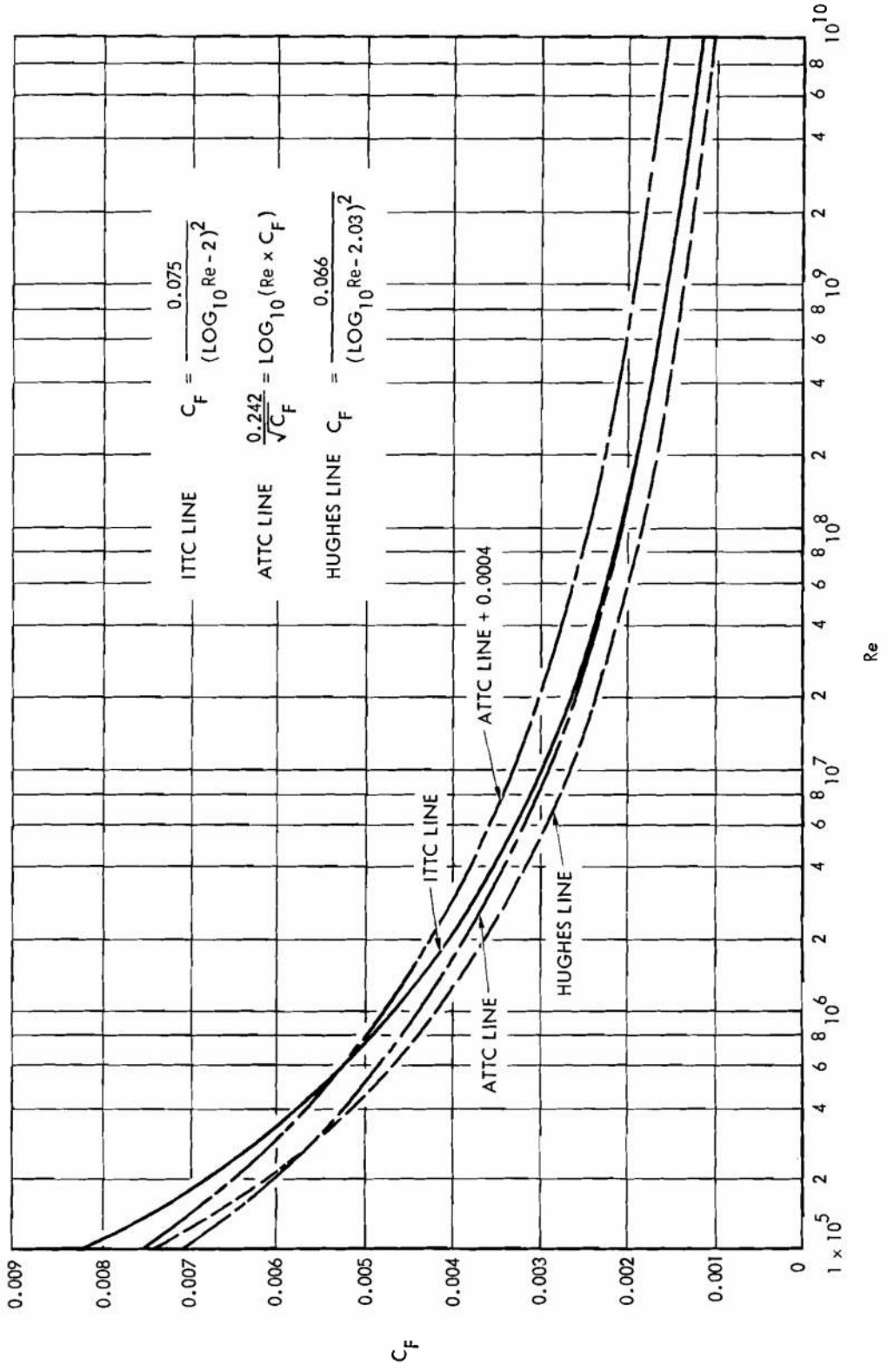

Figure 7-45. Standard Skin Friction Lines

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dimensional form of the Froude number is the speed-length ratio $V_K/\sqrt{L}$. When V_K is given in knots, L in ft, and g in ft/sec^2; the relationship between the two is

$$\frac{V}{\sqrt{gL}} = F_N = 0.298\ \frac{V_K}{\sqrt{L}}$$

or

$$\frac{V_K}{\sqrt{L}} = 3.355\ F_N \qquad (7\text{-}59A)$$

It is important to note that geosims operating at the same Froude number or speed-length ratio will have the same ratio of residuary resistance to displacement, regardless of size. In fact, if the effects of Reynolds number on C_F are neglected, geosims at the same Froude number will have the same ratio of total resistance to displacement, regardless of size. The proof of this is given in par. 7-4.1.1.3.

7-4.1.1.3 Scaling Laws and Model Tests

In the design of an amphibian the prediction of resistance must depend on data from model tests. The expansion of the measured resistance of a model to the resistance of the full scale craft is based on the relationship between the components of the resistance, and the Reynolds number and Froude number presented above. The residuary resistance coefficient C_R will be the same for a model and full size craft if they are operating at the same Froude number. Then the ratio of full size resistance to model resistance is given by

$$\frac{R_{Rs}}{R_{Rm}} = \frac{\frac{1}{2}\rho_s V_s^2 S_s C_{Rs}}{\frac{1}{2}\rho_m V_m^2 S_m C_{Rm}} \qquad (7\text{-}59B)$$

where the subscripts s and m refer to full size and model, respectively. At the same Froude number C_{Rs} equals C_{Rm} and the ratio of V_s to V_m is given by

$$\frac{V_s^2}{V_m^2} = \frac{L_s}{L_m} \qquad (7\text{-}60)$$

If Eq. 7-60 is substituted into Eq. 7-59B and ρ_s is assumed equal to ρ_m, then

$$\frac{R_{Rs}}{R_{Rm}} = \frac{L_s S_s}{L_m S_m} = \frac{L_s^3}{L_m^3} = \frac{\Delta_s}{\Delta_m} \qquad (7\text{-}61)$$

where Δ = displacement, lb.

Thus, the ratio of residuary resistance to displacement is constant between the full scale craft and the model. The relationship among the linear scale ratio λ, the speeds, and resistance ratio of the full size craft and the model are given by

$$\left.\begin{aligned} \frac{L_s}{L_m} &= \lambda \\ \frac{V_s}{V_m} &= \sqrt{\lambda} \\ \frac{R_{Rs}}{R_{Rm}} &= \lambda^3 \end{aligned}\right\} \qquad (7\text{-}62)$$

In a typical model test ρ_s does not equal ρ_m. As a result, the model is tested at the displacement that gives the correct scale waterline rather than at a displacement determined by the scale ration λ^3.

The relationship given in Eqs. 7-57 and 7-62 would hold true for the case of frictional resistance if the values of C_{Fs} and C_{Fm} were the same for a test with the speeds scaled by Eq. 7-60. However, the values of C_F are equal only if the Reynolds numbers are equal. For equal Reynolds numbers the relationship between full size and model speed is

$$\frac{V_s}{V_m} = \frac{L_m}{L_s} \qquad (7\text{-}63)$$

Clearly this relationship cannot be satisfied in the same model test that satisfies the relationship given in Eq. 7-60.

The practical means for dealing with this difficulty is by considering the total resistance R_T to be equal to the sums of the frictional resistance and residuary resistance. Thus

$$\frac{R_T}{\frac{1}{2}(\rho V^2 S)} = C_T = C_F + C_R \qquad (7\text{-}64)$$

The expansion of the model data involves taking the C_T obtained at a given Froude number (speed-length ratio) and subtracting from it the value of C_F at the resulting Reynolds number. The remainder is the value of C_R at the given Froude number. The Reynolds number of the full size craft is calculated at the given Froude

number and the value of C_F for the full size craft obtained. This is then added to the C_R from the model, with a ΔC_F (incremental ΔC_F) for roughness to give the C_T, and thus total resistance, of the full size craft. The values of C_F as a function of Reynolds number are obtained from the friction lines illustrated in Fig. 7-45. The expansion procedure described above is illustrated graphically in Fig. 7-46.

For typical wheeled amphibians such as the LARC series, the DRAKE and DUKW, the residuary resistance is very large compared to the frictional resistance due to the effects of wheels and other appendages. Also, the scale ratio is smaller than is usual for a typical ship model test. As a result, the effect of Reynolds number on the C_F difference between model and full size is small, and the resulting change in C_F is a very small part of C_T. Thus it is common practice to expand the model resistance to full scale by the ratio of the displacements, neglecting the effects of Reynolds number. Whether this simplification should be used in model tests of new amphibian designs will depend on the hull form and appendage geometry involved.

7-4.1.2 Amphibian Resistance Data

From past model tests on wheeled amphibian designs, there are data available on vehicle resistance. These data can serve two purposes in the design of a wheeled amphibian. In the early stages of a design, or in the event a model test is not possible, these data can be used to estimate the waterborne resistance. In this case the procedure is to select the design nearest in characteristics to the new design and use the earlier resistance data in making an estimate. Of course, corrections must be made for displacement, different hull shape, and appendages. The influence of these items on resistance is covered in pars. 7-4.1.2.2 and 7-4.1.2.3.

The other use of available resistance data is for making comparisons between new and older designs. If a new design has unexpectedly greater resistance than those of the past, it is probable

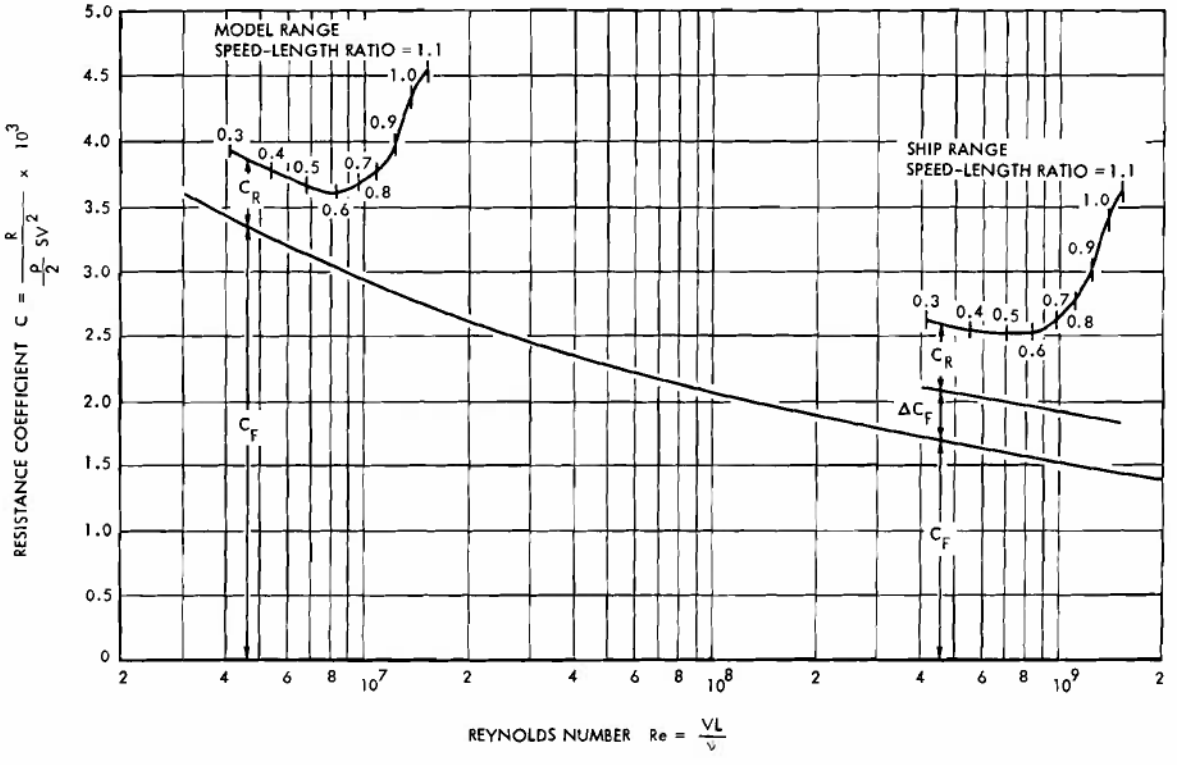

Figure 7-46. Comparison of Resistance Coefficients for Model and Full-scale Vessel

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that a redesign effort and further tests would be justified. Refs. 11 and 54 through 60 present model test data on the resistance of past wheeled amphibians.

7-4.1.2.1 Data Plots

The model test data from the references are plotted in a consistent form in Figs. 7-47 through 7-53. These plots are in the form of the total drag-to-displacement ratio as a function of speed-length ratio. Speed is in knots and the length, on the at-rest waterline, in feet. Data are presented for the DUKW, GULL, DRAKE, LARC V, LARC XV, LVW, and LVH-X2. In the case of the LVW and LVH-X2 high-speed amphibians, the data are for operation in the displacement modes.

7-4.1.2.2 Influence of Basic Hull Form on Resistance

In the selection of the basic hull form or in developing a resistance estimate, it is necessary to consider the influence of hull shape. The hull forms used on conventional amphibians are quite different from boat hulls of similar displacement. Amphibians are generally shorter for a given displacement, which results in full hulls with chines at the turn of the bilge and transom. In some vehicles—such as the DUKW, SUPERDUCK, and DRAKE—a scow-type bow has been adopted. The high displacement-length ratio results in high wavemaking drag and the chines cause high eddymaking drag.

The only type of marine craft with displacement-length ratios as large as those of amphibians are landing craft. Fig. 7-54 presents a comparison between the drag-displacement ratio of various landing craft and "faired" hull forms of the DRAKE, LARC V, and LARC XV, as a function of displacement-length ratio and speed-length ratios. Models of the DRAKE, LARC V, and LARC XV were tested with the wheels removed and the wheel pockets filled in to produce a faired hull, thus permitting realistic comparison of the resistance of the basic hull forms without the influence of the wheels. At speed-length ratios around 1.0 the drag-displacement ratios of the "faired" amphibian hull forms are about the same as those of the landing craft. At higher-speed-length ratios the drag-displacement ratios of the amphibian hull forms are higher. This is probably the result of the effects of the propeller tunnels and sloped transoms which prevent the development of dynamic lift as in the case of the landing craft. These features are present in amphibians because of the need for adequate ground clearance and departure angles.

Since it is known that a large part of the total resistance of an amphibian is due to eddymaking, it is useful to compare the total drag coefficients of various amphibian hull forms. The total drag coefficient is similar to the C_F or C_R developed in par. 7-4.1.1 except that it is based on the total drag and the projected frontal area instead of the wetted surface, i.e., $C_D = R_T/(\frac{1}{2}\rho V^2 A)$. When eddymaking drag and frictional drag are the dominant part of the total drag, the total drag coefficient will tend to be constant with speed-length ratio. When wavemaking drag is a large part of the total, the total drag coefficient will increase with speed-length ratio.

The total drag coefficients as a function of speed-length ratio for several amphibians are presented in Fig. 7-55. As expected the "faired" hull forms of the DRAKE, LARC V, and LARC XV have drag coefficients which increase rapidly with speed-length ratio. The LARC's with their ship-like bows have lower drag coefficients than the DRAKE with the scow-type bow. However, it should be noted that for the same projected frontal area the DRAKE has a higher displacement than the LARC's, so that its resistance-displacement ratio is about the same. Thus the choice between the scow form or the ship form bow must not be made on the basis of calm water resistance. Considerations of resistance in waves and seakeeping will also affect the choice between the two.

7-4.1.2.3 Influence of Appendages on Amphibian Resistance

On conventional amphibians, the exposed wheels are the most important appendages. Figs. 7-49 through 7-53 indicate the large increase in resistance between the "faired" hull form and the actual hull with wheels. Depending on the displacement, the presence of wheels and wheel wells increases the resistance 50 to 100 percent.

The effect of appendages on the total drag coefficient is presented in Fig. 7-55. As expected, the effect of the wheels reduces the change in drag coefficient with speed-length

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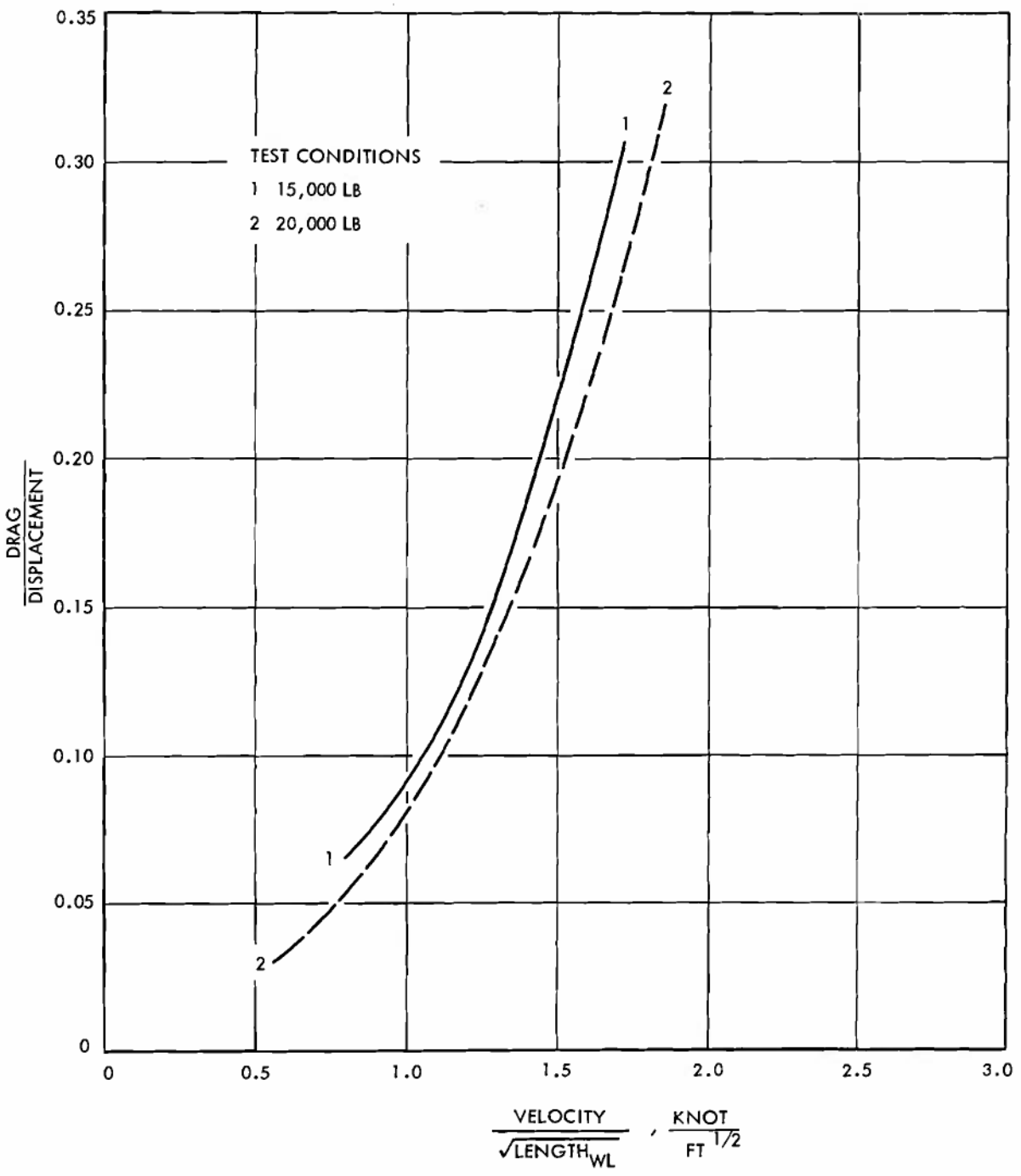

Figure 7-47. Resistance of DUKW

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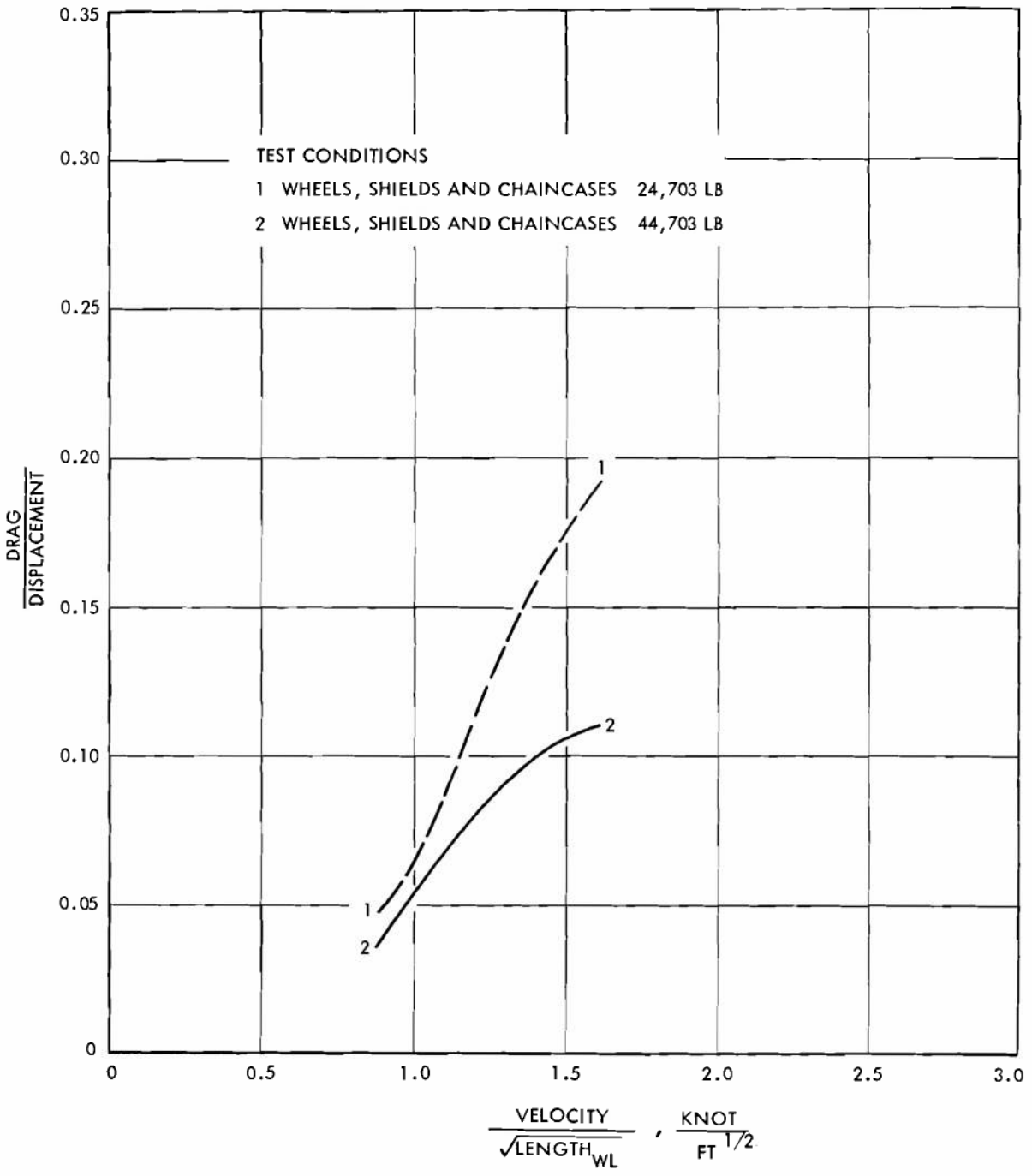

Figure 7-48. Resistance of GULL

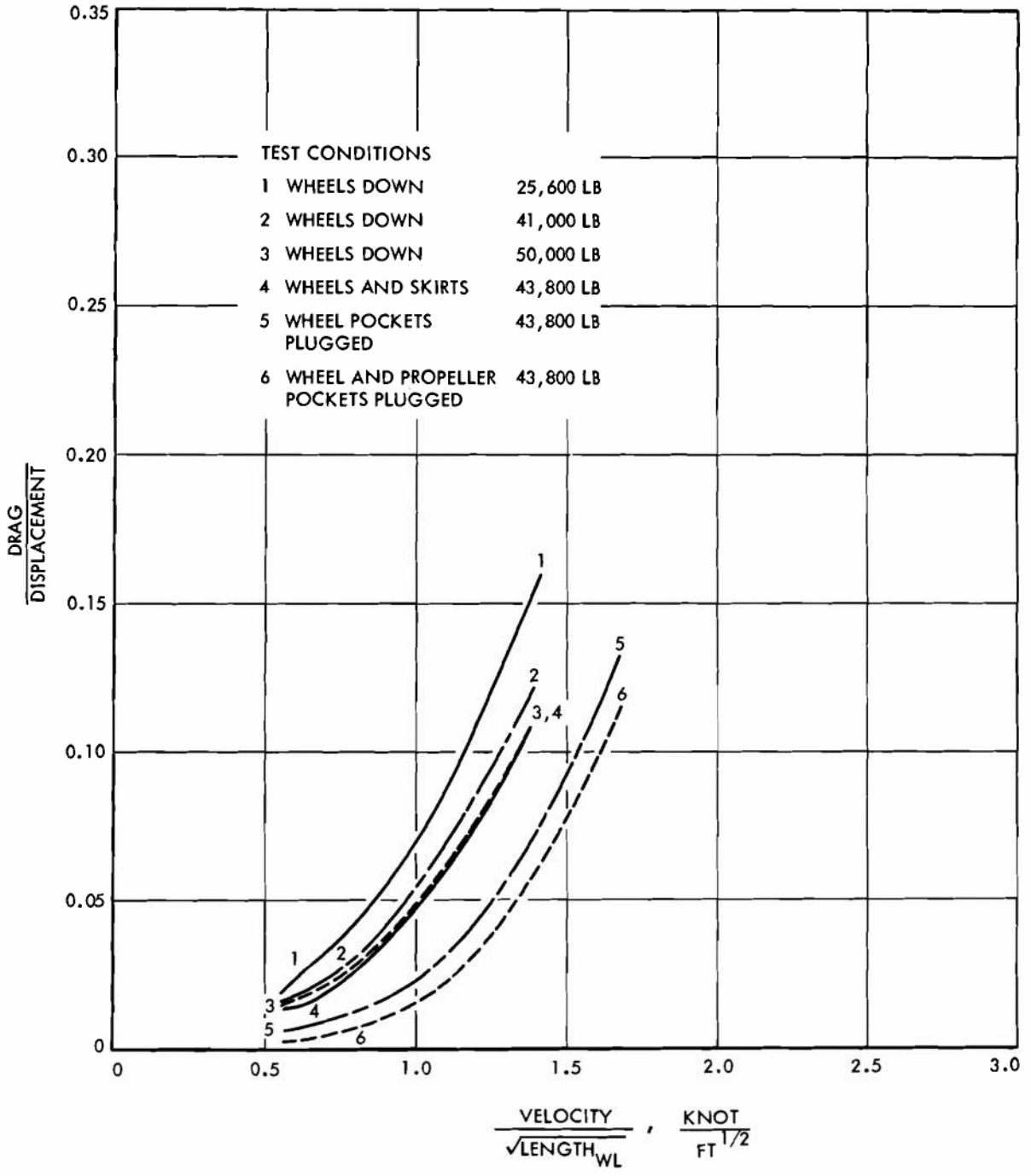

Figure 7-49. Resistance of DRAKE

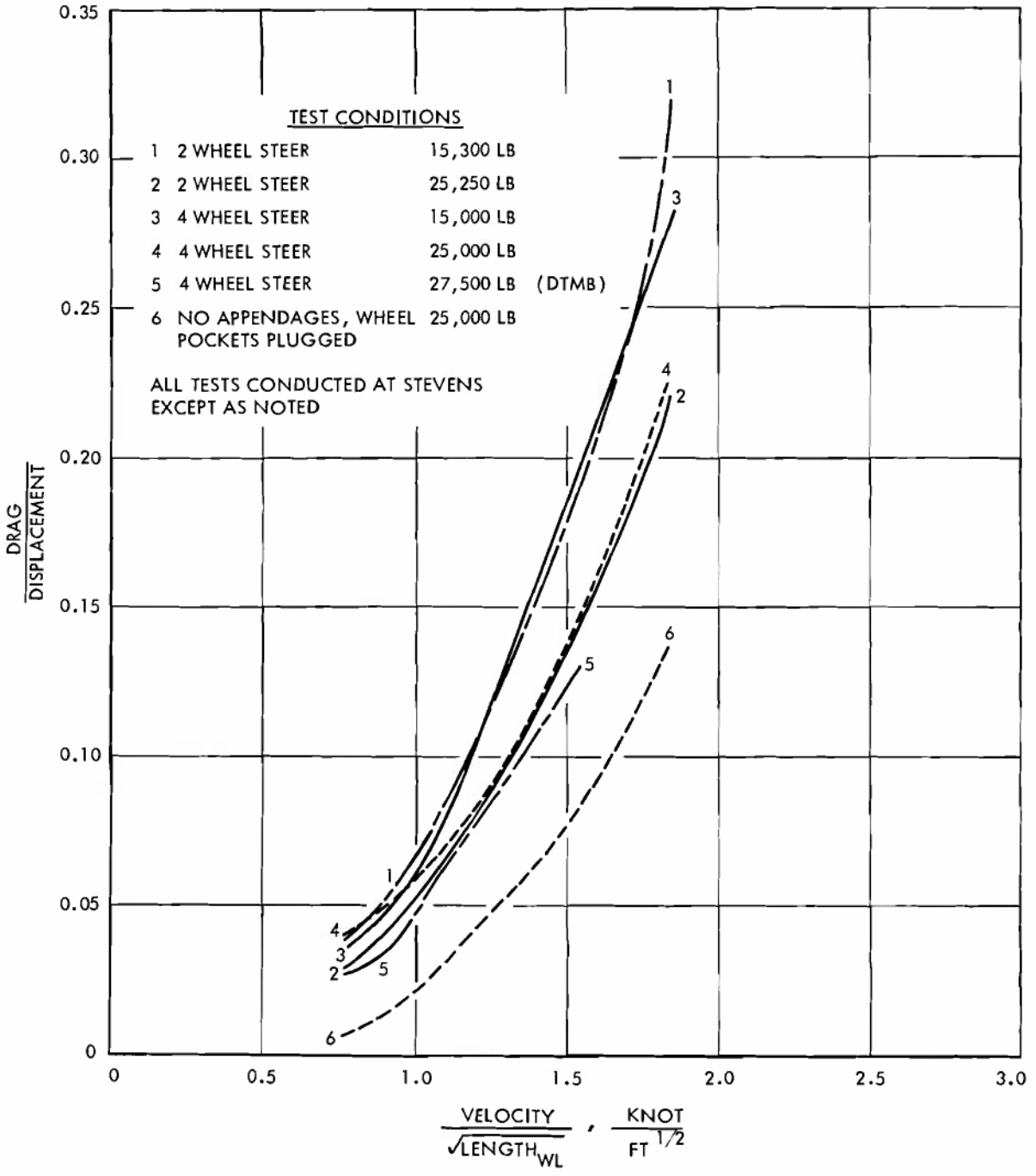

Figure 7-50. Resistance of LARC V

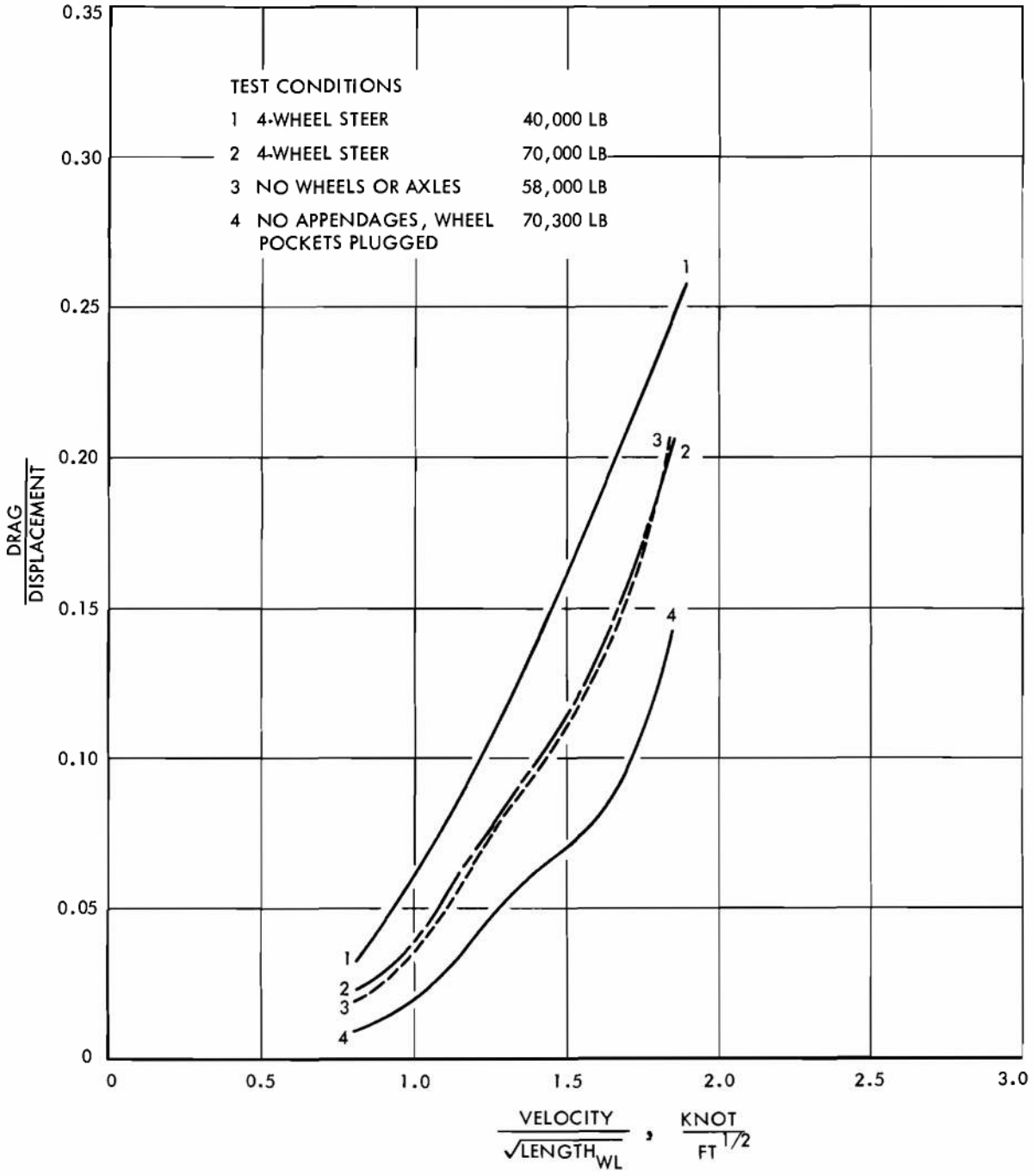

Figure 7-51. Resistance of LARC XV

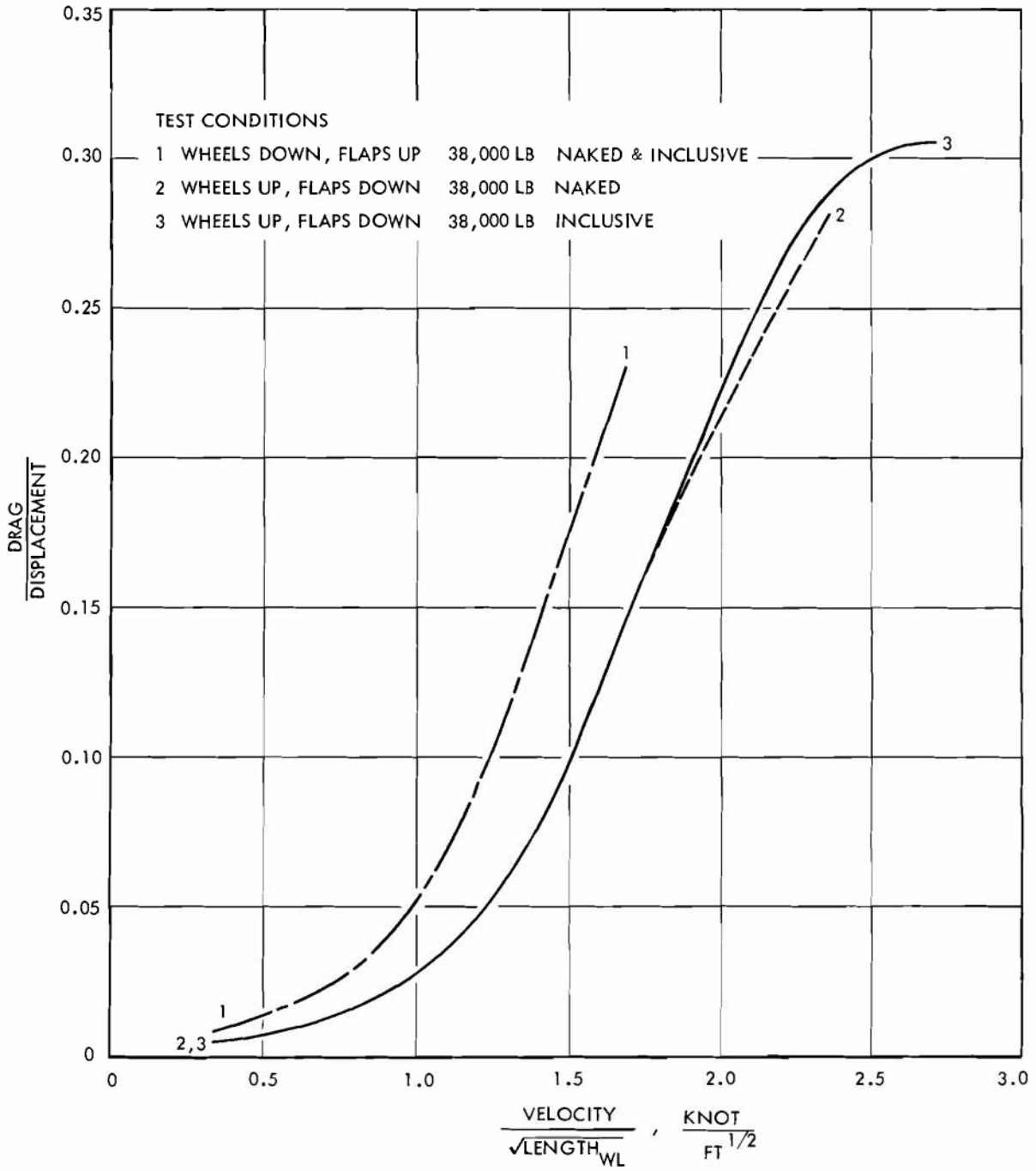

Figure 7-52. Resistance of LVW

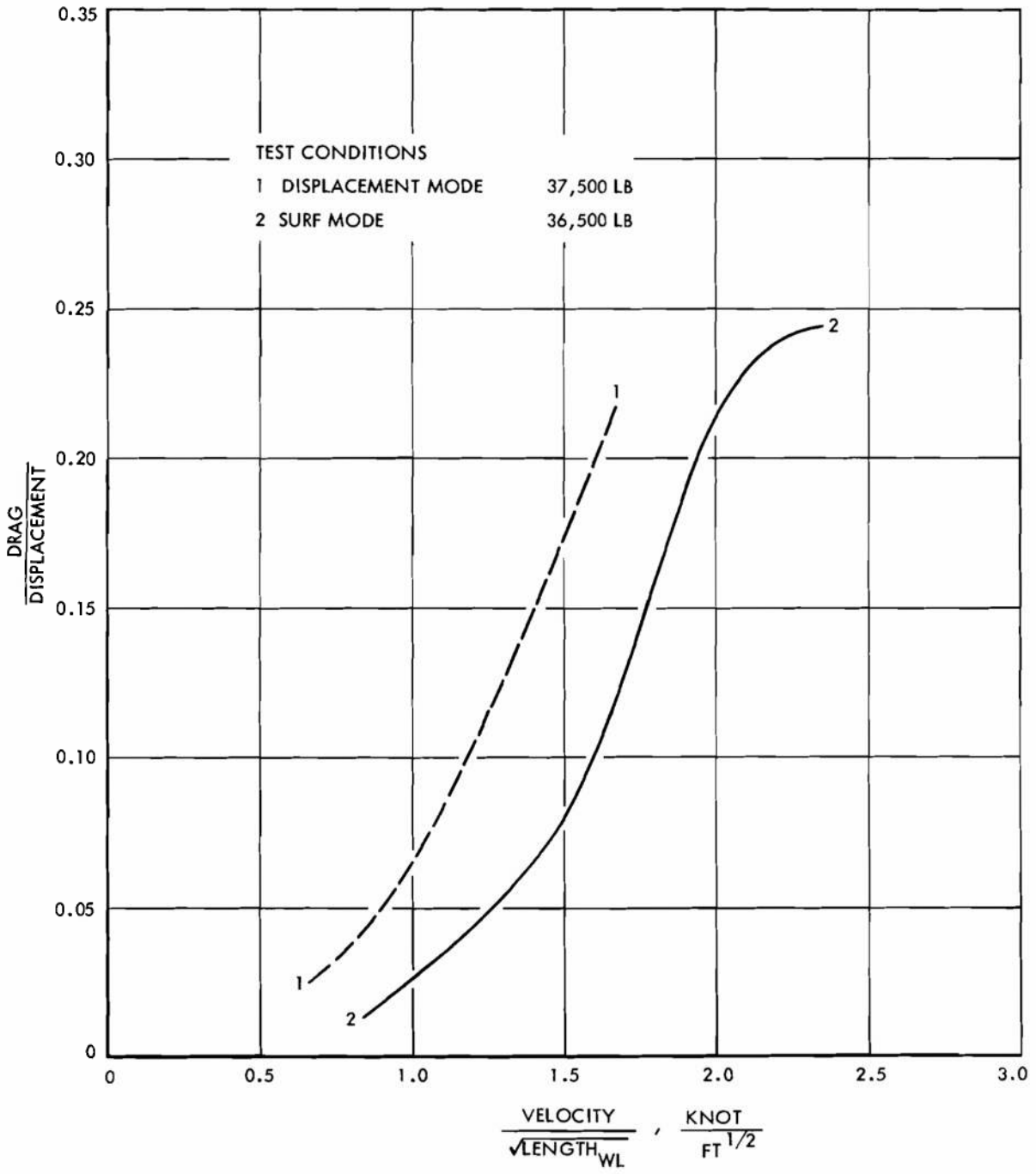

Figure 7-53. Resistance of LVH-X2

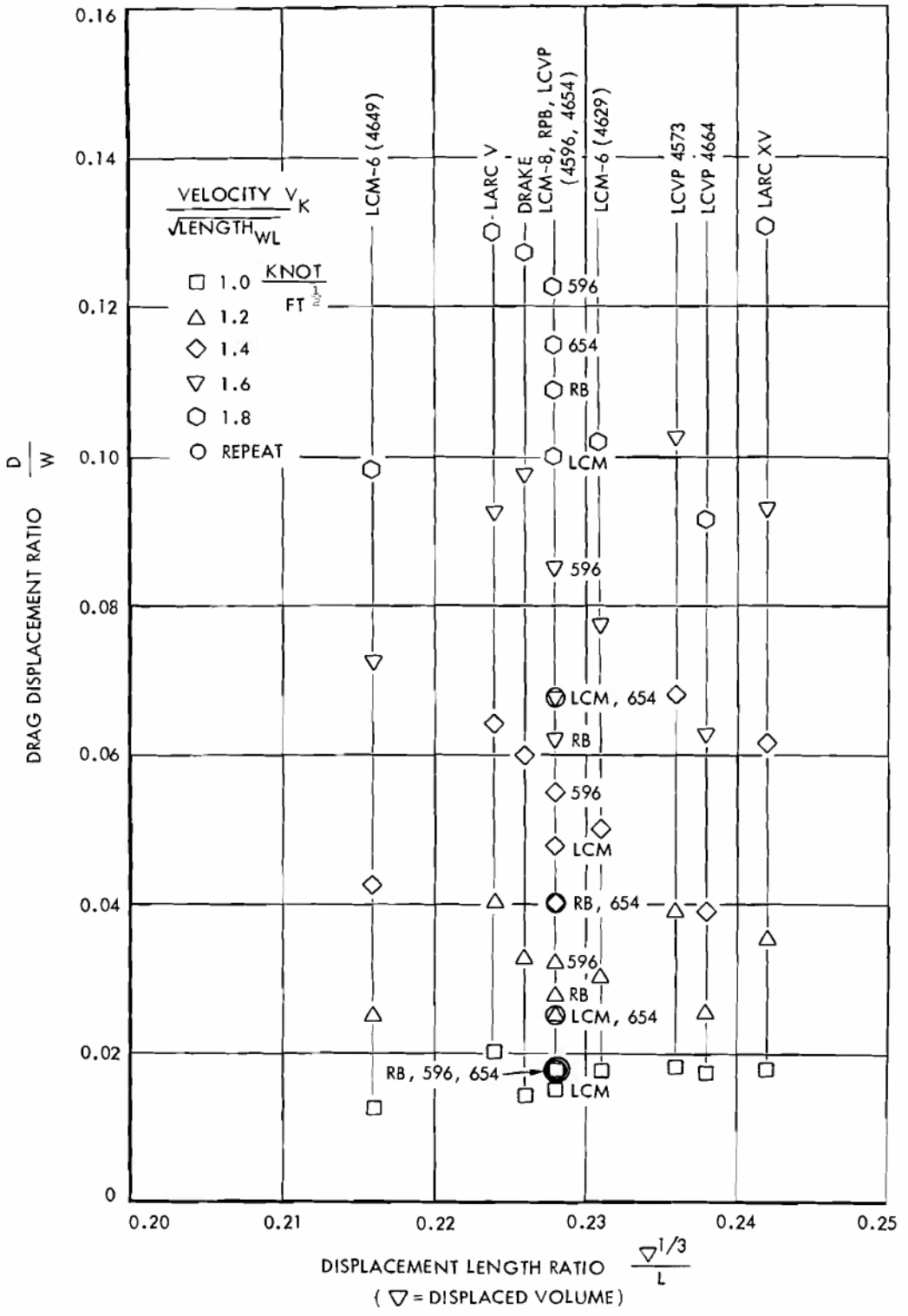

Figure 7-54. Comparison of Amphibian and Landing Craft Resistance

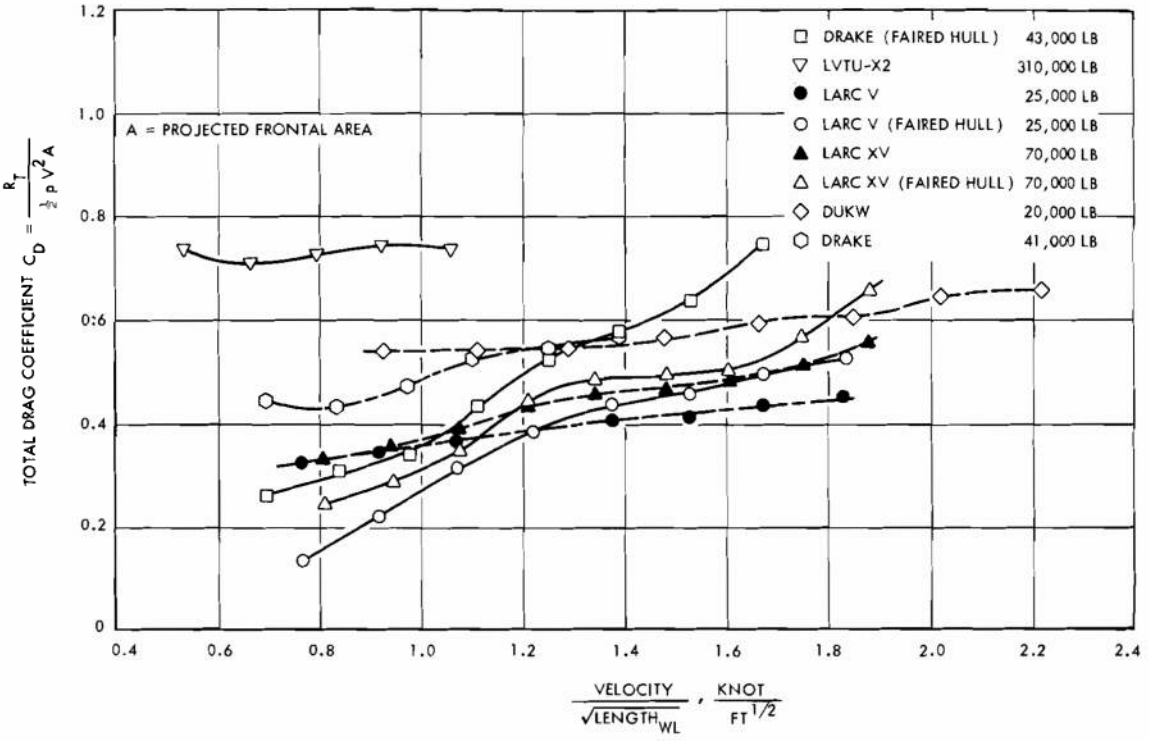

Figure 7-55. Amphibious Vehicle Drag Coefficients

ratio. Since the exposed frontal area of all of the wheels is included in the area term of the drag coefficient, the numerical value of the coefficient does not increase. Data on the drag coefficient of the LVTU-X2 have been included in Fig. 7-55 to indicate the expected upper limits of the drag coefficient of an amphibian with appendages. The LVTU-X2 was a tracked amphibian with an unfaired box type hull form of very high displacement-length ratio.

The apparent drag coefficient of the wheels and wheel wells were obtained for the DRAKE, LARC V, and LARC XV by calculating the difference between the drag of the hull with wheels and the faired hulls. The area used in the drag coefficient is the exposed frontal area of all of the wheels, viz., 4 in the case of the LARC's and 8 for the DRAKE. The resulting drag coefficients are presented in Fig. 7-56. In general, there is a trend of decreasing wheel drag coefficient with speed-length ratio. At speed-length ratios above 1.1 the wheel drag coefficient has a value of 0.42, with all data within = 10 percent of the mean.

7-4.1.2.4 Influence of Rough Water on Amphibian Resistance

Depending on the performance requirements for a given design, it may be necessary to estimate the resistance in waves. As in the case of smooth water resistance, model tests of the design or data from model tests of similar designs must be used in making the estimate. Ideally, a test series should be conducted in a model tank in which the required irregular waves could be generated. Such test facilities do exist (see par. 6-9), but no wheeled amphibian has been tested in these conditions. Model tests of the LARC V and LARC XV were conducted in regular waves (waves of constant height and length) and the results reported in Refs. 11 and 57. In order to make such estimates for an amphibian for which no test data are available, the added resistance from the model tests of the LARC V in head waves has been deduced. These data are presented in Fig. 7-57 as cross plots with respect to speed-length ratio and the number of wave lengths per water line length.

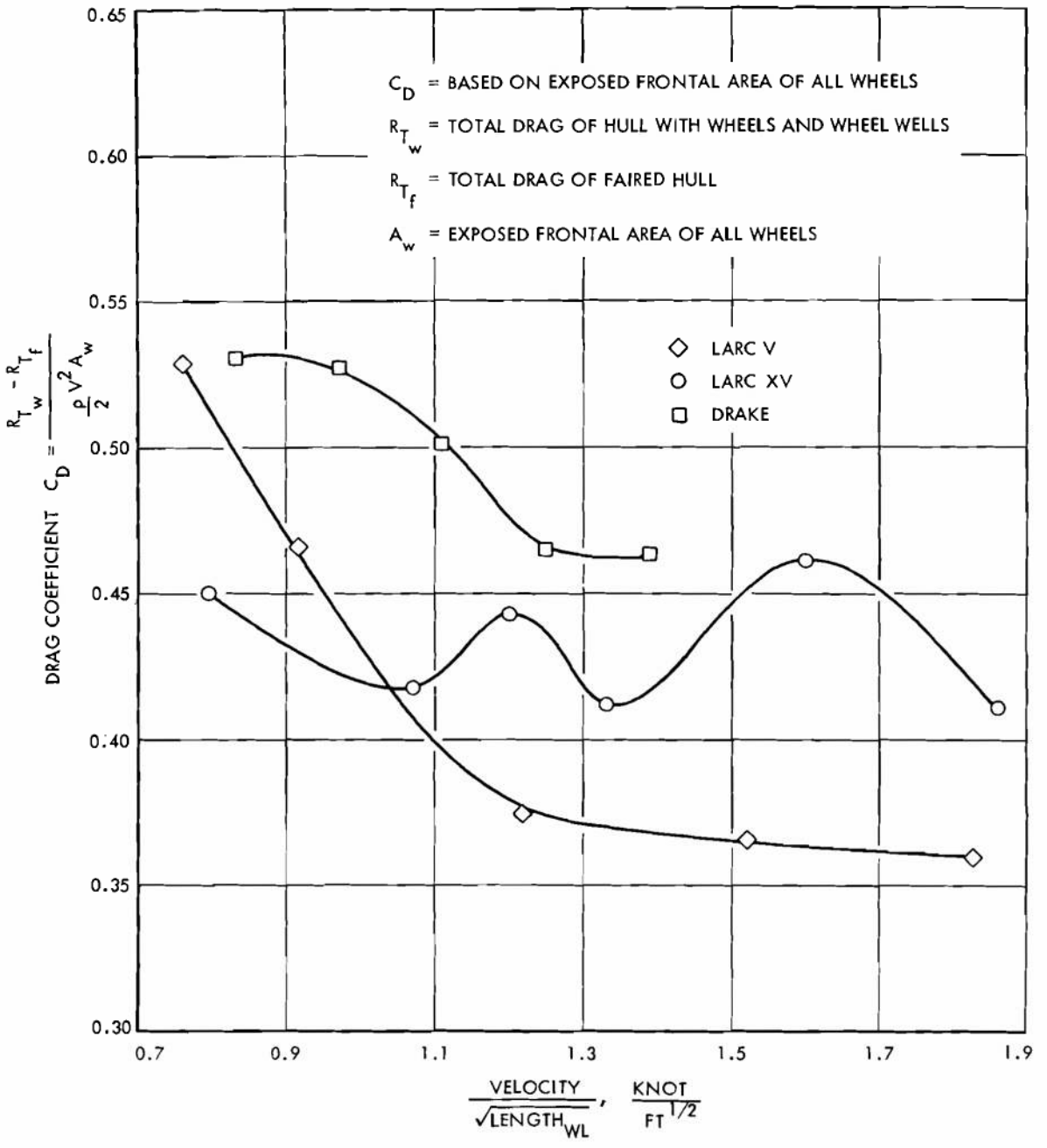

Figure 7-56. Drag Coefficient of Wheels and Wheel Wells

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Theory and experiments with conventional ship forms have shown that the resistance increase of a ship in waves is mainly due to the heaving and pitching motions, and the phases of these motions with respect to the waves. The resistance increase is not a function of the smooth water resistance. As a result, the data in Fig. 7-57 should not be sensitive to minor changes in appendages and hull shape.

A procedure for estimating the added resistance in irregular head seas from regular wave data is given in Ref. 61. For theoretically correct estimates, the added resistance must increase as the square of the wave height. Experimental findings on ship forms differ somewhat with theory. However, no other estimating procedure is available at this time. The expression for the average wave-induced added resistance of an amphibian, when proceeding at an average speed in long crested irregular seas from directly ahead, is given by

$$R_{AW}^{*} = 2\Delta \int_{o}^{\infty} \Phi_{\xi\xi}^{+}(\omega) N_R(\omega) d\omega \qquad (7\text{-}65)$$

$$N_R(\omega) = \frac{R_w}{\Delta A^2}$$

where

R_{AW}^{*} = average added resistance, lb
Δ = displacement, lb
$\Phi_{\xi\xi}^{+}$ = wave spectral density ordinate, ft^2-sec
R_W = added resistance in regular wave of amplitude A and frequency ω, lb
A = regular wave amplitude, ft
ω = wave frequency, rad/sec

The N_R term of Eq. 7-65 is given as a function of wave length/water line length ratio in Fig. 7-57. The relationship between wave length and frequency for deep water waves is given by

$$\left.\begin{aligned} \lambda &= \frac{64.4\pi}{\omega^2} \\ \omega &= \sqrt{\frac{64.4\pi}{\lambda}} \end{aligned}\right\} \qquad (7\text{-}66)$$

where

λ = wave length, ft
ω = wave frequency, rad/sec

The following example illustrates the calculation procedure, based on Eq. 7-65:

Given: It is required to estimate the average added resistance of the LARC V proceeding in head Sea State 3 at an average speed of 8 mph $V_K/\sqrt{LWL}$ = 1.22 knot/ft$^{1/2}$, where LWL is water line length.

1. It is first necessary to have an analytical description of a Sea State 3. This description must be in the form of a ½ amplitude wave spectrum. This spectrum is a description of the distribution of wave energy as a function of wave frequency. The concept of the wave spectrum is covered in detail in Ref. 62. The wave spectrum in most general use at this time is that due to Pierson and Moskowitz, which is given by:

$$\Phi_{\xi\xi}^{+}(\omega) = \left(\frac{8.10 \times 10^{-3}\, g^2}{\omega^5}\right) \exp\left[-0.74\left(\frac{g}{U\omega}\right)^4\right] \qquad (7\text{-}67)$$

where

$\Phi_{\xi\xi}^{+}(\omega)$ = wave spectral density ordinate, ft^2-sec
g = acceleration due to gravity, ft/sec^2
ω = wave frequency, rad/sec
U = wind speed, ft/sec

It is assumed that a Sea State 3 is described by a Pierson-Moskowitz spectrum for a wind speed of 15 knots.

2. The integration in Eq. 7-65 can best be carried out numerically using Simpson's rule since the analytical expression for N_R as a function of ω is not available. Fig. 7-57 indicates that the numerical integration need be carried out only for a range of ω that covers the range of λ/LWL from 1.0 to 4.0. Outside of this range N_R equals zero. The details of the calculation are given in Table 7-31.

7-4.1.3 Design Waterborne Power Estimate

From the previous paragraphs it is possible to define some general considerations that apply to the determination of required waterborne power. If the amphibian design is to be a success, the power required must be determined on the basis of the most demanding quantitative performance requirement in the QMR or other specification. This consideration is of the greatest importance. If at all possible the waterborne power required should be determined from a model test that, as closely as possible, duplicates the conditions given in the QMR or

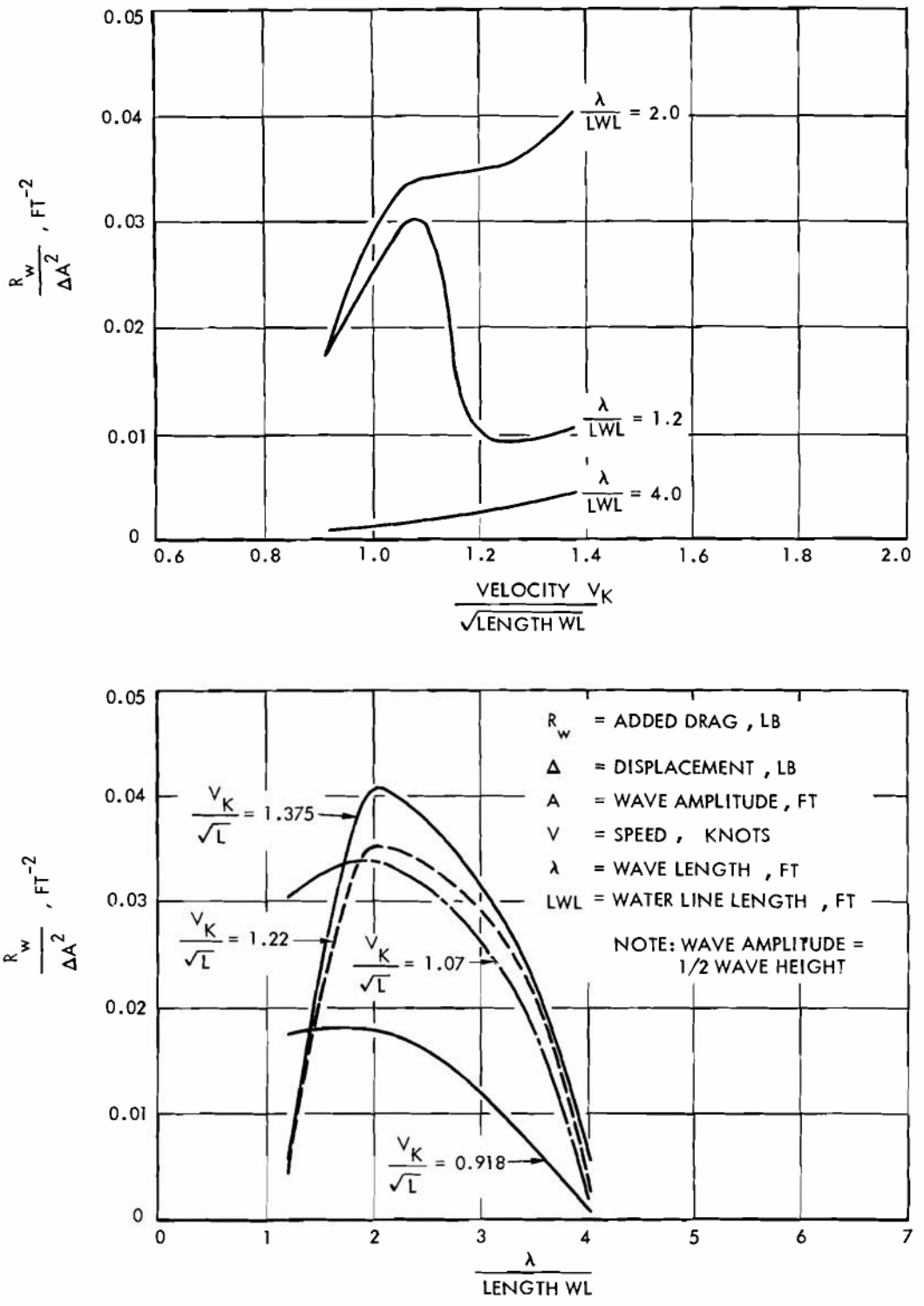

Figure 7-57. LARC V Added Resistance in Regular Head Waves

TABLE 7-31 ESTIMATE OF ADDED RESISTANCE OF LARC V IN SEA STATE 3

Average Speed = 8 mph; $\frac{V_K}{\sqrt{LWL}} = 1.22$ knot/ft$^{1/2}$

(1) ω	(2) λ	(3) $\frac{\lambda}{LWL}$	(4) $\Phi^{+}_{\xi\xi}(\omega)$	(5) $N_R(\omega)$	(6) S.M.†	(7) *Product* (4)(5)(6)
1.2	140	4.35	1.39	0.0	1	0.0
1.3	119	3.7	1.18	0.0155	4	0.0731
1.4	103	3.2	0.97	0.0215	2	0.0513
1.5	90	2.8	0.77	0.0310	4	0.0955
1.6	79	2.45	0.61	0.0337	2	0.0410
1.7	70	2.18	0.47	0.0350	4	0.0658
1.8	62.4	1.94	0.38	0.0345	2	0.0262
1.9	56	1.74	0.24	0.0300	4	0.0348
2.0	50.5	1.56	0.23	0.0220	2	0.0101
2.1	45.8	1.42	0.18	0.0155	4	0.0113
2.2	41.7	1.24	0.15	0.0100	2	0.0030
2.3	38.0	1.18	0.12	0.0050	4	0.0024
2.4	35.0	1.04	0.10	0.0	1	0.0

† Simpson multiplier

Σ (7) = 0.4145

$$R^{*}_{AW} = 2\Delta\left[\frac{\Sigma(7)d\omega}{3}\right]$$

$$R^{*}_{AW} = 2(27500)\left(\frac{0.4145}{3}\right)(0.1) = 760 \text{ lb}$$

other specifications. In the event that such a model test is not possible, the data and procedures presented in pars. 7-4.1.2 and 7-7 should be used. Considering the scatter in these data, the resulting estimate of power required should be within ± 10 percent of that determined from a model test. In any event, the waterborne power requirements of a new design should be compared to those of similar past designs. This will reveal any unexpected trends and the need for a design review.

7-4.2 LAND OPERATION POWER REQUIREMENTS

The required performance of an amphibian on land is given in the QMR or other vehicle specifications. In the past, the requirements that affect the power required have been given in terms of a required top speed, required grade climbing ability, and possibly, the requirement to tow another vehicle.

As indicated in par. 7-4.1, for almost all amphibians the waterborne performance will require more power than the land performance. The usual design procedure is to choose an engine based on the waterborne power requirements and then determine that the land performance will be satisfactory. The factors involved in the choice of the engine are covered in par. 7-5. Preliminary to the final check of the land performance, information must be available on the tire selected and the arrangement of the

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drive train. The selection of tire size will depend on mobility requirements and is covered in par. 7-8. The arrangement of the drive train is influenced by the engine chosen as well as the required tractive effort. The design of the drive train is covered in par. 7-6. The check on land performance is made by determining the required tractive effort as a function of speed and comparing it with the available tractive effort.

7-4.2.1 Required Tractive Effort

The required tractive effort is simply the thrust that must be developed by the tires in order to meet the land performance requirements. This thrust must overcome the resistance of the amphibian to forward motion and provide the force needed to overcome obstacles and grades. The resistance to forward motion is due to the rolling resistance of the tires and the aerodynamic resistance of the amphibian. The rolling resistance of the tire is the work done in compacting the underlying soil, deflecting the tire carcass, and bulldozing soil in front of the tire. Thus, the rolling resistance must be a function of the tire selected and the soild characteristics. Refs. 26 and 63, which are readily available to an amphibian designer, contain a detailed discussion of the rolling resistance and equations for its calculations. The rolling resistance used in the design of the LARC V and LARC XV are given in Table 7-32.

During the engineering tests of the prototype LARC V, tests were conducted to determine the actual rolling resistance and the results of the tests are presented in Figs. 7-58 and 7-59. These data indicate that the rolling resistance varies with soil conditions, tire pressure, and speeds.

In general, the land speed of an amphibian will be low enough that the aerodynamic drag will be small. However, if an estimate of aerodynamic drag is required, it can be obtained from

$$R_{aero} = C_{D_A} \tfrac{1}{2}\rho V^2 A \qquad (7\text{-}68)$$

where

R_{aero} = aerodynamic drag, lb
ρ = mass density of air ≈ 0.00238, slug/ft^3
V = relative speed, ft/sec
A = projected frontal area, ft^2
C_{D_A} = aerodynamic drag coefficient, nd

For typical trucks the value of C_{D_A} is between 0.8 and 2.0. No wind tunnel tests have been conducted to determine the aerodynamic drag coefficient of typical amphibian forms.

The resistance to climbing a grade is given by

$$R_y = W_T \sin \varphi \qquad (7\text{-}69)$$

where

R_y = grade resistance, lb
W_T = vehicle weight, lb
φ = angle of grade with the horizontal, deg

Grades are often given in terms of a percentage, i.e., a 60 percent grade. This notation represents the ratio of vertical distance to horizontal distance, expressed as a percentage.

In the event the amphibian is required to tow equipment, the required tractive effort can be determined from the rolling resistance and weight of the particular item.

7-4.2.2 Available Tractive Effort

The available tractive effort is the maximum thrust that the wheels could develop at a given

TABLE 7-32 DESIGN ROLLING RESISTANCE OF LARC V AND LARC XV

LARC V 4 18.00 X 25 in. tires 12-ply rating
LARC XV 4 24.00 X 29 in. tires 16-ply rating

Conditions	*LARC V*	*LARC XV*
Hard Surface	70-80 lb/ton	70 lb/ton
Cross Country (average)	130 lb/ton	130 lb/ton
Dry Sand at 10 mph	180 lb/ton	
Dry Sand at 25 mph	200 lb/ton	

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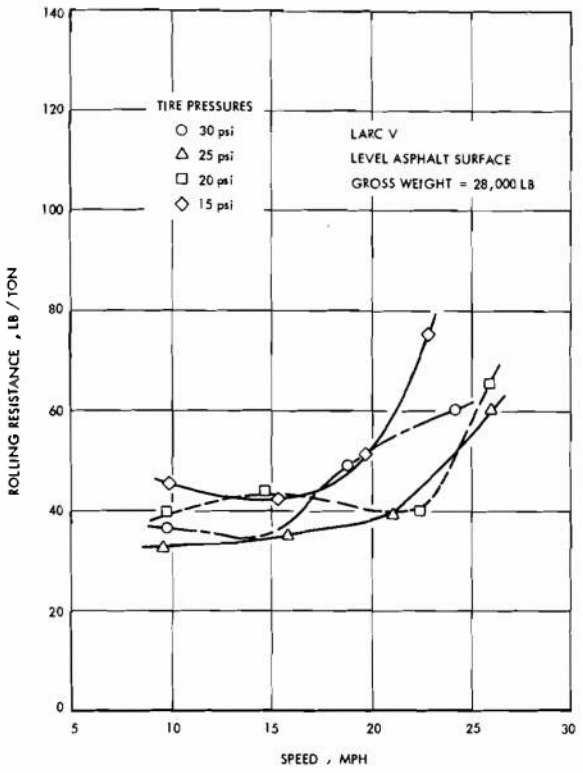

Figure 7-58. Rolling Resistance vs Speed on Level Asphalt Surface

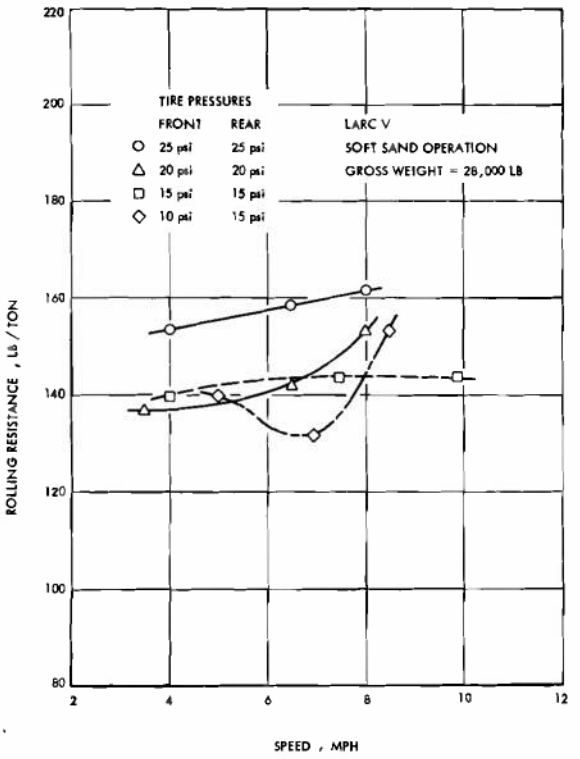

Figure 7-59. Rolling Resistance vs Speed on Soft Sand Surface

speed if the maximum available torque could be absorbed. This is an ideal case since the soil conditions may not allow the maximum available torque to be used.

The calculations of available tractive effort are illustrated in Table 7-33 in a sample calculation for the LARC XV. The engine converter performance curves on which this calculation is based are presented in Fig. 7-60. The resulting tractive effort curves are presented in Fig. 7-61. The required tractive efforts for level ground and for grades are also presented in Fig. 7-61. These curves are based on a rolling resistance of 130 lb/ton which is the assumed cross country average. Under these idealized conditions the LARC XV would have a top speed of 30 mph and a speed of 1.5 mph on a 60 percent grade.

7-4.3 SPECIAL PERFORMANCE REQUIREMENTS, WATER-LAND INTERFACE

In order to serve its function as an amphibious vehicle, the wheeled amphibian must be able to operate in the water-land interface. This ability was shown to be of great importance in World War II and since then in Southeast Asia. The QMR or other specifications for a wheeled amphibian may establish performance requirements on two distinct water-land interfaces, which include surf and river banks. The requirements for each are different and are considered here separately.

7-4.3.1 Surf Operations

The ability of an amphibian to operate through surf is determined by a number of factors in addition to the installed power. These include stability, water-tight integrity, arrangement, and maneuverability and are covered in pars. 7-1, 7-2, and 7-4.

In an operation over a beach the amphibian must pass through the surf coming into and exiting from the beach. In exiting from a beach the amphibian will be headed into the surf and take breaking waves over the bow. The forces developed by a large breaking wave are sufficient

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to momentarily stop an amphibian, no matter how much power is installed. This is not important since forward progress will resume as soon as the breaker passes, allowing the amphibian to eventually clear the breaker line.

In crossing surf to reach the beach, there is the danger that the amphibian will be overtaken by a wave as the wave breaks. If the surf is plunging this will result in large quantities of water on the decks as well as the danger of broaching and capsizing. In a plunging surf the crest of the wave breaks in such a way that it falls on the face of the wave in front of the breaking point. In the event that the amphibian does not have a self-bailing cargo deck, the incoming water could sink it. This happened to the SUPERDUCK prototype during surfing trials. Amphibians of the LARC family have been tested in and survived the breaking of 10 to 12 ft high plunging surf. In actual operations it may not be practical to operate amphibians in as high a surf as they can safely survive because of probable damage to the cargo. An amphibian may be designed to have sufficient speed to outrun the breakers, thus avoiding the possibility of being caught in breaking seas. The speed required to do this is, to a first approximation, a function of the breaker height. It is known that a wave slows down as it enters shallow water. The relationship between wave speed, wave length, wave period, and water depth is shown in Fig. 7-62. It is also known

TABLE 7-33 CALCULATION OF AVAILABLE TRACTIVE EFFORT FOR LARC XV

$$\text{Wheel rpm} = 303\frac{\text{rev}}{\text{mi}} \times \frac{1}{60}\frac{\text{hr}}{\text{min}} \times \text{mph} = 5.05 \times \text{mph}$$

Converter output rpm = Wheel rpm X overall gear ratio
Converter output torque from engine converter match curves
Wheel torque = Converter output torque X overall ratio X efficiency*
Tractive effort = Wheel torque/tire rolling radius

Converter Unlocked					
mph	*Wheel rpm*	*Conv. rpm out*	*Conv. Torque-out, lb-ft*	*Wheel Torque, lb-ft*	*Tractive Effort, lb*
Hi Gear Ratio= 20.302:1					
0	0.0	0	3376	59,000	21,450
2	10.1	205	3000	53,000	19,100
4	20.2	410	2620	46,250	16,700
6	30.3	615	2260	39,900	14,250
8	40.4	820	1960	34,600	12,500
10	50.5	1025	1700	30,000	10,800
12	60.6	1230	1510	26,650	9,620
14	70.7	1434	1350	23,800	8,580
16	80.8	1640	1220	21,550	7,770
18	90.9	1840	1110	19,600	7,070
20	101.0	2050	1000	17,650	6,370
22	111.0	2255	930	16,420	5,920
24	121.0	2460	900	15,900	5,730
26.35**	133.0	2700	840	14,840	5,250

* Power train efficiency from converter to wheels is estimated to be 87 percent.
** Calculated

(cont'd)

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TABLE 7-33 (Concluded)

Lo Gear Ratio = 51.105:1					
0	0.0	0	3376	151,700	54,700
2	10.1	515	2450	110,000	36,450
4	20.2	1030	1680	75,400	27,200
6	30.3	1547	1280	57,500	20,650
8	40.4	2065	1010	45,300	16,400
10.46	52.8	2700	840	37,800	13,630
Converter Locked-Up					
mph	*Wheel rpm*	*Conv. * rpm Out*	*Conv.* Torque Out, lb-ft*	*Wheel Torque, lb-ft*	*Tractive Effort, lb*
Hi Gear Ratio = 20.302:1					
17.55	88.6	1800	969.0	17,100	6,170
19.50	98.5	2000	986.0	17,400	6,275
21.50	108.4	2200	980.9	17,300	6,240
23.40	118.2	2400	969.0	17,100	6,170
25.40	128.0	2600	948.6	16,740	6,030
27.30	138.0	2800	923.1	16,300	5,880
29.30	147.8	3000	892.5	15,740	5,680
Lo Gear Ratio = 51.105:1					
6.97	35.2	1800	969.0	43,100	15,520
7.75	39.2	2000	986.0	43,800	15,800
8.52	43.1	2200	980.9	43,600	15,700
9.30	47.0	2400	969.0	43,100	15,520
10.07	50.9	2600	948.6	42,200	15,200
10.85	54.8	2800	923.1	41,100	14,800
11.62	58.7	3000	892.5	39,600	14,300

* Same as engine speed and torque.

that there is a relationship between surf height at the point of breaking and the water depth; this relationship is shown in Fig. 7-63. The data for Figs. 7-62 and 7-63 were obtained from Ref. 64. If a depth-to-height ratio of 0.85 is considered typical, the water depth and, thus speed, can be approximated for a breaker of a given height. The resulting speed is indicated by the solid line on the extreme right of Fig. 7-64. An amphibian with a speed greater than that indicated could outrun the breaker thus avoiding the danger. This, however, is not the only possibility. Since the breaking zone is fixed by water depth, the amphibian may be able to pass through it in the time between successive waves. The success of such a maneuver will depend on the skill and judgment of the operator, and the speed of the amphibian. There is still some minimum speed below which the amphibian could not cross the breaker zone without being caught by the next wave.

It is estimated that the breaker zone that would be troublesome to an amphibian would extend for a distance of 15 breaker heights. Based on this assumption it is possible to establish the minimum speed for an amphibian

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that will not be overtaken in the breaker zone, assuming perfect timing on the part of the operator. These minimum speeds for several wave periods are also indicated in Fig. 7-64. Between the needed speed to outrun the breaker and minimum speed needed with perfect timing, is a marginal speed range in which the skill of the operator becomes increasingly important.

The actual operational surf height and speed of the LARC series of amphibians are included in Fig. 7-64, to indicate present practice. The point for the LARC LX indicates the importance of factors in addition to speed in determining surf ability. In this case the large size of the LARC LX relative to the other LARC's increases its surfing ability, despite (or regardless of) its lower speed.

Thus, Fig. 7-64 may be used for guidance in estimating the speed required of a wheeled amphibian in surf operations.

7-4.3.2 Exiting from Rivers

As a result of recent operations in Southeast Asia, it has been realized that the ability to rapidly exit from rivers is of great importance. The transition from water to land as an amphibian climbs a river bank involves a number of complex phenomena both in "terramechanics" and hydrodynamics. Because of the complexity of the problem, at the time of this writing there are no procedures available to the designer to relate river exiting requirements to required power or other vehicle characteristics. A considerable amount of research is being done at this time on the river exiting problem, hence the designer must consult current literature to determine the state-of-the-art. Refs. 65 and 66 contain the results of some of the early research on the problem. These studies provide limited qualitative information for the designer. The most important points seem to be that efficient exiting aids are required (e.g., winches, anchors) and that approaching the bank at as high a speed as possible is very helpful.

7-5 FINAL ENGINE SELECTION

As indicated in par. 6-3.1, it is very unlikely that an engine will be specifically developed for a wheeled amphibian design. As a result, it will be necessary to select an engine from the military or modified commercial engines that are available. In the course of the preliminary and final design, the choice of possible engines must be narrowed down to the one that will result in the minimum cost wheeled amphibian that will meet the QMR or other requirements. A number of criteria that can be applied during the preliminary and final design phases to select the most suitable engine are presented in pars. 7-5.1 through 7-5.2.

7-5.1 GENERAL DISCUSSION

The probable requirements of a wheeled amphibian are such that it should be equipped with an engine which can meet the operational requirement of a tactical or Type I engine, as described in par. 7-14.1 of Ref. 63. These requirements deal with the atmospheric environment in terms of temperature, altitude or barometric pressure, and humidity; and establish longitudinal and lateral slope and waterproofing requirements.

To make a rational engine selection, it is necessary to consider the engine and the drive train as a unit. Only in this way can the combination that will meet the end product requirements at the minimum cost be selected. It would not be impossible to find two engines with similar performance capabilities but different output rpm and torque characteristics. In this case one of the engines is likely to be more compatible with a drive train using standard or available components and, accordingly, would be the better choice. The considerations and criteria that apply to the design of the drive train are given in pars. 7-6 through 7-6.5.

7-5.2 CRITERIA FOR WHEELED AMPHIBIAN ENGINES

A number of general criteria which apply to engines of all military vehicles, including wheeled amphibians, include reliability, durability, maintainability, availability, efficiency, weight, and economy. Since these criteria are common to the engine selection for all Army vehicles, they are covered in detail in Ref. 63 and need not be discussed further here. There are, however, several criteria that are unique to wheeled amphibians and the circumstances in which the application to a

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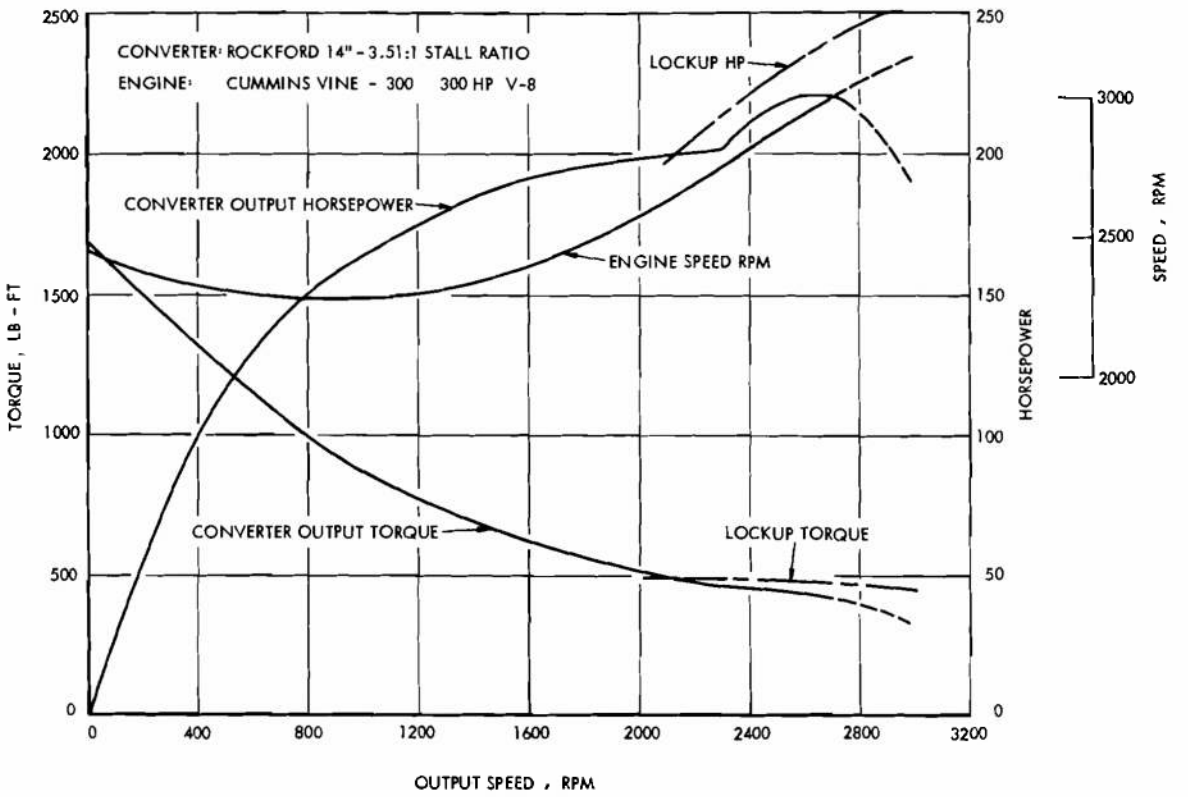


Figure 7-60. Engine-converter Performance

wheeled amphibian is unusual. These cases are presented in pars. 7-5.2.1 through 7-5.2.3.

7-5.2.1 Engine Rating

During waterborne operation, the engine of a wheeled amphibian will be required to deliver maximum power continuously. This condition is more demanding of an engine than any automotive application, where the engine need not deliver maximum power on level ground and down hills. As a result an engine selected for a wheeled amphibian must be capable of delivering the required power for a high percentage of its life, as discussed in pars. 7-4 through 7-4.3.

In establishing the required power the designer must remember to include the load for the auxiliary systems as well as the main propulsion system. This includes the power for the electrical, hydraulic, and cooling systems which in some cases may be as high as 10 percent of the total.

In comparing the required power with the rated power of the engine, the designer must determine the corrections to the rated power for the environmental condition expected. This is most important in the case of the temperature of the inlet air. If the engine takes air from the engine compartment, the temperature may be considerably above that outside the vehicle.

In general, the power rating of an engine and its reliability, life, and maintenance requirements when run at that rating are determined by test. During such tests the engine is run through a duty cycle which includes a certain percentage of the cycle at rated power and the remainder of the cycle at different fractions of the rated power. This test cycle for U. S. Army qualified Diesel engines is given in MIL-STD-1400, and engines that have passed this test are listed in Qualified Products List (QPL) 11276. The U. S. Navy also performs an endurance test to establish the ratings of Diesel engines as given in MIL-E-2357A (Ships). The Navy test reflects the service of an engine in a Navy boat and may be more applicable to wheeled amphibians than the Army test. In the

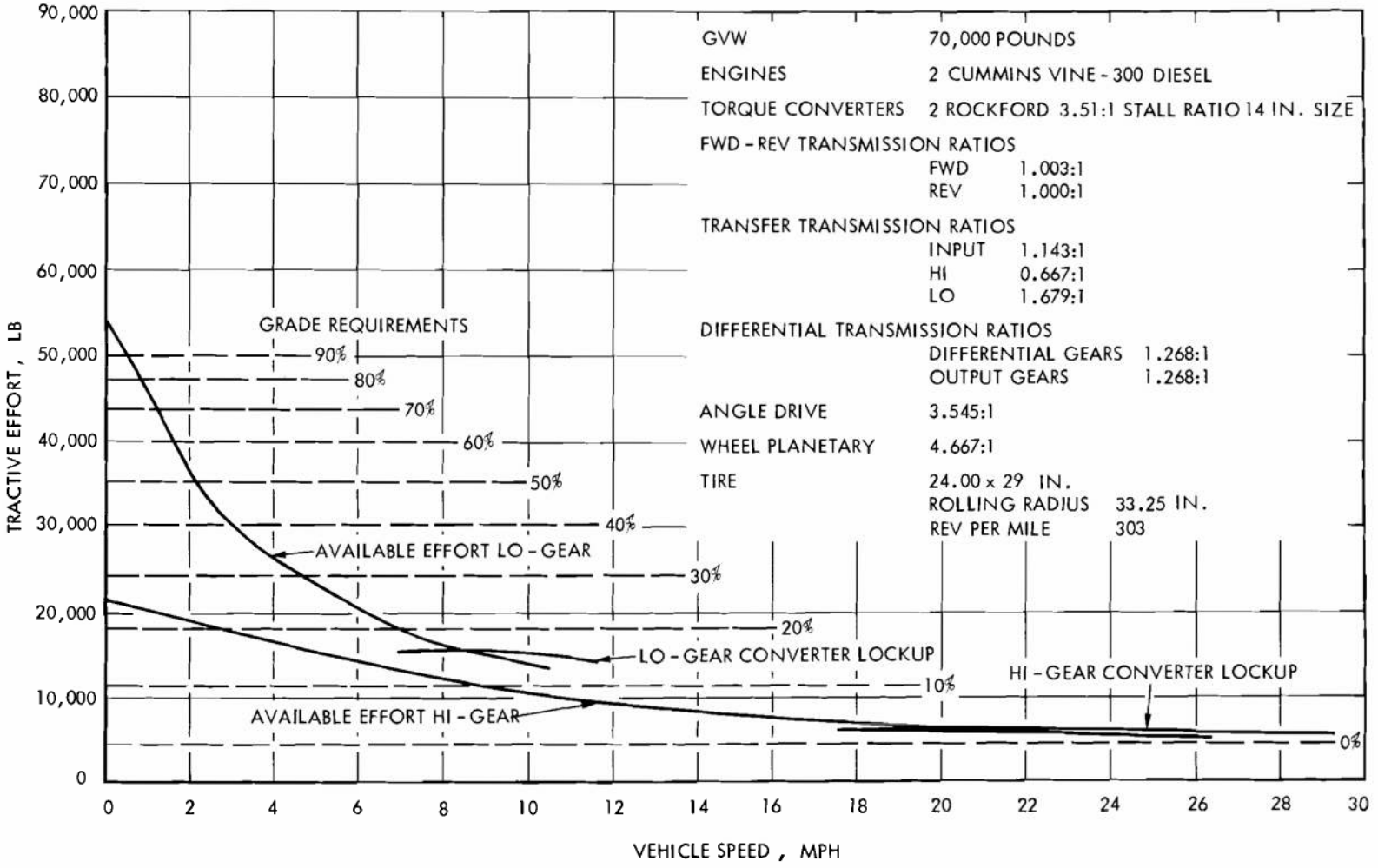
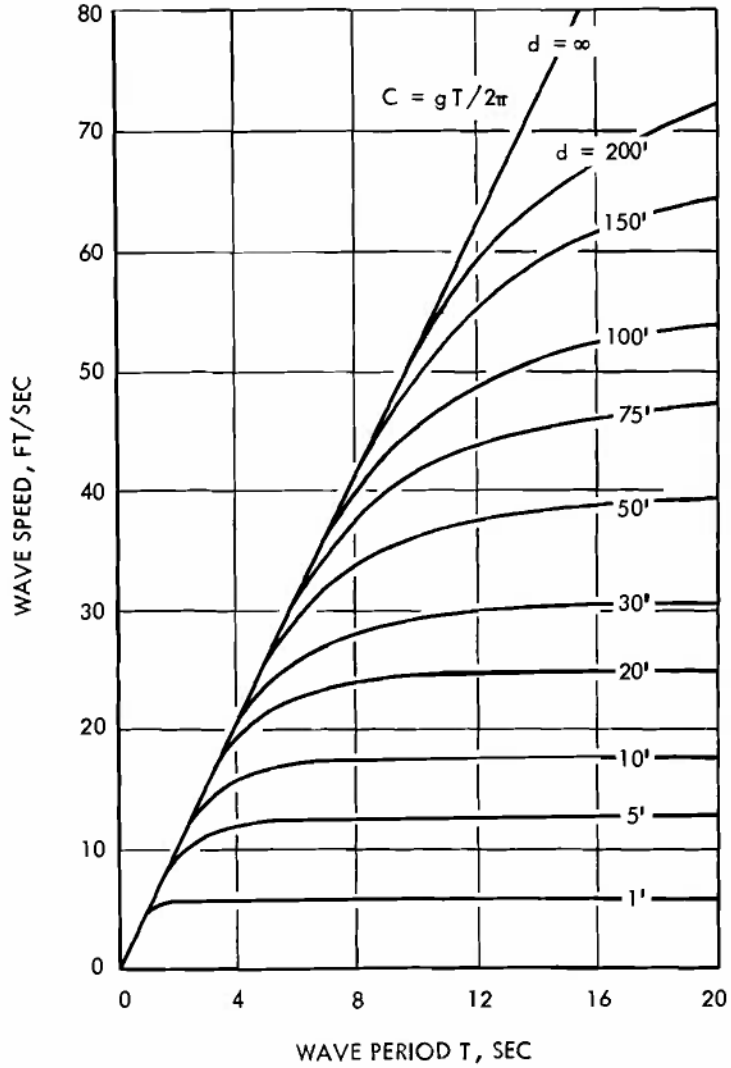


Figure 7-61. Predicted Land Performance of LARC XV



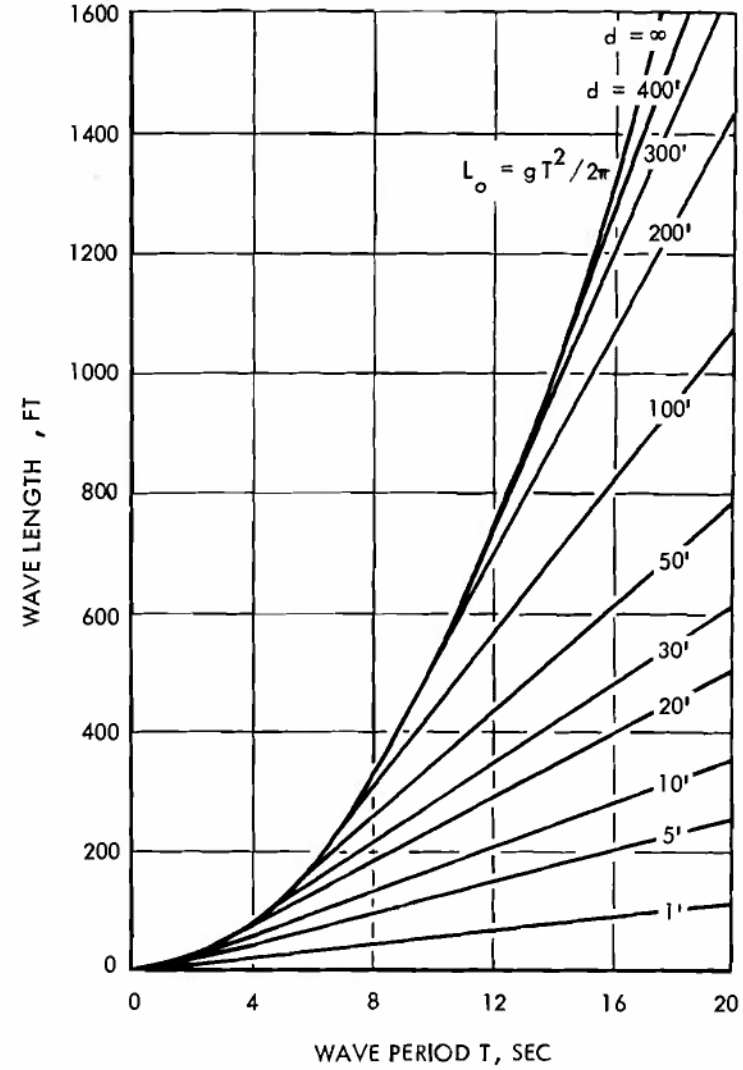
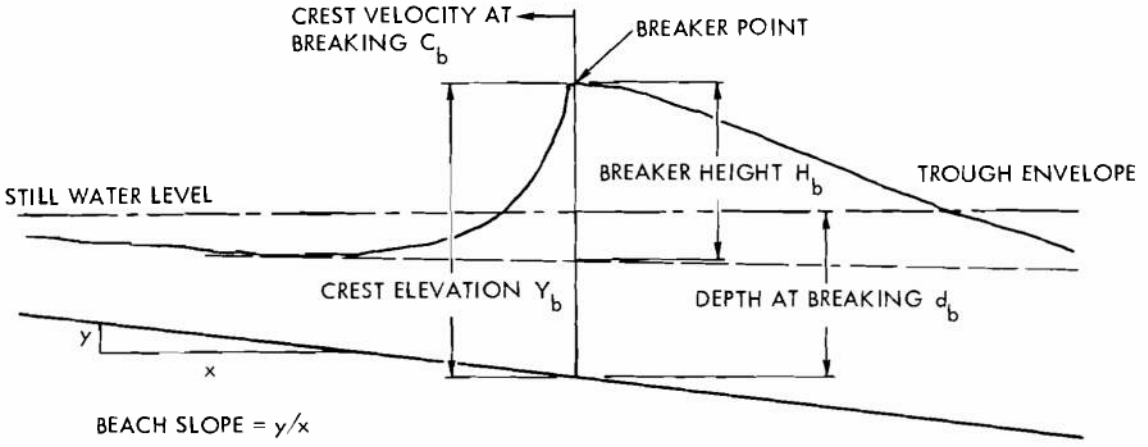


Figure 7-62. Relationships Between Wave Period and Wave Speed and Between Wave Length and Water Depth



H_o = DEEP WATER WAVE HEIGHT
T = DEEP WATER WAVE PERIOD

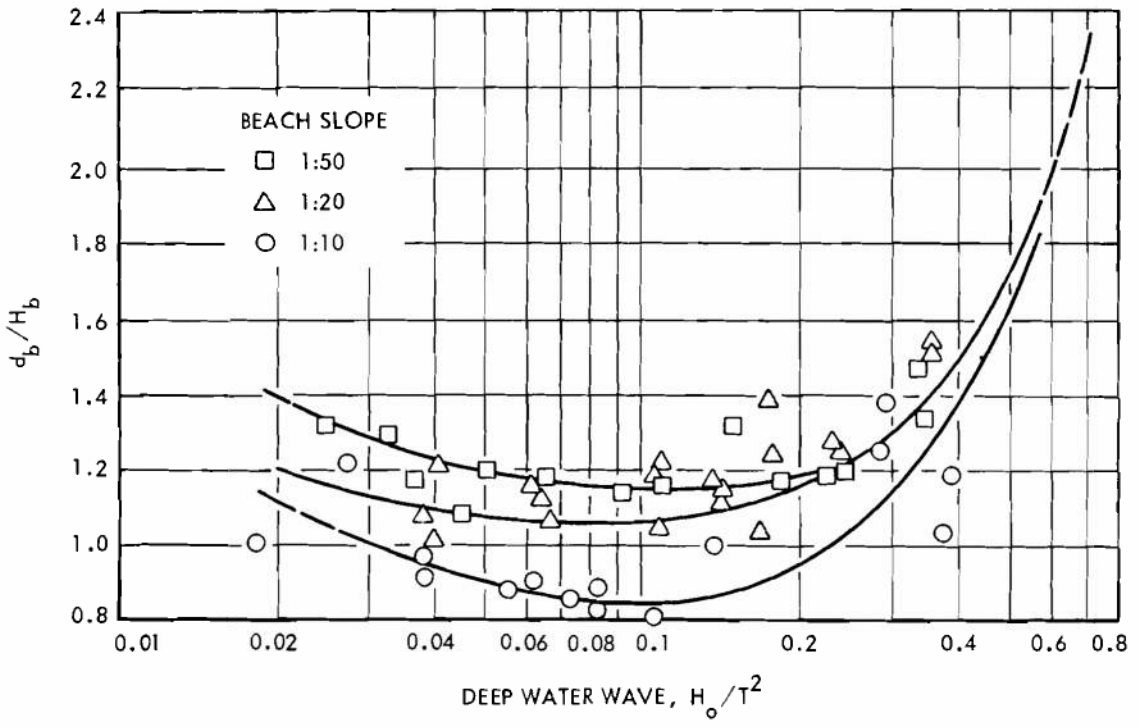


Figure 7-63. Breaker Height vs Water Depth

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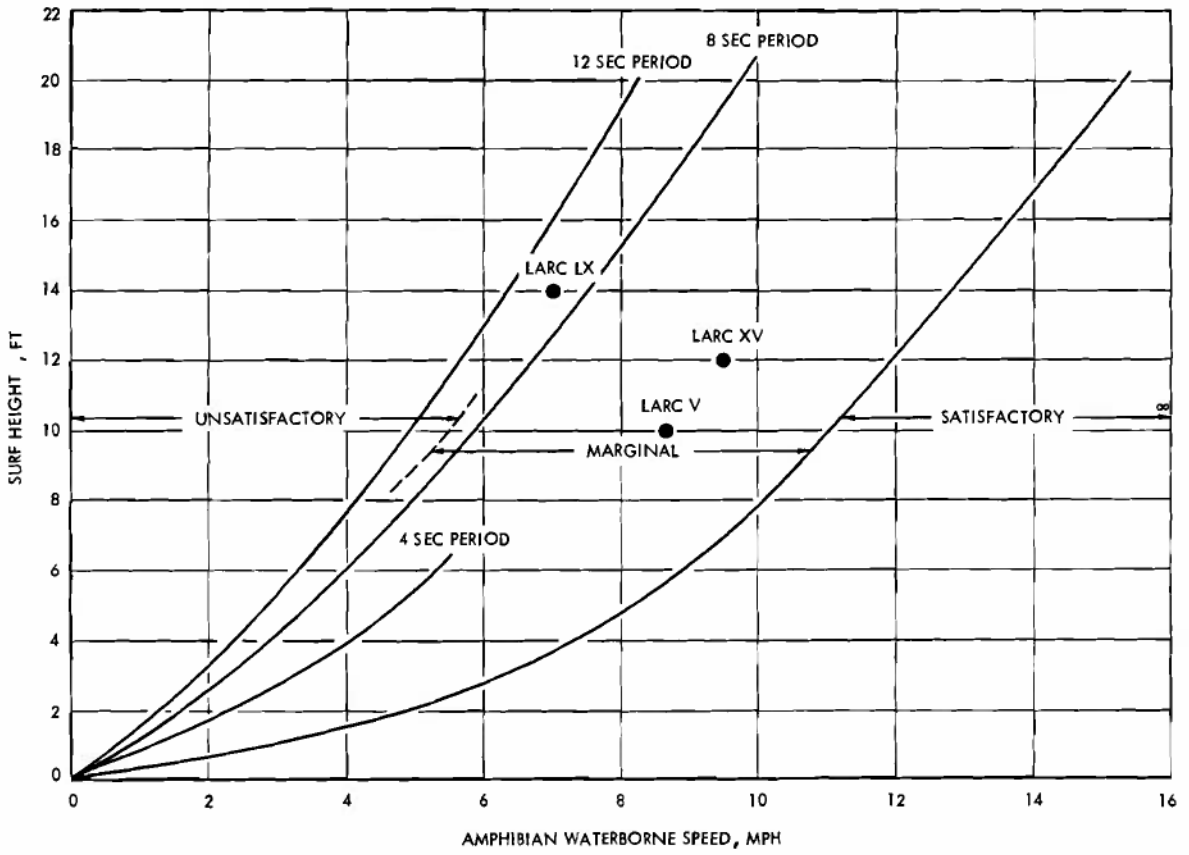

Figure 7-64. Surf Operation Diagram for Wheeled Amphibian

event that these Army and Navy tests do not provide enough information to the wheeled amphibian designer, a candidate engine can be tested with any desired duty cycle. The U. S. Army Tank-Automotive Command Propulsion Systems Laboratory at Warren, Michigan, has the facilities for such a test.

7-5.2.2 The Amphibian Environment

The environment in which the wheeled amphibian engine must operate imposes certain requirements on the selection of the engine. The first such requirement is the tolerance of the engine to salt water. An engine in an amphibian must be capable of withstanding the effects of being wet with salt water and of ingesting salt water or salt particles in the air intake. After an amphibian has been in service for some time, it would not be unusual for the hatches over the engines to leak in rough water and surf. This requires that the engine be waterproofed in accordance with the requirements referenced in par. 7-5.2. It should be noted with respect to the engine's electrical system that salt water is a much better conductor than fresh water.

The problem of salt water or salt particles in the intake air is much more serious than the problem of direct wetting if the engine is properly waterproofed. This is particularly important for gas turbine engines where compressor fouling and sulfidation are involved. Compressor fouling occurs when salt water droplets in the intake air impinge at high velocities on compressor blades and stators. The water scatters and is evaporated. The salt crystals adhere to the blade surfaces and to each other, thus distorting the airfoils and lowering component efficiency. Additional fuel must be provided to restore power, causing the engine to run hotter and closer to surge condition. The engine power may be restored simply by washing the compressor with fresh water and, accordingly, a gas turbine in a wheeled

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amphibian must be fitted with such a fresh water wash system (see par. 7-10.10).

In order to reduce the number of fresh water washings required and increase the life of the engine, the amount of salt water and salt particles ingested in the intake air must be minimized. Several types of separators have been developed, including mesh, inertial, and electrostatic types. These can be designed to remove particles of 5-micron diameter and larger with flow velocities between 10 and 75 ft/sec. The electrostatic type can be overloaded if the amount of salt in the air exceeds 10 parts per million by weight. The U. S. Naval Boiler and Turbine Laboratory has been developing separators for Naval vessels and should be contacted by the amphibian designer for the latest developments.

Sulfidation is a much more serious problem with respect to gas turbine engine life. At temperatures above 1,550°F the sulfur in the fuel combines with salt in the intake air to form a slag which is very corrosive to nozzle guide vanes and turbine blades fabricated from nickel base and cobalt base superalloys. Unprotected nickel base alloy blades that have been run in tests in a marine environment at temperatures above 1,550° F have failed in less than 200 hr. Metallic coatings may be used to overcome this corrosion problem. However, to date coatings have not been developed that will allow a time between overhaul equal to that of the same engine in a nonmarine environment.

The amphibian designer should be cautious in the choice of an automotive or aircraft gas turbine in an amphibian application unless the engine has been modified and tested for use in a marine environment. In no case should such an engine be the final selection until such modifications have been made and the engine subsequently tested to the satisfaction of all criteria.

Safety with respect to fire and explosion hazards is a major engine selection criterion. The hull of an amphibian is closed so that any fuel leakage from the engine or fuel system will collect in the bilge. If the flash point of the fuel is sufficiently low, the hull will fill with vapor in sufficient quantity to form an explosive mixture. Thus a gasoline engine should not be selected for a wheeled amphibian unless no suitable engine that burns Diesel oil is available. The design characteristics of a fuel system to avoid fire and explosion hazards are covered in par. 7-10.3.

7-5.2.3 Weight, Volume, and Cost Effectiveness

In the course of the preliminary and final design phases, the number of possible engines for a given design can be narrowed by use of the criteria given in pars. 7-5.2, 7-5.2.1, and 7-5.2.2. In many cases this will result in only one engine with suitable characteristics. This was the case with the selection of the Diesel engines for the production LARC V and LARC XV. The designer should note that multiple engine installations are more practical for a wheeled amphibian than for a conventional vehicle. This fact affects the number of engines that must be considered in designing an amphibian. In the event that two or more engines are available with suitable performance characteristics, the final selection should be made on a cost-effectiveness basis. This is not to imply that the lowest cost engine should be selected. Rather the engine which results in the lowest life cycle cost for the amphibian should be chosen. This requires the consideration of the engine as well as the drive train, fuel capacity, auxiliary systems, and interactions with the hull. In this way, it is possible to make a rational choice between engines with differing initial costs, weights, volume, and fuel consumption. This procedure may result in an increase in the design costs, especially if the engines have output characteristics different enough to require the design of different drive trains. However, the design costs of a wheeled amphibian are a very small percentage of the total life cycle cost. Thus a large increase in the design costs are justified, even if they result in a small percentage reduction in procurement or operational costs.

7-6 POWER TRAIN DESIGN

An extensive introduction to the subject of Army automotive power trains is presented in Ref. 63. The limited space available in this handbook makes it possible to present information only on the differences between wheeled amphibian power trains and those used on conventional Army wheeled vehicles.

7-6.1 GENERAL DISCUSSION

The function of the power train on a wheeled

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amphibian is the transmission of power from the engine to the wheels and water propulsor. The engine torque and rotational characteristics must also be modified by the power train to suit the wheels and water propulsor requirements.

A major design consideration in both the preliminary and final design involves the choice of standard military or commercial components, or the development of custom components. In the preliminary design phase this decision involves major components such as transmissions and transfer cases and, in the final design phase, minor components such as propeller shafts. In both the preliminary and final design phase the selection depends on considerations of performance, arrangement, weight, reliability, maintainability, and cost. The advantages of standard components with respect to reliability, maintainability, and cost are discussed in Chapter 2. However, requirements for performance, arrangements, or weight may prevent the use of standard components. Pars. 7-6.2 through 7-6.5 present the characteristics, criteria, and functions that are unique to wheeled amphibian power trains. This information may be used for the selection of the correct standard components or in the design of custom components.

7-6.2 CHARACTERISTICS AND CRITERIA

In order for a wheeled amphibian to operate successfully with maximum effectiveness, the power train must have certain characteristics, as discussed in the paragraphs which follow.

7-6.2.1 Necessary Power Train Characteristics

a. Flexibility in Power Distribution. A wheeled amphibian must be able to apply power to either the marine propulsor or wheels separately, or to both simultaneously. The ability to selectively power the marine propulsor or wheels is needed for efficiency when operating on land or water. This is most important in water operations since rotating the wheels wastes a great deal of power. The marine propulsor and the wheels must both be powered when the amphibian enters or exits from the water to maintain the necessary speed in order to reduce the danger of broaching in the surf or bogging down on a river bank.

b. Durability. In addition to the usual loads and shocks that the power train of a conventional wheeled military vehicle must withstand (see Ref. 63), the power train of a wheeled amphibian must withstand loads and shocks peculiar to its environment. In particular, in crossing the surf zone or approaching a river bank the wheels must be engaged to provide quick acceleration onto the beach or bank. If we assume a mechanical drive, the wheels will turn at some ratio of the propulsor speed. Contact with the beach or bank will result in high shaft and transmission torque due to the momentum change and the transfer of power to the more resistive medium. This condition is even more serious if a free turbine type gas turbine engine is used. In this case the energy change due to the sudden deceleration of the power turbine must be dissipated.

c. Controllability. When a wheeled amphibian approaches a beach through surf, the driver will be under considerable stress. As a result, the control of the power train must be as simple and foolproof as possible. In particular, there must be no chance that the wheel drive can be put in reverse. The resulting stop when the wheels make contact could cause the vehicle to broach or bog down.

7-6.2.2 Desirable Power Train Characteristics

A number of desirable characteristics are useful in a wheeled amphibian power train to enhance its effectiveness. The extent to which these desirable characteristics are included in a given power train design should be determined by a trade-off study which considers the entire vehicle. Increases in effectiveness must be traded off against any increases in the life cycle cost of the vehicle. Desirable characteristics for a wheeled amphibian power train include the following:

a. High Transmission Efficiency for Waterborne Propulsor. The marine propulsor will probably have a much larger power demand than the land propulsor. As a result, considerable savings in engine power and fuel consumption may be possible if the marine part of the power train has a high efficiency. In particular, the efficiency of a drive train with a torque converter can be increased from about 85 percent to above 95 percent by including a mechanical "lock-up" with the converter. The control of the mechanical lock-up can be either

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manual or automatic.

b. Independent Marine Propulsor and Wheel Speeds. When approaching a beach or river bank it is useful to be able to adjust the rotational speed of the marine propulsor and the wheels independently. This will reduce the landing shock in the drive train and reduce the chance of bogging down during the water-land transition. This has been accomplished in the LARC V and LARC XV by arranging the transmission so that the land drive can be placed in the high or low range without affecting the speed of the marine propulsor.

c. Simplicity in Automotive Transmission. Because of the high power installed in wheeled amphibians, the automotive transmission requires fewer gear ratios than comparable equipment in trucks. Accordingly, a less complex automotive transmission can be provided for an amphibian making it simpler to drive on land. For example, the LARC V and XV have only 2 forward speeds whereas a military truck may have 5 or more. However, if a suitable standard transmission is available it may be cost effective to accept its complexity instead of developing a simpler new unit.

d. Independent Control of Multiple Marine Propulsors. Large wheeled amphibians may be equipped with twin marine propulsors. In this case a significant gain in waterborne maneuverability can be obtained if the marine propulsors can produce thrust in opposite directions. This feature is most useful for maneuvering alongside a cargo ship and may reduce loading time.

7-6.2.3 Power Train Criteria

In general, the same criteria that apply to the selection or design of power trains for conventional wheeled military vehicles apply to wheeled amphibians. These criteria are covered in Ref. 63. There are, however, several criteria that are of particular importance to a wheeled amphibian and are similar to those that apply to the engine selection, as presented in pars. 7-5.2 through 7-5.2.3. These criteria, as they apply to wheeled amphibian power trains, are presented in pars. 7-6.2.3.1 through 7-6.2.3.3.

7-6.2.3.1 Power Ratings

The life of the power train components must be compatible with the requirements given in the QMR. Those components that supply power to the marine propulsor must be able to transmit the high power required for a high percentage of their life. This could be a serious problem if an automotive transmission were used to provide power to both the marine propulsor and the wheels. The low gear ratios in such transmissions may not have sufficient life for the marine propulsor requirements.

7-6.2.3.2 The Amphibian Environment

It is probable that the power train components will be located low in the amphibian hull and, as a result, will be periodically wetted with bilge water. Accordingly, the components must be waterproofed and made of corrosion resisting materials. As a minimum, the components should be protected with proper paint or coatings.

7-6.2.3.3. Weight, Volume, and Cost Effectiveness

The final selection or design of the power train must depend on obtaining the most cost-effective vehicle to meet the requirements. This involves the same considerations as govern the engine selection and are covered in par. 7-5.2.3.

7-6.3 THE MARINE POWER TRAIN

The function of the marine part of the power train is the transmission of power at a suitable rotational speed to the marine propulsor. The typical elements of the marine power train, with their functions or characteristics, as applied to wheeled amphibians, are considered in the paragraphs which follow.

7-6.3.1 Transfer Case

In a mechanical drive train, the transfer case receives power from the drive train and delivers it to the marine propulsor shaft. The transfer case may provide any needed change in rotative speed and displacement of the output shaft needed to suit arrangements. The transfer case may include a clutch to disengage the propeller for land operation. The transfer case must transmit the full power for long periods and must be designed for adequate life. It must also be designed to withstand the maximum torque

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that will result if the marine propulsor is suddenly stopped by floating debris.

7-6.3.2 Propulsion Motor

In a hydrostatic or electric drive train, a propulsion motor will supply power directly to the marine propulsor shaft. This motor serves the same purpose as the transfer case in the mechanical system and must satisfy the same criteria.

7-6.3.3 Propulsor Shaft

The propulsor shaft transmits the output torque from the transfer case or propulsion motor to the marine propulsor. The propulsor shaft may include a slip clutch or shear pin to limit the torque in the drive train if the propulsor is fouled by debris. Considerable savings in maintenance time may be realized if the propulsor shaft is arranged in a manner to permit rapid removal. This will allow the rapid changing of a damaged propeller or other associated components.

7-6.3.4 Bearings and Seals

The bearings and seals support the propulsor shaft and provide a seal where the shaft penetrates the hull. On small boats the bearings outside the hull are water lubricated. This type of bearing is not suitable for a wheeled amphibian since the marine propulsor may be run when out of the water. To save wear on all the shaft bearings, a shaft lock can be provided to keep the propulsor shaft from free-wheeling when the marine drive is declutched. Before doing this, it must be determined that serious wear will not occur on the marine clutch due to drag against the locked shaft.

7-6.3.5 Marine Propulsor

The marine propulsor converts engine power into useful thrust to propel the amphibian in water. Design of the marine propulsor is covered in pars. 7-7.1 through 7-7.6.4.

7-6.4 THE AUTOMOTIVE POWER TRAIN

The function of the automotive part of a wheeled amphibian drive train is the transmission of power from the engine to the wheels and the marine transfer case or drive motor. The automotive drive train modifies the rotational speed and torque as required for the wheels and provides reversing for the wheels and, possibly, for the marine propulsor. The types and typical elements of the automotive power train, with their functions or characteristics that apply especially to wheeled amphibians, are considered in the discussion which follows. Those functions and characteristics that apply to conventional wheeled vehicles as well as amphibians are discussed in Ref. 63.

7-6.4.1 Power Train Types

Three basic types of power trains can be used on a wheeled amphibian—mechanical, hydrostatic, and electric. Each type has certain advantages and disadvantages for use in a wheeled amphibian. These are presented in pars. 7-6.4.1.1 through 7-6.4.1.3. The selection of the power train type should be made on the basis of the characteristics and criteria presented in pars. 7-6.2 through 7-6.2.3.3.

7-6.4.1.1 Mechanical

In a mechanical power train there is a direct mechanical connection through gears and shafts between the engine, and the wheels and marine propulsor. Mechanical power trains have been used on all wheeled amphibians built to date as well as on the vast majority of all wheeled military vehicles. As a result, there exists a wide variety of standard components familiar to maintenance and operating personnel. The advantages that result from the use of standard components are presented in Chapter 2.

Further advantages of a mechanical drive include a high transmission efficiency and light weight relative to the other drive train types. High transmission efficiency is very important for the parts of the drive train that supply the marine propulsor since they must transmit high power for long periods. Improvements in the efficiency of the marine drive will thus appear directly as reductions in engine power and fuel consumption. If the amphibian has multiple engines, the power train should be arranged so that one engine alone can propel the amphibian in emergencies.

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The disadvantages of a mechanical drive train include a lack of flexibility in power distribution between the wheels and marine propulsor, and a lack of flexibility in arrangements. This latter factor is of importance in high performance wheeled amphibians which may be fitted with retractable wheels and propulsors.

7-6.4.1.2 Hydrostatic

In a hydrostatic power train, the power is transferred from the engine to the wheels and marine propulsor by the flow of hydraulic fluid under static pressure. The pressure and flow is supplied by a pump driven directly by the engine and converted to useful work by hydraulic motors connected directly to the wheels or marine propulsor. Hydrostatic drive trains have been used on small commercial wheeled vehicles and in experimental military vehicles. Research and development in this area have been carried out by the U. S. Army Tank-Automotive Command Propulsion Systems Laboratory at Warren, Michigan. It is of interest to note that a hydrostatic drive train was fitted as an experiment in one of the prototype LARC XV's in the early 1960's. Unfortunately a fire destroyed the vehicle before the test program was completed. The results at the time of the fire indicated that the system was practical.

The advantages of a hydrostatic drive train in a wheeled amphibian include great flexibility in power distribution and in physical arrangements. In a hydrostatic drive train, power can be transmitted to retractable wheels and marine propulsors without the use of complex shafts, gear trains, and universal joints. A hydrostatic drive train may also allow high engine efficiency to be obtained in land operation. The engine can be automatically controlled to run at its most efficient speed under all circumstances. Vehicle speed control is obtained by regulating the pump output. This may be a particular advantage in the case of gas turbine engines since their efficiency and life are improved if rapid speed changes are avoided.

The disadvantages of a hydrostatic drive train include lower transmission efficiency than a mechanical drive train, probability of higher weight, and fewer available standard components. These disadvantages are likely to be overcome by the rapidly advancing state-of-the-art. As a result, a hydrostatic drive train should be seriously considered for a wheeled amphibian if the number of vehicles to be built justifies the necessary engineering and design work.

7-6.4.1.3 Electric

Electric drive trains have been used in a wide variety of vehicles ranging from electric automobiles to railroad locomotives and ships. These applications have included experimental military vehicles and very large gas turbine powered earth movers. Research and development work has been carried out on electric drive trains by the U. S. Army Tank-Automotive Command Propulsion System Laboratory at Warren, Michigan, and the U. S. Army Mobility Equipment Research and Development Center at Fort Belvoir, Virginia.

The advantages of an electric drive train are similar to those of a hydrostatic drive train and include flexibility in power distribution, arrangements, and control for maximum engine efficiency and life.

The disadvantages of an electric drive train are also similar to those of the hydrostatic drive train and include relatively low efficiency, high weight, and a lack of available standard components. If the number of vehicles under consideration justifies it, the engineering and design time required should be devoted to the serious study of an electric drive train for a wheeled amphibian.

7-6.4.2 Power Train Components

7-6.4.2.1 Torque Converter

A torque converter is required in a mechanical automotive drive train of a wheeled amphibian powered with a reciprocating internal combustion engine or single shaft gas turbine to provide the necessary speed-torque characteristics. If the torque converter also transmits power for the marine propulsor, it should be equipped with a mechanical lock-up feature to improve the marine power train efficiency. The lock-up should be controlled so that it occurs only in the marine mode. In a wheeled amphibian, when power is supplied to the wheels or wheels and marine propulsor, torque converter lock-up is not required or desirable.

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7-6.4.2.2 Transmissions and Transfer Cases

In a mechanical automotive drive train, the transmission and transfer case provide the required changes in rotative speed, direction, and displacement of power output shafts. In the LARC V and LARC XV, two separate transmissions are provided—one supplies forward, neutral, and reverse to the wheels and the marine propulsor; and the other provides speed ratios to the wheels only. In this way the required flexibility for beaching is obtained with a minimum number of components. There are a number of transmissions available for conventional wheeled vehicles that may be considered for use in a wheeled amphibian. In general these combine a torque converter, forward, neutral, and reverse, and a number of gear ratios into one unit. If such a transmission supplies power to the wheels only with a separate forward, neutral, and reverse transmission for the marine propulsor; no special problem occurs. This was the arrangement used on the LVH-X2 high-speed wheeled amphibian. However, if such a transmission supplies both the wheels and marine propulsor, it must be designed for life at the high marine power levels and peak torques that may occur from a jammed marine propulsor. If a gas turbine engine is used, the peak torques that can be developed on a cold day must also be considered.

7-6.4.2.3 Differentials, Drive Shafts, and Universal Joints

These components serve the same functions on a wheeled amphibian as on a conventioanl wheeled vehicle. However, if the amphibian has a rigid suspension system, unusual loads are applied to these components. The great torsional stiffness of an amphibian hull combined with a rigid suspension results in the certainty that in rough terrain it will occasionally be suspended on diagonally opposite wheels, as illustrated in Fig. 7-65. The amphibian must be propelled when suspended in this manner. The simplest and most direct way to accomplish this is to drive the wheels on each side with a common shaft, shown in Fig. 7-65. A single differential is provided between the drives on each side of the amphibian. The conventional truck arrangement with limited slip differentials between each pair of wheels will not provide as good mobility since the limited slip differentials can only support about a 3 to 1 torque difference. If the arrangement shown in Fig. 7-65 is used; the differential, shafts, gears, and universal joints must be designed to take the high torque that can occur in the suspended condition. These torques are roughly twice the value that would occur in the drive train of conventional wheeled vehicles of similar weight, power, and running gear arrangement. In some arrangements the drive shafts may become long enough that torsional vibrations are a problem. Stiffer shafts or vibration dampers may then be required.

7-6.4.2.4 Pumps, Motors, and Generators

These components are used in hydrostatic and electric drive trains to take the place of the mechanical components listed in pars. 7-6.4.2.1 through 7-6.4.2.3. The design, selection, and arrangement of these components for a wheeled amphibian drive train are similar to those for a

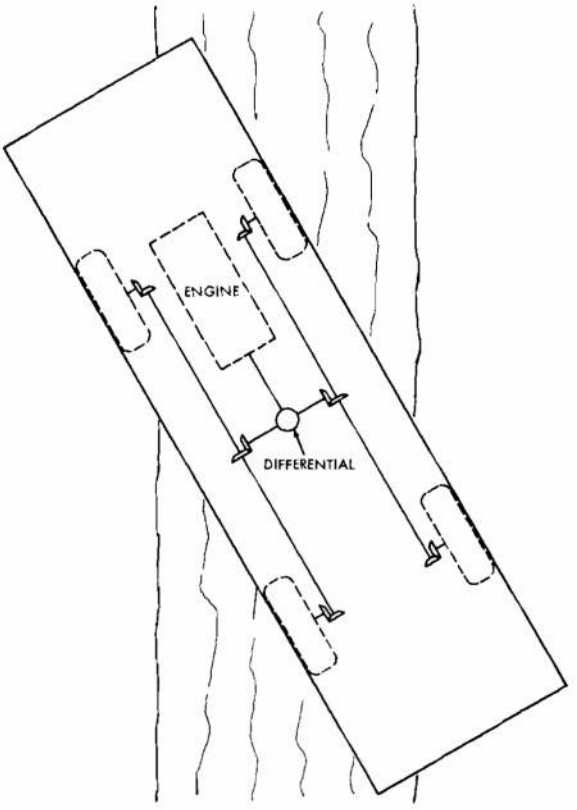

Figure 7-65. LARC-type Land Power Train

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conventional wheeled vehicle as covered in Ref. 63. It should be remembered that the hull of a wheeled amphibian is completely enclosed so that heat buildup could be a problem. As a result, a cooling system for the drive train may be necessary.

7-6.5 BRAKES

A discussion of the theory of retardation, types of brakes and brake mechanisms, and systems as applied to conventional wheeled vehicles is presented in Ref. 63. In general, the same brake mechanisms and systems can be applied to wheeled amphibians. There are, however, some special considerations imposed by the amphibian environment.

The brakes used on the WW II DUKW were of the internal-expanding type mounted on the wheel. When the vehicle was driven into the water, the rapid cooling of the brakes that were hot from land operation created a partial vacuum in the brake housing. This combined with the hydrostatic pressure would fill the brake housings with water despite all attempts to seal them. The resulting corrosion and damage caused by sand carried in with the water caused failures and a tremendous amount of maintenance work.

As a result of this experience, all production wheeled amphibians since then have been fitted with brakes on the drive shafts inside the hull. These brakes have been of the disk type. The major problem with locating the brakes in the hull is dissipating the heat generated and maintaining the brake temperature at an acceptable level. This problem can be solved by providing an adequate air flow through the hull during land operations.

As an example of the amounts of energy that must be dissipated, consider the case of stopping an amphibian on a 20 percent grade from a speed of 20 mph with a deceleration of ½ g. The energy dissipated is given by

$$E = \frac{(Mb - F)V_o^2}{2b} \qquad (7\text{-}70)$$

where

E = total energy, ft-lb
M = mass of vehicle, slugs
b = deceleration, ft/sec^2 (consider positive)
V_o = initial speed, ft/sec
F = external forces on vehicle, lb (rolling resistance—grade effect)

If the gross weight is 30,000 lb and the rolling resistance is 40 lb/ton the total energy dissipated is 715,000 ft-lb or 920 BTU. This energy is dissipated by the brakes in the time it takes to stop the vehicle which is 1.82 sec. As a result, the temperature of the brakes rises which causes a transfer of the energy to the surrounding air. The breaking forces and the rate at which the brakes must dissipate energy must be determined on the basis of the performance requirements given in the QMR.

In addition to brakes, some wheeled vehicles have been fitted with hydraulic retarders to dissipate energy. These retarders dissipate mechanical energy in hydraulic fluid in the form of heat which is, in turn, rejected by the fluid in a cooler. Hydraulic retarders are often combined with the torque converter. A retarder has the advantage of reducing wear on the brakes. A disadvantage is the need to include additional equipment (i.e., the retarder and oil cooler) in the vehicle. This is a serious problem in an amphibian where space and weight are at a premium.

7-7 MARINE PROPULSOR DESIGN

7-7.1 GENERAL DISCUSSION

The resistance of a ship to motion through water is overcome by an equal and opposite propelling force. The energy for propulsion in an amphibian is supplied by an internal combustion engine, either a Diesel or gas turbine. This energy is transmitted to the amphibian as a propulsive force by the marine propulsor. This chapter discusses: (1) the criteria upon which the selection of the type of propulsor is made, (2) the advantages of various types of propulsors, (3) the basic theory of marine propellers, (4) the design of screw propellers, and (5) the governing laws and application of model tests.

7-7.2 CRITERIA FOR PROPULSION UNITS

A large number of factors must be considered in the selection of the type of marine propulsion system for an amphibian. Once the type of unit has been selected, these same factors will enter into the details of the particular design. The

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relative importance of each factor will depend on the particular requirements specified in the QMR. Factors to be considered include, but are not limited to: maintenance, simplicity, durability, vulnerability, reliability, availability, efficiency, weight, arrangements, effectiveness, and economy. These factors are not independent. For example, ease-of-maintenance, reliability, and economy are all associated with simplicity. Also, the factors may not always be applied to the propulsion unit alone but must consider the amphibian and its propulsor as a system. These factors are discussed in par. 5-1.3.

7-7.3 PROPELLER TYPES

The selection of the marine propulsor type for an amphibian will be affected by special considerations such as low speed maneuverability, and general criteria such as cost and dependability. No particular type will exhibit all of the desired qualities. The designer must consider the trade-offs that result from conflicting requirements. For example, momentum theory shows that efficiency increases with propeller diameter whereas the shallow draft requirements may favor the selection of a small propeller which can be protected from damage while the amphibian is passing through the surf. Some alternative solution may satisfy both objectives (shallow draft and high efficiency), but with penalties in terms of added complexity or cost. Two small propellers may be just as efficient as one large propeller and can have an added premium in maneuverability. The propellers on the high-speed amphibian LVW are supported by a plate which retracts into the hull so that the propellers are less vulnerable to damage in the landing configuration. Contra-rotating propellers could be used to achieve relatively high efficiency with small diameter. Kort nozzles (see par. 7-7.3.2) have been installed on many existing amphibians because they increase the effective area of a propeller and affort a good deal of protection.

The type, size, location, and special features of the marine propulsor can all affect the basic hull geometry and arrangements of the amphibian and should be selected in the early stages of the design to assure compatibility between the hull and propeller. This section presents various types of propellers which may be suitable for amphibians. The advantages and shortcomings of each type will be discussed.

7-7.3.1 Screw Propeller in Tunnel

The screw propeller is the most common marine propulsor. It is a relatively efficient thrust-producing mechanism when properly designed and installed on a suitable hull. Open water efficiencies on the order of 80 percent of ideal efficiency can be realized and propulsive coefficients as high as 0.70 are common for conventional ships. A great deal of series data has been collected, and design procedures and charts have been developed to aid the designer in selecting the optimum propeller characteristics for standard type screws. A design method and some diagrams are presented in par. 7-7.5. Thus, in many cases, a suitable screw may be selected with a minimum of computation and no development costs. In addition, the screw may be selected so that it is an off-the-shelf item; hence actual hardware costs are the smallest possible.

Most recent amphibian designs have placed the screw propeller in a tunnel. Fig. 7-66 shows a scale model of the LARC V (note that the propeller here is enclosed in a shroud). The incorporation of a tunnel in the hull is predicated by the requirement for ground clearance when the vehicle is on land. The propeller is well protected from damage from grounding or debris. However, there are disadvantages which must be accepted in such a design. Valuable buoyancy is lost in way of the tunnel and must be recovered by a subsequent increase in draft, beam, or length. The inflow to the propeller is highly disturbed and nonuniform, and the thrust duduction (see par. 7-7.4.4) too may be large. Hence, the propulsive efficiency of this type of propeller-hull combination will suffer. Model test results of the LARC V, Ref. 11, indicate that the propulsive efficiency may be lower than 0.35. In addition, the bare hull drag of the hull is increased by separation in the flow about the tunnel (see par. 7-1.4).

Future developmental work in the form of model tests should reveal areas of improvement in the design of tunnels and propeller-hull-interactions so that the drag and efficiency of this type of configuration would be less objectionable. It is not clear whether the

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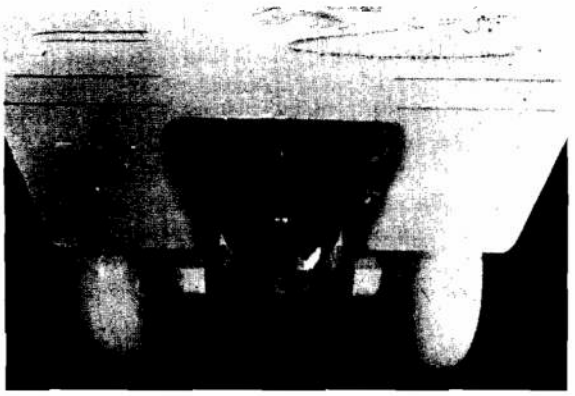
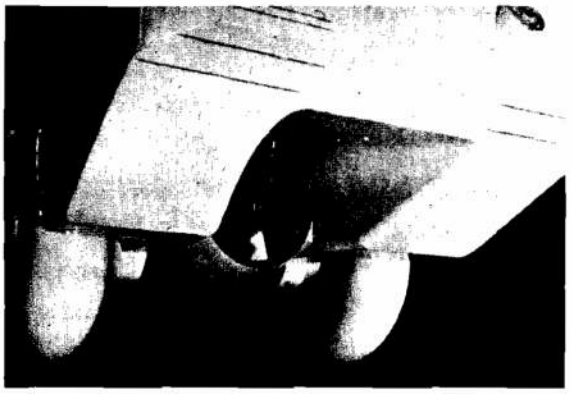


(A)



(B)

Figure 7-66. Two Views of a Model LARC V

improvements would justify the necessary costs. However, this is an area in which significant gains may be realized.

7-7.3.2 Kort Nozzles

A Kort nozzle propulsor is simply a screw propeller enclosed in a shroud. Nozzles are found on most of the recent amphibian designs including the LARC V and LARC XV. Advantages of nozzles include increased thrust or efficiency, decreased cavitation and vibration, and protection to the propeller. These advantages may not all be achieved simultaneously, however, and the design of a particular nozzle-propeller combination will be directed to exploit one or more of these features.

The increase in thrust or efficiency of a shrouded propeller may be explained as follows: A close-fitting shroud prevents the normal contraction in the slipstream behind the propeller so that the velocity here is less than with an open propeller, hence less kinetic energy is carried off in the propeller race and efficiency is thereby increased. The suppression of the race contraction amounts to a virtual increase in the diameter of the screw. The ideal efficiency of a shrouded propeller can be found if certain assumptions are made about the area of the slipstream far downstream from the propeller disc. Ref. 67 presents a table of gain in ideal efficiency as a function of the loading coefficient where the area of the slipstream is equal to the propeller disc area. These results are reproduced in Table 7-34.

The highest and lowest load coefficients are typical for towboats when towing a barge train or large merchant ships, respectively. An amphibian propeller will normally be moderately loaded with a coefficient somewhere between these two extremes.

In practice, the efficiency gains indicated above will not be attained. First, any added resistance of the shroud should be charged to the propulsion system (actually, a properly designed Kort nozzle will augment the propeller by producing thrust). Second, the propeller diameter must be reduced on the amphibian to fit the shroud and yet maintain the same road clearance. And third, the close proximity to the hull may decrease the shroud's effectiveness. Nevertheless, a Kort nozzle propulsion system should give some improvement in performance over open propellers for amphibians.

Two more desirable qualities of shrouded propellers should be mentioned. First, the propeller naturally operates at higher rotative speeds in a shroud (unless it is designed to prevent cavitation, in which case the nozzle-propeller combination is commonly called a pumpjet). This effect, when combined with the higher speeds of the smaller diameter propeller (dictated by the clearance criteria), will result in weight savings in terms of engines, transmissions, shafting, and in the propeller itself. Second, the bollard pull or towline thrust of a shrouded propeller is higher than for open propellers. Model tests of the utility landing craft, LCU class, (Ref. 68) show that the addition of Kort nozzles increased the bollard pull by about 50 percent. At the same time, however, reverse thrust may be degraded unless

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TABLE 7-34 GAIN IN IDEAL EFFICIENCY FOR SHROUDED PROPELLERS

Load Coefficient $CT = \frac{T}{\frac{\rho}{2}\left(V_a^2 A\right)}$	Efficiency Gain in Percent of η_i over unshrouded propeller
0.60	1.0
1.00	2.0
2.00	4.5
4.00	7.8
6.00	10.0
8.00	12.0
10.00	13.7

C_T = loading coefficient, nd
T = thrust, lb
ρ = mass density, slug/ft^2
V_a = advance speed. ft/sec
A = propeller disc area, ft^2
η_i = ideal efficiency defined by momentum theory in par. 7-7.4.1.

special attention is given to this aspect in the shroud design.

Series data for the design of Kort nozzle propulsion systems are not so prevalent as for open screws. Van Manen has published data (Ref. 69), some of which is reproduced in par. 7-7.5. A number of theoretical methods have been developed for shroud design; see Refs. 70 and 71. The design of a Kort nozzle should be only slightly more difficult than an open screw. More data may be available for future nozzle designs.

The disadvantages of a shrouded propeller are generally the same as for open propellers. It is therefore reasonable to suggest that Kort nozzles be considered for all future amphibians with screw propellers in view of the advantages they offer.

7-7.3.3 Controllable-reversible Pitch Propellers

Controllable pitch screws resemble conventional propellers, but mechanical linkages in the hub allow the pitch of the blades to be altered without interrupting rotation of the propeller. Thus the pitch can be adjusted to improve the performance over a wide range of operating conditions such as would be encountered by a tug in the towing and free running conditions. In addition, the blades may be rotated far enough so that the pitch is reversed to give astern thrust without reversing the engines or resorting to reversing transmissions. If twin propellers are installed, steering can be effected by controlling their pitch differentially to vary the thrust between the port and starboard screws. The disadvantages of controllable pitch propellers lie in their increased complexity and accompanying costs. Also, the efficiency at the design point should be slightly lower than for a fixed pitch propeller because a larger hub is required.

It has been suggested that controllable pitch propellers be considered for application on high-speed amphibians where two critical operating points exist. The propeller would normally be designed for the crafts' high-speed operation. But in this case such a propeller may not produce enough thrust at low speed to cross the hump, a characteristic high drag region which planing boats display in transition from the low-speed displacement mode to the high-speed planing mode of operation. The thrust at the hump speed could be increased by about 15 percent for a typical case using a controllable pitch propeller (Ref. 72). This could provide the thrust margin necessary to cross the hump, which seems to be an attractive alternative to either increasing the installed horsepower or designing the propeller with the hump speed as the design point.

Controllable-reversible pitch propellers should be considered for amphibians only if the operating conditions vary widely so that high efficiency is required at more than one operating point, or, if their application will eliminate a transmission which would otherwise be needed for reverse power. Some series test data for open water performance of controllable pitch propellers are presented in Ref. 73.

7-7.3.4 Contra-rotating Propellers

A set of contra-rotating (CR) propellers consists of two axially spaced screws on concentric shafts which rotate in opposite directions. They are more efficient than a single propeller because less energy is lost to rotational flow in the slipstream (rotational velocities are not considered in the simple momentum theory presented in par. 7-7.4.1). Also, for a given disc area the loading on each propeller in a CR set is half of that for a single propeller. CR propellers are widely used on torpedoes because they are

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designed to operate with the torque balanced so that there is no rolling moment on the torpedo. CR propellers have also been applied to VTOL aircraft in conjunction with annular wings (Kort nozzles).

The disadvantages of the CR propeller are greater mechanical complexity and more difficult design procedures. There are interactions between the two propellers—the aft propeller operates in the wake of the forward propeller whose inflow is, in turn, affected by the aft propeller. A design method is available, however, which is based on Lerbs' Propeller Theory, Ref. 74.

The contra-rotating propeller may be an attractive propulsor for amphibians where the clearance criteria impose severe limitations on the propeller diameter, with resulting high propeller loading.

7-7.3.5 Vertical Axis Propellers

Unlike the preceding propeller types, vertical axis propellers are completely unrelated to the screw propulsor. These propellers consist of a number of spade-like blades projecting into the water from a circular disc set flush with the bottom of the vessel. The disc rotates about a vertical or near vertical axis. The blades, which are spaced evenly about the periphery of the disc, rotate about their own axes and this rotation is controlled to give thrust force in any desired direction in the plane of the disc. The principles of operation of two vertical axis propellers, the Kirsten-Boeing and Voith-Schneider types, are given in Ref. 67.

Two vertical axis propellers located either fore and aft or port and starboard would provide complete maneuverability in view of their ability to provide thrust and/or moment in any direction. If the blades are permitted to extend below the baseline to get good flow, the vertical axis propellers can achieve high propulsion efficiencies, about as good as for an open screw. Openwater efficiencies as high as $\eta_o = 0.66$ have been measured, Ref. 75. However, these propellers would be extremely vulnerable to damage. Large cutouts in the hull are necessary to bring the blades above the baseline which will compromise their performance considerably. Model test results of the research vessel T-AGOR, Ref. 76, show that vertical axis propellers are very sensitive to changes in the hull lines with respect to wake fraction and thrust deduction.

It does not seem likely that vertical axis propellers will be used on amphibians in spite of the advantages they might afford in terms of maneuverability. The large cutouts that would be required for adequate protection would seriously compromise buoyancy and problems with arrangements might be foreseen. In any case, a great deal of model testing would be required to develop a good relationship between the hull and propulsor.

7-7.3.6 Vertical Shaft, Right-angle Drives

Right angle drive units derive their name from the fact that the propeller can be rotated about the vertical shaft axis which is perpendicular to the propeller rotation axis. Thus the propeller thrust may be directed in any direction in the horizontal plane. The propeller may be open or in a Kort nozzle. The propeller may be designed to retract by pivoting the vertical shaft about a horizontal axis. Recent amphibians with vertical shaft outboard drives are the MOFAB and LVW-X3, Refs. 77 and 78. These vehicles are characterized by the absence of any tunnel in the hull. This results in decreased drag and better propulsive efficiency than for comparable amphibians with conventional drives with the propeller in a tunnel.

The main drawback of the vertical shaft, right-angle drive is its extreme complexity and cost. Also, the propeller, which operates below the baseline, is rather vulnerable and must be partially retracted in the surf for protection in which case the performance is seriously compromised.

7-7.3.7 Water Jets

Water jet propulsors consist of an inlet, pump, and jet. Thrust is developed by the change in momentum between water entering the inlet and leaving the jet. The inlet may be a scoop type or flush with the hull. The pump can be centrifugal, mixed flow, or axial-flow depending on the specific pump speed. The jet can be above or below the waterline and can be controllable to provide excellent maneuverability. A most desirable feature of water jets is the fact that all of the machinery is contained within the hull so that shallow water

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operations pose no hazard to the propulsor.

Disadvantages of water jets include relatively poor efficiency, high cost, and weight and space penalities. Some of these disadvantages may not be prohibitive if water jets are compared with the alternative of a propeller in a tunnel. The low efficiency of a water jet is acceptable if the hull efficiency and drag of such an amphibian combine so as to require the same shaft horsepower as a hull with a tunnel and its characteristic high drag and low hull efficiency. A large percentage of the weight associated with water jets is due to the water entrained in the system. This may be considered as lost buoyancy and may be no worse than the loss in buoyancy due to a large tunnel cutout in the hull. Similarly, the internal space devoted to the water jet may be of the same order as taken by a large tunnel. Refs. 2, 5, 10, 79, and 80 give data for the design of water jets and their inlets.

7-7.4 Introduction to Theory of Propellers

Before any attempt can be made by the designer to design a propulsor or even select an "off-the-shelf" propeller, he must have an understanding of the basic principles which govern their performance. The presentation which follows is only of an introductory nature. However, it is felt that enough information is contained in this text to allow the designer to select a screw propeller from design charts derived from screw series model tests. If it is decided—in the preliminary design stage—that a detailed design will be made or if another type of propulsor is chosen, the designer is directed to the list of references. In cases where a detailed propeller design will be made, the design charts can still be used to make preliminary propulsion estimates.

7-7.4.1 Momentum Theory

Simple momentum theory was developed by Rankine (1865) and improved by R. E. Froude (1883). It is based on the principle that propellers derive thrust by accelerating the fluid in which they operate. The magnitude of the force is governed by Newton's first law of motion which may be expressed

$$F = ma = m\left(\frac{dv}{dt}\right), \text{ lb} \qquad (7\text{-}71)$$

where

F = force, lb
m = mass, slug
dv/dt = acceleration or time rate of change of the velocity, ft/sec^2

For the special case of steady flow through a propeller this equation may be written

$$T = \dot{m}\ (V_1 - V_a), \text{ lb} \qquad (7\text{-}72)$$

where

T = thrust produced by the propeller, lb
$\dot{m}$ = mass rate of flow through the propeller disc, slug/sec
V_1-V_a = ultimate change in axial velocity of fluid passing through the propeller, where V_a is the initial or upstream velocity and V_1 the final or downstream velocity, ft/sec

We can say then that the thrust is equal to the change in momentum per unit time or the rate change in momentum of the fluid.

The propeller in the simple momentum theory is assumed to be an actuator disc which is capable of imparting an axial change in momentum to the fluid. It is assumed that the velocity imparted to the fluid is uniformly distributed over the disc and that friction is negligible (inviscid flow). The flow is shown in Fig. 7-67 where V_a is the uniform free stream flow equal to the speed of advance of the propeller. V_1 is the velocity in the stream tube far downstream. $V_1 = V_a + u$ so that u is the change in axial velocity imparted by the propeller. The cross-sectional areas of the tube far upstream, at the propeller disc, and far downstream are given by a_1, A, and a_2, respectively.

From the principle of conservation of mass we can write, for the mass rate of flow in through the propeller disc

$$\begin{aligned} m &= \rho V_a a_1 = \rho(V_a + u')\, A \\ &= \rho(V_a + u)a_2, \text{ slug/sec} \end{aligned} \qquad (7\text{-}73)$$

where

A = disc area, ft^2
ρ = mass density of the fluid, slug/ft^3
(V_a+u') = flow velocity through the plane of the propeller, ft/sec

Eq. 7-72 can be rewritten using the above relation to get

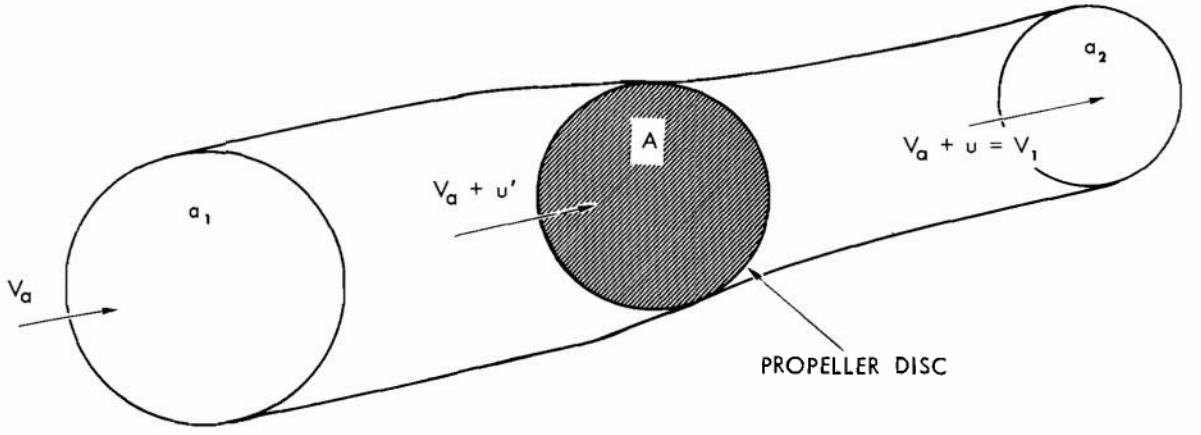

Figure 7-67. Principle of Actuator Disc Propeller

$$T = \rho(V_a + u')A(V_a - V_1) = \rho A(V_a + u')u, \text{ lb} \quad (7\text{-}74)$$

The thrust may also be equated to the change in pressure Δp across the propeller disc times the disc area

$$T = \Delta pA, \text{ lb} \quad (7\text{-}75)$$

The change in pressure is equal to the change in velocity head (dynamic pressure) far upstream and far downstream

$$\Delta p = \tfrac{1}{2}\rho[(V_a + u)^2 - V_a^2] = \rho\left(V_a + \frac{u}{2}\right)u, \text{ lb/ft}^2 \quad (7\text{-}76)$$

Thus,

$$T = \rho A\left(V_a + \frac{u}{2}\right)u, \text{ lb} \quad (7\text{-}77)$$

Comparing Eqs. 7-74 and 7-77, we note that

$$u' = \frac{u}{2} \quad (7\text{-}78)$$

This relation shows that one-half of the ultimate velocity increase imparted to the fluid in the stream tube is imparted ahead of the propeller. Substituting this relation in Eq. 7-73 shows that the area a_2 must be smaller than the disc area A. Experimental evidence confirms this contraction in the propeller race predicted by momentum theory.

Eq. 7-77 may be rewritten in nondimensional form

$$C_T = (2 + s')s' \quad (7\text{-}79)$$

where

load coefficient $C_T = \dfrac{T}{\tfrac{1}{2}\rho V_a^2 A}$, nd

slip ratio $s' = u/V_a$, nd

conversely,

$$s' = \sqrt{C_T + 1} - 1 \quad (7\text{-}80)$$

The efficiency of this ideal actuator disc propelller can be calculated by considering the ratio of the rate of useful work P_{out} to the rate of work done on the fluid P_{in}. The rate of useful work is simply

$$P_{out} = TV_a$$

The power absorbed by the fluid is given by

$$P_{in} = \Delta p\left(V_a + \frac{u}{2}\right)A$$

Thus, the ideal efficiency η_i may be expressed

$$\eta_i = \frac{P_{out}}{P_{in}} = \frac{TV_a}{(V_a + u/2)A\Delta p} = \frac{\Delta pAV_a}{(V_a + u/2)A\Delta p}$$

$$= \frac{V_a}{V_a + u/2} = \frac{2}{2 + s'} = \frac{2}{1 + \sqrt{C_T + 1}} \quad (7\text{-}81)$$

Fig. 7-68 shows a plot of ideal efficiency η_i versus load coefficient C_T.

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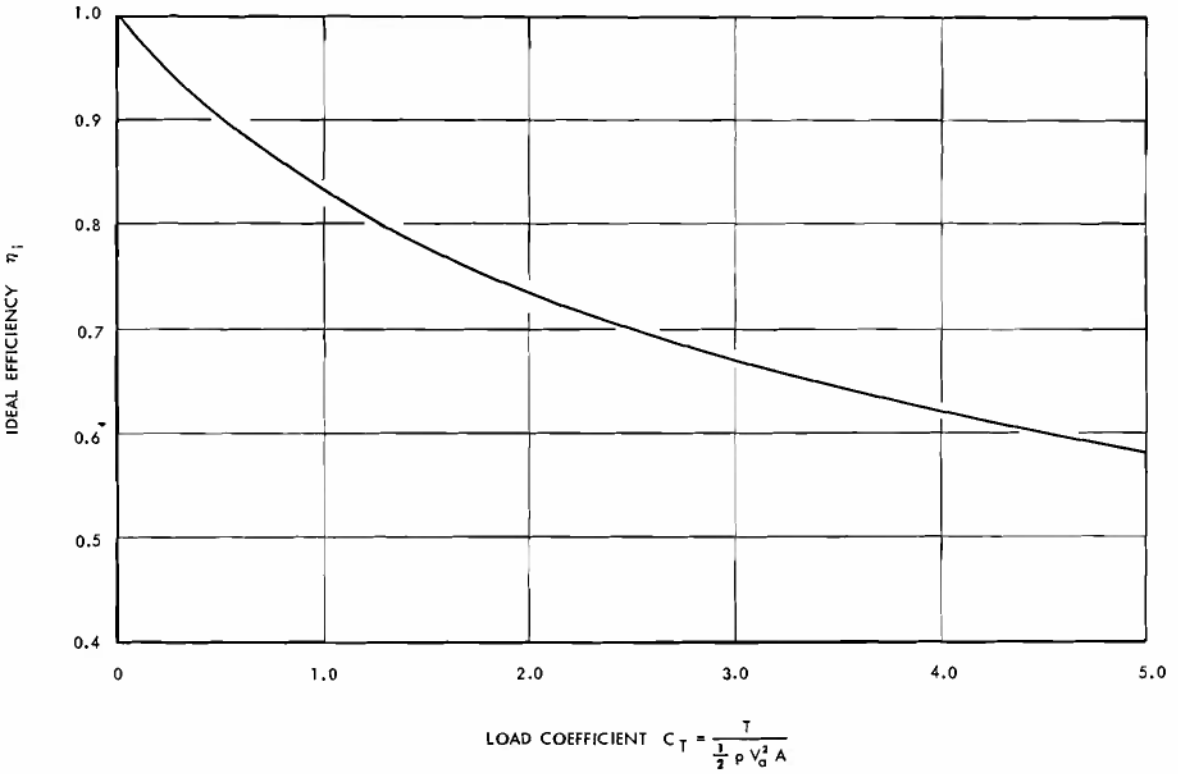

Figure 7-68. Ideal Efficiency (from Simple Momentum Theory)

Some very important conclusions can be drawn from this simple momentum approach to propeller theory. Kinetic energy is carried away in the propeller race which results in ideal efficiencies less than one. The actuator disc is the most ideal propeller imaginable. Hence, the ideal efficiency represents the upper limit of efficiency for real propellers. This upper limit is a function of the propeller loading. A propeller working at a high load coefficient is less efficient (ideally) than one working at a low load coefficient. This leads to the important conclusion that the propeller with the largest disc area is generally most efficient.

Refinements can be made to the momentum theory to account for viscous effects and losses due to rotational velocities in the slipstream. However, the main drawback of any momentum theory is that it yields no information about the geometry (blade shape, pitch distribution, camber, etc.) of the propeller. Theories do exist which take into account the geometrical properties of a screw propeller, and they will be discussed briefly.

7-7.4.2 Blade Element and Circulation Theories

In blade element theory each blade is divided into a number of annular elements. Each element is treated as a foil section. The axial and tangential inflow velocities relative to each blade element are combined vectorially to find the angle of attack (the induced velocities predicted by the momentum theory should be taken into account here). The lift and drag are calculated using suitable airfoil data, and then these forces are resolved into a thrust and torque force. The thrust and torque of the propeller are found by integrating the forces over all of the blade elements.

Blade element theory combined with momentum theory provides a basic conception of screw propeller action, but certain factors are neglected such as interaction between blades and the decrease in lift at the blade tips. These factors are considered in the modern circulation theory. Development of these theories will not be pursued here. However, Refs. 81 through 85 may be studied to gain an understanding of

modern developments in propeller theory.

7-7.4.3 Factors Which Influence Propeller Performance

7-7.4.3.1 Propeller Advance Speed

The performance of a propeller behind a ship differs from that of the same propeller in open water. The flow of fluid into the propeller is affected by the wake of the ship and the flow about the ship is in turn affected by the velocities induced by the propeller. The speed of advance which the propeller "sees" is generally less than the forward speed of the ship. The propeller works in the wake of the vessel which is made up of both potential and boundary layer flow. The relation between ship speed and propeller advance speed is given in terms of the Taylor wake fraction in the equation

$$V_a = V_s(1 - w), \text{ ft/sec} \qquad (7\text{-}82)$$

where

V_a = speed of advance of the propeller, ft/sec
V_s = ship speed, ft/sec
w = wake fraction, nd

7-7.4.3.2 Thrust Deduction

The thrust which a propeller must supply is is generally greater than the bare hull towline resistance of a ship. The action of the propeller changes the flow about the hull in its vicinity. The effect is usually to increase the drag on the hull. The relation between towing resistance and necessary thrust for a given speed is given in terms of the thrust deduction t by

$$R_T = T(1 - t), \text{ lb} \qquad (7\text{-}83)$$

where

R_T = resistance of the hull alone at some speed V_o, lb
T = thrust which must be supplied by the propeller to sustain the same speed V_o, lb
t = thrust deduction, nd

7-7.4.3.3 Relative Rotative Efficiency

The relative rotative efficiency η_r is used to account for the difference in performance between a propeller operating in a uniform and nonuniform wake. The wake fraction discussed previously is an average figure used to define the average effective speed of advance through the plane of the propeller. However, the wake through the propeller plane is nonuniform and varies both radially and circumferentially. The relative rotative efficiency η_r is defined in the "thrust identity" equations

$$\left.\begin{aligned} Q_o &= Q\eta_r \\ n_o &= n \\ T_o &= T \end{aligned}\right\} \qquad (7\text{-}84)$$

where

Q = torque, ft-lb
n = rotative speed, rps
T = thrust, lb

and the subscript o denotes uniform flow.

Thus, the relative rotative efficiency η_r relates the efficiency η_B of the propeller in the nonuniform wake of the hull to the open water efficiency η_o of the propeller producing the same thrust at the same rotative speed in uniform flow

$$\eta_B = \frac{TV_s(1 - w)}{2\pi nQ} = \frac{T_o V_a \eta_r}{2\pi n_o Q_o} = \eta_o \eta_r \qquad (7\text{-}85)$$

7-7.4.3.4 Propulsive Efficiency

The propulsive efficiency η_p is defined as the ratio of effective horsepower EHP to delivered horsepower DHP (also called the propeller horsepower PHP)

$$\eta_p = \frac{EHP}{DHP} = \frac{RV_s}{2\pi Qn} \qquad (7\text{-}86)$$

This useful factor is related to the open water efficiency η_o, the wake fraction w, the thrust deduction t, and the relative rotative efficiency η_r in the following manner

$$\eta_p = \frac{RV_s}{2\pi Qn} = \frac{T(1 - t)V_s(1 - w)}{2\pi Qn(1 - w)}$$

$$= \eta_B \frac{(1 - t)}{(1 - w)} = \eta_o \eta_r \frac{(1 - t)}{(1 - w)} \qquad (7\text{-}87)$$

The term $(1 - t)/(1 - w)$ is called the hull

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efficiency η_h so that we may write

$$\eta_p = \eta_o \eta_h \eta_r \qquad (7\text{-}88)$$

Thus, the propulsive efficiency is the product of the open water efficiency, hull efficiency, and relative rotative efficiency. Strictly speaking, the last two factors are not true efficiencies and they may very likely have numerical values greater than unity. Some designers prefer the names hull factor and relative rotative factor for this reason.

7-7.4.3.5 Hull Efficiency

The hull efficiency (hull factor) η_h is increased by reducing the thrust deduction t and increasing the wake fraction w. However, it can be shown that the thrust deduction is related to the wake fraction and, in particular, to the wake from potential flow so that an increase in wake fraction is often accompanied by an increase in the thrust deduction. The hull efficiency can be increased by locating the propeller in a region of high friction wake. The effect in this case is achieved by recovering energy imparted to the fluid due to the drag of the body, and converting it to thrust.

7-7.4.3.6 Propulsion Factor Data

The wake fraction, thrust deduction, and relative rotative efficiency for several amphibians are included in Tables 7-35 through 7-39. These tables give data from model tests. The reference material from which the data were derived is given at the top of each table. All numbers are based on thrust identity which is discussed in detail in par. 7-7.6.3.

7-7.4.4 Propeller Cavitation

7-7.4.4.1 Theory of Cavitation

Cavitation is a type of fluid flow breakdown caused by the formation of cavities in regions of low pressure. Severe cavitation of marine screws should be avoided because it is accompanied by a loss in performance and erosion or pitting of the blade material. The formation of cavities is usually associated with a reduction in local pressure to the vapor pressure, a function of temperature, of the liquid. Depending on the condition of the liquid (air or solid matter content, etc.) cavitation may begin at pressures above or below the vapor pressure. However, for engineering design purposes it may be assumed that inception of cavitation occurs at the vapor pressure p_v. Table 7-40 gives the vapor pressure of water as a function of temperature.

The local pressure about a body in an ideal fluid is related to the local velocity by Bernoulli's theorem which is stated in the equation

$$p = P_o + \frac{\rho}{2}(U^2 - u^2) \qquad (7\text{-}89)$$

where

p = local pressure, lb/ft^2
P_o = reference pressure, usually taken as the pressure in the undisturbed fluid, lb/ft^2
u = local velocity, ft/sec
U = reference velocity, taken in the undisturbed fluid, ft/sec
ρ = mass density of the fluid, slug/ft^3

Thus, the pressure p may drop to a very low value depending on the velocity u. Cavitation will occur when the local pressure p is less than or equal to the vapor pressure p_v.

The cavitation number σ is defined by the equation

$$\sigma = \frac{P_o - p_v}{\frac{1}{2}(\rho U^2)} = \frac{P_o - p_v}{q} \qquad (7\text{-}90)$$

where q = dynamic pressure of the undisturbed fluid, lb/ft^2.

The cavitation number is nondimensional and offers a convenient index with which to determine the existence of cavitation and its relative extent. Combining Eqs. 7-89 and 7-90:

$$\sigma = \frac{p - p_v}{q} + \left(\frac{u^2}{U^2} - 1\right) \qquad (7\text{-}91)$$

Now, we can define the critical cavitation number σ_{cr} as the value at which the local pressure p is equal to the vapor pressure p_v. Thus,

$$\sigma_{cr} = \frac{(u')^2}{U^2} - 1 \qquad (7\text{-}92)$$

where u' = maximum local velocity of the fluid, ft/sec.

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TABLE 7-35 LARC V PROPULSION CHARACTERISTICS

Ref. 11

Ship Particulars:

Length, ft	32.2
Beam, ft	8.7
Trim, ft	0.79 by stern
Appendages	Rudder
Draft, ft	1.56 fwd, 2.35 aft

Propeller Particulars:	Open Propeller (Tests 1 - 4)	Nozzle Propeller (Test 6)
DTMB† propeller number	3660	3760
Diameter, ft	2.5	2.5
Pitch, ft	1.93	2.5
Number of blades	4	3
Expanded area ratio	0.620	0.540
Blade thickness fraction	0.055	0.036
Hub diameter, ft	—	0.38

† David Taylor Model Basin

Ship Speed, mph	7	8	9	7	8	9
EHP, hp	30	50	70	30	50	70
Drag, lb	1600	2340	2910	1600	2340	2910
N, rpm	647	806	911	525	630	705
Thrust, lb	2270	3660	4500	1470	2150	2690
K_T	0.25	0.26	0.25	0.246	0.250	0.250
η_o	0.34	0.31	0.33	0.530	0.525	0.525
$1 - t$	0.73	0.64	0.647	1.09*	1.09*	1.08*
$1 - w$	0.707	0.685	0.748	1.14*	1.175*	1.168*
η_h	1.03	0.96	0.865	0.956*	0.93*	0.93*
η_r	1.0	0.925	0.955	0.96	0.93	0.93
EHP/SHP or η_p	0.35	0.275	0.272	0.485	0.455	0.452

* Note: These include the effects of the nozzle and are not the true propulsion factors; they may be called the apparent propulsion factors.

At cavitation numbers above the critical value there is no cavitation. The degree of cavitation increases with decreasing cavitation numbers below σ_{cr}. The term on the right hand side of Eq. 7-92 may be written as $-\Delta p'/q$ using Bernoulli's equation where $-\Delta p' = P_o - p'$, the maximum local decrease in pressure about a body.

Fig. 7-69 shows the pressure distribution about a typical foil section at some positive angle of attack. In this figure the ordinates of the curves are the differences ($-\Delta p$) between the local pressures and the pressure in the undisturbed medium normalized by the stagnation pressure q; the abscissas are fractional distances along the chord of the foil. The maximum decrease in pressure on the back of this foil occurs at 10 percent of the chord where $-\Delta p'/q = 2.0$. Thus, the critical cavitation number for the foil is $\sigma_{cr} = 2.0$ and inception of

TABLE 7-36 LARC XV PROPULSION CHARACTERISTICS

Ref. 57

Ship Particulars:

Length, ft	41.8
Beam, ft	12.5
Draft, ft	2.47 fwd, 2.90 aft
Appendages	Rudder and Kort nozzle

Propeller Particulars:

DTMB† Propeller No.	3760
Diameter, ft	3.0
Pitch, ft	3.0
No. of blades	3
Expanded area ratio	0.54
Blade thickness fraction	0.036
Hub diameter, ft	0.46

† David Taylor Model Basin

Ship Speed, mph	8	10	12
Thrust, lb	3,600	6,500	10,900
SHP, hp	190	450	765
N, rpm	580	765	980
K_T	0.242	0.250	0.256
η_o	0.540	0.525	0.513
$1-w$	1.345*	1.370*	1.425*

*Note: This wake fraction includes the effect of the nozzle on the inflow to the screw, hence, it is not a true wake fraction.

TABLE 7-37 DRAKE PROPULSION CHARACTERISTICS

Ref. 54

Vehicle displacement, lb	45,000
Propeller diameter, in.	31 (Twin screws in tunnels)
Propeller pitch, in	24.5

Ship Speed, mph	7	8	9
SHP, hp	38	68	111
N, rpm	494	595	706
$1-t$	0.84	0.815	0.78
$1-w$	0.82	0.860	0.85
η_h	1.03	0.950	0.92

cavitation would occur on the back of the foil at the 10 percent chord point. For a numerical example, assume that this foil ($\sigma_{cr} = 2.0$) is operating in fresh water at a depth such that the undisturbed pressure $P_o = 20$ psia and the temperature is 59° F (at 59° F, from Table 7-40, $p_v = 0.025$ psia)

$$\sigma_{cr} = \frac{P_o - p_v}{\frac{1}{2}(\rho U_{cr}^2)}$$

$$U_{cr}^2 = \frac{P_o - p_v}{\frac{1}{2}(\rho \sigma_{cr})} = \frac{(20 - 0.25)144}{(0.5)1.938(2.0)} = \frac{(19.75)144}{1.938}$$

$$U_{cr} = 38.3 \text{ ft/sec}$$

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TABLE 7-38 GULL PROPULSION CHARACTERISTICS

Ref. 92

Ship Particulars:		Propeller Particulars:	
Length, ft	35	Diameter, ft	3.01
Beam, ft	9.17	Pitch (0.7R), ft	2.93
Displacement, lb	44,703	Number of blades	3

Test - 4M Single Screw in Tunnel

Ship Speed, mph	7	8	9
EHP, hp	42	66	91
$1 - w$	1.04	1.02	1.06
$1 - t$	1.11	1.03	0.98
η_h	1.07	1.01	0.93

TABLE 7-39 LVW (HULL MODE) PROPULSION CHARACTERISTICS

Ref. 39

Hull Particulars:		Propeller Particulars:	
Length, ft	3.60	Diameter, ft	2.0 (Twin screws)
Beam, ft	11.33	Pitch, ft	2.4
Displacement, lb	38,000	No. of blades	3
Trim, ft	1.5 by stern	Expanded area ratio	0.945
		Blade thickness fraction	0.06

	Wheel Flaps Up		Wheel Flaps Down	
Ship Speed, mph	6.93	11.5	6.93	11.5
$1 - w$	0.92	1.15	1.04	1.10
$1 - t$	0.70	0.80	0.92	0.71
η_h	0.77	0.70	0.89	0.65
η_o	0.35	0.40	0.51	0.42
η_r	0.80	1.01	0.79	0.89
η_p	0.22	0.28	0.36	0.24

The foil will be free of cavitation below the critical speed. At any other angle of attack the pressure distribution will be changed and, thus, the critical speed will be different.

A schematic diagram of the critical cavitation number for cavitation inception on a foil as a function of angle of attack is shown in Fig. 7-70. The shaded side of each curve is the region in which each type of cavity will occur—leading edge face, leading edge back, and back bubble. Another type of cavitation common to propellers, tip vortex cavitation, is not shown here. This type of diagram is often referred to as a cavitation bucket.

The lift coefficient of the foil shown in Fig. 7-69 is proportional to the area enclosed by the

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TABLE 7-40 VAPOR PRESSURE OF FRESH WATER*

Temperature T		Vapor Pressure	
°F	°C	p_v, psia	h_v, ft of water
32	0	0.09	0.20
40	4.4	0.12	0.28
50	10.0	0.18	0.41
59	15.0	0.25	0.57
60	15.6	0.26	0.59
70	21.1	0.36	0.84
80	26.7	0.51	1.17
90	32.2	0.70	1.61
100	37.8	0.95	2.19
120	48.9	1.7	3.9
150	65.6	3.7	8.6
180	82.2	7.5	17.3
212	100.0	14.7	33.9

*Salt water has a vapor pressure about 98 percent of that of fresh water.

pressure curve. Note that the area about the back of the foil is greater than the area about the face. The largest part of the lift (thrust for a propeller) is contributed by the low pressure region on the back of the foil. The critical cavitation number is a function of the peak of the pressure curve and not the area (lift) enclosed by the curve. Hence, in designing a propeller to avoid cavitation it is desirable to use sections whose pressure distributions are nearly rectangular and are devoid of sharp peaks.

Many alternative forms of the basic cavitation number are used when dealing with propellers. However, all of these are easily related to the number in which the reference pressure P_o is the static pressure at the axis of the screw and the dynamic pressure q is related to the speed of advance of the screw. The general cavitation number σ_o for propellers is given by

$$\sigma_o = \frac{P_o - p_v}{\frac{1}{2}(\rho V_a^2)} = \frac{(h_A + h_H) - h_v}{\frac{V_a^2}{2g}} \qquad (7\text{-}93)$$

where

h_A = atmospheric pressure, ft(of propeller water)
h_H = depth of immersion of the screw axis, ft
h_v = vapor pressure (Table 7-40), ft
V_a = advance speed, ft/sec
g = acceleration, constant, ft/sec^2

7-7.4.4.2 Cavitation Effects

The damage to screw propellers caused by cavitation is well documented. The erosion of blade material is associated with the collapse of cavities as they flow from a low pressure region to a region where the local pressure is greater than the cavity vapor pressure. The mechanism of this damage will not be pursued here.

The effect of cavitation on performance can be seen in Fig. 7-71 which shows the thrust coefficient K_T and torque coefficient K_Q as functions of speed coefficient J with cavitation number σ_o as a parameter. These coefficients are defined in the figure. The lower the cavitation number, the greater the loss in thrust and torque (larger cavities). The loss in torque is generally proportional to the loss in thrust so that efficiency is relatively independent of the cavitation number. The loss in thrust is caused by a change in the pressure distribution over the backs of the blades. The minimum pressure which the liquid can sustain is its vapor pressure.

While the curve of efficiency is not necessarily affected by cavitation, a propeller on a ship will operate at lower than design efficiency if it

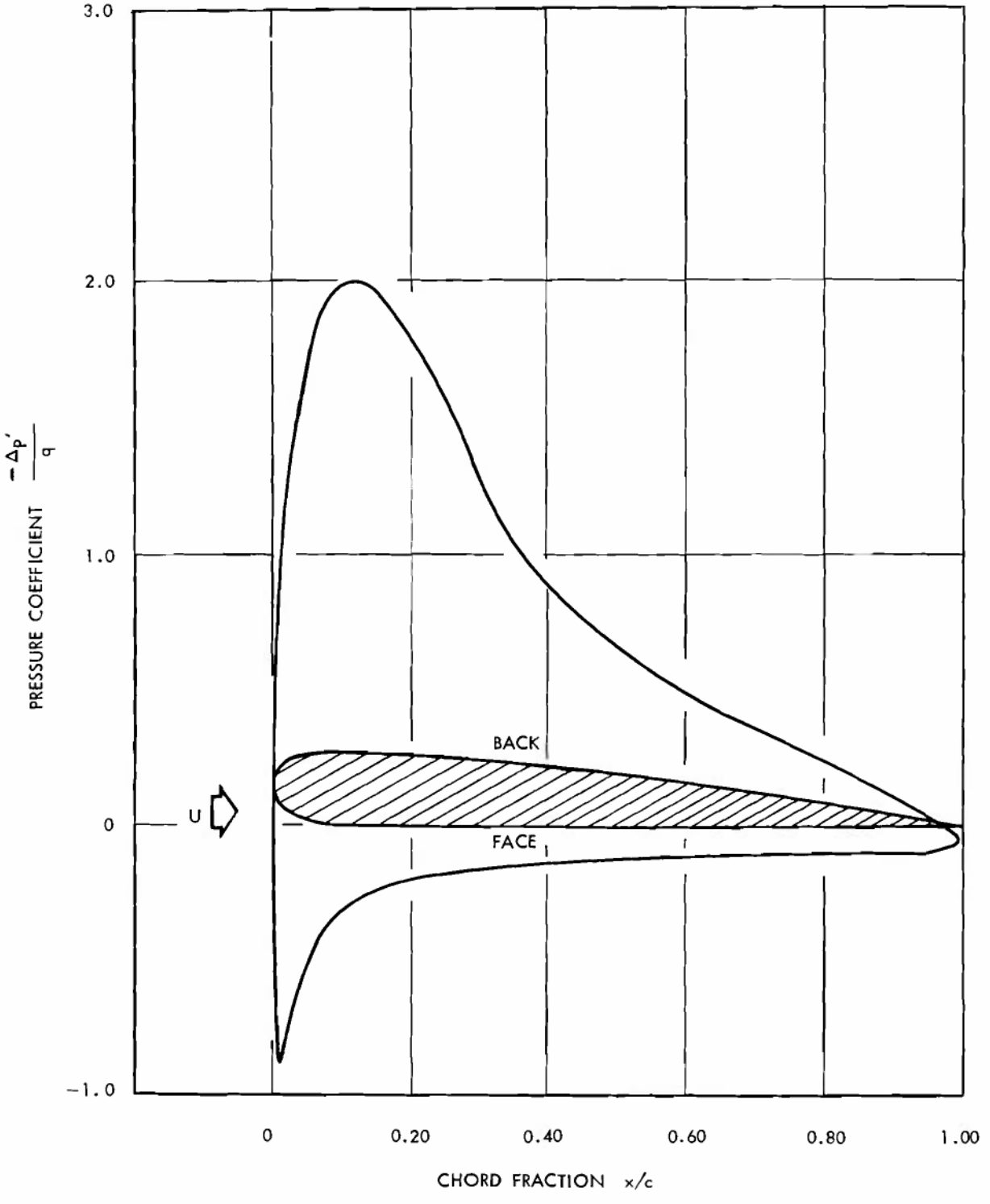

Figure 7-69. Pressure Distribution for a Typical Foil Section

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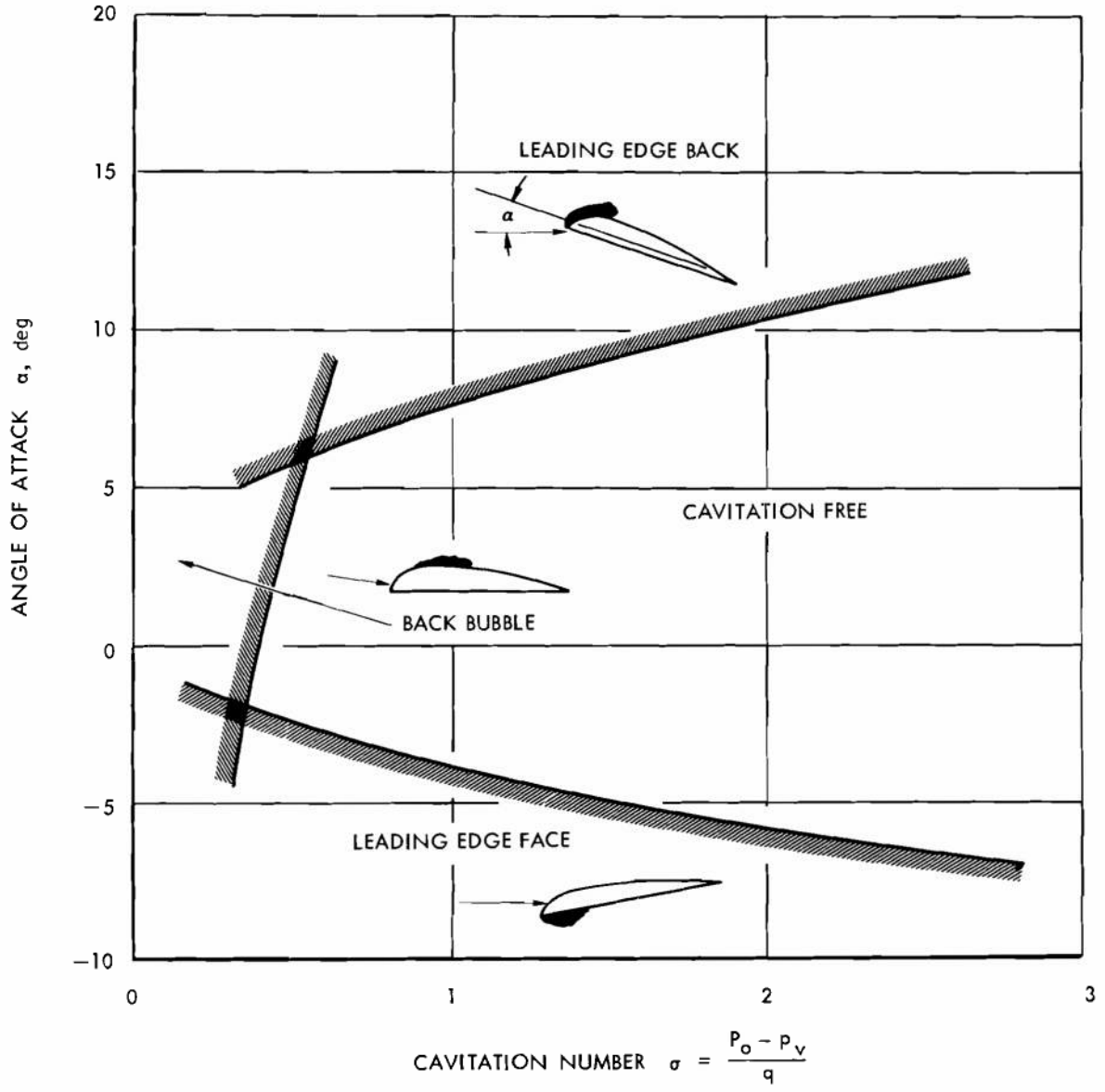

Figure 7-70. Schematic Diagram of Critical Cavitation Number as a Function of Foil Angle of Attack

should cavitate heavily. This is due to the fact that it must operate at higher rpm to develop the design thrust, hence it operates at lower speed coefficient J where the efficiency η is lower (see Fig. 7-95).

Prediction of cavitation for propellers and design features to prevent cavitation are discussed in par. 7-7.5.3. Ref. 87 contains information on the mechanism of cavitation and includes a list of 101 references.

7-7.5 SCREW PROPELLER DESIGN

Screws can be selected by the use of design charts based on standard series data or designed by the application of detailed calculation methods. Chart methods enable standard-type screws to be designed with a minimum of computation. The geometrical features of such screws generally lead to simplification of manufacture. Detailed calculation methods

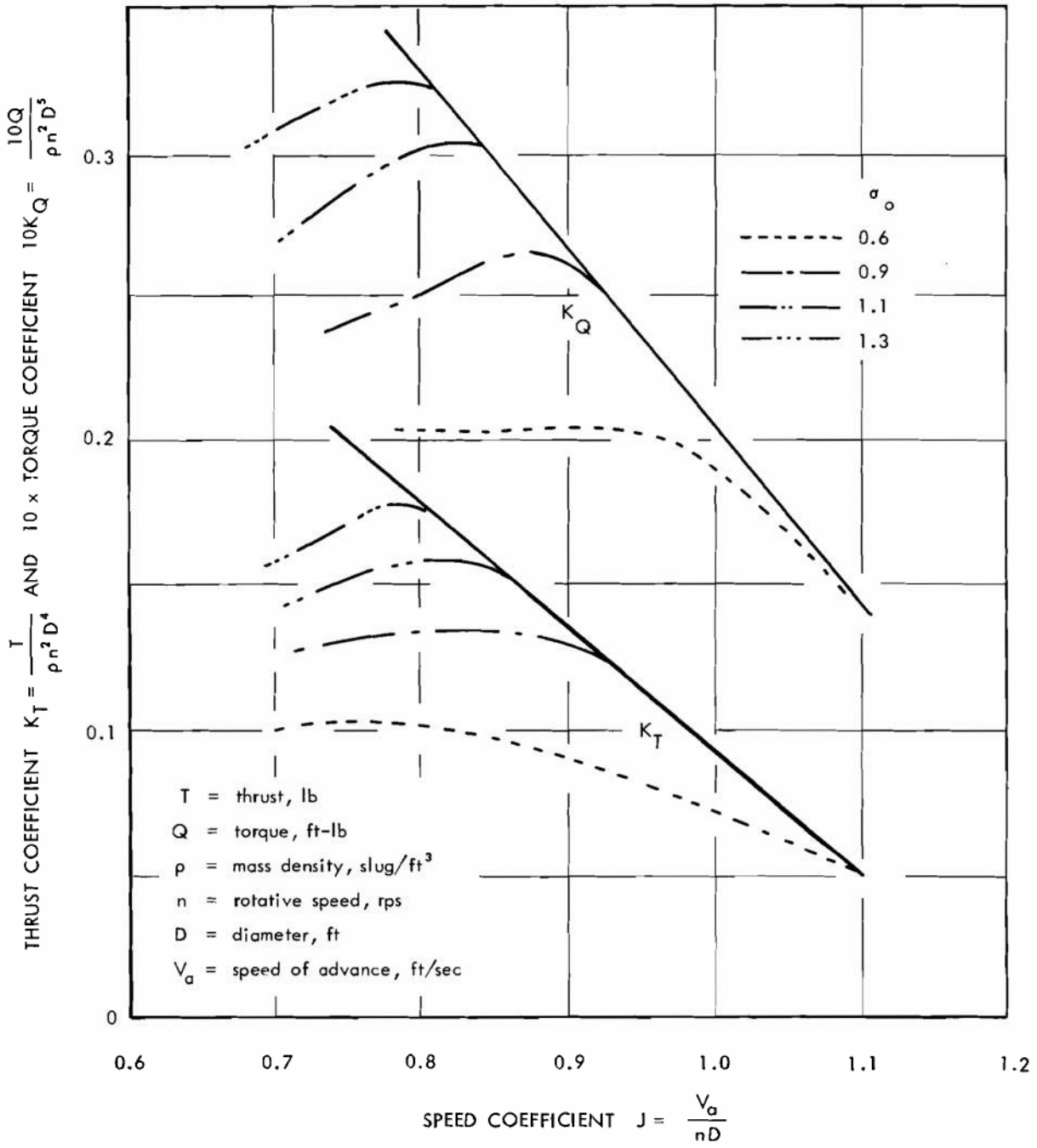

Figure 7-71. Typical Propeller Performance Curves as a Function of Cavitation Number σ_o

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involve more computation and result in more complex characteristics which can mean that the screw may operate more efficiently and with a greater margin against cavitation than would be possible for a standard-type screw. For screws required to operate at only light-duty low-speed conditions in relatively uniform flow, there is little to be gained in adopting nonstandard type screws which require detailed calculations. This is not true regarding the design of heavily loaded and wake-adapted propellers.

The combination of chart and detailed design methods provides a procedure which includes some of the advantages of both and may be profitably applied to the design of amphibian propellers. Much of the preliminary design work can be based on standard series design charts. In the early stages of the design many of the requirements will be provisional and some parameters such as hull resistance, wake fraction, and thrust deduction will be based on engineering estimates. The final design work can be related to detailed calculation methods once the requirements have been firmly established and model tests have been performed to confirm the choice of hull and determine its characteristics.

Design charts based on the Troost B-Series of propellers are included in this text to provide a convenient source for amphibian screw propeller design. A limited number of charts are also presented for nozzle-propeller combinations based on data from Ref. 69. Numerical examples are also included to illustrate the use of these charts.

Space limitations preclude the development of detailed design data and methods in this text. However, Refs. 81 to 86 should be studied if a detailed propeller design is to be undertaken.

7-7.5.1 Requirements

The design of a propeller starts with the preliminary propulsion estimate. The designer is given the required design speed, estimates of EHP, thrust deduction, wake fraction, and design stipulations (if any) such as maximum diameter, minimum rpm, type and number of blades, and specified material. With this information, the designer can use design charts to estimate the propeller characteristics, propeller efficiency, propulsive efficiency, and engine horsepower. In the final stages of the design, after a particular power plant has been chosen and model tests have been made, the designer will select the optimum screw characteristics from design charts or from detailed design calculations.

The designer will supply data on the screw particulars—e.g., type of screw, number of blades, diameter, blade area, pitch, rake, skew, thickness, blade section offsets and outlines, etc.—including drawings where necessary. The maximum speed and efficiency should be estimated along with performance over a range of operating conditions at various vehicle displacements and in rough water.

7-7.5.2 Selecting Blade Characteristics

Before we describe the use of screw-series data diagrams in selecting the optimum propeller characteristics, some general discussion on the influence that various factors have on performance is in order.

7-7.5.2.1 Design Variables

a. *Number of Blades Z.* The number of blades is usually selected to minimize vibrations. Variations in wake around the propeller plane induce fluctuations in thrust and torque on each blade. The number of blades determines the phase relationships between blades, and thus whether the oscillating forces tend to augment or cancel one another. Also, the blade frequency *(nZ)* must not coincide with the natural and lower harmonic frequencies of the hull or machinery. Propeller efficiency is usually a secondary consideration in the choice of the number of blades.

b. *Expanded Area Ratio EAR.* *EAR* is the ratio of the expanded area (see par. 7-7.5.9) of all the blades to disc area. The efficiency of the screw decreases with increasing blade area due to increasing surface friction. In nearly all cases, however, the minimum allowable blade area is determined by the requirement that the propeller shall be noncavitating, as far as possible. If there is little risk of cavitation, the minimum blade area is restricted by considerations of backing power and strength to about $EAR = 0.35$. Below this value the necessary short, thick sections will result in decreased efficiencies.

c. *Diameter D.* The diameter of a propeller

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for an amphibian is usually limited by practical considerations, i.e., tip clearance. In general, the largest allowable propeller will be the most efficient, as shown by momentum theory, par. 7-7.4.1. If diameter is unrestricted, the optimum diameter can be found from design charts and will depend on the restrictions placed on rpm.

d. *Rate of Rotation rpm.* The propeller rpm is often limited by the engine characteristics and reduction ratio of the transmission system. If the optimum rpm for a specified diameter lies below the allowable range, the pitch must be reduced below optimum to increase rpm with some loss in efficiency.

e. *Pitch Ratio P/D.* The pitch ratio is simply the ratio of pitch to diameter. The pitch is the length that the propeller would move in the axial direction per revolution with zero slip. The pitch determines the rate at which a propeller must rotate to produce a given loading coefficient C_T. The pitch ratio for best efficiency is low ($P/D \approx 0.6$) for heavily loaded propellers, and high ($P/D \approx 1.4$) for lightly loaded propellers. Many propellers are designed with radial variation in pitch. This is usually in the form of a pitch reduction at the blade roots and blade tips. Moderate variations in pitch distribution have little, if any, effect on the overall efficiency of a screw but can be favorable from a cavitation standpoint.

f. *Blade Section Shape.* The blade section shapes have important effects on efficiency and the cavitation properties of the screw. Comparison of lift-drag indicates that airfoil shapes are preferable for the inner portions of the blade but are equal to ogival sections for the outer portions of the blade from an efficiency standpoint. However, ogival sections are preferable for the outer portions of the blade from the cavitation standpoint. The Troost Series B screws employ airfoil inner sections and ogival outer sections as shown in Fig. 7-72.

g. *Blade Outline.* The blade outline for best efficiency is one for which the enclosed area distribution approaches that of an ellipse with the major axis along a radial. Blades with broader tips absorb more power and give more thrust at the same slip but are generally less efficient, except for shrouded propellers.

h. *Thickness.* The thickness of the blade sections is determined by strength considerations. The distribution of thickness between the root and tip may be specified as linear or may be determined by strength calculations at a number of radii in order to save weight through the most efficient use of material. Increased thickness results in lower efficiencies and increased cavitation.

i. *Rake and Skew.* Rake and skew are defined by Fig. 7-72. Forward rake is rarely found since it serves no useful purpose. Rake aft is commonly found and is used to increase the tip clearance from the hull. Rake is limited for heavily loaded propellers by the centrifugal bending stresses which are induced. Skew is used to smooth out the fluctuations in thrust caused by abrupt changes in wake behind sternposts and struts.

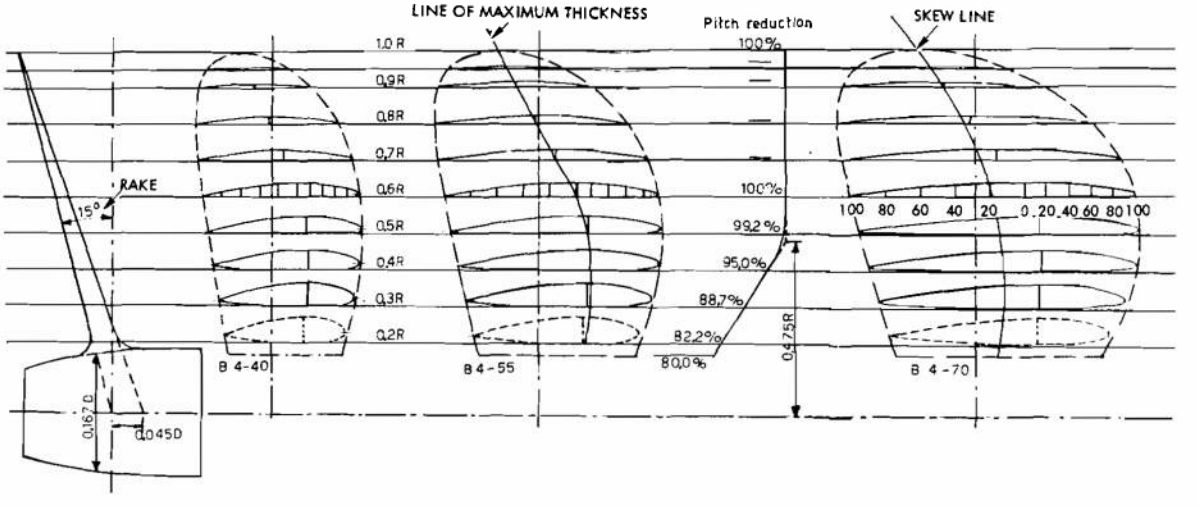

Figure 7-72. General Arrangement of Troost B-4 Series Screws

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7-7.5.2.2 Design Charts

The K_T-J diagrams for the Troost B Standard Screw Series are presented in Figs. 7-73 to 7-81. Table 7-41 summarizes the main characteristics of the B-series.

The contour, ordinates, and thickness of the blades are presented in Table 7-42. All have 15 deg rake and some skew. The skew and maximum thickness lines for the 2- and 3-bladed screws differ from that for the 4- and 5-bladed screws. The maximum thickness varies linearly from root to tip. The pitch is defined as the pitch of the blade face rather than the usual nose-tail line. The pitch is constant except for the 4-bladed screws which have a 20 percent reduction at the root. Fig. 7-72 shows the expanded outlines of the 4-bladed series.

Figs. 7-82 to 7-85 are K_T-J diagrams for several Troost B-Series propellers in a shroud. The nozzle characteristics are defined in Fig. 7-86 and are tabulated on each K_T-J diagram.

7-7.5.2.3 Procedures

The use of these design charts for three design problems will be discussed briefly. Numerical examples are included in par. 7-7.5.8 to illustrate these procedures.

Problem No. 1

Given: Design speed V_s, towing resistance R, diameter D, thrust deduction t, wake fraction w, and relative rotative efficiency η_r.

Problem: To find optimum rpm, pitch ratio P/D, and necessary delivered power DHP.

Analysis: a. The coefficient K_{T_d} is calculated from the definition

$$K_{T_d} = \frac{K_T}{J^2} = \frac{T}{\rho V_a^2 D^2} = \frac{R_T}{\rho(1-t)(1-w)^2 V_s^2 D^2} \qquad (7\text{-}94)$$

where units are consistent so that K_{T_d} is dimensionless.

With the calculated value of K_{T_d} a parabola from the equation $K_T = J^2 K_{T_d}$ is drawn on the appropriate K_T-J diagram for the desired number of blades and area ratio. The point where this parabola crosses the curve "η_{max} for K_{T_d} constant" is the design point. K_T and J are read off directly. η_o and P/D are found by linear interpolation between lines of constant efficiency and pitch ratio.

b. Rotative speed rps is calculated from the speed coefficient J:

$$n = \frac{V_s(1-w)}{JD}, \text{ rps} \qquad (7\text{-}95)$$

c. DHP is found from

$$DHP = \frac{R_T(1-w)V_s}{(1-t)\eta_r\eta_o 550}, \text{ hp} \qquad (7\text{-}96)$$

Problem No. 2

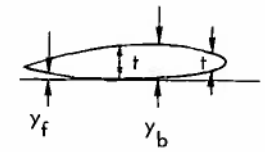
Given: The same as the previous problem with the exception that n is given.

TABLE 7-41 CHARACTERISTICS OF TROOST B-SERIES PROPELLERS

Distribution	Number of Blades Z	Expanded Area Ratio EAR	Blade Thickness Fraction BTF	Pitch Distribution
B-2.30	2	0.30		Constant
B-3.35	3	0.35	0.50	Constant
B-3.40	3	0.50	0.50	Constant
B-3.55	3	0.60	0.50	Constant
B-4.40	4	0.40	0.45	20% Decrease at hub
B-4.55	4	0.55	0.45	
B-4.70	4	0.70	0.45	
B-5.45	5	0.45	0.40	Constant
B-5.60	5	0.60	0.40	Constant

TABLE 7-42 TROOST B-SERIES PROFILES, ORDINATES, AND THICKNESS

DISTANCE OF THE ORDINATES FROM THE MAXIMUM THICKNESSES



$y_b = y_f + t$

NOTES:
1. r/R RADIUS FRACTION: THE SECTION RADIUS DIVIDED BY THE PROPELLER RADIUS.
2. t AND y_f ARE GIVEN AS A PERCENTAGE OF THE MAXIMUM THICKNESS AT THE CORRESPONDING SECTION
3. T.E. AND L.E. REFER TO TRAILING AND LEADING EDGE, RESPECTIVELY

	PERCENTAGE OF LENGTH FROM POINT OF MAXIMUM THICKNESS TO TRAILING EDGE						PERCENTAGE OF LENGTH FROM POINT OF MAXIMUM THICKNESS TO LEADING EDGE						
r/R	100%	80%	60%	40%	20%	0%	20%	40%	60%	80%	90%	100%	r/R
	ORDINATES FOR FACE = y_f												
0.6	5.10										0.50	10.25	0.6
0.5	9.70	1.75							0.35	1.70	4.45	17.05	0.5
0.4	17.85	6.20	1.50					0.30	1.75	5.90	9.90	24.35	0.4
0.3	25.35	12.20	5.80	1.70			0.45	1.30	4.65	10.90	16.25	31.00	0.3
0.2	30.00	18.20	10.90	5.45	1.55		0.45	2.80	7.40	15.50	21.65	36.75	0.2
B 2 - 3 - 4 - 5 - 6 - 7						THICKNESS = t							
0.95		44.80	72.00	88.80	97.20	1.00	97.20	88.80	72.00	44.80	29.50		0.95
0.90		45.15	70.00	87.00	97.00	1.00	97.00	87.00	70.00	45.15	30.10		0.90
0.80		40.95	67.80	85.30	96.70	1.00	97.00	86.30	70.00	47.00	31.65		0.80
0.70		39.40	66.90	84.90	96.65	1.00	97.60	89.15	73.20	49.00	32.95		0.70
0.60		40.20	67.15	85.40	96.80	1.00	98.10	90.65	75.40	51.65	34.35		0.60
0.50		41.65	68.40	86.10	96.95	1.00	97.00	89.70	77.40	55.75	37.55		0.50
0.40		41.50	68.75	86.55	97.00	1.00	97.50	90.10	77.20	55.70	38.85		0.40
0.30		38.75	65.80	85.10	96.80	1.00	97.70	90.05	75.80	53.95	37.45		0.30
0.20		35.15	61.75	81.45	94.90	1.00	97.70	89.65	74.95	51.95	35.55		0.20

THE PERCENTAGES OF THE ORDINATES AND THICKNESSES HAVE REFERENCE TO THE MAXIMUM THICKNESS OF THE CORRESPONDING SECTIONS

BLADE CONTOUR THE FOLLOWING VALUES ARE PERCENTAGES OF THE BLADE WIDTH AT 0.6 R										
B 4 - B 5 - B 6 - B 7					B 2 - B 3					
r/R	T.E.	L.E.	TOTAL WIDTH	POINT OF MAXIMUM THICKNESS TO GENERATOR LINE	r/R	T.E.	L.E.	TOTAL WIDTH	POINT OF MAXIMUM THICKNESS TO GENERATOR LINE	r/R
1.00	20.14	—	—	-20.14	1.00	14.87	—	—	-14.87	1.00
0.95	42.71	11.75	54.46	-15.48	0.95	39.86	18.10	57.96	-10.88	0.95
0.90	47.00	25.35	72.35	-10.83	0.90	45.01	30.76	75.77	- 7.12	0.90
0.80	48.35	41.65	90.00	- 1.37	0.80	47.77	45.08	92.85	+ 0.70	0.80
0.70	46.68	51.40	98.08	+ 8.05	0.70	46.95	52.24	99.19	+ 8.40	0.70
0.60	43.92	56.08	100.00	+17.18	0.60	44.08	55.92	100.00	+16.22	0.60
0.50	40.78	57.60	98.38	+22.68	0.50	40.53	56.52	97.05	+22.07	0.50
0.40	37.30	56.32	93.62	+23.65	0.40	36.62	54.91	91.53	+22.97	0.40
0.30	33.32	52.64	85.96	+22.55	0.30	32.67	51.24	83.91	+21.87	0.30
0.20	29.18	46.90	76.08	+20.27	0.20	28.68	46.05	74.73	+19.89	0.20

BLADE WIDTH AT 0.6 R
2 BLADE = 1.1040 x EAR x D
3 BLADE = 0.7396 x EAR x D
4 BLADE = 0.5467 x EAR x D
5 BLADE = 0.4373 x EAR x D
6 BLADE = 0.3628 x EAR x D
7 BLADE = 0.3174 x EAR x D

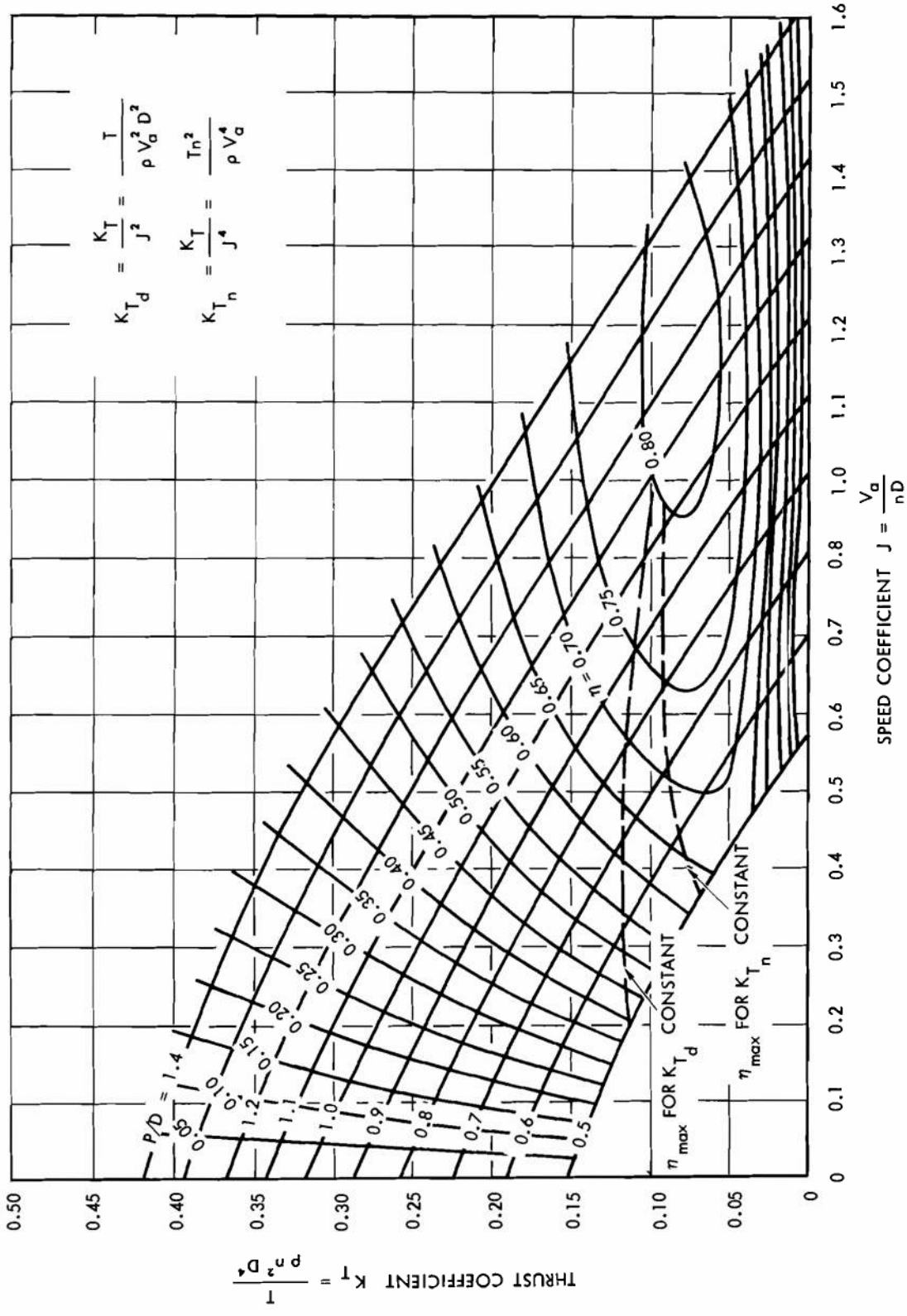


Figure 7-73. Design Chart Based on Troost B-2.30 Series Data

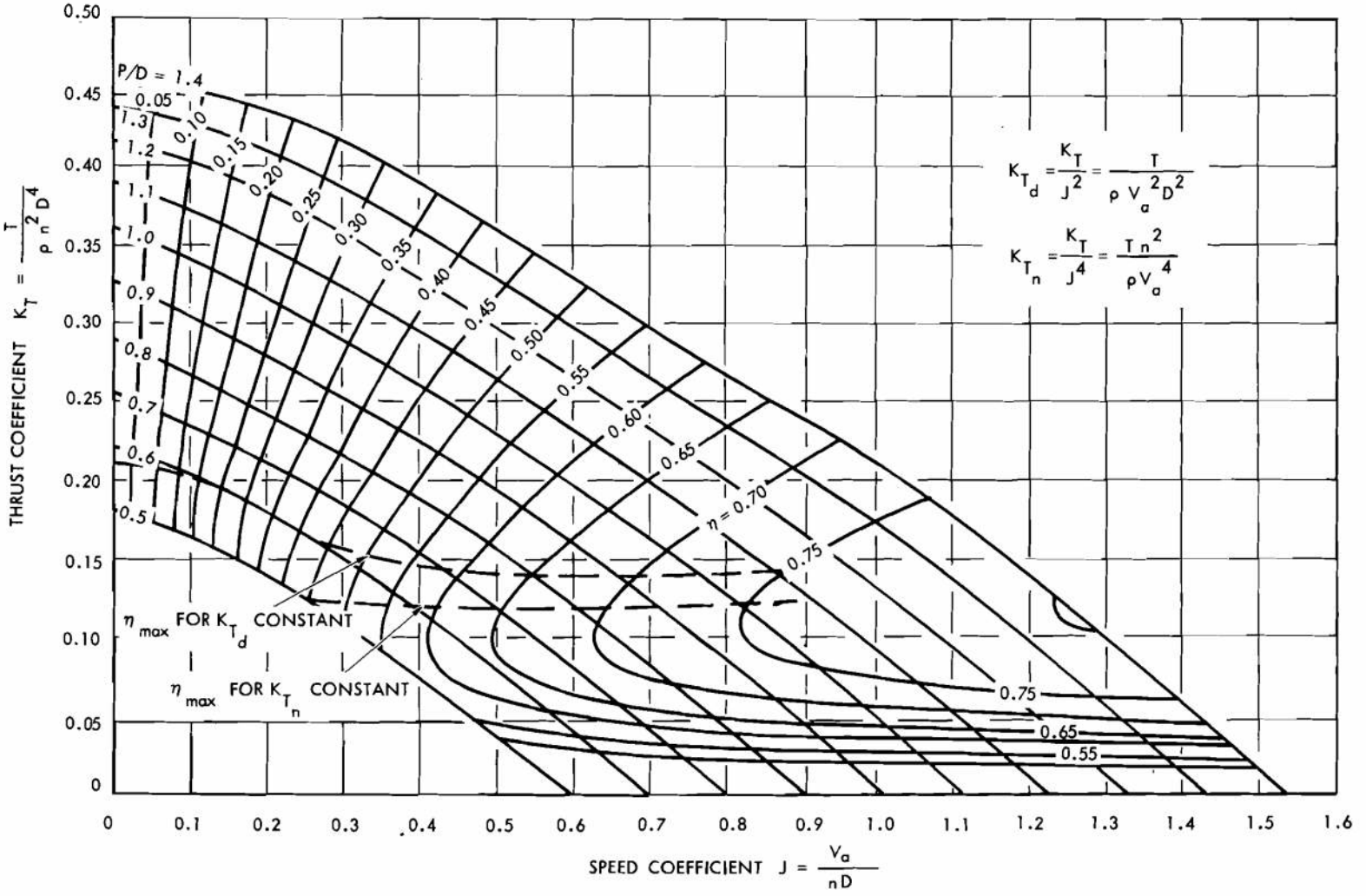


Figure 7-74. Design Chart Based on Troost B-3.35 Series Data

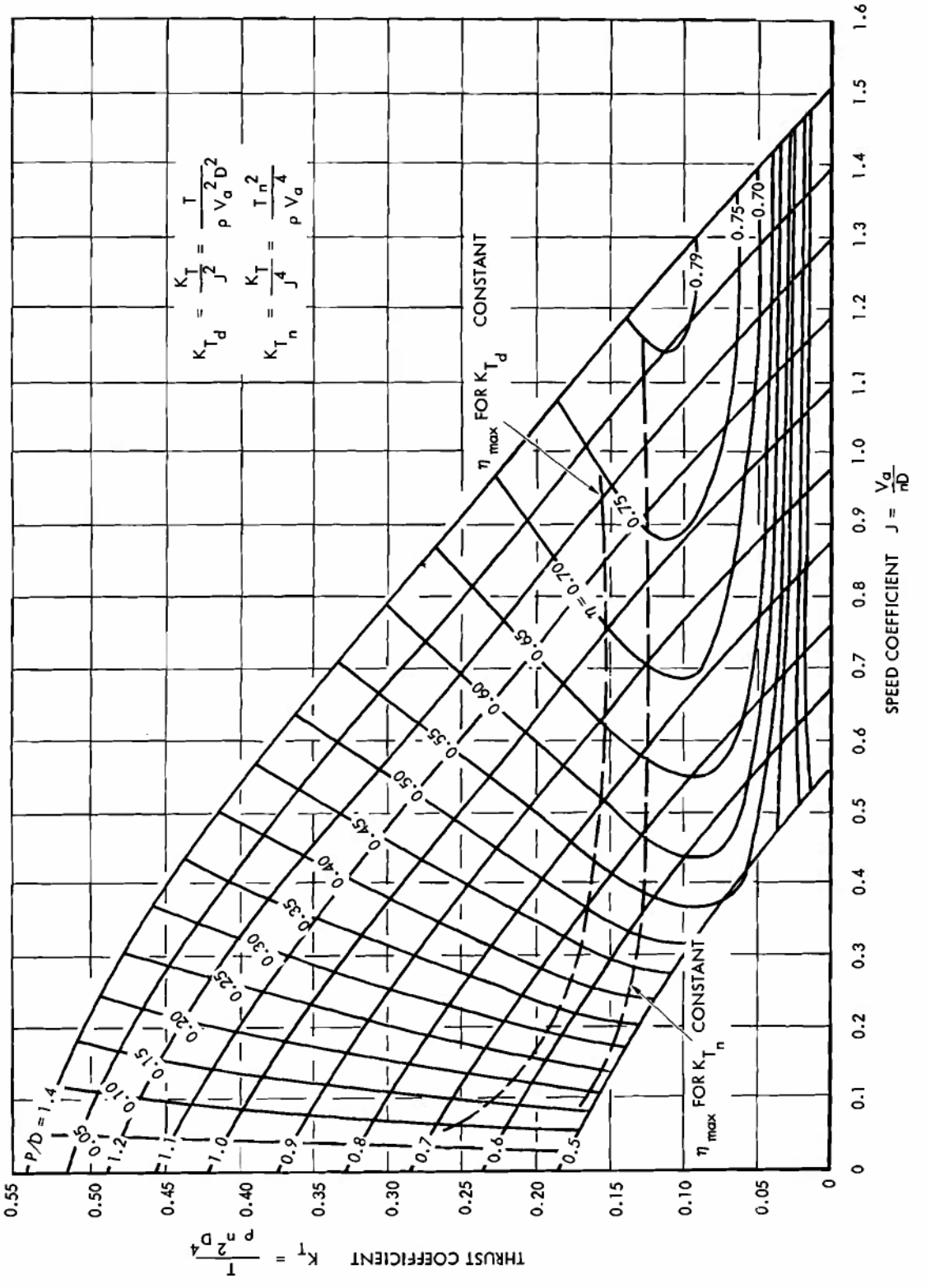


Figure 7-75. Design Chart Based on Troost B-3.50 Series Data

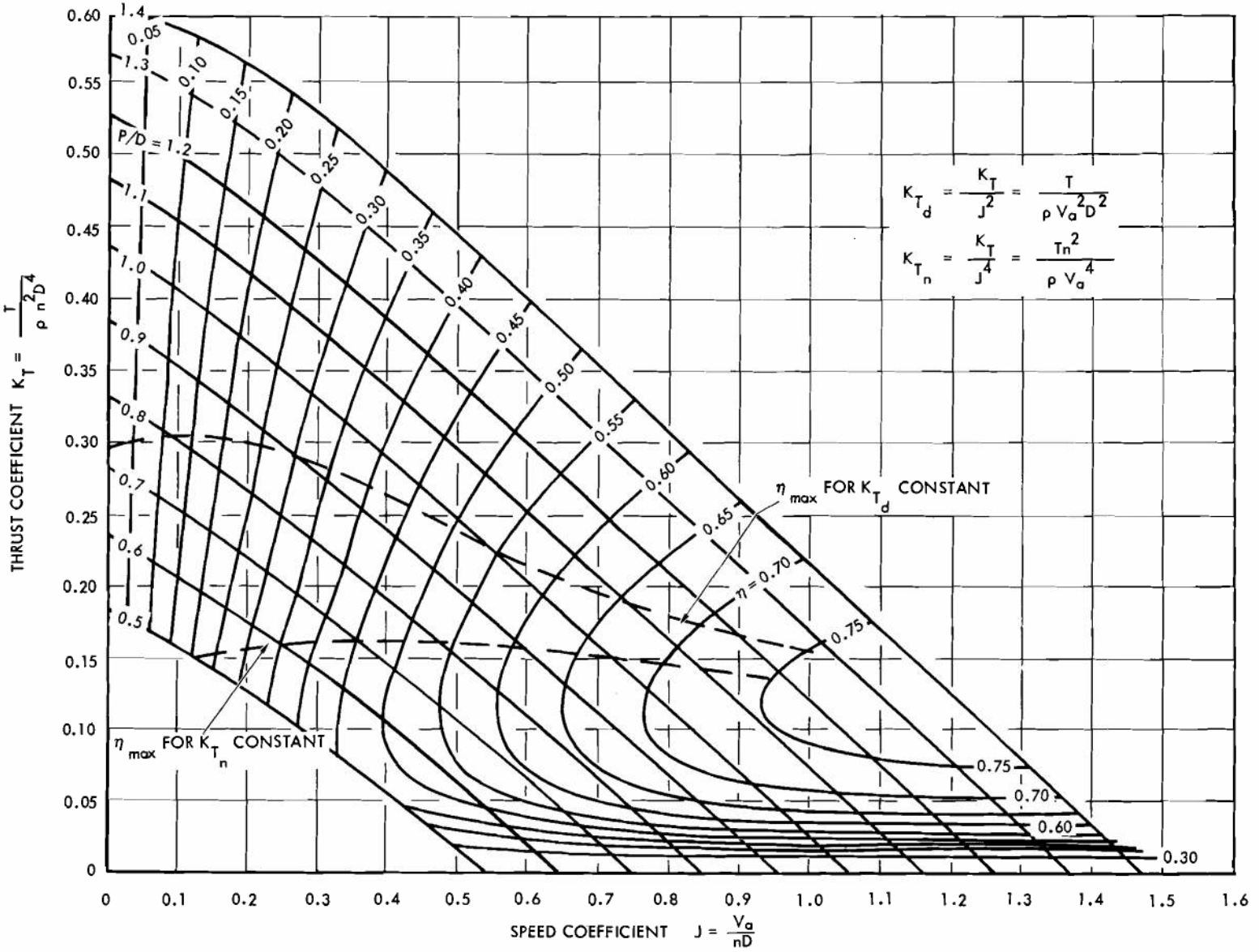


Figure 7-76. Design Chart Based on Troost B-3.65 Series Data

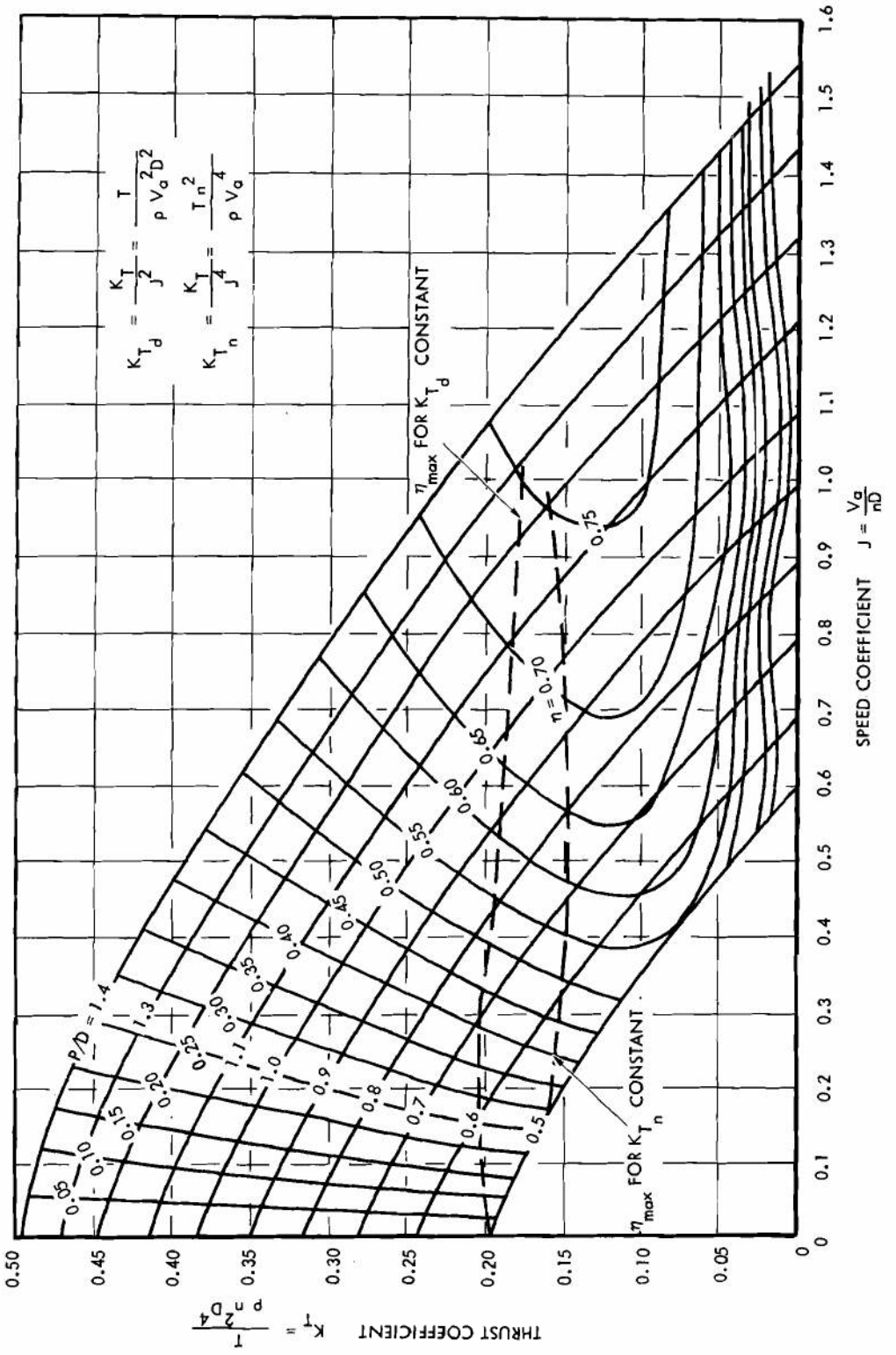


Figure 7-77. Design Chart Based on Troost B-4.40 Series Data

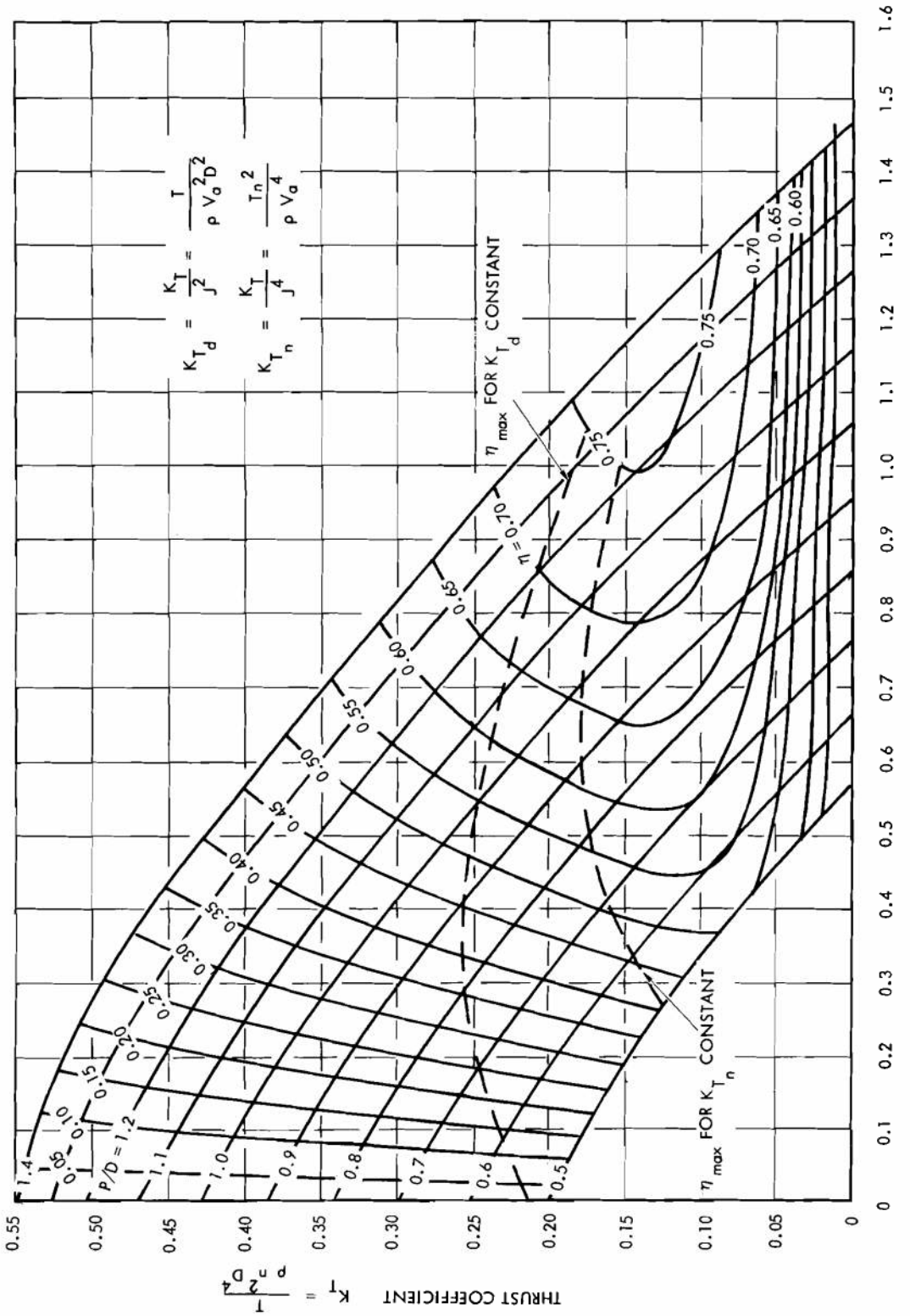


Figure 7-78. Design Chart Based on Troost B-4.55 Series Data

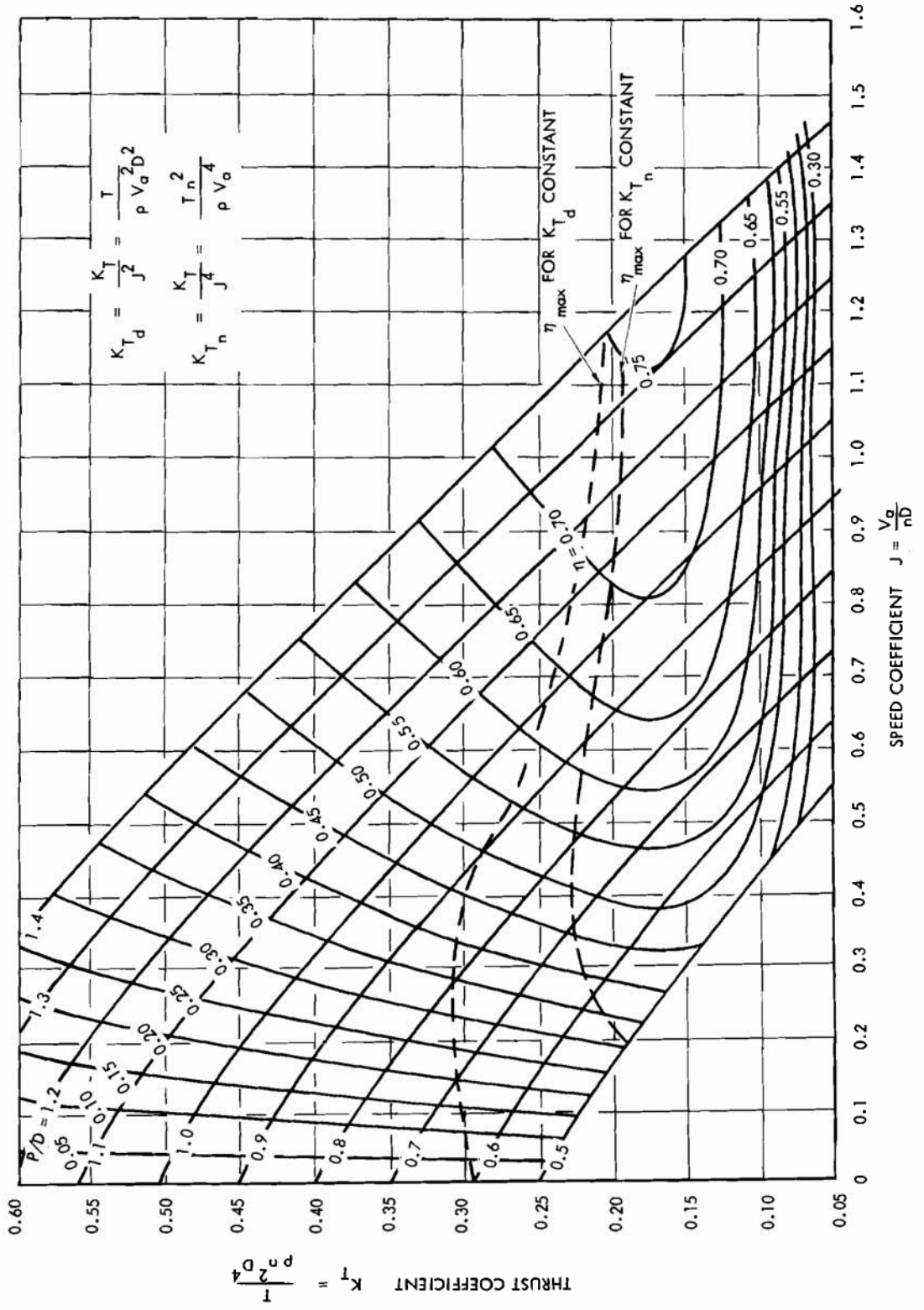


Figure 7-79. Design Chart Based on Troost B-4.70 Series Data

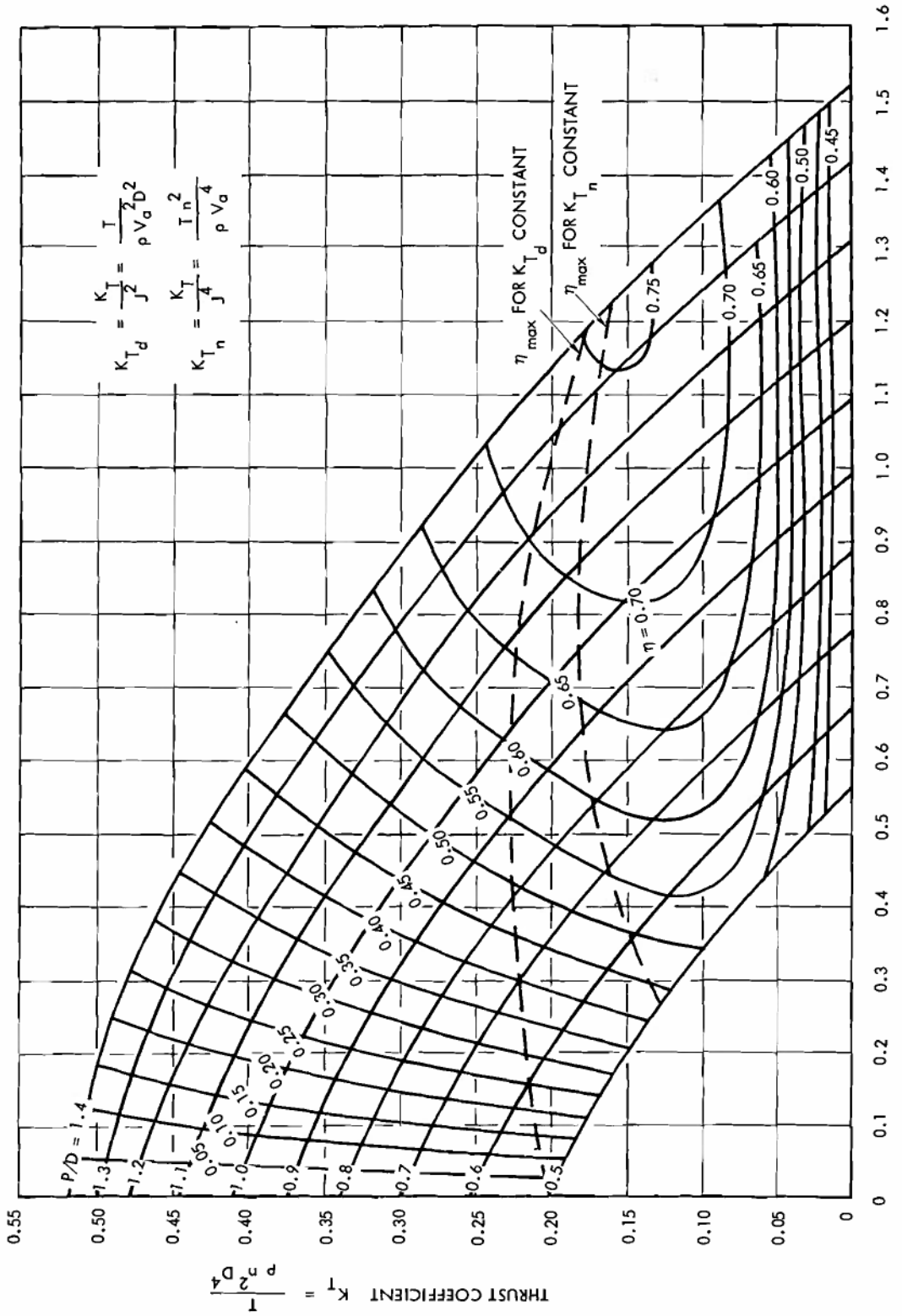


Figure 7-80. Design Chart Based on Troost B-5.45 Series Data

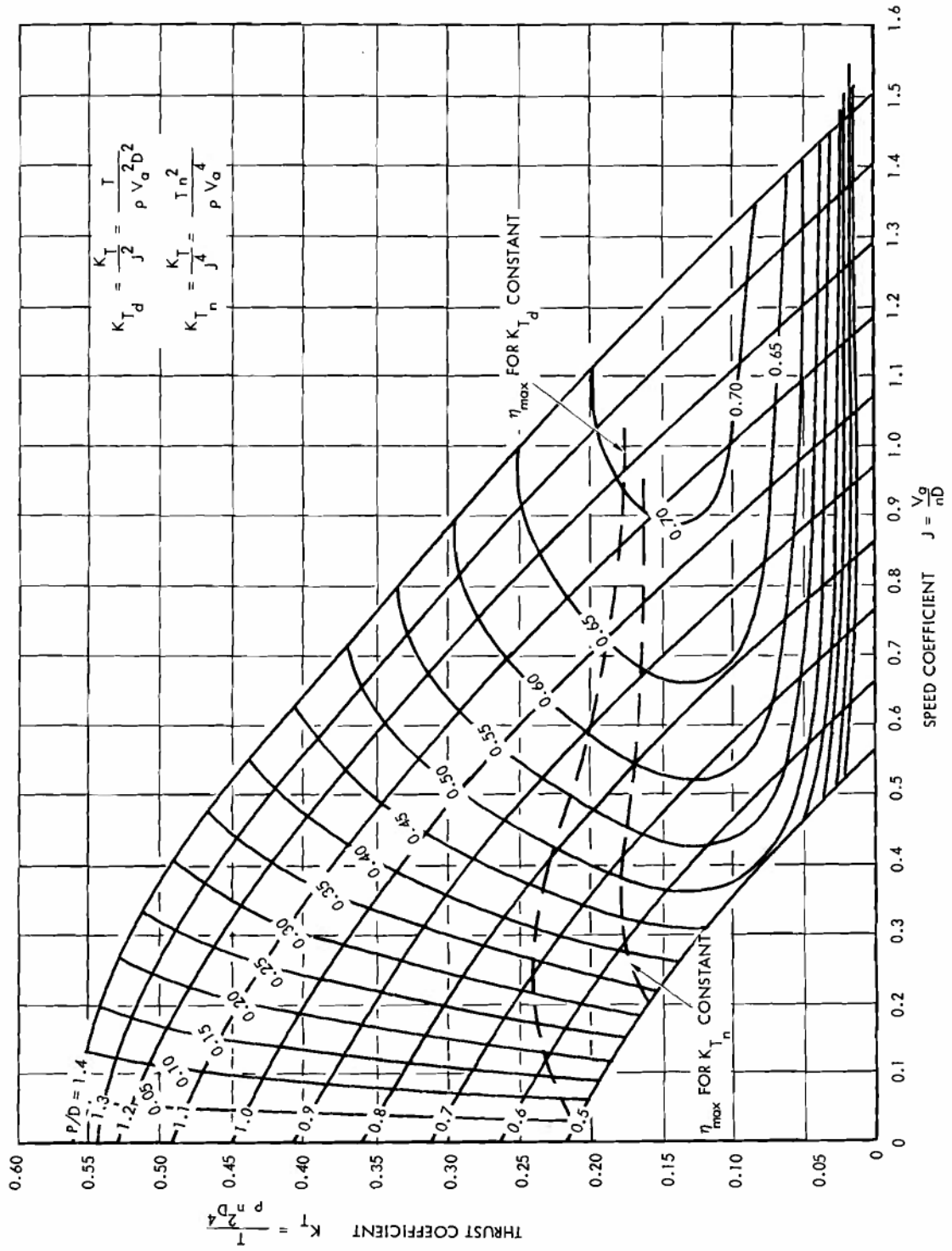


Figure 7-81. Design Chart Based on Troost B-5.60 Series Data

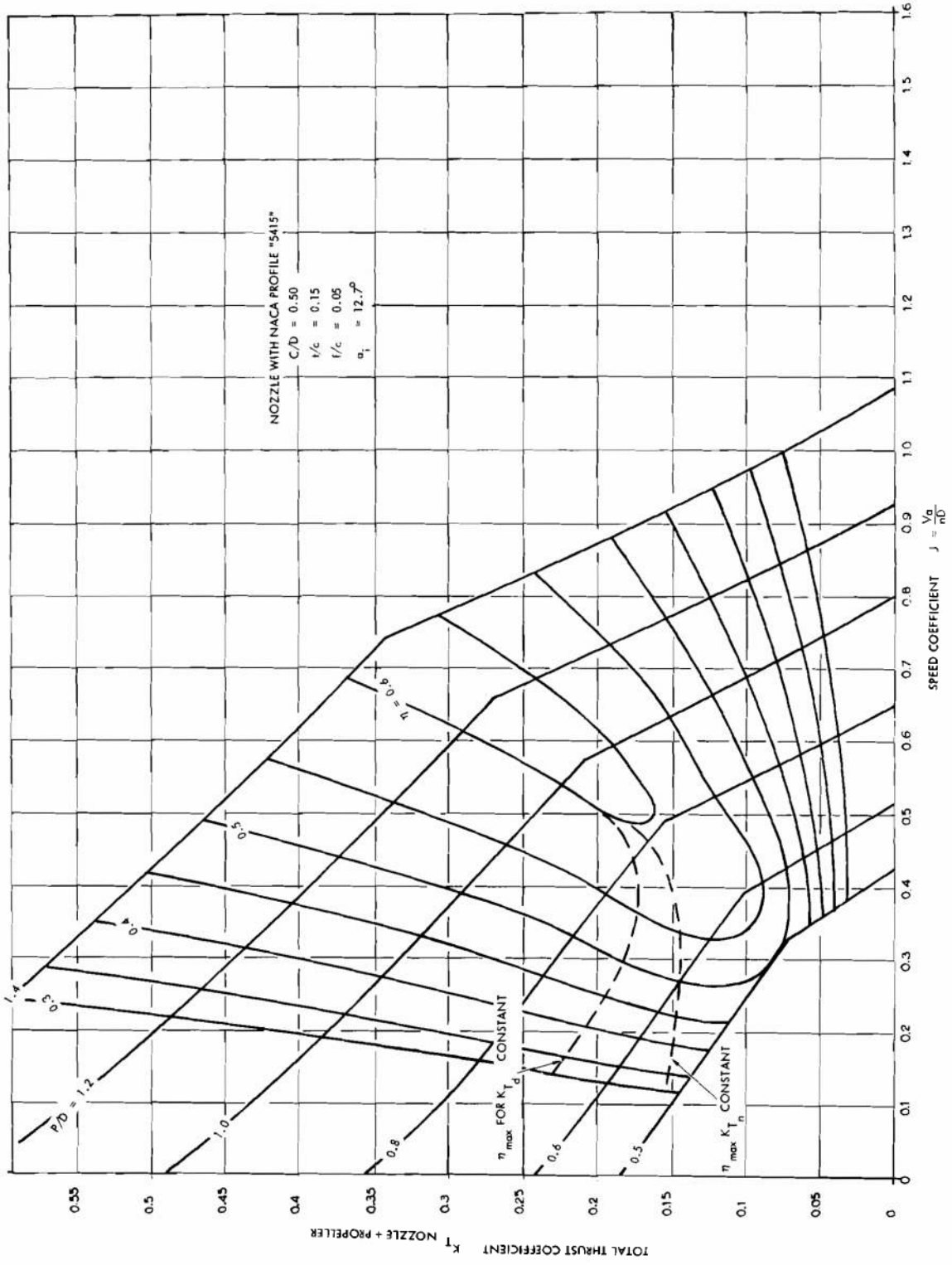


Figure 7-82. Design Chart for Troost B-3.50 Screw in Nozzle

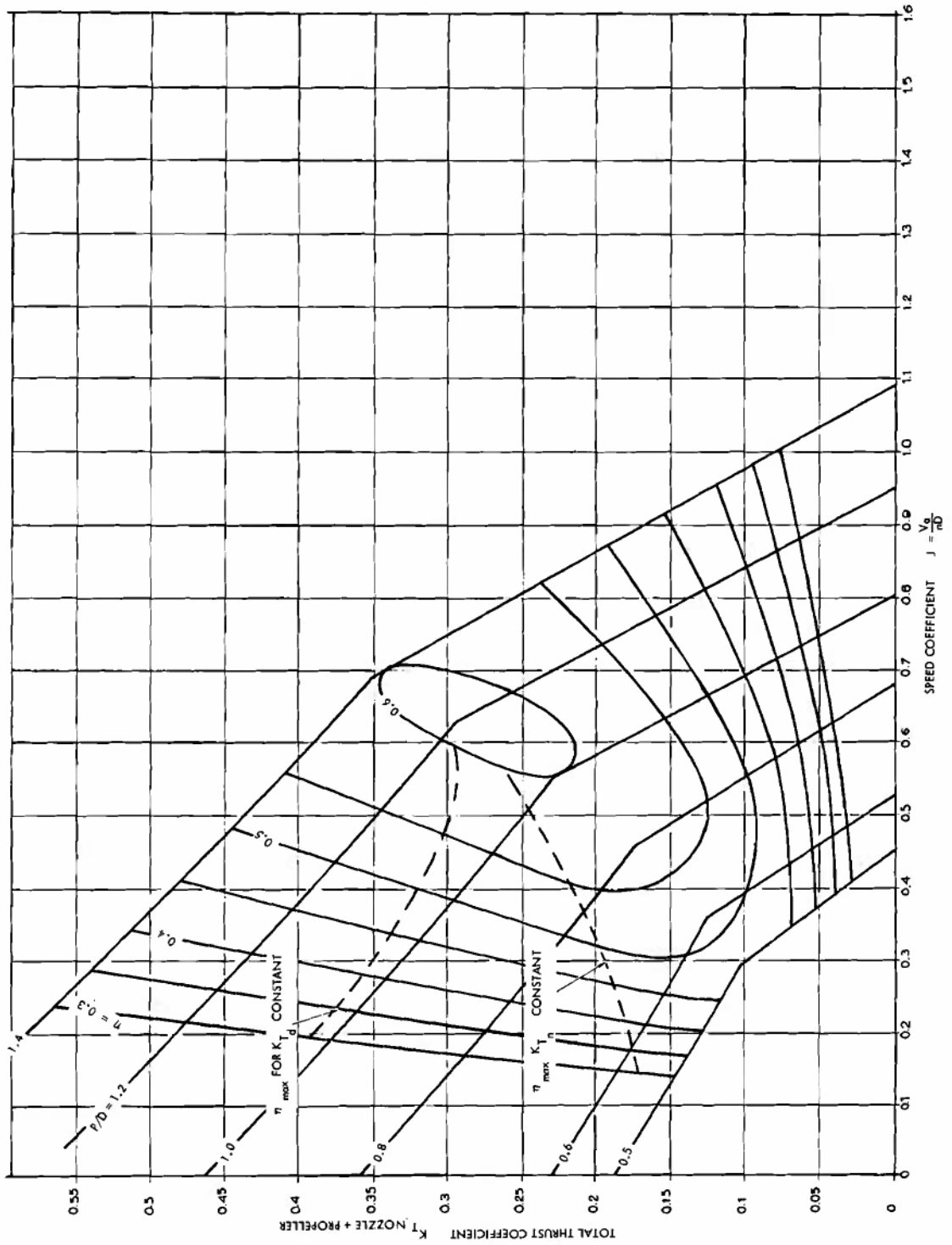


Figure 7-83. Design Chart for Troost B-4.40 Screw in Nozzle

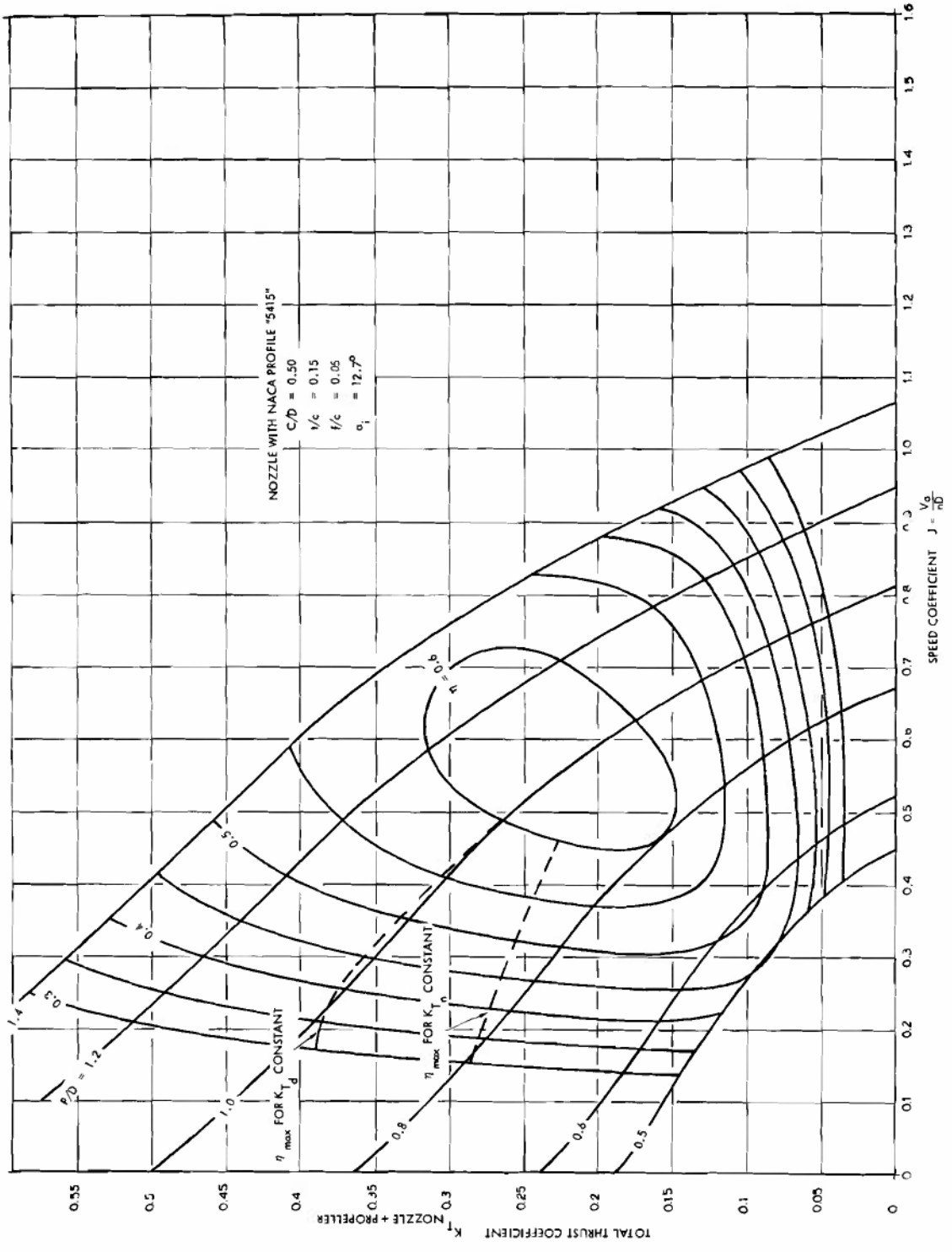


Figure 7-84. Design Chart for Troost B-4.55 Screw in Nozzle

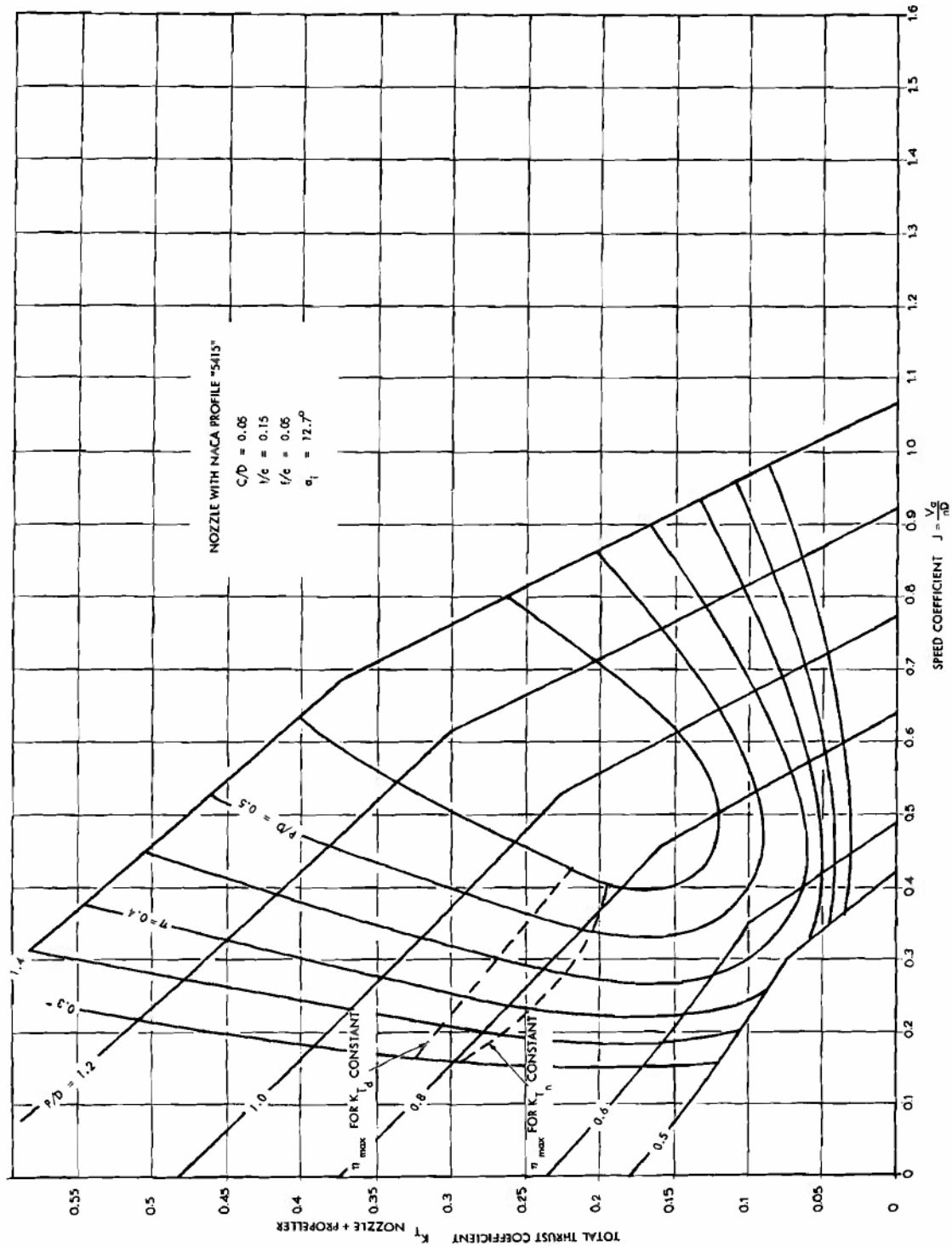


Figure 7-85. Design Chart for Troost B-4.70 Screw in Nozzle

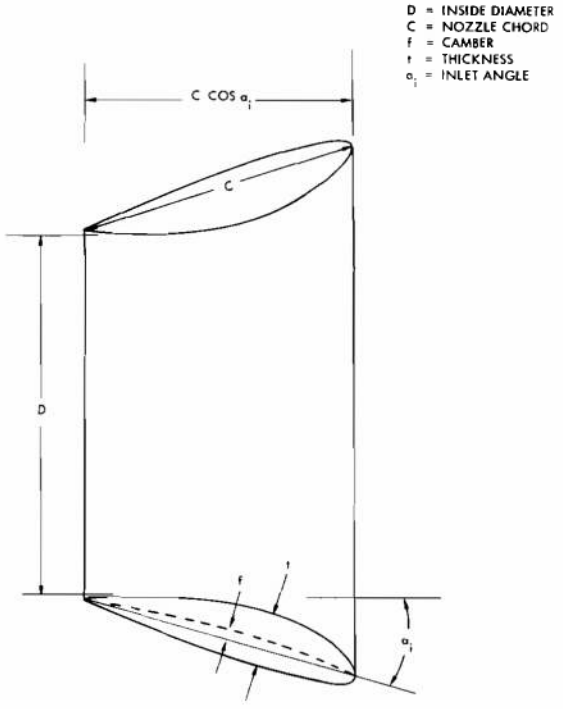


Figure 7-86. Nozzle Definition Sketch

Problem: To find the optimum diameter of the propeller.

Analysis: a. The coefficient K_{T_n} is calculated from the definition

$$K_{T_n} = \frac{K_T}{J^4} = \frac{T_n^2}{\rho V_a^2} = \frac{R\,n^2}{\rho(1-t)(1-w)^4 V_s^4} \qquad (7\text{-}97)$$

where units are consistent so that K_{T_n} is dimensionless.

A fourth order parabola is drawn from $K_T = J^4 K_{T_n}$ and the intersection with the "η_{max} for K_T constant" curve determines the design point.

b. The diameter is calculated from the value of J read off:

$$D = \frac{V_s\,(1-w)}{Jn}\ ,\ \text{ft} \qquad (7\text{-}98)$$

Delivered power is calculated by Eq. 7-96.

Problem No. 3

Given: The delivered power *DHP* at design rpm are specified for a particular engine. Diameter is fixed and resistance R is given as a function of ship speed. The hull factors t, w, and η_r are also given as functions of speed.

Problem: To find the pitch, efficiency, and highest speed obtainable under the given conditions.

Analysis: a. K_T and J are calculated for several speeds

$$J = \frac{V_s(1-w)}{nD} = \frac{V_a}{nD}\ ,\ \text{nd} \qquad (7\text{-}99)$$

$$K_{T_{(1)}} = \frac{R}{\rho(1-t)n^2D^4} = \frac{T}{\rho n^2 D^4}\ ,\ \text{nd} \qquad (7\text{-}100)$$

b. A point is plotted for each set of K_T and J on the appropriate design chart, and corresponding values of efficiency η_o are found by interpolation. These values are used to calculate K_T for each speed from the relation

$$K_{T_{(2)}} = \frac{DHP\ 550\ \eta_r\eta_o}{V_s(1-w)\rho n^2 D^4}\ ,\ \text{nd} \qquad (7\text{-}101)$$

c. Values of K_T are also plotted with corresponding values of J and curves are drawn through points of $K_{T_{(1)}}$ and $K_{T_{(2)}}$ (see Figs. 7-74 through 7-85). The intersection of these two curves determines the design point. The pitch ratio and efficiency at the design point are found by interpolation. The ship speed is calculated from the speed coefficient J at the design point.

7-7.5.3 Cavitation Diagram

The cavitation diagram, Fig. 7-87, is taken from Ref. 86. The data are for screws designed according to vortex theory. However a 25 percent safety margin has been applied to the data so that the chart is conservative and may be used for an approximate determination of the area ratio EAR (A_E/A in the diagram) for screws of the Troost B-Series. The cavitation number in this diagram is the section cavitation number (plus 25% allowance) at the 0.8 radius at minimum immersion using the dynamic pressure q at the section, thus

$$\sigma_{0.8} = \frac{P_{0.8} - p_v}{q_{0.8}} = \frac{P_{0.8} - p_v}{\tfrac{1}{2}(\rho V_a^2)\left[1 + \left(\frac{2.51}{J}\right)^2\right]}\ ,\ \text{nd} \qquad (7\text{-}102)$$

where

$$q_{0.8} = \tfrac{1}{2}\left(\rho V_a^2\right)\left[1+\left(\frac{2.51}{J}\right)^2\right]$$

The ordinate is the thrust normalized by the projected blade area A_p and the resultant velocity at the 0.8 radius:

$$\frac{T}{A_p q_{0.8}} = \frac{T}{\tfrac{1}{2}(\rho V_a^2)\left[1+\left(\frac{2.51}{J}\right)^2\right]A_p}, \text{ nd} \qquad (7\text{-}103)$$

The projected area A_p is related to the expanded area A_E by the approximate relation

$$A_p \approx A_E(1.067 - 0.229\,P/D), \text{ ft}^2 \qquad (7\text{-}104)$$

Eqs. 7-102 and 7-103 are used to plot a point on Fig. 7-87. If the point falls above the upper limit (Burrill line for heavily-loaded propellers), the area A_p must be increased by an increase in diameter and/or expanded area ratio EAR. If the point falls below the Burrill line and on the right side of the appropriate data, the propeller will be free of cavitation.

This cavitation diagram should not be considered as a design chart because it does not provide a unique solution for any given problem. The chart should be used as a check on cavitation in the design procedure. The Burrill line may be used to estimate the minimum projected area from values of thrust T, advance speed V_a, and estimates of the speed coefficient J.

The thrust deduction and wake factor of the nozzle must first be calculated in order to use the cavitation diagram for shrouded propellers. Figs. 7-88 to 7-91 given the thrust produced by the nozzle for the propeller-nozzle combinations in Figs. 7-82 to 7-85. The speed coefficient J, pitch ratio P/D, and thrust coefficient K_T for the nozzle + propeller are taken from the design point and the thrust coefficient produced by the nozzle is read at corresponding J and P/D. The nozzle thrust deduction θ_n is then calculated:

$$1 - \theta_n = \frac{K_{T\ nozzle\ +\ propeller}}{K_{T\ propeller}} \qquad (7\text{-}105)$$

where

$$K_{T_{propeller}} = K_{T_{nozzle\ +\ propeller}} - K_{T_{nozzle}}$$

The value of $K_{T_{propeller}}$ is then entered (with the pitch ratio) into the appropriate open water characteristic curve (Figs. 7-73 to 7-81) to find $J_{open\ water}$. With this value, the nozzle wake fraction Ψ_n is calculated:

$$1 - \Psi_n = \frac{J_{open\ water}}{J} \qquad (7\text{-}106)$$

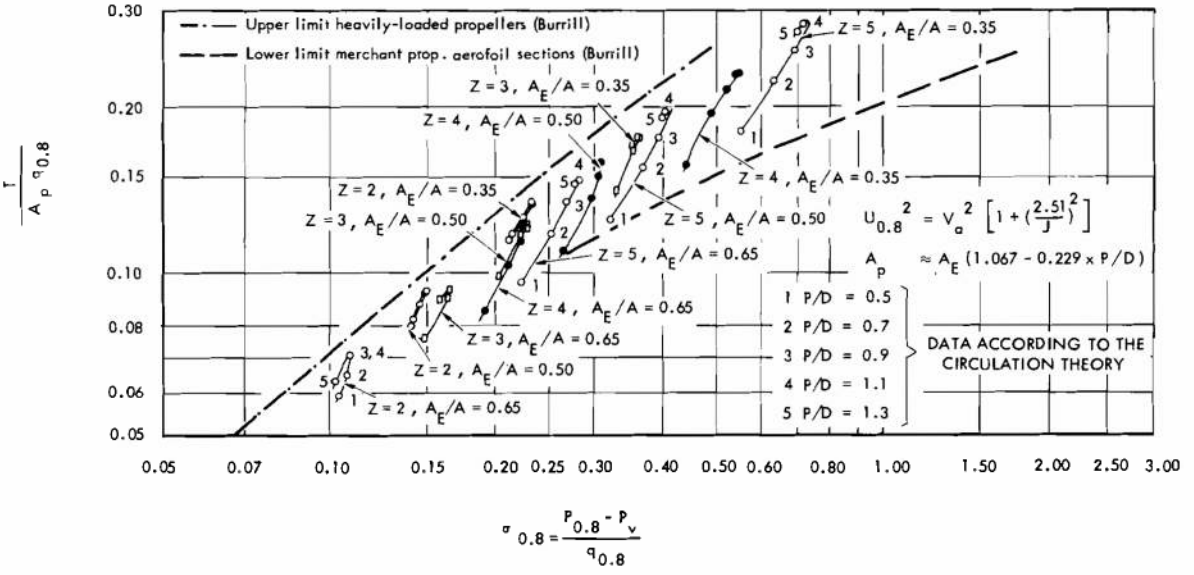


Figure 7-87. Cavitation Diagram for Screw Designed According to the Circulation Theory for a Homogeneous Velocity Field

Now we can enter the cavitation diagram, Fig. 7-87, with the values of

$$\frac{T}{q_{0.8}A_p(1-\theta_n)} \text{ and } \frac{P_{0.8}-p_v}{q_{0.8}} \qquad (7\text{-}107)$$

where

$$q_{0.8} = \tfrac{1}{2}(\rho V_a^2)\left[(1-\Psi_n)^2 + \left(\frac{2.51}{J}\right)^2\right] \qquad (7\text{-}108)$$

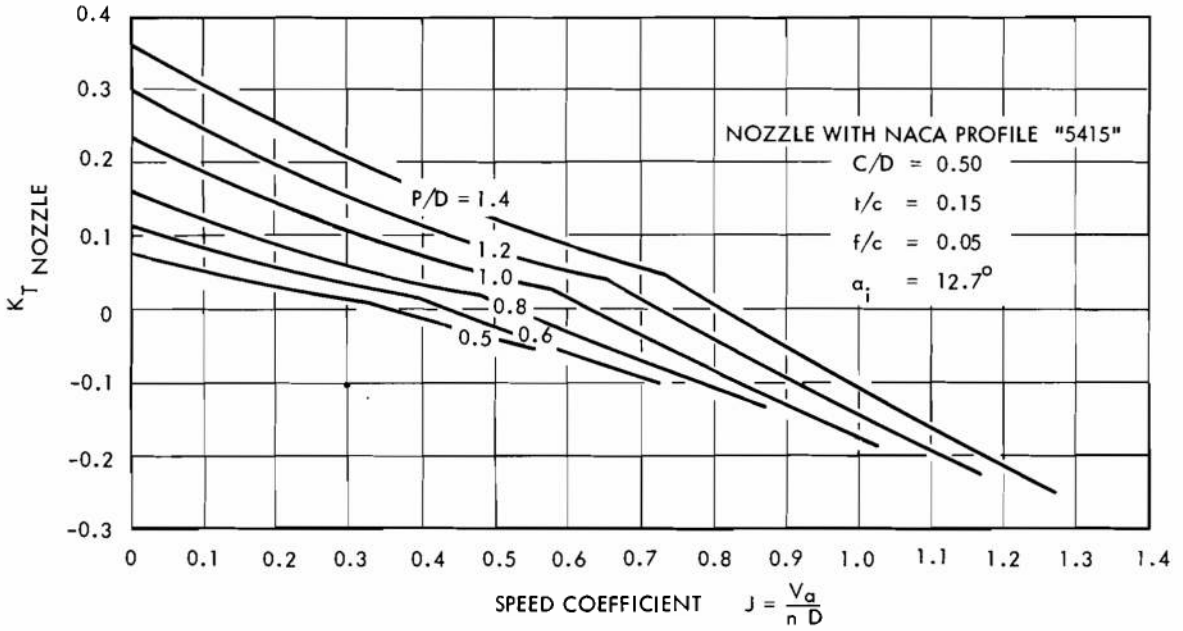


Figure 7-88. Axial Force on Nozzle With the B-3.50 Screw Series

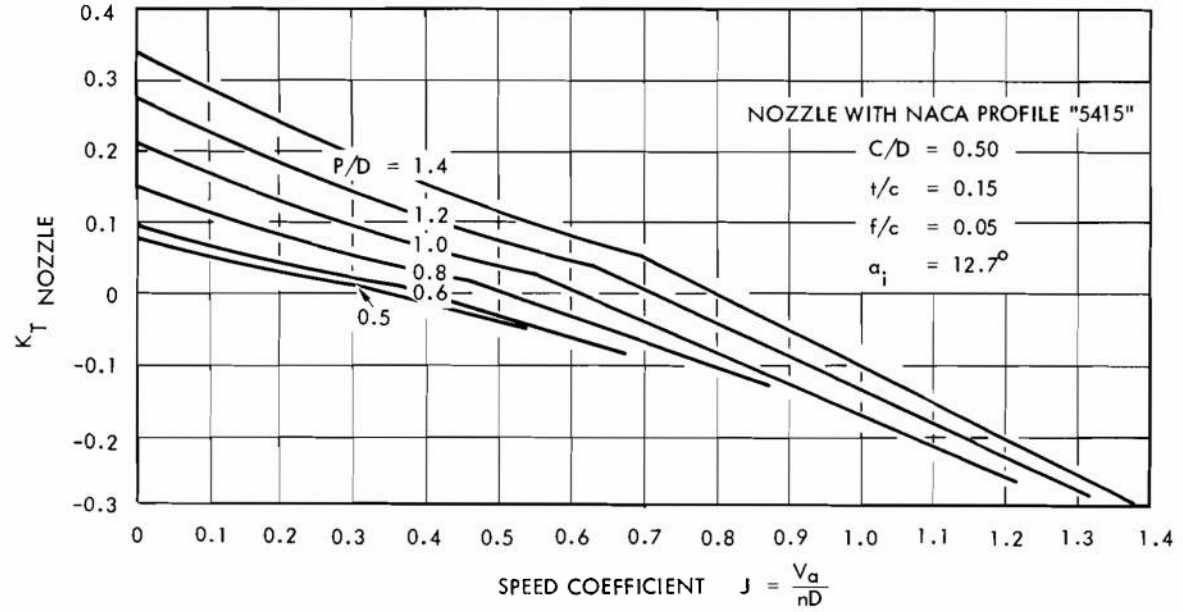


Figure 7-89. Axial Force on Nozzle With the B-4.40 Screw Series

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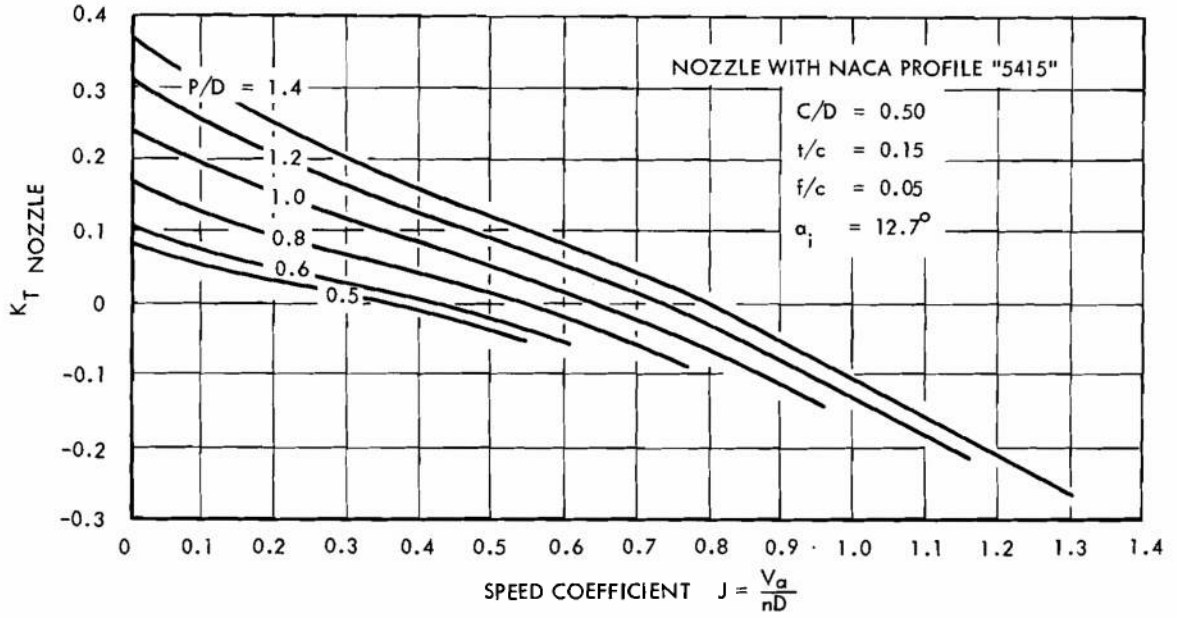

Figure 7-90. Axial Force on Nozzle With the B-4.55 Screw Series

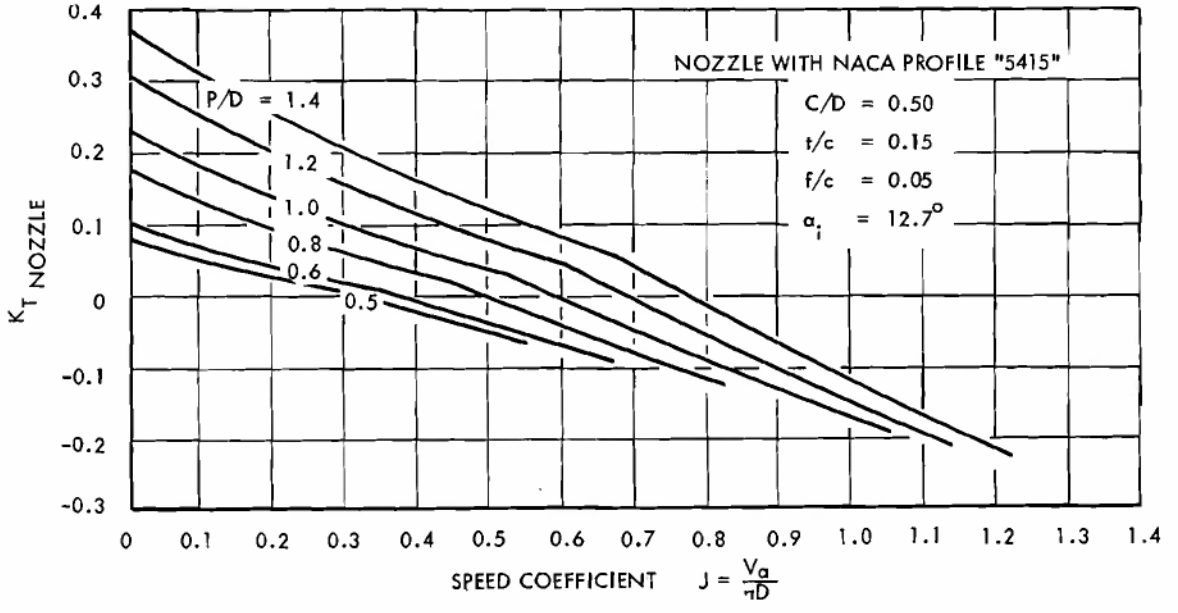

Figure 7-91. Axial Force on Nozzle With the B-4.70 Screw Series

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7-7.5.4 Strength

The propeller must have sufficient strength to stand up under normal service conditions. It is important that the minimum blade thickness for adequate strength be chosen from a standpoint of efficiency and weight. It is common practice to calculate the thickness at a typical section near the root and use a linear thickness distribution between this section and the blade tip to determine the thickness at any section (the thickness of any section is defined as the thickness at the point of maximum thickness of that section profile). Some reduction in weight may be realized by making strength calculations at a number of sections to determine the minimum allowable thickness at each section.

The formula which follows is found in the American Bureau of Shipping (ABS) Rules. The derivation of this formula is given in Ref. 88. It is used to calculate the minimum acceptable thickness at the 25 percent radius. The nomenclature used in the ABS Rules is not consistent with this handbook. However, ABS symbols have been retained for this formula.

$$t = 41\left(\frac{AH}{BRN}\right)^{1/3} \pm \frac{1.72CK}{B} \qquad (7\text{-}109)$$

where

t = thickness of blade at one-quarter radius, in.
H = SHP at maximum continuous rating, hp
R = rpm at maximum continuous rating
N = number of blades
$P_{0.25}$ = pitch at one-quarter radius divided by propeller diameter, nd
$P_{0.7}$ = pitch at seven-tenths radius divided by propeller diameter, nd
W = width of blade at one-quarter radius, in.
a = expanded blade area divided by disc area, nd
D = propeller diameter, ft
K = rake of propeller blade, in./ft, multiplied by $D/2$ (with forward rake, use minus sign in formula; with aft rake, use plus sign), in.

$$A = 1.0 + \frac{6.0}{P_{0.7}} + 4.3P_{0.25}$$

$$B = (1 + 1.5P_{0.25})(Wf - C)$$

$$C = \frac{4300Wa}{N}\left(\frac{R}{100}\right)^2\left(\frac{D}{20}\right)^3$$

f,w = material constants from Table 7-43.

TABLE 7-43. REPRESENTATIVE PROPELLER MATERIALS

		f	w
Type 1	Manganese bronze	68	0.30
Type 2	Nickel-manganese bronze	73	0.29
Type 3	Nickel-aluminum bronze	85	0.27
Type 4	Manganese-nickel-aluminum bronze	85	0.27
Type 5	Cast iron	25	0.26

For an example, consider a cast iron Troost B-4.55 series propeller with 3.0 ft diameter and 3.0 ft pitch turning 400 rpm at an advance speed of 13.7 fps (9.3 mph). The calculations are made as follows:

$$J = \frac{V_a}{nD} = \frac{13.7}{3.0\left(\frac{400}{60}\right)} = 0.687$$

$P/D = 3.0/3.0 = 1.0$

$K_T = 0.19$
$\eta_o = 0.65$
} Read off Fig. 7-78

$$K_Q = \frac{K_t J}{\eta_o 2\pi} = \frac{(0.19)(0.687)}{(0.65)2\pi} = 0.032$$

$\rho = 1.99$, slug/ft^3 (salt water)

$$H = \frac{2\pi Qn}{550} = \frac{2\pi K_Q n^3 D^5 \rho}{550}$$

$$= \frac{2\pi(0.032)\left(\frac{400}{60}\right)^3 3^5(1.99)}{550} = 52.5 \text{ hp}$$

$R = 400$ rpm

$N = 4$

$P_{0.25} = 0.855$ from Fig. 7-72

$P_{0.7} = 1.0$

$a = 0.55$

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W = 12 (factor for 0.25 radius) a (factor for 4-blades) D
= 12 (0.793) 0.55 (0.547) 3.0 = 8.6, in. (from Table 7-42)

$$K = 12 (\tan 15°) \frac{3.0}{2} = 4.83$$

$$A = 1.0 + \frac{6.0}{1.0} + 4.3(0.855) = 10.68$$

$$C = \frac{4300}{400} (0.26)0.55\left(\frac{400}{100}\right)^2\left(\frac{3}{20}\right)^3 = 0.082$$

$$B = [1 + (1.5 \times 0.855)][(8.6)25 - 0.082] = 490$$

$$t = 41\left[\frac{(10.68)52.5}{490(400)4}\right]^{1/4} + \frac{1.72(0.082)4.83}{490}$$

$$= 1.10$$

$$(t/D)_{0.25} = \frac{1.10}{36} = 0.031$$

With linear thickness distribution, the thickness at any section can be calculated from the thickness at the blade tip $t_{1.0}$ and hub center t_o.

$$t_{r/R} = t_{1.0}(r/R) + t_o(1 - r/R) \qquad (7\text{-}110)$$

where
r = section radius
R = propeller radius

Assuming the tip thickness $t_{1.0}$ to be 0.3 percent of the diameter, the blade thickness fraction $BTF = (t/D)_o$ of the propeller is

$$BTF = \frac{t_{0.25} - r/R\ t_{1.0}}{D(1 - r/R)} = \frac{0.031 - 0.25(0.003)}{0.75}$$

$$= 0.040$$

This is slightly below the standard thickness ($0.045D$) for Troost B-Series four-bladed propellers.

Any increase in the blade thickness for Troost B propellers (over the values given in Table 7-41) should be accompanied by decreases in the pitch and efficiency. As a rule of thumb, the pitch ratio P/D and efficiency η should be reduced by a factor of 0.1 and 0.5, respectively, times the increase in thickness $\Delta t/t$. Thus, if thickness were increased by 40 percent, pitch should be reduced by 4 percent and efficiency by 2 percent.

7-7.5.5 Towing or Overload Conditions

After a propeller has been chosen for the design point of the amphibian, it may be desired to estimate the speed at which a disabled sister ship might be towed or the reduction in speed due to fouling of the hull. The engine characteristics and loading must be given, i.e., available horsepower as a function of rpm and the total drag as a function of ship speed. The wake fraction and thrust deduction may be affected by fouling and thrust loading, respectively. Estimates of these effects should be made. With this information, the following procedures can be executed. An auxiliary plot of $K_{T_d} = K_T/J^2$ versus J can be made from the open water characteristics of the propeller in question. It will be convenient to use semi-log paper for this curve. Now, several values of speed are selected over the range of the expected solution and K_{T_d} is calculated at each value from Eq. 7-94. The auxiliary plot is entered to find J and, hence, rotative speed n for each speed. The open water efficiency is found for each speed from the corresponding value of J entered in the characteristic curves. Propulsive efficiencies ($\eta_p = \eta_o \eta_h \eta_r$) are computed and then the required delivered horsepower DHP:

$$DHP = \frac{R_T V_s}{550\eta_p}, \text{ hp} \qquad (7\text{-}111)$$

where
R_T = total resistance, lb
V_s = ship speed, ft/sec

Finally, a plot is made with speed, required DHP, and available horsepower as functions of rotative speed n. The desired speed corresponds to the point n at which the two horsepower curves cross.

Some minimum static thrust or bollard pull produced by the propulsor may also be required. The static thrust (thrust at zero advance speed) of a propulsion system is a function of both the engine and propulsor characteristics. Their torque characteristics, together, determine the maximum rpm which can be attained with zero advance speed and thus the power absorbed in this condition. The bollard pull is a function of

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the static thrust, and the interaction of hull and propulsor given by the zero speed thrust deduction. A simple test may be included with model self-propulsion tests to determine both the propeller thrust and the bollard pull. Otherwise, the propeller open water characteristics may be used to estimate the static thrust as follows. The thrust and torque coefficients (K_{T_s} and K_{Q_s}) are obtained from the characteristics curves at $J = 0$. Torque is plotted as a function of rpm from the relation

$$Q_s = (\rho K_{Q_s} D^5) n^2, \text{ ft-lb} \qquad (7\text{-}112)$$

The engine torque curve is also plotted, and the intersection of the two lines gives the desired torque which is used to calculate the static thrust T_s

$$T_s = \frac{K_{T_s} Q_s (1 - t_s)}{K_{Q_s} D}, \text{ lb} \qquad (7\text{-}113)$$

where t_s = estimated zero speed thrust deduction.

7-7.5.6 Astern Thrust

Astern thrust is important for maneuvering and stopping. The reach (stopping distance) of a vessel is a function of both the propeller characteristics and the engine-transmission characteristics. Propeller characteristics for a model series operating both ahead and astern are reported in Ref. 89. An analytical method for calculating the reach is presented in Ref. 90. It should be noted that these calculations are rather complex. Consideration might be given to including stopping tests with the self-propulsion studies. At any rate, while a short reach is desirable, the stopping distance of the amphibian is not generally given as a design requirement.

7-7.5.7 Service Allowance

The service shaft horsepower is the power required to maintain an average (design) speed over a long period of time (life of the vessel). It is the power predicted from the model tests augmented by a percentage known as the service allowance. It includes the power necessary to offset the effects of wind and waves, rolling, random steering about the straightline course, fouling of the bottom, and losses in propeller efficiency due to increased loading and roughening of the blades. The service allowance is like a factor of safety. A good value for the service allowance for amphibians is around 25 percent. This value may be modified with increased design experience.

7-7.5.8 Numerical Examples

(1) Given:

Design Speed V_s	=	9 mph (13.2 ft/sec)
Resistance R_T	=	2,900 lb
Diameter D	=	2.5 ft
$1 - t$	=	0.65; thrust deduction $t = 0.35$
$1 - w$	=	0.75; wake fraction $w = 0.25$
η_r	=	0.96
ρ	=	1.99 slug/ft^3

Find: Optimum rpm, pitch, and required horsepower for a B-4.55 propellerr(4-bladed with $EAR = 0.55$)

a. From: Eq. 8-94:

$$K_{T_d} = \frac{2900}{1.99(0.65)(0.75)^2(13.2)^2(2.5)^2} = 3.62$$

$K_T = K_{T_d} J^2$ so a parabola may be constructed on Fig. 7-78.

Points for parabola:

J	K_T
0.2	0.145
0.25	0.226
0.3	0.326
0.35	0.445

At the intersection of the parabola and the curve "η_{max} for K_{T_d} constant" read off the following design information.

Design Point:

K_T	= 0.255
J	= 0.265
η_o	= 0.33
P/D	= 0.778 (Pitch = 1.94 ft)

b. Eq. 7-95 yields,

$$n = \frac{13.22(0.75)}{0.265(2.5)} = 15.0 \text{ rps} \quad (900 \text{ rpm})$$

c. Eq. 7-96:

$$DHP = \frac{2900(0.75)13.2}{(0.65)0.96(0.33)550} = 254 \text{ hp}$$

Cavitation check

Assume depth of 1.0 ft at 0.8 radius, then

$P_{0.8} = P_{atmospheric} + P_{head}$
$= 2116 + 64 = 2180 \text{ lb/ft}^2$

$p_v = 0.98\,(0.25)\,144$
$= 35 \text{ lb/ft}^2$ (salt water at 59° F, Table 7-40)

From Eq. 7-102,

$$q_{0.8} = \tfrac{1}{2}\rho V_a^2 \left[1 + \left(\frac{2.51}{J}\right)^2\right]$$

$$= \frac{1.99}{2}\,[13.2*(0.75)]^2 \left[1 + \left(\frac{2.51}{0.265}\right)^2\right]$$

$$= 8{,}840 \text{ lb/ft}^2$$

*Note, $V_a = V_s\,(1 - w)$
Eq. 7-102:

$$\sigma_{0.8} = \frac{2180 - 35}{8{,}840} = 0.243$$

$$A_E = \left(\frac{\pi D^2}{4}\right) EAR$$

From Eq. 7-104

$$A_p \approx \frac{\pi(2.5)^2\ 0.55}{4}\ [(1.067 - 0.229)\ (0.778)]$$

(since $EAR = 0.55$ as given)

$$\approx 2.7(0.887) \approx 2.39 \text{ ft}^2$$

$$T = \frac{2900}{(1 - t)} = \frac{2900}{0.65}$$

Eq. 7-103:

$$\frac{T}{q_{0.8} A_p} = \frac{2900}{(0.65)8{,}840(2.39)} = 0.213$$

Plotting this point $[\sigma_{0.8}\ T/(q_{0.8}\ A_p)]$, i.e., (0.243, 0.213) on Fig. 7-87 shows that this design lies above this limit for heavily loaded propellers and, therefore, an increase in EAR is in order. $T/q_{0.8}\ A_p$ should be reduced to about 0.14 to insure cavitation-free operation. Thus, the expanded area ratio EAR should be increased to about $(0.213/0.14)\ 0.55 \approx 0.85$ and the design cycle repeated. The changes in rpm, pitch, and power should be small.

(2) Given:

Design Speed V_s	=	7.5 mph (11.0 ft/sec)
Resistance R_T	=	4,200 lb
Diameter D	=	2.5 ft
rpm	=	900 (15 rps)
$1 - t$	=	0.75
$1 - w$	=	0.80
η_r	=	1.0

Find: Optimum diameter, pitch, and required horsepower for a shrouded B-455 propeller (nozzle characteristics the same as in Fig. 7-84) with $EAR = 0.55$

a. From Eq. 7-97

$$K_{T_n} = \frac{4200(15)^2}{1.99(0.75)(0.80)^4(11.0)^4} = 105.5$$

Since $K_T = K_{T_n} J^4$, we can construct a 4th order parabola on Fig. 7-84.

Points for parabola:

J	K_T
0.2	0.169
0.22	0.248
0.24	0.350

At the intersection of this parabola read off the following information at the curve "η_{max} for K_{T_n} constant", design point

$K_{T_{nozzle\ +\ propeller}} = 0.274$

$\eta_o = 0.40$

$J = 0.226$

$P/D = 0.82$

b.

$$D = \frac{V_a}{nJ} = \frac{V_s(1 - w)}{nJ} = \frac{11.0(0.80)}{15.0(0.226)}$$

$= 2.6$, ft

(since $V_a = V_s(1 - w)$ by Eq. 7-82)

$P = (0.82)2.6 = 2.10$, ft

c. Eq. 7-96:

$$DHP = \frac{4200(0.80)11.0}{0.75(1.0)0.40(550)} = 280 \text{ hp}$$

Cavitation check

Since the propeller is in a nozzle, the performance factors of the nozzle must first be determined from Fig. 7-90:

$$K_{T_{nozzle}} = 0.095$$

Eq. 7-105:

$$K_{T_{propeller}} = K_{T_{nozzle + propeller}} - K_{T_{nozzle}}$$

$$= 0.274 - 0.095 = 0.179$$

Eq. 7-105:

$$1 - \theta_n = \frac{K_{T_{nozzle + propeller}}}{K_{T_{propeller}}} = \frac{0.274}{0.179} = 1.53$$

Enter Fig. 7-88 with $K_T = 0.179$ and $P/D = 0.82$ to find:

$$J_{open\ water} = 0.50$$

Eq. 7-106:

$$1 - \Psi_n = \frac{0.50}{0.226} = 2.21$$

Eq. 7-108:

$$q_{0.8} = \frac{1.99}{2}[11.0(0.80)]^2\left[(2.21)^2 + \left(\frac{2.51}{0.226}\right)^2\right]$$

$$= 9{,}850 \text{ lb/ft}^2$$

Using the same values for stagnation pressure and vapor pressure as in the previous example,

Eq. 7-102:

$$\sigma_{0.8} = \frac{P_{0.8} - p_v}{q_{0.8}} = \frac{2{,}145}{9{,}850} = 0.218$$

Eq. 7-104:

$$A_p \approx A_E(1.067 - 0.229\,P/D)$$

$$\approx \pi\frac{(2.5)^2}{4}0.55\,[1.067 - 0.229(0.82)]$$

$$\approx 2.56 \text{ ft}^2$$

Eq. 7-108:

$$\frac{T}{q_{0.8}(1 - \theta_n)A_p} = \frac{4{,}200}{(0.75)9{,}850(1.53)2.56}$$

$$= 0.145$$

(since $T = R/(1 - t)$ by Eq. 7-83)

Once again, the point $[\sigma_{0.8}, T/[q_{0.8}(1 - \theta_n)A_p]]$, i.e., (0.218, 0.145) lies slightly above the upper limit in Fig. 7-87 indicating that a slight increase in blade area is in order if this type of propeller is used.

(3) Given: B-4.55 screw ($Z = 4$, $EAR = 0.55$)

Diameter = 2.5 ft

DHP = 130 at 700 rpm and the following data (from LARC V, Table 7-35)

Ship Speed, mph	7	8	9
ft/sec	10.3	11.7	13.2
Resistance, lb	1600	2340	2910
$1 - t$	1.09	1.09	1.08
$1 - w$	1.14	1.175	1.168
η_r	0.96	0.93	0.93

Find: Optimum pitch and highest possible speed. From Eqs. 7-99, 7-100, and 7-101 find corresponding values of:

J	0.402	0.474	0.530
$K_{T_{(1)}}$	0.139	0.203	0.254
η_o	0.515	0.530	0.535
$K_{T_{(2)}}$	0.285	0.241	0.218

Now, plot values of $K_{T_{(1)}}$ and $K_{T_{(2)}}$ on Fig. 7-78 versus J.

The intersection gives the design point at $J = 0.50$ and $P/D = 0.92$.

$$\text{Maximum speed } V_s = \frac{JnD}{(1 - w)} = 0.50\left(\frac{700}{60}\right)\frac{2.5}{1.17}$$

$$= 12.5 \text{ ft/sec} = 8.50 \text{ mph}$$

where $(1 - w)$ is found by interpolation

(4) Given: The same engine and propeller as in example (3) above. Assume engine torque is constant with respect to rpm.

$1 - t_s = 0.90$ (at zero ship speed)

Find: Static thrust and bollard pull.

with P/D = 0.92,

$K_{T_{J=0}}$ = 0.395 (from Fig. 7-78)

$K_{Q_{J=0}}$ = 0.50 (from Fig. 42 of Ref. 86)

$$Q = \frac{DHP\,550}{2\pi n} = \frac{130(60)550}{2\pi 700}$$

= 975 ft-lb

Eq. 7-113:

$$T_s = \frac{(0.395)975(0.90)}{(0.050)2.5}$$

= 2770 lb (bollard pull)

Eq. 7-112:

$$n = \left(\frac{975}{1.99(0.050)(2.5)^5}\right)^{1/2} = 10.0 \text{ rps}$$

(600 rpm)

Note that these estimates do not take into account the effect that the hull may have on the propeller inflow and hence, on rotative speed, and static thrust.

7-7.5.9 Geometry of the Screw Propeller (Drawings)

Standing behind a ship and looking forward, one sees the face (high-pressure surface) of the propeller blade. The other side is the back (low-pressure surface). These are both complex warped surfaces. In the simplest case the face lies on a helicoidal surface which is generated by a radial line rotating at constant velocity about an axis and simultaneously moving along this axis at a constant velocity (Fig. 7-92). The axial distance covered in one revolution is the pitch P. If the pitch is allowed to vary with radius, the surface is no longer a true helicoid. In Fig. 7-93 the pitch at the hub is less than at the tip and the pitch distribution is linear. The radial pitch distribution of a propeller, however, is not restricted to being constant nor linear.

Many propellers are designed so that the nose-tail line of each section lies on the reference helicoidal surface. In this case the pitch at each section is the true pitch of the propeller. In the case of the Troost series propellers, the face lies on the reference surface (the sections are "flat-faced") and the pitch of the face at each section is called the nominal pitch.

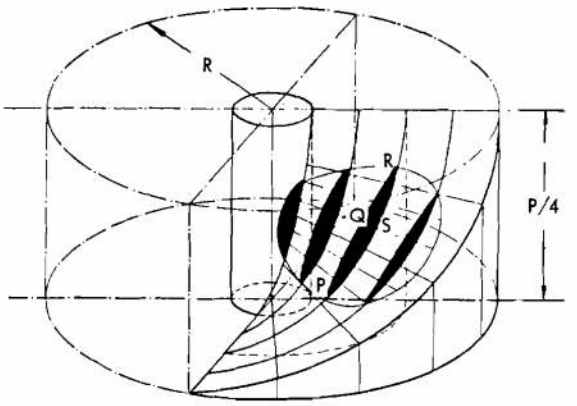

Figure 7-92. Helicoidal Surface With Constant Pitch

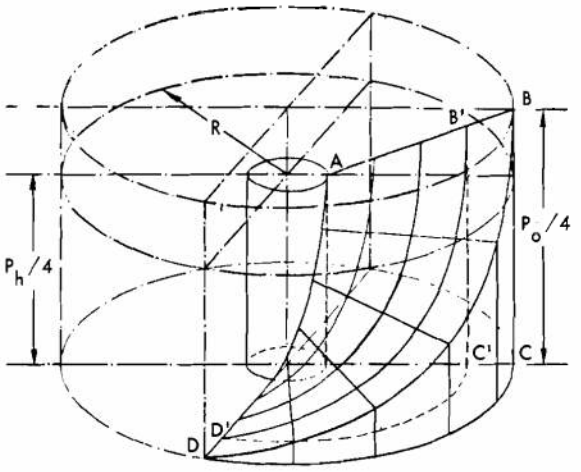

Figure 7-93. Helicoidal Surface With Radially Varying Pitch

Drawings of the propellers are restricted to plane surfaces, so certain conventions are used in delineating a propeller on paper. Two important reference lines are the screw axis and the generatrix (also called the blade reference line). The three projections of the blade show the actual outline of the propeller blade as viewed from above, the side, and from behind. The first projection is often omitted from propeller drawings. The projected area of the blade is the area enclosed by the projected outline in the second projection (see Fig. 7-94) exclusive of the hub.

The developed and expanded outlines are conventions which are imaginary in that they

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cannot be seen on an actual propeller. The developed outline is obtained by rotating each section about the generatrix so that the nose-tail line (or the nominal face pitch line) lies in the plane of the paper in the second projection. The angle of rotation for each section is the pitch angle θ_r of that section:

$$\theta_r = \mathrm{Tan}^{-1}\left(\frac{P_r}{2\pi r}\right) \qquad (7\text{-}114)$$

where

r = radius of the section, ft

P_r = pitch at that particular section, ft

The expanded outline is of greater importance and is generated by "unrolling" the developed sections into straight lines. The section shapes are drawn in the expanded outline at several radii. The expanded area A_E is simply the area enclosed by the expanded outlines of all the blades.

If the pitch is not constant, the radial variation is shown as in Fig. 7-72. A blade skew line and maximum thickness line are also seen in expanded outlines in this figure. The projected outline is omitted from the third projection in this figure which merely shows the radial distribution of maximum thickness and the extent of blade rake.

7-7.6 MODEL TESTS

Model propeller testing is an important phase in the design of any ship. Open water tests are used to confirm the propulsion characteristics predicted by a detailed design study. Design charts are based on the test results for a series of models. Self-propulsion tests are required to find the hull efficiency η_h of the propeller-hull combination in cases where past experience does not provide sufficient data to make a good estimate. Cavitation testing may be indicated for designs requiring quiet operation, freedom from cavitation damage, or where heavy loadings may result in thrust breakdown.

There are many factors which favor model testing over full scale or prototype testing in the early stages of a design. Eventually, of course, a prototype vehicle must be tested to show that the performance requirements of the design have been fulfilled. Savings in both time and money are the main advantages afforded by scale model tests. In addition, unwanted effects from wind, waves, tides, etc., are avoided by testing under the controlled conditions of a towing tank. Dynamometry and data are more reliable and accurate in a controlled environment.

The scaling laws which apply to propeller model testing will be discussed before describing the various tests and their usage.

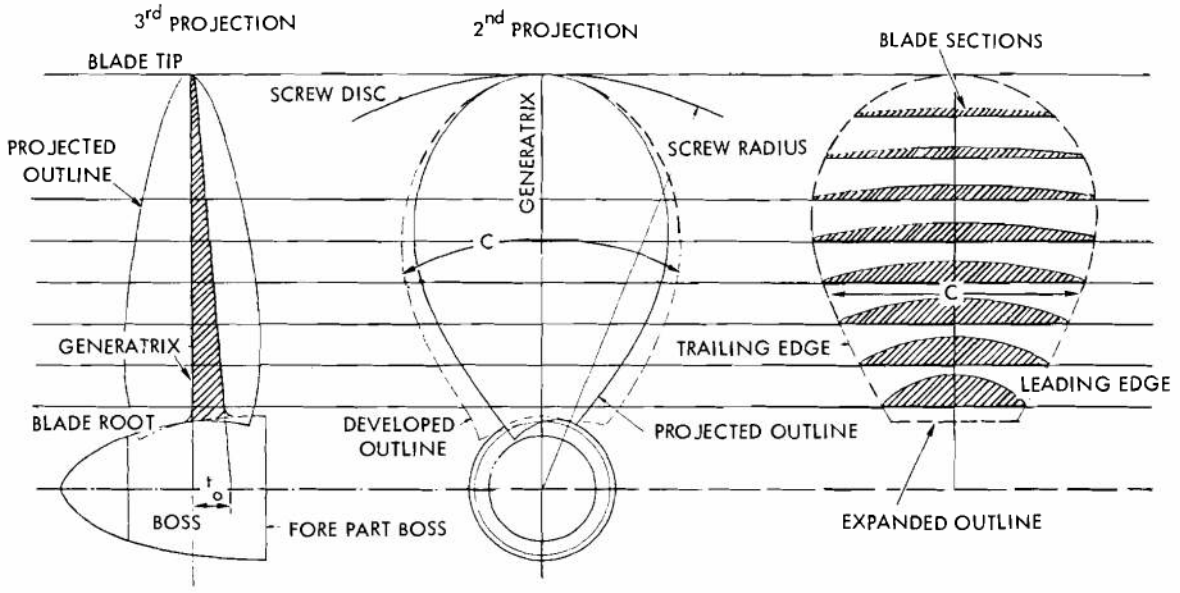

Figure 7-94. Various Projections of a Screw

7-7.6.1 Laws of Similitude

Propeller model tests are governed by laws of similitude or scaling laws in a similar manner to ship model tests. First, the model must be geometrically similar to the prototype propeller with all dimensions reduced by the scale ratio λ; thus the diameter is

$$D_m = D_p/\lambda \qquad (7\text{-}115)$$

where the subscripts m and p refer to model and prototype, respectively. The blade thickness, chord, pitch, etc., are all defined in the same manner. Dynamic similitude must be satisfied by operating the model at the same speed coefficient as the prorotype

$$\left(\frac{V_a}{nD}\right)_m = \left(\frac{V_a}{nD}\right)_p \qquad (7\text{-}116)$$

In order to completely satisfy the conditions for dynamic similitude, the ratio of inertia forces to friction forces and gravitation forces should be made constant by Reynolds scaling and Froude scaling. When the propeller is working at or near the water surface, gravitational forces become important so that the Froude number of the model must be the same as for the prototype, i.e.,

$$\text{Froude number } F_N = \left(\frac{V_a}{\sqrt{gD}}\right)_m = \left(\frac{V_a}{\sqrt{gD}}\right)_p, \text{ nd} \qquad (7\text{-}117)$$

where g = gravitational acceleration, ft/sec^2

Combining Eqs. 7-115 and 7-117 (with g constant) we obtain

$$V_{a_m} = V_{a_p}\sqrt{\lambda} \qquad (7\text{-}118)$$

Similarly, by equating the speed coefficients of model and prototype (Eq. 7-117) we deduce, with the aid of Eqs. 7-115 through 7-118, that

$$n_m = n_p\sqrt{\lambda} \qquad (7\text{-}119)$$

If, for example, one were testing a quarter scale semi-submerged propeller (λ = 4.0), he should run the model at twice prototype rpm (Eq. 7-119) and one-half the speed (Eq. 7-118) of advance of the prototype. In addition, the depth of submergence should be geometrically scaled. Thus, the restriction imposed by Froude scaling is not too serious so that model tests of surface propellers are practical. We shall see, however, that the conditions imposed by Reynolds scaling are not so easily satisfied. Generally, propellers operate deeply submerged so that gravitational forces are insignificant and Froude scaling (Eqs. 7-117 and 7-118) need not be applied in propeller tests.

The Reynolds number Re for a propeller may be written

$$Re = \frac{DV_a}{\nu} \qquad (7\text{-}120)$$

where ν is the kinematic viscosity, ft^2/sec.

To assure that the ratio of friction forces to inertia forces are the same for model and prototype, the Reynolds numbers must be equated. If the viscosity is held constant we can derive:

$$V_{a_m} = V_{a_p}\,\lambda \qquad (7\text{-}121)$$

and

$$n_m = n_p\,\lambda^2 \qquad (7\text{-}122)$$

These requirements are difficult if not impossible to fulfill in practice. If we take the same quarter scale model and apply Reynolds scaling, the propeller should be run at sixteen times prototype rpm and four times the advanced speed. It is customary in propeller model testing work to be satisfied with as near an approach to the theoretical requirement as is practical. To this end, the models are made large and tested at the highest speeds obtainable with the available equipment. Fortunately, blade friction has no appreciable influence on the propeller forces above a certain critical value (Ref. 67). Even when the test Reynolds number is below the critical value, the resulting "scale-effect" errors are small and conservative; predicted efficiencies from model tests will be on the low side.

The conclusion that blade friction is usually negligible simplifies matters considerably. In this case only the inertia forces are considered and the necessary condition for similitude, Eq. 7-116, becomes sufficient for dynamic similitude. If gravitational forces from free surface effects are involved; Froude scale, Eq. 7-117, must also be applied.

The laws of similitude must be extended in cases where the propeller is affected by cavitation. The cavitation number σ_o is modeled to assure similarity of the cavitation process (Eq. 7-93). Strictly speaking, Froude scaling should also be applied in this case because local cavitation number on a blade element varies with change in depth due to rotation. In practice, however, this refinement is overlooked with no sensible error being introduced.

7-7.6.2 Open Water Tests

Model propeller open water tests are generally conducted in towing tanks but may also be made in recirculating flow channels in which case the propeller rotates in a stationary plane and the water speed past the propeller determines the advance speed V_a. In a towing tank the propeller is supported by a horizontal drive shaft protruding from a streamlined housing attached to the towing carriage. The housing contains the dynamometer and the drive shaft is made sufficiently long so that the presence of the housing will not affect the inflow to the propeller which advances into undisturbed water. A streamlined fairwater is placed in front of the propeller hub.

Test runs are made over a range of speed coefficient J which is controlled by varying the towing carriage speed (advance speed) and/or the propeller rotative speed rpm. Thrust, torque, advance speed, and rpm are measured for each run. These data are then reduced to coefficient form and presented graphically as open water characteristic curves. The nondimensional coefficients which are most generally used are

$$\left.\begin{aligned} K_T &= \frac{T}{\rho n^2 D^4} \\ K_Q &= \frac{Q}{\rho n^2 D^5} \\ \eta_o &= \frac{TV_o}{2\pi Qn} = \frac{K_T J_o}{K_q 2\pi} \\ J_o &= \frac{V_o}{nd} \end{aligned}\right\} \quad (7\text{-}123)$$

where the subscript o is used to denote "open water".

The open water characteristics of a typical propeller are presented in Fig. 7-95. The curve for torque coefficient K_Q may be omitted in some presentations because it can be derived directly from the curves of thrust coefficient K_T and efficiency η_o.

7-7.6.3 Self-propulsion Tests

Self-propulsion tests are conducted to determine the interactions between the propeller and hull and in particular the wake fraction, thrust deduction, and relative rotative efficiency. An open water test of the propeller alone and a resistance test of the hull alone are required along with the self-propulsion test in order to obtain the desired results.

The model propeller is located in its proper position on the hull model with all the appendages. The model scale for the propeller and hull must, of course, be the same. An electric motor drives the propeller, and arrangements are made so that thrust, torque, and rpm can be measured. The hull is attached to the towing dynamometer in the same manner as for resistance tests.

The test is conducted as follows: (1) the towing carriage is brought up to the desired speed (Froude scaling), and (2) then the propeller rpm is adjusted until the drag force on the dynamometer is equal to a predetermined value D_f. The thrust, torque, and rpm are recorded. The dynamometer force D_f arises from the difference in friction resistance coefficient between model and prototype (Reynolds scaling effect—see par. 7-4.1.1.3). In practice, the effects of frictional resistance scaling for amphibian models have been neglected because the friction resistance is a small percentage (about 5 percent) of the total resistance. Hence, the dynamometer force for an amphibian self-propulsion test would be set at zero. For the determination of D_f in tests where Reynolds effects are important see Ref. 67, p. 146.

The thrust deduction t is found from a comparison of the measured thrust T necessary to propel the model at a given speed V_s and the resistance R of the hull alone at the same speed

$$(1 - t) = \frac{R}{T} \quad (7\text{-}124)$$

The efficiency of a propeller η_B behind a model hull generally differs from the efficiency

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NUMBER OF BLADES	3
EXP. AREA RATIO	0.559
MWR	0.393
BTF	0.039
P/D	0.804
DIAMETER	7.460 IN.
PITCH	6.000 IN.
ROTATION	R. H.
MAXIMUM HUB DIAMETER	2.51 IN.
MINIMUM HUB DIAMETER	1.66 IN.
HUB LENGTH	2.375 IN.

DESIGNED BY MICHIGAN WHEEL
An 8 - inch M - P type with hub built up by DTMB and diameter cut to 7.46 inches. The final dimensions are given above.

TESTED FOR LYCOMING DIVISION OF AVCO CORPORATION

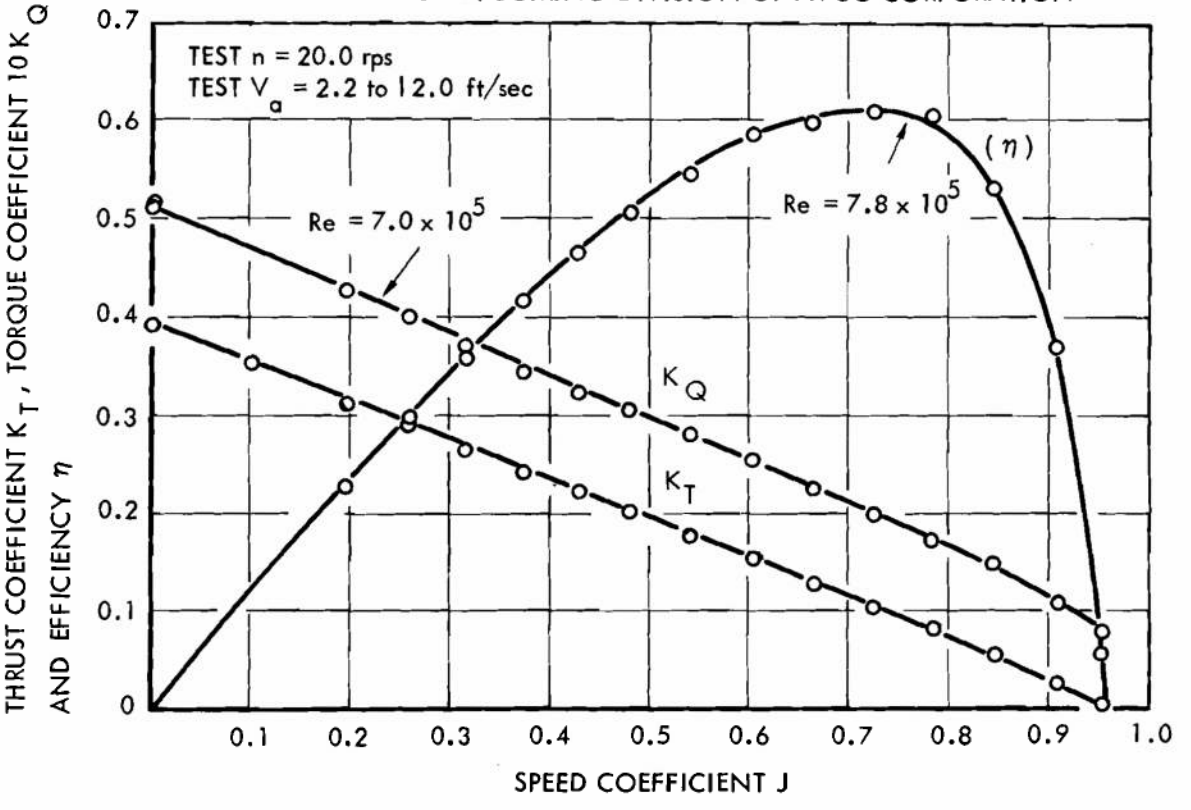

Figure 7-95. Open-water Characteristics for DTMB Propeller 4008

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η_o, in open water. They are related by the relative rotative efficiency η_r as in Eq. 7-85. In this equation, the values of the wake fraction w and relative rotative efficiency η_r are not unique. Their values depend upon whether they are determined by thrust or torque identity. With thrust identity the thrust coefficient K_T is calculated from the measured self-propulsion thrust and rpm. With this value of K_T, the open-water characteristic curves are entered to find the speed coefficient J and corresponding open water efficiency η_o, and torque coefficient K_{Q_o}. The advance speed is then calculated

$$V_a = JnD \tag{7-125}$$

The wake is then determined

$$(1 - w) = \frac{V_a}{V_s} \tag{7-126}$$

Finally, the relative rotative efficiency is given by

$$\eta_r = \frac{K_{Q_o}}{K_Q} = \frac{Q_o}{Q} \tag{7-127}$$

With torque identity, a similar procedure is followed, but the open water curves are entered with a calculated (test) value of torque coefficient K_Q which will result in a slightly different value of speed coefficient J and, consequently, η_o. With torque identity, the relative rotative efficiency is redefined by

$$\eta_r = \frac{K_T}{K_{T_o}} = \frac{T}{T_o} \tag{7-128}$$

Thrust identity is more commonly used in this country than torque identity. An alternative method is to use the average speed coefficient found from both thrust and torque identity.

The wake fraction found from self-propulsion tests is known as the effective wake fraction and must not be confused with the "nominal" wake which is obtained from measurements of the velocities in the propeller planes of a towed model without a propeller.

7-7.6.4 Cavitation Tests

Modeling of the cavitation number σ_o necessitates that cavitation tests of a model propeller be conducted in a variable pressure flow channel or water tunnel. In this type of facility a vacuum pump is used to control the ambient air pressure over the free surface. In this manner, the static pressure P_o at the propeller axis can be varied to provide a wide range of cavitation numbers σ_o (see Eq. 7-93) for testing. The facility discussed in Ref. 91 allows model propeller tests to be made for a range of σ_o from about 0.2 to 5.0.

Tests are usually conducted at fixed values of σ_o, i.e., P_o and water speed are held constant. The speed coefficient J is then varied with propeller rpm. The results of propulsion tests can be presented as open water characteristic curves with cavitation number as a parameter as in Fig. 7-71. In addition to measurements of thrust and torque, cavitation inception studies may be made by observing the blade cavities with stroboscopic illumination.

SECTION III SUSPENSION SYSTEM DESIGN

7-8 SUSPENSION SYSTEMS APPROPRIATE FOR USE ON WHEELED AMPHIBIANS

The suspension system provides flexible support between the ground and the amphibian's hull or frame. This support must be flexible in order to reduce the transmission of shock and vibrations to the hull and personnel, arising from encounters with uneven terrain. The maximum overland speed of an amphibian is often limited by the operator's ability or willingness to tolerate large motions and accelerations.

The suspension system provides the necessary clearance between the ground and hull in order to enable the amphibian to traverse uneven terrain and to surmount obstacles. It also has an important effect on the stability of the amphibian on side slopes.

The suspension system provides the contact area between the amphibian and the ground. Mobility in soft soils is a function of the ground pressure exerted by the tires. Hence, both the gross vehicle weight and the total ground contact area provided by the suspension system help to determine the amphibian's mobility.

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The principal components of suspension systems for wheeled vehicles are springs, shock absorbers, bogies, axles, wheels, and tires. Not all of these components are necessary for a suspension system. In some cases, the particular component(s) may be modified to perform the function of one or several of the other components. Suspension components suitable for wheeled amphibians are essentially the same as for any military wheeled vehicle and are discussed in another Handbook, Ref. 26.

7-8.1 CRITERIA FOR SUSPENSION SYSTEMS

Criteria which must be considered in the design of the suspension system include maintainability, simplicity, durability, reliability, vulnerability, mobility, weight, and, of course, economy. Most of these qualities are defined and discussed in par. 5-1.3. In particular, however, mobility was not included as a criterion for design. In the present context, the term mobility is limited to apply to the ground mobility of the amphibian.

In Ref. 63, mobility is defined as "the competence of a vehicle to perform its mission as measured by its best average speed over a route representative of the terrain where it will operate". The average speed of a vehicle in a given terrain is the proper measure of its mobility for that particular terrain. Thus, an amphibian's mobility might be categorized as soft-soil mobility, sand mobility, etc., or could be based on some particular mission profile. The average speed should be based on the straight line distance between two points regardless of the actual path that the vehicle must travel in order to negotiate the terrain.

7-8.2 GENERAL DISCUSSION OF DESIGN

The strength and dynamic response characteristics of the suspension system components will be designed to withstand the forces (including shock loadings) and to provide the flexibility necessary to isolate the operating personnel from excessive motions and vibrations. Discussion of these forces and motions is presented in par. 7-3.1. More detailed information can be found in Refs. 26, 63, and 120. Design variables include the ratio of unsprung to sprung mass, spring constants, and damping coefficients.

Although the suspension system is primarily an impact absorbing mechanism, its design is influenced greatly by the requirements for power transmission, mobility, and steering. These requirements dictate that all the wheels be powered, hence "live" axle assemblies must be used to drive the wheels. It is also probable that all wheels will be steerable (par. 7-9.4) and that the system will use "independent suspension" in which each wheel is free to oscillate independently of the others. The requirements for marine operation also influence the suspension system design.

7-8.3 EFFECTS OF MARINE ENVIRONMENT

Amphibian waterborne operation requirements affect the design of the suspension (aside from the obvious problems of corrosion and electrolytic action). Most recent amphibian designs have placed increased emphasis on waterborne performance with the result that "unsprung" or rigid suspension systems have been favored. While waterborne, the suspension system serves no useful purpose (with the possible exception of steering by means of the wheels, par. 7-9.3) and only adds to the displacement and drag of the amphibian. It has been estimated that 65 percent of the total water resistance of the DUKW is attributable to the exposed suspension system and its associated wheel-well cutouts. Thus, in order to minimize the weight and drag of the suspension system, springs and shock absorbers have been eliminated, sole reliance being placed in the tire design to provide adequate flexibility and damping in the system.

The LARC V is a good example of an amphibian having a rigid suspension system. While its top water speed is undoubtedly higher than could be achieved by a similar amphibian with a conventionally sprung suspension, its top land speed is decidedly lower (25 mph compared to about 50 mph).

As long as primary interest is focused on the waterborne performance of amphibians, it is reasonable to assume that unsprung suspension systems will prevail.

7-8.4 VEHICLE-SOIL MECHANICS

7-8.4.1 Shearing Strength of Soil

The shearing stress τ which a soil can support is given by the classic Coulomb's equation

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$$\tau = c + \sigma \tan \varphi \qquad (7\text{-}129)$$

where

c = coefficient of cohesion, psi
σ = normal stress on the soil, psi
φ = angle of friction, deg

Dry sand has no cohesion ($c = 0$), whereas in wet clay there is no friction ($\varphi = 0$). Most actual soils are neither purely cohesive nor purely frictional. The important point to remember is that traction in different types of soil is supported by entirely different mechanisms (cohesion and friction) and, thus, mobility in different soils depends upon different parameters. It follows that an amphibian with good (relative) sand mobility does not necessarily have good mobility in clay soils.

7-8.4.2 The Cone Index

The cone penetrometer was developed by the Corps of Engineers to obtain a simple, straightforward measurement of soil "trafficability". It is one of the most widely used instruments for determining an index of the soil strength in the field. The cone penetrometer's value as a tool for measuring bearing and tractive capacity lies in the fact that a vast number of tests have been performed with it to correlate vehicle performance with soil condition.

The cone penetrometer is a right, circular, 30-deg cone with a base area of 0.50 in.^{2} The *cone index* (psi) is the force that must be applied to the penetrometer per square inch of cone end area to force it into the undisturbed ground. The force required is measured at increments of depth so that the gradient of the cone index can be computed. The *rating cone index* is similar to the cone index but is determined after the same soil has been pounded in a mold with 100 blows of a 2½-lb tamper falling 12 in. The ratio of the rating cone index to the cone index (i.e., the ratio of the index after and before tamping) is called the remolding index (dimensionless) and can be greater or less than 1.0. The rating cone index is an overall or final measure of the soil's ability to support sustained traffic. A *vehicle cone index (VCI)* is the minimum value of the rating cone index at which a particular vehicle can negotiate the soil.

The cone index has many shortcomings as a quantitative index of mobility. It has been correlated only empirically with the "go and no-go" soil conditions with respect to particular existing vehicles in a limited number of ground types. While the method is expedient, it does not account for all soil conditions; it is not too accurate; and it does not permit prediction of the performance of nonexistent, unorthodox vehicles in the design stage.

7-8.4.3 The LLL (Land Locomotion Laboratory) Soil Value System

The LLL soil value system (Ref. 93) is a potential design tool to estimate the soft soil mobility of new wheeled amphibians. This system takes into account more of the soil parameters than the vehicle cone index, and incorporates allowances for a number of detailed types of soil-vehicle behavior. Two sets of independent soil parameters are used: (1) the direct shear reactions c and φ (Eq. 7-129) measured by plate penetration tests and a normally loaded annular shear vane, respectively, and (2) the soil sinkage parameters K and n.

$$p = Kz^n, \text{ psi} \qquad (7\text{-}130)$$

where

p = unit ground pressure, psi
K = modulus of deformation
z = sinkage, in.
n = coefficient of sinkage, 0.5 for sandy loam

K and n are experimental coefficients for specific soil structures. K is a function of the form and size of the loading area as well as the soil physics. If K is expressed in terms of the "cohesive" modulus K_c and the frictional modulus K_φ, the parameter is made "independent" of size (Ref. 94).

$$K = \frac{K_c}{b} + K_\varphi \qquad (7\text{-}131)$$

where b = breadth of footing.

For a complete discussion of the refinements and use of LLL soil value system, refer to Ref. 93. The main problem with this system is that it is not fully verified experimentally.

7-8.4.4 Correlation of Various Soft Soil Indexes

There are other indexes in addition to the vehicle cone index and LLL soil value system

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which have been developed to predict relative performance in soft soils, Refs. 26, and 95 to 100. Nuttall, Ref. 101, has attempted to correlate the theories and test results of the various agencies pertaining to soft-soil performance in different soil types. When certain simplifying assumptions are made, one basic parameter—the nominal unit ground pressure *(NUGP)*—is found to be common to all the mobility indexes. The *NUGP* is arbitrarily defined as

$$NUGP = \frac{w}{br}, \text{ psi} \qquad (7\text{-}132)$$

where

w = average gross load carried on a single tire, lb
b = undeflected tire section width, in.
r = undeflected tire radius, in.

The Army Tank-Automotive Command (ATAC) uses a similar expression to calculate the average ground pressure

$$p_{av} = \frac{w}{0.7rb}, \text{ psi} \qquad (7\text{-}133)$$

Thus, p_{av} is related to *NUGP* by the simple constant 0.7 which is introduced as a "shape factor" to account for the elliptical shape of the theoretical footprint area.

A summary of Nuttall's findings is given in Table 7-44. These results show that, in clay soils, reduction of *NUGP* of the tire will clearly extend the operating range into weaker soils. In other words, an amphibian with lower nominal unit ground pressure (less weight or larger, broader tires) will go in soils with less cohesion. In sandy soils, the *NUGP* is, again, a controlling factor. However, larger vehicles (or larger tires) may operate at high *NUGP* without loss in performance relative to smaller vehicles in sand.

Table 7-45 from Ref. 101 presents the critical soft soil mobility indexes for various wheeled amphibians along with their payload and top speeds in water and on land. The indexes are calculated from the original equations of the various agencies (not the equations in Table 7-44). The LARC V has the best relative soft soil mobility of the amphibians presented in the table.

Fig. 7-96 has been included in order to illustrate the relationship between a soft soil mobility index and actual mobility on a "go" or "no-go" basis. This figure must be considered as preliminary; however, more complete data would exhibit the same characteristics. A few examples will illustrate the use of this figure:

(1) The 50-pass vehicle cone indexes for the LARC V and DUKW (from Table 7-45) are given as *VCI* = 53 and 63, respectively. From Fig. 7-96 for the tropical climate during the wet season the frequency of occurrence of soils with rating cone index below the critical value for each vehicle is estimated to be 21 and 27 percent, respectively. Conversely, the percentage of all land area which is trafficable is 79 for the LARC and 73 for the DUKW. Thus, it is estimated that the LARC is capable of negotiating about 22 percent of the area which is impassable for the DUKW or 6 percent more of the total area.

(2) Comparing the single pass mobility of the LARC V and LARC LX (VCI_1 = 34 and 70, respectively) for the temperate climate and high-moisture condition, the respective trafficable areas are estimated to be 82 and 40 percent of the total area, i.e., less than half of this land area open to the LARC V (on a single pass basis) can be negotiated by the LARC LX.

7-8.4.5 Other Aspects of Terrain-vehicle Technology

7-8.4.5.1 Roughness

The dynamic behavior of an amphibian operating at any speed over hard ground with known geometry (roughness) can be treated statistically with methods analogous to those used to predict motions and resistance in waves (par. 7-4.1.2.4). The important parameters are:

a. The geometry of the surface
b. The geometry of the amphibian
c. The mass of the amphibian and its distribution
d. Articulation (if any)
e. Elastic and damping characteristics of the suspension system components
f. Coefficients of traction of the running gear on elements of the surface

The accuracy of motion prediction depends entirely upon the accuracy of the dynamic constants and the detail with which the terrain-vehicle system is mathematically modeled. The vibrational motions and accelerations of a particular amphibian are found as relatively simple functions of speed and the power spectrum density (PSD) of the land

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TABLE 7-44 COMPARISON OF SOFT SOIL MOBILITY INDEXES

Soil Type		Basic Source	Critical Index	Units
Clays	1	FVRDE rigid wheels with sidewall traction	c = the larger of $\begin{cases} 0.25\ NUGP\left(1+\sqrt{1+\frac{D}{4b}}\right) \\ \text{or} \\ 0.264\ NUGP \end{cases}$	psi
	2	FVRDE rigid wheels w/o sidewall fraction	$c = 0.50\ NUGP$	psi
	3	LLL rigid wheels w/o sidewall traction	$\begin{cases} n = 0;\ c = 0.50\ NUGP \\ n = 0.5;\ c = 0.40\ NUGP \end{cases}$	psi
	4	WES single tires in the laboratory	$\overline{CI} = 2.5\ NUGP$	psi
Fine Grained Soils (loams, silts, clays, etc.)	5	WES 50-pass (from	$VCI = 4\ NUGP + 14$	psi
	6	WES single pass (from field tests)	$VCI = 3\ NUGP + 3$	psi
A Sandy Loam	7	LLL rigid wheels w/o sidewall traction	$K = NUGP\ (2/d^{0.5})$ $(NUGP > 4.85\ psi)$	$lb/in.^{2.5}$
"Optimum"	8	EKLUND	$M_e' = NUGP\ (2.2/d^{0.85})$	nd
Sands	9	WES field tests	$G_1 = NUGP\ (6/b^{0.5}d^{0.5})$	psi/in.
	10	WES single tires in laboratory	$G_4 = NUGP\ (8/b^{0.5}d^{0.5})$	psi/in.

NOTES: FVRDE - British Laboratory, Ref.95
LLL - Land Locomotive Laboratory, Ref.93
WES - U. S. Army Engineer Waterways Experiment Station, Refs. 96 to 99
EKLUND, Ref.100
NUGP = w/br, psi

where w = average load on single tire, lb

b = undeflected tire width, in.

$r = d/2$ = undeflected tire radius, in.

D = undeflected tire diameter, in.

The critical index is the minimum value of the index at which a vehicle will just maintain headway in unaccelerated, level, straight-line operation.

c = coefficient of cohesion of soil, psi

$\overline{CI}$ = average cone index of soil, psi

VCI = average rating cone index of field soils for a minimum of 50 passes in the same ruts, psi

VCI_1 = average rating cone index of field soils for single pass, psi

K = soil consistency in selected sandy loam where $n = 0.5$, $c = 0.56$ and $\tan \varphi = 0.31$

n = an exponent expressing the sinkage characteristics of the soil

φ = the angle of friction (Eq.7-129)

M_e' = the inverse of the Eklund Mobility Factor (not in percent). M_e' greater than 100 indicates an overloaded tire and less than optimum off-road performance

G = average gradient to cone index of sand versus depth in 0.6 in. layer

TABLE 7-45 PERFORMANCE CHARACTERISTICS OF SEVERAL WHEELED AMPHIBIANS

Amphibian	Soft Soil Mobility Indexes						Pay-load tons,	Speed, mph	
	VCI	VCI_1	G_{sand}	M'_e	K_{loam}	c_{clay}		Land	Water
1943 DUKW	63	43	4.6	101	4.2	5.1	2.5	50	6.5
1951 SUPERDUCK	82	53	5.3	137	5.0	6.4	4.0	48	6.7
DRAKE	92	56	5.0	125	5.0	6.7	8.0	45	9.0
1960 LARC V(u)	53	34	2.4	85	2.6	4.0	5.0	25	8.6
LARC XV(u)	82	54	3.4	96	3.8	6.5	15.0	20	9.5
LARC LX(u)	103	70	3.2	102	4.2	8.6	60.0	14	7.0
High-speed Amphibians									
1962 LVW-X1(u)	80	53	4.2	103	4.3	6.2	5.0	35	35
1964 LVH-X1	40	81	4.1	104	4.3	6.3	5.0	40	40
Truck									
1960 M34	62	37	3.9	102	3.4	4.4	2.5	—	N.A.

Notes: A lower value of the index indicates greater relative mobility (except M'_e).

(u) = unsprung suspension.
N. A. = not applicable
VCI = average rating cone index of field soils for a minimum of 50 passes in the same ruts, psi
VCI_1 = average rating cone index of field soils for a single pass, psi
G_{sand} = average gradient to cone index of sand vs depth in 0.6 in. layer
M'_e = inverse of Eklund Mobility factor (not in percent)
K_{loam} = soil consistency in sandy loam
c_{clay} = coefficient of cohesion in clay soils, psi

surface, Ref. 102. The human responses to the motions are discussed in par. 9-2.1.2.

7-8.4.5.2 Obstacles

Obstacles, geometric features too large to be considered as roughness, include such things as boulders, trees, stumps, and ditches (see Ref. 103). The parameters which affect an amphibian's potential ability to deal with obstacles are mainly geometrical including:

a. Wheelbase
b. Wheel diameter
c. Approach, departure, and break angles
d. Ground clearance (both static and dynamic)
e. Weight distribution
f. Suspension compliance with features of the terrain

Obstacle crossing is a "go" or "no-go" situation for the most part; speed and vibrations are of secondary importance.

7-8.4.5.3 Bank Egress

The bank egress capability may be considered to be a combination of the soil mechanics and obstacle problems. Stream and river banks are characterized by steep slopes and high, vertical steps. The steep slopes are often wet and slippery; where the slopes are more favorable, the soil is likely to be composed of weak, waterlogged silts as in marshes and bogs. Thus, the problem of bank egress severely limits an amphibian's riverine mobility. It is safe to say that no existing amphibian is capable of crossing a majority of the larger streams and rivers in this country if the point of egress is chosen at random.

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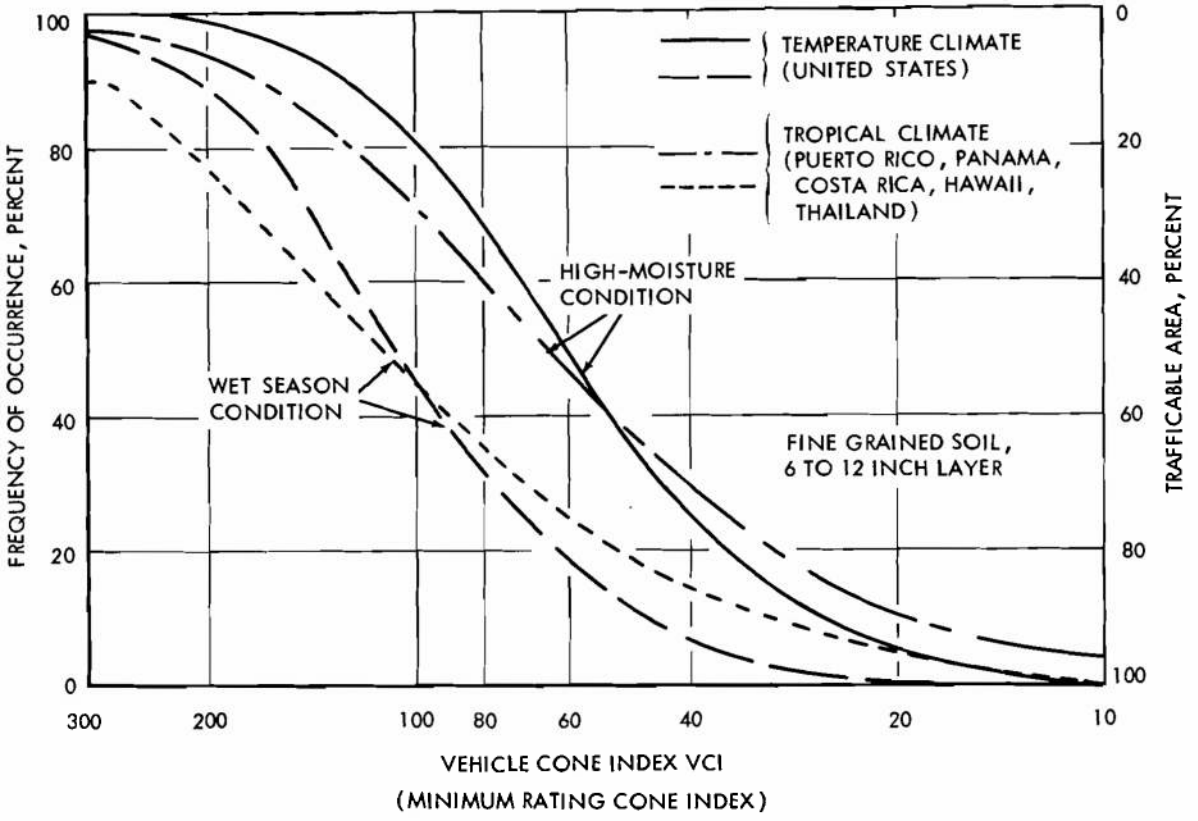

Figure 7-96. Cumulative Frequency of Rating Cone Indexes

7-8.5 TIRE SELECTION

In a rigid suspension system, the pneumatic tire must perform the functions of both a spring and a shock absorber (damping) as well as its normal role of providing traction for propulsion. The spring rate k of a tire is a complicated function of compression of the air in the tire and the flexure of the sidewalls. The spring rate is not a constant, but has definite nonlinearities characterized by an increase in k as deflection begins and then a decrease in k with increased deflection. There is also some damping inherent in the flexure of the tire; however, it is believed that the greater portion of damping with respect to tires is between the tire and the soil surface and within the soil itself (Ref. 120).

The damping in the tires is insufficient with respect to operations on hard surfaced roads. The LARC V land speed is limited to about 25 mph. Any attempt to increase the speed results in large amplitude motions (galloping) at the system's resonant frequency because of underdamping. With suitable damping, the amphibian would be capable of road speeds on the order of 50 mph. Inadequate damping must be accepted in a rigid suspension system unless some future development in tire design results in a major improvement in tire damping without seriously degrading rolling resistance.

7-8.5.1 Tire Tread

The choice of tire tread will be a compromise, in most cases, between conflicting requirements for different soil conditions. For sand, hard soils and roads, a shallow-ribbed pattern is desired. A deeper, lugged tread is needed in soft platic soils where the tires must excavate soil in order to get down to the hardpan. A deeper tread, of course, contributes greatly to the rolling resistance of the tire.

7-8.5.2 Estimating Tire Weight (Ref. 101)

An empirical fit to published data on the weight W_t of a number of existing tires leads to the following equation:

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$$W_t = K_1\left(\frac{bd^2 W_1^{1/3}}{d_r}\right) + K_2 \text{, lb} \qquad (7\text{-}134)$$

where

W_1 = maximum rated load on the tire at its designed inflation pressure, lb. If highway operation is included, the load (and, implicitly, the inflation pressure) for this service is used.

b = undeflected tire section width, in.

d = undeflected tire outside diameter, in.

d_r = rim diameter, in.

K_1 and K_2 = constants which vary somewhat for various types of tires. Average values are tabulated below:

		K_1	K_2
Highway	Mileage Tread, standard	0.0015	10
	Duplex	0.0011	20
	Extra Small	0.0017	1
Off-Road	Grader	0.0014	20
	NDCC* Military(1)	0.0013	0
	Sand	0.0009	20
	Earthmover	0.0011	100
	Rock Tread	0.0015	50
	Duplex, Rock Tread	0.0011	20
	Compactor (slow speed)	0.0011	0
Terra-Tires (2)	Smooth	0.0005	5
	Terragrip Tread	0.0006	30

(1) Casing only: Tubes and flaps add approximately 75 percent.

(2) The scatter of actual Terra-Tire weights versus values computed by this equation is relatively great, suggesting that the form of the equation is not entirely appropriate for these extreme types—which is not surprising. The constants given provide rough guidance, nonetheless.

*NDCC Nondirectional Cross Country

SECTION IV STEERING SYSTEM DESIGN

7-9 STEERING SYSTEM DESIGN

7-9.1 WATERBORNE STEERING THEORY

7-9.1.1 Steering Forces

The forces on a rudder follow the same principles as forces on low aspect ratio airfoils and hydrofoils. They are usually expressed as dimensionless lift, drag, and moment coefficients denoted by C_L, C_D, and C_M, respectively. Lift is defined as the force normal to the direction of inflow and drag is parallel to the inflow. Rudder lift is directed in the horizontal plane and normal or nearly normal to the amphibian centerline. The relationship between the forces and their coefficients is as follows:

$$\left.\begin{aligned} L &= C_L\left(\frac{\rho}{2}\right) Sv^2 \text{, lb} \\ D &= C_D\left(\frac{\rho}{2}\right) Sv^2 \text{, lb} \\ M &= C_M\left(\frac{\rho}{2}\right) Scv^2 \text{, ft-lb} \end{aligned}\right\} \qquad (7\text{-}135)$$

where

L = lift force, lb

D = drag force, lb

M = moment about any reference axis, ft-lb

S = rudder area, ft^2

v = mean flow velocity over rudder, ft/sec

c = chord of rudder, ft

ρ = density of water, $slug/ft^3$

The force and moment coefficients are functions of angle of attack a, aspect ratio A, section shape, and planform. Determination of these coefficients are discussed in par. 7-9.2.2.

The forces generated for any particular rudder are mainly determined by the effective angle of attack a of the rudder and the relative water speed v. In open water, a and v are readily determined, but behind a ship the conditions are not as simple. Fig. 7-97 illustrates these conditions. In this figure, a is the effective angle of attack, δ is the rudder helm angle, ϕ is the drift angle of the ship, and ϵ is due to the straightening influence of the hull, appendages, and propeller. The velocity relative to the rudder is a function of the ship speed, hull wake, and propeller slipstream.

The turning moment applied to the ship by the rudder is given by

$$M = [L\cos(\delta - a) - D\sin(\delta - a)]\ell + M_r \text{, ft-lb} \qquad (7\text{-}136)$$

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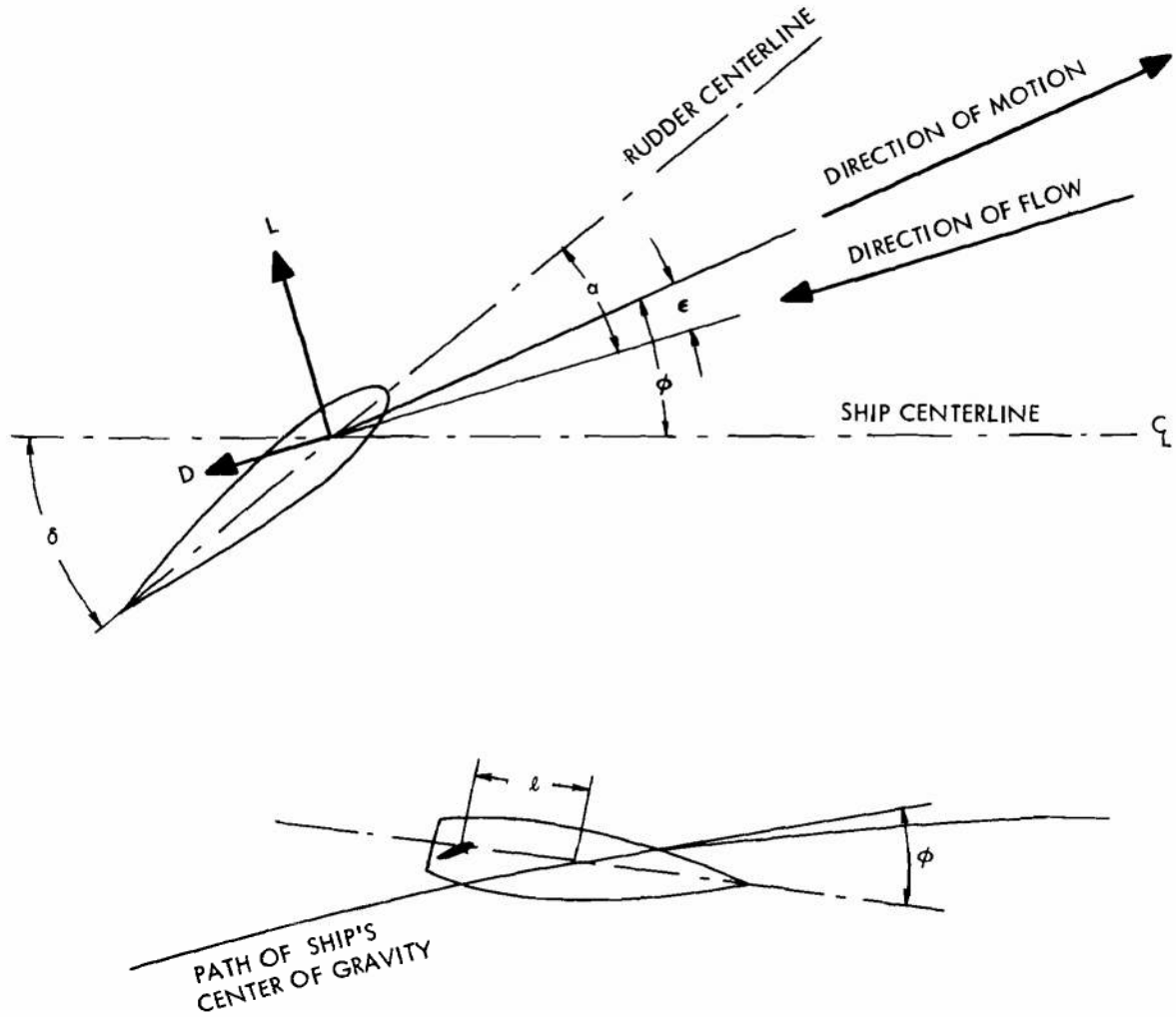

Figure 7-97. Effective Rudder Angle for a Rudder Behind a Ship During a Turn

where

M = moment about the ship's CG, ft-lb
M_r = moment about the rudder stock, ft-lb
L = rudder lift force, lb
ℓ = arm from rudder stock to ship's CG, ft
a = effective inflow angle, deg
δ = rudder helm angle, deg

In a maneuver, the angles a and δ will change from the instant the rudder is put over until a new state of equilibrium is reached. It takes some time to put the rudder over to the desired helm angle, but this time is short enough that the ship's heading has not changed very much when the desired angle is reached. At this instant then, the angles ϕ and ϵ are negligible so that the angle of attack is equal to the rudder helm angle ($a = \delta$) and Eq. 7-136 reduces to:

$$M_i = L\ell + M_r \qquad (7\text{-}137)$$

where

M_i = initial turning moment applied to the ship by the rudder

The initial moment to turn the ship can be made larger by increasing the lift on the rudder and increasing the moment arm by placing the rudder far behind the center of gravity. The moment about the rudder stock M_r is usually negligible. The lift is directly proportional to the lift coefficient C_L, area S, and the square of the inflow velocity v (see Eq. 7-135). The lift coefficient is a function of the angle of attack and is maximum when the rudder is at the "stall angle".

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Once the ship starts turning, hydrodynamic forces are generated by the cross-flow over the hull. This flow is comprised of velocity components due to the drift angle (sway) and angular velocity (yaw) of the ship. On a directionally unstable ship, these hydrodynamic forces create a moment in the same direction as the rudder moment and tend to decrease the turning radius. At the same time the drag on the ship is increased causing a speed reduction. With the rudder helm angle unchanged, the ship will continue to tighten its turn until a steady turning motion is reached. At this equilibrium condition, the hydrodynamic moments on the ship and the rudder are balanced (equal and opposite).

Fig. 7-98 is a schematic diagram of a ship executing a steady turn maneuver. This maneuver is useful in determining some of the parameters which are used to measure a ship's relative maneuverability. The steady turning radius, advance at 90° change in heading, transfer at 90° change in heading, and tactical diameter are often made dimensionless by dividing by the ship's length. For example, the tactical diameter of the LARC V with a rudder angle of 45° is about 2.5 ship lengths with an approach speed of 9 mph.

The ship's inertia forces have not been included in this discussion. The complete equations of motion are presented in Ref. 67.

The moment on the rudder stock M_r is important in determining the strength of the steering gear and linkages. In addition to the static forces, however, consideration must be given to the additional torque needed to attain the desired angular rate of rudder deflection. The product of angular rate and the maximum torque determines the power which must be supplied by the steering gear (or helmsman). The rudder torque in many cases is greatest when the ship is going astern. If so, this condition will determine the strength requirements.

Steering forces can be produced without resorting to rudders. In many cases, the alternatives provide a greater degree of maneuverability and control. Vertical axis propellers, water jets, and right angle drives are

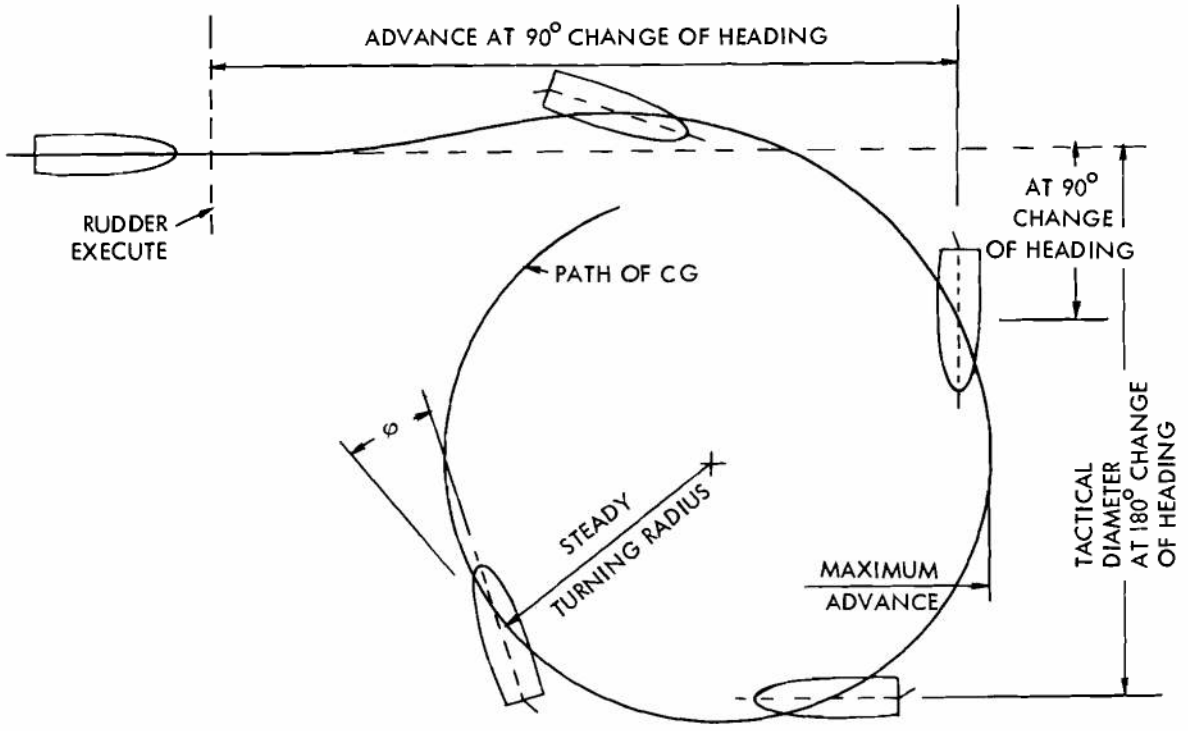

Figure 7-98. Geometry of a Turning Circle

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examples in which the thrust of the main propulsor can be directed in any desired direction to produce a turning moment about the ship's center of gravity. Perhaps the greatest advantage that these devices have over rudders is that large turning moments can be generated at low and zero advance speeds.

The active rudder consists of a small propeller driven by a submersible electric motor which is housed in a nacelle on the rudder. At high speeds the active rudder is used as a conventional rudder. But at low speeds the propeller is activated to produce thrust which is trainable by moving the rudder in the desired direction.

The steering nozzle is simply a Kort nozzle which can be rotated about a vertical axis through the plane of the propeller. This "tube" rudder produces superior turning forces by diverting the entire propeller slipstream while most of the advantages of a Kort nozzle for propulsion are retained. The primary disadvantage lies in the nozzle's vulnerability to damage.

Ducted thrusters are finding increased application on merchant vessels. A transverse tube open to the sea is located deep in the bow of the ship and houses a propeller which may have controllable pitch and is likely to be driven by an electric motor. At slow speeds, activating the bow thruster gives lateral thrust and large turning moments. The ducted thruster becomes less effective at higher speeds and conventional rudders are used for high speed maneuvers. It does not seem very likely that ducted thrusters will be used on future amphibian designs because of problems with arrangements, lost buoyancy, and increased complexity.

Many other devices for producing steering forces are conceivable, but one application which is worthy of particular note concerning wheeled amphibians is the use of the wheels as crude rudders. It is essential that steering of the wheels of an amphibian be coordinated with the rudder when operating in surf so that a smooth transition may be made from water to land operation. The front wheels are quite effective as bow rudders and invaluable for control in a following sea (par. 7-9.1.5). Indeed, the tactical turning diameter of a recent high-speed amphibian in the surf mode of operation was not appreciably changed when the rudder was disconnected and steering was effected with the wheels alone.

7-9.1.2 Directional Stability and Maneuverability

Maneuverability may be defined as a ship's ability to follow a desired course as steered by the helmsman. The degree of maneuverability depends on the rapidity and magnitude of response to the helm and on a consistent, one-to-one relation between rudder angle and steady turning rate. Directional stability implies that this one-to-one relation exists. Unfortunately, a high degree of directional stability in a ship is associated with slow turning rates and large tactical diameters, i.e., limited maneuverability.

The degree of directional stability or instability is commonly determined for a free running scale model by the spiral maneuver. In this test, the rudder is put over in a succession of discrete angle increments to one side, to the other side, and back to zero. Each rudder angle is maintained until a steady yaw rate is established and recorded. The results are plotted with steady yaw rate ω as a function of rudder angle δ as in Fig. 7-99. A stable ship has a single curve through zero rudder angle. The degree of stability is qualitatively indicated by the slope of the curve at the origin; the lower the slope, the higher the stability. However, for a given ship the slope of this curve is a function of the rudder lift-curve slope. Hence, a comparison of stability between two ships should be limited to ships having similar rudder effectiveness. A hysteresis-type loop, Dieudonne loop, around the origin is characteristic of unstable ships. The existence of a Dieudonne loop signifies that continuous rudder activity will be required to maintain a steady course. The size of the loop gives a qualitative measure of instability. Its height indicates the extent to which the turning rate will vary with the rudder held amidships, i.e., its instability. The width of the loop is a fairly good measure of the ship's course keeping ability because it defines the envelope of rudder angles which must be used to hold a course.

The directional stability of a ship depends upon its lines or hull form and its appendages such as skegs or deadwood. The size of the amphibian's appendages should be kept small unless the amphibian is directionally unstable, in

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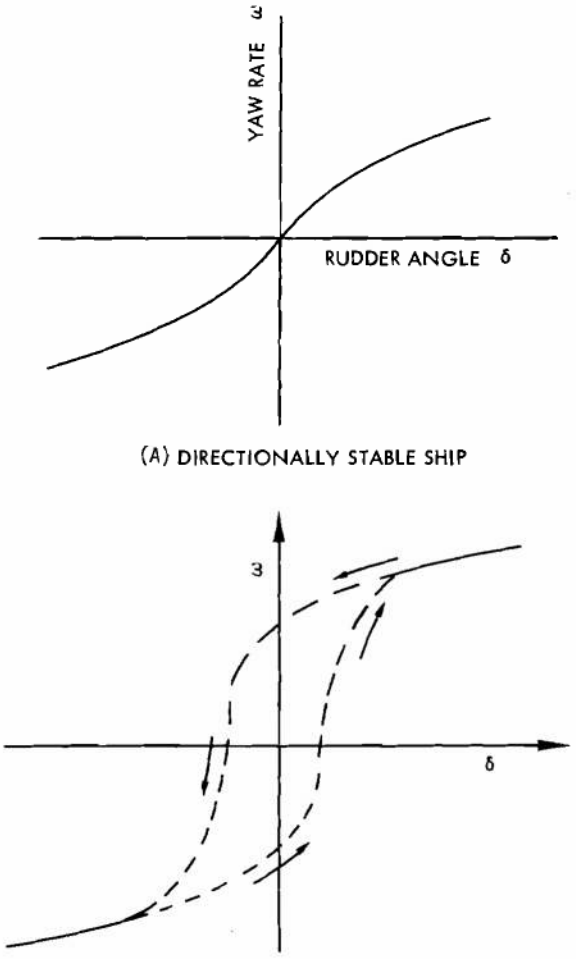

Figure 7-99. Results of Spiral Maneuvers

which case appendages may be enlarged or skegs added to attain stability. It is particularly important that amphibians be directionally stable so that response to the helm is positive and rapid for difficult surf operations. As long as the amphibian is stable, any increase in the degree of stability is undesirable because it leads to slower response and increased turning diameters unless larger more effective rudders are employed.

7-9.1.3 Steering at Very Low or Zero Speed of Advance

The force producing capabilities of a rudder are proportional to the square of the velocity of flow over its surface. As ship speed decreases, the effectiveness of the control surfaces also decreases. At zero speed of advance, any rudder forces are limited to those which arise from velocities in the slipstream of a thrusting propeller. In this case the turning force comes from the change in momentum caused by the rudder deflecting the flow in the propeller race. The lift on the rudder will be a rather small fraction of the propeller thrust. The thrust of the propulsor is more effectively used for low speed maneuvering if it can be trained in any desired direction as with vertical axis propellers, vertical shaft right angle drives, and water jets. With these devices the thrust may be directed at right angles to the centerline so that a turn may be executed without imparting any forward motion to the vessel.

In many amphibian supply operations it is necessary to hold the amphibian next to a large ship for cargo transfer. If a springline is attached to the bow of the amphibian, its rudder may be used to hold the stern against the cargo ship while maintaining propeller thrust against the spring line. With a trainable propulsor, an amphibian may maintain a station next to the supply ship without passing a line between the hulls.

7-9.1.4 Steering When Reversing

The forces supplied by a rudder for steering at low speeds are smaller when the propeller is reversed to apply astern thrust. Inflow velocities to a propeller are small compared to the outflow in the race so that when going astern the flow velocity past the rudder is relatively low. River towboats are often equipped with flanking rudders, ahead of the propeller, which are operated only when the propeller is reversed, at which time they are effective for deflecting the propeller race to produce steering forces.

While the speeds and rudder forces in astern operations are generally low, the torque on the rudder stock may be maximum for this condition. The axis of rotation for a balanced rudder will pass through or near the quarter-chord point of a section. In ahead operations, the center of pressure for a properly designed balanced rudder will be within 0.05 chord length of the axis. However, in astern operation the center of pressure will be at about the 3/4-chord point or about 0.5 (chord) behind

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the axis. Thus, the moment arm of the rudder lift about the rudder stock is about ten times larger for astern operation. The maximum torque, of course, is the product of the lift times its respective moment arm.

7-9.1.5 Steering in Rough Water and in Surf

The steering ability of any ship is adversely affected by waves. The worst condition occurs when the ship is running in a following sea with an advance speed about equal to the wave celerity. This is because the hydrodynamic yaw forces created by following waves are applied over a longer period of time so that the resulting yaw motion is more severe.

Amphibians are required to operate safely through the surf. Waves always become higher and steeper as they approach a beach from open water. Thus, the need for a high degree of maneuverability is most pronounced for an amphibian landing through surf. The greatest pitfall facing the helmsman is the tendency of the amphibian to broach in the surf. He must quickly apply opposite rudder to counteract any tendency of the amphibian to veer off course and the rudder (or other steering device) must be effective in creating a turning moment to resist the yawing motion. If the vessel should broach near the beach line, it is likely that it will subsequently be swamped or overturned.

An amphibian that is directionally stable in calm water may behave as if unstable when it is "riding" a wave through the surf. This behavior is attributable to the orbital velocities of the water particles in the waves, as illustrated in Fig. 7-100. The arrows in this figure are vectors which indicate the direction and velocity of particle motion in the fluid. An amphibian is shown poised on the wave front with its stern at the crest of the wave and bow in the preceding trough. The water velocity relative to the amphibian is nearly zero at the stern and about twice the amphibian's forward speed at the bow. Thus, the stabilizing influence on any appendages at the stern of the vessel is lost because there is no flow there, whereas the yaw forces due to asymmetry of flow past the bow (from some initial yaw perturbation) are larger than normal with the high relative velocities in the bow.

Steering by means of a conventional rudder in the foregoing example is also handicapped by the low relative flow velocity past the stern due to the orbital trajectories in the waves. On the other hand, steering by means of the front wheels is enhanced by the high relative velocities encountered at the bow of amphibian.

7-9.2 DESIGN OF MARINE STEERING SYSTEMS

7-9.2.1 Design Criteria

The main objective of the requirements for the marine steering system is to insure that the amphibian will be able to safely negotiate some prescribed minimum surf. Successful operation through the surf zone depends largely on experience and good seamanship. However, the characteristics of the amphibian with respect to roll stability and maneuverability are also important. Two criteria used to judge maneuverability are directional stability and tactical turning diameter. These qualities are defined and measured only for calm water maneuvering. The tacit assumption is made that an amphibian with good maneuverability in calm water will also exhibit good maneuverability in rough water. In general this assumption is probably well founded. However, for the particular case of an amphibian in following seas, conventional rudder control may be compromised so that some alternative steering device may be desired. The low speed and zero speed maneuverability of an amphibian design may be required to meet some specification so that even in rough water it will be able to reach and maintain a station next to a ship for cargo transfer.

The previous discussion applies to the performance of the amphibian, which is only one of the many design criteria which will be used to evaluate the steering system design. Other criteria are described in par. 5-1.3 and include maintenance, simplicity, ruggedness, vulnerability, reliability, weight, arrangements, and economy.

Much of the time it will not be sufficient to apply the design criteria to the steering system as an entity. For example, the performance of the steering system is reflected in the amphibian's degree of maneuverability. But maneuverability is a function of the hull design and its appendages as well as the steering system effectiveness. Thus, if a change in the steering system also alters the hull in any way, then the

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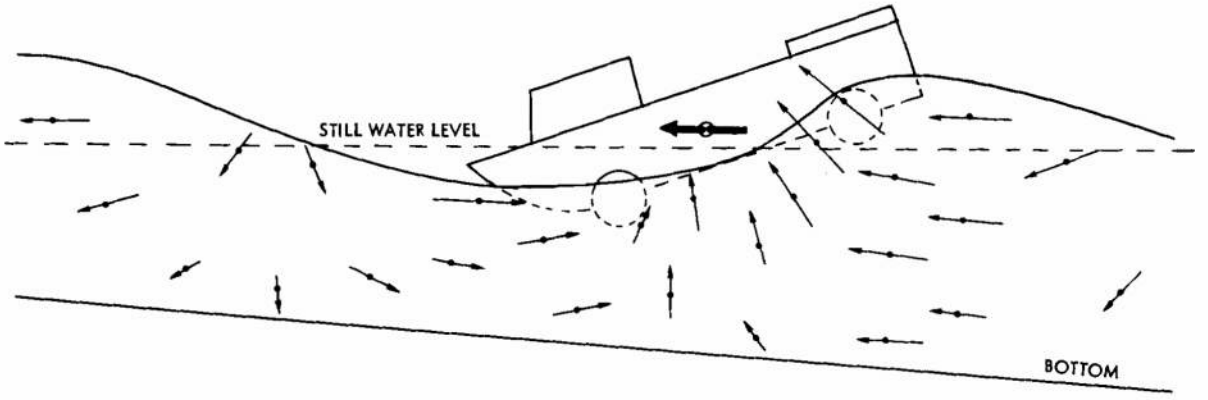

Figure 7-100. Schematic Diagram of a Wave Approaching a Beach Showing the Distribution of Particle Velocities

steering performance and all the other criteria, as well, must be applied to the hull and steering system together. Unfortunately, there are many interrelationships among the various systems on an amphibian design so that evolution of the design based on all the criteria becomes quite complex and difficult.

7-9.2.2 Rudders

7-9.2.2.1 Theory of Operation

The main purpose of the rudder is to produce moments about the center of gravity of a ship with which to initiate and control turning motions. It is important to know the lift of the rudder at a given speed and rudder angle and, especially, the maximum lift force which can be produced by the rudder. The turning moment is a function of rudder lift L as in Eqs. 7-136 and 7-137. The rudder lift is a function of velocity and the lift coefficient C_L (Eq. 7-135). The lift coefficient is, in turn, a function of rudder aspect ratio and angle of attack. The maximum value of lift coefficient is a function of Reynolds number, aspect ratio, and thickness-chord ratio.

The lift coefficient is approximately a linear function of angle of attack up to the stall angle. Thus, the lift coefficient C_L at any angle below the stall angle can be approximated from the lift coefficient slope dC_L/da:

$$C_L = a(dC_L/da) \qquad (7\text{-}138)$$

where a is the rudder angle, deg.

Fig. 7-101, taken from Ref. 104, shows an empirical curve of lift coefficient slope as a function of aspect ratio AR for rectangular lifting surfaces. Aspect ratio is the ratio of span to chord, thus

$$AR = \frac{b^2}{S} \qquad (7\text{-}139)$$

where

AR = aspect ratio of the foil, nd
b = span of the foil, ft
S = area of the foil, ft^2

The lift coefficient slope is relatively independent of the thickness of the foil.

The maximum lift coefficient for symmetrical foils with thickness-chord ratio t/c = 0.15 is shown in Fig. 7-102 taken from Ref. 105. The

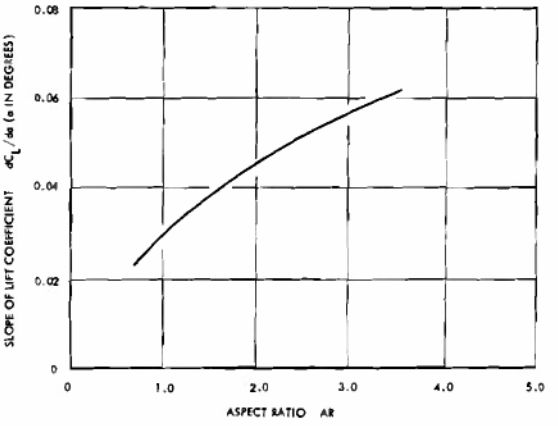

Figure 7-101. Slope of Lift Coefficient as Function of Aspect Ratio for Rectangular Wings

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stall angles which are associated with these maximum lift coefficients are shown in Fig. 7-103 from the same reference. Note that the stall angles for low aspect ratio foils are higher than for high aspect ratio foils. High aspect ratio foils have a higher lift coefficient slope, but their lower stall angles usually result in lower maximum lift coefficients. The thickness-chord ratio has an effect on the maximum lift coefficient of a foil, as discussed in Ref. 67. The thickness of a balanced rudder is seldom less than 15 percent of the chord.

In practice, it is very difficult to determine the stall angle and maximum lift coefficients for rudders on a ship. The flow past the rudder is turbulent so that larger stall angles are found than for foils in undisturbed flow. Interaction with the hull increases the effective aspect ratio of the rudder. Free surface effects are also present. Model tests for stalling are of little use because of serious scale effects. Scale effects may be considered negligible for rudder angles below the stall angle, however.

Lift coefficient data from model tests on spade type rudders are presented in Ref. 106. An empirical fit to these data gives the following equation for the lift coefficient slope C_{L_a} with respect to angle of attack for small angles:

$$C_{L_a}\Big|_{a=0} = \frac{dC_L}{da} = \left[\frac{0.0988\,A_e}{1.8 + \cos\Omega\sqrt{\frac{A_e^2}{\cos\Omega} + 4}}\right] \quad (7\text{-}140)$$

where

A_e = effective aspect ratio and is just twice the value in Eq. 7-139

Ω = sweep angle of the one-quarter chord line, deg

a = rudder angle of attack, deg

The flow velocity past the rudder must include the effects of both the hull wake and the propeller slipstream. If we assume that the ultimate contraction of the slipstream occurs ahead of the rudder, then the mean velocity and diameter of the slipstream are given (by momentum theory):

$$v_1 = \sqrt{V_a^2 + \frac{2T}{\rho A}} \quad (7\text{-}141)$$

$$D_1 = D\sqrt{\frac{v_1 + V_a}{2v_1}} \quad (7\text{-}142)$$

where

D = propeller diameter, ft

D_1 = slipstream diameter, ft

v_1 = mean slipstream velocity ft/sec

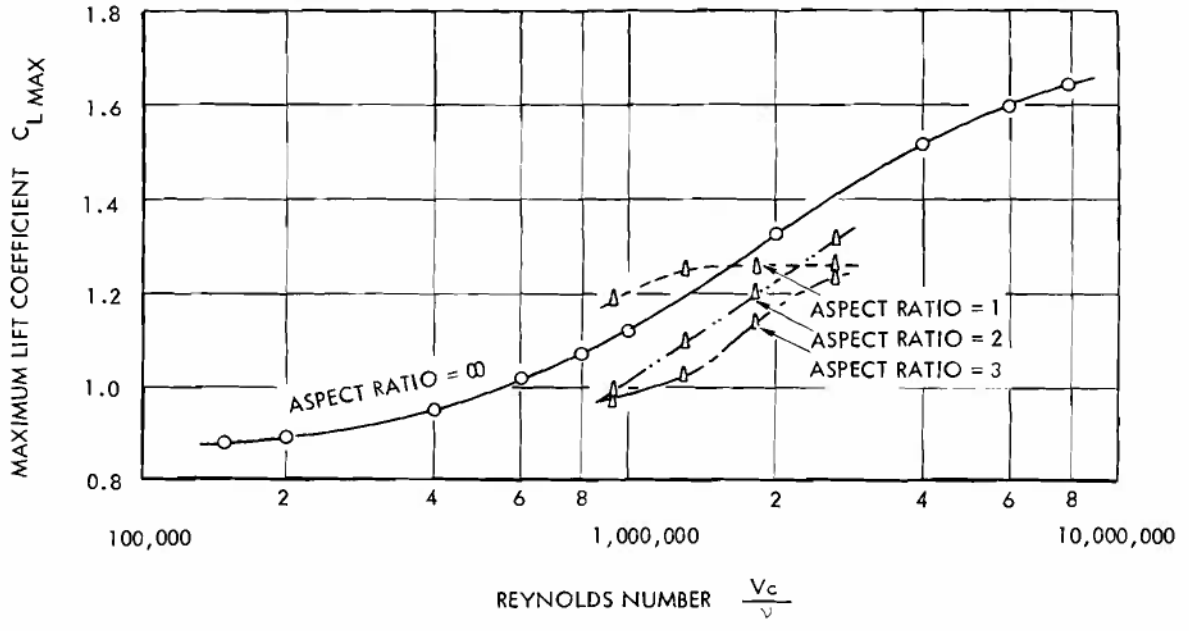

Figure 7-102. Effect of Reynolds Number on Maximum Lift Coefficient for Various Aspect Ratio Foils

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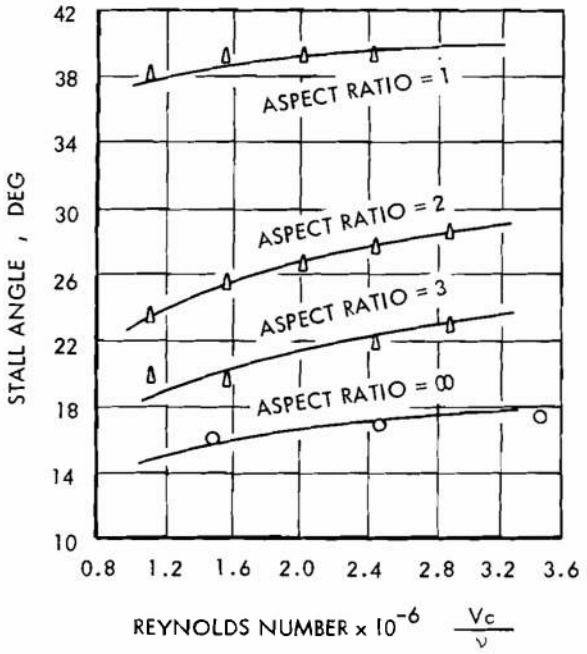

Figure 7-103. Effect of Reynolds Number on Stall Angle for Various Aspects Ratio Foils

V_a = advance speed of the propeller, ft/sec
T = propeller thrust, lb
A = propeller disc area, ft^2
ρ = mass density, $slug/ft^3$

With these values, the following equation may be used to calculate the mean velocity over the rudder surface:

$$v = \frac{D_1 v_1 + V_a (D_1 - b)}{b}, \text{ ft/sec} \qquad (7\text{-}143)$$

where

b = span of the rudder, ft.

If the rudder is behind a Kort nozzle, of course, the assumption about the slipstream contraction will not be valid. In this case the slipstream diameter should be taken as the propeller diameter and the mean slipstream velocity as given by Eq. 7-141, where T is propeller thrust and does not include the thrust contributed by the nozzle.

7-9.2.2.2 Geometrical Considerations

Geometric parameters which must be considered in the design of a rudder include:

a. *Aspect Ratio.* The magnitude of the aspect ratio is limited by considerations of vulnerability. The rudder should not extend below the base line unless there is some other projection such as a skeg or Kort nozzle which affords adequate protection from likely hazards. Structural limitations must also be considered in selecting aspect ratio. The center of pressure is generally about midway between the root and tip of the rudder. Thus, the greater the span, the greater will be the bending moment on the rudder stock.

From the hydrodynamic standpoint, increasing the aspect ratio increases the slope of the lift curve with respect to angle of attack. Thus, the rudder will be more effective at low rudder angles so that less rudder angle is required to counteract deviations in heading (with the same rudder area).

The root of the rudder should be as close to the hull as possible. If the gap between hull and rudder is sufficiently small, the effective aspect ratio is theoretically twice its geometric aspect ratio.

b. *Planform and Section Shapes.* Two principles govern the selection of the rudder planform. First, the advantages of elliptical spanwise loading are minimum induced drag, reduced bending moments, lower critical cavitation numbers, and increased lift curve slope. Elliptical loadings can be achieved by selecting the sweep angle of the quarter chord line with respect to the taper ratio as given in Ref. 105. Of more practical importance is the second principle, namely, to keep the largest possible proportion of the rudder area in the propeller slipstream.

A suitable section for all-movable rudders is the NACA symmetrical section. The ordinates for this section are given in Table 7-46.

The designation NACA 0015 refers to a NACA symmetrical section with a thickness to chord ratio $t/c = 0.15$.

The spanwise thickness distribution usually tapers from a maximum at the root ($t/c \approx 0.18$) to a minimum at the tip ($t/c \approx 0.04$).

c. *Balance.* The objective in balancing the rudder is to minimize the rudder torque. Low torque is, of course, desirable to minimize the size and weight of the steering gear. It is not possible to obtain full balance (zero torque) at all rudder angles because the center of pressure moves aft with increasing angle of attack. Thus,

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TABLE 7-46 OFFSETS FOR NACA SYMMETRICAL SECTIONS

Chord from Leading Edge, %	Percent of Maximum Section Thickness
0	0
2.5	43.6
5	59.3
7.5	70.0
10	78.1
15	89.1
20	95.6
25	99.0
30	100.0
40	96.7
50	88.2
60	76.1
70	61.1
80	43.7
90	24.1
100	2.1

if a rudder were designed to have zero torque at 20 deg rudder angle, the torque would be negative at lower rudder angles and positive at higher angles. Ideally, the maximum negative torque should equal the maximum positive torque in order to minimize the torque. A positive torque is defined as one which opposes an increase in rudder angle. A hand-steered vessel cannot have a negative rudder torque at small angles or the rudder will not trail at zero angle when the rudder is free. With power steering, negative rudder torques are accepted in order to lower the maximum positive torque.

The balance of the rudder is expressed in terms of the percentage of the total rudder area which is forward of the rudder turning axis. This percentage will range between 20 and 30 percent to achieve equal positive and negative maximum torques. The optimum area balance depends on the disposition of rudder area, section shapes and thickness, the effect of propeller race on the rudder center of pressure, and the maximum rudder angle.

The maximum rudder torque in the astern condition depends on the maximum rudder angle and speed, and the degree of rudder area balance. It may be desirable to limit the allowable rudder travel in the astern condition so that the torque does not exceed the maximum ahead torque. Otherwise, the astern torque can be reduced by increasing the balance area so that the rudder is overbalanced in the ahead condition.

d. *Stock Angle.* It was found that the effectiveness of the rudder on the DUKW was increased considerably by raking the rudder axis aft. This rudder was in a tunnel so that there was a large interaction between the rudder and hull. By raking the rudder, the flow was deflected down and clear of the tunnel at large rudder angles to reduce the interaction.

e. *Maximum Rudder Angle.* The effect of aspect ratio on the maximum lift force that a rudder can develop has not yet been determined. It can be shown, however, that rudder angles greater than the stall angles in Fig. 7-103 can be used effectively to decrease an amphibian's turning diameter. The explanation for this lies in the fact that the angle of attack α (Fig. 7-97) is less than the rudder angle δ in a turn. If rudder angles greater than the stall angle can be attained, the helmsman must be careful to avoid inadvertent stalling of the rudder. If the rudder is put hard over so that it stalls, there will be a large increase in rudder drag without the desired maximum lift for turning. For this reason, it is advisable to have a simple rudder angle indicator on the control panel for the operator's use. Maximum rudder angles as high as 65 deg may be practical, but should only be considered if a small turning diameter is essential.

f. *Hull Geometry.* The shape of the hull in the vicinity of the rudder can have an important effect on rudder performance especially if the propeller and rudder are placed in a tunnel. This topic is discussed in par. 7-1.4.

7-9.2.3 Trainable Propulsors

The side force that a trainable propulsor can exert at zero advance speed is just equal to its static thrust. With a steering angle of 90 deg, the turning moment is simply the thrust multiplied by the moment arm from the propulsor to the amphibian's center of gravity.

7-9.2.3.1 Water Jets

The side force of a trainable water jet at some advance speed can be estimated from simple

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momentum theory. The thrust coefficient C_T (neglecting interactions with the hull) may be written

$$C_T = \frac{T}{\frac{1}{2}(\rho A V_a^2)} = 2V_j'(V_j' - 1) \qquad (7\text{-}144)$$

where

T = water jet thrust, lb
A = jet area, ft^2
V_a = advance speed at the water scoop inlet, ft/sec
V_j = jet velocity, ft/sec
V_j' = ratio of jet velocity to advance speed, nd
ρ = mass density, slug/ft^3

Similarly, a lift coefficient corresponding to the side force may be written

$$C_L = \frac{L}{\frac{1}{2}(\rho A V_a^2)} = 2(V_j')^2 \sin a \qquad (145)$$

where

L = component of thrust normal to the vehicle centerline, lb
a = "rudder" angle of jet, deg

Eqs. 7-144 and 7-145 can be combined to give the slope of the lift coefficient curve with respect to angle (in degrees) as:

$$C_{L_a}\Big|_{a=0} = \frac{C_T}{57.3}\left[\frac{\sqrt{1 + 2C_T} + 1}{\sqrt{1 + 2C_T} - 1}\right] \qquad (7\text{-}146)$$

7-9.2.3.2 Outdrive Units

The lift force of a right angle drive with an open propeller will not be considered here because it is believed more likely that a right angle drive unit designed for a future amphibian will have a Kort nozzle propulsor. Annular foils have been tested in a wind tunnel to investigate their lift characteristics, Ref. 107. The results of these experiments indicate that the lift coefficient of a shroud in free stream flow is about twice the lift coefficient of a conventional low aspect ratio rudder (Eq. 7-140) where the aspect ratio AR and projected areas S of the shroud are defined, respectively, as

$$\begin{aligned} AR &= d/c, \text{ nd} \\ S &= dc, \text{ ft}^2 \end{aligned} \qquad (7\text{-}147)$$

where

d = inside diameter of the shroud, ft
c = length of the shroud, parallel to the centerline, ft

Eq. 7-140 may be simplified ($\Omega = 0$) and increased by a factor of two to yield an equation for the slope of lift coefficient with respect to angle of attack for an annular foil in free stream flow:

$$C_{L_{o_a}}\Big|_{a=0} = \frac{dC_{L_o}}{da}\Big|_{a=0} = \frac{0.1976\,AR}{1.8 + \sqrt{(AR)^2 + 4}} \qquad (7\text{-}148)$$

where

$C_{L_o} = \frac{L}{\frac{1}{2}\rho S V_a^2}$ = lift coefficient for a shroud in free stream flow, nd
L = lift or force normal to direction of flow, lb
S = projected area of shroud, ft^2
V_a = advance speed, ft/sec
ρ = mass density, slug/ft^3

This equation gives a good fit to the experimental data in Ref. 107.

The lift of a Kort nozzle shroud will be influenced by the flow velocities induced by the propeller. A rough estimate of this effect can be made from simple momentum theory by assuming that the effective velocity past the shroud is the advance speed augmented by one-half the velocity increment in the slipstream. Thus,

$$C_{L_a} = C_{L_{o_a}}\left(\frac{1 + \sqrt{1 + C_{T_p}}}{2}\right)^2 \qquad (7\text{-}149)$$

where

C_{L_a} = slope of the lift coefficient curve for a shroud enclosing a thrusting propeller, nd
$C_{L_{o_a}}$ = slope of the lift coefficient curve for a shroud in free stream flow, nd
C_{T_p} = thrust coefficient of the propeller, nd

$$C_{T_p} = \frac{T_p}{\frac{1}{2}(\rho A V_a^2)} \qquad (7\text{-}150)$$

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where

T_p = portion of total thrust produced by propeller, lb
A = $\pi D^2/4$ = propeller disc area, ft^2
D = propeller diameter, ft
V_a = advance speed, ft/sec
ρ = mass density, slug/ft^3

To complete the picture, one must consider the propeller thrust component normal to the ship

$$C_{L_T} = \frac{T_p \sin a}{\frac{1}{2}(\rho S V_a^2)} = C_{T_p}\left(\frac{\pi D^2}{4}\right)\left(\frac{1}{cd}\right)\sin a$$

If $D = d$, $C_{L_T} = C_{T_p}\left(\frac{\pi}{4}\right)\left(\frac{d}{c}\right)\sin a$ (7-151)

Then, $C_{L_{a_T}} = 0.0137\,(AR)\,C_{T_p}$ (7-152)

The total lift coefficient slope may be estimated by adding Eqs. 7-149 and 7-151, i.e., $C_{L_a} + C_{L_{a_T}}$

Refs. 108 and 109 present model test data for the normal force of Kort nozzle configurations. One study was made for the design of positioning units for the Project MOHOLE Drilling Platform and the other was made for the design of a tilt-duct VTOL craft.

7-9.2.4 Ducted Thrusters

The static thrust produced by a transverse tube type thruster may be estimated from

$$T = [C^2 P^2 \rho A]^{1/3}, \text{ lb} \qquad (7\text{-}153)$$

where

P = delivered power, ft-lb/sec
A = disc area, ft^2
C = figure of merit, nd
ρ = mass density, slug/ft^3

Ref. 110 shows that the value of C for tunnel thrusters is approximately 0.8. This may be compared with the value of C for Kort nozzles which may be as high as 1.4. Thus, for the same power and diameter, the static thrust produced by a Kort nozzle will be about 40 percent greater than by a tunnel thruster.

The side force of a tunnel thruster is seriously degraded when the ship is underway. The effect of forward speed on the thrust of such a device depends greatly upon flow across the tunnel openings, which is a function of the hull shape. There are no data available for the performance of a tunnel thruster installed in a hull similar to an amphibian. However, based on available data, it is not unreasonable to expect that the side force produced by a tunnel thruster in the bow of an amphibian at cruise speed would be less than 30 percent of its static thrust.

7-9.2.5 Box Rudders

In order to improve the docking performance of the LARC V amphibian, model tests were conducted at the Davidson Laboratory of the Stevens Institute of Technology, Ref. 111. Several rudder configurations were tested:

a. Existing single flat plate rudder
b. Three-parallel-bladed rudder
c. Three-tandem-bladed rudder
d. Circular nozzle* with airfoil section
e. Circular nozzle* with flat plate sections
f. Elliptical plate nozzle*
g. Rectangular plate nozzle*
h. Rectangular plate nozzle* with center plate

*These are more accurately described as tube rudders; they are placed behind the propeller and do not function as a Kort nozzle. The propeller was enclosed in a fixed nozzle, independent of the rudder configuration.

Measurements of side force and yawing moment were made in the static condition; the propeller produced thrust, but the model was constrained so that there was no motion. The various configurations were compared on the basis of a steering performance index which was simply the rudder's lift curve slope (side force per degree of rudder angle). On this basis, the rectangular plate nozzle with center plate (box rudder) was the most effective, yielding some 72 percent improvement over the existing rudder configuration.

The large improvement in side force (per degree of rudder deflection) realized by the box rudder configuration is due largely to the simple fact that more rudder area is placed in the propeller slipstream. This rudder configuration was adopted for the LARC XV and is now standard equipment.

7-9.2.6 Steering Linkages

It is important that the waterborne steering

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system be coordinated with the overland steering system. This coordination allows the transition between waterborne and overland operations to be made smoothly and safely. In addition, as was pointed out earlier, it is desirable to use the wheels as rudders for operations through the surf where steering may alternately be accomplished either by rudder or wheels, or both. These considerations dictate that water and land steering systems be interlocked, and that steering be accomplished by a single control. The linkage should be designed so that the maximum deflection of the rudder will correspond with the maximum cramp angle of the wheels.

The large forces necessary to turn a 40,000-lb amphibian on land will dictate that power steering be employed. Hence, both land and waterborne steering will likely be hydraulically powered.

The strength of the waterborne steering system linkage should be based on the maximum rudder torque, whether it be from ahead or astern operation. The maximum power P which must be supplied is a product of the maximum ahead rudder torque and the desired rudder angular velocity:

$$P = \frac{Q\omega_r}{550(57.3)} \text{ , hp} \qquad (7\text{-}154)$$

where

Q = torque, ft-lb
ω_r = rudder angle rate, deg/sec

The optimum angular velocity of the rudder depends, to a large extent, on the quickness of the ship's response to the rudder. A fast rudder deflection rate is of little use if the ship responds so slowly that the rudder stall angle is almost immediately exceeded. If the ship's response is quick so that the drift angle ϕ (Fig. 7-97) increases rapidly with an increase in rudder angle δ, then the angle of attack α will not exceed the stall angle. Ref. 105 suggests that a suitable rudder rate may be

$$\omega_r = \frac{60\ V}{L} \qquad (7\text{-}155)$$

where

ω_r = rudder angle rate, deg/sec
V = ship speed, ft/sec
L = ship length, ft

If we apply this formula, a 40-ft amphibian with 8 mph speed should have a rudder rate on the order of 17 deg per sec.

The rotational velocities in the propeller slipstream can cause the rudder to have a lift force when it is placed amidships (zero rudder angle). This effect was noticeable on the DUKW. As a result, the steering linkage on the DUKW was modified so that when the helm angle was zero the rudder was at the angle which gave zero turning moment. The linkage was also arranged so that the ratio of rudder travel to helm angle was greater on one side of the zero helm angle than the other. This was done so that the helm would have equal effectiveness to port and starboard even though the rudder did not.

7-9.3 WATERBORNE STEERING BY MEANS OF THE WHEELS

It has already been noted that the wheels can be used effectively as rudders in the surf mode of operation. Their effectiveness is improved by placing faired covers over the hubs which also decreases their form drag. Close attention to the hull design in way of the wheel wells can also improve the flow past the wheels so that their effectiveness as rudders is increased.

Many amphibians, and especially high speed designs, have provisions for retracting the wheels and/or extending flaps or fairings to "clean up" the flow around the wheel wells. These provisions are all directed toward decreasing the form drag which is a large part of the total drag on the amphibian. When the amphibian is operating in the hull mode or some high speed mode with wheels retracted or covered with flaps, the wheels cannot be used as rudders and some provision should be made to automatically disconnect the overland steering system from the waterborne steering system when the wheels are retracted.

7-9.4 OVERLAND STEERING SYSTEM

The overland steering system, in conjunction with the suspension system, determines the degree of control and stability for the amphibian on land. The turning radius is a function of the amphibian geometry and the type of steering employed. Figs. 7-104 and 7-105 show the geometry of various turning radii for conventional Ackermann (2-wheel) steering used on all standard military vehicles and for 4-wheel

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steering, respectively. The angle β is the maximum cramp angle for the inside wheel in a minimum radius turn. The angle α is the cramp angle for the outside wheel. The relationship between α and β is chosen so that the axis of each wheel goes through the center of curvature of the vehicle path. Otherwise, there would be excessive lateral scrubbing of the tires in a turn. The relation between the front wheel steering angles for Ackermann steering is:

$$\cot \beta = \cot \alpha - \frac{W}{L} \qquad (7\text{-}156)$$

where

L = wheelbase, ft

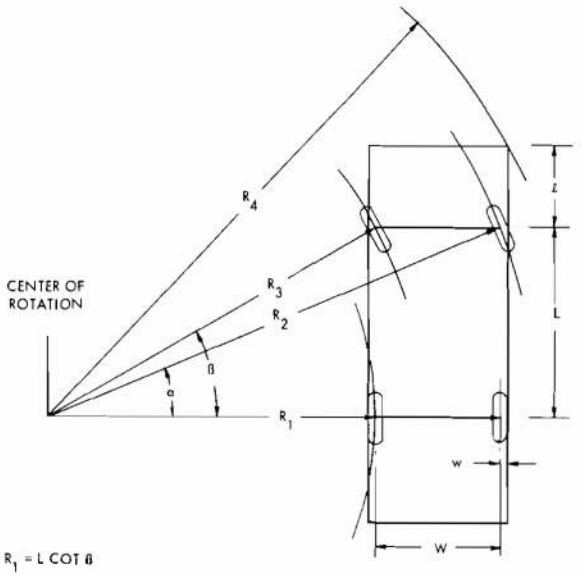
W = length between steering pivots, ft

It can readily be shown that the maximum cramp angle of the front wheels to effect a given radius turn is smaller with four-wheel steering. The maximum cramp angle is of importance for an amphibian design because it determines the depth of the wheel well cutouts. Deep wheel wells are undesirable with respect to drag, buoyancy, arrangements and, especially, strength of the hull. Amphibians with four-wheel steering can be made even more maneuverable by making provision for crab steering, as shown in Fig. 7-106. Crab steering is indispensable for maneuvering a large cumbersome vehicle in close quarters. Of course, the advantages of four-wheel and crab steering are offset to some extent by the increased complexity of the system.

Other factors to be considered in the design of wheeled amphibian steering systems are effects of braking and traction, suspension geometry, inertial and aerodynamic forces, powering, gearing, and alignment. These factors are all discussed in Ref. 63.

7-9.5 LOCATION OF THE STEERING POSITION, CONTROLS, AND INDICATORS

The operator's location on an amphibian will be a compromise between the optimum position for steering on land and steering on water. On land the most desirable position is as far forward as possible so that the operator can see over the bow in order to avoid obstructions. On water, however, safe operation dictates that the operator's station be placed farther aft to afford protection from the impact of the surf and also to improve the helmsman's "feel" of the rudder.



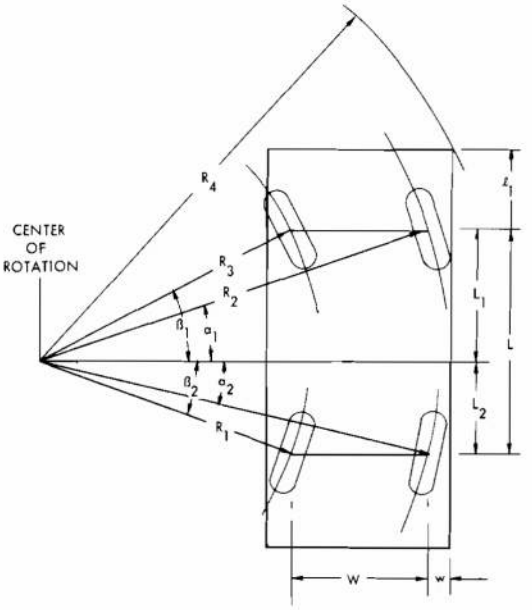
$R_1 = L \cot \beta$

$R_2 = \left[(R_1 + W)^2 + L^2\right]^{1/2}$

$R_3 = L/\sin \beta$

$R_4 = \left[(R_1 + W + w)^2 + (L + l)^2\right]^{1/2}$

Figure 7-104. Ackermann Steering



$L_1 = L_2 (\tan \beta_1 / \tan \beta_2)$

$R_1 = L_2 / \sin \beta_2$

$R_2 = \left[(L_1 \cot \beta_1 + W)^2 + L_1^2\right]^{1/2}$

$R_3 = L_1 / \sin \beta_1$

$R_4 = \left[(L_1 \cot \beta_1 + W + w)^2 + (L_1 + l_1)^2\right]^{1/2}$

Figure 7-105. 4-wheel Steering

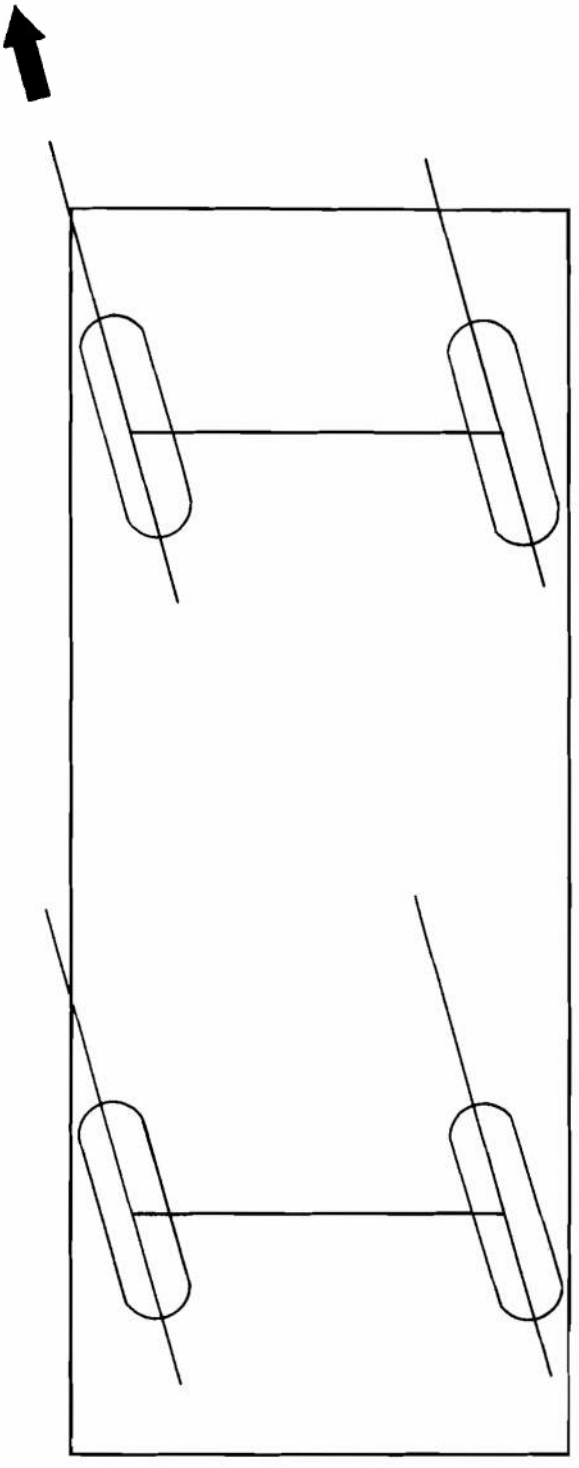


Figure 7-106. Crab Steering

On a ship, the operator senses changes in heading by sighting across some reference point on the bow at a point on the horizon. The spatial relationship between these two points indicates to the operator any change in heading and also the rate of the change. The sensitivity of this type of navigation increases as the distance between the operator and his visual reference point on the ship increases. It should be noted that the inner ear is virtually useless in sensing changes in heading on a tossing vessel. This, along with the fact that there is no feel to the rudder with power steering, points up the need for a rudder angle indicator.

The LARC XV was designed to head in one direction at sea and the other direction on land in an attempt to solve the conflicting requirements for operator location. In this manner, the cab was positioned on the extreme forward end for good road visibility on land and aft for protection at sea. This was not a completely satisfactory solution to the problem, however. Upon reaching land through the surf, the amphibian must come to a stop while the operator changes seats (the seats face in opposite directions, and one of them is elevated to place the operator in a bubble on top of the cab for complete 360 deg visibility at sea) and turns the amphibian around for land operation. The sequence of operations is reversed for entry into the water. This arrangement led to increased complexity in the controls which had to be used for both modes of operation, and certain instruments and indicators were difficult to monitor from one seat or the other.

The LARC V has only one steering position which is placed farther aft than would be considered as ideal for overland operations. As a result, an assistant must climb out of the amphibian to direct the operator over difficult terrain.

An alternative design which should be studied for future amphibians would place the cab far forward. An auxiliary steering station would be located on the aft end of the amphibian. This station would have duplicate controls and instruments needed for safe waterborne operation, and would only be manned during operations in heavy surf and high seas. The feasibility of this type of solution would require further study.

The location of the controls should be

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convenient to the operator, and all instruments and indicators should be in full view and easily read and interpreted. The operator's seat should be adjustable to suit his particular anatomy. The best way to insure against a poor design in which certain vital controls are out of reach and instruments cannot be seen is to build a full scale mock-up of the control station which can be evaluated by experienced amphibian operators.

SECTION V AUXILIARY SYSTEMS

7-10 AUXILIARY SYSTEMS DESIGN

Amphibians are generally multi-mission vehicles operated by a crew of from two to five men. The auxiliary systems must therefore provide basic, remote control, and labor saving services so that the crew-vehicle combination can provide a flexible, cost-effective system. The auxiliary systems necessary to accomplish this goal are numerous, and in some instances, complex. This section of the handbook does not explain the design procedure for each system but it does consider the problems generated by the marine environment and reviews, for each system, the important lessons learned from recent amphibians.

7-10.1 HYDRAULIC SYSTEMS

Hydraulic systems are used to transmit power and to provide remote controls. Amphibian hydraulic systems could transmit and provide power for:

a. Steering
b. Braking
c. Wheel extension and retraction
d. Ramp extension and retraction
e. Winch drives
f. Miscellaneous drives

Hydraulic remote control is normally used only in conjunction with a power transmitting system. Components of a system include:

a. Source of mechanical power such as an electric motor, power take-off (PTO) from the main engine, or manual

b. Power converter (mechanical to hydraulic) such as a rotary or reciprocating pump

c. Hydraulic power transmission system which includes valves, tubes or pipes, regulators, and manifolds

d. Power converter (hydraulic to mechanical) such as a hydraulic cylinder, rotary actuator or hydraulic motor

e. Miscellaneous components such as reservoirs, filters, heat exchangers.

Combinations of these components make up the hydraulic system. Frequently a single hydraulic pump is used to power a number of components.

The design techniques and use of fluid-power and fluid-control systems are expanding rapidly. This implies that present design criteria will change as new components are produced and a larger production base evolves. *Machine Design* magazine publishes annually a reference issue devoted entirely to fluid power which contains current information on hydraulic system design. The Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, maintains the Qualified Products List (QPL) of hydraulic equipment. The QPL's should not be used without consulting the maintaining authority. Some of the design guidelines in use at present (1969) are described in the paragraphs which follow.

For a required performance level, the system weight tends to decrease with an increase in system pressure. The cost and maintenance, however, tend to increase with system pressure. Most system pressures do not exceed 3,000 psi and the variety of available components for higher pressures is limited. Component availability is greatest at 2,000 to 2,500 psi.

Systems in which the pump runs continuously may be either open or closed center systems. When the drive end of the systems is not using fluid, the open center configuration discharges the fluid back to the reservoir through the control valve, while the closed center system returns the fluid through the pressure relief valve. This means, of course, that when there is no power required and the system is on "stand-by", the open-center configuration operates at a reduced pressure and pump power level while the closed-center system pump maintains a full head of pressure. The

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closed-center configuration is used where there are two or more branches in the circuit, operating independently. It is possible to use an open-centered configuration to power more than one cylinder or motor independently if a series arrangement is used. Special precautions are required because the tankport on control valves is usually not designed for full system pressure. In general, the closed system is preferred for multiple branch systems where at least one of the motors is used continuously. Open-center configurations are preferred for simple systems which are not used continuously.

Another important system consideration is the selection of the hydraulic fluid. Ref. 112 is a handbook on hydraulic fluids.

Simple low pressure hydraulic systems are easy to understand, operate, and maintain. Systems on amphibians, however, are complex and are frequently hampered with fluid dynamic problems such as cavitation. In order to obtain a cost-effective trouble-free system, it must be completely designed and tested by engineers who have experience with similar systems in a similar environment. In the past, attempts to reduce the cost using components with marginal capabilities have resulted in systems with low reliability and the added expense of additional development time.

The source of mechanical power is frequently a mechanical power take-off (PTO) from the main engine which is normally a standard optional feature. The power converter is usually a simple piston pump for manual operation or one of a variety of types of motor-driven pumps. Ref. 113 contains a list of available types of motor-driven pumps and a discussion of the general characteristics of each type. Gear pumps were used on the LARC V and LARC XV. In spite of serious development efforts, these pumps had problems which resulted in unpredictable operation and short lives. It is recommended that these problems be reviewed before using this type of pump.

Hydraulic power is transmitted primarily through rigid tubing. Steel is the only tubing material permitted without restriction by the "Joint Industry Conference, Hydraulic and Pneumatic Standards for Industrial Equipment". Tube fittings are selected for minimum resistance to flow in the system, reliability in the environment, resistance to leakage, and life cycle cost, including the initial cost of parts and labor and the maintenance cost. Fittings are made of steel and are connected with mechanical seals which may be flanged, flared, or flareless types. Flanged seals are used only in the larger sizes. Flared tubing for hydraulic applications is normally used with the JIC-SAE 37 deg flare. A 45 deg SAE flare is frequently used for low pressures with copper tubing. For steel tubing, the flareless fitting is leakproof to very high pressures and resists vibrations well. If flared type fittings are used, the nut-and-sleeve type is preferred. Thin wall stainless steel tubing work hardens readily and both the tube-cutter and the various flaring tools can work-harden the tube so that either flareless or flared fittings leak at moderate pressures.

The hull of any vehicle flexes and some machinery components will rock on their foundations so that it is important to arrange the tubing to allow for motion between components. If the relative motions are large, flexible hose should be used. In addition to permitting relative motion, hose can accommodate the following environmental conditions:

a. Severe vibrations
b. Manufacturing tolerances
c. Complex routing for piping runs
d. Hydraulic shock absorption

Flexible hose changes length when pressurized so that it should not be installed in tension. It fails more quickly from twisting than bending so it is desirable to support the hose in such a manner that the motion in any one section is in one plane.

Valves can be classified as follows:

a. Pressure control
b. Flow control
c. Direction control

The flexibility of hydraulic systems is in large measure the result of the variety of control valves available. This constitutes a large complex subject and the manufacturers should be consulted as to the characteristics of available valves. Automatic pressure regulating valves have been a high maintenance component on some past amphibians. In general, complicated control valves cannot be expected to be highly reliable in the amphibian environment. For Navy hydrofoil boats, packaged hydraulic systems have performed better than those assembled at the boat yard.

Hydraulic power is converted back to

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mechanical force by:

a. Linear actuators
b. Hydraulic motors
c. Rotary actuators

Linear actuators include all of the types of hydraulic cylinders. These have high force capability, high power per weight and size, mounting flexibility, and ease of speed control.

Hydraulic motors include a variety of variable and constant volume configurations. Motor-type comparisons are presented in Ref. 113.

Rotary actuators are either vane or piston types. Typical maximum arcs of rotation are 280 deg for single vane and 100 deg for double vane types. Piston-type rotary actuators can exceed 360 deg rotation.

The miscellaneous accessories for a hydraulic system are sometimes neglected since they generally serve only an auxiliary function. Reservoirs, one of the more important of these items, are sized to hold the full flow from the pump for from one to three minutes. Factors which affect the size are:

a. Volume to fill the system at start-up without exposing the intake filter
b. Capacity to accommodate variations in the system requirements during each cycle of the operation
c. Heating and cooling dynamics during extreme temperatures

Other factors that must be considered in selecting the reservoir are:

a. Line location at extreme angles of heel and trim
b. Baffles to reduce surging in the tank
c. Provisions for draining and cleaning the tank
d. Level indicator
e. Air filters to remove the contaminants from the air as the tank breathes

Reliable hydraulic systems require clean hydraulic fluid. Filters are required, even if the system is initially clean, because of the many sources of contamination. Filters are available in a variety of types. The selection criteria include:

a. Fluid characteristics
b. Solids to be removed
c. Piping material
d. Pressure
e. Environment

All hydraulic fluids have limiting values of practical operating temperatures. For systems which operate continuously in normal environmental conditions, a heat exchanger will be necessary to cool the hydraulic fluid. These heat exchangers usually use the same fluid that cools the main engines. Finned tubing has been used effectively for this purpose. In general there is very little air flowing over the reservoir so that the heat exchanger should be designed to carry off the full amount of heat generated in the system.

7-10.2 ELECTRICAL SYSTEM

Electricity is required for lights, horn, controls, gages, electronic equipment, and power for small motors. Components in the electrical system of a typical amphibian include:

a. Batteries
b. Starter solenoid
c. Alternator
d. Starter motor
e. Engine fan disconnect switch
f. Fuel shut-off valve
g. Junction box with contactors, circuit breakers, relays, and a shunt
h. Fuel pump motor
i. Lights, including headlights, taillights, running lights, bow light, stern light, cab lights, machinery space lights, instrument lights
j. Instruments
k. Windshield wiper
l. Radio
m. Horn
n. Slave receptacle
o. Heater fan motor
p. Ramp horn
q. Emergency hydraulic pump motor

The major differences between electrical systems for amphibians and those provided for trucks are that stray current in a metal amphibian can accelerate electrolysis, and salt water spray and salt-laden air accelerate the corrosion of contacts and the deterioration of insulation. Electrolysis caused by stray currents is practically eliminated by using a two wire system where the metal hull is not used as one side of the circuit. Two wire systems, however, are heavier and more expensive. In order to prevent premature failure of the system, it is necessary to select satisfactory materials for the environment and encapsulate or otherwise waterproof the entire system.

Most boats are fitted with a 6- or 12-V system but marine equipment is frequently available for

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24-V service. At the present time 24-V DC systems are standard for all military vehicles. This voltage is prescribed by the Department of the Army in AR 705-19, Ref. 114. Refs. 115 to 119 contain information pertaining to the design and requirements of electrical systems for boats.

Ref. 63 contains discussions of electrical systems for military vehicles. The U. S. Army Tank-Automotive Command, Warren, Michigan, maintains the list of qualified electrical products for use in Army vehicles.

Some design problems and/or solutions from recent amphibian development program are:

a. Wires and components must not be located in the bilge, in areas where there may be excessive spray, or where they will be susceptible to damage by maintenance personnel.

b. Alternators are simpler than marine (nonsparking) DC generators.

c. Most prevalent failures have been waterlogged switches and contacts, and insulation deterioration.

d. In cold weather the batteries may require heating.

e. A receptacle and extension cord for jumping electrical systems between vehicles are desirable.

Some of the present amphibian operators find a high-intensity searchlight useful for finding the low spots in the surf when coming from the sea into shore. These should be located on the cab roof and could be either fixed in position or manually trainable.

7-10.3 FUEL SYSTEMS

Fuel systems for gasoline, or other fuels with a flashpoint of 110°F or lower, must be designed with more safeguards than required when using Diesel fuel. Gasoline vapor is heavier than air and tends to collect at the low point of the bilge. In a truck installation the vapor flows out the bottom and is dissipated. If the concentration is within certain bounds, any spark or open flame will cause an explosion. A safe fuel system should be:

a. Liquid and vapor tight to the interior of the hull

b. Permanently installed with all components properly secured

c. Accessible for inspection and maintenance, particularly the valves and filters or strainers

d. Adequately protected from high pressures caused by thermal expansion of the fuel when the system is secured

e. Properly bonded across components that will not carry electricity and grounded so that all metallic components have a low resistance continuity to ground, thus preventing static electricity sparks

f. In areas that are not subject to accumulation of water which might eventually leak into the system

g. Able to withstand exposure to free burning fuel for a specified time so that the crew can escape in event of fire (Ref. 115 recommends 2.5 min for yachts.)

h. Constructed of materials that are compatible with the fuel

i. Built to withstand the pressures, vibration, shock, and other environmental conditions

j. Fitted with the necessary filters and fuel pick-up tubes since the vehicle motions may be extreme

k. Fitted with connections only on the top to reduce the amount of fuel leakage in case of a fitting failure

l. Fitted with a fill pipe or pipes that open only on deck, with a watertight cap, in a location where spilled fuel and/or fumes will flow overboard

m. Fitted with vent lines that have flame screens to prevent flashbacks

n. Arranged such that a broken distribution line cannot siphon the fuel from the fuel tank into the bilge

o. Able to prime engines for cold starts or after running out of fuel

These vehicles will occasionally be fueled alongside a ship so the location of the fill pipes must be safe for personnel and free from water washing into the fuel system. Fill pipes must be sized so that they do not restrict the refueling operation. Vents must be located so that the fuel vapor flows overboard and, in heavy weather, sea water does not flow back through the vent line. Vent lines should not be tapped into fill lines.

Rigid fuel tanks may be constructed from steel, aluminum, or Fiberglas. Each has advantages and disadvantages which must be evaluated with respect to the particular design. Flexible bladder fuel tanks have also been used to permit fitting into locations which are

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inaccessible to rigid tanks. However, they are susceptible to fire and abrasion.

Electrically driven submerged fuel pumps are dependable and tend to avoid vapor lock.

7-10.4 COOLING SYSTEMS

Boat machinery cooling system heat exchangers are located under or inside the hull. If under the hull, it is normally located alongside the keel where it is well protected and is usually defined as a "keel cooler". For installations with the heat exchanger inboard, the seawater is pumped directly through the engine and the other components or through a heat exchanger. For craft which operate in the surf, such as landing craft or amphibians, where there is a large quantity of suspended solids in the water, a system that pumps water through a piping system is impractical. The Navy LCVP's using this type of system at times experience filling of the interior water passage of the engine with sand. Amphibians, therefore, are fitted with keel coolers located in the position best suited to the hull design.

Three feasible arrangements are:

1. A special recess in the hull with a grille protecting a compact heat exchanger element
2. Tubular or other heat exchanger, without protection, in a natural recess such as a wheel well or propeller tunnel
3. Pipes or special shapes welded or extruded with the bottom shell to provide heat exchange through the bottom

For the land mode, a truck-type radiator is fixed in a recess in the hull with a declutchable fan behind it. The recess is open on the top so that the air can be drawn through the radiator and exhausted. Tests run on amphibians have shown that land cooling must be sized to accommodate maximum engine output for long periods.

The major problems that plagued the LARC V and LARC XV cooling systems were:

a. Electrolytic corrosion of fan drives and heat exchangers

b. Insufficient cooling at high ambient temperatures

c. Magnetic fan clutch failures

7-10.5 CONTROL SYSTEMS

Control systems must be designed to be used by any Army driver in any environment in which the vehicle will operate. Some of the problems experienced in the development of recent amphibians have shown:

a. The need for a throttle locking device in the waterborne mode

b. That the orientation and direction of motion of controls should coincide with the direction of the action controlled

c. In general, the control wires and/or rods are too light and frequently bind, stretch, or bend requiring frequent adjustment and/or repair.

As an example of the complexity of these systems the controls and panel lights for a simple amphibian are listed by type in Table 7-47.

7-10.6 NAVIGATION SYSTEMS

For most operations, navigation of amphibians can be conducted without special devices because the route between the cargo ships and the landing beaches is normally within sighting distance. For those occasions when visibility is restricted, a compass and navigation lights are necessary safety features. A combination chartboard and navigation instrument is useful if a chart is used. It is also desirable to provide dry stowage for charts, maps, and manuals.

For those situations where the destination is not visible for part of the voyage, while following a single given compass course, a more sophisticated navigation system is required. One solution is to furnish, when necessary, a portable homing receiver for each vehicle to indicate to the operator the direction to a transmitter. The transmitters would also be portable and could be stationed on ships, the beach, or buoys. It is necessary that the vehicle crew be capable of setting the receiver to home on a number of different transmitters.

7-10.7 COMMUNICATION SYSTEMS

It is desirable to provide some form of communication between the control personnel and the vehicle crew. This can be accomplished with either portable or fixed equipment. In general, the same equipment provided for trucks will be satisfactory.

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TABLE 7-47 LARC V CONTROLS

Start and Control Switches

Master switch
Ignition switch
Bilge pump switches
Converter lock switch
Horn button
Fan drive switch
Emergency override

Levers and Foot Pedals

Throttle
Forward-neutral-reverse shift lever
Land drive selector
Marine drive selector
Parking brake
Front wheel disconnect
Retarder pedal
Brake pedal
Accelerator

Light and Accessory Switches

Windshield wiper
Panel lights
Driving lights
Navigation lights
Heater controls
Defroster controls

Emergency Equipment Controls

Engine fire control handle
Manual bilge pump
Emergency tiller

Instrument and Warning Lights

Fuel gages
Ammeter
Engine and pressure
Engine water temperature
Fan stopped light
Speedometer
Low oil pressure light

7-10.8 VENTILATION SYSTEM

The air is changed in the enclosed sections of an amphibian for:

a. Engine combustion air requirements
b. Temperature control
c. Removal of noxious gases and resupply of breathing air
d. Removal of fuel vapors in machinery compartment
e. Engine cooling for air cooled engines, e.g., gas turbines

Except for air cooling of engines, the quantities of air involved are relatively small. The requirement is the design of an intake and exhaust system which will allow the air to pass but still not allow dangerous amounts of water into the hull in any reasonable operating condition. In general, no conditioning of the air is required except for possibly heating the air for the cab and passenger spaces.

In the presence of salt-spray, gas turbines salt up causing excessively high operating temperature and accelerated corrosion. This condition reduces the power level until the salt is washed off with fresh water. For this reason, the ventilation system for a gas turbine installation usually includes demisters, and filters. It is recommended that the engine manufacturer be consulted regarding the type and amount of filtering required for any specific design.

For very cold weather, it is desirable to provide for restricting the ventilation in the machinery space so that the temperature inside will stay above freezing and prevent ice from forming in the recesses and on the deck.

The cab should be provided with a fresh air supply, heated when necessary, and a good defroster. A change of air every two minutes is desirable for occupied spaces. For hot weather, devices should be available to secure some of the doors, windows, and hatches in an open position. A hatch in the cab roof is particularly useful for venting the hottest part of the cab. A fan to circulate the air in the engine space is beneficial to maintenance personnel.

7-10.9 LUBRICATION SYSTEM

There is such a large assortment of moving parts on an amphibian that the job of keeping all parts properly lubricated is critical and time-consuming. It is desirable to reduce the number of different lubricants to a minimum. It is also important to eliminate maintenance under the vehicle and in the bilge during the time between maintenance periods. On the LARC V and LARC XV, for example, the

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propeller shaft bearing is to be greased every four hours of operation. For a continuous operation, this requires that the crew crawl under the vehicle while it is still wet and, possibly, while it is being loaded. It is understandable that this preventive maintenance is sometimes overlooked. The universal joints hidden away in the wet and dirty bilge suffer from the same problem.

The lubricating oil sump on engines built for land vehicles is sometimes not designed for the high angles of roll that occur on amphibians. The entire range of practical motions must be considered for the design of the lubricating oil system. Sump drains must be specially considered because the engines are usually mounted as low in the vehicle as possible. In the LARC V, for example, the engine oil was first drained into the bilge and then pumped into a waste container. This is obviously an inefficient procedure which increases maintenance costs.

Elements of a typical lubrication oil system include pumps, filters, heat exchangers, valves, piping, sumps, and level and pressure gages. The engine oil sump is not cooled by the air flow generated by the motion of the vehicle, hence a heat exchanger with sufficient capacity is required.

7-10.10 FRESH WATER SYSTEM

Fresh water systems are normally fitted on amphibians only for water washing gas turbines to eliminate the salt water. The requirements for the service should be obtained from the engine manufacturer.

7-10.11 COMPRESSED AIR SYSTEM

Compressed air may be used for engine starting, tire inflation, air powered tools, and control power, e.g., air brakes. The importance of variable tire inflation with regard to mobility is discussed in Ref. 26.

A compressed air system is relatively simple and consists of a compressor, accumulator piping, valves, and water traps.

7-10.12 CARGO HANDLING SYSTEM

Cargo handling is usually accomplished in three phases:

1. Transfer of cargo from ship to vehicle
2. Vehicle transit to destination
3. Off-load cargo at the land destination point

At sea, the cargo is handled easily with the ship's crane but there are serious difficulties in safely landing and securing the cargo on the amphibian cargo deck while it is rolling, heaving, and pitching. The location of the tie-down pads is important since a lack of pads may limit some types of cargo to a partial load. The lashing arrangements must be capable of being easily and quickly attached and adjusted by one man wearing gloves.

It has been suggested that lashing arrangements, designed to fail if the amphibian rolls in excess of some fixed angle, might be a desirable safety feature.

Heavy swinging drafts of cargo present particular problems. The draft will damage any projection above and adjacent to the cargo area that is not properly designed.

The deck in the cargo area also receives severe punishment from heavy items of cargo with sharp corners. Some remedies are the provision of a layer of rubber bonded to the deck, a layer of plywood, or increased deck plating scantlings. The last solution probably requires the least maintenance.

The transit phase is not a particular problem with regard to the cargo handling system unless the cargo shifts or must be jettisoned. Fabric side curtains supported with wire rope prevent shipping some water in the cargo space and still allow the water trapped on the cargo deck to drain overboard quickly.

The protection of cargo from the weather with a tarpaulin can be useful. The covering and supporting structure must be strong enough to withstand effects of the surf. Configurations with nonwatertight cargo decks must be protected to prevent swamping. Protected storage for all portable equipment must be provided.

The last phase, off-loading the cargo, is a problem because of the great variety of the equipment available to handle the heavy items. A flush deck arrangement with side curtains allows the use of fork lift trucks. Cargo that must be lifted out of a well is particularly difficult to handle. The provision of self-contained unloading gear requires additional weight and space, and penalizes the performance of the vehicle. Ramps can be used for wheeled

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cargo and for rolling off heavy boxes. This is a slow method, however, and requires added weight, increased complexity, and maintenance. A winch with a flexible arrangement of snatch blocks, deck pads, wire rope, nylon line, and assorted fittings can be used in a variety of ways to assist in off-loading in many circumstances.

7-10.13 FIRE FIGHTING SYSTEM

Combustible materials on an amphibian include fuel, electrical equipment, cargo, and possibly the hull of a Fiberglas vehicle. The vehicles are relatively compact and easily disabled by fire so it is necessary that the crew be able to detect and extinguish a fire quickly.

The fire fighting system may include a detection device, and portable and fixed extinguishers with the necessary controls. There are a number of types of detection devices that might be used. The type selected should be quick-acting, repeating, accurate, and reliable. The detector may actuate lights, alarms, and a fixed extinguishing system.

Either carbon dioxide or monobromotrifluoromethane Halon 1301 may be used as the extinguishing agent. The latter is reportedly much more effective than CO_2 and is only a little more expensive. Portable extinguishers should be located in the cab and also at the aft end of the cargo compartment so that at least one is accessible in any situation.

A fixed extinguishing system has a supply of extinguishing agent, distribution system, nozzles, and local or remote control and is normally installed in the engine space. In order for the system to be safe and effective it must:

a. Contain sufficient agent to fill the compartment where the fire is to be extinguished

b. Permit evacuation of personnel from the space

c. Stop the fuel supply

If the engine draws combustion air from the space, it will stop as soon as the agent drives the air from the compartment. The control may be manual or automatic, and local or remote. The control mechanism should be relatively fireproof so that it is not damaged by fire before the system is actuated. If local control is used, it should be located where it can be reached during a fire. Ref. 115 recommends quantities of CO_2 to be installed in fixed systems on boats.

7-10.14 BILGE PUMPING SYSTEM

The primary consideration for the design of the bilge pumping system is the rate at which water can enter the bilge. If the vehicle has a cargo well deck that is open to the bilge, similar to the DUKW arrangement, the safety of the vehicle in the surf or high seas depends on the pumps' removing the water faster than the average flooding rate. Portable covers such as tarpaulins supported by bow frames are very effective in reducing the quantity of water. The covers must be sufficiently strong to prevent failure in the surf. The DUKW's were equipped with tarpaulin covers and, on occasion, they were swamped when the covers were split by the force of the plunging surf.

For vehicles with a watertight deck, the pump must be able to handle the water that can come aboard through the ventilation system, exhaust system, hatches, and, possibly, the machinery cooling system waterpump to allow for a broken water line. The pump capacity should also be greater than the possible inflow through the hull drains so that the vehicle will not founder if the drains are accidentally left open.

When the amphibian is receiving cargo from a ship in rough weather, the amount of water entering the hull may be relatively high due to the interacting wave patterns between the ship and the vehicle. Usually the amphibian will be operating with a moderate amount of ahead thrust to maintain tension on the spring line and, consequently, the engine will probably be operating at a low rpm. The bilge pump system design must provide sufficient pumping capacity at low engine power levels to prevent the accumulation of an excessive amount of bilge water in this situation. Table 7-48 lists bilge pumping rates for amphibians.

Other design requirements include:

a. The pump suctions must be located where the water will collect in any condition. Some craft are lowest forward while at rest and lowest aft underway. If the cargo is off center, the low point will be on one side for vehicles with flat bottoms.

b. Pumps should be self-priming and designed to run dry continuously.

c. Operation can be controlled automatically or manually. The overboard discharge should be located above the waterline where the operator can observe the discharge. A high water alarm

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TABLE 7-48 BILGE PUMP RATES

Vehicle	Power Source	Number of Pumps	Capacity of Each Pump	Total Capacity, GPM
DUKW	Mechanical Mechanical Manual	1 1 1	225 GPM > 75 GPM 25 GPM	> 300
LARC V	Hydraulic Manual	3 1	300 GPM 0.75 gallon per stroke	900
LARC XV	Hydraulic Manual	3 2	300 GPM 0.75 gallon per stroke	900
LARC LX	Hydraulic Hydraulic	3 2	100 GPM (bilge) 2000 GPM (cargo well)	300 4000

can also be provided.

d. Hydraulic drive or submersible electric drive should be used so that high water level in the bilge does not stop the pump.

e. The suctions should be located to be observed during normal maintenance so that rags and other debris that collect at the pump suction can be removed as they collect. The suction should also be accessible when there is at least a one foot depth of water in the bilge. This criterion has been overlooked in boats which have foundered only because the crew could not clear the pump intakes.

f. Bottom drains are normally fitted to keep the hull dry inside during operation on land. It is important that they be designed so that parts are not easily lost, and the drains can be easily removed and reinstalled.

g. The system piping should be designed to withstand the maximum pressure that the pump can provide.

h. The bilge suctions should be installed to provide a free flow area through the strainer at least 1.5 times the suction pipe cross-sectional area.

7-10.15 MOORING AND ANCHORING SYSTEMS

Amphibians are not expected to anchor frequently or for long periods. Accordingly, a lightweight anchor, a short length of anchor chain, and a nylon line are sufficient for the anchoring system.

The present system for holding an amphibian alongside a ship while receiving cargo provides for the ship to furnish a spring line which is attached at the forward inboard corner of the vehicle and led aft to the attachment on the ship. The amphibian is then held against the ship by running the propulsor in the slow ahead condition with the steering device directed to hold the stern against the ship's side.

The mooring system consists of properly placed cleats and nylon mooring lines. The lifting and/or towing pads can be used if they are in the correct position. Ref. 115 may be used for guidance in the selection of components for the mooring and anchoring systems.

7-10.16 EXHAUST SYSTEM

The exhaust systems used for amphibians are similar to those used on trucks, i.e., dry mufflers, and they exhaust out of the top of the vehicle. The entire system must be shielded or insulated for personnel safety. The system must be arranged so that engine motion, thermal expansion, and local hot spots do not crack the exhaust lines. The exhaust should not discharge forward of the operator's position.

Gas turbine exhausts are hot, large, and noisy. The engine manufacturer should be consulted to determine the requirements for a particular engine. The Navy conducts research on this problem and the Boat Engineering Department,

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Norfolk Division of the Naval Ship Engineering Center, Norfolk, Virginia, may be contacted for the latest information.

7-10.17 SAFETY AND LIFESAVING SYSTEMS

Safety has to be discussed throughout the text because it must be considered with each part of the design. Some of the more important features required are:

a. Fast, accessible escape routes from the cab in any situation including a capsized vehicle

b. Handholds so that the entire vehicle is accessible at sea in an emergency

c. Convenient life rings or lifesaving devices

d. Emergency tiller

e. Fire fighting equipment (par. 7-10.13)

7-10.18 HEATING AND DEFROSTING SYSTEMS

Heating and defrosting systems can be provided with hot water from the engine cooling system or require a separately fired burner. The latter should use the same fuel as the engines. Hot water heaters are not as efficient as separately fired heaters but require less maintenance. The heat must be properly distributed and free of fumes. The defroster should be capable of blowing fresh, unheated air, independent of the heater.

7-10.19 ON EQUIPMENT MATERIEL (OEM)

OEM are portable items of basic issue placed on board vehicles, as necessary for proper operation and maintenance by the crew, including:

a. Tool kit

b. Boat hook

c. Boarding ladder (if not built-in)

d. First aid kit

e. Anchor and line

f. Repair parts

g. Portable fire extinguisher

h. Life preservers

i. Mooring lines

j. Lifesaving ring buoy

k. Spotlight/flashlight

l. Lubrication order

m. Technical manual

n. Marine fenders

o. Pyrotechnic pistol

p. Radio set

q. Signal lamp

r. Portable trouble light

s. Emergency steering wrench

Proper storage must be provided for all OEM and some personal equipment for the crew, including such items as coats, boots, hats, helmets, rifles, ammunition, tool boxes, and charts.

7-10.20 COLD WEATHER KIT

Operating in very cold weather is a severe condition for any vehicle. If an air heater is used in the bilge of an amphibian and the air is circulated throughout the vehicle while the fresh air ventilation is restricted, many of the problems are modified. The procedure warms up all of the interior components and reduces the amount of external icing on the hull. When securing the vehicle, any seawater entrained in the hull or machinery must be removed.

Engine starting problems are the same for amphibians as they are for trucks.

SECTION VI COST ESTIMATING

7-11 COST ESTIMATING AND THE OVERALL DESIGN PROCESS

The financial and technical resources allotted to our national defense are inadequate to develop and produce all of the possible weapons and logistical systems that would assure continued superiority in our defense posture. As a result, a system analysis approach has been initiated to permit rational selection between alternative systems so that the greatest return for a fixed expenditure will be assured. With this approach, certain decisions will have been made long before a specific vehicle design is begun, i.e.:

a. How the vehicle concept fits into the total plan for national defense, thus establishing performance requirements

b. How the vehicle will be transported, supplied, maintained, and manned as a

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subsystem in the total integrated logistic support plan, thus defining support requirements

c. What expenditure will be allocated to the system based on its total life cycle cost, thus defining budget requirements

Any given vehicle, despite its actual excellent physical performance, will not represent an effective solution to the total defense problem if it cannot be developed within an established budget. Cost estimating performs two vital functions in the development of a new amphibian design. The first is to provide the system analyst or planner an appraisal of the amount of performance and capability that can be reasonably expected for a given expenditure. The second function is the provision of the necessary tools to permit the designer to control costs so that the system will be developed, constructed, and operated within the allowed budget. The discussion that follows will consider cost estimating methods that are useful to the designer. The methods used by the system analyst in the planning stages are complex and beyond the scope of this handbook.

7-11.1 THE TOTAL, OR LIFE CYCLE, COST CONCEPT

To illustrate the concept of total life cycle cost, it is useful to consider the actual costs that would be incurred by a change in design of a small fitting to be made of a new material. Such costs might include:

a. The cost of research to study the properties of the new material

b. The development cost of adapting the new material to the specific requirements of the fitting

c. The cost of redesigning the particular fitting and any corresponding changes that become necessary in the overall design

d. The cost of buying the particular part including purchase price, tooling charges, and possible costs due to long lead times, delays, etc.

e. The cost of testing necessary to verify the performance of the new fitting and the systems of which it is a part, including alterations or replacements needed to make the new fitting acceptable

f. The cost of operating, maintaining, and repairing the fitting including any special training needed to operate an unusual system, and costs for shipping and storing sufficient inventories of replacement parts

While this example is directed toward a small part of a vehicle, it can be seen that it would apply to changes in subsystems such as alternative power plants or to total vehicle concepts. Thus, life cycle cost is the total cost of a system over the entire lifetime of the vehicle.

7-11.2 COST ESTIMATING METHOD

The following two principles are basic to the philosophy of cost estimating:

1. The higher the degree to which the cost estimate is broken down into types of costs and divisions of systems into subsystems and individual parts, the more reliable the estimate should be. This follows because the costs of different systems are characterized by different, but predictable, rules. For example, the cost of constructing an aluminum hull structure can probably be expressed as a function of hull weight in dollars per pound, whereas fuel costs are related to engine size and time in operation in terms of dollars per horsepower-hour.

2. Cost estimating is largely based on past experience. Hence, the more complete, accurate, and detailed the past cost figures are, the more reliable the future cost estimate should be. The historical cost data figures may be adjusted to allow for known changes such as inflation. Where undefined areas exist, the designer must use good judgment in modifying estimating methods until he is satisfied that it represents a reasonable approach.

It should be emphasized that high cost estimates by the designer in order to prevent apparent cost growth is not a responsible approach to cost estimating. Conversely, unreasonably low estimates must be considered unresponsive.

Cost estimating of individual systems or components are treated in the paragraphs which follow.

7-11.3 RESEARCH AND DEVELOPMENT COSTS

Research includes the studies, experiments, and calculations needed to develop and verify new solutions to the basic engineering problems encountered during the evolution of an amphibian design. Development is the process whereby the results of research and advancing technology are integrated with the vehicle performance requirements to establish a

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satisfactory design configuration. Included in this process are the construction, testing, and evaluation of new prototype subsystems, systems, and complete vehicles. The process may be continued through change orders and product improvement studies.

Research and development (R & D) costs are probably the most difficult to estimate because every new vehicle concept will present new problem areas requiring R & D. Since the solution is not known, it is difficult to estimate how much cost will be involved in arriving at a solution. However, R & D costs are typically a very small part of the vehicle total life cycle cost. Hence, accuracy in estimating this part is not critical to the accuracy of the total estimate.

Before a cost estimate can be made, the problem areas must be recognized and defined. This requires a thorough study of the vehicle performance requirements in light of current technology. R & D costs are directly related to the number and magnitude of such problems that require solution. The further removed from past vehicles and the more difficult the performance requirements, the higher the cost for R & D. A thorough understanding of the technological problem areas and insight concerning the probable solutions, coupled with past experience and data, are all necessary to make reasonable cost estimates of R & D.

7-11.4 DESIGN COSTS

Design costs are incurred in transforming the vehicle concept and performance requirements into specific written instructions (plan and specifications) from which the final product can be built. Sometimes termed engineering costs, design costs can be derived from historical data:

a. For a given type of vehicle, the design labor may be expressed as a constant ratio of direct construction labor for one vehicle. The design material (drawings and specifications) is, in turn, proportional to design labor. Thus, the estimate of design costs may be made by adding factors for design labor and design material and multiplying by the projected number of construction labor hours.

b. If no similar vehicle has been constructed, an alternative method would be to estimate the average cost of preparing an engineering drawing and a page of written specifications, based on experience. These cost figures would then be multiplied by projected numbers of drawings and pages of specifications, again based on experience.

In either case, allowances should be made for contingencies such as travel expense, and cost of evaluating new equipment and manufacturers' proposals if they differ from the general conditions upon which the historical data were based.

The design costs are likely to be divided between the designer and the builders, where these are different agencies. Care should be exercised in allocating this cost since the builder's portion will show up as construction costs and will depend on the share of the design work furnished by the builder.

It should be noted that the total cost of R & D and design will be only a small percentage of the total life cycle cost for any vehicle produced in large quantities. Research and development costs for new aircraft designs range from 1 to 5 percent of life cycle cost. Aircraft are very complex systems and evolve from intensive R & D efforts. Research, development, and design efforts for amphibians are small by comparison. For example, the LARC V and LARC XV designs were each bought for less than $250,000.

7-11.5 CONSTRUCTION COSTS

Total construction costs may be considered to include:

a. Initial contract estimate

b. Cost of Government-furnished material (GFM)

c. Cost for change orders

d. Cost for inspection and administration

e. Cost of delays and unforeseen technical problems

f. Cost of increased labor rates and material prices over long construction periods.

7-11.5.1 Estimating Methods

Various designers have their proprietary methods for estimating construction costs. The method given in the paragraphs which follow represents one approach to the problem. The vehicle components are catalogued into suitable cost groups. These are the same groups used in weight estimating as given in Table 6-6:

A. Hull Structure

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B. Machinery
C. Main Drive Train
D. Marine Drive Train
E. Running Gear and Suspension System
F. Miscellaneous Systems

Two additional groups should be included:

G. Engineering and Procurement—includes the cost of engineering supervision in addition to design work to be performed by the builder and the cost of purchasing components

H. Construction Services—jigs, fixtures, performance bonds, and insurance, to be charged against the specific contract.

Group A, Hull Structure, costs can be characterized by a price per pound for materials and a number of man-hours per pound for construction labor. These numbers are based on historical data. The same technique is used for the items in Groups B to F.

Group G, Engineering and Procurement, can be expressed as a function of the total labor in groups B to F above. Group G materials are a fixed cost per man-hour of Group G labor. Group H labor and material, likewise, are functions of the total labor of Groups B to F.

The sum of labor in Groups A to H is adjusted by a multiplier to reflect overhead and is priced at an average labor rate. The total labor cost is added to the total material cost and then multiplied by a suitable factor for the builder's profit.

The above discussion shows some of the complexity of the cost estimating process. More important, it demonstrates the reliance on previous cost data. Available cost records must be accurate and clearly understood with respect to category groupings. Unfortunately, cost data for existing amphibians are not readily available. Hopefully, more attention to cost accounting will be given for future amphibians and will be available to the designer.

7-11.5.2 Multiple Construction Savings

The cost of succeeding duplicate vehicles should be less than the first vehicle because of the following savings that result from duplication:

a. Nonrecurring charges, including costs of molds, patterns, jigs, and fixtures

b. Vendors' savings, such as quantity price discounts from manufacturers and suppliers

c. Labor savings, due to increased efficiency for succeeding vehicles

To estimate the effects of these savings it is customary to:

a. Estimate the total of nonrecurring changes, adjusted for such items as mold repairs, jig and fixture replacement, etc. This total is divided by the number of vehicles contemplated to obtain a cost per unit.

b. Obtain quotations from manufacturers regarding quantity price discounts to be expected on major vendor items.

c. From past experience with labor for multiple vehicles, plot a curve of hours expended on each subsequent vehicle, expressed as a percentage of the first. This "learning curve" can then be applied to the hours estimated for the first vehicle to determine the hours spent on subsequent vehicles. Fig. 7-107 shows a typical learning curve.

7-11.5.3 Manufacturer's Estimates

In order to confirm cost estimates it is necessary to obtain quotations from a representative number of suppliers. Two distinct types of estimates are common in industry and are considered here:

1. Budget Prices. These figures are requested from manufacturers in order to ascertain the price range of certain services. Prepared as a courtesy by manufacturers, these figures are usually very approximate and obligate neither party. In asking for budget estimates the designer should realize that they are provided out of courtesy, and care should be exercised to avoid taking undue advantage of manufacturers.

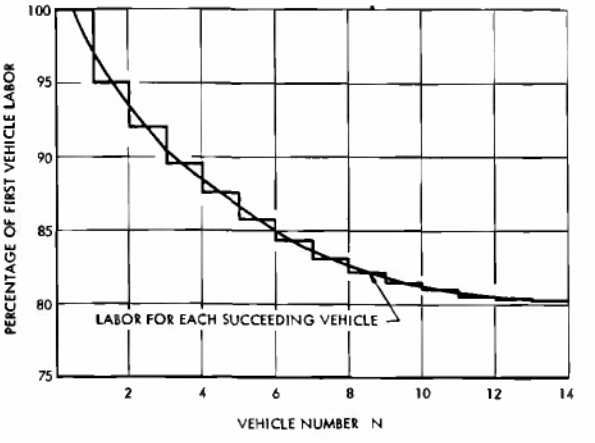

Figure 7-107. Typical Learning Curve

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It is also important to ask the manufacturer to state weights, probable delivery schedules, and to include allowances for crating, loading, and freight.

2. Quotations. These represent offers on the part of the manufacturer to supply an exact item by a specified delivery date, satisfying certain performance and construction requirements. Usually the quoted price is firm for a limited time, such as 90 days from date of quote. This type of response represents a legal commitment on the part of the supplier and is prepared after detailed estimates.

7-11.5.4 Current Costs

Current (1968) catalog prices for the LARC series of amphibians are given here for information:

LARC V	$ 44,207 each, for 250 vehicles
LARC XV	$165,000 each, for 110-115 vehicles
LARC LX	$390,000 each, for 10 vehicles

7-11.6 TESTING COSTS

A certain amount of the testing of any vehicle is usually conducted by the builder to demonstrate compliance with the vehicle specifications (proof tests). This testing cost is included in the contract cost and is not of concern to the designer as a separate item.

Costs associated with operational tests (from R & D to acceptance tests) conducted by the Army are of the following types:

a. Repairs and alterations to vehicle

b. Fuel and lubricants

c. Wages for operating personnel and consultants

d. Transportation charges for operating personnel and materials to and from test site

e. Overhead associated with the test facility

Historical cost data in this category should be sufficiently well documented for cost estimates, provided the number of tests and their probable duration (allowing for delays for repairs and inclement weather) can be estimated.

7-11.7 OPERATION, MAINTENANCE, AND REPAIR COSTS

Operation, maintenance, and repair costs are major items in the total life cycle cost. These costs include:

a. Cost of materials (fuel, lubricant, etc.) consumed during the life of the vehicle

b. Wages paid to operators and support personnel

c. Cost of special training necessary to operate and maintain vehicle

d. Cost for repairs including labor and parts The largest portion of these costs is expended in wages to operate and support the vehicle. The wages for operating personnel are easily estimated from the number of crew that are needed to operate the vehicle. However, the wages for support personnel needed to maintain the vehicle are a function of the maintenance requirement which, in turn, depends on how much effort is directed toward improved maintenance in the development and design stages of the amphibian life cycle. Table 7-49 presents maintenance data reported by field units in Southeast Asia for the LARC V and LARC LX from The Army Equipment Record System (TAERS) (TM 38-750), along with forecasts quoted from U. S. Army Mobility Equipment Command (MECOM) studies for comparison. Organizational maintenance includes the routine servicing, adjustment, inspection, and minor repairs that are performed by the vehicle user-operator. Support maintenance includes inspection, complicated adjustment, major repairs and modifications, and major replacement performed by support unit personnel who are better equipped and trained for more complex maintenance jobs. Maintenance is reported in terms of man hours of maintenance required per hour of vehicle operation.

TAERS records do not include organizational level maintenance. However, the MECOM studies may be considered accurate and representative of actual requirements with respect to organizational maintenance. The projected estimates of support maintenance were on the high side, almost twice the actual man hours reported in the case of the LARC V. As a result, the estimated total maintenance for this vehicle was approximately 25 percent greater than the actual maintenance.

The other costs involved in operation, maintenance, and repair are best estimated using experience, records of similar vehicles, and good judgment.

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TABLE 7-49 LARC AMPHIBIAN MAINTENANCE, MAN-HOURS/OPERATION HOUR

	LARC V	LARC XV	LARC LX
Organizational Maintenance (MECOM-projected)	0.46	0.58	1.48
Support Maintenance (MECOM-projected)	0.35	0.41	0.34
Support Maintenance (TAERS-recorded)	0.19	—	0.32

SECTION VII DETAIL DESIGN COORDINATION, SUMMARY, AND OUTPUT

7-12 DESIGN COORDINATION, SUMMARY, AND OUTPUT

Preparation of the detail design, or working plans, is normally accomplished with the prototype construction within a single contract. This provides for good communications between the designer and the builder. In addition to the main contract, there may be component or system subcontractors, research contractors, and contractors furnishing components directly to the Army. For the detail design to proceed smoothly in an orderly fashion, many segments of the design must be conducted simultaneously. This requires flexible planning and continuous communications.

7-12.1 SCHEDULING

Scheduling the detail design requires the gathering, at the proper time, of qualified designers and the necessary information. Ideally, the critical categories of information are determined and the availability dates are established. With these dates as a framework, each item of work can be scheduled. This, of course, is ideal and in practice there are many conflicts and gaps in the information available to the planners. One typical problem is the long period of time required to manufacture and test a waterborne model. The delay in obtaining these results places a greater importance on the initial resistance and propulsion estimates because a significant error in these estimates may cause major changes in the design close to the completion of the design.

7-12.2 DETAIL DESIGN PLANWORK

The plans and specifications must furnish sufficient information so that the materials can be ordered and fabricated by a competent manufacturer who is familiar with vehicle construction. Any necessary information omitted increases the construction cost. Military specifications for each class of vehicle contain lists of the applicable documents, including a list of required plans. This plan list for a similar vehicle may be used to estimate the type and number of drawings required for a new design.

7-12.3 FINAL DESIGN REPORT

The final design report is used by the vehicle development team and by the designers for their work in designing later generations of amphibians.

The final design report should contain:

a. Final vehicle description
b. Final vehicle performance data
c. Design history
d. Major design decisions
e. Summary of design techniques and assumptions

The major design decisions must be recorded periodically or the reasons for each decision will be lost.

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PART THREE EVALUATION AND TESTING OF WHEELED AMPHIBIANS

CHAPTER 8 EVALUATION AND TESTING

8-1 OBJECTIVE OF TESTS AND GENERAL DISCUSSION

For any given test there are two basic possible reasons for its conduct. One reason is to determine the characteristics of some unknown phenomenon or to determine a not readily predictable result. A second basic purpose of testing, in general, is to verify (or disprove) an expected or previously predicted result.

The purpose or objective of a test is, therefore, usually related to the stage of development of the test item. For example, research or feasibility tests fall into the area of testing where the test results indicate whether a concept is feasible or attainable. On the other hand, tests are performed on prototype amphibians and other Army materiel to determine whether a predicted or designed characteristic or result has actually been attained.

This chapter will deal mainly with the latter type testing where the feasibility of a concept or vehicle has been proven or accepted, and the interest of further tests is to verify (or disprove) that the requirements (i.e., the QMR's) of a design have been met. This limitation has been made for two reasons. First, a complete dissertation on testing and testing philosophy would require a Handbook in itself and, second, the maximum benefit to the designer can be realized by a knowledge of the amphibian tests which will eventually lead to an item's acceptance into Army service.

This chapter is of value to the amphibian designer, but is no substitute for a thorough knowledge of the U.S. Army philosophy of research and testing. This entire picture is a necessary tool for the program manager, project manager, and planning personnel involved in an amphibian design and, of course, is mandatory knowledge for the designer. Ref. 1 presents a good basic description of the Army test organizations, testing concepts, testing documents, testing terms and definitions, funding, etc., along with pertinent references from which greater detail in any specific area of interest may be obtained.

The primary objective of Army materiel testing as stated in Ref. 1 is "to insure that materiel for Army use satisfies the minimum operational, technical, and safety requirements in all types of environments of intended use as described in the QMR.... or equivalent requirements, and to determine what changes are required to make new materiel suitable and safe for Army use".

What this means to the designer of a wheeled amphibian is that the (usual) ultimate goal of a vehicle design is to become "Type Classified" in accordance with the design objectives and QMR.

Army materiel is Type Classified in order to associate the particular item of materiel with regard to development or service status relative to other Army items. The levels of Type Classification and description are as follows:

a. Development Type. Materiel (amphibian) being developed or tested to meet a QMR.

b. Limited Production Type. Materiel in limited production that has not yet passed all tests required; however, urgency of the situation warrants initiation of production and the confidence level of meeting minimum requirements is high.

c. Standard Type. Materiel which has completed all tests satisfactorily; is authorized for Army use; and is included in published adopted item lists.

d. Contingency and Training Type. Materiel which is not acceptable for U.S. Army operational requirements, but may be used for training or to fill a need until a standard (type) item becomes available.

e. Obsolete Type. Materiel which is no longer acceptable for U.S. Army use and is being or has been phased out of the supply system.

The methods and requirements for type classification of Army materiel are presented in detail in Ref. 1, pages II-12 through II-15.

There is another, sometimes overlooked, objective of testing which is of major importance to the designer. That is the

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"feedback" to the designer of quantitative test data which can be compared with the performance predicted during the design and development phases. In this manner, the design methods and predictions can be modified to provide more accurate or more quantitative design predictions for future vehicle developments.

From the long range viewpoint, this feedback of test data to the designer is of equal or greater importance than the short range objective of vehicle type classification since it is these data which, in part, should prevent repetition of design errors and lay the groundwork for further improvement of amphibian designs.

Acquisition of test data is the responsibility of the development command (designer). Each development program organization should establish channels for the procurement of test data. Methods of obtaining data and its presentation should be specified so that the test results are in a useful form (comparable with other amphibians or design data). The paragraphs which follow are intended to aid the designer in establishing a meaningful test program including test specifications, conduct of tests, and data formats which fall under his cognizance.

8-2 TYPES OF TESTS

According to the definitions or doctrines of the U.S. Army Test and Evaluation Command, (USATECOM), there are three broad classifications of testing: Category I Tests, Category II Tests, and Special Tests.

Category I Tests are those in which USATECOM is responsible for the establishment of the test objectives, preparation and approval of the plan of test, and processing and distribution of the report of test. The basic philosophy of Category I Tests is the provision of timely, objective, and factual test results to HQ, AMC, in order that decisions affecting type classification include materiel performance considerations. These results are obtained by independent testing and evaluation of the item, and normally lead to type classification of the materiel undergoing tests. USATECOM has sole primary responsibility for the planning and conducting of Engineering Tests, Service Tests, Integrated Engineering Service Tests, Environmental Tests, Confirmatory Tests (Type I), and Check Tests.

Category II Tests are those in which USATECOM is performing a testing service for the requesting agency and in which the test objectives, plan of tests, and processing and distribution of the report of test are the responsibility of the requester. The concept of Category II Tests is the providing of USATECOM facilities and knowledge to using commands and agencies in order to expedite the conduct of development and procurement test programs.

The above definitions were extracted from Ref. 1, and are of value in attempting to establish a logical sequence of testing and a test program. The significant inference in these definitions is that the Development Command or Agency has no control over the Category I Tests on an amphibian. Category I Tests are the sole responsibility of USATECOM and are developed directly from the amphibian QMR. These Category I Tests, alone, determine whether the vehicle has been successfully designed to meet the requirements for Type Classification.

Category II Tests are the responsibility of the Developing Agency or Command, and therefore are directly influenced by the designer. In this regard, it is important that the Technical Characteristics (TC) developed by the designers from the QMR's are based on the interpretation of the QMR made by the USATECOM in conjunction with the committee composed of personnel from the Development Command or Agencies which generated the QMR. This is important since the tests undertaken by the development agencies, whether performed by USATECOM or not, will most likely refer to the TC as opposed to the QMR; however, the final amphibian design will be required to pass the tests prescribed by USATECOM, which are strictly based on interpretation of the QMR. This point is discussed further in par. 8-3.

8-2.1 CATEGORY I TESTS

The following are Category I Tests which are conducted on a vehicle after it is released to USATECOM by the Development Command(s) for Type Classification. It should be noted that all Category I Tests are intended to verify (or disprove) that an amphibian meets the QMR.

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8-2.1.1 Engineering Tests

The purpose of Engineering Tests is to determine to what degree the test item meets the performance characteristics expressed in the QMR and whether the item is safe for use by troops during Service Tests. The basic concept of Engineering Tests is the elimination of human bias and errors in judgment so far as possible through the use of engineering and scientific methods of testing.

The results of the Engineering Tests should provide sufficient information to permit determination of:

a. Degree to which the technical performance of the item meets the requirements of the QMR

b. Relative safety of the item in the hands of Army troops

c. Suitability of the item for conduct of Service Tests

8-2.1.2 Service Tests

The purpose of Service Tests is to determine to what degree the test item meets the Military Characteristics expressed in the QMR, and the suitability of the item and the maintenance package for use by the Army. During the various tests that comprise a complete Service Test Program, factual records are maintained showing the item's performance under specific conditions. This record must be complete and explicit since it forms the primary basis for decisions by higher headquarters on the merits of the tested item. Except in the most unusual circumstances, the test results should provide sufficient information to permit determination of the degree to which the item meets the current military requirements of the prospective user.

Service Tests use subjective approaches to produce test results. The tests prescribed are conducted from the user standpoint under simulated or actual field conditions.

8-2.1.3 Integrated Engineering Service Tests

The purpose of an Integrated Engineering Service Test is to minimize testing time and cost by running Engineering and Service Tests at one location. Complete integration or partial integration constitutes an integrated test.

8-2.1.4 Environmental Tests

Environmental Tests are performed to determine if an item performs effectively in the environments of its intended use. Environmental Tests form an integral part of testing, at all phases, whether it be Engineer Design Tests, Engineering Tests, Service Tests, or Troop Tests. Testing in simulated climatic extremes is normally used to the maximum extent in the Engineer Design and Engineering test phases. Testing in extreme natural climatic environments is used to substantiate or supplement data obtained from simulated tests. Category I testing in natural environments will normally be an Integrated Engineering Service Test. Since testing in natural locations of extreme climate is costly in terms of manpower, money, materiel, and time; each individual item's requirements for testing in natural environments must be carefully determined before submitting the item for such testing. Such predetermination of necessary testing in natural environments is vitally important and should not be omitted in test design.

8-2.1.5 Confirmatory Tests (Type I)

A Confirmatory Test, Type I, is the test or investigation conducted on an item or system, after type classification as standard or limited production, using early production models to insure that required modifications not previously tested are acceptable and to insure that the modifications have not adversely affected the Technical and Military Characteristics of the item or system. Service Test procedures are utilized to insure that no deficiencies or shortcomings have been created.

8-2.1.6 Check Tests

The purpose of Check Tests is to determine on Service Test models of items whether major deficiencies found in the Service Test have been corrected, these deficiencies being of such a nature that the item was found unsuitable for type classification. The philosophy of Check Tests is to retest items using the Service Test procedures to insure that previous deficiencies and shortcomings have been eliminated, and no new ones have been created.

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8-2.2 CATEGORY II TESTS

Category II Tests are the responsibility of the Development Command and are conducted by anyone selected by that Command (i.e., private contractor, USATECOM, or the Development Command).

8-2.2.1 Research Tests

Tests conducted during the research phase in order to confirm concepts and to further research projects and tasks.

8-2.2.2 Feasibility Tests

The determination of a process of technical examination and study of the possibility of attainment of end-item materiel development. Technical feasibility consists of two parts:

1. Long range or state-of-the-art study wherein the probability of attaining general technological goals is determined
2. Feasibility study of a desired end-item after the Military Characteristics are known

8-2.2.3 Component Engineering Tests

Engineering-type tests are conducted by or under the direction of the developing agency where the objective is the development of component design concepts, or the evaluation of components embodying new and advanced state-of-the-art principles. The test item need not be specifically related to any existing end-item development.

8-2.2.4 Engineer Design Tests

These tests are conducted to determine inherent structural, electrical, and other physical and chemical properties of materials and items, including the effects of environmental stresses on these properties. These tests collect design data; confirm preliminary concepts and calculations; and determine the compatibility of the components. For complex systems, e.g., an amphibian system, these tests may include a complete system demonstration. The Engineer Design Tests will be formulated by the developer after approval of the design concept and prior to the initiation of prototype fabrication. Applicable Engineer Design Test data will be made available by the developing agency for use in Engineering and Service Tests.

Engineer Design testing is primarily for the purpose of obtaining data necessary for initial design of the prototype item, or specific components thereof, whereas determining the performance characteristics of the prototype is the purpose of the Engineering Test. In the interest of expediting testing and completion of development, requirements for design data for further refinement and completion of the development can and should be provided by the Engineer Design Test, including Research and Development Acceptance testing of a contract item, particularly when complex elements of design or development are involved.

8-2.2.5 Research and Development Acceptance Tests

Research and Development (R&D) Acceptance Tests are conducted on an item or system designed and developed by a contractor to insure that the specifications of the development contract have been fulfilled. Acceptance of the item or system for Engineering and Service Tests is dependent on the results of the R&D Acceptance Test. The effectiveness, or readiness, of a given development project, however, is measured at the time of type classification, not at the time it begins Engineering and Service Tests. Early initiation of Engineering and Service Tests, irrespective of minor deficiencies anticipated in these tests, as a means of expediting an overall development process should be the goal of both developing and testing agencies.

8-2.2.6 Product Improvement Tests

Product Improvement Tests are conducted on modified standard items of Army materiel to verify that essential Military Characteristics have not been adversely affected and to establish the durability, operational capability, and maintainability of the modified item.

8-2.2.7 Preproduction Tests

Preproduction Tests are Engineering-type tests of a preproduction model or initial production sample—produced in accordance with the supply procurement specifications and drawings using the same methods, material, and

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equipment as will be used during regular production—to verify production drawings, processes, and materials.

8-2.2.8 Initial Production Tests

Initial Production Tests are tests of an early item or system from the first production run which are used to verify the adequacy and quality of the materiel when manufactured according to the production drawings and of the mass production processes.

8-2.2.9 Comparison Tests

Comparison Tests of random samples of production line items are conducted as a quality assurance measure in order to detect any design, manufacturing, or inspection deficiencies that may reduce the effective operation of the items by the using agency.

8-2.2.10 Acceptance Tests

Acceptance Tests are conducted on individual products, or lots of materiel items, which have been submitted for acceptance to determine conformance of the products or lots with requirements and specifications prior to acceptance.

8-2.2.11 Reconditioning Tests

Reconditioning Tests are conducted on standard items, which have been modified to correct deficiencies discovered during use, to verify that essential Military Characteristics have not been adversely affected, and to establish the durability, operational capability, and maintainability of the modified item.

8-2.3 SPECIAL TESTS

Special Tests are so named and categorized because of their unusual nature in regard to reporting and control procedures, method of conduct, facilities, and services required. Special Tests which are generally applicable to wheeled logistic amphibians are defined in the paragraphs which follow.

8-2.3.1 Confirmatory Tests (Type II)

Type II Confirmatory Tests are used to evaluate a selected item or system of early production materiel, after type classification as Standard or Limited Production, by expedited and intensive testing in the field to preclude time-consuming retrofit programs. Items may be recommended for Type II Confirmatory Testing by project managers, commodity commands, separate installations and activities reporting directly to AMC Headquarters, and the directorates of AMC Headquarters. DCSLOG, in coordination with the other members of the Army General Staff, acts on recommendations of the major developing agencies in the selection of items and furnishes the major developing agencies an approved list of items to undergo Type II Confirmatory Tests. Service Test procedures are utilized to insure that no deficiencies or shortcomings have been created.

8-2.3.2 Surveillance Tests

Surveillance Testing is performed on items that are subject to rapid deterioration of materiel or performance. These items are stored and tested on a continuing basis in all climatic environmental conditions to determine the extent of deterioration as compared with the original requirements. Facilities and test personnel of the commodity commands, separate installations, and activities reporting directly to USAMC as well as USATECOM test sites are utilized. The basic responsibility for such programs on an item by item basis has been assigned to the cognizant AMC command. The Commanding General, USATECOM, however, is responsible for assuring existence of adequate surveillance test programs.

8-2.4 SEQUENCE OF TESTS

Fig. 8-1 illustrates a logical sequence of tests performed during the life cycle of any Army amphibious vehicle.

8-3 RESPONSIBILITY FOR VEHICLE TESTS

The scope of this discussion on test responsibility is limited to the specific areas of responsibility for prescribing the tests and associated test formats, and the responsibility for conducting the tests.

As indicated earlier in this chapter, the total

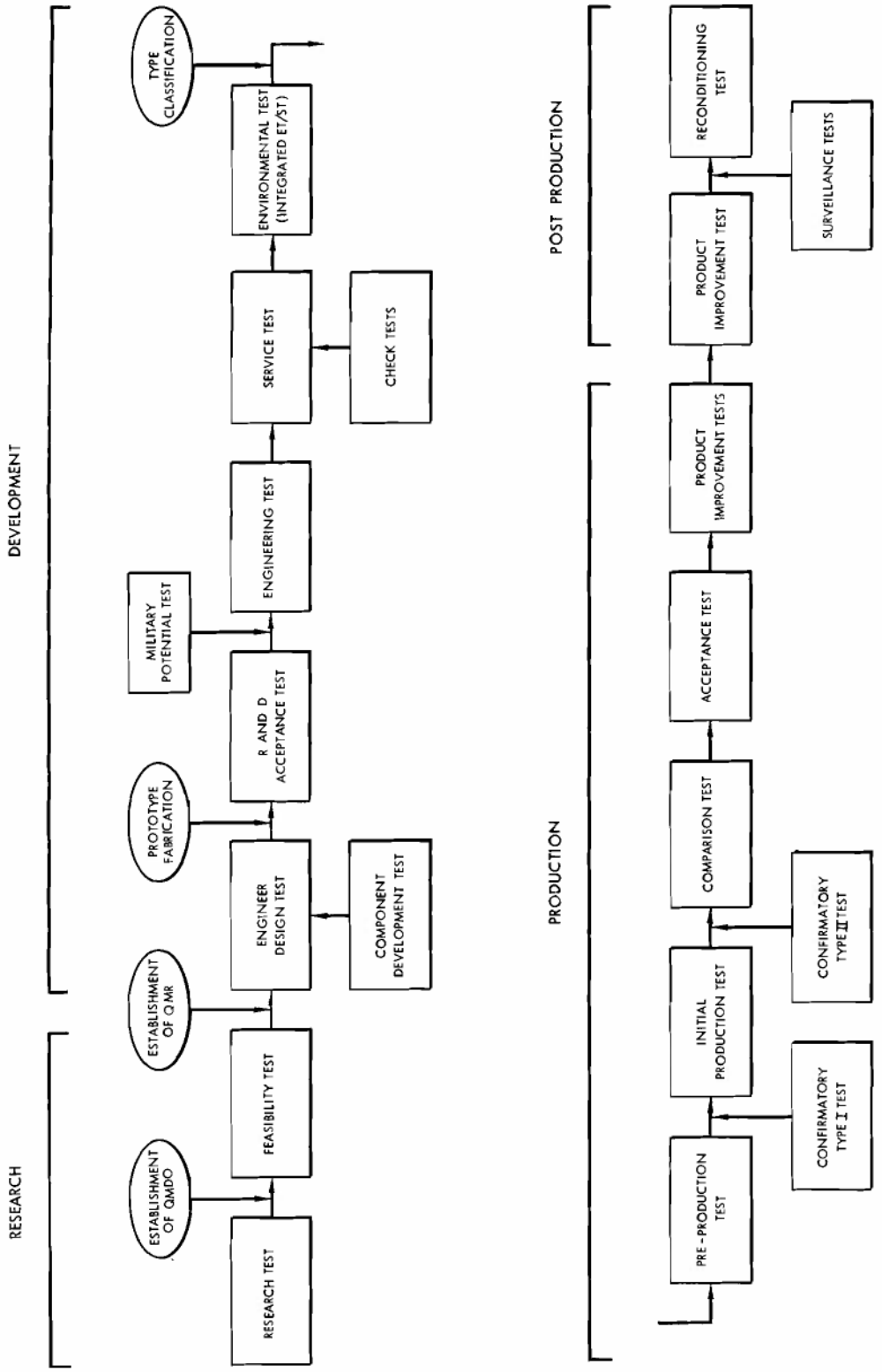

Figure 8-1. Testing Performed at Various Stages in the Life Cycle of an Army Wheeled Amphibian

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responsibility for testing a vehicle with regard to Type Classification and Army acceptance falls under the USATECOM. Therefore, the responsibility of USATECOM is to insure that a vehicle meets the military requirements of the QMR. Results of these tests will be quantitative only insofar as the QMR or its interpretation is quantitative, i.e., Category I Test results will be of little or no use to the designer with regard to solving design deficiencies; these results will only indicate the problem areas.

It is the responsibility of the amphibian development command(s) to supply a vehicle to USATECOM which meets the military requirements and/or provide a "fix" when a performance requirement is not met. It logically follows (and is in fact the case) that responsibility for obtaining quantitative test data (design data) with which to predict vehicle performance and to correct design deficiencies lies with the cognizant development commands. The commands and agencies most likely involved with wheeled logistic amphibians, along with their areas of cognizance, are listed in Table 8-1.

The responsibility for administering a test program, conducting tests, and test data retrieval can be delegated by the cognizant development command(s) to private contractors, and/or USATECOM. Of course, the ultimate responsibility for the amphibian meeting the QMR and for rectification of design deficiencies lies with the amphibian project office, usually under the Mobility Equipment Command (MECOM).

In this regard, it is the responsibility of the project office to determine and to be aware of high risk areas evolving from the military requirements which may require test and evaluation during the amphibian development stage. For example, if requirements dictate a propulsion system or hull form which is unique or "border line state-of-the-art", a component development program including engine-transmission test or hull testing may be required. More specifically, in the case of engines and transmission systems, for example, test facilities at ATAC permit simulation of loads and environmental conditions on propulsion systems which exactly duplicate those experienced under any selected operational condition. It is under controlled test conditions such as these that high risk areas should be initially evaluated for several reasons—detailed and accurate engineering data are easier to obtain than on a completed amphibian, and it is obviously much more desirable to make as many design changes as possible before a prototype amphibian is built.

There are, of course, a number of trade-offs with regard to testing components before or after installation in the amphibian. These trade-offs involve such things as probability of failure (risk), scheduling, funding, and the availability of equipment and test site. Clearly, the responsibility for making the engineering

TABLE 8-1 AMPHIBIAN DEVELOPMENT COMMANDS

Command or Agency	*Cognizance*
U. S. Army Tank-Automotive Command (ATAC) Warren, Michigan	Engines, power trains, suspensions, tires, soil analysis, environmental factors.
U. S. Army Mobility Equipment Command (MECOM) St. Louis, Missouri	Amphibious Lighters
U. S. Army Mobility Equipment Research and Development Center (MERDC) Ft. Belvoir, Virginia	Research, development, testing, and evaluation of mobile equipment and amphibious vehicles.
U. S. Army Combat Developments Command Transportation Agency (CDCTA) Fort Eustis, Virginia	Development of Logistic Over-the-shore (LOTS) capability.

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decisions, with regard to establishing an optimum test program for development, rests with the development command(s), the individual designers, and program officers.

With the above testing responsibilities defined, it is important that the designer be aware of how USATECOM achieves its prime responsibility—testing and type classification of materiel. The ultimate goal (Standard Type Classification) must be considered throughout the amphibian development cycle.

For the past several years, USATECOM has been engaged in a program of standardizing their test procedures to the greatest extent possible. This program entails the establishment of Materiel Test Procedures (MTP's) which outline, as specifically as possible, the tests performed on all possible items of Army materiel. At the present time, it is anticipated that the basic series of MTP's will be completed in the early 1970's; however, continual updating will be required.

Theoretically, at some future date, an entire test format will be developed by calling for the appropriate MTP's. The MTP's will provide the basic guidelines for amphibian testing; but the details and ramifications will be described within the framework of the set procedures or will supersede the MTP's, if necessary.

The significance of the MTP's to the amphibian designer is that an awareness of the tests, test objectives, and methods which will be applied to the amphibian, will enable him to better design an acceptable item. Also, it should give some insight as to what areas of design require quantitative test data retrieval or updating, such that the risk of test failure is minimized. It is possible that the test procedures should be updated to result in more quantitative results which will allow the designer to compare items on an equal basis, and evaluate design concepts and changes.

Materiel Test Procedures and information regarding the status of the above mentioned program can be obtained from the USATECOM, Aberdeen Proving Ground, Maryland. The basic concept of MTP usage and a comprehensive list of available and planned MTP's are included in Ref. 1.

In areas of low risk, it may be possible to obtain the necessary design test data at the same time USATECOM is conducting the Category I Tests, provided the tests are compatible and agreement can be reached between USATECOM and the cognizant development or commodity command.

There are several test sites available to the designer to which the responsibility for conducting amphibian tests may be delegated. Each of the various test sites has the environmental facilities for conducting tests of a specific type. For example, Aberdeen Proving Ground, Maryland, has extensive facilities for determining land mobility. Table 8-2 includes a list of the major amphibian test sites with their corresponding areas of test capability.

Other contractor test facilities are available to the designer through the amphibian manufacturer. The selection of appropriate test sites for an amphibian test program is obviously dependent on availability, logistics, and test requirements.

8-4 DESCRIPTION OF AMPHIBIAN TESTS AND TEST PROCEDURES

8-4.1 GENERAL

The detailed description of all possible amphibian tests including procedure, data accuracy, and instrumentation would take undue space. The details of test procedures are not as important to the designer as the desired end product or the basic concept motivating the test. In line with the scope of this handbook, an attempt will be made in the discussion which follows to indicate types of tests, the specific objectives of each type of test, the general methods or procedures involved, accuracy required, and application of test results by the designer.

Another limitation must also be imposed on the discussion of tests, i.e., quantitative or engineering tests will be covered in some degree of detail, and qualitative (e.g., endurance, service) tests will be mentioned only briefly. The reason for this is that qualitative test data are of value in indicating problem areas; however, where the solutions to these problems are not intuitive or obvious, the application of quantitative test data is generally the best means of reaching a sophisticated solution to a given problem.

A statement about accuracy is considered necessary at this time since the difference between qualitative and quantitative tests is

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TABLE 8-2 AMPHIBIAN TEST SITES AND CAPABILITIES

Site	*Capabilities (Facilities)*
Aberdeen Proving Ground (APG), Maryland	Land mobility testing
Fort Story, Virginia	Water operations, LOTS, evaluation, land mobility, surf performance (limited)
Monterey, California	Surf tests
Yuma Proving Ground Yuma, Arizona	Environmental (desert), land mobility tests
Camp Pendleton, California	Land endurance testing, beach and water-borne performance testing
General Equipment Test Activity Fort Lee, Virginia	Water performance, beach operations and coordinated ship and amphibian operations
Harts Lake Proving Ground, Michigan	Land mobility and water testing
Warren Dunes, Michigan	Sand beach and dunes, water tests
Twenty Nine Palms, California	Desert environment tests

really an undefined difference in accuracy of test measurements, whether "go-no go", gross human observation and comment, or instrument readouts. In general, the degree of accuracy of test measurements is basically a function of such items as the test objective, the available instrumentation, sensitivity of the amphibian design performance to the measured parameter, cost, and time. As far as the designer is concerned, the motivation for greater accuracy at additional cost and time, is a direct function of the sensitivity or effect of the test data on the design and performance of the amphibian. As an example, the developed engine power varies approximately as the waterborne speed cubed (i.e., $HP \propto V^3$); therefore, in order to have a balanced effect, design water speed measurements might warrant more attention to accuracy than does power measurement. This example is presumptuous in that other factors such as guaranteed (under contract) power availability may dictate a high degree of accuracy in engine power measurements.

It should be noted that more accurate test data can give rise to improved methods of performance prediction, resulting in lower design margins or ignorance factors and, thus, enhance the optimization of amphibians by the evolution process.

8-4.2 ENGINEERING (QUANTITATIVE TESTS)

For convenience, the testing of an amphibian is divided into four categories.

1. Static tests, instrumentation, and calibration
2. Land tests
3. Water tests
4. Surf tests

The nature of an amphibian does not readily permit such a division or categorizing of tests since many functions and tests will overlap into other areas; however, the division is necessary for establishing a framework within which to discuss amphibian tests.

Instrumentation required for obtaining the desired test data will generally include thermocouples, pressure sensors, pyrometers,

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gages, flow meters, load cells, scales, strip recorders, surveying instruments, stop watches, ohmmeters, thermometers, torsion meters, inclinometers, accelerometers, thrust meters, etc. These types of instruments are commercially available with accuracy ranges of 1 to 3 percent (plus or minus).

All instrumentation should be calibrated, both prior to and at completion of engineering tests. Calibration checks should also be made during tests if erratic readings are noticed or instrumentation damage is suspected for any reason.

In the test descriptions which follow, the types of instruments will be related to specific tests, and the significance of the data obtained will be noted where appropriate. In many tests, the usefulness of the test and instrumentation required is obvious. Refs. 2-4 provide additional information.

8-4.2.1 Static Tests, Instrumentation, and Calibration

The preparatory tests or checkout tests are grouped under this category, namely:

a. Measure and record physical dimensions and characteristics of amphibian.

b. Fill all fluid systems with prescribed type and amount of fluids (except fuel). Flush and bleed as required.

c. Check visually all lubrication points for lubricant and accessibility.

d. Check resistance of all electrical circuits with ohmmeter for open and closed resistance within required limits. Check insulation for adequate resistance.

e. Hydrostatic test of hydraulic and other pressurized fluid systems to 1.5 to 2.0 times working pressure and check for leaks.

f. Fill fuel systems and check for leaks.

g. Test operation of amphibian components and systems including:

(1) Starter system
(2) Engines
(3) Generator (alternator)
(4) Hydraulic pumps
(5) Steering mechanism(s)
(6) Transmission-drive train
(7) Brakes including emergency brake
(8) Lights
(9) Tire pressure and pressure control system operation
(10) Operation of all installed gages
(11) Winch and ramp operation
(12) Heaters and ventilators operation
(13) Cooling fans operation
(14) Bilge pumps operation
(15) Windshield wipers operation
(16) Exhaust system integrity
(17) Short test of power to marine propulsor
(18) Safety equipment, fire extinguishers, tools, etc.
(19) Check lifting rings, hand rails, towing eyes, hold down attachment points, etc.
(20) Check communication system operation
(21) Test hatches, cab, etc., for watertightness

The purpose of the static tests outlined is to insure that the amphibian is ready for the actual engineering tests to follow. The values of hydrostatic test pressure, electrical resistances, steer time, etc., should be obtained and checked against the amphibian specifications. All deficiencies and malfunctions should be corrected prior to conduct of further tests. Any corrective measures can usually be carried out during the instrumentation installation phase of the test agenda.

8-4.2.2 Land Tests

8-4.2.2.1 Determination of Weight, Center of Gravity, and Adequacy of Lifting Eyes

These three tests lend themselves to simultaneous performance in most cases. The object of the test is evident by its title. The reason for measuring weight and CG location is their relation to design weight and amphibian stability, respectively.

The first step of the test procedure is to accurately record the condition of the amphibian with regard to fuel load and location of movable items of onboard equipment.

Weight of the amphibian is usually determined by measuring and recording weight on each wheel. The center of gravity location is located by hanging the amphibian from slings as shown in Fig. 8-2. A vertical line from the point of suspension will always pass through the *CG*. By heeling the amphibian in both directions, the vertical and transverse location of the *CG* is indicated by the point at which these (plumb) lines do intersect.

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NOTE: Both of the sling methods indicated in Fig. 8-2 locate the vertical center of gravity. This provides a cross check of the tests.

By recording all added or subtracted weights and their location, the weight and *CG* location of the amphibian can be determined for any given condition.

8-4.2.2.2 Maximum Draw Bar Pull and Towing Pad Tests

Fig. 8-3 shows a method for conducting towing pad tests. A specified load is applied, and after the test the tow pads and attachment structure are checked for evidence of failure or overstress. The tension is applied slowly in increments. Then, if a failure does occur, a reasonable estimate of the failure load may be made. Measurements of pad eye diameter and length are made prior to and following the test in order to detect any deformation.

Maximum draw bar pull tests are conducted in much the same manner as the towing pad tests. However, only one end of the amphibian is bridled and the tension is applied by the engines through the tires of the amphibian. The engine speed is set at or near the maximum torque rpm with torque converter in a stall condition (static vehicle) and the maximum attainable tension is measured. Temperatures and pressures of engine oil, cooling water, torque converter fluid, etc., must be closely monitored during this test so as not to cause failure or damage.

During this test, torsion meters and tachometers may be employed to determine engine power and torque converter characteristics.

8-4.2.2.3 Bilge Pump Tests

Bilge pumps are tested in order to determine that capacity requirements are met. For each pump, the discharge capacity is measured as a function of the prime mover rpm. This is usually accomplished by maintaining a level of water in the amphibian's bilges and recording the time required for the pump to discharge a predetermined quantity of water. Water flow meters may also be used for this test.

By recording elapsed time and measured water quantities (or flow rates) for increments of prime mover speed (rpm), the bilge pump capacity (gpm) can be determined as a function of pump or engine speed. It should be noted that bilge pumps are usually driven hydraulically by the main engine.

Another measurement which is recorded is the elapsed time between actuation of bilge pumps and start of discharge.

Hand or emergency bilge pumps are similarly tested.

8-4.2.2.4 Minimum Turn (Steering) Radius and Response Time Tests

The amphibian is driven over a surface which will clearly define the tire tracks of all wheels. Condition of the amphibian (i.e., weight, tire pressures, etc.) is recorded (or specified). For "hard over" turns to the right and left, for both two-wheel and four-wheel steering, if applicable, the mean radius of the center of the inside wheel track and outside wheel tracks for a 360 deg turn, are measured and recorded. See Fig. 8-4.

The steering response test measures the elapsed time for steering from stop to stop or hard right to hard left. The time varies with amphibian load, tire pressure, engine speed (hydraulic pressure and flow), and surface conditions.

8-4.2.2.5 Winch Tests

For various engine speeds (hydraulic pressures and flow rates), line speed is measured in feet per second for pulling a known heavy load mounted on wooden skids over dry pavement. From these test data, winch capability can be established and compared with design data.

8-4.2.2.6 Tire Inflation System Tests

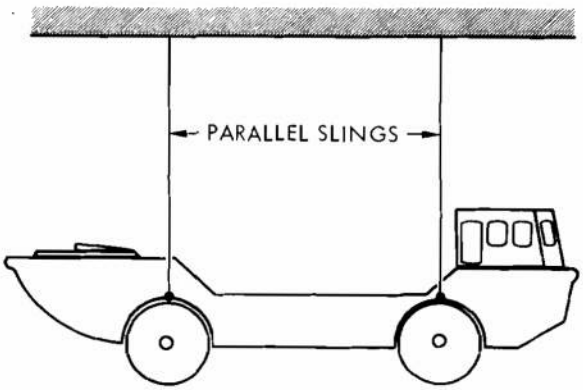
Each tire is inflated to an overdesign pressure and isolated from the compressor system. Pressure loss is recorded after 24 hr.

8-4.2.2.7 Ramp Tests

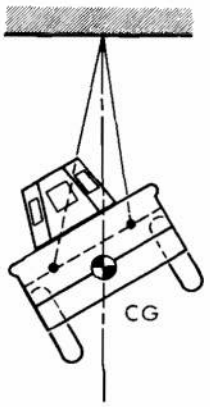
The ramp is repeatedly opened and closed. The time for each operation is measured and related to various parameters such as engine speed, number of engines running, and hydraulic pressure and flow rate.

8-4.2.2.8 Fan (Cooling) Tests

Each fan is tested over a range of engine rpm

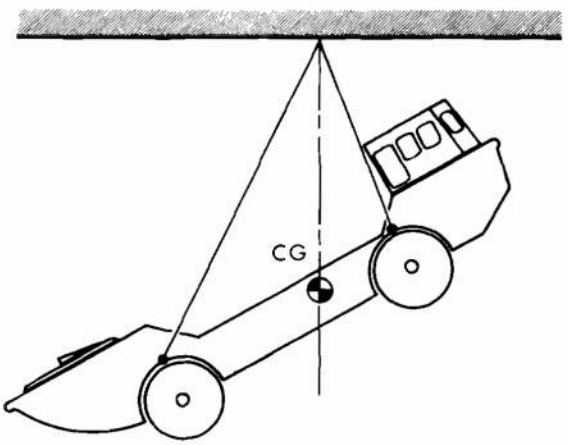


MAINTAIN ZERO INCLINATION DURING HEELING OF LIGHTER ATHWARTSHIPS

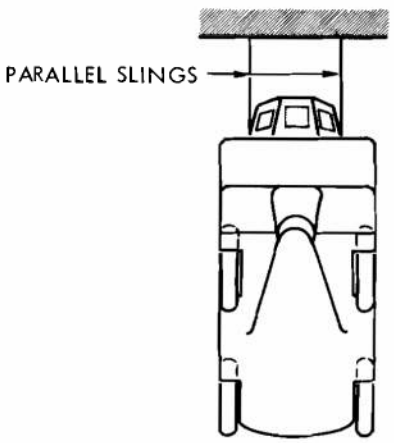


HEEL AS SHOWN ABOVE (30° min) REPEAT FOR HEEL OF OPPOSITE HAND

(A) TRANSVERSE AND VERTICAL CENTER OF GRAVITY DETERMINATION



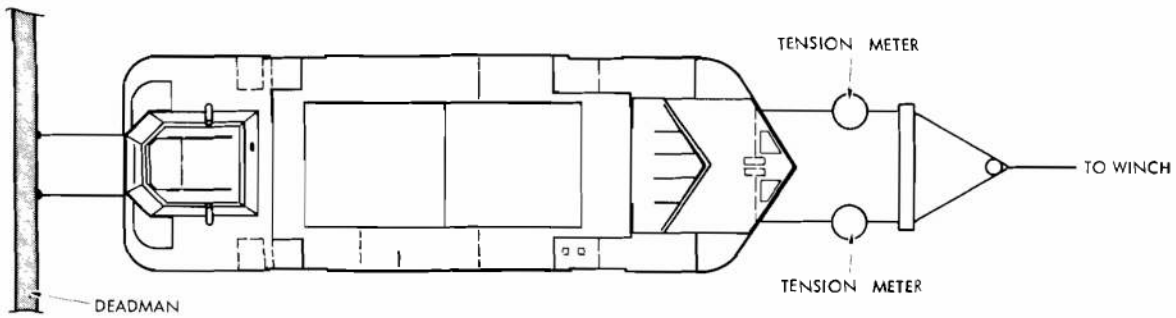
INCLINE AS SHOWN ABOVE (30° min) REPEAT FOR INCLINATION OF OPPOSITE HAND



MAINTAIN ZERO HEEL DURING INCLINING OF LIGHTER FORE AND AFT

(B) LONGITUDINAL AND VERTICAL CENTER OF GRAVITY DETERMINATION

Figure 8-2. Center of Gravity Determination



PLAN VIEW

Figure 8-3. Towing Pad Test Procedure

and fan rpm. Air temperatures (to and from the fan), velocities, and flow rates are measured. These data are used to determine the fan's cooling capacity.

8-4.2.2.9 Brake System Tests

With the amphibian in a known load condition, emergency stops are made on dry pavement from a range of speeds including reverse. The speeds and corresponding stopping times, and distances are measured and recorded. Accelerometers are sometimes used in these tests to record braking "g" levels.

8-4.2.2.10 Parking Brake Tests

Two types of tests are performed on the system. One is a static pressure test which measures loss of pressure over a period of hours. Another is determination of the maximum grade on which the brake will hold the loaded amphibian in both forward and reverse directions at the design holding pressure.

8-4.2.2.11 Speed Trials (Maximum)

Speed trials are conducted on a level, dry, improved surface. At a specified load condition, the amphibian is run through a measured distance at maximum (constant) engine speed in forward high gear and the elapsed time determined. Velocity is then calculated. Runs are made in both directions and sufficient distance is provided for acceleration to constant maximum speed prior to entering the measured course.

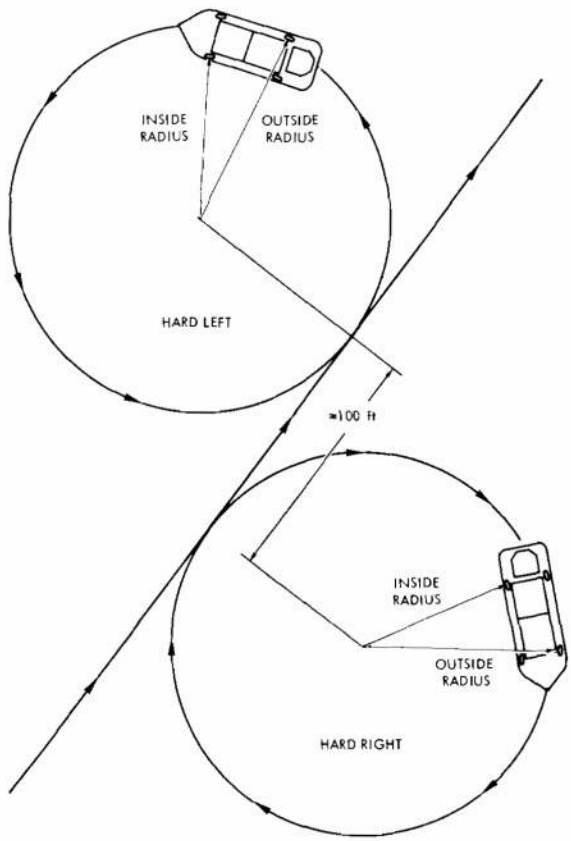


Figure 8-4. Diagram of Steering Radius Test

8-4.2.2.12 Fuel Consumption Tests

The fuel consumption (as a function of speed) tests are usually run for full and light load conditions on a level improved surface. The method used to measure fuel consumption is to time the consumption of a premeasured quantity of fuel which is placed in a calibrated auxiliary fuel tank. This tank can be cut in and out of the fuel service system as required.

8-4.2.2.13 Gradability Tests

With the amphibian in low gear, it is slowly driven up a gradually increasing grade until forward motion is impossible due to the grade. The test conditions which may be varied include grade surface condition, tire pressure(s), and load condition. Care should be taken not to over heat, over torque, or cause damage to the power system.

Results of this type of test are sometimes presented in terms of maximum attainable speed for various specified grades. Again, these data are functions of road surface, load, etc.

8-4.2.2.14 Rolling Resistance Tests

The purpose of this test is to determine the rolling resistance of the amphibian as a function of speed for various land surfaces.

One method of obtaining this information is to run the amphibian through a calibrated (posts or stripes placed at regular intervals) course at constant speed. Upon entering the course, power is removed from the wheels (declutch) and the amphibian is allowed to coast to a stop. Movie films are taken and analyzed to determine the change in amphibian speed versus time. From these data, the deceleration force (rolling resistance) can be calculated.

The same method can be used in braking tests to determine braking force, i.e., total deceleration force = rolling resistance + braking force.

Another method which can be used to determine the rolling resistance is to tow the amphibian at constant speeds and measure the towing forces with a tension dynamometer.

8-4.2.2.15 Off-road Mobility and Obstacle Tests

The amphibian is run over prescribed courses consisting of swamps, marshes, mud slopes, clays, and sands to determine its off-road mobility—i.e., the range of soil conditions over which it can operate—and to define the operating limitations. Similar tests are conducted to determine the ability and limitations (go or no-go) of the amphibian to negotiate specified obstacles such as vertical banks and ditches.

A related test is used to determine the amphibian's bank egress capability. However, the conditions are very difficult to define and measure for this particular type of test.

8-4.2.3 Water Tests

8-4.2.3.1 Stability Tests

The stability tests are performed to determine an amphibian's righting moment (i.e., stability) for roll angles up to the point where capsizing is imminent. Tests are run for both light and loaded conditions.

Fig. 8-5 shows a typical method of inclining the amphibian with a series of cable attachments, winches, and anchors. This figure also indicates the data recorded (i.e., cable tension, roll angle, and rigging geometry) along with the method of calculating the righting moment. It is important that the amphibian weight and center of gravity be known by relating added weights and their locations back to the light condition center of gravity determined during land tests.

Heel angles should be increased by approximately 5 deg increments until the heeling force (cable tension) drops off sharply. This drop in tension indicates approaching instability (imminent capsizing) and the test is then discontinued. Safety ropes or cables must be used during these tests in order to prevent possible capsizing, but these ropes must not restrain the heeling.

The data obtained provide a good measure of waterborne static stability and can easily be compared to other amphibian data. An accepted means of representing these data and typical test results is shown in Fig. 8-6.

8-4.2.3.2 Moment to Trim One Inch (MT1)

For a specified loading condition, the moment required to cause the sum of forward

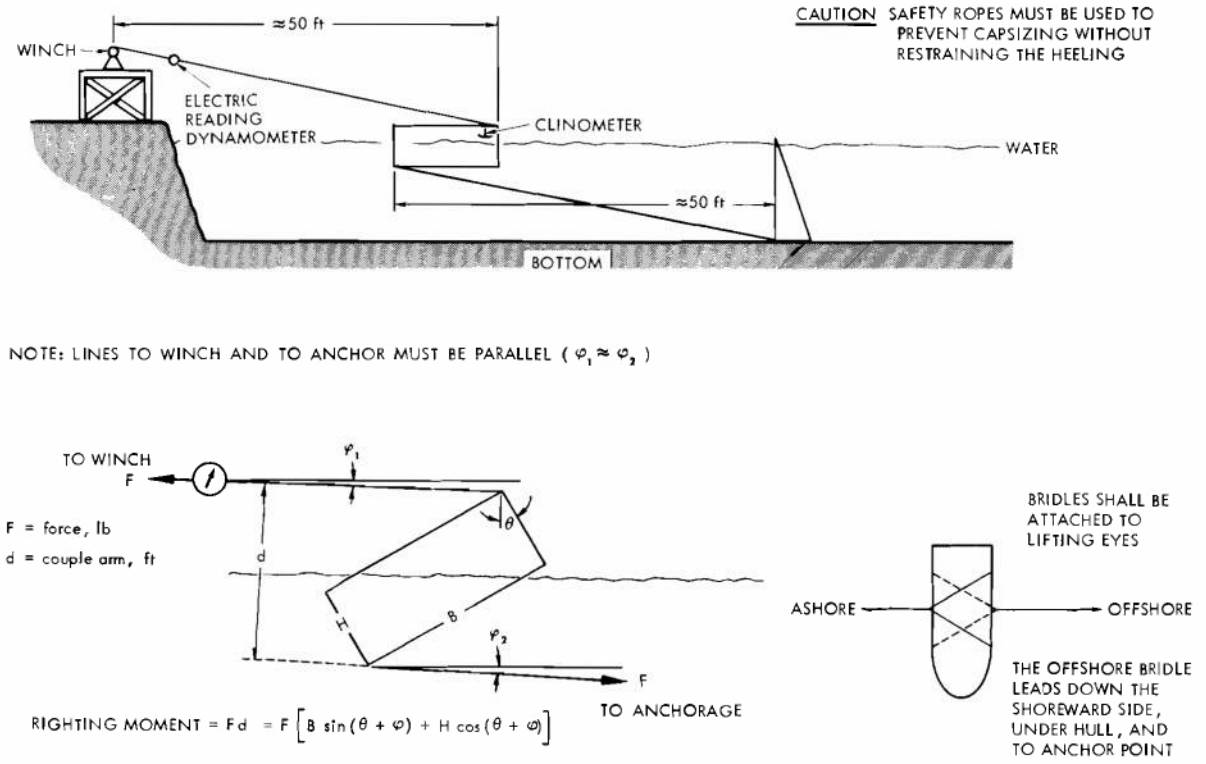


Figure 8-5. Righting Moment Determination by Inclining Test

waterline elevation plus the aft waterline depression to equal one inch is determined. The locations (stations) at which waterline measurements are made are usually specified and/or coincide with the fore and aft draft markings.

The moment variation is accomplished by moving a weight longitudinally along the amphibian centerline.

Data obtained from this test confirm the design objectives and are used to determine the best cargo placement in order to minimize waterborne resistance or to maximize directional stability since these characteristics are a function of trim.

8-4.2.3.3 Speed Trials (Power and Fuel Consumption)

Waterborne speed trials are accomplished in much the same manner as land speed tests, except that the added complications of determining the exact position of the amphibian and straight course running are involved. Fig. 8-7 shows a typical water course from which the methods used for orientation and course keeping may be inferred.

The amphibian is run through the calm water course at specified (constant) engine speeds, and elapsed time is measured. Waterborne speed is then calculated.

Power, trim, fuel consumption, engine data, etc., may also be obtained at this time, if required.

Power measurements are made in several ways depending on the accuracy required. The easiest, and usually least accurate method, is to record engine speed and fuel rack (throttle) setting. With these data and the manufacturer's engine curve, an estimate of power *(BHP)* can be made. Power can also be calculated from measured torque (torsion-meter) and rpm, or from propeller thrust(s) and amphibian speed.

8-4.2.3.4 Tactical Diameter (Turning Circle) Tests

This test determines the waterborne port and starboard turning circle diameters for various conditions as specified or required. Many variables influencing the test results must be

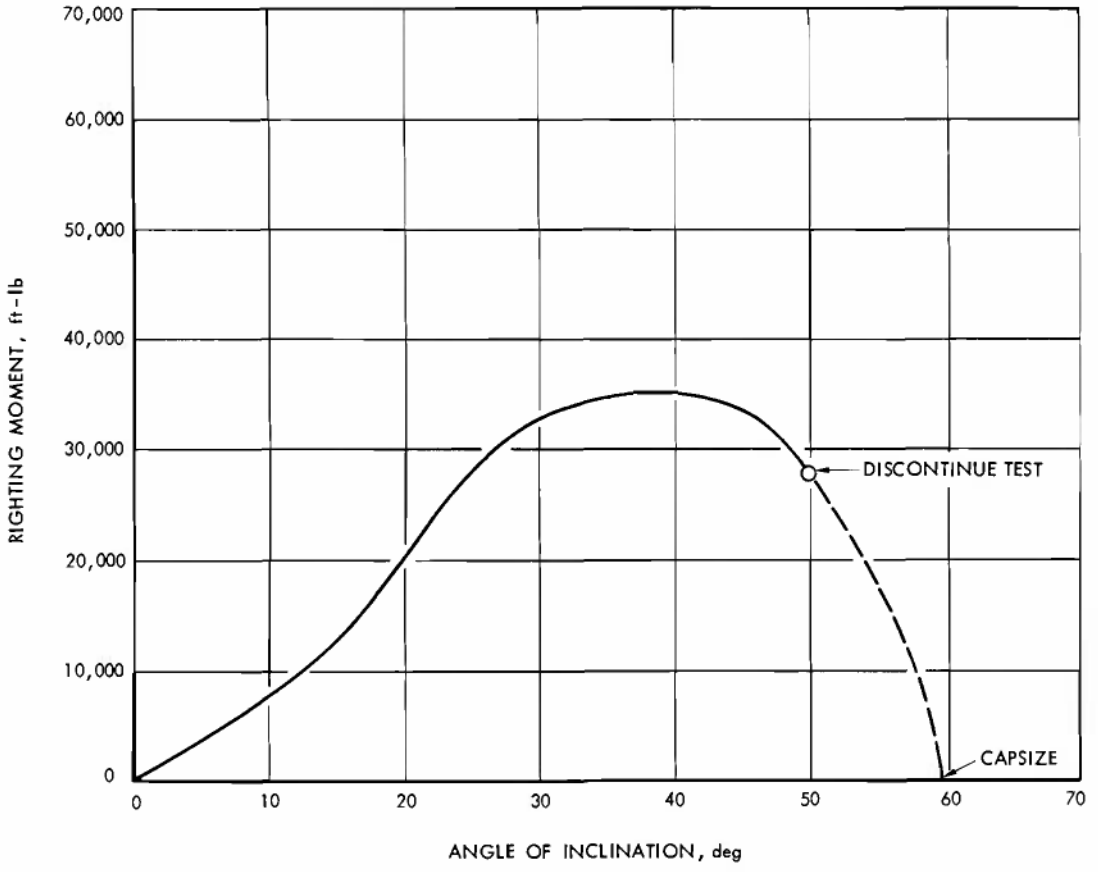


Figure 8-6. Typical Waterborne Statical Stability Curve for an Amphibian

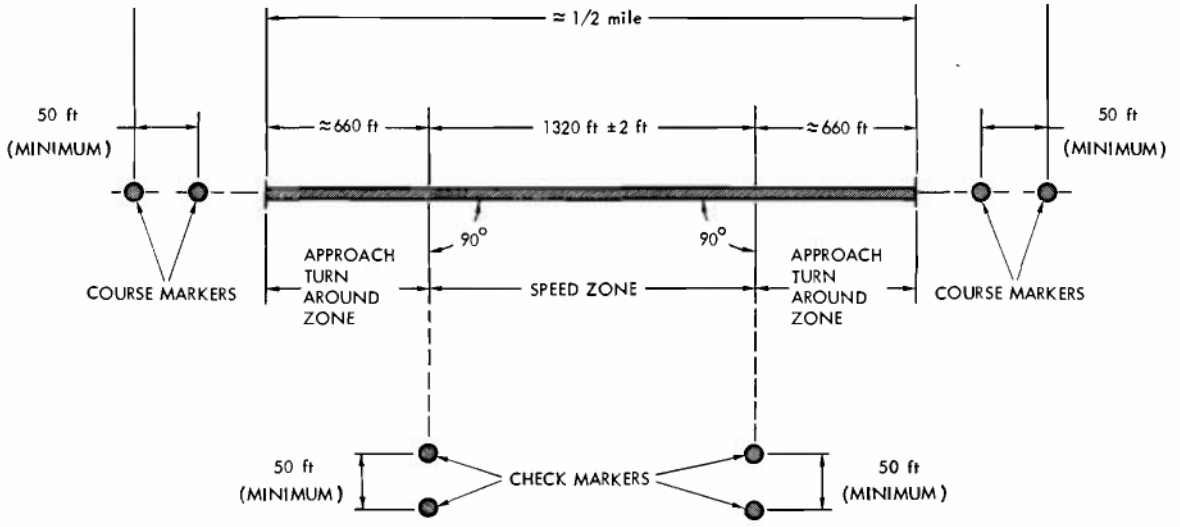


Figure 8-7. Plan View of Typical Water Course for Amphibian Speed Runs

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taken into consideration including load condition, approach speed, and rudder angle set at execution of turn. If two propulsion devices are employed, the minimum turning circle will result when reverse or astern power is applied to the inboard (with respect to direction of the turn) propulsor.

As with the waterborne speed trails, the determination of the amphibian's position and path during the turn is the complication. Methods which have been used in the past include calculating the amphibian's position by triangulation from shore stations at regular intervals during the execution of a turn; see Fig. 8-8. Another method consists of dropping buoys at regular intervals during the turn and measuring the turning circle diameter by triangulation or direct tape measurement.

8-4.2.3.5 Crash Stop Tests

These tests are used to determine minimum distance (ahead reach) from the point of execution of astern power to a dead stop in the water.

The method used is to approach a marked course at full speed. When range posts are lined up, astern power is applied to the propulsor. Distance is then measured or triangulated from point of execution to the point where forward motion is stopped.

During this maneuver, care should be taken not to over torque the engines; close monitoring of the machinery operation should be maintained.

8-4.2.3.6 Astern Operation and Maneuvering Tests

The amphibian is operated with full power astern for a sustained period of time. During this period, rudder response is recorded and the sustained astern power capability is evaluated in terms of pressures, temperatures, vibration, etc. One method of evaluating rudder response is to measure the rate of change in heading (compass) at maximum astern speed for various rudder

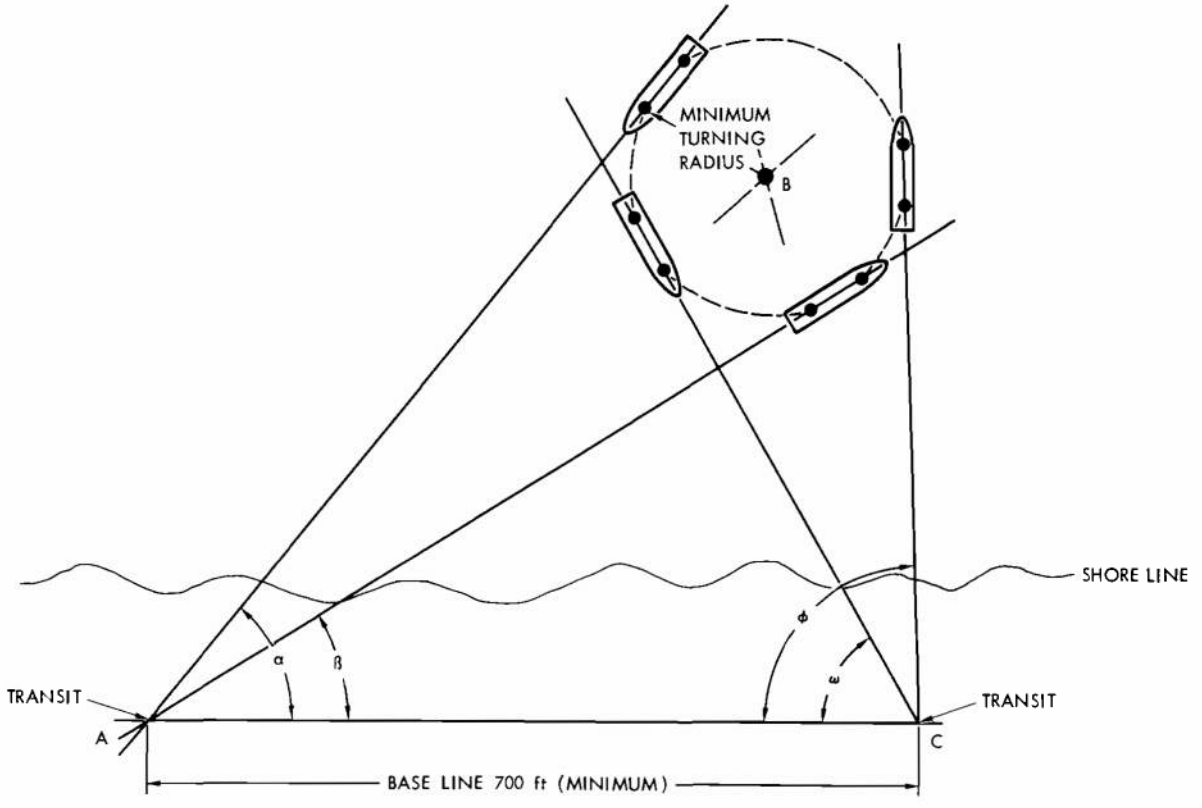

Figure 8-8. Method for Determination of Waterborne Turning Radius

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angles. Rudder angle required to maintain a steady (straight) course astern should also be recorded.

8-4.2.3.7 Bollard Pull Tests

Bollard pull tests are somewhat analogous to the draw bar pull tests on land. The amphibian is moored to a rigid structure such that the line lies in the vertical plane passing through the propeller shaft or line of thrust. The mooring line should also be as close as possible to horizontal.

A tension dynamometer is placed in this line, and tensions recorded for increments of propeller or propulsor speed (rpm).

For multiple propulsor amphibians, each system should be tested independently. See Fig. 8-9 for a sample test method.

8-4.2.3.8 Towing Tests

These tests are performed to determine an amphibian's towing capability and its ability to be towed. Selected vehicles are towed by the test amphibian and tow line tension, speed, and power are measured.

The test amphibian may also be towed in various load conditions without propellers to determine its waterborne resistance at various speeds of advance. The effective horsepower *(EHP)* can then be calculated.

8-4.2.4 Surf Tests

The state-of-the-art in surf testing amphibians with regard to qualitative analyses is very limited. One of the major variables involved in surf testing is the capability of the operator. With this in mind, the test methods which follow represent those that attempt to determine surf performance.

Under various load conditions and for various surf heights, the amphibian is run through the breakers in both directions, i.e., landing on the beach and re-entering the water. Films are taken of the tests and degree of directional stability is measured in terms of the amphibian's extent of "wallowing", tendency to broach, and amount of rudder control required. Another important factor with regard to surfing ability is the ability of the amphibian to withstand water impact of breaking waves over its cab and decks, and the ease with which this water is shed.

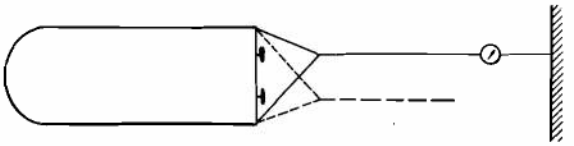

Figure 8-9. Bollard Pull Test Method

Surf tests in the past have simply compared a new design amphibian with other amphibians by operating them side by side in the surf. Evaluation is made by the operators, observers, and, at times, by the surf (when sinking results).

8-4.2.5 Other Tests

Other types of tests which are performed on amphibians during typical confirmatory testing, are tabulated in Table 8-3. The breakdown is, for the most part, self-explanatory. It is recommended that test reports for previous amphibians be reviewed for greater detail with regard to these tests.

Endurance testing involves much the same procedure as the confirmatory type test. However, many operational hours are accumulated and gross amphibian reliability, maintainability, and logistic requirements may be determined.

During the design phase of an amphibian, the designer should be aware of all the standard tests, and be acutely aware of the possibility of improving these tests and developing new tests as required for the particular amphibian with its related areas of high risk, high performance sensitivity, and degree of complexity.

TABLE 8-3 TYPICAL TYPE II CONFIRMATORY TEST AGENDA

A.	Familiarization and Training
B.	Preoperational Inspection
C.	Road Mobility
D.	Off-road Mobility
E.	Fuel and Oil Consumption
F.	Ease of Operation (Crew Safety and Comfort)
G.	Maintenance Evaluation
H.	Water Operations
I.	Towing Test
J.	Surf Performance
K.	Operation with Landing Ships
L.	Loading and Unloading
M.	Movement Adaptability (Transportability)

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1. *USATECOM Materiel Test Procedures*, Vol. I, *Introduction to Organization, Format, Style, and Index*, Pamphlet 700-700, AMSTE-RP-702-100, Aberdeen Proving Ground, Maryland, October 1966.
2. *Standard Tests for Engineering Testing of Amphibious Landing Vehicles (Tracked)*, Report No. 105-1-1004, Selwood Research, Inc., Kensington, Md., June 1967.
3. *Ordnance Proof Manual*, Vol. II, *Automotive Testing*, Aberdeen Proving Ground, Maryland.
4. *Surf Testing Procedure*, Amphibian Vehicle Division, Landing Forces Development Center, Quantico, Virginia.

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PART FOUR HIGH SPEED AMPHIBIANS

CHAPTER 9 HIGH SPEED AMPHIBIANS

9-1 INTRODUCTION

There has been considerable interest in the design of wheeled amphibian vehicles with high water speed since the late 1950's. The first studies of high-speed amphibians were initiated by U. S. Army Transportation Evaluation Command, Fort Eustis, Virginia, under contract with Ingersoll-Kalamazoo Div., Borg-Warner Corp., Kalamazoo, Michigan. After a design study, further work was suspended due to pressing work on the development of the LARC V and LARC XV, and limited funding.

A study conducted by the U. S. Army Transportation Combat Development Group (Ref. 1) indicated that a high water speed will greatly increase the productivity of a logistical amphibian if the one-way water distance is on the order of 10 miles or greater. Thus for some mission requirements a wheeled amphibian with a high water speed may be desirable.

During the period from the early 1960's until 1968, the Amphibian Vehicle Division, Development Center, Marine Corp Development and Education Command, conducted an extensive study of high-speed wheeled amphibians. In order to increase the water speed, the study revealed that—among other things—the hydrodynamic drag must be reduced below that of the conventional wheeled amphibian displacement hull. This fact led naturally to the consideration of other hull configurations including planing hulls, hydrofoils, surface effect or air cushion craft, and catamarans.

As may be expected, the waterborne performance requirements will have the greatest single influence on the characteristics of a high speed amphibian. Thus the performance required by the craft's mission must be carefully considered and defined. This is particularly true with respect to sustained speed in waves, range or endurance, and maneuverability. It should be noted that a high-speed amphibian may have its speed limited by the available power or its motions in waves. The power-limited speed is simply the highest speed possible in a given sea condition using all of the available power. The motion-limited speed is the speed at which the amphibian's wave induced motions, and in particular the acceleration, exceed the tolerance of the crew. The selection of these required speeds should be consistent with the other aspects of waterborne ability (i.e., loading at ship side and surfing) and the expected occurrence of various sea conditions. Ref. 2 provides some information on the latter topic. The price—in terms of weight, complexity, and cost for a high speed amphibian with performance in excess of that actually required for the mission—will be very high.

This chapter on high (water) speed amphibians is intended to provide data and projections of performance and characteristics of different vehicle types, and information on design problems that are unique to high speed amphibians. The design procedures and much of the data presented in previous chapters apply to high-speed amphibians and thus will not be repeated. No attempt will be made to present detailed procedures for the hydrodynamic design of a high-speed amphibian since this would require an effort beyond the scope of this handbook. However, a list of suitable references for each vehicle type is included.

9-2 PLANING HULL AMPHIBIANS

One possible type of high-speed amphibian is based on the use of a planing hull form. On a planing hull form a large part of the weight is carried by dynamic lift at high speed. There is little wavemaking drag at high speed so that the power required is reasonable. At intermediate speeds (15 to 20 mph for a 35-ft vehicle) the wavemaking drag is high which may, in fact, fix the power required. This problem is discussed in par. 9-3.1.

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9-2.1 EXISTING PLANING HULL AMPHIBIANS (LVW-X1 and LVW-X2)

Numerous planing hull amphibian forms were studied and model tested by the Stevens Institute of Technology in the late 1950's and reported in Ref. 3. From this work evolved the concept that was ultimately built. In early 1960 a contract was let by the Navy Bureau of Ships to the Ingersoll-Kalamazoo Div. of the Borg-Warner Corp. for the design and fabrication of two planing hull amphibians designated LVW-X1 and LVW-X2. The two vehicles were accepted by the Marine Corps in early 1964. The support of these vehicles was later taken over by the Chrysler Corp.

The LVW-X1 and LVW-X2 are nearly identical vehicles. Both have identical all welded aluminum "V" bottom hulls, retractable propellers, retractable aft wheel flaps to increase the planing surface, and an unsprung suspension system with fully retractable wheels. The major differences are that the LVW-X1 employs side loading and 2-wheel, 4-wheel, or oblique steering; whereas the LVW-X2 employs stern loading and 2-wheel steering. The LVW-X1 is also equipped with small trim control wedges on the wheel flaps.

The LVW's are each powered by a Lycoming TF-2036 gas turbine which drives the propellers, the wheels, or both as required.

For waterborne operation, two propellers and rudders are provided. These are mounted on a hinged propeller retracting plate which provides a smooth flat bottom for high speed planing operation. This plate retracts by pivoting around its forward end. Thus in the retracted position the propellers are in a tunnel, protected for land and surf operations.

In the land mode of operation, four-wheel drive is provided. Wheel retraction and extension are handled by a pivoting mechanism which allows the wheel to swing in the fore and aft direction. The operator's cab is located forward of the cargo well and is designed for both land and water operation with a crew of two. The fully enclosed cab is fitted with 3/4-in. shatterproof glass for protection in surf operation.

Figs. 9-1 and 9-2 show an LVW operating at high speed in the water and on land, respectively. The vehicle characteristics of the LVW-X1 and LVW-X2 are given in Tables 9-1 and 9-2, respectively; and an outline drawing of the LVW-X1 is given in Fig. 9-3.

9-2.1.1 Waterborne Speed and Power of LVW-X1 and LVW-X2

As indicated in par. 9-1, it is necessary to carefully define the waterborne speed of a high-speed amphibian and the conditions under which it was obtained: In order to obtain these data, the U. S. Marine Corps conducted a series of engineering tests on the LVW vehicles. The results are summarized in Ref. 4. After initial testing it was realized that, because of problems with weight and various components, the LVW vehicles should not be considered as prototypes for a planing hull amphibian. As a result, they were tested in the water as test bed craft for planing hull amphibian performance. These tests were conducted at a gross weight of about 38,000 lb which corresponds to the original full load design displacement. Tests at the actual full load displacement of 44,000 lb would not have been meaningful because of the increased weight over the design conditions.

The measured thrust horsepower, shaft horsepower, and propeller rpm as a function of speed in calm water for the LVW-X1 are presented in Fig. 9-4. The lines represent model test data scaled to full size and the points represent measured full scale data. An important item to note in this figure is the peak or hump in *SHP* at a speed of 20 knots, i.e., it requires as much power to reach 20 knots as 30 knots. This hump in *SHP* is due to high drag from wavemaking, poor flow conditions to the propeller, and low propeller efficiency due to a high thrust coefficient (see par. 7-7). This condition is typical of high-speed amphibians and means that the power required must be checked over a range of speeds in addition to the design point.

The actual top speed obtained by the LVW vehicles in calm water and Sea States 1, 2, and 3 are presented in Table 9-3. The speeds given in Table 9-3 represent the speed obtained when operating at full power. The Sea State numbers given refer to Table 9-4.

9-2.1.2 Accelerations of the LVW Vehicles

The LVW-X2 vehicle was instrumented and the accelerations in head seas were measured at

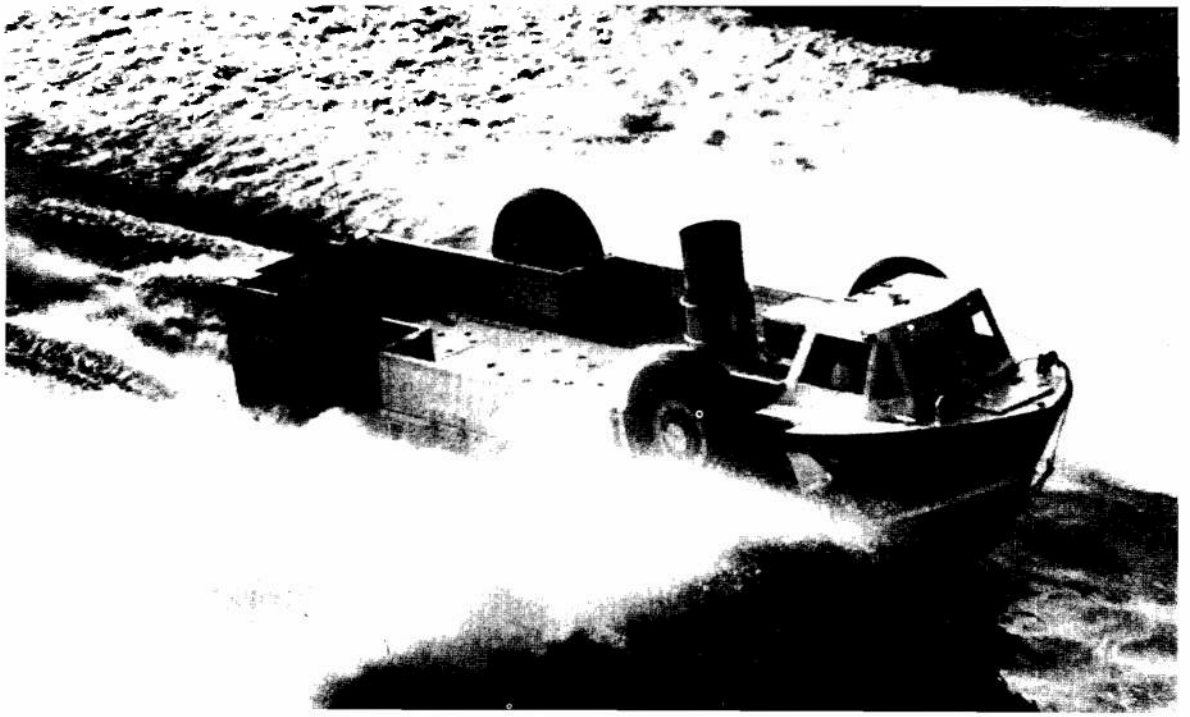

Figure 9-1. LVW-X1 in High-speed Waterborne Mode

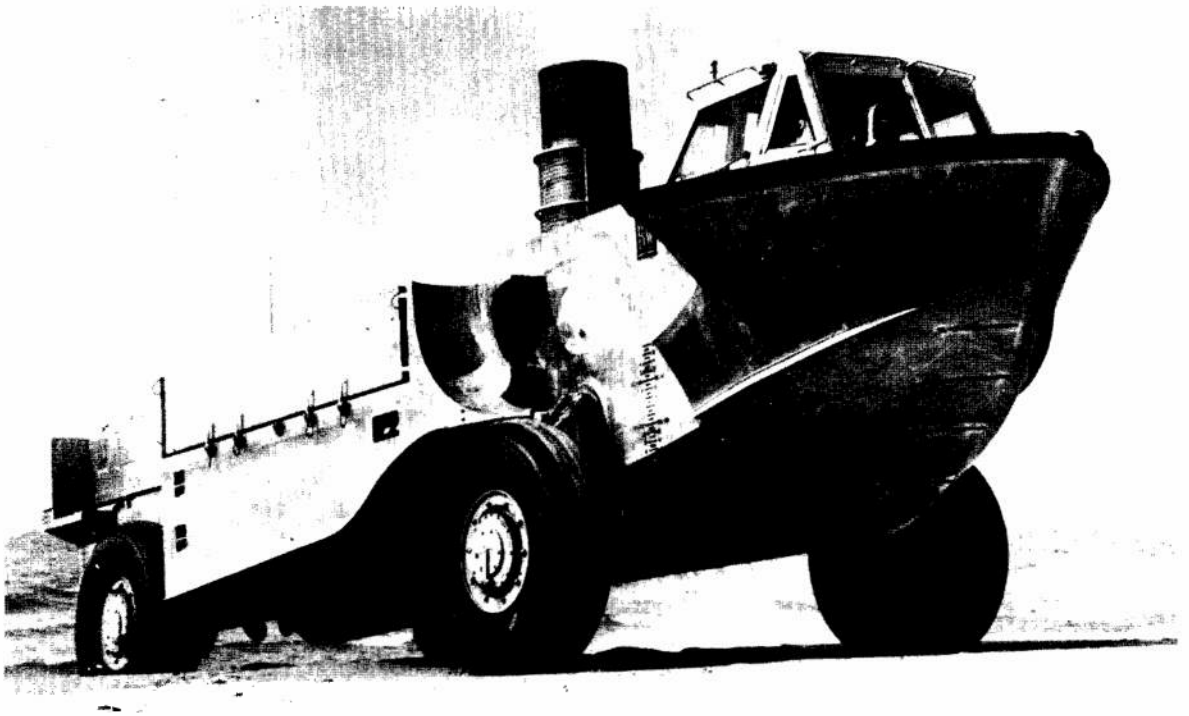

Figure 9-2. LVW-X2 in Land Mode

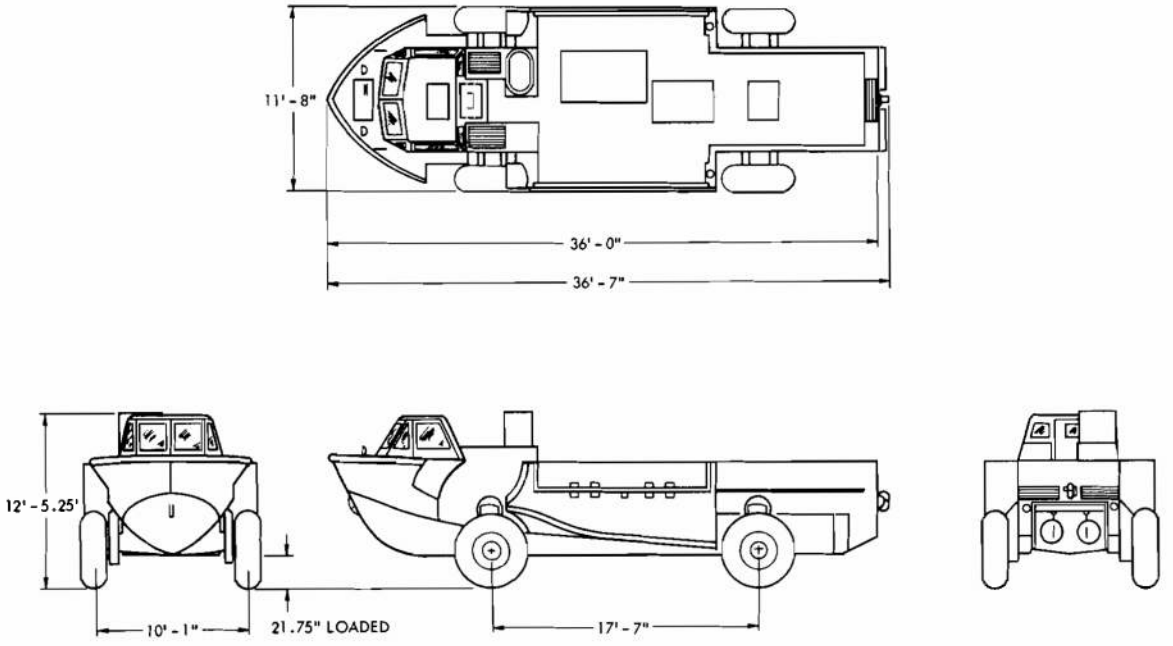

Figure 9-3. External Dimensions of LVW-X1

the bow (crew cab) and at the center of gravity. These data are presented in Ref. 4. Fig. 9-5 presents the average of the 1/3 highest upward (or impact) accelerations in "g's" of the LVW-X2 as a function of nondimensional wave heights and volume Froude numbers. The average of the 1/3 highest occurrences of a random variable such as wave height or vehicle accelerations is often called the significant value. The volume Froude number is a nondimensional measure of speed for a planing hull the same as the conventional Froude number or speed length ratio is for a displacement hull (see par. 7-4.1.1.3). The relationship between displacement, speed, and volume Froude number is given by:

$$F_{\nabla} = \frac{V}{\sqrt{g\left(\frac{\Delta}{\rho g}\right)^{1/3}}} \qquad (9\text{-}1)$$

where

F_{∇} = volume Froude number, nd
V = speed, ft/sec
Δ = displacement, lb
g = acceleration due to gravity, ft/sec^2
ρ = mass density of water, slug/ft^3

A nomograph for the solution of Eq. 9-1 is presented in Fig. 9-6.

The data in Fig. 9-5 apply to the condition of head seas. In following seas, the accelerations are reduced considerably. Table 9-5 presents this reduction for typical planing hulls.

As previously indicated above, in order to define a "motion-limited speed" it is necessary to know the motions as a function of speed and sea state (wave height), and the tolerance level of the crew to the motions. During the testing of the high-speed amphibians some data on the crew tolerance were developed. These data are summarized in Table 9-6.

The reactions given in Table 9-6 are based on a limited sample and thus, must be regarded with caution. They are, however, the only data known to exist in which the crew reactions and measured accelerations were obtained simultaneously for high speed marine craft. More data of this type will be developed in the future, and as it becomes available should be used to revise Table 9-6.

If a waterborne transit time of 1 hr is assumed, the allowable significant upward acceleration level would be 0.9 g. In this case the actual sustained speed of the LVW in various sea states would be as given in Table 9-7.

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TABLE 9-1. LVW-X1 VEHICLE CHARACTERISTICS

Manufacturer	Ingersoll-Kalamazoo Division of Borg-Warner
Width, ft-in.	11-8
Length, ft-in.	36-7
Height (Top of Cab), ft-in. (Top of Stack), ft-in.	11-0 12-5¼
Min Ground Clearance, in.	21¾
Wheelbase, ft-in.	17-7
Track Width, ft-in.	10-1
Angle of Approach, deg	25
Angle of Departure, deg	26
Break Angle, deg	15
Land Speed (Governed), mph	35
Water Speed	See par. 9-2.1.1
Land Range, mi	330 at 25 mph
Turn Radius (Land)	See par. 9-2.1.3
Turn Radius (Water)	See par. 9-2.1.3
Cargo Capacity (Design), lb	10,000
Cargo Space (L X W), ft-in.	21-10 X 10-10; Area = 183 ft^2
Total Weight, lb	44,000
Grade Ability (Design), %	60
Side Slope (Design), %	30
Surf Ability (Design), ft	10
Engine Data	Lycoming TF-2036-B1A Gas Turbine, 1,500 *BHP* (cont.) at 3,600 rpm and 80° F
Fuel Type	Marine Diesel, JP-3, -4, or -5
Fuel Capacity, gal	806
Marine Propulsor	(2) propellers; D = 24 in., P/D = 1.3, BAR = 0.945; Retractable
Suspension	Unsprung rigid system, 4 X 4
Brake System	Fawick, Caliper, Hydraulic-actuated, 4 sets of spot disc type
Tires	18 X 25 in., 12-ply
Land Steering	Hydraulic; Selective 2-wheel, 4-wheel, or oblique
Marine Steering	Hydraulic-actuated twin rudders
Electrical System	24-V DC, Single-wire
Hydraulic System	3,000 psi, 15 gpm at 2,000 rpm; 3,000 psi, 33 gpm at 2,400 rpm
Crew	2
Hull	Welded Aluminum 5456
Planing Surface	Retractable plate with mounted propeller

TABLE 9-2. LVW-X2 VEHICLE CHARACTERISTICS

Manufacturer	Ingersoll-Kalamazoo Division of Borg-Warner
Width, ft-in.	11-7¼
Length, ft-in.	36-7¼
Height (Top of Cab), ft-in. (Top of Stack) ft-in.	11¾ 12-5½
Min Ground Clearance, in.	21½
Wheelbase, ft-in.	17-7
Track Width, ft-in.	10-1
Angle of Approach, deg	25
Angle of Departure, deg	25
Break Angle, deg	15
Land Speed (Governed), mph	35
Water Speed	See par. 9-2.1.1
Land Range, mi	330 at 25 mph
Turn Radius (Land)	See par. 9-2.1.3
Turn Radius (Water	See par. 9-2.1.3
Cargo Capacity, lb	10,000
Cargo Space (L X W), ft-in.	21-10 X 10-10 ; Area = 180 ft^2
Total Weight, lb	44,000
Grade Ability (Design), %	60
Side Slope (Design), %	30
Surf Ability (Design), ft	10
Engine Data	Lycoming TF-2036-B1A Gas Turb., 1,500 *BHP* (cont.) at 3,600 rpm and 80°F
Fuel Type	Marine Diesel, JP-3, -4, or -5
Fuel Capacity, gal	806
Marine Propulsor	(2) propellers; D = 24 in., P/D = 1.3, BAR = 0.945; Retractable
Suspension	Unsprung rigid system, 4 X 4
Brake System	(4) Spot discs
Tires	18 X 25 in., 12-ply
Land Steering	Hydraulic, 2-wheel only
Marine Steering	Hydraulic-actuated twin rudders
Electrical System	24-V DC, single-wire
Hydraulic System	3,000 psi 15 gpm at 2,000 rpm; 3,000 psi 33 gpm at 2,400 rpm
Crew	2
Hull	Welded Aluminum 5456
Planing Surface	Retractable plate with mounted propeller

TABLE 9-3 POWER LIMITED SPEEDS OF LVW PLANING HULL AMPHIBIAN

Sea State	0	1	2	3
Speed, mph	41	40	35.5	26.5

TABLE 9-4 WIND AND SEA SCALE FOR FULLY ARISEN SEA

SEA-GENERAL			WIND				SEA				
							WAVE HEIGHT FEET				
U.S. CODE NO.	DESIGNATION	(BEAUFORT WIND FORCE)	DESCRIPTION	RANGE (KNOTS)	WIND VELOCITY AVERAGE	SIGNIFICANT AVERAGE OF HIGHEST 1/3	SIGNIFICANT RANGE OF PERIODS (SECONDS)	PERIOD OF MAXIMUM ENERGY OF SPECTRUM T_{max} (SECONDS)	T_1 (AVERAGE PERIOD) (SECONDS)	AVERAGE WAVE LENGTH (NAUTICAL MILES)	MINIMUM DURATION (HOURS)
(0)	Sea like a mirror	0	Calm	Less than 1	0	0	0	0	-	- - - -	
(0)	Ripples with the appearance of scales are formed, but without foam crests.	1	Light Airs	1-3	2	0.05	0.08	0.10	up to 1.2 sec	0.7 0.5 10 in.	5 18 min
(1)	Small Wavelets, still short but more pronounced; crests have a glassy appearance, but do not break	2	Light Breeze	4-6	5	0.28	0.29	0.37	0.4 - 2.8	2.0 1.4 6.7ft	8 39 min
(1)	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	3	Gentle Breeze	7-10	8.5	0.6	1.0	1.2	0.8 - 5.0	3.4 2.4 20 9.8	1.7 hr
					10	0.88	1.4	1.8	1.0 - 6.0	4 2.9 27 10	2.4
(2)	Small waves, becoming larger; fairly frequent white horses	4	Moderate Breeze	11-16	12	1.4	2.2	2.8	1.0 - 7.0	4.8 3.4 40 15	3.4
					13.5	1.8	2.9	3.7	1.4 - 7.6	5.4 3.9 42 24	4.8
(3)					14	2.0	3.3	4.2	1.5 - 7.8	5.6 4.0 49 28	5.2
					16	2.9	4.6	5.8	2.0 - 8.8	6.5 4.7 71 40	6.6
(4)	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray).	5	Fresh Breeze	17-21	18	3.8	6.1	7.8	2.5 - 10.0	7.2 5.1 90 55	8.3
					19	4.3	6.9	8.7	2.8 - 10.6	7.7 5.4 99 64	9.2
(5)					20	5.0	8.0	10	3.0 - 11.1	8.1 5.7 111 75	10
(6)	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).	6	Strong Breeze	22-27	22	6.4	10	13	3.4 - 12.2	8.9 6.3 134 100	12
					24	7.9	12	16	3.7 - 13.5	9.7 6.8 160 130	14
					24.5	8.2	13	17	3.8 - 13.6	9.9 7.0 164 140	15
					26	9.6	15	20	4.0 - 14.5	10.5 7.4 188 180	17
(7)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. (Spindrift begins to be seen).	7	Moderate Gale	28-33	28	11	18	23	4.5 - 15.0	11.3 7.9 219 230	20
					30	12	22	28	4.7 - 16.7	12.1 8.6 250 280	23
					24.5	14	23	29	4.8 - 17.0	12.4 8.7 258 290	24
					32	16	26	33	5.0 - 17.8	12.9 9.1 285 340	27
(7)	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well marked streaks along the direction of the wind. Spray affects visibility.	8	Fresh Gale	34-40	34	19	30	38	5.6 - 18.5	13.6 9.7 322 420	30
					36	21	35	44	5.8 - 19.7	14.5 10.3 363 500	34
					37	23	37	46.7	6.0 - 20.5	14.9 10.6 370 530	37
					38	25	40	50	6.2 - 20.8	15.4 10.7 392 600	38
(8)					40	28	45	56	6.5 - 21.7	16.1 11.4 484 710	42
(8)	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Visibility affected.	9	Strong Gale	41-47	42	31	50	64	7 - 23	17.0 12.0 492 830	47
					44	36	58	73	7 - 24.2	17.7 12.6 534 960	52
					46	40	64	81	7 - 25	18.6 13.1 590 1100	57

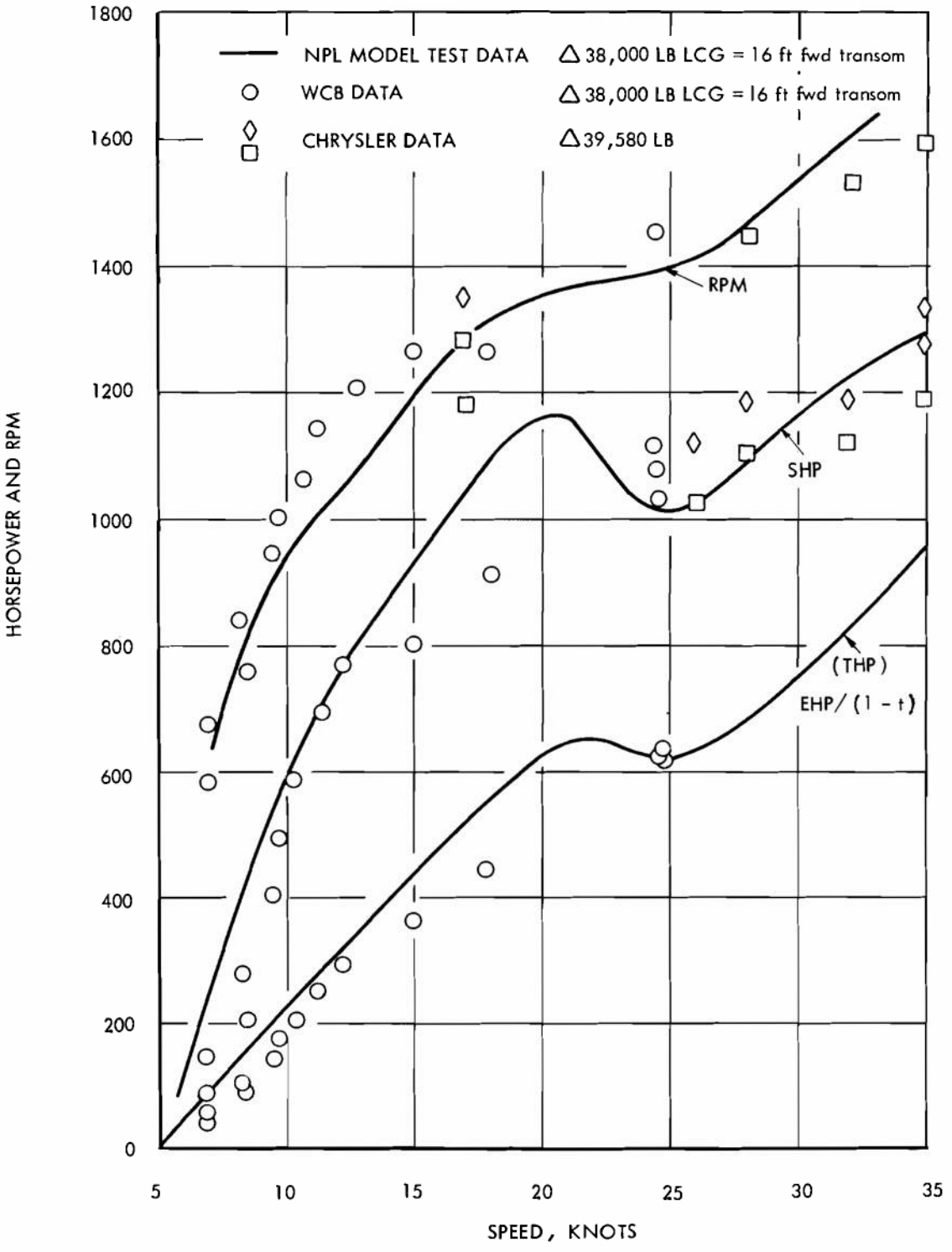

Figure 9-4. LVW-X1 Speed and Power; Model Test and Full Scale Data

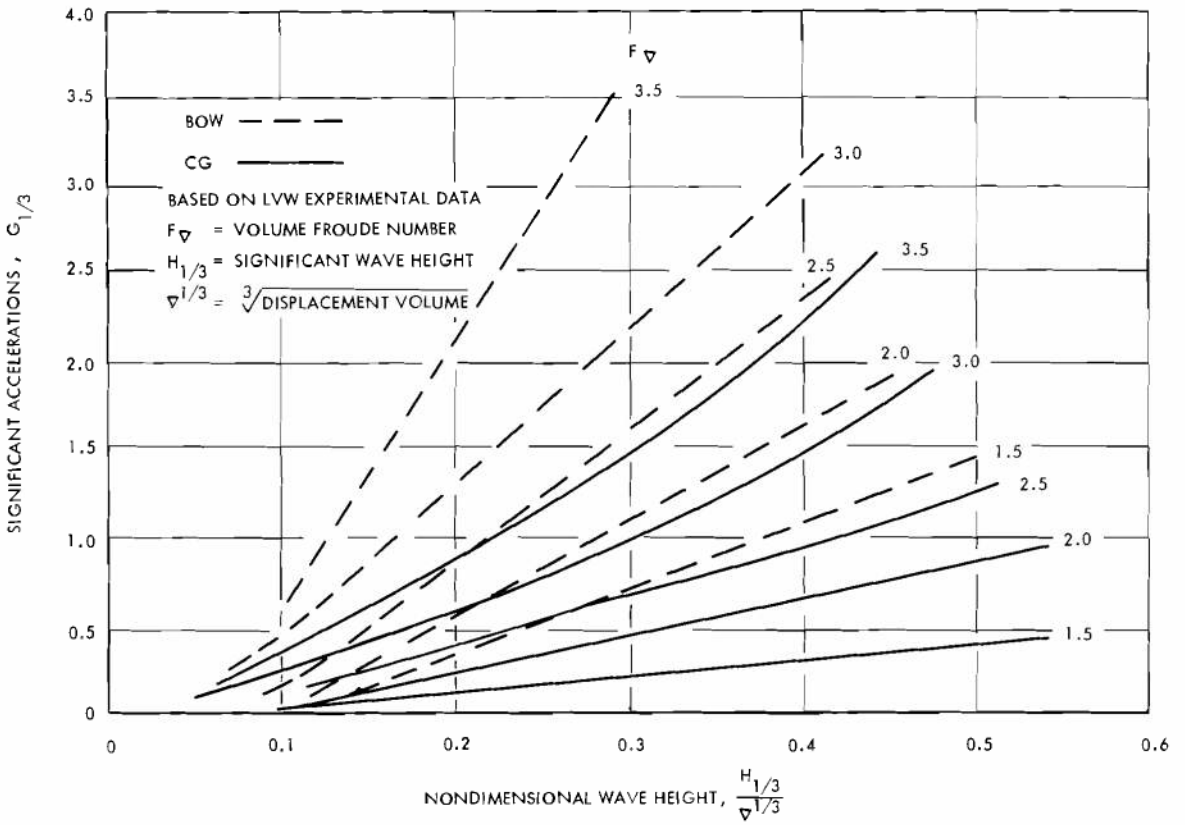

Figure 9-5. "V" Bottom Planing Hull Vertical Accelerations for LVW-X2 in Head Seas

Table 9-7 indicates the considerable increase in sustained speeds in high sea states that will result if the crew is located in the area of minimum accelerations aft of the center of gravity.

9-2.1.3 Control

The control characteristics of the LVW-X2 were measured at high and low speeds, and the results reported in Ref. 5. The observed turning diameters at high and low speeds are presented in Tables 9-8 and 9-9, respectively.

In high-speed turns the LVW heels inboard and in general shows satisfactory stability characteristics. Fig. 9-7 presents the arrangement of the propellers and rudders on the LVW.

Because of the very low reliability of the LVW steering and suspension systems, only limited data are available on the control characteristics on land. Ref. 6 indicates turning diameters of 138 ft to the right and 120 ft to the left with 2-wheel steering. No tests were conducted with 4-wheel steering.

9-2.2 FUTURE PLANING HULL AMPHIBIANS

From data obtained with the LVW-X1 and LVW-X2 and other studies of planing hull performance, it is possible to make some projections of the possible characteristics and performance of future planing hull amphibians. Projections of this type have been made and are reported in Refs. 4 and 7.

9-2.2.1 Drag

Experimental studies (Refs. 8 and 9) indicate that more recent "V" bottom and inverted "V" bottom planing hulls with sizes and displacements suitable for amphibians can be designed with less resistance than the LVW-X1 and LVW-X2. A comparison between the drag of the LVW-X1 and that of a Series 62 "V" bottom hull and LVW-X3 inverted "V" bottom hull is

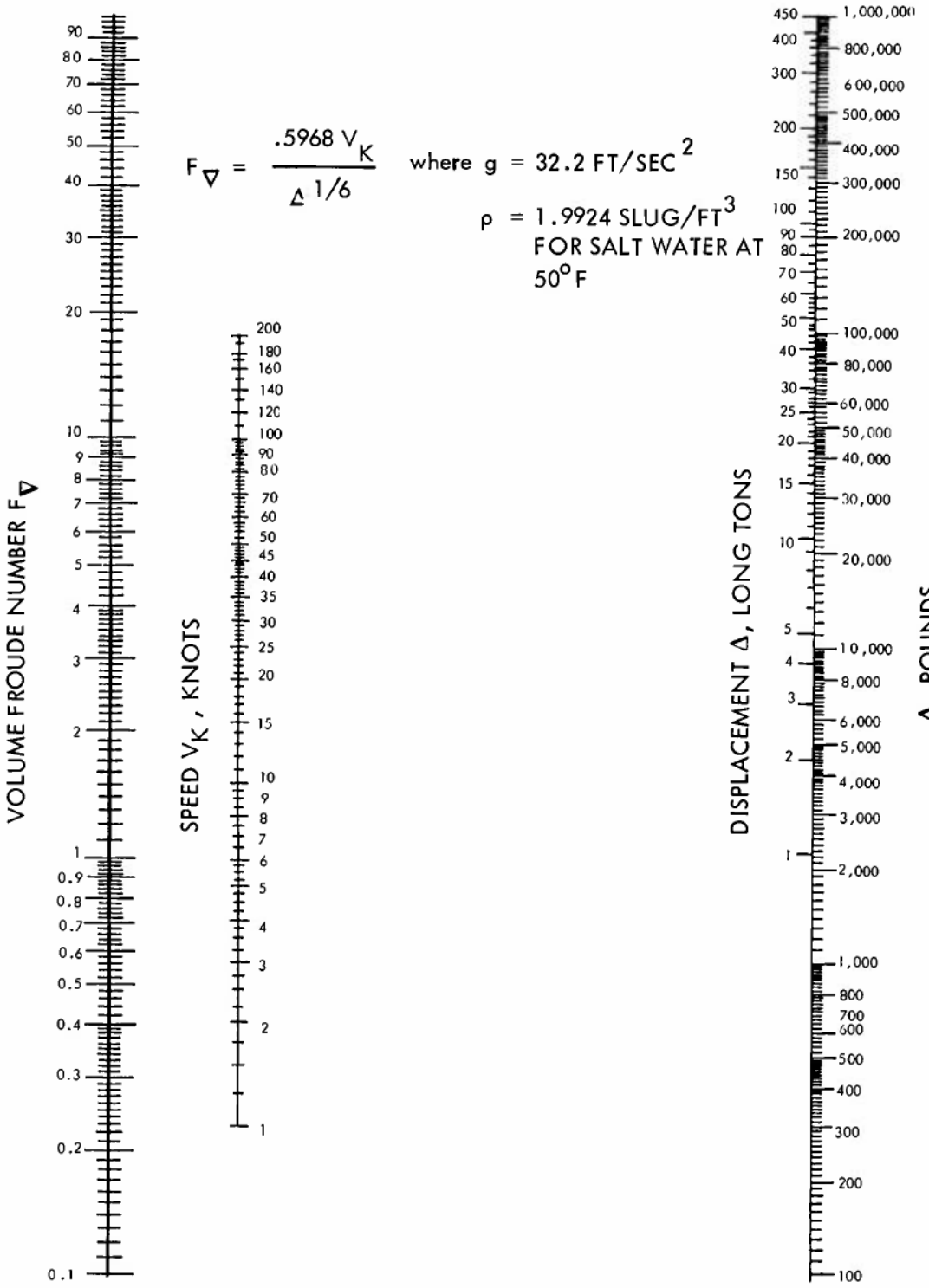

Figure 9-6. Nomograph of Speed, Displacement, and Froude Number

TABLE 9-5 PLANING HULL ACCELERATIONS IN FOLLOWING SEAS

Volume Froude Number F_{∇}	*Acceleration (as Percentage of Acceleration in Head Seas)*
1.5	20%
2.0	21%
2.5	29%
3.0	33%
3.5	43%
4.0	64%
4.5	79%

TABLE 9-6 SUBJECTIVE REACTIONS OF PERSONNEL TO HIGH-SPEED AMPHIBIAN MOTIONS

Significant Upward Acceleration $G_{1/3}$	*Reaction*
0.35	Motion Inconsequential
0.9	Tolerance Level = 1 hr
1.3	Tolerance Level = 0.5 to 1 hr
2.1	Tolerance Level = 10 to 15 min
2.3-2.6	Beyond Limit of Endurance

TABLE 9-7 SUSTAINED SPEED OF LVW IN HEAD SEAS GROSS WEIGHT 39,500 POUNDS

	Crew Forward				*Crew Aft*			
Sea State	0	1	2	3	0	1	2	3
Speed, mph	41	39	25	12	41	40	35	24

presented in Fig. 9-8. The sizes and displacements indicated would be suitable for an amphibian with a 10,000-lb payload capability. Figs. 9-9 and 9-10 present the characteristics of the Series 62 and LVW-X3 hull forms, respectively. Neither of these hull forms has wheel wells, and thus the forms are representative of amphibians with completely faired wheel wells. In practice it will be very difficult to provide covers for the forward wheels because of the high hydrodynamic loads in rough water. Based on data in Ref. 3 an estimate was made of the drag of a "V" bottom planing hull form with open bow wheel wells and completely covered aft wheel wells. These data are also included in Fig. 9-3. As expected, the drag of such a form is between that of the completely faired hulls and the LVW-X1 with open bow and stern wheel wells.

For the purpose of a very preliminary estimate of the drag of a planing hull amphibian design, the data in Fig. 9-8 may be replotted in the form of a drag-weight ratio as a function of volume Froude number. A new planing hull amphibian may be assumed to have the same drag-weight ratio at the same volume Froude number. As soon as possible, however, a more exact drag estimate that accounts for differences in hull form, displacement, and center of gravity location should be prepared. Refs. 3, 8, 9, and 10 may be used for this purpose.

For planing hulls, the drag in waves is often estimated by a percentage increase over calm water drag. The percentage used must be based on experience. Fig. 9-11 presents the percentage drag increase in rough water as a function of nondimensional wave height and volume Froude number. Data are included from tests of several planing hull forms whose characteristics are given in Ref. 9, 11, and 12. The data in Fig. 9-11 may be used with the calm water drag data previously discussed to obtain the estimate of the drag of a future planing hull amphibian in waves.

The power required for a high-speed planing hull amphibian may be determined once the drag is estimated by using the procedures described in par. 7-7.

9-2.2.2 Accelerations in Waves

In considering future planing hull amphibians, it will be necessary to predict their acceleration characteristics. The data presented in Fig. 9-5 for the LVW-X2 may be used for this purpose. A comparison between the acceleration of the LVW-X2 and other planing hulls has been made and the results are presented in Fig. 9-12. The accelerations of the LVW-X2 follow a similar trend with speed as that of the other planing hulls considered. The deadrise angle (at a location 30 percent of the length aft of the bow) has a significant effect on the accelerations. This is consistent with the expected effect of deadrise as reported in Ref. 13. It is of interest to note that the accelerations of the LVW-X3 inverted "V" hull are similar to those of the "V" bottom hulls with deadrise angles between 25 and 30

TABLE 9-8 LVW-X2 HIGH-SPEED TURNING DIAMETERS

Direction	*Diameter, ft*	*Time, sec*	*Average Speed, mph*	*Turn Diameter/Vehicle Length*
Starboard	720	53	29.0	20
Port	640	53	26	17.8
Starboard	720	53	29	20
Port	670	53	27	18.6
Starboard	710	52	29	19.7
Port	690	54	27	19.2
Starboard	780	55	30	21.7
Port	870	58	32	24.2

TABLE 9-9 LVW-X2 SURF MODE TURNING DIAMETERS

Direction	*Speed, mph*	*Diameter, ft*	*Trim,*(1) *deg*	*Heel, deg*	*Turn Diameter/Vehicle Length*
Port	5.5(2)	81	4	2.5 Stbd	2.25
Starboard	5.5	95	4	7 Port	2.64
Port	6.6	91	4.5	4 Stbd	2.52
Starboard	6.6	100	4.5	8 Port	2.78
Port	8.5	104	6	7 Stbd	2.89
Starboard	8.5	136	6	11 Port	3.78
Port	10.5(3)	150	9	9 Stbd	4.16
Starboard	10.5	140	9	14 Port	3.88

NOTES:

(1) Trim by the stern; Static trim = 3 deg; *GVW* = 39,500 lb; Four (4) personnel on board; *KG* = 3.2 ft; Load *VCG* approximately 20 in. above deck

(2) Minimum speed dictated by high turbine exhaust temperature

(3) Maximum speed in surf mode

deg. Based on the above comparisons, it is concluded that the accelerations of the LVW-X2 are typical of what can be expected of a future planing hull amphibian.

9-2.2.3 Vehicle Characteristics

Ref. 7 presents a parametric study of high-speed amphibian characteristics. The configuration of the base planing hull amphibian developed in this study is shown in Fig. 9-13. Parametric variations were made of this configuration to determine the effects of payload and range on vehicle characteristics. The results in terms of gross vehicle weight, power, principal dimensions, and payload fraction—all as a function of payload—are presented in Fig. 9-14. All of these characteristics are for craft

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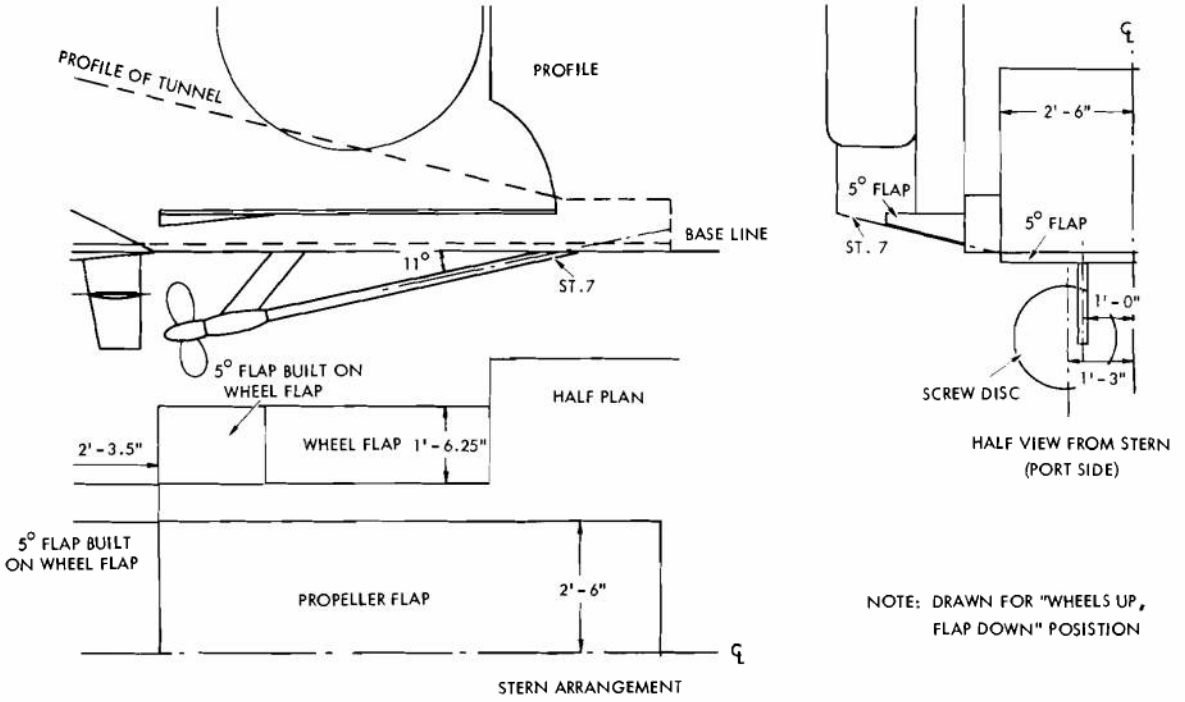


Figure 9-7. LVW-X1 Stern Arrangement

with power limited speeds of 30 knots in Sea State 2. This performance was estimated on the basis of data similar to those presented in Fig. 9-8 for a vehicle with open bow wheel wells and faired aft wheel wells. The increased drag due to waves was determined from the data presented in Fig. 9-11. The craft were assumed to be propelled with a gas turbine engine with a specific weight of 2 lb/hp and a fuel rate of 0.75 lb/hp-hr. The vehicle characteristics presented in Fig. 9-14 are believed to reflect the current (1968) state-of-the-art in planing hull amphibians.

9-3 HYDROFOIL AMPHIBIANS

Another vehicle type which may be suitable for use as a high-speed amphibian is the hydrofoil. On a hydrofoil amphibian at high speed, foils in the water supply sufficient lift to support the main hull above the water surface. This eliminates the large wave drag associated with displacement-type amphibians, making high speeds possible at reasonable power levels. As in the case of a planing hull amphibian, a hydrofoil amphibian may require higher power at an intermediate speed. This may occur at speeds between 12 and 25 mph before the hull lifts

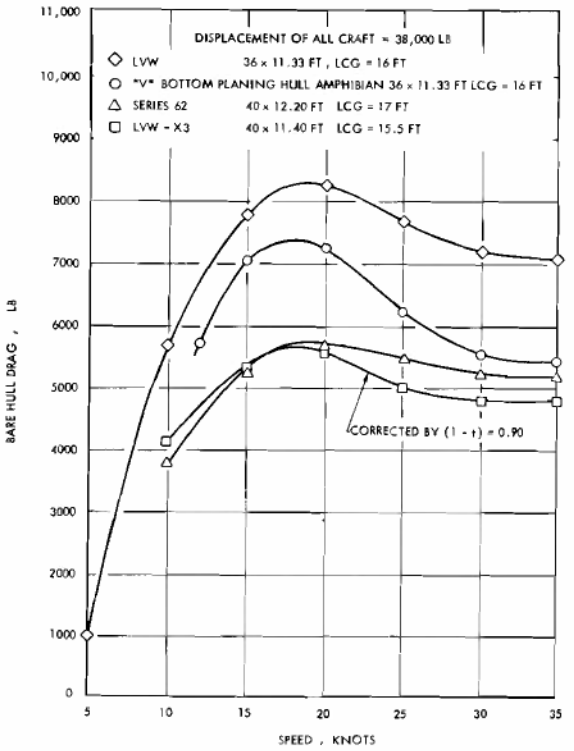
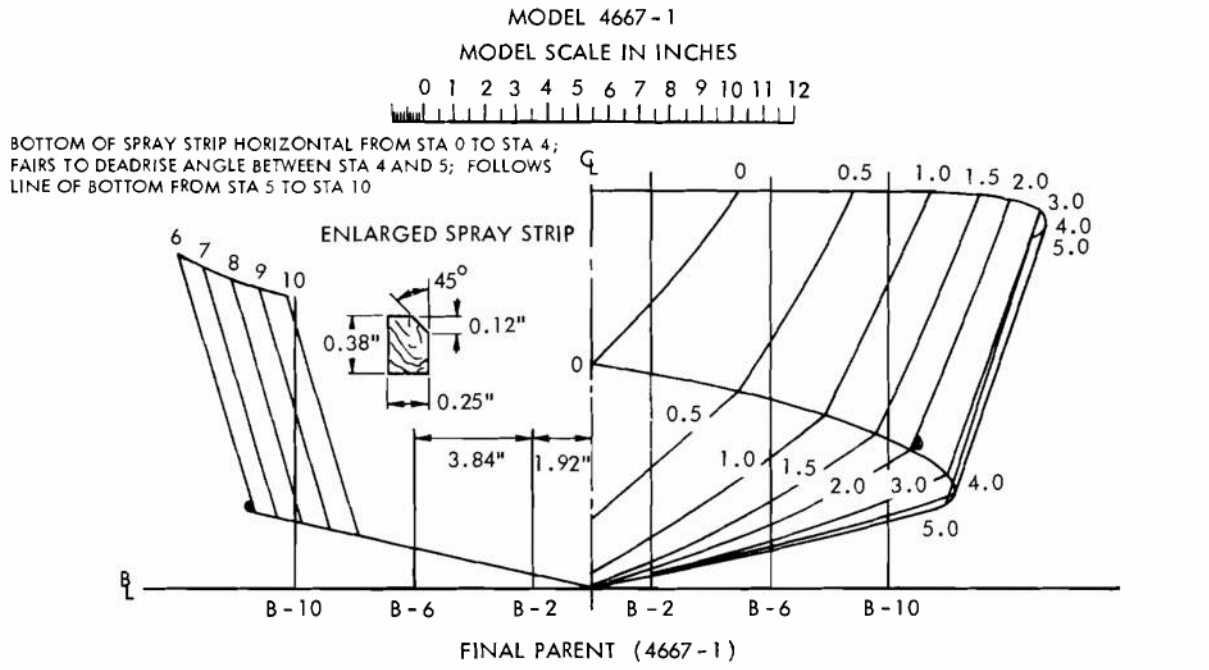
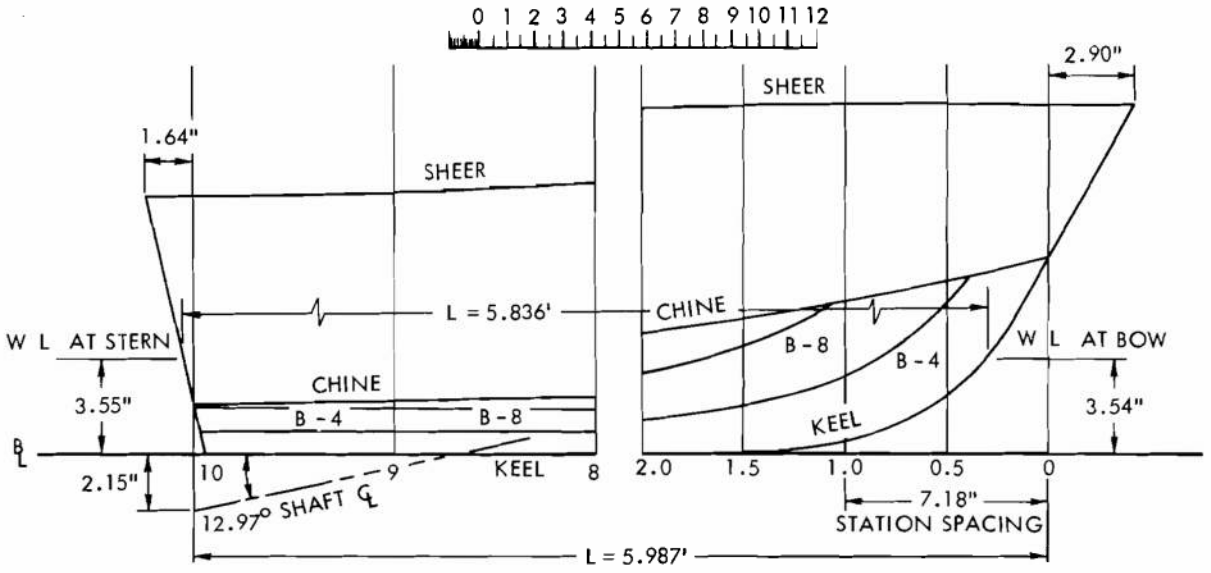


Figure 9-8. Comparison of Planing Hull Amphibian Drag



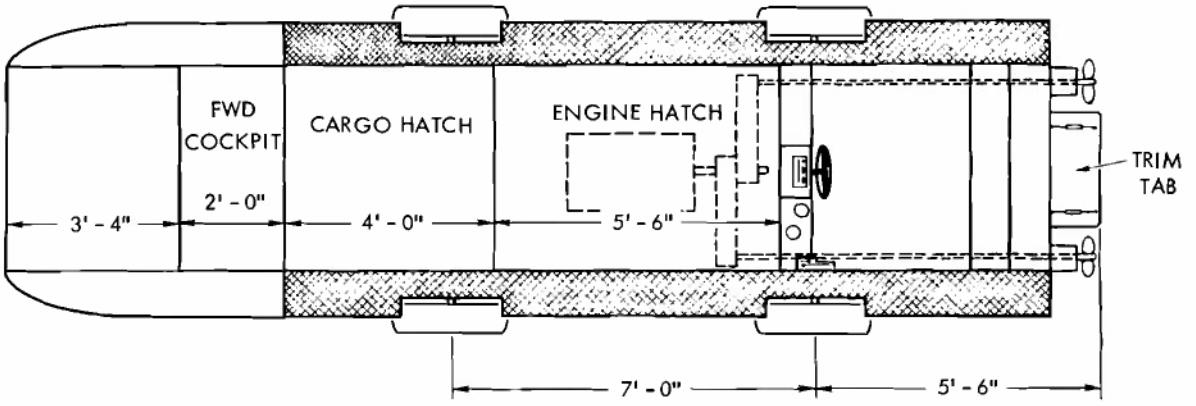
BODY PLAN OF SERIES 62 PARENT MODEL

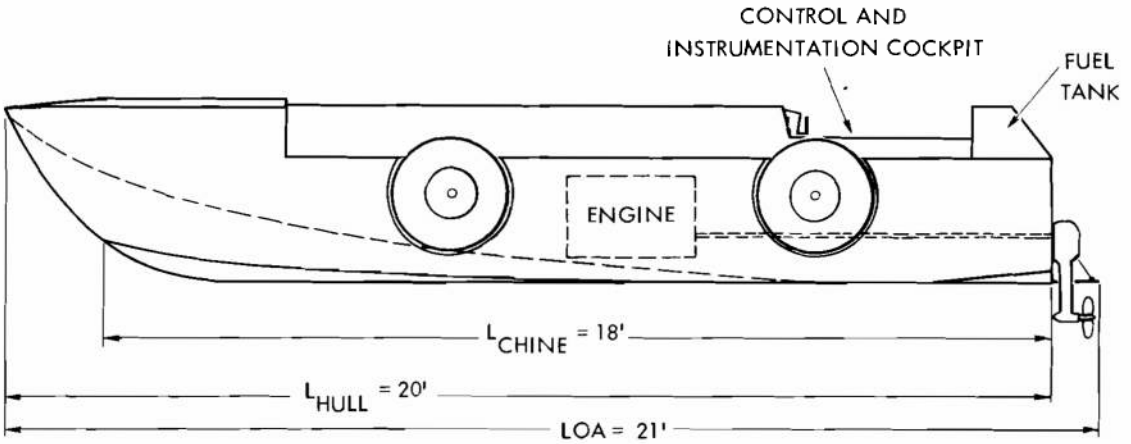


(L/B = 3.06)

BOW AND STERN ENDINGS OF SERIES 62 MODEL

Figure 9-9. Series 62 Lines





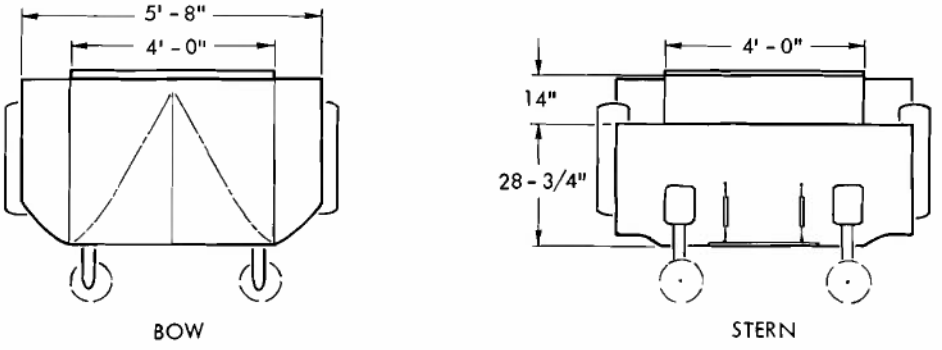


Figure 9-10. General Arrangement of LVW-X3 (Model)

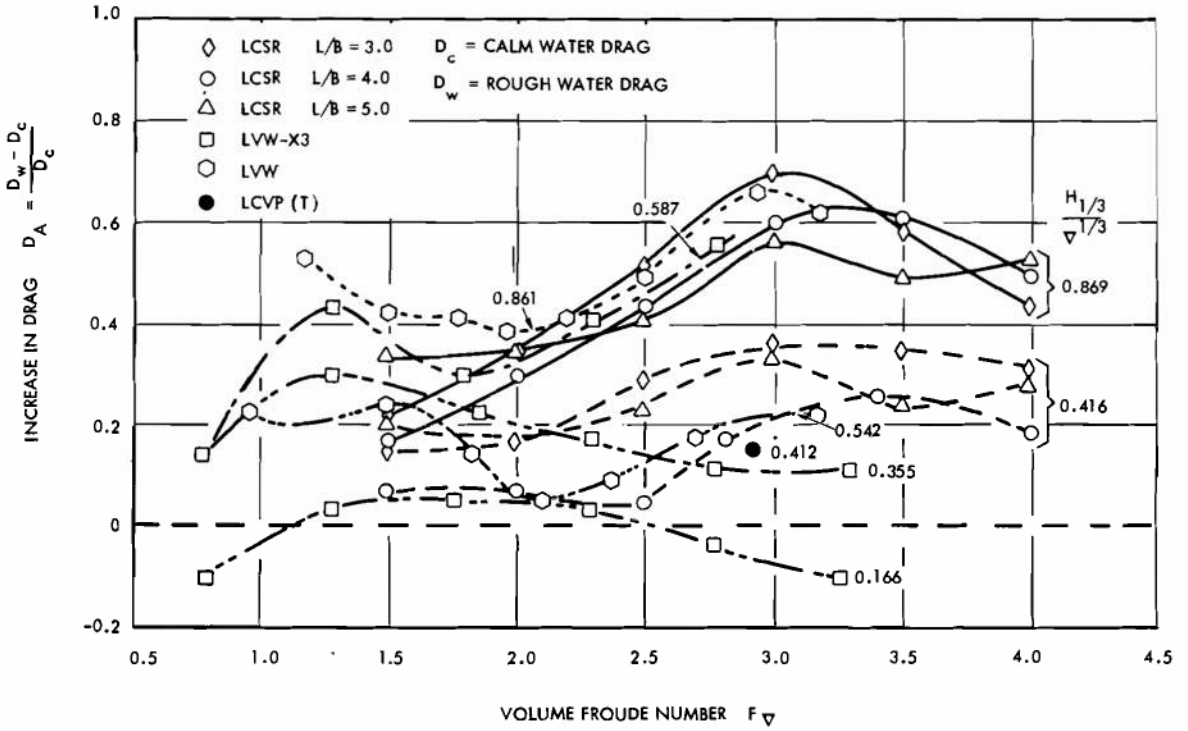


Figure 9-11. Planing Hull Added Drag in Waves

clear of the water. This problem is discussed in par. 9-3.1.4.1. Other problems with hydrofoil amphibians include the difficulty of foil retraction and structural reinforcement in way of the foils.

9-3.1 EXISTING HYDROFOIL AMPHIBIANS

The concept of a hydrofoil high speed amphibian was first proposed in the middle 1950's. Work on craft of this type was first sponsored by the U. S. Army Ordnance Corps and later by the Navy Bureau of Ships for the U. S. Marine Corps. As a result of these efforts three vehicle types were built. These include the "Flying DUKW", the LVH-X1, and the LVH-X2.

9-3.1.1 The Flying DUKW

In April of 1956 the Lycoming Division of the AVCO Corporation undertook a feasibility study for the U. S. Army Ordnance Corps to determine from theoretical and towing tank studies whether a WW II DUKW could be flown on hydrofoils. This study showed that it would be possible to do this and a contract was let to so equip a WW II DUKW. The conversion amounted to adding fully submerged hydrofoils, stern drive assembly, Lycoming T-53 gas turbine, and associated equipment. The actual conversion work was done by the Miami Shipbuilding Corporation. The basic conversion was completed in 1959 and the craft was reported to have operated at a gross weight of 29,600 lb and at a water speed in excess of 34 mph. Fig. 9-15 is a photograph of the Flying DUKW foilborne. The Flying DUKW experienced difficulty in becoming foilborne in waves because of increased drag.

The Flying DUKW was not intended to be a prototype for an operational vehicle. The addition of the foils, stern drive, and gas turbine engine more than used up the weight and volume available for cargo. Its purpose was to act as a test bed craft which would prove the feasibility of a hydrofoil amphibian and provide data for its design.

9-3.1.2 The LVH-X1

The U. S. Marine Corps Landing Force

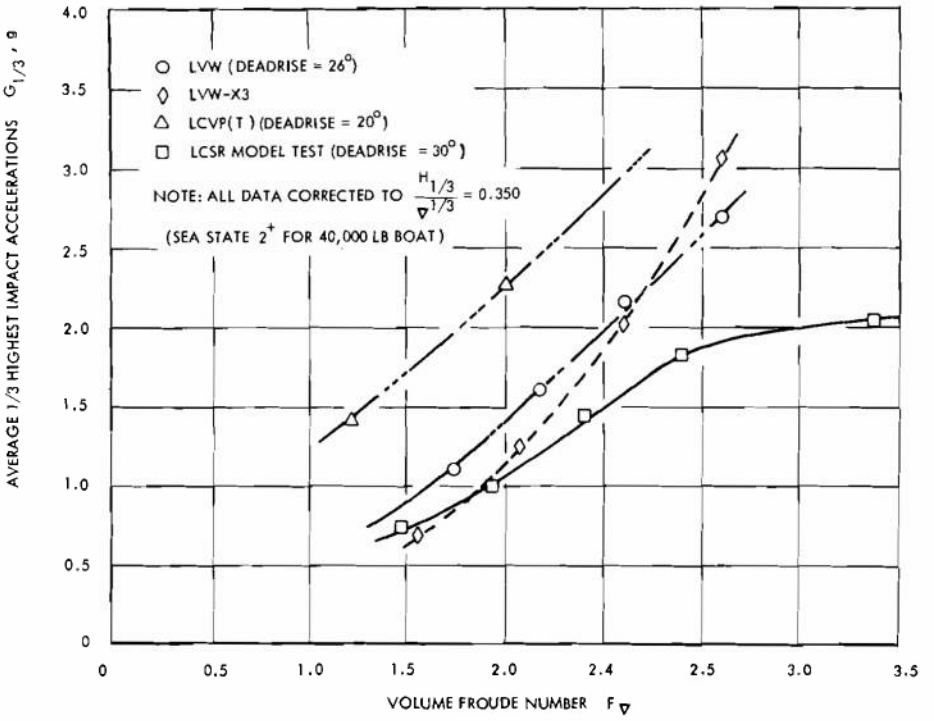


Figure 9-12. Planing Hull Accelerations at Bow (1 of 2)

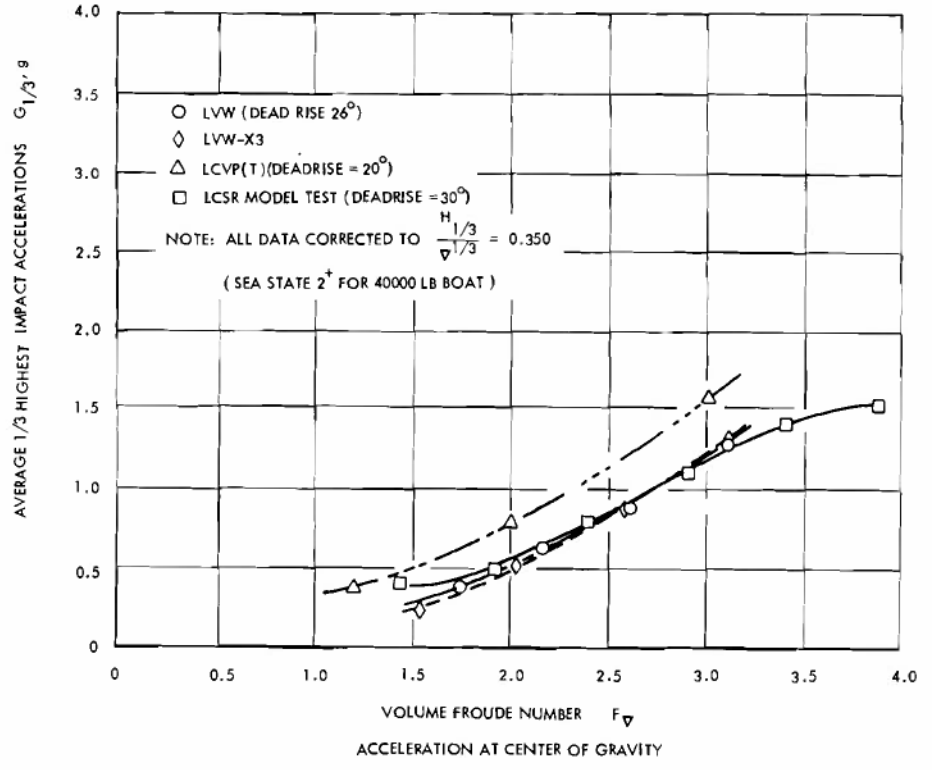


Figure 9-12. Planing Hull Accelerations at Bow (2 of 2)

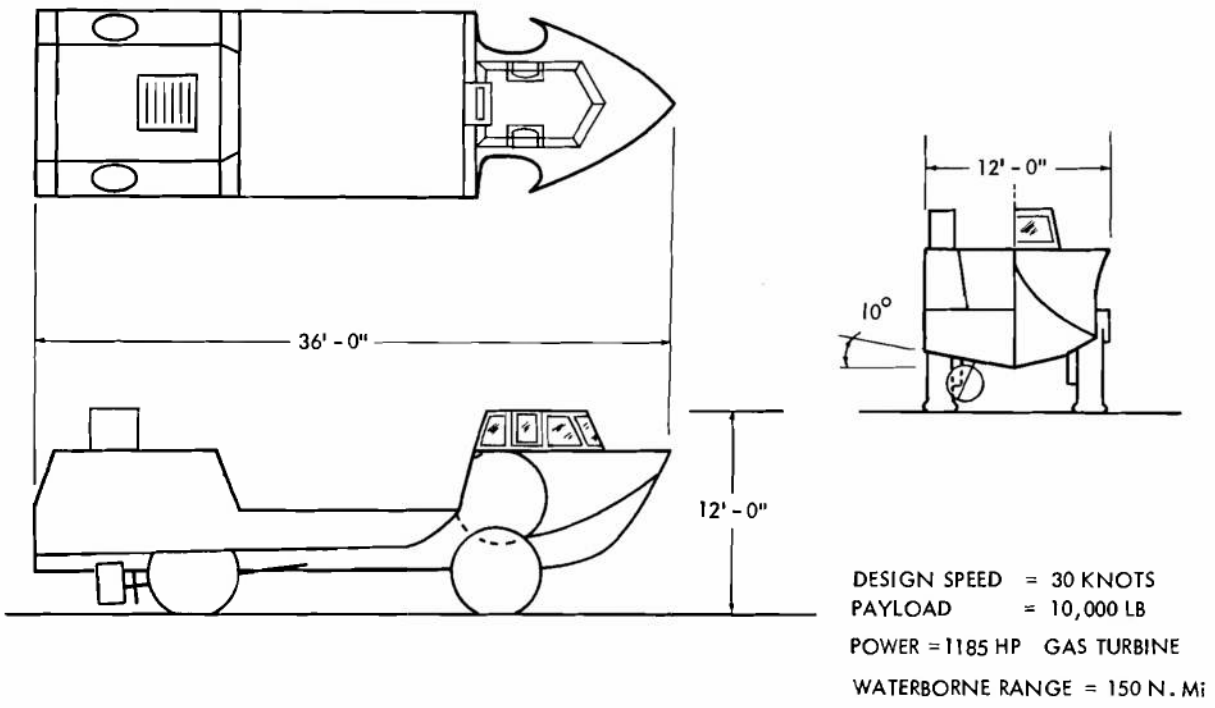


Figure 9-13. High-speed Amphibian—Planing Hull Type, Base Vehicle Configuration

Development Center was assigned responsibility for coordination of the testing and evaluation of a hydrofoil amphibian (LVH). Contracts were awarded by the Navy Bureau of Ships for the design and construction of two different hydrofoil amphibians. The first contract was awarded to the Lycoming Division of AVCO Corp. and was designated LVH-X1. Two identical vehicles were constructed. The vehicle concept that became the LVH-X1 was first proposed by Lycoming in 1959. Actual design of the LVH-X1 started in 1961 and the two vehicles were accepted in late 1964 and early 1965, respectively.

The foil system used in the LVH-X1 was based on fully submerged incidence-controlled foils. This type of foil system has no inherent stability and depends on an auto-pilot to control flying height and attitude. The advantage of this type of foil system is that very low motions in waves are possible. In the foil mode, additional control forces are generated by flaps on the forward foils controlled by the auto-pilot. A sonic height sensor was used to provide the auto-pilot with information on foil immersion.

9-3.1.2.1 Characteristics

The LVH-X1 was powered with a TF-1460-B1A gas turbine. This engine was a marine conversion of an aircraft gas turbine with a continuous rating of 1,000 *BHP* and an intermittent rating of 1,225 *BHP* on an 80°F day. The hydrofoils were supported on two hydraulically actuated rotating struts. Thrust for operation in the foil mode was supplied by a conventional propeller mounted on the forward end of a pod on the aft strut assembly. For operation in the displacement mode, the LVH-X1 was propelled by a single retractable directionally controllable propeller in a Kort nozzle.

For land operation, the vehicle was equipped for 2- and 4-wheel drive and hydraulically controlled steering of the forward wheels. The power train had an overall ratio (engine to wheel) in low gear of 194.6:1 and in high gear of 68.9:1. The transmission was a 2-speed mechanical dry-sump type. Service brakes were disc-type, hydraulic-actuated. Parking brakes were the internal-expanding-type, mounted to

the forward differential shaft. All wheels retracted hydraulically into the hull for the boating and flying modes, and to facilitate ease of loading/unloading in the land mode.

The LVH-X1 was designed to carry a payload of 10,000 lb on land and water. The design water speed was 30 mph and the design land speed was 40 mph.

Figs. 9-16 and 9-17 present photographs of the LVH-X1 operating on land and water, respectively. The characteristics of the LVH-X1 are presented in Table 9-10 and the external arrangement in Fig. 9-18.

9-3.1.2.2 Performance of LVH-X1

No engineering data are available on the high-speed waterborne performance of the LVH-X1. Because of reliability problems, the two LVH-X1 vehicles never underwent engineering tests to determine their foilborne performance. All testing of the LVH-X1 vehicle stopped when one sank after the failure of a drive shaft in foilborne operation.

Some engineering tests were conducted on the LVH-X1 in the displacement mode and are reported in Refs. 14 and 15. The most important finding of these tests was that the trainable propeller used for hullborne steering provided excellent control. The tactical diameters were reported to be 121 ft to starboard and 63 ft to port in the surf mode. Because of the high rate at which water leaked into the vehicle, it was not possible to conduct an inclining experiment and determine the static stability.

Land performance tests for the LVH-X1 are reported in Ref. 16. It was concluded that the performance of the vehicle under desert conditions was satisfactory but deficiencies were encountered with respect to vehicle durability and/or reliability. The maximum speed of the vehicle was 45 mph and it was successfully driven up a 60 percent slope in both forward and reverse gear. The vehicle was not safe on a 30 percent side slope. The minimum turning radii were 48 ft to the right and 53 ft to the left.

9-3.1.3 The LVH-X2

A second contract for the design and construction of a hydrofoil amphibian was awarded by the Navy Bureau of Ships to the FMC (Food Machinery Corp.) Corporation. Two identical vehicles were built and were designated LVH-X2. The design of the LVH-X2 began in 1961, and the two vehicles were accepted in late 1963 and early 1964.

The foil system used on the LVH-X2 is based on a surface-piercing foil forward and a fully submerged foil aft. This foil system has inherent stability in heave, pitch, and roll so that foilborne operation without an auto-pilot is possible in calm water. For foilborne operation in high sea states (Sea State 3), an auto-pilot is required. The auto-pilot on the LVH-X2 uses a sonic height sensor and exerts control forces with flaps on the fore and aft foils.

The foil system retracts by allowing the struts to pass vertically into the hull and the foils to pivot or seat in faired recesses in the hull. Retraction is accomplished by hydraulic motor driven ball screw actuators.

9-3.1.3.1 Characteristics

The LVH-X2 is powered with a Solar Saturn gas turbine engine with a continuous rating of 1,050 *BHP*. Power produced by the turbine is delivered through a primary reduction gear to the transfer case which distributes power to the land drive train, the marine drive train, or both, depending on the mode of operation. Land power is transmitted to the wheels through a 6-speed TX 365-2 transmission and differentials.

In the land mode, hydraulically powered 2-wheel, 4-wheel, or oblique steering can be accomplished. Each wheel is retractable using an air hydraulic cylinder which also provides spring and damping action. In all waterborne modes, thrust is provided by a single propeller mounted on the forward end of a pod on the aft foil strut. In the foilborne mode, steering is provided by a rudder mounted on the aft strut. In the displacement condition, this rudder along with the wheels provide the steering forces.

The LVH-X2 was designed to carry a payload of 10,000 lb on both land and water. The foilborne design speed was 35 knots, the boating mode design speed was 12 knots, and the land design speed was 40 mph.

Figs. 9-19 and 9-20 present photographs of the LVH-X2 operating on land and water, respectively. The characteristics of the LVH-X2 are presented in Table 9-11, and the external dimensions and foil retraction arrangement in Figs. 9-21 and 9-22, respectively.

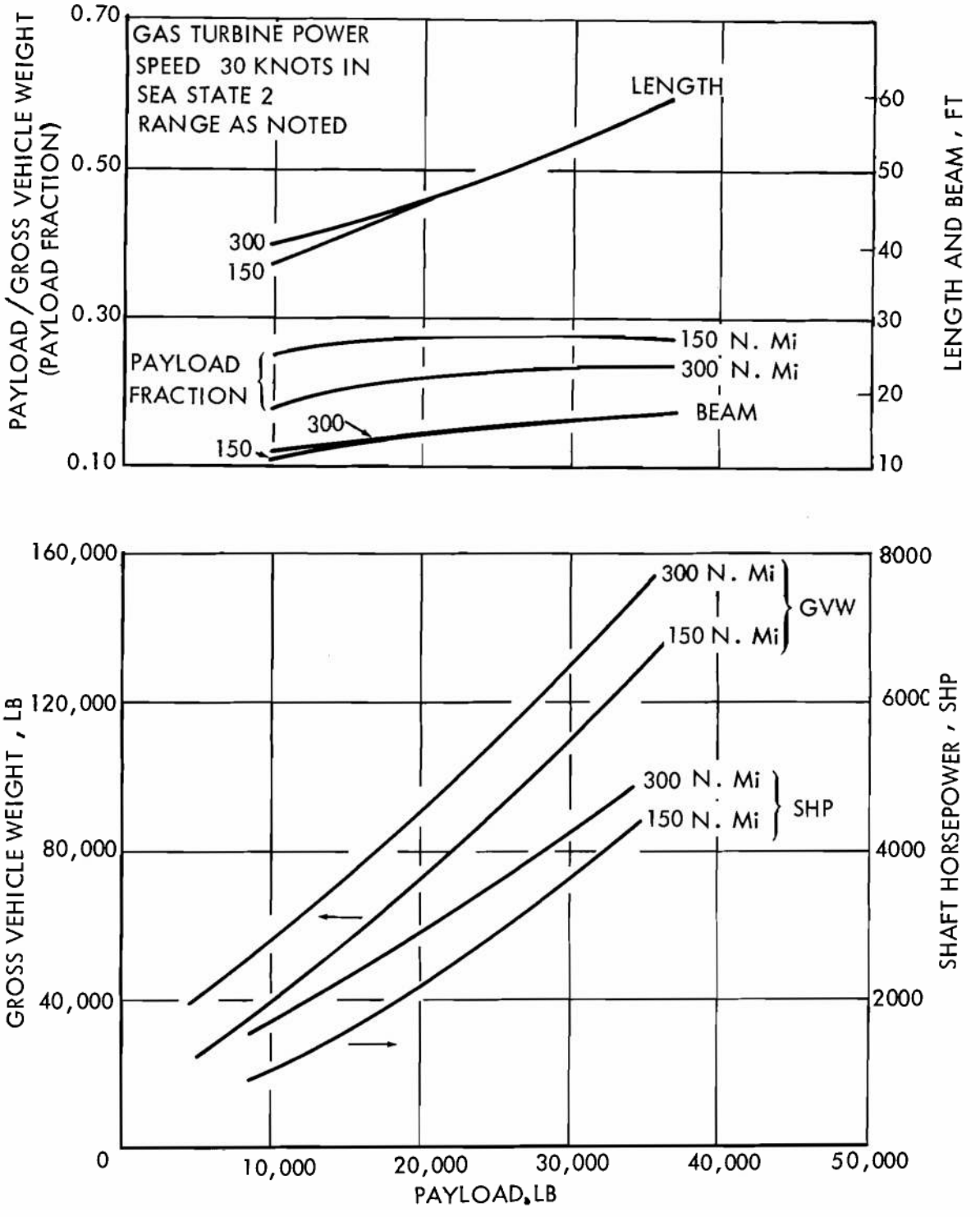


Figure 9-14. High-speed Amphibian—Planing Hull Type, Effect of Payload

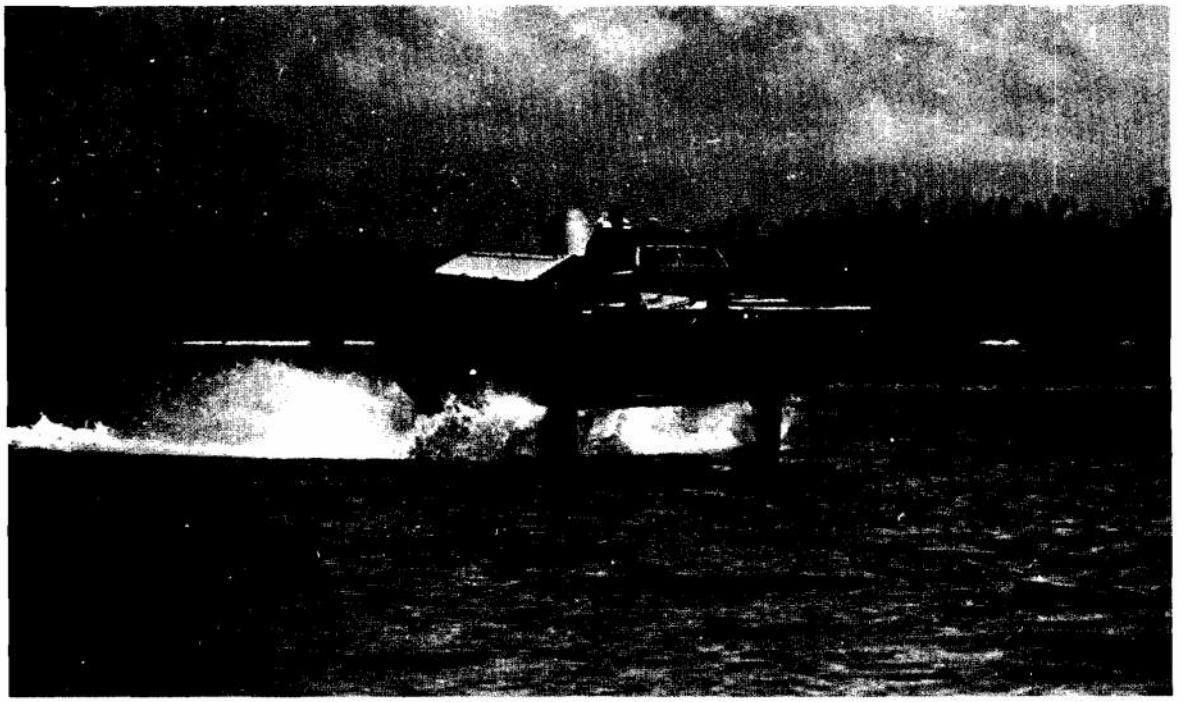


Figure 9-15. Flying DUKW, Foilborne

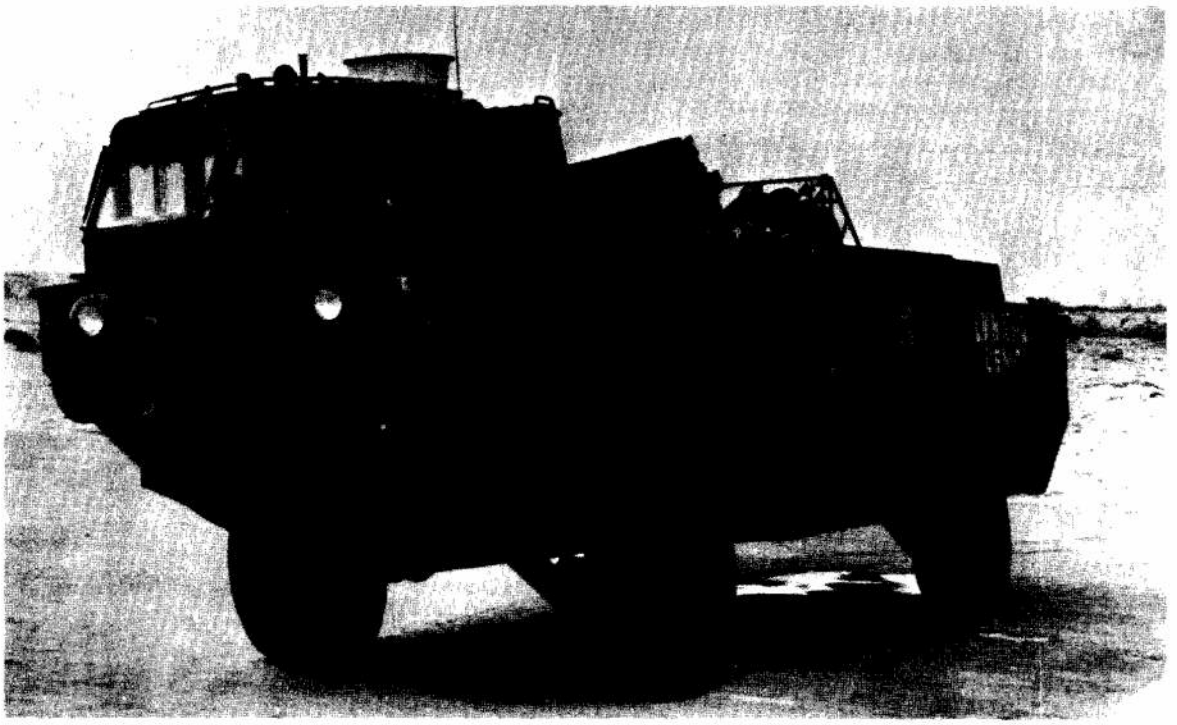


Figure 9-16. LVH-X1 on Land

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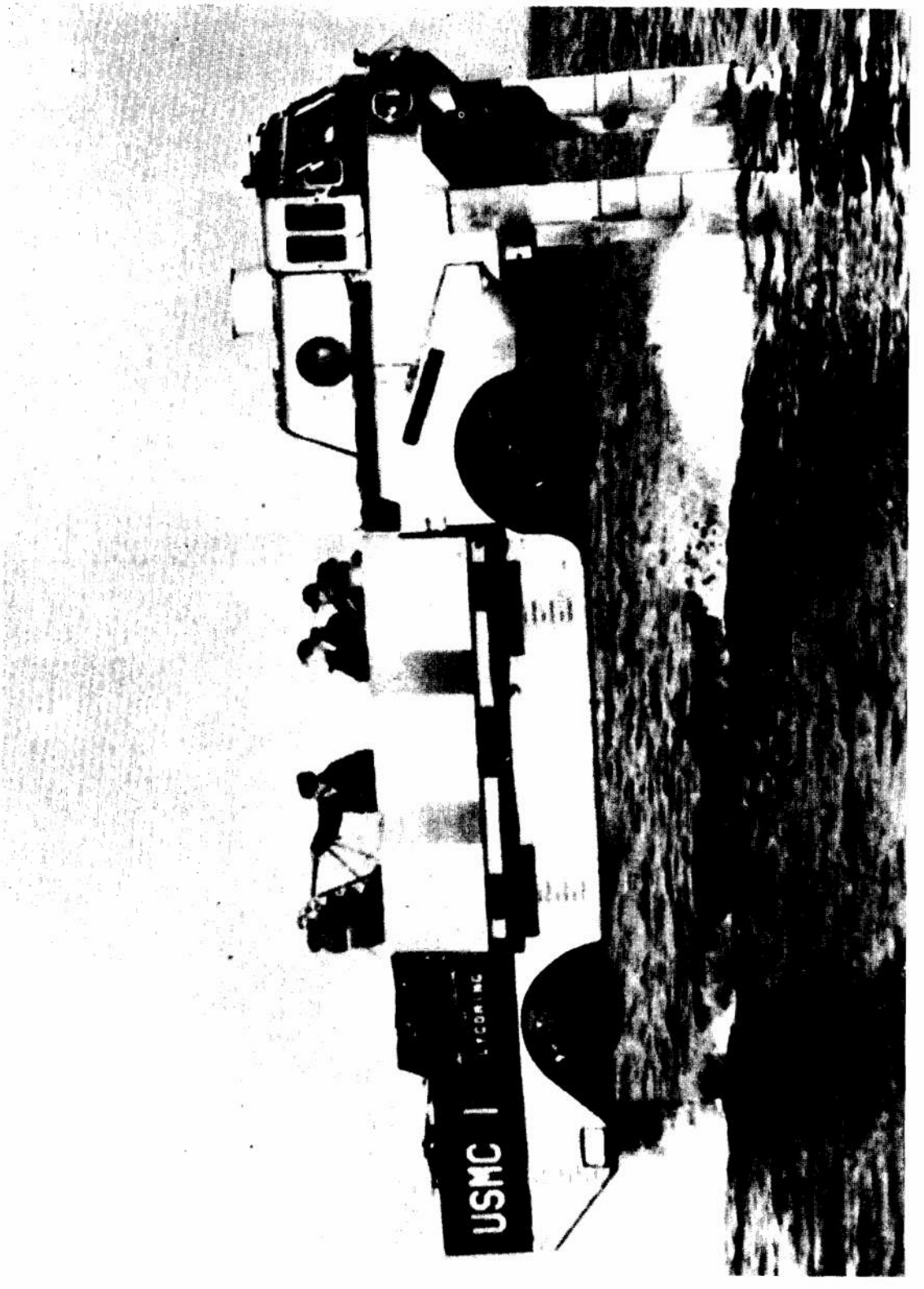

Figure 9-17. LVH-X1 Operating Foilborne

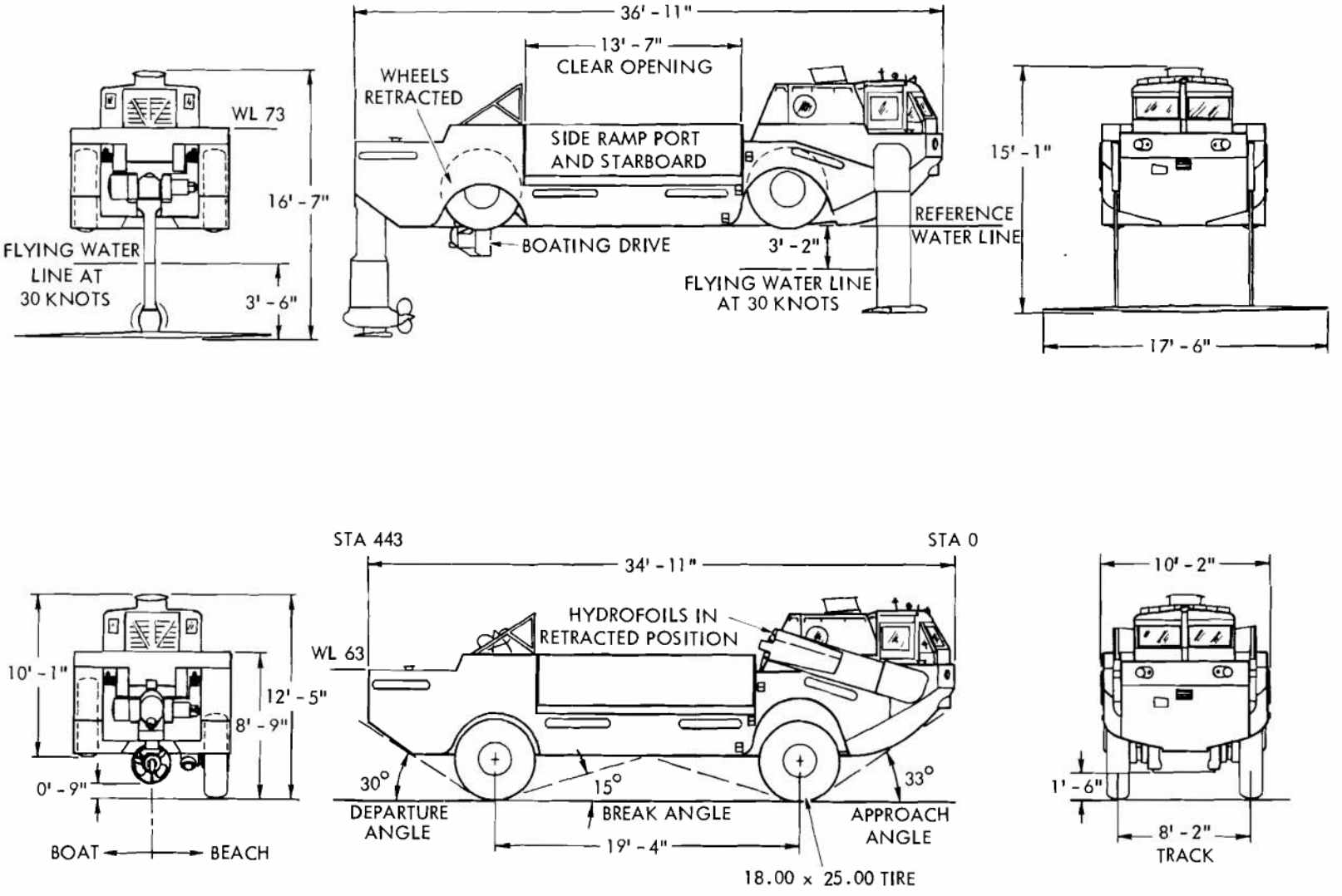

Figure 9-18. External Dimensions of LVH-X1

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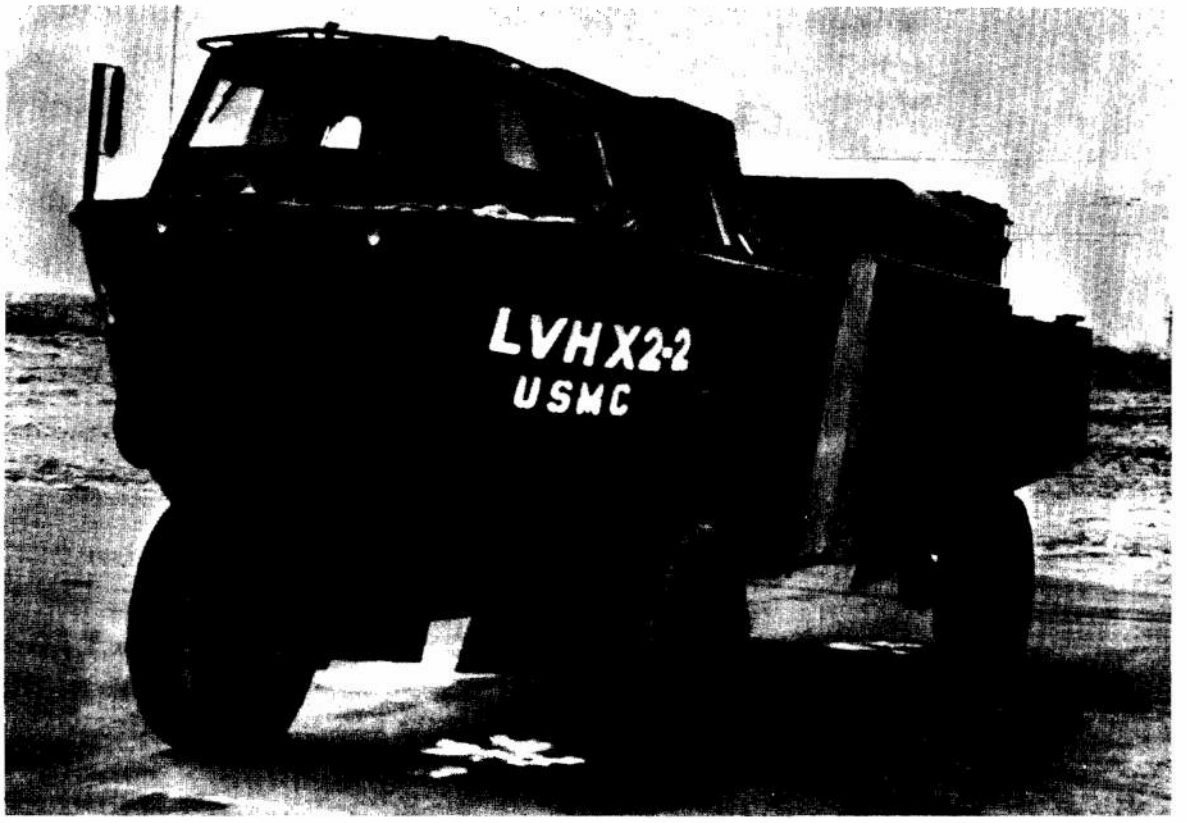

Figure 9-19. LVH-X2 on Land

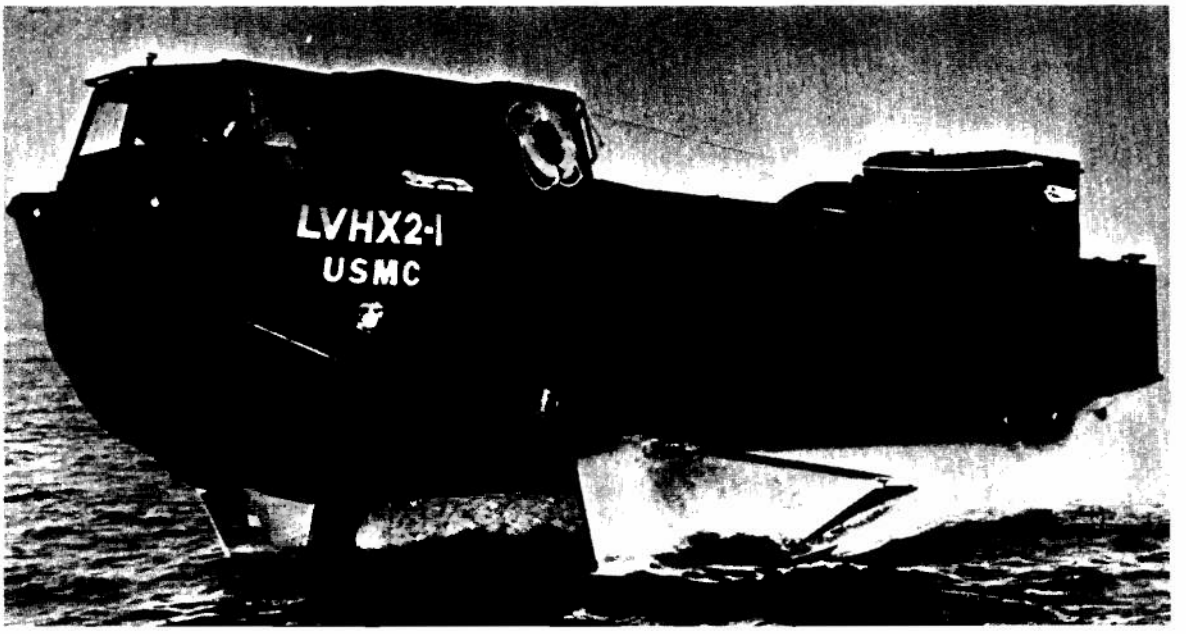

Figure 9-20. LVH-X2 Operating Foilborne

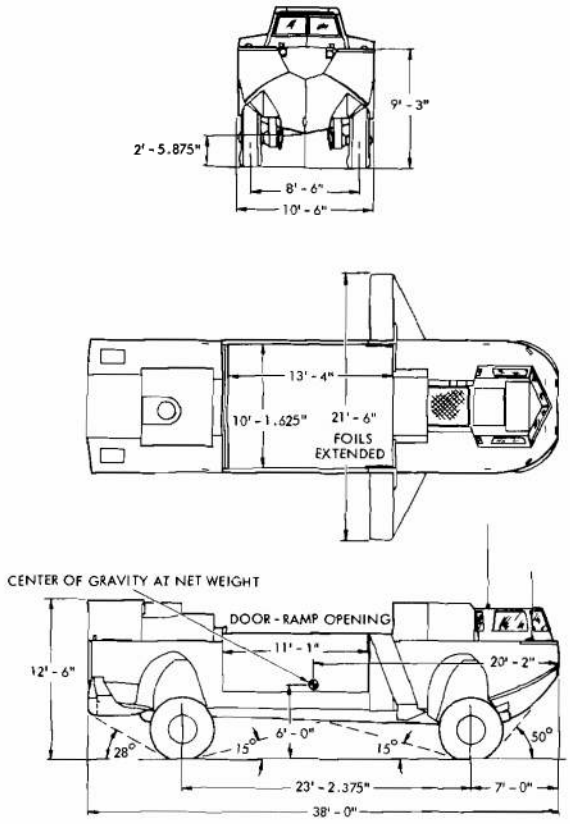

Figure 9-21. External Dimensions of LVH-X2

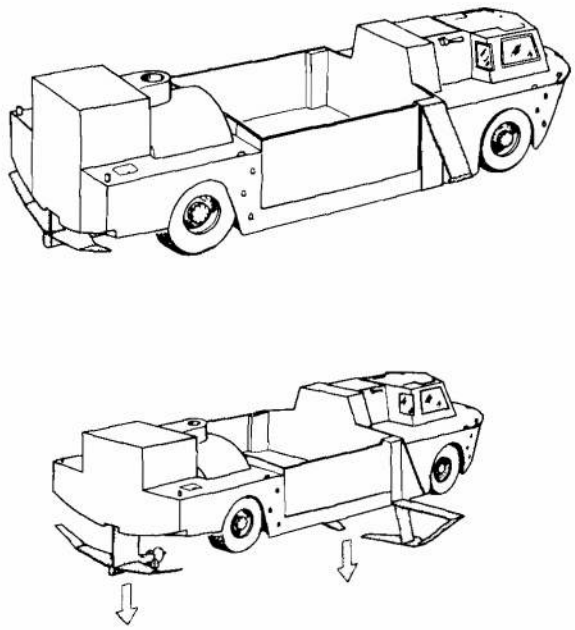

Figure 9-22. Hydrofoil System for LVH-X2

9-3.1.3.2 Waterborne Speed and Power of LVH-X2

As with the case of the LVW planing hull amphibian, the U. S. Marine Corps sponsored a series of engineering tests to determine the waterborne performance characteristics of the LVH-X2. The results of the speed resistance and powering tests are reported in Ref. 17. These tests were conducted over a range of gross weights in calm water and waves. Fig. 9-23 presents a summary of the calm water drag data obtained from Ref. 17. The data labeled deduced drag were obtained from measured thrust during acceleration runs by subtracting the force due to the measured acceleration. These are only approximate since they do not account for any unsteady effects. However, the deduced drag does show a large drag hump at speeds between 10 and 20 knots. This will cause a high power requirement and means that the power available in a hydrofoil amphibian must be checked at take-off as well as the design point.

Fig. 9-24 presents some data on the percentage drag increase in waves. The volume Froude number and nondimensional wave height are the same as defined in par. 9-2.1.2. Also presented in Fig. 9-24 are some data on the added drag in waves of the H. S. DENISON, a large hydrofoil boat with a foil system of similar geometry to that of the LVH-X2.

Based on these data, the top speeds (power limited) of the LVH-X2 in calm water and waves was estimated in Ref. 4. These speeds are given in Table 9-12.

9-3.1.3.3 Accelerations of LVH-X2 in Waves

The LVH-X2 was instrumented and the accelerations in head seas were measured at the bow (crew cab) and at the center of gravity. These data are presented in Ref. 4. Fig. 9-25 presents the average of 1/3 highest upward acceleration in g's for the LVW-X2 as a function of volume Froude number.

If the same 0.9 g allowable acceleration level is assumed as for a planing hull amphibian (see par. 9-2.1.2), a motion limited speed for a hydrofoil amphibian can be defined. This level and the resulting speed and wave heights are included in Fig. 9-25. Some data have also been included for the H.S. DENISON.

The motions of the LVH-X2 are quite different from those of the LVW. The

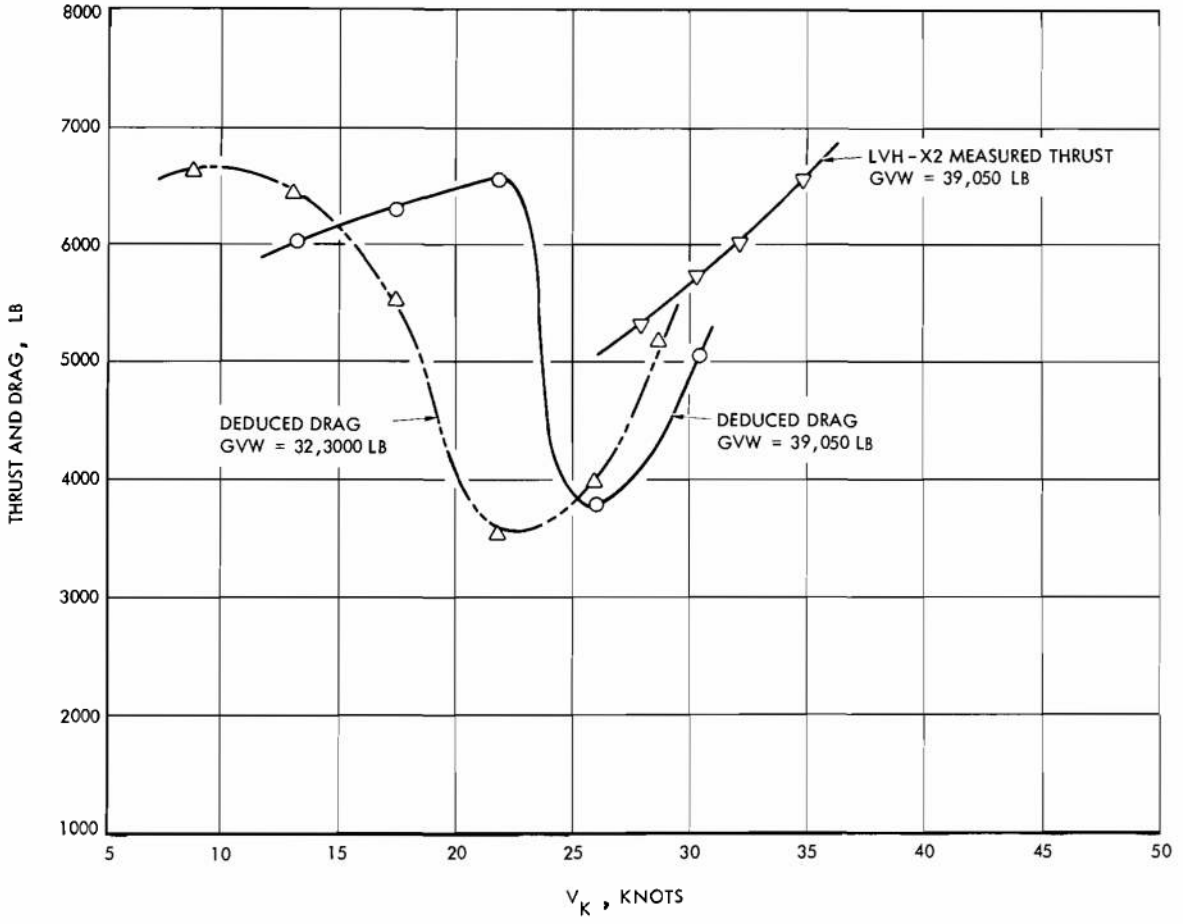

Figure 9-23. Hydrofoil Drag

accelerations are lower and in general there is little difference between the values at the bow and center of gravity. It should be realized that the acceleration of a hydrofoil amphibian will be strongly influenced by the characteristics of the auto-pilot used for control in waves. Also, a hydrofoil amphibian will have difficulty flying in following seas although the acceleration will be low. In actual practice the performance of the LVH-X2 in high waves (Sea State 3) was limited by the ingestion of salt water into the gas turbine. The resulting loss of power made it impossible to operate for long periods. In the design of a new hydrofoil amphibian it should be possible to eliminate this problem (see par. 7-5.2.2).

9-3.1.3.4 Control Characteristics of LVH-X2

The control characteristics of the LVH-X2 were measured at high and low speeds, and the results reported in Ref. 18. The observed turning diameter at high and low speeds are presented in Tables 9-13 and 9-14, respectively.

The natural tendency of a hydrofoil amphibian is to heel outboard in a turn. In the LVH-X2 this tendency is counteracted by the roll control ability of the auto-pilot system. If too tight a flying turn is attempted, the flaps reach full deflection and the increase in drag is sufficient to slow the craft below flying speed. It may be expected that the high-speed control characteristics of a hydrofoil amphibian will be greatly affected by the auto-pilot and control surface characteristics.

9-3.2 FUTURE HYDROFOIL AMPHIBIANS

Projections of the characteristics and performance of future hydrofoil amphibians

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TABLE 9-10 LVH-X1 VEHICLE CHARACTERISTICS

Manufacturer	Lycoming Div. of AVCO Corporation
Width, ft-in.	10-10
Length, ft-in.	36-11
Height, ft-in.	11-3
Min Ground Clearance, in.	18
Draft (foilborne), ft	2 fwd; 3½ aft
Wheelbase, ft-in.	19-4
Track Width, ft-in.	8-2
Angle of Approach, deg	33
Angle of Departure, deg	30
Break Angle, deg	15
Land Speed, mph	40
Water Speed (Design), knots (see par. 9-3.1.3 for actual)	Hullborne - 12; flying - 30; takeoff - 12.5
Land Range (Design), mi	295 at 25 mph
Water Range (Design), N.mi	Boating - 53 at 11.5 knots; flying - 195 at 35 knots
Turn Radius (Land), ft	44, 2-wheel steer
Turn Radius (Water) (Design), ft	50 boating; 370 flying
Cargo Capacity, lb	10,000
Cargo Space (L×W), ft-in.	13-7 × 10-2
Total Weight (Gross), lb	43,055
Grade Ability (Design), %	60
Side Slope (Design), %	30
Surf Ability, ft	10
Engine Data	Lycoming TF-1460 B1A Gas turb.; compr. ratio = 6.5; *BHP* at 80°F = 1000 (cont'd), 1,225 (intermittent)
Fuel Type	JP-5 or Marine Diesel
Fuel Capacity, gal	500
Marine Propulsor	Flying: (1) propeller on rear strut, D = 29 in., P = 25 in. Hullborne: steerable, retractable propeller in Kort nozzle; D = 22 in., P = 17 in.
Suspension	Oleo strut, retractable on land, with tire inflation system, 4 × 4 or 2 × 4
Brake System	Hydraulic discs
Tires	18 × 25 in., 12-ply (nylon)
Land Steering	Hydraulic selective, 2-wheel steering
Marine Steering	Foil flaps and directed propeller thrust
Electrical System	24-V DC
Hydraulic System	3,000 psi, 20 gpm; 500 psi, 10 gpm
Crew	2
Hull Material	Aluminum
Foil Type	Submerged
Foil Retraction	Hydraulic-actuated, rotary struts

TABLE 9-11. LVH-X2 VEHICLE CHARACTERISTICS

Manufacturer	FMC (San Jose)
Width, ft-in.	10-6
Length, ft - in.	38-0
Height, ft-in.	11-3
Min Ground Clearance, in.	20-3/8
Wheelbase, ft-in.	28-2-3/8
Track Width, ft-in.	8-6
Angle of Approach, deg	50
Angle of Departure, deg	28
Break Angle, deg	15
Land Speed, mph	41
Water Speed (Design), knots (See par. 9-3.1.4.1)	Hullborne - 11; flying - 35
Land Range (Design), mi	250 at 25 mph
Water Range (Design), N.mi	(Flying) 210 at 35 knots
Turn Radius (Land)(Design), ft	35, 4-wheel steer
Turn Radius (Water)	Hullborne (see par. 9-3.1.4.3)
Cargo Capacity, lb	10,000
Cargo Space (LXW), ft-in.	13-4 X 10-1-5/8
Total Weight (Gross), lb	39,000
Grade Ability (Design), %	60
Side Slope (Design), %	30
Surf Ability, ft	10
Engine Data	Solar TS-1000 gas turb.; 1,040 *BHP* (cont'd) at 22,300 rpm and 80°F
Fuel Type	JP-5
Fuel Capacity, gal	430
Marine Propulsor	(1) Propeller; D = 26 in., P = 31.2 in., MWR = 0.62; 3-bladed
Suspension	Retractable airspring; hydraulic shock absorbers; 2- or 4-wheel drive
Brake System	Hydraulic-actuated spot and disc type
Tires	18 X 25 in.; 2-ply
Land Steering	Hydraulic selective, 2-, 4-wheel, or oblique
Marine Steering	Rudder on aft strut plus fwd and aft foil flaps, rudder and wheels in surf mode
Electrical System	24-V DC, single-wire system
Hydraulic System	(1) 3,000 psi at 2,400 rpm; (2) 15,000 psi at 2,000 rpm
Crew	2
Hull Material	Aluminum
Foil Type	Surface-piercing
Foil Retraction	Hydraulic motor-driven ball screws (vertical retraction)

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TABLE 9-12. LVH-X2 POWER LIMITED SPEEDS

Sea State	0	1	2	3
Speed, mph	42	38	36	33

have been made and are presented in Refs. 4 and 7. The characteristics and performance of a hydrofoil amphibian will depend largely on the requirements, restrictions, and type of foil system used. As a result, it is not possible to present as generalized information on performance in calm and rough water as for a planing hull. Fig. 9-26 illustrates this problem. In Fig. 9-26 the sustained speeds of a number of hydrofoil boats are presented as a function of nondimensional wave height. In calm water, the top speed is a function of installed power, foil configuration, take-off speed, and cavitation limits—and thus varies widely for the craft shown. At nondimensional wave heights ($H_{1/3}/\nabla^{1/3}$) above 0.3, the speeds of all craft shown are affected by motions. The PT 20 and PT 50 are craft with surface-piercing foils and no auto-pilots, and thus are most affected by waves. The LVH-X2 and the DENISON have surface-piercing foils and auto-pilots, and thus are less affected. The DOLPHIN with submerged foils and an auto-pilot has the highest sustained speeds in high sea states. Thus the foil system for a hydrofoil amphibian should be chosen only after careful consideration of all the mission requirements. If it is necessary to make a performance estimate for a given foil configuration, use should be made of references such as Ref. 19.

Ref. 7 presents a parametric study of the characteristics of hydrofoil high speed amphibians. The craft considered were based on the use of surface-piercing foil systems of two configurations. The basic vehicle and foil configurations are presented in Figs. 9-27

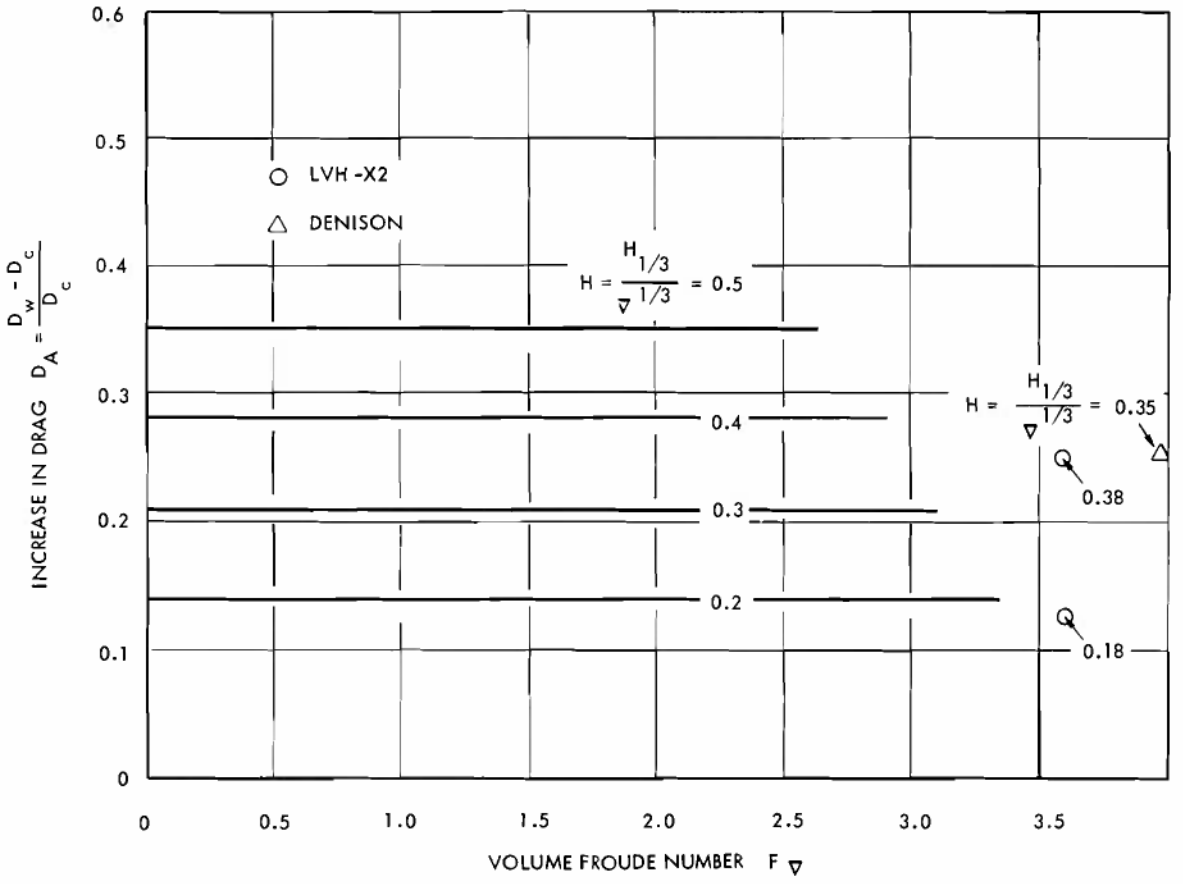

Figure 9-24. Hydrofoil Added Drag in Waves

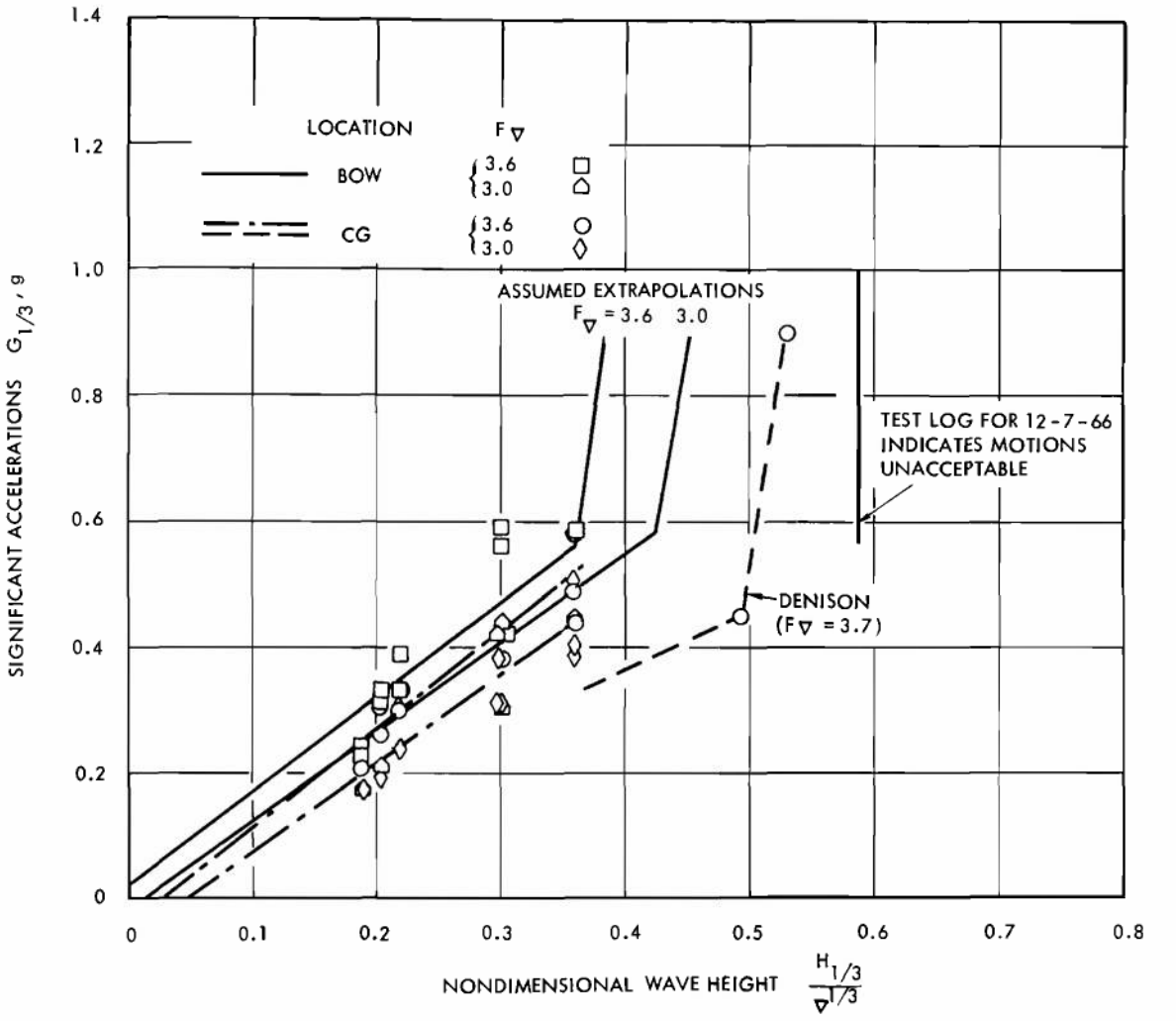

Figure 9-25. LVH-X2 Vertical Accelerations in Head Seas

through 9-30. Configuration 1 is intended to provide minimum drag at some sacrifice in motion in waves and maneuverability. Configuration 2 is intended to provide minimum motions in waves and maximum maneuverability at some sacrifice in drag. It is probable that a future hydrofoil amphibian design would be between the two extremes represented by Configurations 1 and 2. Thus the performance and characteristics of these two configurations define the range to be expected of future hydrofoil amphibians.

A parametric study was conducted to determine the effects of design payload and range on the characteristics of the two configurations. The results are presented in Fig. 9-31. The power estimates were based on a power limited speed of 40 knots in a Sea State 2. The craft were assumed to be propelled with a gas turbine engine with a specific weight of 2 lb/hp and a fuel rate of 0.75 lb/hp-hr. As indicated above, the characteristics presented in Fig. 9-31 for the two configurations span the range that may be expected with current (Summer 1968), state-of-the-art, subcavitating, surface-piercing foils.

9-4 SURFACE EFFECT AMPHIBIANS

In addition to the vehicle types already considered, it is possible that the surface effect concept may be suitable for use in a high water speed wheeled amphibian. In a surface effect craft the lift is provided by a region of

TABLE 9-13 LVH-X2 HIGH-SPEED TURNING DIAMETER

Direction	*Diameter, ft*	*Time, sec*	*Average Speed, mph*	*Turn Diameter / Vehicle Length*
Starboard	920	55	35	24.2
Port	580	40	31	15.3
Starboard	700	42	35	18.4
Port	590	39	32	15.5

TABLE 9-14 LVH-X2 SURF MODE TURNING DIAMETERS[1]

	Speed, mph	*Diameter, ft*	*Trim,*[4] *deg*	*Heel, deg*	*Turn Diameter / Vehicle Length*
Port	3.4[2]	126	2.0	3 stbd	3.31
Starboard	3.4	96	2.0	2 port	2.52
Port	7.0	134	3.0	7 stbd	3.52
Starboard	7.0	106	3.0	7 port	2.79
Port	9.3	153	4.0	8 stbd	4.03
Starboard	9.3	107	4.0	8 port	2.82
Port	10.8[3]	158	6.5	9 stbd	4.16
Starboard	10.8	111	6.5	9 port	2.92

Notes: (1) Four-wheel steer; *GVW* = 39,500 lb, two (2) personnel on board, *KG* = 10.3 ft load *VCG* approximately 20 in. above deck
(2) Minimum practical operating speed recommended by vehicle manufacturer
(3) Maximum speed obtainable in the surfing mode
(4) Trim by stern (static trim = 1.0 deg)

pressurized air contained under the craft. As a result, at high speeds the wavemaking drag and frictional drag are greatly reduced from that of a conventional form. However, as with the planing hull and hydrofoil, wavemaking drag may be large enough at intermediate speeds to cause a hump in the drag curve. The extent of this hump drag region will depend on the vehicle configuration and the air cushion pressure.

There are two basic types of surface effect craft that have been studied and developed. One of these is the rigid sidewall-type and the other the flexible skirt-type. In the sidewall-type, the air cushion is contained between two rigid sidewalls that are in contact with the water surface. The fore and aft ends of the air cushion may be sealed with flexible or rigid seals. Since the sidewalls remain in contact with the surface, this type of craft is not amphibious unless equipped with wheels. In the flexible skirt-type, the air cushion is contained by an inflated skirt around the periphery of the craft. These skirts are currently made from a neoprene-coated nylon or Dacron fabric. In general, the flexible skirts do not contact the surface but have a small clearance. As a result, these craft are amphibious if propelled by air screws or by wheels.

9-4.1 RIGID SIDEWALL SURFACE EFFECT AMPHIBIANS

Two concepts have been proposed for rigid sidewall surface effect craft that could be applied to wheeled amphibians. The first is the hydrokeel concept in which the air cushion is

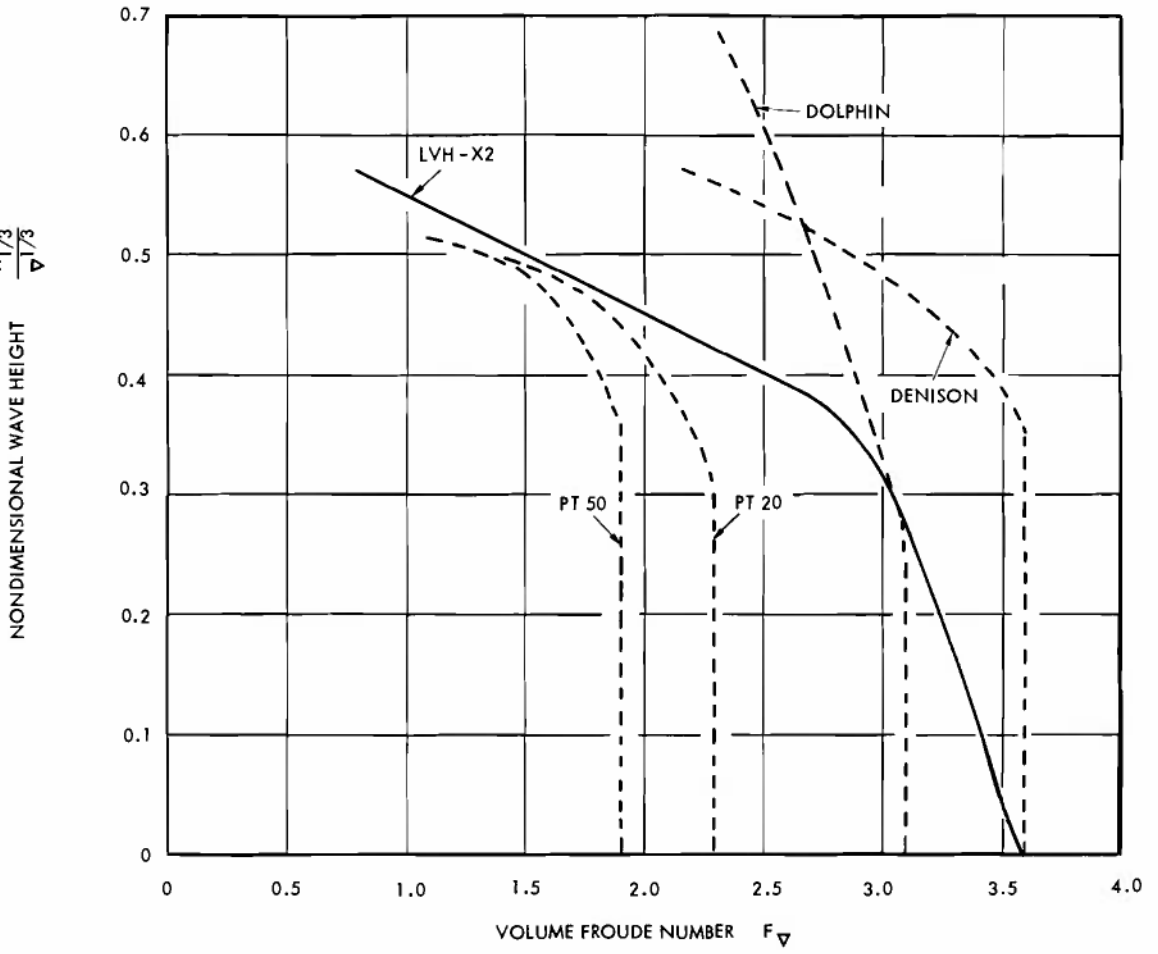

Figure 9-26. Hydrofoil Motion Limited Speeds

contained between two shallow and thin sidewalls, a flap forward and a conventional planing surface aft. The other is the Captured Air Bubble (CAB) concept in which the air cushion is contained between two deep and thick sidewalls, and flexible flaps at the forward and aft ends.

9-4.1.1 Hydrokeel Amphibians

Considerable effort has been devoted by the U. S. Marine Corps to the study of the application of the hydrokeel concept—a type of sidewall air cushion vehicle—to a wheeled amphibian. As part of this effort a hydrodynamic test craft called the ARC(K)-X1 was built and tested. This craft was intended only to study waterborne performance and thus was not equipped with wheels. To date (1969) no actual hydrokeel amphibian has been built.

The characteristics of the ARC(K)-X1 are presented in Fig. 9-32. The results of tests on the ARC(K)-X1 are summarized in Ref. 4. The measured drag of the ARC(K)-X1 in calm and rough water is presented in Fig. 9-33. The percentage increase in drag in rough water is presented in Fig. 9-34. A comparison of these data with similar data previously presented for the planing hull and hydrofoil amphibians indicates that the hydrokeel has lower drag in calm water. However, the drag of a hydrokeel increases more rapidly as wave height increases so that in a State 3 Sea a 40,000 lb hydrokeel has higher drag than the planing hull and hydrofoil.

Measurements were made of acceleration of the ARC(K)-X1 in head seas. The resulting data

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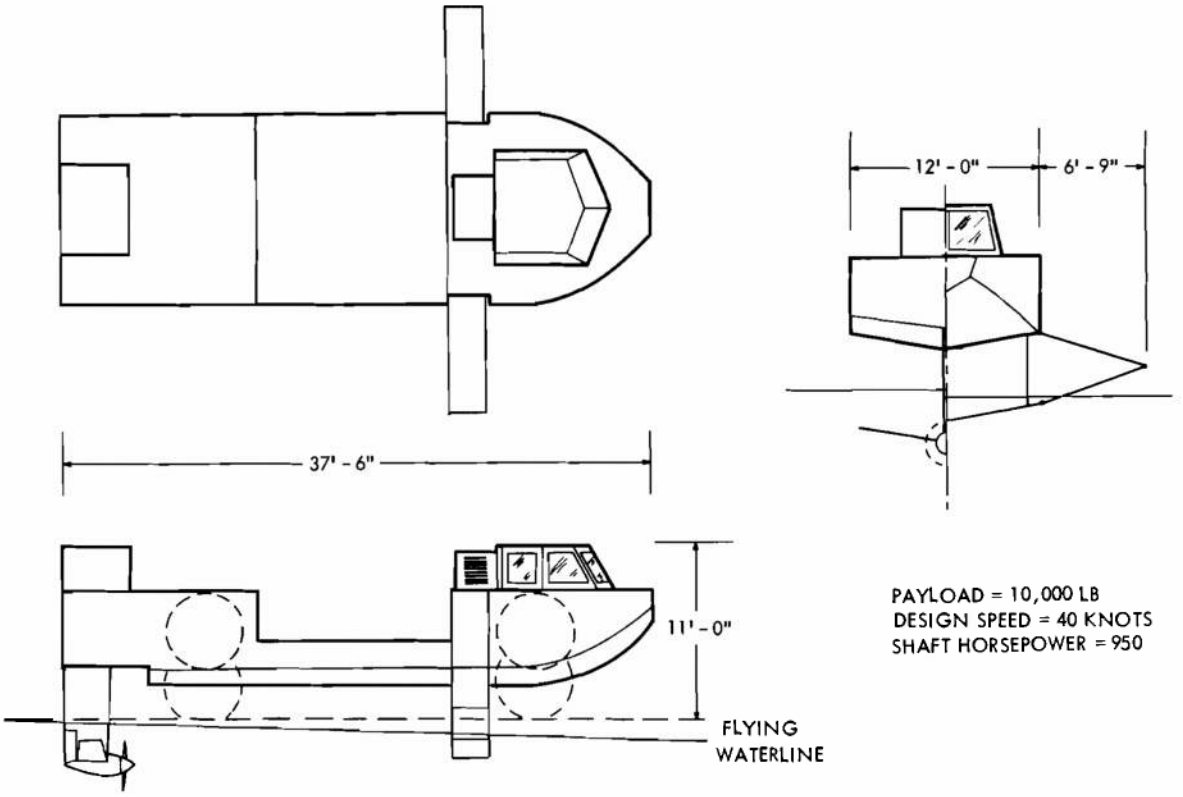

Figure 9-27. High-speed Amphibian—Hydrofoil Type, Configuration 1

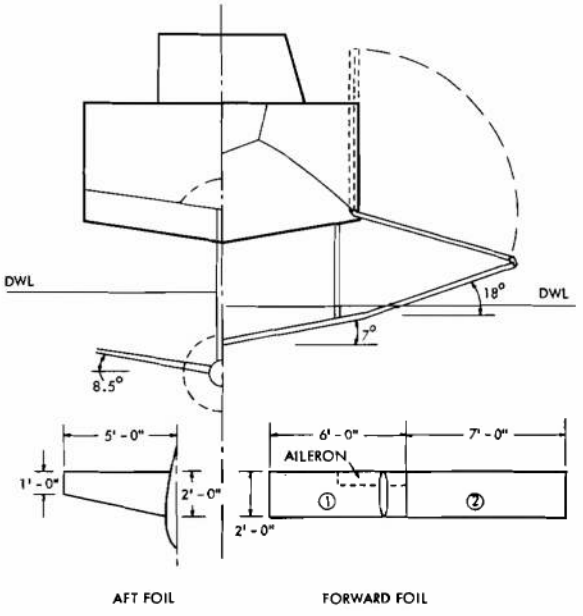

Figure 9-28. High-speed Amphibian—Hydrofoil Type, Configuration 1, Principal Foil Dimensions

are presented in Fig. 9-35. Data are also included in this figure on the acceleration of the LCVP(K), another hydrokeel of about the same size and characteristics as the ARC(K)-X1. Fig. 9-35 indicates that the accelerations of a hydrokeel amphibian will be similar to those of a planing hull amphibian and considerably greater than those of a hydrofoil amphibian.

Studies were also conducted to determine the stability and control characteristics of the ARC(K)-X1. Based on those studies it was concluded that the stability and control characteristics of a hydrokeel amphibian would be satisfactory. However, it was determined that a hydrokeel amphibian would be much more sensitive to the placement of cargo center of gravity than the planing hull or hydrofoil. Also it was felt that for stability in high speed turns a hydrokeel amphibian should be equipped with sponsons similar to those on the ARC(K)-X1.

A parametric study was conducted in Ref. 7 to determine the expected characteristics of a hydrokeel amphibian. The base vehicle developed in the study is shown in Fig. 9-36.

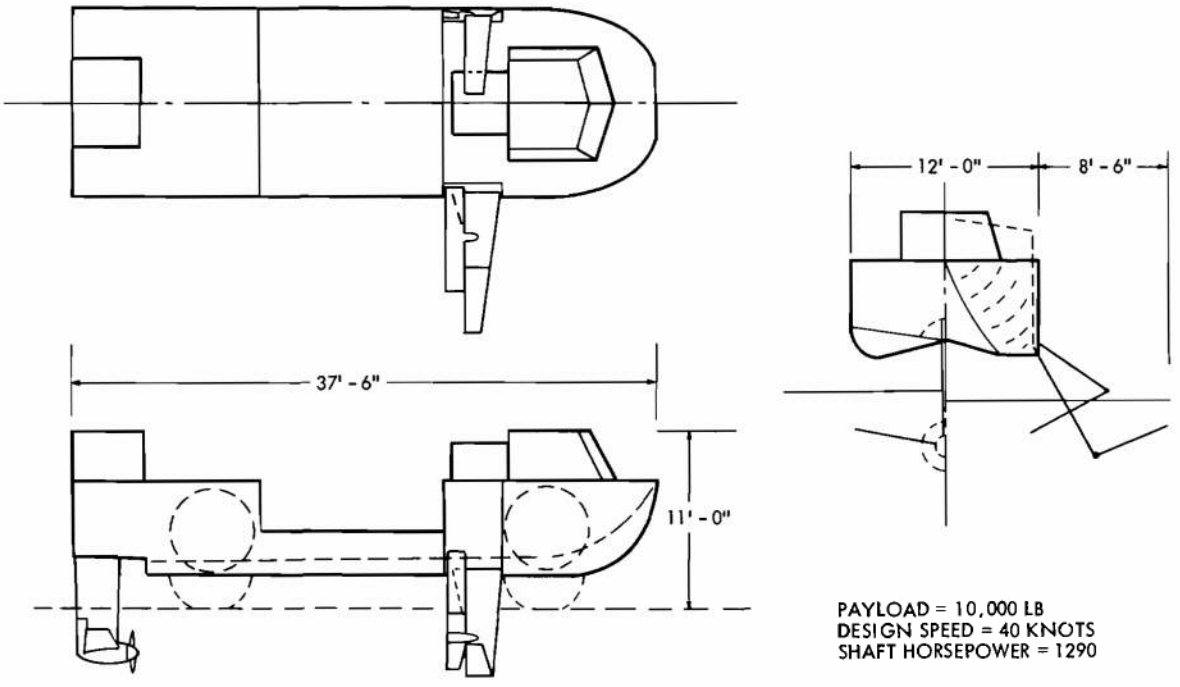

Figure 9-29. High-speed Amphibian—Hydrofoil Type, Configuration 2

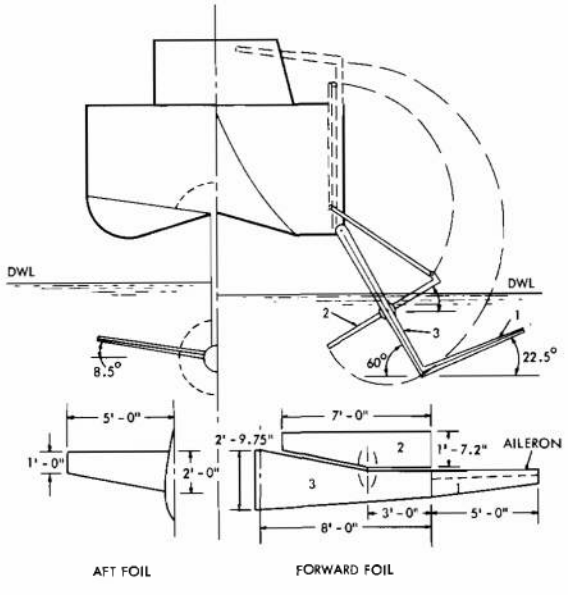

Figure 9-30. High-speed Amphibian—Hydrofoil Type, Configuration 2, Principal Foil Dimensions

This craft is intended to reach its power limited design speed in a Sea State 2. The effects of range and payload on the characteristics of a hydrokeel amphibian are presented in Fig. 9-37. These characteristics are based on the use of a gas turbine propulsion system with a specific weight of 2 lb/hp and a fuel rate of 0.75 lb/hp-hr. Since no actual hydrokeel amphibian has been built, the estimated characteristics shown in Fig. 9-37 are less certain than those given above for future planing hull and hydrofoil amphibians.

9-4.1.2 Captured Air Bubble (CAB) Amphibians

Very large surface effect craft of the CAB-type have been studied in some detail. However, no test craft have been built of a size and displacement suitable for a wheeled amphibian vehicle. There are theoretical procedures reported in Ref. 20 that can be used to make an estimate of the performance of a CAB amphibian. Such estimates were made and a parametric study of CAB amphibian characteristics are reported in Ref. 7. The base

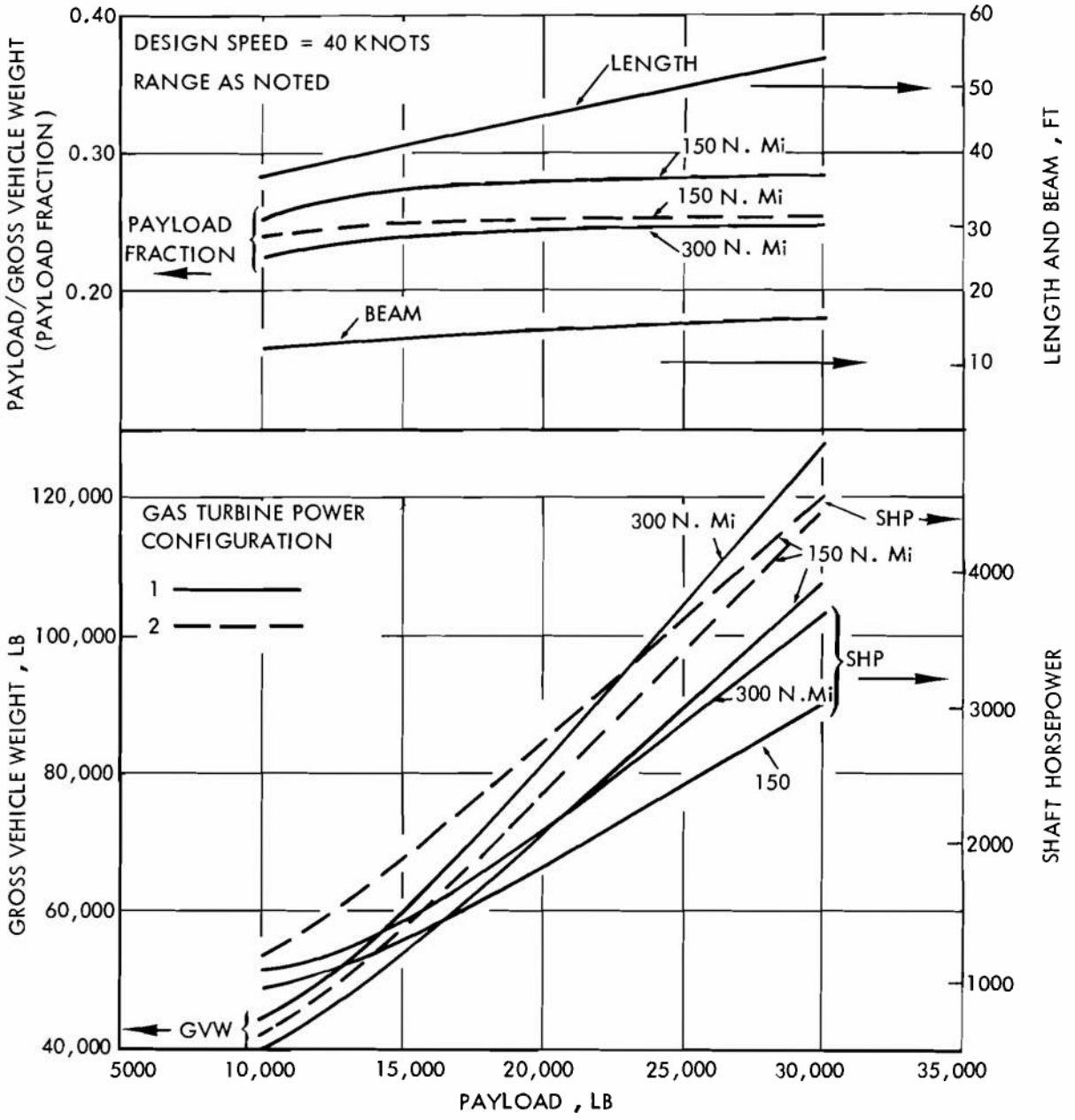

Figure 9-31. High-speed Amphibian—Hydrofoil Type, Effect of Design Payload

DIMENSIONS

SHIP	
KEEL LENGTH L_K	32.30 FT
LOA	36.00 FT
BEAM I	10.35 FT
BEAM II	11.91 FT
L_K/B_I	3.12 FT
L_K/B_{II}	2.71 FT

PROPELLERS	
NUMBER (2)	4177 - 4178
DIAMETER	26.00 IN.
PITCH	32.50 IN.
NO. OF BLADES	3
APPROXIMATE BAR	0.52
P/D	1.25
DIRECTION OF ROTATION	OUTWARD
STYLE	MICHIGAN WHEEL CO. DYNA - JET

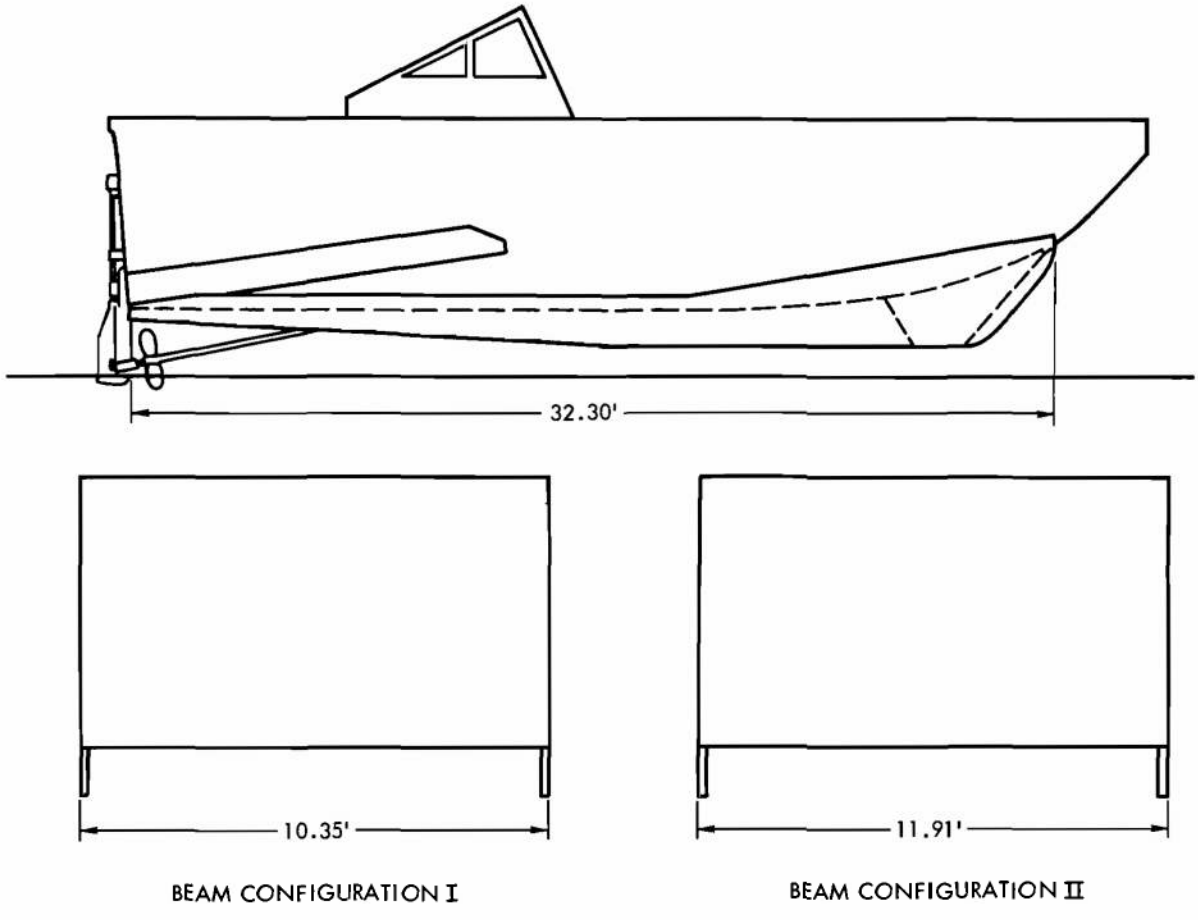

Figure 9-32. ARC(K)-X1 Dimensions

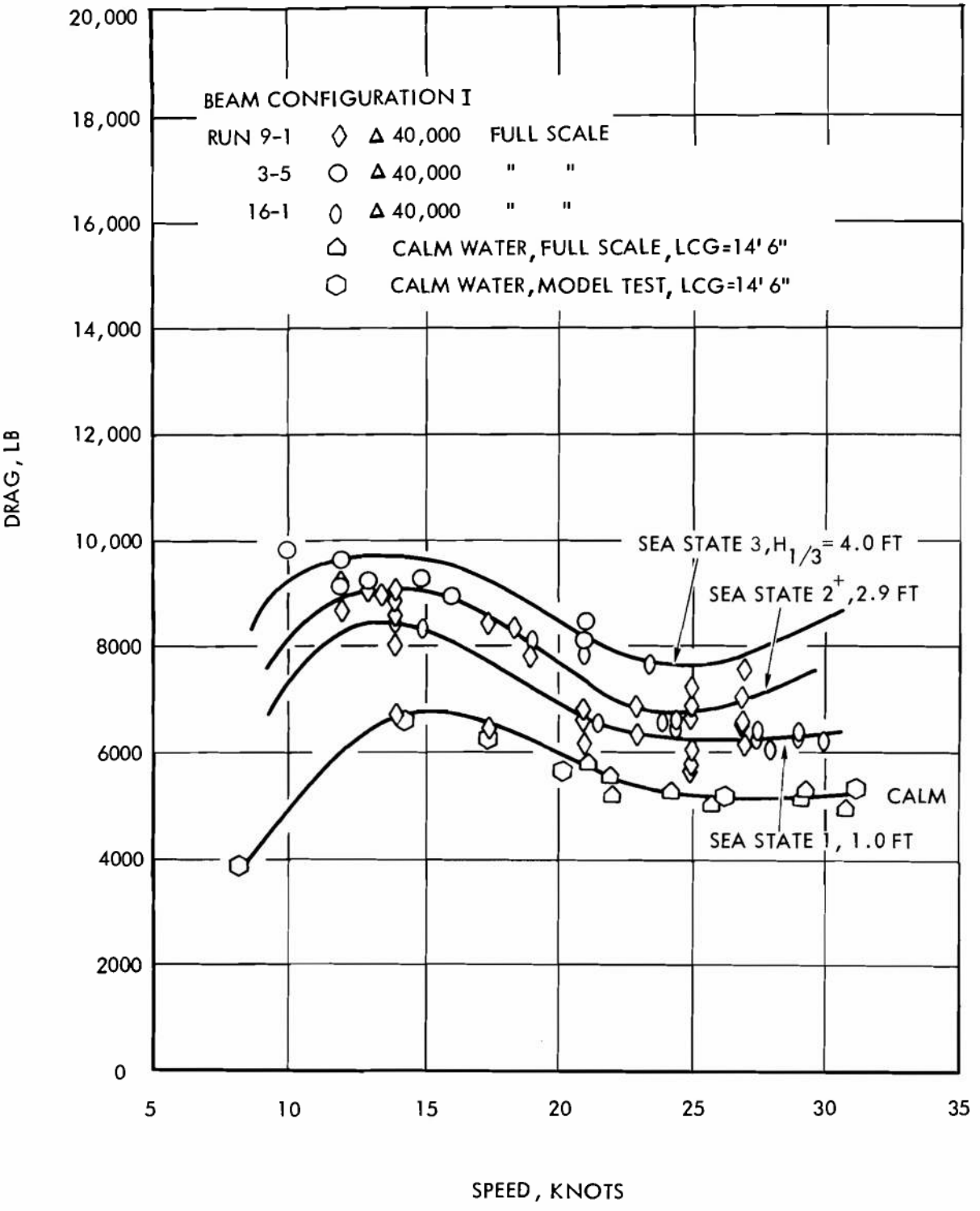

Figure 9-33. ARC(K) Rough Water Data

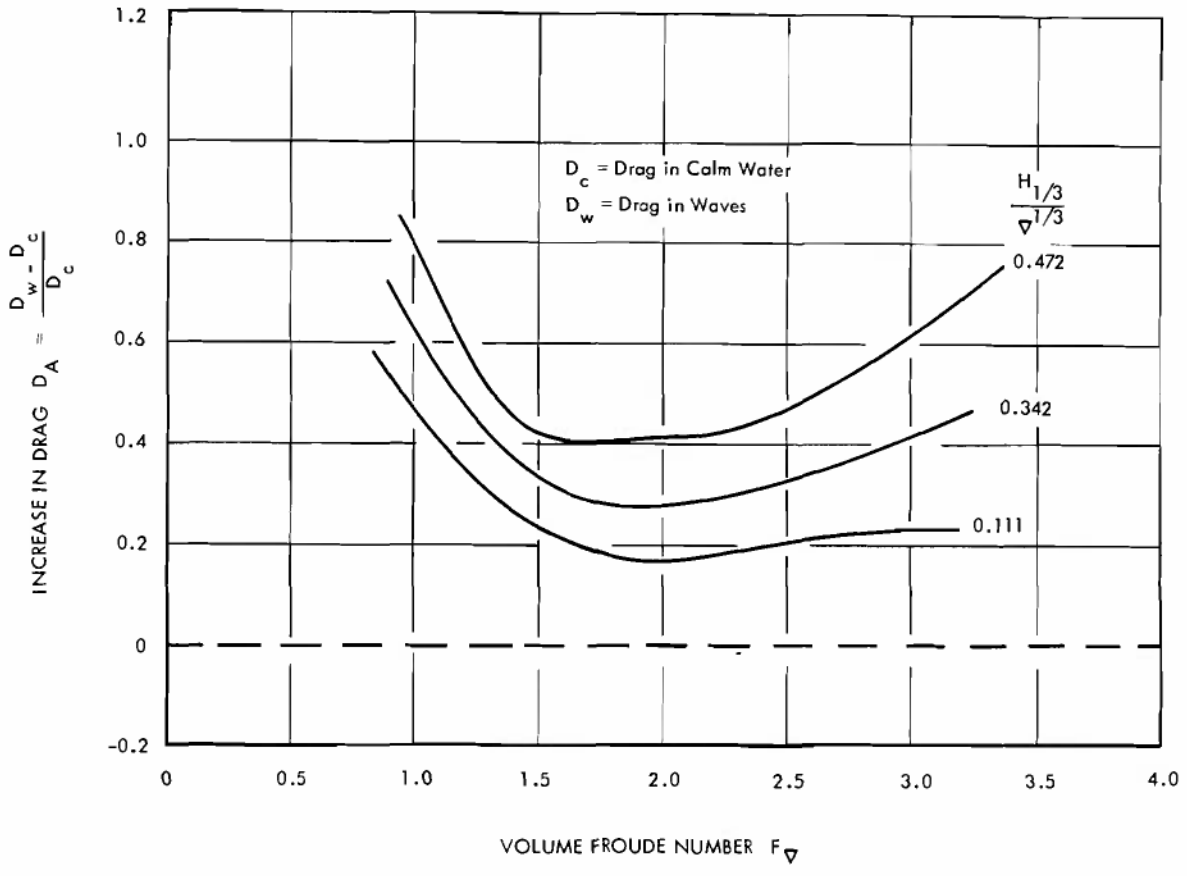

Figure 9-34. ARC(K) Added Drag in Waves

vehicle developed in this study is shown in Fig. 9-38. The effect of range and payload on craft characteristics is presented in Fig. 9-39. The most notable characteristic of a CAB amphibian is the wide beam required for stability in the "on bubble" condition. This has the effect of greatly increasing the empty weight of the craft. It should be noted that the characteristics given in Fig. 9-39 are very approximate because of the lack of experimental and prototype data.

9-4.2 FLEXIBLE SKIRT SURFACE EFFECT AMPHIBIANS

As previously indicated, the flexible skirt surface effect craft has an amphibious capability without wheels if it is propelled by an air screw. A number of vehicles of this type have been proposed for the amphibious support mission (Ref. 21). The advantages of this type of craft include a very high water speed (70 knots or more), excellent mobility over open flat ground regardless of the soil conditions, and the ability to land on a beach through very high surf (i.e., they can outrun the surf, see par. 7-4). The disadvantages of this type of craft include its large dimensions relative to the payload carried, its poor maneuverability in restricted places, its limited ability to climb grades, and its limited ability to exit from a beach through high surf. To take advantage of the characteristics of this type of vehicle, changes in the operational techniques now used with wheeled amphibians would be required.

In order to avoid some of the disadvantages of air propellers on flexible skirt surface effect vehicles, studies have been made of the possibilities of using wheels for partial support and propulsion on land (Ref. 22). No vehicle of this type has been built that could provide data

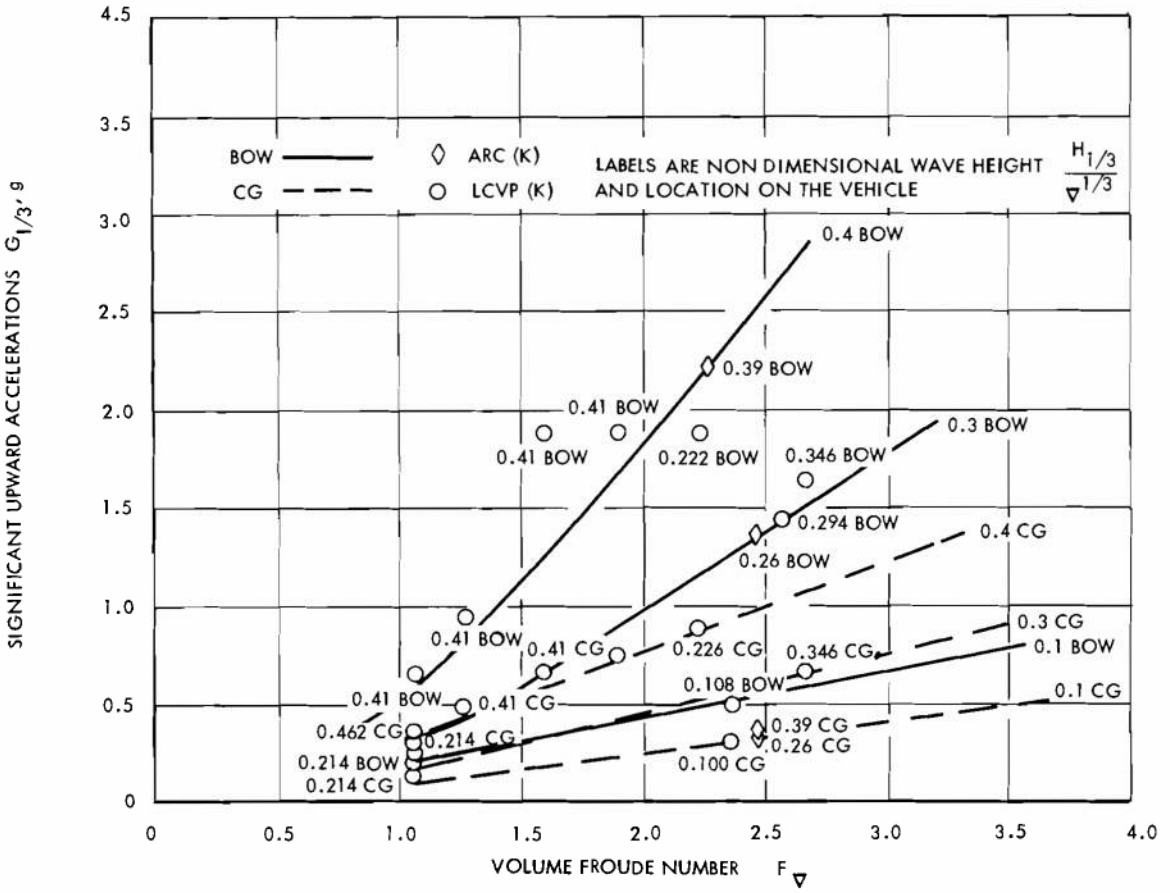

Figure 9-35. Hydrokeel Accelerations in Head Seas

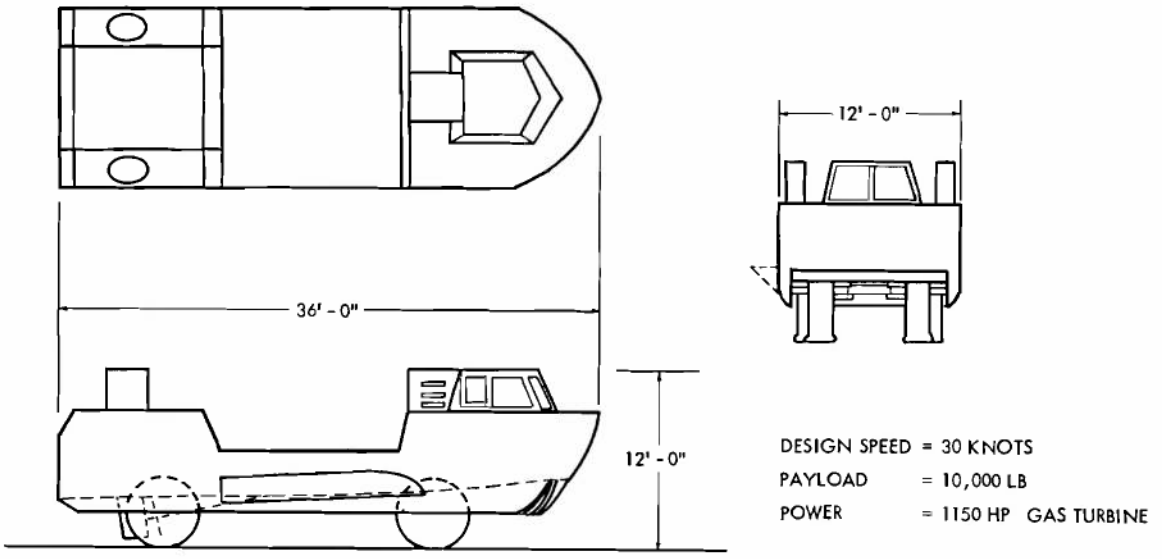

Figure 9-36. High-speed Amphibian—Hydrokeel Type, Base Vehicle Configuration

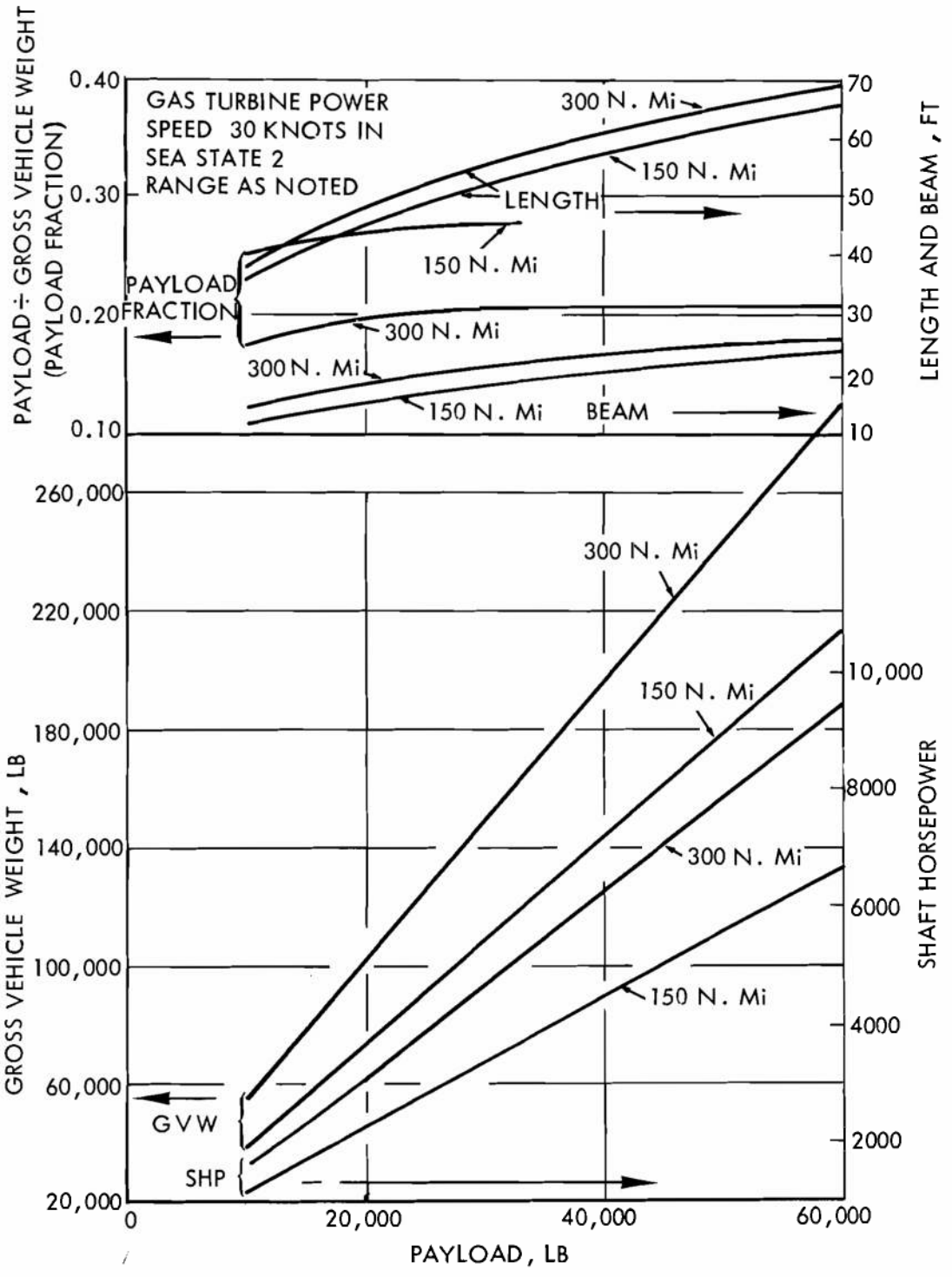

Figure 9-37. High-speed Amphibian—Hydrokeel Type, Effect of Payload

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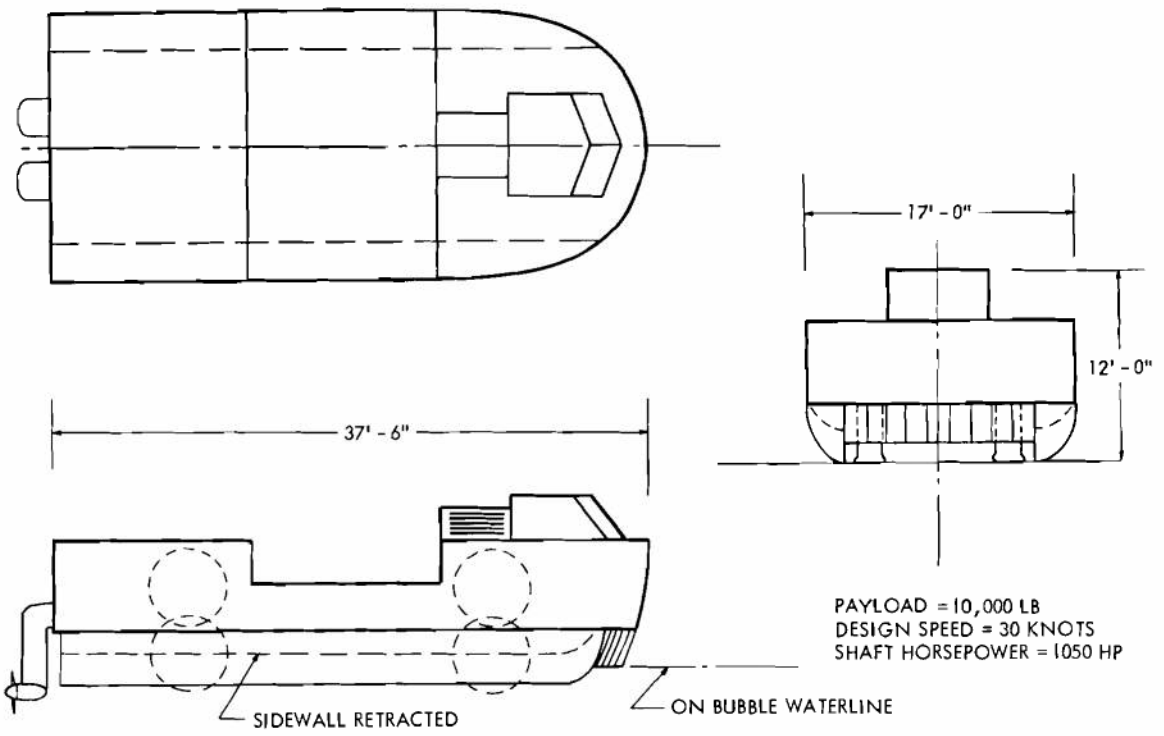

Figure 9-38. High-speed Amphibian—CAB Type

for application to a high-speed wheeled amphibian. However, a prototype air cushion truck has been built in France in which the wheels supply propulsion and carry 5 to 20 percent of the weight on land (Ref. 23). This vehicle has about the same dimensions as a LARC V and carries about 6,000 lb payload. It has the ability to "swim" in protected waters at speeds up to 4.5 mph. Future developments with this type of vehicle should be reviewed by the designer since they may have direct application to high-speed wheeled amphibians.

9-5 DISPLACEMENT FORM HIGH-SPEED AMPHIBIANS

All of the possible high-speed amphibian types considered so far depend on dynamic forces for lift at high speed and are characterized by high drag at intermediate speeds. As a result, there is a speed gap between conventional amphibians with a top speed of 10 to 12 mph and high-speed amphibians with minimum practical speeds of 18 to 20 mph. Some missions may require an amphibian that can operate economically in this intermediate speed range.

In a displacement type vehicle, high water speeds can be achieved at moderate power levels if low displacement length ratio hull forms are used. Because of the large size required for such a concept, a single hull would not be practical for an amphibian. However, a catamaran hull form could be developed, with each hull having an acceptable displacement-length ratio, and still remain within an acceptable size. Such a configuration is illustrated in Fig. 9-40. In this concept the overall length, for land operations, can be reduced by folding the bow and stern sections of the hulls back on the mid-body.

9-5.1 CHARACTERISTICS

Since the catamaran is a displacement type, it will not have a high hump drag at moderate speeds. As a result, moderate speeds should be possible with low installed powers. The configuration shown in Fig. 9-40 is estimated to have a top speed in calm water of 22.5 knots with 600 hp delivered to the propeller shaft. The drag estimate was based on the data presented for the Series 64 high-speed displacement hull

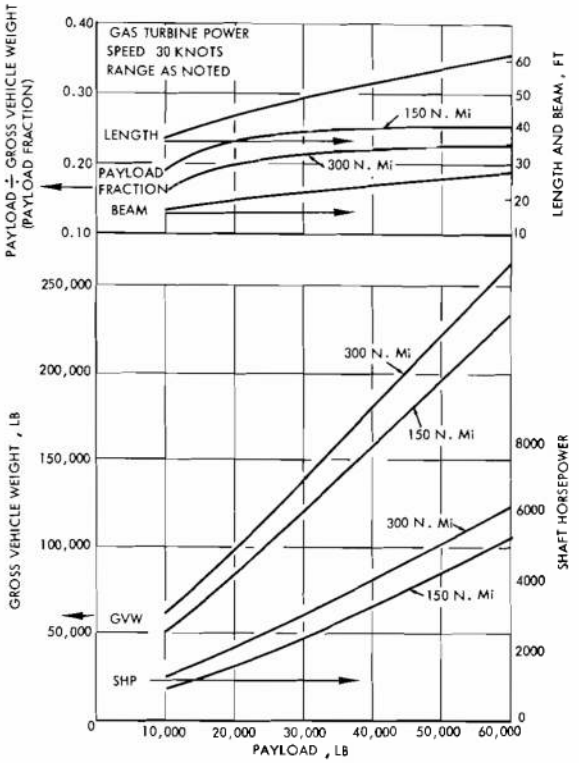

Figure 9-39. High-speed Amphibian — CAB Type, Effect of Payload

forms. An additional advantage of this type of hull form is that it should have good seakeeping characteristics because of the long slender hulls.

The catamaran amphibian shown in Fig. 9-40 has a design payload of 10,000 lb. The characteristics of this concept are presented in Table 9-15. As already noted, the bows and sterns fold back for land operations. The wheels would retract into the hulls for high speed water operation. This is a feature the catamaran has in common with all of the high speed amphibian types. Waterborne, propulsion is provided by a single propeller out-drive unit, rotatable to provide steering control. At low water speeds the wheels will also provide some steering control if in the extended position.

The catamaran configuration is not suitable for surf operations because of the small buoyancy of the fine bows. The forward end will tend to dig into the back of a breaker, causing the vehicle to broach. There is also a danger of the fine bows or sterns hitting the bottom as the vehicle pitches in a breaker. To avoid these problems, the catamaran amphibian must cross the surf with the bows and sterns folded back. In this configuration the catamaran amphibian should act like the other high speed amphibian types in the surf. Also, the roll angle

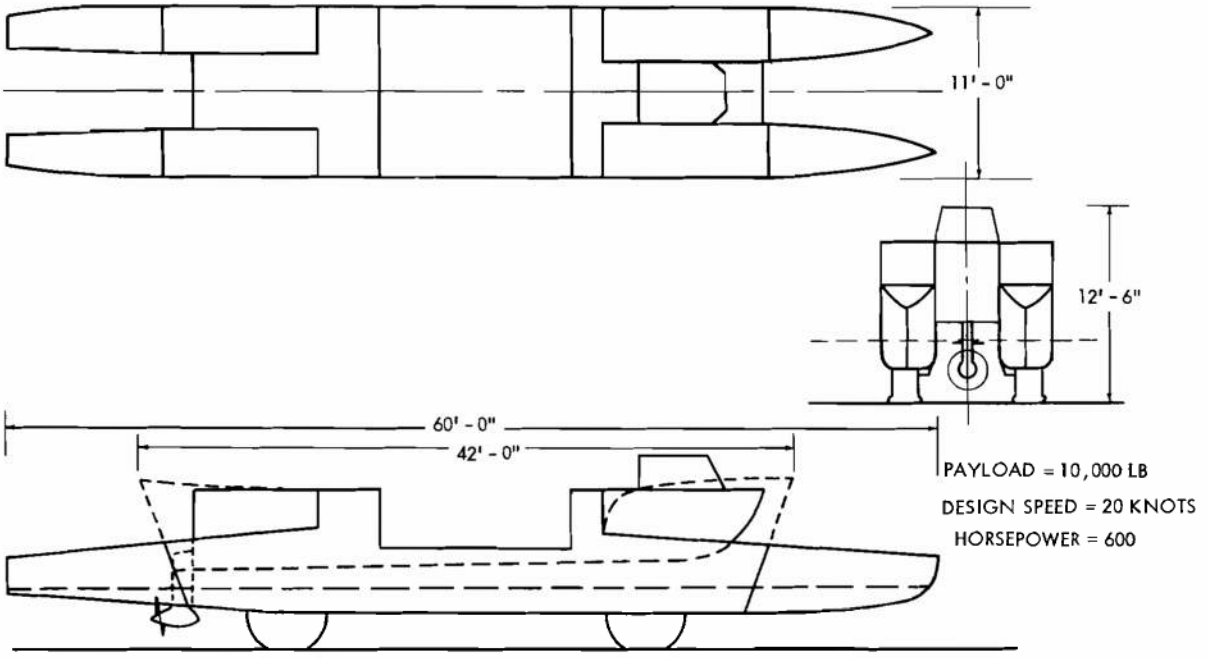

Figure 9-40. High-speed Amphibian—Catamaran Type

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to capsize (range of stability) would be increased somewhat since the folded bows and sterns have the effect of increasing the freeboard.

The advantages of moderately high speeds with low power, and good seakeeping out of the surf zone, make a catamaran type amphibian appear attractive. There are, however, a number of disadvantages with a catamaran form. The major disadvantage involves the arrangement of internal components. There is very little internal volume in a catamaran suitable for the machinery and drive train components. A detailed study would be required to determine if a satisfactory arrangement could be developed.

TABLE 9-15 HIGH-SPEED SUPPORT AMPHIBIAN–CATAMARAN TYPE

Payload - 10,000 lb

Power Limited Speed - Calm Water, 22.5 knots
Sea State 3, 20 knots

Length, Overall
Hull, Unfolded - 60 ft
Hull, Folded - 42 ft
Breadth - 11 ft
Height - Wheel Down, 12.5 ft
Wheels Up, 10.5 ft

Power - 600 horsepower gas turbine

Range - 150 N.mi

Water Propulsion - single propeller out-drive

Gross Vehicle Weight - 40,000 lb

Weight Summary

Item	*Weight, lb*
Hull Structure	10,000
Folding Bows and Sterns	3,000
Machinery Weight	1,200
Main Drive Train	2,800
Marine Drive	600
Land Gear	6,000
Misc. Systems	2,500
Empty Weight	26,100
Crew	500
Fuel	3,400
Payload	10,000
Gross Weight	40,000

The folded bows will cause a visibility problem from the cab when on land unless the vehicle height is increased above that shown in Fig. 9-40. The overall length of the catamaran amphibian may be a disadvantage for land operations. The configuration shown in Fig. 9-40 is 2 to 6 ft longer than existing high-speed amphibians. The length could be reduced by reducing the intersection angle between the mid-body and the bows and sterns. This, however, would reduce the already small approach and departure angles.

9-5.2 PERFORMANCE

The major unknown from a hydrodynamic standpoint is the problem of interference drag between the two hulls. There are no experimental data on this subject which apply to configurations suitable for a catamaran amphibian. The performance estimates have been made assuming that interference drag will be small. If this is not the case, many of the justifications for a catamaran configuration are lost. The best way of determining the importance of interference drag would be through a small model test program. This is beyond the scope of this handbook and it was decided not to continue with a parametric study of a catamaran amphibian at this time. However, it is felt that the potential of a catamaran amphibian is great enough to justify a small model test program at some future date.

9-6 COMPARISON OF VEHICLE TYPES FOR USE AS HIGH-SPEED AMPHIBIANS

The major decision that must be made in the design of a high speed amphibian is the selection of the vehicle type. This selection must depend on the mission requirements since no one type is superior in all areas. Table 9-16 has been developed to aid in this selection by providing the relative rankings of planing hull, hydrofoil, and hydrokeel types in a number of areas. The other types discussed are not included in this ranking since reliable prototype or experimental data are not available for them. A rank of 1 indicates the vehicle type that is best in the particular area. The quantitative differences between vehicle types can be obtained from the previous descriptions.

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TABLE 9-16 RELATIVE RANKING OF VEHICLE TYPES FOR USE AS HIGH-SPEED AMPHIBIANS

	Item	*Planing Hull*	*Hydrofoil*	*Hydrokeel*
1.	Gross Weight	1	3	2
2.	Low Speed Stability and Seaworthiness	1	1	1
3.	Sensitivity to Variation of Cargo CG Location	1	2	3
4.	Calm Water Top Speed	3	2	1
5.	Power Limited Speed in Sea State 3	2	1	3
6.	Motion Limited Speed in Sea State 3	2	1	2
7.	Maneuverability and Control at Low Speed	1	2	1
8.	High Speed Stability in a Turn	1	2	3
9.	Compatibility with Secondary Road Nets	1	1	1
10.	Complexity	1	3	2

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GLOSSARY

active rudder. A rudder fitted with a submersible motor and propeller to provide directional thrust at low speeds.

aft. Toward, at, or near the stern.

amidships. In the vicinity of the mid-length of the vehicle, as distinguished from the ends; also 'midships.

angle of approach. Angle formed by a line connecting the tangent of the front tires and the lowest portion of the vehicle body, and the horizontal.

angle of departure. Angle formed by a line connecting the tangent of the rear tires and the lowest portion of the vehicle body, and the horizontal.

appendages. Portions of the vehicle extending beyond the hull outline; rudders, shafting, struts, wheels, gear cases, etc.

area moment of inertia. Second moment of the area; for a discrete area this is the area multiplied by the square of the distance from the centroid to the axis of reference.

aspect ratio. Ratio of the chord to span of a rudder, foil, or propeller blade.

athwartship. Across the vehicle, perpendicular to the fore and aft center plane.

ballast. Any solid or liquid weight placed in a vehicle to change the trim or to regulate the stability.

baseline. A fore and aft reference line at the lower surface of the bottom plating at the center of the vehicle. The base plane is a horizontal plane through the baseline, parallel to the waterplane.

bilge. Curved section of the hull and underbody between the vehicle bottom and vertical side; recess into which the water drains from cargo and machinery spaces.

bilge pump. A pump used to remove the water and other liquids from the bilge.

bitt, mooring. Short metal column extending from a base plate on the deck, used for securing the vehicle.

block coefficient. Ratio of the actual underwater volume to the volume of a rectangular block, which has dimensions of the length, beam, and draft.

body plan. Composite drawing outlining the intersection of the section planes or stations with the hull surface.

bollard pull. Thrust delivered by the propulsor at zero forward speed.

Bonjeans curves. A plan giving the underwater area for each station or section along the vehicle as a function of draft.

bow. The forward end of the vehicle.

break angle. The angle formed by a line from a point on the hull midway between the wheels and tangent to lower edge of the tire (the angle labeled 22° in Fig. 5-7 is an example).

bulkhead. A vertical partition which divides the vehicle into compartments. Bulkheads may be nontight, water-tight, oil-tight, or gas-tight, depending on construction.

buoyancy. Upward force exerted by the fluid on a body; proportional to the volume of water displaced by the body.

buttocks (planes). Vertical longitudinal planes, parallel to the longitudinal center plane, perpendicular to the base plane and water planes.

catamaran. Twin hulled craft which is generally symmetrical about the centerline.

centerline. The middle line extending the fore-and-aft length of the vehicle. More accurately described as a center plane.

chine. Intersection between side and bottom shell, or between two bottom shell planes.

chord. The length from leading edge to trailing edge of a foil or shape, in line with the direction of flow.

coaming. A vertical plate surrounding a hatch or cargo well, serves to restrict water from flowing into the opening and to strengthen the hatch edge.

conceptual design. Phase of design in which basic vehicle characteristics, and realistic and specific requirements are developed.

correlation allowance. Incremental increase in the resistance coefficient to account for surface roughness.

cross curves of stability. A plan giving the righting arm *(GZ)* as a function of draft, for various heel angles.

curves of form. A plan giving various hydrostatic properties of the hull as a function of draft.

damaged stability. Stability of an amphibious vehicle when in the damaged (flooded) condition.

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deadrise. Rise of bottom of a midship frame from the keel to the bilge.
deck. A deck or platform of a vehicle; corresponds to the floors of a building.
delivered horsepower. Power delivered to the propulsor.
depth. Distance from hull bottom to deck.
directional stability. The property of a vehicle that indicates course-keeping ability.
displacement. The weight of water the hull displaces, which equals its total weight.
draft. The distance from the static waterline to a reference plane. The reference plane usually passes through the lowest point on the vehicle.
draw bar pull. The maximum towline force the landborne amphibian can develop.
effective horsepower (EHP). Power actually delivered by the propulsor. It is defined by (DV/C) where D = drag, V = speed, C = constant; the value of C depends on the units of D and V (550 for lb, ft, sec system).
failure. A deficiency which prevents a component or subassembly from performing its intended function within previously established limits.
factor of safety. The ratio of the design load to the expected actual load of a structural member.
fair (line). A line which is smooth with no abrupt changes in the radius of curvature.
final design. Design phase, following preliminary design, in which the final plans are developed.
floor. Vertical, transverse member supporting the bottom shell plating.
fore. A term pertaining to portions of the vehicle at or adjacent to the bow.
forward (fwd). In the direction of the bow of the vehicle.
frame. A transverse or longitudinal member of the vehicle's structure which provides support for the shell plating and acts to maintain longitudinal and transverse hull shape.
frame spacing. The longitudinal distance between transverse frames. Varies with the structure and location along the vehicle's length.
freeboard. Distance from the waterline to the weather deck.
freeing port. An opening in a bulwark or coaming to permit water to drain overboard.
frictional resistance. Resistance due to viscous forces acting on the vehicle; frictional resistance is directly proportional to the density, square of the velocity, and the surface area.
Froude number (F_N). A nondimensional ratio of the speed and length; $(V/\sqrt{gL})$. *See* **volume Froude number (F_∇).**
fuel rate. The fuel consumption per horsepower hour.
galvanic action. The production of an electric current when two dissimilar metals are immersed in an electrolyte.
galvanic series. The order of metals according to their tendency to corrode galvanically.
geosim. A model which is geometrically similar to a parent model or prototype vehicle.
girth. Any expanded length around a curved section.
gross vehicle weight (GVW). Total weight of a vehicle which includes cargo, fuel, crew, and empty vehicle weight.
ground clearance. Height above the ground of the lowest part of the vehicle.
half breadth plan. Composite drawing outlining the intersection of the waterline planes with the hull surface.
heave. Motion of a vehicle in the vertical direction.
heel. Static inclination of a ship to one side, caused by off-center loads or external forces.
hogging condition. Temporary or permanent deformation of the hull in the longitudinal plane such that the hull is deflected convex upward between hull ends.
hull. The primary structural body of an amphibian, including the shell plating, frames, longitudinals, and bulkheads.
hull efficiency. One minus the thrust deduction divided by one minus the wake fraction, i.e., $1-t/(1-w)$.
hydrokeel. A type of sidewall air cushion vehicle.
hydrostatic pressure. The pressure of the water at a given depth.
inboard. Inside the ship; towards the centerline or away from the sides.
inclining test. An experiment performed on a floating vehicle to determine the initial stability, or GM.
intact stability. Stability of the vehicle in the intact, undamaged condition.
keel. Principal fore-and-aft member of the vehicle framing, extending along the bottom centerline.
knot. Unit of speed, equals one nautical mile per hour, = 1.689 ft/sec or 1.15 mph.
length, overall. Extreme length of vehicle from maximum extent of vehicle stem and stern.

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length, waterline. Length of vehicle on the water, at a given draft, excluding overhangs.
lines drawing. A plan containing the three orthogonal views of the vehicle hull geometry.
longitudinals. Fore and aft structural members.
maneuverability. Property of a marine vehicle relating to ability to control, change, or retain direction of motion and speed.
margin. An allowance for weights and center of gravity location to allow for items which might be overlooked during design or incorporated in the vehicle after design has been completed.
mass moment of inertia. The second moment of mass; for a discrete mass, the mass moment of inertia is the mass multiplied by the square of the distance from the reference axis to the center of mass, slug-ft^2.
materiel. The equipment, apparatus, and supplies required for the operation of a military installation.
metacenter. The intersection of a line drawn vertically through the heeled center of buoyancy and the ship centerline plane. The heeled center of buoyancy is not on the centerline.
metacentric height. Distance from the metacenter to the center of gravity of the vehicle, symbolically GM.
metacentric radius. Distance from the center of buoyancy to the metacenter.
midship. Midway between the ends of the vehicle; for a vehicle with twenty-one stations (0,1,.....20), the midship is station 10.
mobility. The ease with which a vehicle can move from one point to another under its own power.
offsets. Coordinates defining the geometric hull form.
open center system. Hydraulic system equipped with a relief valve which allows the fluid from the pump to empty into the reservoir when it is no longer required to run a power take-off.
outboard. Direction away from the centerline towards the side.
peel strength. The force required to peel adhesives from a surface.
pitch. Dynamic rotation of the ship about the transverse axis in the longitudinal plane.
pitch, propeller. The theoretical distance that a point on the surface of a propeller blade will advance in one revolution.
planform. Contour or outline of a body when viewed from above.
port. The left side of a ship or vehicle, when looking from aft to forward.
power train. System which transmits power from the engine to the wheels and water propulsor.
preliminary design. Design phase in which the characteristics developed in the conceptual design are checked and modified until the requirements are satisfied.
profile plan. Composite drawing outlining the intersection of the buttock planes with the hull surface.
propulsor. The system which propels the vehicle when waterborne, e.g., screw propeller, water jets, paddles.
relative rotative efficiency. A factor which accounts for the difference in performance between a propeller operating in a uniform and nonuniform wake.
reserve buoyancy. Volume of the watertight hull above the design waterlinc.
reserve stability. Area between the righting arm and the heeling arm curves on a statical stability diagram.
residuary resistance. Sum of the eddy-making and wave-making resistance.
Reynolds number. Nondimensional parameter containing speed and length parameters. For ship: $Re = VL/\nu$ where L = ship length, V = ship speed, and ν = kinematic viscosity.
roll. Dynamic angular rotation of the ship in a transverse plane about the longitudinal axis.
rolling resistance. Resistance to land motion of a moving vehicle; i.e., with tires turning.
running gear. Wheels and other related components of the amphibian land system.
sagging condition. Temporary or permanent deformation of the hull in the longitudinal plane such that the hull is deflected convex downward between hull ends.
scantlings. The dimensions and thickness of structural members.
sea state. An arbitrary scale of sea conditions, based on significant wave height.
section planes. Vertical planes which cut the hull transversely.
sheer. Longitudinal curve in the deck height in a vertical plane.
significant wave height. The average height from crest to trough of the 1/3 highest waves.
Simpson's rule. A numerical integration procedure.
soil index. Quantitative measure of some physical property of the soil which can be empirically related to vehicle trafficability.

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span. The tip to tip length of a wing or foil, perpendicular to the flow.

spray strip. A strip or wedge on a planing hull, just above the waterline, which deflects water or spray downward.

stability. Tendency of a marine vehicle to remain upright or the ability of a vehicle to return to upright when heeled by wind, wave, or other forces.

starboard. The right side of a ship or vehicle, when viewed from aft to forward.

stations. Divisions of the length of a vehicle into ten, or a multiple of ten, equal spaces; also, transverse section planes at these divisions.

stem. The bow frame forming the forward sides of the vehicle.

stern. After end of the vehicle.

sulfidation. A reaction between sulfur in fuel and salt in air intake of gas turbine, forming a corrosive slag.

surface effect craft. A vehicle which is supported on a cushion of pressurized air.

surge. Motion of a vehicle; longitudinal displacement in the horizontal direction.

sway. Motion of a vehicle; transverse displacement in the horizontal plane.

tactical diameter. The steady turn diameter of a waterborne vehicle with rudder hard over.

thrust deduction. The augment of ship resistance resulting from action of the propeller in changing the pressure field around the hull.

towing pad. An eye on the front or rear of a vehicle to permit attachment of a towing line.

tractive effort. Thrust that the tires must develop to meet land performance requirements.

transom. Aft transverse shell of vehicle.

transportability. The ease with which a vehicle can be moved from one location to another by different modes of transport when not under its own power.

transverse. Perpendicular to the fore-and-aft or longitudinal axis.

trim. Difference between forward and after drafts.

volume Froude number (F_∇). A nondimensional measure of speed for a planing hull. *See* **Froude number (F_N).**

wake fraction (w). Relationship between ship speed and propeller advance speed.

waterline (planes). Horizontal planes orthogonal to the section and buttock planes.

wheelbase. Distance between the points of contact of the front and rear axles of a vehicle.

wind drag. Resistance to the vehicle's motion caused by the wind.

yaw. Dynamic rotation of a vehicle about the vertical centerline axis.

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49 Code of Federal Regulations Part 831

Title 49. Transportation
Subtitle B. Other Regulations Relating to Transportation
Chapter VIII. National Transportation Safety Board
➞ Part 831. Accident/Incident Investigation Procedures

➞ § 831.1 Applicability of part.

Unless otherwise specifically ordered by the National Transportation Safety Board (Board), the provisions of this part shall govern all accident or incident investigations, conducted under the authority of title VII of the Federal Aviation Act of 1958, as amended, and the Independent Safety Board Act of 1974. Rules applicable to accident hearings and reports are set forth in Part 845.

§ 831.2 Responsibility of Board.

(a) Aviation.

(1) The Board is responsible for the organization, conduct, and control of all accident and incident investigations (see § 830.2 of this chapter) within the United States, its territories and possessions, where the accident or incident involves any civil aircraft or certain public aircraft (as specified in § 830.5 of this chapter), including an investigation involving civil or public aircraft (as specified in § 830.5) on the one hand, and an Armed Forces or intelligence agency aircraft on the other hand. It is also responsible for investigating accidents/incidents that occur outside the United States, and which involve civil aircraft and/or certain public aircraft, when the accident/incident is not in the territory of another country (i.e., in international waters).

(2) Certain aviation investigations may be conducted by the Federal Aviation Administration (FAA), pursuant to a "Request to the Secretary of the Department of Transportation to Investigate Certain Aircraft Accidents," effective February 10, 1977 (the text of the request is contained in the appendix to part 800 of this chapter), but the Board determines the probable cause of such accidents or incidents. Under no circumstances are aviation investigations where the portion of the investigation is so delegated to the FAA by the Board considered to be joint investigations in the sense of sharing responsibility. These investigations remain NTSB investigations.

[1] The authority of a representative of the FAA during such investigations is the same as that of a Board investigator under this part.

(3) The Board is the agency charged with fulfilling the obligations of the United States under Annex 13 to the Chicago Convention on International Civil Aviation (Eighth Edition, July 1994), and does so consistent with State Department requirements and in coordination with that department. Annex 13 contains specific requirements for the notification, investigation, and reporting of certain incidents and accidents involving international civil aviation. In the case of an accident or incident in a foreign state involving civil aircraft of U.S. registry or manufacture, where the foreign state is a signatory to Annex 13 to the Chicago Convention of the International Civil Aviation Organization, the state of occurrence is responsible for the investigation. If the accident or incident occurs in a foreign state not bound by the provisions of Annex 13 to the Chicago Convention, or if the accident or incident involves a public aircraft (Annex 13 applies only to civil aircraft), the conduct of the investigation shall be in consonance with any agreement entered into between the United States and the foreign state.

(b) Surface. The Board is responsible for the investigation of: railroad accidents in which there is a fatality, substantial property damage, or which involve a passenger train (see part 840 of this chapter); major marine casualties and marine accidents involving a public and non-public vessel or involving Coast Guard functions (see part 850 of this chapter); highway accidents, including railroad grade-crossing accidents, the investigation of which is selected in cooperation with the States; and pipeline accidents in which there is a fatality, significant injury to the environment, or substantial property damage.

[2] Part 850 also governs the conduct of certain investigations in which the Board and the Coast Guard participate jointly.

(c) Other Accidents/Incidents. The Board is also responsible for the investigation of an accident/incident that occurs in connection with the transportation of people or property which, in the judgment of the Board, is catastrophic, involves problems of a recurring character, or would otherwise carry out the policy of the Independent Safety Board Act of 1974. This authority includes, but is not limited to, marine and boating accidents and incidents not covered by part 850 of this chapter, and accidents/incidents selected by the Board involving transportation and/or release of hazardous materials.

§ 831.3 Authority of Directors.

The Directors, Office of Aviation Safety, Office of Railroad Safety, Office of Highway Safety, Office of Marine Safety, and Office of Pipeline and Hazardous Materials Safety, subject to the provisions of § 831.2 and part 800 of this chapter, may order an investigation into any accident or incident.

§ 831.4 Nature of investigation.

Accident and incident investigations are conducted by the Board to determine the facts, conditions, and circumstances relating to an accident or incident and the probable cause(s) thereof. These results are then used to ascertain measures that would best tend to prevent similar accidents or incidents in the future. The investigation includes the field investigation (on-scene at the accident, testing, teardown, etc.), report preparation, and, where ordered, a public hearing. The investigation results in Board conclusions issued in the form of a report or "brief" of the incident or accident. Accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties. They are not subject to the provisions of the Administrative Procedure Act (5 U.S.C. 504 et seq.), and are not conducted for the purpose of determining the rights or liabilities of any person.

§ 831.5 Priority of Board investigations.

Any investigation of an accident or incident conducted by the Safety Board directly or pursuant to the appendix to part 800 of this chapter (except major marine investigations conducted under 49 U.S.C. 1131(a)(1)(E)) has priority over all other investigations of such accident or incident conducted by other Federal agencies. The Safety Board shall provide for the appropriate participation by other Federal agencies in any such investigation, except that such agencies may not participate in the Safety Board's determination of the probable cause of the accident or incident. Nothing in this section impairs the authority of other Federal agencies to conduct investigations of an accident or incident under applicable provisions of law or to obtain information directly from parties involved in, and witnesses to, the transportation accident or incident, provided they do so without interfering with the Safety Board's investigation. The Safety Board and other Federal agencies shall assure that appropriate information obtained or developed in the course of their investigations is exchanged in a timely manner.

§ 831.6 Request to withhold information.

(a) Trade Secrets Act (18 U.S.C. 1905), Exemption 4 of the Freedom of Information Act (5 U.S.C. 552) (FOIA), and The Independent Safety Board Act of 1974, as amended.

(1) General. The Trade Secrets Act provides criminal penalties for unauthorized government disclosure of trade secrets and other specified confidential commercial information. The Freedom of Information Act authorizes withholding of such information; however, the Independent Safety Board Act, at 49 U.S.C. 1114(b), provides that the Board may, under certain circumstances, disclose information related to trade secrets.

(2) Procedures. Information submitted to the Board that the submitter believes qualifies as a trade secret or confidential commercial information subject either to the Trade Secrets Act or FOIA Exemption 4 shall be so identified by the submitter on each and every page of such document. The Board shall give the submitter of any information so identified, or information the

Board has substantial reason to believe qualifies as a trade secret or confidential commercial information subject either to the Trade Secrets Act or FOIA Exemption 4, the opportunity to comment on any contemplated disclosure, pursuant to 49 U.S.C. 1114(b). In all instances where the Board determines to disclose pursuant to 49 U.S.C. 1114(b) and/or 5 U.S.C. 552, at least 10 days' notice will be provided the submitter. Notice may not be provided the submitter when disclosure is required by a law other than FOIA if the information is not identified by the submitter as qualifying for withholding, as is required by this paragraph, unless the Board has substantial reason to believe that disclosure would result in competitive harm.

(3) Voluntarily-provided safety information. It is the policy of the Safety Board that commercial, safety-related information provided to it voluntarily and not in the context of particular accident/incident investigations will not be disclosed. Reference to such information for the purposes of safety recommendations will be undertaken with consideration for the confidential nature of the underlying database(s).

(b) Other. Any person may make written objection to the public disclosure of any other information contained in any report or document filed, or otherwise obtained by the Board, stating the grounds for such objection. The Board, on its own initiative or if such objection is made, may order such information withheld from public disclosure when, in its judgment, the information may be withheld under the provisions of an exemption to the Freedom of Information Act (5 U.S.C. 552, see part 801 of this chapter), and its release is found not to be in the public interest.

§ 831.7 Right to representation.

Any person interviewed by an authorized representative of the Board during the investigation, regardless of the form of the interview (sworn, unsworn, transcribed, not transcribed, etc.), has the right to be accompanied, represented, or advised by an attorney or non-attorney representative.

§ 831.8 Investigator-in-charge.

The designated investigator-in-charge (IIC) organizes, conducts, controls, and manages the field phase of the investigation, regardless of whether a Board Member is also on-scene at the accident or incident site. (The role of the Board member at the scene of an accident investigation is as the official spokesperson for the Safety Board.) The IIC has the responsibility and authority to supervise and coordinate all resources and activities of all personnel, both Board and non-Board, involved in the on-site investigation. The IIC continues to have considerable organizational and management responsibilities throughout later phases of the investigation, up to and including Board consideration and adoption of a report or brief of probable cause(s).

§ 831.9 Authority of Board representatives.

(a) General. Any employee of the Board, upon presenting appropriate credentials, is authorized to enter any property where an accident/incident subject to the Board's jurisdiction has occurred, or wreckage from any such accident/incident is located, and do all things considered necessary for proper investigation. Further, upon demand of an authorized representative of the Board and presentation of credentials, any Government agency, or person having possession or control of any transportation vehicle or component thereof, any facility, equipment, process or controls relevant to the investigation, or any pertinent records or memoranda, including all files, hospital records, and correspondence then or thereafter existing, and kept or required to be kept, shall forthwith permit inspection, photographing, or copying thereof by such authorized representative for the purpose of investigating an accident or incident, or preparing a study, or related to any special investigation pertaining to safety or the prevention of accidents. The Safety Board may issue a subpoena, enforceable in Federal district court, to obtain testimony or other evidence. Authorized representatives of the Board may question any person having knowledge relevant to an accident/incident, study, or special investigation. Authorized representatives of the Board also have exclusive authority, on behalf of the Board, to decide the way in which any testing

will be conducted, including decisions on the person that will conduct the test, the type of test that will be conducted, and any individual who will witness the test.

(b) Aviation. Any employee of the Board, upon presenting appropriate credentials, is authorized to examine and test to the extent necessary any civil or public aircraft (as specified in § 830.5), aircraft engine, propeller, appliance, or property aboard such aircraft involved in an accident in air commerce.

(c) Surface.

(1) Any employee of the Board, upon presenting appropriate credentials, is authorized to test or examine any vehicle, vessel, rolling stock, track, pipeline component, or any part of any such item when such examination or testing is determined to be required for purposes of such investigation.

(2) Any examination or testing shall be conducted in such a manner so as not to interfere with or obstruct unnecessarily the transportation services provided by the owner or operator of such vehicle, vessel, rolling stock, track, or pipeline component, and shall be conducted in such a manner so as to preserve, to the maximum extent feasible, any evidence relating to the transportation accident, consistent with the needs of the investigation and with the cooperation of such owner or operator.

§ 831.10 Autopsies.

The Board is authorized to obtain, with or without reimbursement, a copy of the report of autopsy performed by State or local officials on any person who dies as a result of having been involved in a transportation accident within the jurisdiction of the Board. The investigator-in-charge, on behalf of the Board, may order an autopsy or seek other tests of such persons as may be necessary to the investigation, provided that to the extent consistent with the needs of the accident investigation, provisions of local law protecting religious beliefs with respect to autopsies shall be observed.

§ 831.11 Parties to the investigation.

(a) All Investigations, regardless of mode.

(1) The investigator-in-charge designates parties to participate in the investigation. Parties shall be limited to those persons, government agencies, companies, and associations whose employees, functions, activities, or products were involved in the accident or incident and who can provide suitable qualified technical personnel actively to assist in the investigation. Other than the FAA in aviation cases, no other entity is afforded the right to participate in Board investigations.

(2) Participants in the investigation (i.e., party representatives, party coordinators, and/or the larger party organization) shall be responsive to the direction of Board representatives and may lose party status if they do not comply with their assigned duties and activity proscriptions or instructions, or if they conduct themselves in a manner prejudicial to the investigation.

(3) No party to the investigation shall be represented in any aspect of the NTSB investigation by any person who also represents claimants or insurers. No party representative may occupy a legal position (see § 845.13 of this chapter). Failure to comply with these provisions may result in sanctions, including loss of status as a party.

(4) Title 49, United States Code § 1132 provides for the appropriate participation of the FAA in Board investigations, and § 1131(a)(2) provides for such participation by other departments, agencies, or instrumentalities. The FAA and those other entities that meet the requirements of paragraph (a)(1) of this section will be parties to the investigation with the same rights and privileges and subject to the same limitations as other parties, provided however that representatives of the FAA need not sign the "Statement of Party Representatives to NTSB Investigation" (see paragraph (b) of this section).

(b) Aviation investigations. In addition to compliance with the provisions of paragraph (a) of this section, and to assist in ensuring complete understanding of the requirements and limitations of party status, all party representatives in aviation

investigations shall sign "Statement of Party Representatives to NTSB Investigation" immediately upon attaining party representative status. Failure timely to sign that statement may result in sanctions, including loss of status as a party.

§ 831.12 Access to and release of wreckage, records, mail, and cargo.

(a) Only the Board's accident investigation personnel, and persons authorized by the investigator-in-charge to participate in any particular investigation, examination or testing shall be permitted access to wreckage, records, mail, or cargo in the Board's custody.

(b) Wreckage, records, mail, and cargo in the Board's custody shall be released by an authorized representative of the Board when it is determined that the Board has no further need of such wreckage, mail, cargo, or records. When such material is released, Form 6120.15, "Release of Wreckage," will be completed, acknowledging receipt.

§ 831.13 Flow and dissemination of accident or incident information.

(a) Release of information during the field investigation, particularly at the accident scene, shall be limited to factual developments, and shall be made only through the Board Member present at the accident scene, the representative of the Board's Office of Public Affairs, or the investigator-in-charge.

(b) All information concerning the accident or incident obtained by any person or organization participating in the investigation shall be passed to the IIC through appropriate channels before being provided to any individual outside the investigation. Parties to the investigation may relay to their respective organizations information necessary for purposes of prevention or remedial action. However, no information concerning the accident or incident may be released to any person not a party representative to the investigation (including non-party representative employees of the party organization) before initial release by the Safety Board without prior consultation and approval of the IIC.

§ 831.14 Proposed findings.

(a) General. Any person, government agency, company, or association whose employees, functions, activities, or products were involved in an accident or incident under investigation may submit to the Board written proposed findings to be drawn from the evidence produced during the course of the investigation, a proposed probable cause, and/or proposed safety recommendations designed to prevent future accidents.

(b) Timing of submissions. To be considered, these submissions must be received before the matter is calendared for consideration at a Board meeting. All written submissions are expected to have been presented to staff in advance of the formal scheduling of the meeting. This procedure ensures orderly and thorough consideration of all views.

(c) Exception. This limitation does not apply to safety enforcement cases handled by the Board pursuant to part 821 of this chapter. Separate ex parte rules, at part 821, subpart J, apply to those proceedings.

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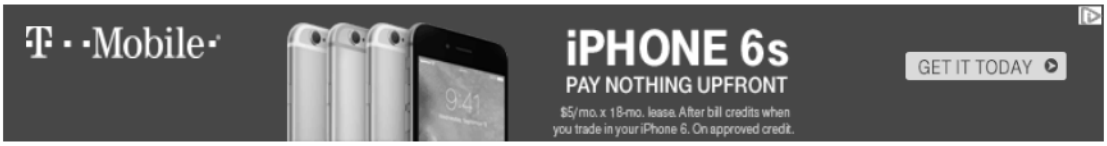

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NTSB: Duck boat in Seattle crash didn't have recommended fix

AP By GENE JOHNSON
September 28, 2015 1:13 AM

SEATTLE (AP) — A Seattle duck boat that swerved wildly into an oncoming charter bus last week, killing five people and injuring dozens, did not have an axle repair that was recommended for at least some of the amphibious vehicles in 2013, the National Transportation Safety Board said Sunday.

Ride the Ducks International, which refurbished the boat in 2005, issued a warning to its customers

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two years ago about potential axle failure and recommended a specific repair or increased monitoring, NTSB member Earl Weener said.

"This particular duck had not had the fix," he told a news conference.

Witnesses described seeing the duck boat's left front tire lock up before it veered into the bus on the Aurora Bridge, and federal investigators announced Saturday that they found the duck boat's left front axle sheared off — though they said it wasn't clear if the axle had broken before or after the collision.

Ride the Ducks International informed investigators late Saturday that it had issued the warning, he said. It's unclear if the company that owns the vehicle — Ride the Ducks of Seattle — was aware of the warning, Weener said.

"We're going to be following that," he said.

Seattle Police officers look under a "Ride the Ducks" tourist vehicle as a tire and wheel …

Ride The Ducks of Seattle owner Brian Tracey said Sunday night the company was cooperating fully with authorities. And in a statement Tracey said he was in "complete agreement" with calls by Gov. Jay Inslee and Seattle Mayor Ed Murray that the duck boats remain sidelined pending a state inspection of all the vehicles.

Tracey said the company was "absolutely heartbroken" about the accident.

Four international college students died at the scene of the crash, and a fifth — identified as a 20-year-old woman — died Sunday, Harborview Medical Center said. They were among about 45 students and staff from North Seattle College who were on the bus on the six lane bridge with no median when the tourist-carrying duck boat swerved into it.

More than 50 people were taken to hospitals. At least 13 people remained at Seattle hospitals Sunday.

The amphibious vehicle tours are offered around the world, including in Philadelphia; Austin, Texas; Miami; Fort Lauderdale, Fla.; and London. They feature former military landing craft

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repurposed as tour vehicles.

The vehicle involved in the Seattle crash was an Army surplus craft built in 1945. It was refurbished with a General Motors engine and chassis in 2005, Weener said.

A towing worker stands in front of a charter passenger bus that was involved in a fatal crash with a …

The NTSB had few details Sunday about the warning Ride the Ducks International issued. It wasn't clear what prompted the warning or how the potential failure was discovered, or whether it applied to all duck boats or only those that the company had refurbished, he said. It wasn't clear how many of the 100 duck boats in service nationally may have had the repair, he said.

The warning included specific instructions for inspecting the area where the shaft could fail, as well as instructions for the repair, which involved welding collars around the axle shaft, Weener said.

Results of the federal probe are not expected for a year, he said. Investigators have interviewed 11 surviving passengers, including eight who were on the duck, as well as first responders. They expect to interview the drivers of the charter bus and the duck this week.

Weener described Ride the Ducks of Seattle as cooperative, and said the company had turned over training records and maintenance documents for the duck.

It's the first time the NTSB has looked into a land crash of the amphibious vehicles, which critics say are too dangerous for city streets. The federal agency has scrutinized duck tour vehicles several times when they've been in accidents on water.

State regulators also have opened an investigation, which entails inspecting all vehicle and driver records. The Washington Utilities and Transportation Commission will meet Monday to discuss its authority to shut down the company until that review is complete, Inslee said.

The amphibious vehicle involved in the crash — known as Duck No. 6 — underwent regular annual examinations by a federally certified inspector, most recently in 2015 and 2014, and met federal standards, said commission spokeswoman Amanda Maxwell.

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NTSB: Duck vehicle didn't have recommended axle repair

KING-TV, Seattle *8:46 a.m. EDT September 28, 2015*

Officials say a 20-year-old woman has become the fifth person to die from a duck boat crash in Seattle. Also, the National Transportation Safety Board found the duck boat did not have an axle repair that was recommended in 2013. VPC

(Photo: KING)

SEATTLE — The National Transportation Safety Board says a duck boat involved in a fatal Seattle crash didn't have an axle repair that was recommended (/story/news/local/seattle/2015/09/27/duck-in-seattle-crash-didnt-have-recommended-fix/72946356/) for the amphibious vehicle in 2013.

NTSB member Earl Weener said Sunday that investigators only recently learned that Ride the Ducks International issued a warning in 2013 about potential axle failure and recommended a specific repair. But Weener says the boat involved in Seattle crash didn't have the fix.

Weener says it's unclear if the company that owns the vehicle — Ride the Ducks of Seattle — was aware of the warning.

USA TODAY

Feds: Axle of duck boat in deadly crash 'sheared off'

(http://www.usatoday.com/story/news/2015/09/27/front-axle-of-duck-boat-in-seattle-crash-with-bus-that-killed-four-student-was-sheared-off-investigators-say/72918604/)

"We're going to be following that up as we continue to gather facts back in Washington, D.C., as well," he said.

Late Sunday, Washington Gov. Jay Inslee said the state will seek to suspend the operations of Seattle's duck boat fleet pending the outcome of the investigation.

Inslee and Seattle Mayor Ed Murray said in a statement Sunday night that the Washington Utilities and Transportation Commission will meet Monday to discuss its authority to suspend Ride the Ducks of Seattle until the review is complete.

The company says it has already temporarily halted its operations while it assists investigators.

The commission says it wants to inspect each amphibious tour vehicle in the company's fleet and review the records of every driver.

USA TODAY

Bus-Duck vehicle crash kills students from 4 countries

(http://www.usatoday.com/story/news/nation/2015/09/25/students-killed-bus-duck-vehicle-crash/72806212/)

Investigators said Saturday that the left front axle of the duck boat was sheared off, but they hadn't determined if that damage happened before the collision or during it.

The federal probe is expected to take months.

It's the first time the NTSB has looked into a land crash of the amphibious vehicles, which critics say are too dangerous for city streets. The federal agency has scrutinized duck tour vehicles several times when they've been in accidents on water.

State regulators also have opened an investigation, which entails inspecting all vehicle and driver records.

The amphibious vehicle involved in the crash — known as Duck No. 6 — underwent regular annual examinations by a federally certified inspector, most recently in 2015 and 2014, and met federal standards, Washington Utilities and Transportation Commission spokeswoman Amanda Maxwell said.

Ride the Ducks International refurbished the duck boat in 2005.

The crash last week between that vehicle and a charter bus left four international college students dead at the scene. A fifth student, (/story/news/local/seattle/2015/09/27/5th-victim-of-aurora-bridge-crash-dies/72947364/) a 20-year-old woman attending North Seattle College, died Sunday, according to Harborview Medical Center, where more than a dozen people remain hospitalized from the accident.

The amphibious vehicle tours are offered around the world, including in Philadelphia; Austin, Texas; Miami; Fort Lauderdale, Fla.; and London.

Contributing: The Associated Press

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Questions for NHTSA:

1. Should Ride the Ducks have been required to submit SB -00-14-13 to NHTSA under 579.5?
2. Should Ride the Ducks have been required to recall the axle issue under 573?
3. Should Ride the Ducks vehicles be required to meet FMVSS?

The answers to these questions depend on if the vehicles meet the definition of motor vehicle and if Ride the Ducks meets the definition of a manufacturer.

In order to determine if Ride the Ducks is a manufacturer, NHTSA needs to understand how the duck vehicles were manufactured or remanufactured and what changes were made to the original vehicle.

877-887-8225

Ride the Ducks

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Ride The Ducks is headquartered in Atlanta, GA with development and training facilities in Branson, MO.

Ride The Ducks was hatched in 1977 in Branson, Missouri when local entrepreneur Bob McDowell acquired a small sightseeing business and quickly adopted the mission to build a better guest experience. Today, our fleet exceeds 95 vehicles, carrying over 1,500,000 guests each year in 8 USA locations.

1977

The McDowell's launch Ride The Ducks in Branson, MO

1994

Ride The Ducks agrees to provide vehicles to Boston Duck Tours, a relationship that continues today.

1997

Ride The Ducks agrees to provide vehicles to Ride The Ducks of Seattle, also a relationship that continues today.

1999

RTD subsidiary Amphibious Vehicle Manufacturing receives USCG approval for patented “Stretch Duck,” significantly improving the classic WWII DUKW

2003

Ride The Ducks opens in Philadelphia and Stone Mountain Park (GA).

2004

Herschend Family Entertainment acquires Ride The Ducks International

2006

Amphibious Vehicle Manufacturing receives USCG approval for patented “Truck Duck,” an entirely new and modern design based on nearly 30

years of operating experience

2008

Ride The Ducks launches in Newport, KY (across the river from Cincinnati).

2012

Ride The Ducks becomes an independent company.

2014

Ride The Ducks opens in Guam.

Branson Philadelphia Stone Mountain Newport, KY Guam

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Let's talk!

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Ride The Ducks International

World Class Ducks

Featuring

Splash DUCKS™

Branson Philadelphia Stone Mountain Newport, KY
Guam

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Seattle Aurora Bridge Accident
Media Statement
September 28, 2015

STATEMENT FROM RIDE THE DUCKS INTERNATIONAL, LLC REGARDING THE SEATTLE AURORA BRIDGE ACCIDENT

We continue to monitor developments surrounding the tragedy in Seattle and offer our prayers and profound sympathy to those affected by this accident.
The National Transportation Safety Board ("NTSB") has requested Ride The Ducks International ("RTDI") to serve as a technical resource to its investigation team. We have agreed, as we are committed to gaining a full understanding of the possible causes of this tragic accident. While the NTSB process is very thorough, it significantly limits public discussion of findings until the investigation is complete. As a result, it would be inappropriate for RTDI to share details of the NTSB's ongoing investigation, or engage in speculation.

Ride The Ducks of Seattle is an independently owned and operated licensee. It purchased the vehicle involved in the accident from RTDI in January 2005. The terms of our agreement do not allow us to independently inspect or audit the equipment after delivery. However, we do continue to provide all licensees access to our knowledge base – this includes service bulletins, regular conference calls, and sharing of best practices. The Seattle team has been a part of this process.

The NTSB has released information about a 2013 service bulletin issued by RTDI to our company-owned locations and our licensees regarding a recommended front axle housing repair involving 57 Duck vehicles. This bulletin is typical of the ongoing communication we have with all operators of

these vehicles, all of which are either owned by RTDI or one of our licensees. We had no reason to believe that Seattle had not complied with the bulletin. We can say that the operators of the other in-service vehicles covered by the bulletin in Stone Mountain Park, GA, Branson, MO, Newport, KY, and Philadelphia, PA had complied. This maintenance work involved inspection and reinforcement of the front axle housing assembly.

Safety:

All vehicles used by RTDI and its licensees are fully modern designs, built to DOT specifications and under supervision by the United States Coast Guard, with ongoing periodic inspections by various state and federal agencies. While our vehicles contain limited elements of their military origins such as the original frame rails, the vehicle is fully refurbished, modernized and updated to meet and exceed DOT standards. This includes everything from engine, suspension, interior, and safety equipment similar to what is found in a modern bus or heavy duty truck.

After delivery, many RTDI owned & licensed locations such as Branson, Stone Mountain Park, Newport, and Philadelphia regularly utilize independent third-party inspectors (in addition to state and federal agencies) to audit and further confirm our vehicles' safety on the road and on the water. Finally, every vehicle is inspected multiple times each operating day by specially trained personnel using a multi-point safety checklist.

Across the United States, these vehicles carry more than 1.5 million passengers on over 50,000 trips each year.

Branson Philadelphia Stone Mountain Newport, KY
Guam

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York, Bruce (NHTSA)

From: Matheke, Otto (NHTSA)
Sent: Thursday, November 10, 2016 4:27 PM
To: Thomas, Bryan (NHTSA); York, Bruce (NHTSA)
Subject: FW: DUCKSDRAFTConsent OrderNov10 CLEAN.docx
Attachments: DUCKSDRAFTConsent OrderNov10 CLEAN.docx

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Matheke, Otto (NHTSA)
Sent: Thursday, November 10, 2016 4:25 PM
To: Jacqueline Glassman (jglassman@kslaw.com)
Cc: Kolodziej, Kerry (NHTSA); Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA); O'Donnell, Melanie (NHTSA)
Subject: DUCKSDRAFTConsent OrderNov10 CLEAN.docx

Jackie:

Our responses to your suggestions to the last draft are incorporated in this document. From our perspective, there is very little in this version that we consider to be negotiable.

You will see that Paragraph 36 contains language addressing your concern that some compliance issues may require additional time to resolve. In regard to your concerns about VIN issues, I know you now understand our position regarding the importance of complying with the VIN requirements. You will also note that we are not agreeing to your suggestion that the compliance plan not be made public. I don't see any basis for us not making the document public even if we were inclined to do so. We have also deleted your suggested language about the existing engineering analysis of the axles being sufficient. You will note that the document explicitly states that credit will be given for work already done when considering the compliance plan and other requirements.

I will be out of the office tomorrow but will be checking my email and can be reached either on my personal cel phone at 202-236-2958 or my work cel number below.

I expect that Mr. Herschend and Mr. Hultz will be coming to town for the NTSB hearing on Tuesday. If they have not done so already, I strongly suggest that their travel plans include arriving early on Monday to either execute an agreement or come in with you in on Monday morning to hammer out a deal and sign an agreement.

York, Bruce (NHTSA)

From: Chris Herschend <no-reply@evernote.com>
Sent: Tuesday, September 27, 2016 10:06 AM
To: York, Bruce (NHTSA)
Subject: Here is my contact info
Attachments: Chris Herschend.vcf

It was nice meeting you. Here is my contact info.

Chris Herschend
President
Ride The Ducks LLC

Phone
(678) 466-7090
(404) 272-6460
Email
chris@herschendfamily.com
Twitter
@chris_herschend
Address
1380 W Paces Ferry Rd, Suite 1210
Atlanta GA 30327
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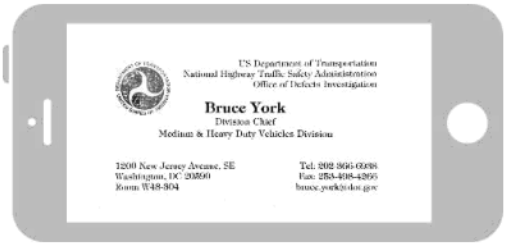

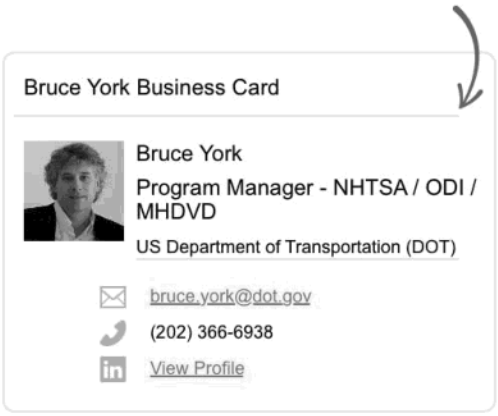

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York, Bruce (NHTSA)

From: Matheke, Otto (NHTSA)
Sent: Tuesday, September 13, 2016 4:48 PM
To: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA); York, Bruce (NHTSA)
Subject: FW: Ride the Ducks
Attachments: RTDI Audited Financial Statements FYE 1-3-16.pdf; RTDI 2016 Financial Forecast.pdf

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Iannetta, Christie [mailto:CIannetta@KSLAW.com]
Sent: Monday, September 12, 2016 5:49 PM
To: Matheke, Otto (NHTSA)
Cc: Glassman, Jacqueline
Subject: Ride the Ducks

Otto –

As discussed, here is the RTDI 2014 and 2015 audited financial statement as well as a preliminary financial forecast for 2016.

Thanks. Christie.

Christie L. Iannetta
KING & SPALDING LLP
1700 Pennsylvania Ave, N.W.
Washington D.C. 20006
Direct: (202) 626-9229
E-mail: ciannetta@kslaw.com

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(202) 366-5253

From: York, Bruce (NHTSA)
Sent: Wednesday, August 31, 2016 10:51 AM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Otto,

Thanks for the copy. What should I be saying to NTSB?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
Room W48-304

(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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www.safercar.gov, www.safertruck.gov

From: Matheke, Otto (NHTSA)
Sent: Wednesday, August 31, 2016 10:48 AM
To: York, Bruce (NHTSA)
Subject: FW: Ducks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 30, 2016 5:21 PM
To: Matheke, Otto (NHTSA)
Cc: Torres, Justin; Iannetta, Christie
Subject: RE: Ducks

Otto –

I have checked on the status of the campaign with RTDI. The modifications specified in RTDI service bulletin SB-00-14-13 were completed on all affected, active and in-service Stretch Amphibious Passenger Vessels (APVs), except the 10

York, Bruce (NHTSA)

From: Matheke, Otto (NHTSA)
Sent: Wednesday, August 31, 2016 10:48 AM
To: York, Bruce (NHTSA)
Subject: FW: Ducks
Attachments: WKG-#5597025-v1-RTDI_Assembly_Timeline_Stretch_Duck_Application RTDI-NTS....pdf

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 30, 2016 5:21 PM
To: Matheke, Otto (NHTSA)
Cc: Torres, Justin; Iannetta, Christie
Subject: RE: Ducks

Otto –

I have checked on the status of the campaign with RTDI. The modifications specified in RTDI service bulletin SB-00-14-13 were completed on all affected, active and in-service Stretch Amphibious Passenger Vessels (APVs), except the 10 Stretch APVs owned and operated by RTD Seattle. RTDI's understanding is that those Stretch APVs have not been in service since the incident.

Of the 57 Stretch APVs affected by the service bulletin, the vessels with the modification completed are located as follows:

Branson, MO - 19 Stretch APVs
Philadelphia, PA - 12 Stretch APVs
Stone Mountain Park, GA - 5 APVs
Newport, KY - 4 APVs
Mobile, AL - 3 APVs

One Stretch APV was dismantled and there are 3 non-operable, partially dismantled Stretch AVPs located in storage in Branson that have not operated in more than five years and were not modified. That accounts for all 57 Stretch APVs. There have been no issues reported on vessels where the modification was completed.

RTDI also issued a subsequent service bulletin SB-00-01-16 regarding Non-Destructive Testing that included testing of the axle housing modification. This testing was also completed on all Stretch APVs where the modification was completed and on all inventoried replacement axle housings. No issues were reported.

Attached is a confidential timeline provided to NTSB that led to the issuance of SB-00-14-13. If necessary, I can provide the full confidentiality submission, but wanted to send this information to you as quickly as possible. The agency may already have this timeline from NTSB.

In light of the fact that the modifications have been made to all operable APVs, and we understand that RTD Seattle would need to do so before placing their vessels back into service, we do not see the need for a Part 573 letter with regard to this particular issue. As we discussed last week, RTDI intends prospectively to provide the agency with service bulletins, and the Part 573 and accompanying recall reports when a recall is appropriate.

Please let me know whether you need any further information on this point. We would like to meet with the agency to resolve the remaining issues, preferably in mid to late September.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Monday, August 29, 2016 5:25 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Thanks for the information.

What is your client's position regarding filing a 573 for the front axle issue?

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, August 25, 2016 5:56 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Amphibious vehicle manufacturers are:

Advanced Amphibious Design (Hawaii) – which also uses older military vehicles
Cool Amphibious Manufacturing International (Bluffton, SC) – which uses modern chassis
Salamander (Northern Ireland) is not selling into the US as of yet – also uses modern chassis

---

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 5:12 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Yes. I am in a meeting from 2 until 4 but free all day otherwise. Pick a time and let me know.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 23, 2016 5:09 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Can we talk on Thursday?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 4:57 PM
To: Glassman, Jacqueline
Subject: Ducks

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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December 22, 2017

VIA OVERNIGHT MAIL
Jonathan C. Morrison
Chief Counsel
National Highway Traffic Safety Administration
West Building, Room W41-227
1200 New Jersey Avenue SE
Washington, DC 20590

Re: Request for Confidential Treatment – Ride the Ducks International, LLC

Dear Mr. Morrison:

Ride the Ducks International, LLC ("RTDI") submits this request for confidential treatment for certain information submitted to the agency on September 12, 2016. After careful review, RTDI has concluded that this information is competitively sensitive and should be withheld from public disclosure under Exemption 4 of the Freedom of Information Act, 5 U.S.C. § 552(b)(4), and 49 C.F.R. Part 512.

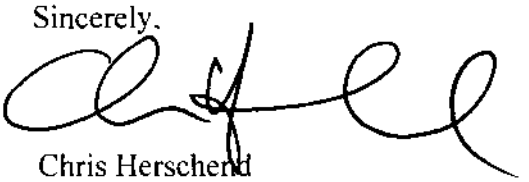
Specifically, RTDI seeks confidential treatment for two documents in their entirety: (1) RTDI's financial forecast statement for 2016, and (2) the Ride the Ducks International, LLC Independent Auditor's Report and Consolidated Financial Statements - January 3, 2016 and December 28, 2014. The information is thus entitled to confidential treatment pursuant to the standard set forth in *Critical Mass Energy Project v. NRC*, 975 F.2d 871 (D.C. Cir. 1992). The information for which RTDI seeks confidential treatment includes detailed breakdowns and descriptions of RTDI's finances. RTDI is a privately held company and this information would provide competitor organizations and the public at large with an understanding of its financial status and organization. Disclosure of this type of information would provide competitors with an unfair competitive advantage over RTDI. RTDI presented this information to the agency voluntarily and does not generally share financial information of this type with the public. The disclosure of this type of information will impede the agency's ability to obtain similar information in the future. The information for which RTDI seeks confidential treatment is also protected under the standard set forth in *National Parks & Conservation Ass'n v. Morton*, 498 F.2d 765 (D.C. Cir. 1974), because disclosure of the information would likely cause substantial competitive harm to RTDI.

The information for which RTDI seeks confidential treatment has been appropriately marked on the confidential versions of the documents which are enclosed with this request. Public versions have also been enclosed. The requisite number of copies has also been provided pursuant to the agency's regulations. RTDI seeks confidential treatment into perpetuity.

We would appreciate notification should you receive a request for disclosure of this information and, if necessary, a further opportunity to substantiate why this information is entitled to confidential treatment.

Please contact me if you have any questions.

Sincerely,



Chris Herschend
President
Ride the Ducks International, LLC

Enclosures: 2 copies of complete submission marked Confidential
1 copy with public redacted version of submission
Certificate in Support of Request for Confidential Treatment

Certificate in Support of Request for Confidentiality

I, Chris Herschend, pursuant to the provisions of 49 C.F.R. Part 512, state as follows:

(1) I am Ride the Ducks International, LLC's ("RTDI") President, and I am authorized by RTDI to execute this certificate on its behalf;

(2) I certify that the information contained in the enclosed attachment is confidential and proprietary data and is being submitted with the claim that it is entitled to confidential treatment under 5 U.S.C. § 552(b)(4);

(3) I hereby request that the information contained in the attached documents be protected permanently or until such time as the information is no longer held confidential by RTDI;

(4) This certification is based on the information provided by the responsible RTDI personnel who have authority in the normal course of business to release the information for which a claim of confidentiality has been made to ascertain whether such information has ever been released outside RTDI;

(5) Based upon that information, to the best of my knowledge, information and belief, the information for which RTDI has claimed confidential treatment has never been released or become available outside RTDI;

(6) I make no representations beyond those contained in this certificate and, in particular, I make no representations as to whether this information may become available outside RTDI because of unauthorized or inadvertent disclosure; and

(7) I certify under penalty of perjury that the foregoing is true and correct.

Executed on this the 27th day of December, 2017.

(b)(6)

Chris Herschend

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

FEB - 5 2018

Chris Herschend
President
Ride the Ducks International, LLC
1380 W Paces Ferry Road, NW
Suite 1210
Atlanta, GA 30327

Re: Confidentiality Determination/RTDI's Financial Forecast Statement and Independent Auditor's Report and Consolidated Financial Statements

Dear Mr. Herschend:

This responds to your letter of December 22, 2017 requesting confidential treatment for Ride The Ducks International's ("RTDI") financial forecast statement for 2016 as well as RTDI's Independent Auditor's Report and Consolidated Financial Statement – January 3, 2016 and December 28, 2014. RTDI notes that the documents contain detailed breakdowns and descriptions of RTDI's finances. Specifically, RTDI requests confidential treatment for the documents indefinitely.

RTDI describes the two documents as containing information about the financial status and organization of the privately held company that is competitively sensitive. RTDI states that the documents have not been publicly disclosed. RTDI contends that disclosure of these documents would provide its competitors with an unfair competitive advantage over it.

Your request is granted.

Because RTDI submitted this information voluntarily, I reviewed your claim of confidential treatment under the test announced in *Critical Mass Energy Project v. NRC*, 975 F.2d 871, 878 (D.C. Cir. 1992). Under that test, information is confidential if it was submitted voluntarily to the Agency and the information would not customarily be released to the public by the submitter.

I have reviewed your submission, including the documents that you claim are entitled to confidential treatment and the arguments that you assert in support of your claim. I have determined that the information at issue was provided voluntarily and is not customarily

disclosed to the public. RTDI has taken measures to ensure that the material has been treated confidentially and has not been publicly released. Further, releasing such information could potentially hinder the government's ability to obtain such information.

Therefore, this information is entitled to confidential treatment pursuant to Exemption 4 of FOIA, 5 U.S.C. § 552(b)(4). Subject to the conditions below, this grant of confidential treatment will remain in effect indefinitely.

This grant of confidential treatment is subject to certain conditions. The information may be disclosed under 49 CFR § 512.22 based upon newly discovered or changed facts, and you must inform the Agency of any changed circumstances that may affect the protection of the information (49 CFR § 512.10). If necessary, you will be notified prior to the release of any information under the procedures established by our regulations (49 CFR § 512.22(b)). Furthermore, this information may be disclosed if such disclosure would be in the public interest, pursuant to the procedures established in 49 CFR § 512.23.

Sincerely,

(b)(6)

Otto G. Matheke, III
Senior Trial Attorney

Ride The Ducks International, LLC

Independent Auditor's Report and Consolidated Financial Statements

January 3, 2016 and December 28, 2014

BKD LLP
CPAs & Advisors

York, Bruce (NHTSA)

From: Umberger, Rodney <rumberger@williamskastner.com>
Sent: Tuesday, April 26, 2016 1:34 PM
To: York, Bruce (NHTSA)
Subject: RE: Ride The Ducks International Responses to Information Requests

Bruce –

The documents and letters were mailed on Friday, April 22.

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com | Bio | V-Card

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From: Bruce.York@dot.gov [mailto:Bruce.York@dot.gov]
Sent: Tuesday, April 26, 2016 10:27 AM
To: Umberger, Rodney <rumberger@williamskastner.com>
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. Umberger,

Was the RTDI response sent in?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
Room W48-304

(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Thursday, April 21, 2016 8:55 PM
To: York, Bruce (NHTSA)
Cc: ODI_IRresponse (NHTSA)
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. York –

I inadvertently omitted ODI_IRresponse@dot.gov on the notification below, and therefore, have cc'd them here.

Regards,

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com | Bio | V-Card

WASHINGTON OREGON ALASKA

From: Umberger, Rodney
Sent: Thursday, April 21, 2016 5:47 PM
To: Bruce.York@dot.gov
Cc: Robby Hultz <rhultz@ridetheducks.com>
Subject: Ride The Ducks International Responses to Information Requests

Mr. York:

Thank you for your courtesies in allowing us additional time to complete these responses.

This email serves as notification that Ride the Ducks International, LLC ("RTDI") will be formally responding to your office's information requests tomorrow. In accordance with the instructions in your February 25 letter, RTDI will be submitting two copies of documents containing confidential information, along with a third copy omitting the confidential information, to the Office of Chief Counsel. As explained in a cover letter that RTDI will be mailing to your office tomorrow morning, RTDI has characterized its answers to the information requests from your office as confidential information, along with many of the documents attached in relation to those answers.

Please do not hesitate to give me a call should you have any questions or concerns.

Very truly yours,

- Rod

York, Bruce (NHTSA)

From: Umberger, Rodney <rumberger@williamskastner.com>
Sent: Thursday, April 21, 2016 8:55 PM
To: York, Bruce (NHTSA)
Cc: ODI_IRresponse (NHTSA)
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. York –

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Regards,

- Rod

Rodney L. Umberger
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601 Union Street, Suite 4100
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WASHINGTON OREGON ALASKA

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Sent: Thursday, April 21, 2016 5:47 PM
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Cc: Robby Hultz <rhultz@ridetheducks.com>
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Mr. York:

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Please do not hesitate to give me a call should you have any questions or concerns.

Very truly yours,

York, Bruce (NHTSA)

From: Umberger, Rodney <rumberger@williamskastner.com>
Sent: Monday, April 11, 2016 3:54 PM
To: York, Bruce (NHTSA)
Subject: RE: Ride The Ducks International - NHTSA Request for Information

Bruce -

I apologize for not getting back to you sooner, but I've been out of the office taking depositions for an upcoming trial and that has had me a bit swamped. I think we have now gathered most of the information you requested and will be in a position to produce that to you this week.

Thanks,

- Rod

Rodney L. Umberger
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WASHINGTON OREGON ALASKA

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-----Original Message-----
From: Bruce.York@dot.gov [mailto:Bruce.York@dot.gov]
Sent: Friday, March 25, 2016 10:28 AM
To: Umberger, Rodney <rumberger@williamskastner.com>
Subject: RE: Ride The Ducks International - NHTSA Request for Information

Rod,

Please do contact me. Thirty days is a big extension. I was thinking 2 weeks. I would look to have some reasonable justification to offer that kind of extension.

Thank You,
Bruce York

Division Chief

Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
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bruce.york@dot.gov

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-----Original Message-----
From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Friday, March 25, 2016 12:36 PM
To: York, Bruce (NHTSA)
Subject: Re: Ride The Ducks International - NHTSA Request for Information

Bruce,

We believe we can get this done within an additional 30 days of time if that is okay.

Thank you, and I will try to call you next week to discuss this a bit further.

Thank you,

- Rod

On Mar 25, 2016, at 6:58 AM, "Bruce.York@dot.gov<mailto:Bruce.York@dot.gov>"
<Bruce.York@dot.gov<mailto:Bruce.York@dot.gov>> wrote:

Rod,

How much additional time is required?

Thank You,
Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
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Rodney L. Umberger
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www.williamskastner.com<http://www.williamskastner.com> |
Bio<http://www.williamskastner.com/attorneys/umberger-rodney-l/> | V-Card<http://www.williamskastner.com/v-cards/RodneyUmberger.vcf>

WASHINGTON OREGON ALASKA

From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Wednesday, March 23, 2016 9:35 PM
To: York, Bruce (NHTSA)
Subject: Ride The Ducks International - NHTSA Request for Information

Bruce –

Thank you very much for calling me back today. In accordance with your instructions, I am following up on my earlier telephone request with a written email request for additional time to respond to the NHTSA's request for information from my client. We are diligently working on the response but will not be able to provide all responsive information by March 28, 2016. Thank you for your anticipated courtesy and cooperation, and I look forward to speaking with you soon. Unfortunately, I am involved in depositions this week and meetings with experts such that it will be difficult for me to reach you until probably Friday afternoon, but I will endeavor to call you then.

Best regards,

- Rod

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www.williamskastner.com<http://www.williamskastner.com> |
Bio<http://www.williamskastner.com/attorneys/umberger-rodney-l/> | V-Card<http://www.williamskastner.com/v-cards/RodneyUmberger.vcf>

WASHINGTON OREGON ALASKA

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Thank you,

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www.williamskastner.com<http://www.williamskastner.com> |
Bio<http://www.williamskastner.com/attorneys/umberger-rodney-l/> | V-Card<http://www.williamskastner.com/v-cards/RodneyUmberger.vcf>

WASHINGTON OREGON ALASKA

From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Wednesday, March 23, 2016 9:35 PM
To: York, Bruce (NHTSA)
Subject: Ride The Ducks International - NHTSA Request for Information

Bruce –

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Best regards,

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
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P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com<http://www.williamskastner.com> |
Bio<http://www.williamskastner.com/attorneys/umberger-rodney-l/> | V-Card<http://www.williamskastner.com/v-cards/RodneyUmberger.vcf>

WASHINGTON OREGON ALASKA

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- Rod

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WASHINGTON OREGON ALASKA

Cc: Jackson, Angel (NHTSA)
Subject: Media Inquiry: Service Bulletins and OEMs Notifying States

Good morning, all. See the inquiry below re: service bulletins and OEMs notifying the states. What's the appropriate response? The reporter's deadline is COB.

UTC = Utilities and Transportation Commission
Washington State UTC: http://www.utc.wa.gov/Pages/default.aspx

Thanks,
Troy

From: Jeff Burnside [mailto:jburnside@komotv.com]
Sent: Tuesday, September 29, 2015 5:01 PM
To: Public.Affairs, Public.Affairs (NHTSA)
Subject: KOMO TV News Seattle requesting info related to fatal bus-duck boat collision

NHTSA,

Your colleagues at FMSCA suggest I ask you (see string below): We're trying to find out more about "safety bulletins" issued by vehicle manufacturers (this is a question in general but related to the recent fatal collision of the charter bus and Duck boat). The Washington state UTC staff says manufacturers are not required to share "service bulletins" with the UTC, but bulletins from state or federal agencies are shared with them. Is that your understanding for state's nationwide? If so, is there a point in time when state inspectors are made aware of such "service bulletins" so they can verify whether the service action was taken?

Our deadline is 4pm Wednesday Seattle time.

Jeff Burnside
Investigative Reporter
KOMO 4 News (ABC) Seattle
206-795-9973 cell direct 24/7

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http://www.facebook.com/profile.php?id=581701633&ref=tn_tnmn
Bio
http://tinyurl.com/burnsidebio
Society of Environmental Journalists
www.sej.org

From: Jeff Burnside [mailto:jburnside@komotv.com]
Sent: Tuesday, September 29, 2015 4:48 PM
To: DeBruyne, Duane (FMCSA)
Cc: FOIA (FMCSA); Coleman, Tiffanie (FMCSA)
Subject: RE: FOIA request on deadline for KOMO TV Seattle re: fatal bus collision

Duane, Tiffanie, et al;

Thank you again for working to respond to our FOIA so quickly when the Duck boat collided with the charter bus here in Seattle the other day.

I'm now requesting more information on a related issue. The Washington UTC staff tells us that manufacturers are not required to share "safety bulletins" with the Washington state UTC, whose spokesperson told me today they believe this is also the case with other state UTCs nationwide. They suggest I confirm this with FMSCA. Are you able to shed more light on whether manufacturers are not required to share "service bulletins" with state regulators and inspectors? Is there a point during the inspection process where such "safety bulletins" are shared with field inspectors in order for them to verify the safety action has taken place? Is there any system in place to make sure regulators can check on whether "safety bulletins" were acted upon?

The WA UTC says "safety bulletins" and such are shared with them **when issued by state or federal agenices**, but not manufacturers. Here is what the WA UTC staff told me:

The manufactures are not required to file these types of notifications with the commission. If a federal or state agency were to file a notice regarding motor carrier service notifications or issues, the commission would receive notice and take action. The Code of Federal Regulations is what Washington state adopts, under a memorandum of understanding - lead by the Washington State Patrol as lead motor carrier safety agency, and there are no reporting requirements of this type in the CFR. It is my understanding that most states follow the same standards. You might want to check with FMCSA to see which states participate.

Thoughts?

Jeff Burnside
Investigative Reporter
KOMO 4 News (ABC) Seattle
206-795-9973 cell direct 24/7

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http://www.facebook.com/profile.php?id=581701633&ref=tn_tnmn
Bio
http://tinyurl.com/burnsidebio

York, Bruce (NHTSA)

From: York, Bruce (NHTSA)
Sent: Thursday, January 05, 2017 11:11 AM
To: 'Glassman, Jacqueline'
Subject: RE: Independent Engineering Report -- Ride The Ducks International

Jackie,

I have started discussions with NTSB on FEA discrepancies.

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
Room W48-304

(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, December 15, 2016 4:48 PM
To: Sorg, Sarah (NHTSA); York, Bruce (NHTSA)
Subject: Independent Engineering Report -- Ride The Ducks International

Sarah – Attached is the Independent Engineering Report pursuant to Paragraph 45 of the RTDI Consent Order.

Thanks, Jackie

Jacqueline Glassman
King & Spalding LLP
1700 Pennsylvania Avenue, NW
Washington DC 20006
Jglassman@kslaw.com
202-626-9228

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(202) 366-5253

From: York, Bruce (NHTSA)
Sent: Wednesday, August 31, 2016 10:51 AM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Otto,

Thanks for the copy. What should I be saying to NTSB?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
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(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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From: Matheke, Otto (NHTSA)
Sent: Wednesday, August 31, 2016 10:48 AM
To: York, Bruce (NHTSA)
Subject: FW: Ducks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 30, 2016 5:21 PM
To: Matheke, Otto (NHTSA)
Cc: Torres, Justin; Iannetta, Christie
Subject: RE: Ducks

Otto –

I have checked on the status of the campaign with RTDI. The modifications specified in RTDI service bulletin SB-00-14-13 were completed on all affected, active and in-service Stretch Amphibious Passenger Vessels (APVs), except the 10

Stretch APVs owned and operated by RTD Seattle. RTDI's understanding is that those Stretch APVs have not been in service since the incident.

Of the 57 Stretch APVs affected by the service bulletin, the vessels with the modification completed are located as follows:

Branson, MO - 19 Stretch APVs
Philadelphia, PA - 12 Stretch APVs
Stone Mountain Park, GA - 5 APVs
Newport, KY - 4 APVs
Mobile, AL - 3 APVs

One Stretch APV was dismantled and there are 3 non-operable, partially dismantled Stretch AVPs located in storage in Branson that have not operated in more than five years and were not modified. That accounts for all 57 Stretch APVs. There have been no issues reported on vessels where the modification was completed.

RTDI also issued a subsequent service bulletin SB-00-01-16 regarding Non-Destructive Testing that included testing of the axle housing modification. This testing was also completed on all Stretch APVs where the modification was completed and on all inventoried replacement axle housings. No issues were reported.

Attached is a confidential timeline provided to NTSB that led to the issuance of SB-00-14-13. If necessary, I can provide the full confidentiality submission, but wanted to send this information to you as quickly as possible. The agency may already have this timeline from NTSB.

In light of the fact that the modifications have been made to all operable APVs, and we understand that RTD Seattle would need to do so before placing their vessels back into service, we do not see the need for a Part 573 letter with regard to this particular issue. As we discussed last week, RTDI intends prospectively to provide the agency with service bulletins, and the Part 573 and accompanying recall reports when a recall is appropriate.

Please let me know whether you need any further information on this point. We would like to meet with the agency to resolve the remaining issues, preferably in mid to late September.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Monday, August 29, 2016 5:25 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Thanks for the information.

What is your client's position regarding filing a 573 for the front axle issue?

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, August 25, 2016 5:56 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Amphibious vehicle manufacturers are:

Advanced Amphibious Design (Hawaii) – which also uses older military vehicles
Cool Amphibious Manufacturing International (Bluffton, SC) – which uses modern chassis
Salamander (Northern Ireland) is not selling into the US as of yet – also uses modern chassis

---

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 5:12 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Yes. I am in a meeting from 2 until 4 but free all day otherwise. Pick a time and let me know.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 23, 2016 5:09 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Can we talk on Thursday?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 4:57 PM
To: Glassman, Jacqueline
Subject: Ducks

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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York, Bruce (NHTSA)

From: York, Bruce (NHTSA)
Sent: Wednesday, August 31, 2016 10:51 AM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Otto,

Thanks for the copy. What should I be saying to NTSB?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
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bruce.york@dot.gov

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From: Matheke, Otto (NHTSA)
Sent: Wednesday, August 31, 2016 10:48 AM
To: York, Bruce (NHTSA)
Subject: FW: Ducks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 30, 2016 5:21 PM
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Cc: Torres, Justin; Iannetta, Christie
Subject: RE: Ducks

Otto –

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Please let me know whether you need any further information on this point. We would like to meet with the agency to resolve the remaining issues, preferably in mid to late September.

Thanks, Jackie

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Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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Subject: RE: Ducks

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Cool Amphibious Manufacturing International (Bluffton, SC) – which uses modern chassis
Salamander (Northern Ireland) is not selling into the US as of yet – also uses modern chassis

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Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

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Sent: Tuesday, August 23, 2016 4:57 PM
To: Glassman, Jacqueline
Subject: Ducks

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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York, Bruce (NHTSA)

From: York, Bruce (NHTSA)
Sent: Wednesday, May 18, 2016 8:13 AM
To: Umberger, Rodney
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. Umberger,

We have received the RDTI response to the information request. Thank you for your assistance.

In the response to question number one, a hard copy of a spread sheet was submitted. Can you please email me the spread sheet as a Microsoft Excel file?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
Washington, D.C. 20590
Room W48-304

(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Tuesday, April 26, 2016 1:34 PM
To: York, Bruce (NHTSA)
Subject: RE: Ride The Ducks International Responses to Information Requests

Bruce –

The documents and letters were mailed on Friday, April 22.

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com | Bio | V-Card

WASHINGTON OREGON ALASKA

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From: Bruce.York@dot.gov [mailto:Bruce.York@dot.gov]
Sent: Tuesday, April 26, 2016 10:27 AM
To: Umberger, Rodney <rumberger@williamskastner.com>
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. Umberger,

Was the RTDI response sent in?

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
Office of Defects Investigation
1200 New Jersey Avenue, S.E.
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(202) 366-6938
(877) 536-8368 Ext. 66938
bruce.york@dot.gov

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From: Umberger, Rodney [mailto:rumberger@williamskastner.com]
Sent: Thursday, April 21, 2016 8:55 PM
To: York, Bruce (NHTSA)
Cc: ODI_IRresponse (NHTSA)
Subject: RE: Ride The Ducks International Responses to Information Requests

Mr. York –

I inadvertently omitted ODI_IRresponse@dot.gov on the notification below, and therefore, have cc'd them here.

Regards,

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com | Bio | V-Card

WASHINGTON OREGON ALASKA

From: Umberger, Rodney
Sent: Thursday, April 21, 2016 5:47 PM
To: Bruce.York@dot.gov
Cc: Robby Hultz <rhultz@ridetheducks.com>
Subject: Ride The Ducks International Responses to Information Requests

Mr. York:

Thank you for your courtesies in allowing us additional time to complete these responses.

This email serves as notification that Ride the Ducks International, LLC ("RTDI") will be formally responding to your office's information requests tomorrow. In accordance with the instructions in your February 25 letter, RTDI will be submitting two copies of documents containing confidential information, along with a third copy omitting the confidential information, to the Office of Chief Counsel. As explained in a cover letter that RTDI will be mailing to your office tomorrow morning, RTDI has characterized its answers to the information requests from your office as confidential information, along with many of the documents attached in relation to those answers.

Please do not hesitate to give me a call should you have any questions or concerns.

Very truly yours,

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
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From: Umberger, Rodney
Sent: Thursday, April 21, 2016 5:47 PM
To: Bruce.York@dot.gov
Cc: Robby Hultz <rhultz@ridetheducks.com>
Subject: Ride The Ducks International Responses to Information Requests

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Very truly yours,

- Rod

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WASHINGTON OREGON ALASKA

Earlier I asked you if you might help me find a direct contact at Ride The Ducks International. If possible, could you also see if the NTSB team on site has acquired the vehicle title and registration? We would like to know the vehicle and its history a little better.

Thank You,

Bruce York

Division Chief
Medium & Heavy Duty Vehicles Division
U.S. Department Of Transportation
National Highway Traffic Safety Admin.
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bruce.york@dot.gov

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From: Kolly, Joseph (NHTSA)
Sent: Tuesday, September 29, 2015 10:57 AM
To: York, Bruce (NHTSA)
Subject: FW: service bulletin

Bruce,

Here is the TSB you asked me to help you obtain. Please see Acting Director Molloy's request for a heads up if NHTSA is planning any action.

Thanks,
Joe

From: Ritter James [mailto:ritterj@ntsb.gov]
Sent: Tuesday, September 29, 2015 10:54 AM
To: Kolly, Joseph (NHTSA); Kolly Joseph
Subject: service bulletin

Fyi- and please let us know if they decide to take any actions.

From: Molloy Robert
Sent: Tuesday, September 29, 2015 10:51 AM
To: Ritter James
Subject:

Per your request—I would like to get a heads up if NHTSA is planning action.

Rob

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Ride the Ducks Component Summary/History

Design version	Axle Model #	Axle Origin	Transmission Model #	Transmission Origin	Engine Model #	Engine Origin	Hull Origin	Chassis Origin
FleetDukw								
StretchDuck PS 1-29								
StretchDuck PS 30-57								
TruckDuck								
Duck Boat #47								

For origin cells please indicate one of the following:
Original (retained from the original duck vehicle)
Used (transferred from another used vehicle)
New (newly manufacturerd component)
Old/New (very old part still in original packaging)

NHTSA Current Assesment:

Design version	Axle Model #	Axle Origin	Transmission Model #	Transmission Origin	Engine Model #	Engine Origin	Hull Origin	Chassis Origin
FleetDukw	M-211/M-135	Used			427 GMC gas		Original	Original
StretchDuck PS 1-29	M-211/M-136	Used			428 GMC gas		Original	Original
StretchDuck PS 30-57	M-211/M-137	Used			429 GMC gas		New	Original
TruckDuck		Used			7.3 Ford Powerstroke diesel		New	New
Duck Boat #47	M-211/M-136	Used			429 GMC gas		New	Original

Ride the Ducks Component Summary/History

VIN	Make	Design version/Model	Model Year	Re-Manufacture Date	Axle Model #	Axle Origin	Transmission Model #	Transmission Origin	Engine Model #	Engine Origin	Hull Origin	Chassis Origin

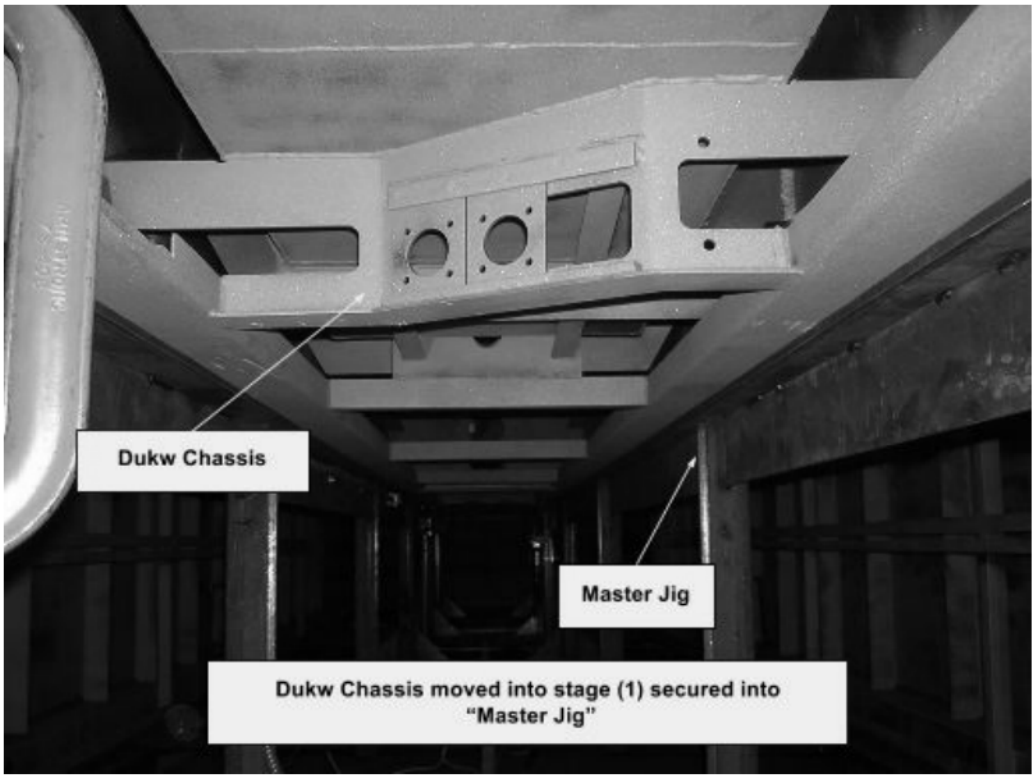
For origin cells please indicate one of the following:
Original (retained from the original duck vehicle)
Used (transferred from another used vehicle)
New (newly manufacturerd component)
Old/New (very old part still in original packaging)

NHTSA Example Data:

VIN	Make	Design version	Model Year	Re-Manufacture Date	Axle Model #	Axle Origin	Transmission Model #	Transmission Origin	Engine Model #	Engine Origin	Hull Origin	Chassis Origin
xxxxxxxxxxxxxxxxx	General Motors	FleetDukw	1953	1/21/2005	M-211/M-135	Used			427 GMC gas		Original	Original
xxxxxxxxxxxxxxxxx	RDTI	StretchDuck PS 1-29	1953	3/12/2007	M-211/M-136	Used			428 GMC gas		Original	Original
xxxxxxxxxxxxxxxxx	RDTI	StretchDuck PS 30-57	1954	4/5/2009	M-211/M-137	Used			429 GMC gas		New	Original
xxxxxxxxxxxxxxxxx	RDTI	TruckDuck	1957	10/3/2011		Used			7.3 Ford Powerstroke diesel		New	New

ES18-002672 1330

Restoration of original Dukw chassis
Sandblasting


Dukw Chassis
Master Jig
Dukw Chassis moved into stage (1) secured into
"Master Jig"

3 TON
5 TON

RIDE THE DUCKS INTERNATIONAL
Fleet Operations & Safety
2320 West Highway 76
Branson MO 65616

Bulletin No. SB-00-14-13
Release Date: 10/01/13
Effective Date: 10/01/13
Supersedes: N/A
Completion Date: Prior 2014
Applicable to: All Stretch Ducks
Total Pages: 7

SERVICE BULLETIN

REASON FOR RELEASE: To avoid axle fractures and to strengthen the connection where the knuckle housing ball connects to the axle housing. See Fig 1

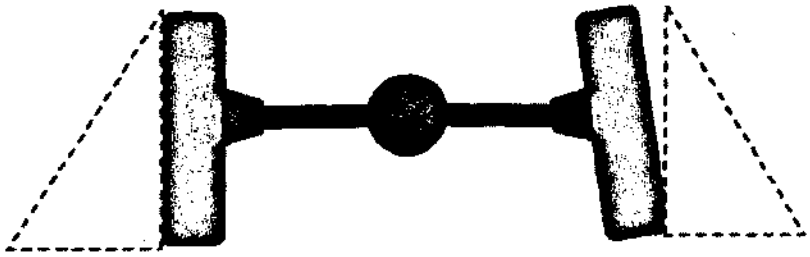
Urgency: As soon as practical and prior to operating 2014. Until such time this bulletin is reconciled, all maintainers are to add the daily visual inspection of the front wheels.

Daily Inspection: Due to the axle knuckle boots covering the connection in question, the visual detection of a failing axle housing is not possible. However, during visual examination, with the (front wheels straight) you identify a wheel or wheels as being (vertically canted) the Duck should be removed from service, the damaged axle housing removed (scrapped) and replaced with an axle housing that has been modified in accordance with this Service Bulletin.

Directions: Provide below are instructions of the modification that once completed will reconcile this Bulletin.

1. Parts required for modification Fig 2
2. Preparations for modification Fig 3
3. Example of parts fit-up Fig 4
4. Welding Fig 5
5. View of mods complete Fig 6

EXAMPLE
CANTED FRONT WHEEL



NOTE: All work must be performed by qualified personnel. Use only authorized components, specified or provided by Ride The Ducks. All applicable OSHA safety standards and safe industry practices must be observed. Observe all safety information contained in the manufacturers manuals. Make available this bulletin and all related technical information to personnel using the equipment.

CONTACT US VIA EMAIL
RTDI FLEET OPS HOTLINE: 417 266 7676
RTDI PARTS: 417 266 7626

RIDE THE DUCKS INTERNATIONAL
Fleet Operations & Safety
2320 West Highway 76
Branson MO 65616

Bulletin No. SB-00-14-13
Release Date: 10/01/13
Effective Date: 10/01/13
Supersedes: N/A
Completion Date: Prior 2014
Applicable to: All Stretch Ducks
Total Pages: 7

Fig 1

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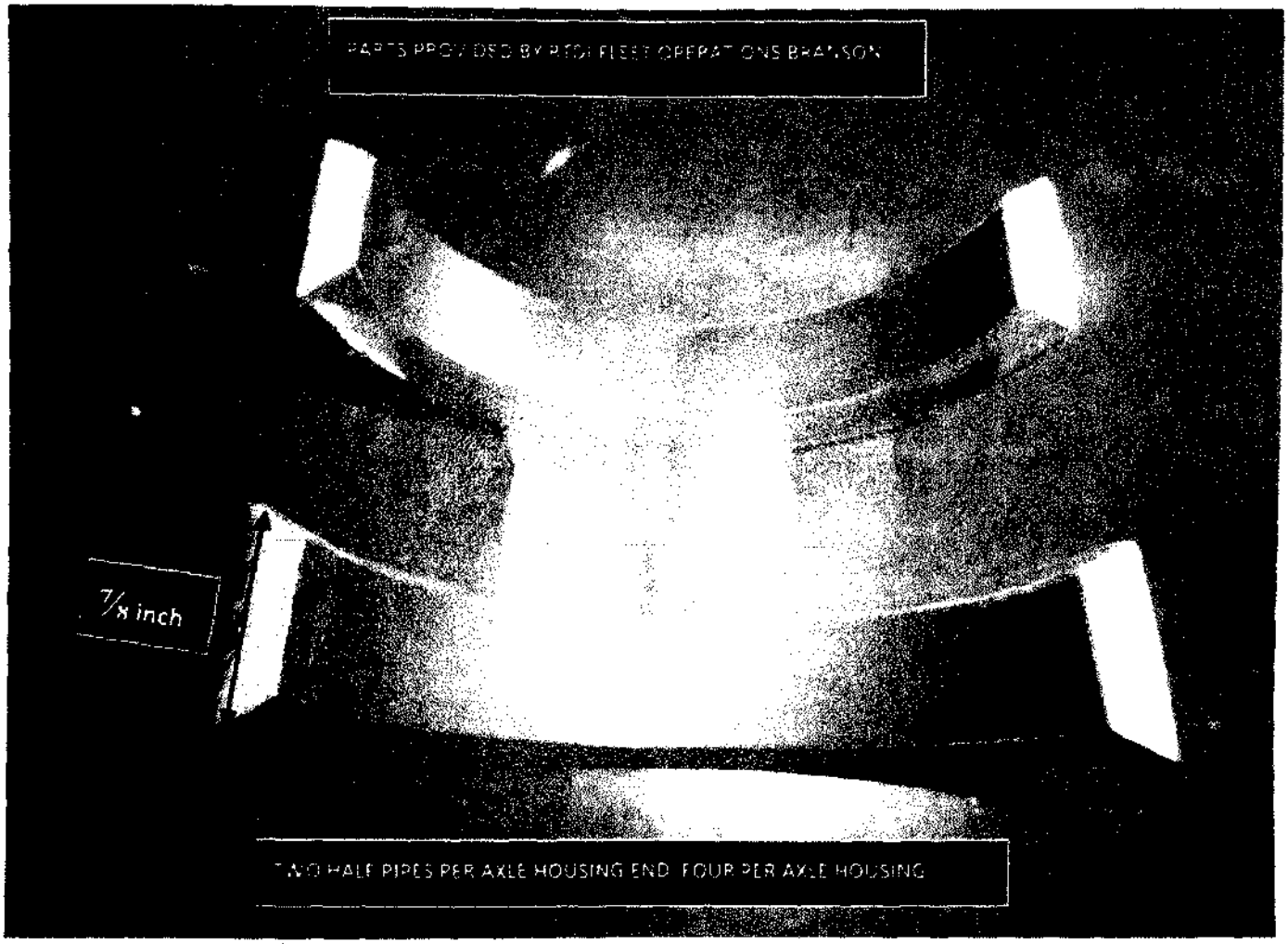
Applicable to: All Stretch Ducks
Total Pages: 7

Fig 2



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Total Pages: 7

Fig 3

1. Remove axle from the Duck
2. Set axle housing on a secure stand
3. Remove Boot and Hardware
4. Thoroughly clean (remove all grease)
5. Examine axle housing for fractures

Note: Bent or fractured axle housings are not to be modified.

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Fig 4

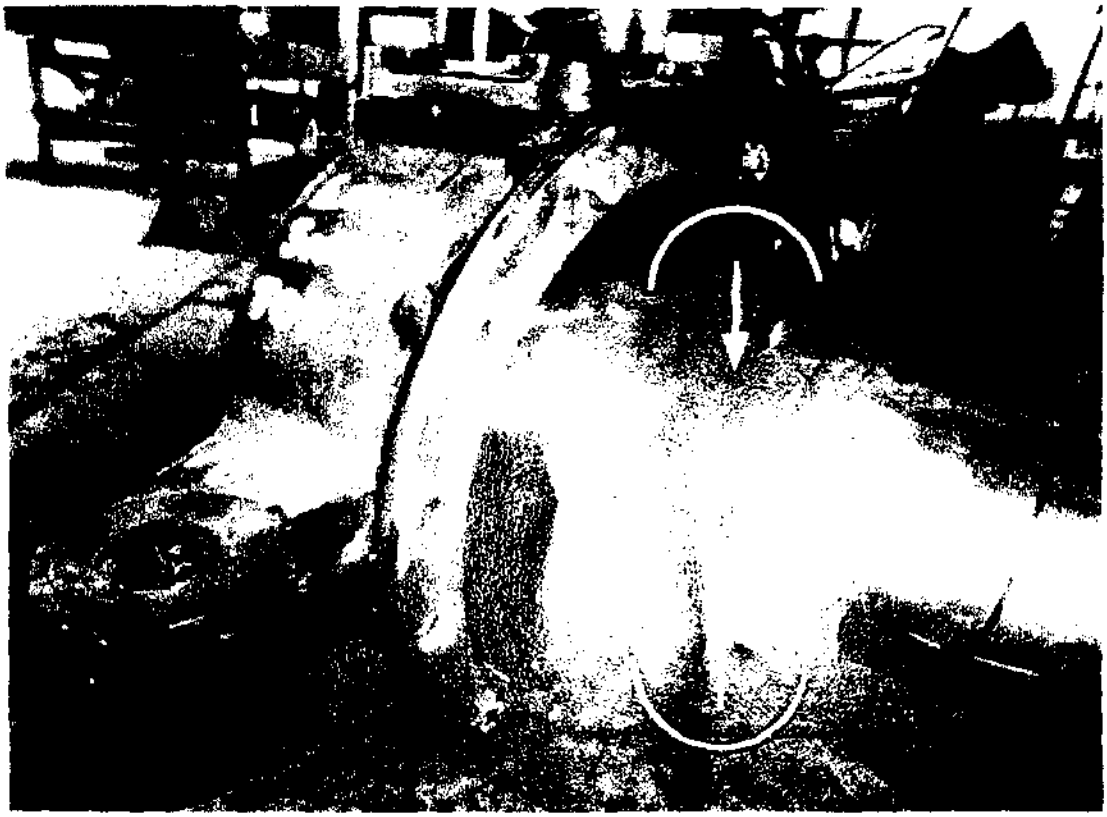

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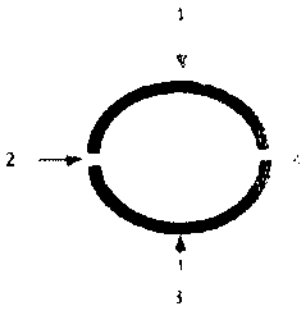
Fig 5

Tack weld half pipes in place as shown in photo

1. Center half pipe in detent gap between ball end and axle housing
2. Secure pipes in place with (vise grip) finger clamp
3. Tack weld in the sequence provided below
4. Ensure the axle housing stand is capable to allow the axle housing to rotate
5. All welds must be done in a flat position
6. Welder setting (spray arc)
   - [illegible] hard wire
   - [illegible] Carbon Dioxide or 90% - 10%
   - [illegible] 30
7. [illegible]
8. [illegible] 200-210



TACK WELDING

WELDING

1. Apply 2 inches of weld in flat position then rotate axle housing 180 degrees
2. Continue step (1) until all weld joints are filled

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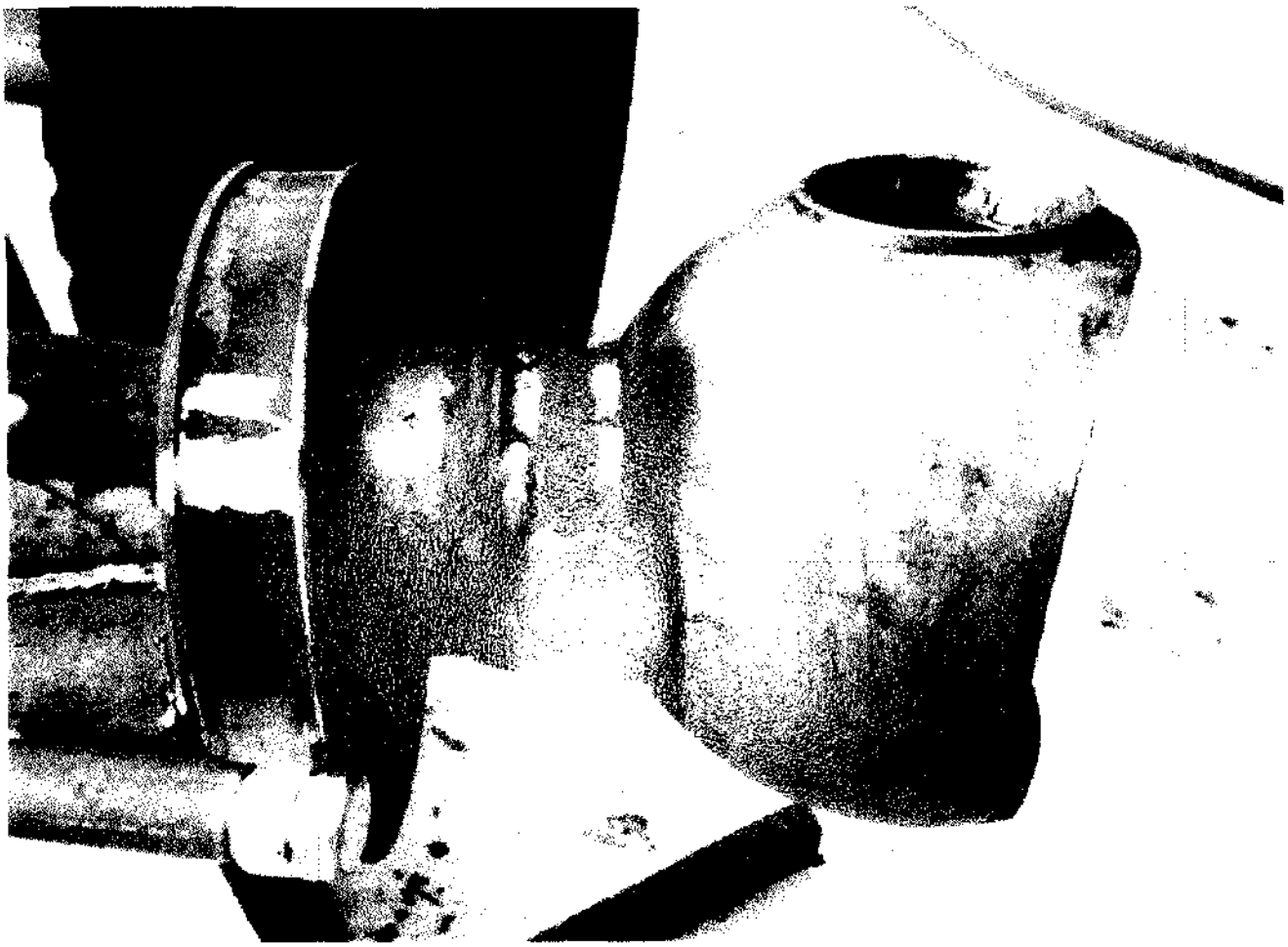
Fig 6



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U.S Department of Transportation
Office of Public Affairs
1200 New Jersey Avenue, SE
Washington, DC 20590
www.transportation.gov/briefingroom

News

NHTSA 32-16
Tuesday, December 06, 2016
Contact NHTSA
Email: Public.Affairs@dot.gov
Tel.: (202) 366-9550

U.S. DOT Issues Consent Order and Fines up to $1 Million to Ride the Ducks International, LLC

Amphibious tour vehicle manufacturer must comply with Federal Motor Vehicle Safety Standards

WASHINGTON – The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) has entered into a Consent Order to Ride the Ducks International, LLC (RTDI). NHTSA had found RTDI to be in violation of the National Traffic and Motor Vehicle Safety Act and under this terms of this consent order the company has agreed to pay fines of up to $1 million. Five people were killed in 2015, when an amphibious tour vehicle was involved in a crash with a motor coach in Seattle, Washington.

"Companies have an obligation to understand their responsibilities under the law, especially when those laws are in place to protect the public's safety," said Transportation Secretary Anthony Foxx. "This action shows that the Department of Transportation is always on the lookout to protect those who travel on our roads."

The consent order details RTDI's responsibilities to remedy it's noncompliance with the Safety Act, including obtaining an outside consultant to advise the company on their legal responsibilities under the Safety Act and to bring the company into compliance with the requirements of the Safety Act. RTDI will pay $480,000 in civil penalties and spend $20,000 to ensure completion of the terms of the consent order. The company will owe up to another $500,000 if it further violates the Safety Act or the Consent Order.

"Whether in their own car or riding a tour vehicle, American motorists and passengers must be protected from dangerous mechanical defects," said NHTSA Administrator Dr. Mark Rosekind. "This Consent Order sends an important message that NHTSA will continue exercising its authority to protect the public's safety with all vehicle manufacturers."

A NHTSA investigation of the company found the vehicle involved in the crash had been manufactured by RTDI using some donor parts from a military surplus vehicle. The vehicle had a front axle defect that had been noted in a bulletin from RTDI, but the company had not issued a motor vehicle safety recall. NHTSA established that RTDI is a manufacturer of motor vehicles

under the Safety Act and was therefore in violation by not filing a defect information report and initiating a full recall in compliance with the law.

In compliance with the Consent Order, RTDI has now filed a defect information report with NHTSA.

###

From: Rice, Michelle (NHTSA)
Sent: 4 May 2017 13:50:12 +0000
To: Hennig, Jordan (NHTSA)
Subject: FW: NHTSA Ride the Ducks of Seattle
Attachments: NHTSA.docx

From: Brian Tracey [mailto:btracey@seattleducktours.net]
Sent: Friday, March 31, 2017 1:02 AM
To: Rice, Michelle (NHTSA) <Michelle.Rice@dot.gov>
Subject: NHTSA Ride the Ducks of Seattle

Michelle: Attached is my letter to you addressing our concerns about the recall notice from Ride the Ducks International. If you have any questions please contact me at btracey@seattleducktours.net or my cell phone 206-679-5000. Thank you for all your help. I look forward to hearing from you.

Brian Tracey

President/CEO

Ride the Ducks of Seattle

Michelle Rice March 30, 2017

NHTSA

Dear Michelle:

Thank you for getting back to me right away. The issue we are having relates to NHTSA Recall: 16V-859 issued ~~the recall of all "stretch ducks "recalled~~ by Ride the Ducks International on ~~dated~~ 12/14/16. We were told in the Safety Recall Notice ~~16V-859~~ that RTDI was conducting an independent engineering analysis of the repair procedures in SB-00-14-13 and if any further action is required they would notify us promptly.

We are aware of an engineering study dated 12/15/16 by R&C vehicle design for Ride the Ducks (ESI project #55440G) that was reported to Brian Deckard of Ride the Ducks International. To date, we have not received any updates in regards to this engineering study or the Safety Recall. ~~from RTDI. Our concern is that no NDT testing or DT testing was done to verify that their fix recommended in the Service Bulletin (SB-00-14-13) would hold up and could possibly create more problems.~~ Currently we have 9 Stretch Ducks out of ~~service~~~~not being used because~~service because we have not been able to get any information ~~confirmation~~ from RTDI as to whether SB-00-14-13 is still ~~recommdend~~recommended. ~~that your organization has given the seal of approval to their solution provided in the original service bulletin or if they have had qualified engineers do the appropriate testing to verify that RTDI's solution is the correct solution.~~ Have you been given any engineering analysis ~~documentation fr~~from RTDI concerning SB -00-14-13?~~showing that their fix has been approved by qualified engineers or has your organization done the appropriate testing?~~ The UTC in the state of Washington will not allow us to run our "Stretch Ducks" until they feel confident that the appropriate governing body signs off on the replacement or repair of the axle housing. We appreciate all the information and help you can give us. My phone number is 206-679-5000 and email is btracey@seattleducktours.net.

Sincerely,

Brian Tracey

President/CEO

Ride the Ducks of Seattle

Brian Tracey

President/CEO

Ride the Ducks of Seattle

From: Rice, Michelle (NHTSA)
Sent: 31 Mar 2017 12:03:19 +0000
To: Matheke, Otto (NHTSA)
Subject: FW: NHTSA Ride the Ducks of Seattle
Attachments: NHTSA.docx, RCLRPT-16V859-5023.pdf, RCONL-16V859-0487.docx

Good morning Otto:

Attached is a letter from Mr. Tracey from Ride the Ducks in Seattle, Washington. The letter is his summary of his ordeal in trying to get his fleet of vehicles remedied.

I have attached the 573 report and the owner notification with the remedy for your review.

Michelle

From: Brian Tracey [mailto:btracey@seattleducktours.net]
Sent: Friday, March 31, 2017 1:02 AM
To: Rice, Michelle (NHTSA) <Michelle.Rice@dot.gov>
Subject: NHTSA Ride the Ducks of Seattle

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Sincerely,

Brian Tracey

President/CEO

Ride the Ducks of Seattle

Brian Tracey

President/CEO

Ride the Ducks of Seattle

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	JAN 30, 2017
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
Address :	2320 W Highway 76 PO BOX 1837 BRANSON MO 65616
Company phone :	417 266 7600

Population :

Number of potentially involved :	57
Estimated percentage with defect :	100 %

Vehicle Information :

Vehicle 1 :	1996-2005 RTDI "Stretch" Amphibious Passenger Vehicles
Vehicle Type :	
Body Style :	
Power Train :	NR
Descriptive Information :	Amphibious Passenger Vehicle
Production Dates :	JAN 01, 1996 - DEC 31, 2005
VIN Range 1 : Begin :	NR End : NR ☐ Not sequential

Description of Defect :

Description of the Defect :	The axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue.
FMVSS 1 :	NR
FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Part 573 Safety Recall Report 16V-859

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR
	NR
Country :	NR

Chronology :

See attached document amending chronology

Description of Remedy :

Description of Remedy Program :	The remedy program applied was set forth in the Service Bulletin issued on October 1, 2013. The remedy involved strengthening the connection where the knuckle housing ball connects to the axle housing.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

Description of Recall Schedule :	RTDI will send formal customer notification letters to its company-owned operators and licensors as set forth in the Consent Order with NHTSA. To the extent that Ride the Ducks Seattle requests parts to conduct the repair, they are available. Ride the Ducks International will offer reimbursement to any licensor that has already conducted the repairs.
Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

* NR - Not Reported

IMPORTANT SAFETY RECALL

NHTSA Recall: 16V-859
12/14/2016

This notice applies to your vehicle, Duck No. _____.

Dear RTDI Stretch Duck Operator:

This notice is sent to you in accordance with the National Traffic and Motor Vehicle Safety Act.

Ride the Ducks International (RTDI) has decided that a defect relating to motor vehicle safety exists or existed in certain "Stretch" Amphibious Passenger Vehicles ("Stretch Ducks"). As a result, RTDI is conducting a safety recall.

RTDI is conducting a recall because of the possibility that over time the axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue. If the axle housing fractures, this condition could cause a driver to lose control of the vehicle, increasing the risk of a crash.

In October 2013, RTDI issued a Service Bulletin (SB-00-14-13) instructing vehicle operators and licensees to repair and reinforce the connection where the knuckle housing ball connects to the axle housing. If you have already performed this repair on your vehicles, you are entitled to reimbursement for the costs associated with having done so. If you have not yet performed this repair on your vehicles, you must do so expeditiously and the service will be performed for you at **no charge.**

Pursuant to a recent agreement with the National Highway Traffic Safety Administration, RTDI is conducting an independent engineering analysis of the repair procedures in SB-00-14-13. If any further action is required, we will notify you promptly.

If after contacting RTDI, you are not satisfied we have done our best to remedy this condition without charge and within a reasonable time, you may wish to write to the following:

Administrator
National Highway Traffic Safety Administration,
1200 New Jersey Avenue, SE.,
Washington, DC 20590

You may also call the toll-free Vehicle Safety Hotline at 1.888.327.4236 (TTY 1.800.424.9153), or go to http://www.safercar.gov.

The National Highway Traffic Safety Administration Campaign ID Number for this recall is 16V-859.

From: Brian Tracey
Sent: 31 Mar 2017 05:01:38 +0000
To: Rice, Michelle (NHTSA)
Subject: NHTSA Ride the Ducks of Seattle
Attachments: NHTSA.docx

Michelle: Attached is my letter to you addressing our concerns about the recall notice from Ride the Ducks International. If you have any questions please contact me at btracey@seattleducktours.net or my cell phone 206-679-5000. Thank you for all your help. I look forward to hearing from you.

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President/CEO

Ride the Ducks of Seattle

Michelle Rice March 30, 2017

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Sincerely,

Brian Tracey

President/CEO

Ride the Ducks of Seattle

Brian Tracey

President/CEO

Ride the Ducks of Seattle

From: Rice, Michelle (NHTSA)
Sent: 4 May 2017 15:03:22 +0000
To: JGLASSMAN@KSLAW.COM
Subject: Question

Good morning,

I wanted to reach out about 16V-859. I am not sure if you are still involved with the Ride the Ducks. We are waiting for Ride the Ducks to submit a 573 amendment for recall 16V-859 with the new remedy that was discussed with Bruce York. He said he spoke with Ride the Ducks more than 5 days ago and we have yet to receive the amendment 573. Hopefully you are still involved and can move some mountains for me on this.

Thank you in advance,

Michelle

Michelle Rice
Recall Analyst
Office of Defects Investigations
National Highway Traffic Safety Administration
United States Department of Transportation
(202) 366.1060
www.safercar.gov

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	JAN 30, 2017
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
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FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Part 573 Safety Recall Report 16V-859

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR
	NR
Country :	NR

Chronology :

See attached document amending chronology

Description of Remedy :

Description of Remedy Program :	The remedy program applied was set forth in the Service Bulletin issued on October 1, 2013. The remedy involved strengthening the connection where the knuckle housing ball connects to the axle housing.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

Description of Recall Schedule :	RTDI will send formal customer notification letters to its company-owned operators and licensors as set forth in the Consent Order with NHTSA. To the extent that Ride the Ducks Seattle requests parts to conduct the repair, they are available. Ride the Ducks International will offer reimbursement to any licensor that has already conducted the repairs.
Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

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IMPORTANT SAFETY RECALL

NHTSA Recall: 16V-859
12/14/2016

This notice applies to your vehicle, Duck No. _____.

Dear RTDI Stretch Duck Operator:

This notice is sent to you in accordance with the National Traffic and Motor Vehicle Safety Act.

Ride the Ducks International (RTDI) has decided that a defect relating to motor vehicle safety exists or existed in certain "Stretch" Amphibious Passenger Vehicles ("Stretch Ducks"). As a result, RTDI is conducting a safety recall.

RTDI is conducting a recall because of the possibility that over time the axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue. If the axle housing fractures, this condition could cause a driver to lose control of the vehicle, increasing the risk of a crash.

In October 2013, RTDI issued a Service Bulletin (SB-00-14-13) instructing vehicle operators and licensees to repair and reinforce the connection where the knuckle housing ball connects to the axle housing. If you have already performed this repair on your vehicles, you are entitled to reimbursement for the costs associated with having done so. If you have not yet performed this repair on your vehicles, you must do so expeditiously and the service will be performed for you at **no charge.**

Pursuant to a recent agreement with the National Highway Traffic Safety Administration, RTDI is conducting an independent engineering analysis of the repair procedures in SB-00-14-13. If any further action is required, we will notify you promptly.

If after contacting RTDI, you are not satisfied we have done our best to remedy this condition without charge and within a reasonable time, you may wish to write to the following:

Administrator
National Highway Traffic Safety Administration,
1200 New Jersey Avenue, SE.,
Washington, DC 20590

You may also call the toll-free Vehicle Safety Hotline at 1.888.327.4236 (TTY 1.800.424.9153), or go to http://www.safercar.gov.

The National Highway Traffic Safety Administration Campaign ID Number for this recall is 16V-859.

IMPORTANT SAFETY RECALL

NHTSA Recall: 16V-_____

Insert Date

This notice applies to your vehicle, Duck No. _____.

Dear RTDI Stretch Duck Operator:

This notice is sent to you in accordance with the National Traffic and Motor Vehicle Safety Act.

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The National Highway Traffic Safety Administration Campaign ID Number for this recall is 16V___.

From: Rice, Michelle (NHTSA)
Sent: 4 May 2017 16:01:54 +0000
To: Glassman, Jacqueline
Subject: RE: Question

Thank you so very much for this.

Michelle

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, May 04, 2017 12:00 PM
To: Rice, Michelle (NHTSA) <Michelle.Rice@dot.gov>
Subject: RE: Question

I will look into it. Thanks, Michelle.

From: Rice, Michelle (NHTSA) [mailto:Michelle.Rice@dot.gov]
Sent: Thursday, May 04, 2017 11:03 AM
To: Glassman, Jacqueline
Subject: Question

Good morning,

I wanted to reach out about 16V-859. I am not sure if you are still involved with the Ride the Ducks. We are waiting for Ride the Ducks to submit a 573 amendment for recall 16V-859 with the new remedy that was discussed with Bruce York. He said he spoke with Ride the Ducks more than 5 days ago and we have yet to receive the amendment 573. Hopefully you are still involved and can move some mountains for me on this.

Thank you in advance,

Michelle

Michelle Rice
Recall Analyst
Office of Defects Investigations
National Highway Traffic Safety Administration
United States Department of Transportation
(202) 366.1060
www.safercar.gov

King & Spalding Confidentiality Notice:

This message is being sent by or on behalf of a lawyer. It is intended exclusively for the individual or entity to which it is addressed. This

communication may contain information that is proprietary, privileged or confidential or otherwise legally exempt from disclosure. If you are not the named addressee, you are not authorized to read, print, retain, copy or disseminate this message or any part of it. If you have received this message in error, please notify the sender immediately by e-mail and delete all copies of the message.

From: Rice, Michelle (NHTSA)
Sent: 4 May 2017 13:57:38 +0000
To: 'BDECKARD@RIDETHEDUCKS.COM'
Subject: Recall 16V-859

Good morning,

I am currently reviewing the recall file for recall 16V-859 and I noticed that we do not have a service bulletin with remedy instructions on file. The 573 report remedy section specifies that remedy repair instructions would be present in the service bulletin. Can you please upload a copy this service bulletin to the recall portal?

Michelle

Michelle Rice
Recall Analyst
Office of Defects Investigations
National Highway Traffic Safety Administration
United States Department of Transportation
(202) 366.1060
www.safercar.gov

From: Rice, Michelle (NHTSA)
Sent: 4 May 2017 14:31:30 +0000
To: 'BDECKARD@RIDETHEDUCKS.COM'
Subject: Recall 16V-859

Good morning,

I am reaching out to see when we will receive the amendment that includes the new remedy for this recall.

Michelle

Michelle Rice
Recall Analyst
Office of Defects Investigations
National Highway Traffic Safety Administration
United States Department of Transportation
(202) 366.1060
www.safercar.gov

From: Rice, Michelle (NHTSA)
Sent: 6 Dec 2016 18:57:20 +0000
To: BDECKARD@RIDETHEDUCKS.COM
Subject: Recall 16V-859

Good afternoon,

I have reviewed and approved the draft for recall 16V-859. Please upload a final copy along with the mailing dates one distribution has begun.

Thank you,

Michelle

Michelle Rice
Recall Analyst
Office of Defects Investigations
National Highway Traffic Safety Administration
United States Department of Transportation
(202) 366.1060
www.safercar.gov

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	MAY 04, 2017
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
Address :	2320 W Highway 76 PO BOX 1837 BRANSON MO 65616
Company phone :	417 266 7600

Population :

Number of potentially involved :	57
Estimated percentage with defect :	100 %

Vehicle Information :

Vehicle 1 :	1996-2005 RTDI "Stretch" Amphibious Passenger Vehicles
Vehicle Type :	
Body Style :	
Power Train :	NR
Descriptive Information :	Amphibious Passenger Vehicle
Production Dates :	JAN 01, 1996 - DEC 31, 2005

VIN Range 1 : Begin : NR End : NR ☐ Not sequential

Description of Defect :

Description of the Defect :	The axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue.
FMVSS 1 :	NR
FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Part 573 Safety Recall Report 16V-859

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR
	NR
Country :	NR

Chronology :

See attached document amending chronology

Description of Remedy :

Description of Remedy Program :	RTDI will replace each of the front axles with one that has a coupler welded to the axle. Prior to the installation of the coupler, the axles will undergo magna particle testing. The axles will also be inspected on an annual basis.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

Description of Recall Schedule :	RTDI will send formal customer notification letters to its company-owned operators and licensors as set forth in the Consent Order with NHTSA. Ride the Ducks International will offer reimbursement to any licensor that has already conducted the repairs.
Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

* NR - Not Reported

Description of Chronology (Amended) 16v-859:

On July 27, 2013, the driver of SD14 in Branson, Missouri observed that the left front axle housing on SD14 had broken at the knuckle ball. Based on the recollection of multiple RTDI staff members, as well as available photographs, SD14 was turned onto its left side during a 2012 tornado and then lifted back onto its wheels by a crane. RTDI later suspected that a fracture may have occurred due to the pressure being placed on the wheel while SD14 was being uprighted by the crane. There was no accident on July 27, 2013, and no injuries were associated with this fracture in the SD14 left front axle housing.

On August 10, 2013, RTDI inspected SD12 in Branson, Missouri and determined that the left front wheel was canted in at the top. Upon further inspections and examinations, RTDI determined that the axle housing was fractured between the knuckle ball and where the axle end is pressed into and welded to the housing. The stretch duck had been subject to prior repair to weld a small section of pipe to the bottom of the knuckle ball, which had been the subject of a prior service bulletin.

RTDI developed a modification to strengthen the axle housing, and on October 1, 2013, RTDI distributed Service Bulletin SB-14-13 – regarding a recommended front axle housing repair to the 57 affected stretch amphibious passenger vehicles – to its company-owned locations and licensees. The company-owned locations and licensees were directed to perform the required modification on their respective vehicles "as soon as practical and prior to operating 2014." The service bulletin further directed that the vehicles should be inspected daily until the repair could be conducted and removed from service if found to be vertically canted. RTDI additionally discussed the importance of conducting the repair on calls with its licensees.

After a crash involving a vehicle owned and operated by Ride the Duck of Seattle, NHTSA initiated an investigation and entered into discussions with Ride the Ducks International with regard to whether the amphibious passenger vehicles built and sold by RTDI are "motor vehicles" subject to NHTSA regulations and processes.

RTDI has provided NHTSA with confirmation with regard to the stretch ducks subject to the service bulletins. Of the 57 affected vehicles, forty three operating vehicles had already been repaired, one had been dismantled and three had been partially dismantled and are non-operable. The remaining ten vehicles, all owned by Ride the Ducks Seattle, are currently out of service.

Pursuant to its discussions with the agency, RTDI agreed to submit a formal Defect Information Report and to follow the procedures set forth in NHTSA's regulation.

Description of Chronology:

On July 27, 2013, the driver of SD14 in Branson, Missouri observed that the left front axle housing on SD14 had broken at the knuckle ball. Based on the recollection of multiple RTDI staff members, as well as available photographs, SD14 was turned onto its left side during a 2012 tornado and then lifted back onto its wheels by a crane. RTDI later suspected that a fracture may have occurred due to the pressure being placed on the wheel while SD14 was being uprighted by the crane. There was no accident on July 27, 2013, and no injuries were associated with this fracture in the SD14 left front axle housing.

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RTDI has provided NHTSA with confirmation with regard to the stretch ducks subject to the service bulletins. Of the 57 affected vehicles, forty four operating vehicles had already been repaired, one had been dismantled and three had been partially dismantled and are non-operable. The remaining vehicles, all owned by Ride the Ducks Seattle, are currently out of service.

Pursuant to its discussions with the agency, RTDI agreed to submit a formal Defect Information Report and to follow the procedures set forth in NHTSA's regulation.

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue SE.
Washington, DC 20590

FEB 25 2016

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. Robby Hultz
Ride The Ducks International LLC
P.O. Box 1837
Branson, MO 65615

NEF-140bby

Dear Mr. Hultz:

This letter is to inform you that the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration (NHTSA) is collecting information related to the crash of a Ride The Ducks of Seattle vehicle that occurred in Seattle, WA on September 24, 2015, and any other similar incidents to determine if a safety related defect exists in the axles of vehicles sold by RDTI.

Unless otherwise stated in the text, the following definitions apply to these information requests:

- **Subject Vehicles:** all Duck (DUKW) style vehicles modified, refurbished, re-manufactured, or manufactured by RDTI for sale or lease in the United States.
- **Subject Component**: any axle subject to RDTI service bulletin SB-00-14-13.
- **Alleged Defect:** any front axle failure on a subject vehicle following first use as an amphibious tour vehicle.
- **RDTI:** Ride The Ducks International LLC, all of its past and present officers and employees, whether assigned to its principal offices or any of its field or other locations, including all of its divisions, subsidiaries (whether or not incorporated) and affiliated enterprises and all of their headquarters, regional, zone and other offices and their employees, and all agents, contractors, consultants, attorneys and law firms and other persons engaged directly or indirectly (e.g., employee of a consultant) by or under the control of RDTI (including all business units and persons previously referred to), who are or, in or after 1977, were involved in any way with any of the following related to the alleged defect in the subject component:
  a. Design, engineering, analysis, modification or production (e.g. quality control);
  b. Testing, assessment or evaluation;

Certificate in Support of Request for Confidentiality

I, Brian Deckard, pursuant to the provisions of 49 C.F.R. Part 512, state as follows:

1. I am Brian Deckard, and I am a senior official at Ride The Ducks International (RTDI) and I am authorized to execute this certificate on its behalf;

2. I certify that the information contained in the enclosed attachments and marked as Confidential Business Information is confidential and proprietary data, in the form of confidential business information, and is being submitted with the claim that it is entitled to confidential treatment under 5 U.S.C. § 552(b)(4) (as incorporated by reference in and modified by 49 C.F.R. Part 512);

3. I hereby request that the information contained in the enclosed documents be protected permanently or until such time as the information is no longer held confidential by the company;

4. This certification is based on the information provided by the responsible RTDI personnel who have authority in the normal course of business to release the information for which a claim of confidentiality has been made to ascertain whether such information has ever been released outside RTDI;

5. Based upon that information, to the best of my knowledge, information and belief, the information for which has claimed confidential treatment has never been released or become available outside RTDI;

6. I make no representations beyond those contained in this Certificate and, in particular, I make no representations as to whether this information may become available outside RTDI because of unauthorized or inadvertent disclosure, except as noted in paragraph 5 above; and

I certify under penalty of perjury that the foregoing is true and correct.

Executed on this 18 day of Jan, 2017.

Brian Deckard

c. Consideration, or recognition of potential or actual defects, reporting, record-keeping and information management, (e.g., complaints, field reports, warranty information, part sales), analysis, claims, or lawsuits; or
d. Communication to, from or intended for zone representatives, fleets, dealers, or other field locations, including but not limited to people who have the capacity to obtain information from dealers.

- **Document:** "Document(s)" is used in the broadest sense of the word and shall mean all original written, printed, typed, recorded, or graphic matter whatsoever, however produced or reproduced, of every kind, nature, and description, and all non-identical copies of both sides thereof, including, but not limited to, papers, letters, memoranda, correspondence, communications, electronic mail (e-mail) messages (existing in hard copy and/or in electronic storage), faxes, mailgrams, telegrams, cables, telex messages, notes, annotations, working papers, drafts, minutes, records, audio and video recordings, data, databases, other information bases, summaries, charts, tables, graphics, other visual displays, photographs, statements, interviews, opinions, reports, newspaper articles, studies, analyses, evaluations, interpretations, contracts, agreements, jottings, agendas, bulletins, notices, announcements, instructions, blueprints, drawings, as-builts, changes, manuals, publications, work schedules, journals, statistical data, desk, portable and computer calendars, appointment books, diaries, travel reports, lists, tabulations, computer printouts, data processing program libraries, data processing inputs and outputs, microfilms, microfiches, statements for services, resolutions, financial statements, governmental records, business records, personnel records, work orders, pleadings, discovery in any form, affidavits, motions, responses to discovery, all transcripts, administrative filings and all mechanical, magnetic, photographic and electronic records or recordings of any kind, including any storage media associated with computers, including, but not limited to, information on hard drives, floppy disks, backup tapes, and zip drives, electronic communications, including but not limited to, the Internet and shall include any drafts or revisions pertaining to any of the foregoing, all other things similar to any of the foregoing, however denominated by RDTI, any other data compilations from which information can be obtained, translated if necessary, into a usable form and any other documents. For purposes of this request, any document which contains any note, comment, addition, deletion, insertion, annotation, or otherwise comprises a non-identical copy of another document shall be treated as a separate document subject to production. In all cases where original and any non-identical copies are not available, "document(s)" also means any identical copies of the original and all non-identical copies thereof. Any document, record, graph, chart, film or photograph originally produced in color must be provided in color. Furnish all documents whether verified by RDTI or not. If a document is not in the English language, provide both the original document and an English translation of the document.

- **Other Terms:** To the extent that they are used in these information requests, the terms "claim," "consumer complaint," "dealer field report," "field report," "fire," "fleet," "good will," "make," "model," "model year," "notice," "property damage," "property damage claim," "rollover," "type," "warranty," "warranty adjustment," and "warranty claim,"

whether used in singular or in plural form, have the same meaning as found in 49 CFR 579.4.

In order for my staff to evaluate the alleged defect, certain information is required. Pursuant to 49 U.S.C. § 30166, provide numbered responses to the following information requests. Insofar as RDTI has previously provided a document to ODI, RDTI may produce it again or identify the document, the document submission to ODI in which it was included and the precise location in that submission where the document is located. When documents are produced, the documents shall be produced in an identified, organized manner that corresponds with the organization of this information request letter (including all individual requests and subparts). When documents are produced and the documents would not, standing alone, be self-explanatory, the production of documents shall be supplemented and accompanied by explanation.

Repeat the applicable request verbatim above each response. After RDTI's response to each request, identify the source of the information and indicate the last date the information was gathered.

1. State, by make, model and model year, the number of subject vehicles RDTI has manufactured for sale or lease in the United States. Separately, for each subject vehicle manufactured to date by RDTI, state the following:

   a. VIN;
   b. Make;
   c. Model;
   d. Model Year;
   e. Vehicle date of manufacture;
   f. Vehicle date of refurbishment / re-manufacture for use as an amphibious tour vehicle
   g. Model number of axle installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   h. Origin of axle installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   i. Model number of transmission installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   j. Origin of transmission installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   k. Model number of engine installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   l. Origin of engine installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   m. Origin of hull installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle; and
   n. Origin of chassis installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle.

Provide the table in Excel, or a compatible format, entitled "PRODUCTION DATA." A pre-formatted Data Collection File, which provides further details regarding this submission, will be emailed to you.

2. State the number of each of the following, received by RDTI, or of which RDTI is otherwise aware, which relate to, or may relate to, the alleged defect in the subject vehicles:

   a. Consumer complaints;
   b. Field reports, including dealer field reports;
   c. Reports involving a crash, fire, injury or fatality;
   d. Property damage claims;
   e. Third-party arbitration proceedings where RDTI is or was a party to the arbitration; and
   f. Lawsuits, both pending and closed, in which RDTI is or was a defendant or codefendant.

   For subparts "a" through "f," state the total number of each item (e.g., consumer complaints, field reports, etc.) separately. Multiple incidents involving the same vehicle are to be counted separately. Multiple reports of the same incident are also to be counted separately (i.e., a consumer complaint and a field report involving the same incident in which a crash occurred are to be counted as a crash report, a field report and a consumer complaint).

   In addition, for items "c" through "f," provide a summary description of the alleged problem and causal and contributing factors and RDTI's assessment of the problem, with a summary of the significant underlying facts and evidence. For items "d" through "f," identify the parties to the action, as well as the caption, court, docket number, and date on which the complaint or other document initiating the action was filed.

3. Separately, for each item (complaint, report, claim, notice, or matter) within the scope of your response to Request No. 2, state the following information:

   a. RDTI's file number or other identifier used;
   b. The category of the item, as identified in Request No. 2 (i.e., consumer complaint, field report, etc.);
   c. Vehicle owner's name, mailing address, email address, and telephone number;
   d. VIN;
   e. Mileage at time or incident, if known;
   f. Time in service at time of incident, if known;
   g. Date of original retail sale;
   h. Incident date;
   i. Report or claim date;
   j. Whether a crash is alleged;
   k. Whether property damage is alleged;
   l. Number of alleged injuries, if any; and
   m. Number of alleged fatalities, if any.

   Provide this information in Excel, or a compatible format, entitled "REQUEST NUMBER TWO DATA." A pre-formatted Data Collection File, which provides further details regarding this submission, will be emailed to you.

4. Produce copies of all documents related to each item within the scope of Request No. 2. Organize the documents separately by category (i.e., consumer complaints, field reports, etc.) and describe the method RDTI used for organizing the documents.

5. State, by make, model and model year, a total count for all of the following categories of claims, collectively, that have been paid by RDTI to date that relate to, or may relate to, the alleged defect in the subject vehicles: warranty claims; extended warranty claims; claims for good will services that were provided; field, zone, or similar adjustments and reimbursements; and warranty claims or repairs made in accordance with a procedure specified in a technical service bulletin or customer satisfaction campaign.

   Separately, for each such claim, state the following information:

   a. RDTI's claim number;
   b. Vehicle owner's name, mailing address, email address, and telephone number;
   c. VIN;
   d. Repair date;
   e. Vehicle warranty start date;
   f. Mileage at time of repair;
   g. Time in service at time of repair;
   h. Repairing dealer's or facility's name, telephone number, city and state or ZIP code;
   i. Labor operation number;
   j. Problem code;
   k. Replacement part number(s) and description(s);
   l. Concern stated by customer; and
   m. Comment, if any, by dealer/technician relating to claim and/or repair.

   Provide this information in Excel, or a compatible format, entitled "WARRANTY DATA." A pre-formatted Data Collection File, which provides further details regarding this submission, will be emailed to you.

6. Describe in detail the search criteria used by RDTI to identify the claims identified in response to Request No. 5, including the labor operations, problem codes, part numbers and any other pertinent parameters used. Provide a list of all labor operations, labor operation descriptions, problem codes, and problem code descriptions applicable to the alleged defect in the subject vehicle. State, by make, model, and model year, the terms of the new warranty coverage offered by RDTI covering the subject and peer vehicles (i.e., the number of months and mileage for which coverage is provided and the component systems that are covered). Describe any extended warranty coverage option(s) that RDTI offered for the subject and peer vehicles and state by option, make, model, and model year, the number of subject and peer vehicles that are covered under each such extended warranty.

7. Produce copies of all service, warranty, and other documents that relate to, or may relate to, the alleged defect in the subject vehicles or subject component, that RDTI has issued to any dealers, regional or zone offices, field offices, fleet purchasers, or other entities. This includes, but is not limited to, bulletins, advisories, informational documents, training documents, or other documents or communications, with the exception of standard shop

manuals. Also include the latest draft copy of any communication that RDTI is planning to issue within the next 120 days.

8. Describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations (collectively, "actions") that relate to, or may relate to, the alleged defect in the subject vehicles or subject component that have been conducted, are being conducted, are planned, or are being planned by, or for, RDTI. For each such action, provide the following information:

   a. Action title or identifier;
   b. The actual or planned start date;
   c. The actual or expected end date;
   d. Brief summary of the subject and objective of the action;
   e. Engineering group(s)/supplier(s) responsible for designing and for conducting the action; and
   f. A brief summary of the findings and/or conclusions resulting from the action.

   For each action identified, provide copies of all documents related to the action, regardless of whether the documents are in interim, draft, or final form. Organize the documents chronologically by action.

9. Describe all modifications or changes made by, or on behalf of, RDTI in the design, material composition, manufacture, quality control, supply, or installation of the axles installed on the subject vehicles, from the start of production to date, which relate to, or may relate to, the alleged defect. For each such modification or change, provide the following information:

   a. The date or approximate date on which the modification or change was incorporated into production;
   b. A detailed description of the modification or change;
   c. The reason(s) for the modification or change;
   d. The part number(s) (service and engineering) of the original component;
   e. The part number(s) (service and engineering) of the modified component;
   f. Whether the original unmodified component was withdrawn from production and/or sale, and if so, when;
   g. When the modified component was made available as a service component; and
   h. Whether the modified component can be interchanged with earlier production components.

   Also, provide the above information for any modification or change that RDTI is aware of which may be incorporated into vehicle production within the next 120 days.

10. Furnish RDTI's assessment of the alleged defect in the subject vehicle, including:

    a. The causal or contributory factor(s);
    b. The failure mechanism(s);
    c. The failure mode(s);
    d. The risk to motor vehicle safety that it poses;

e. What warnings, if any, the operator and the other persons both inside and outside the vehicle would have that the alleged defect was occurring or subject component was malfunctioning; and
f. The reports included with this inquiry.

Legal Authority for This Request

This letter is being sent to RDTI pursuant to 49 U.S.C. § 30166, which authorizes NHTSA to conduct any investigation that may be necessary to enforce Chapter 301 of Title 49. It constitutes a new request for information.

Civil Penalties

RDTI's failure to respond promptly and fully to this letter could subject RDTI to civil penalties pursuant to 49 U.S.C. § 30165 or lead to an action for injunctive relief pursuant to 49 U.S.C. § 30163. (Other remedies and sanctions are available as well.) The Vehicle Safety Act, as amended, 49 U.S.C. § 30165(b), provides for civil penalties of up to $7,000 per day, with a maximum of $17,350,000 for a related series of violations, for failing or refusing to perform an act required under 49 U.S.C. § 30166. See 49 CFR 578.6 (as amended by 77 Fed. Reg. 70710 (November 27, 2012)). This includes failing to respond completely to ODI information requests.

If RDTI cannot respond to any specific request or subpart(s) thereof, please state the reason why it is unable to do so. If on the basis of attorney-client, attorney work product, or other privilege, RDTI does not submit one or more requested documents or items of information in response to this information request, RDTI must provide a privilege log identifying each document or item withheld, and stating the date, subject or title, the name and position of the person(s) from, and the person(s) to whom it was sent, and the name and position of any other recipient (to include all carbon copies or blind carbon copies), the nature of that information or material, and the basis for the claim of privilege and why that privilege applies.

Confidential Business Information

All business confidential information must be submitted directly to the Office of Chief Counsel as described in the following paragraph and should not be sent to this office. In addition, do not submit any business confidential information in the body of the letter submitted to this office.

If RDTI claims that any of the information or documents provided in response to this information request constitute confidential commercial material within the meaning of 5 U.S.C. § 552(b)(4), or are protected from disclosure pursuant to 18 U.S.C. § 1905, RDTI must submit supporting information together with the materials that are the subject of the confidentiality request, in accordance with 49 CFR Part 512, as amended, to the Office of Chief Counsel (NCC-111), National Highway Traffic Safety Administration, Room W41-227, 1200 New Jersey Avenue, S.E., Washington, D.C. 20590. RDTI is required to **submit two copies of the**

documents containing allegedly confidential information (except only one copy of blueprints) and one copy of the documents from which information claimed to be confidential has been deleted. Please remember that the phrase "ENTIRE PAGE CONFIDENTIAL BUSINESS INFORMATION" or "CONTAINS CONFIDENTIAL BUSINESS INFORMATION" (as appropriate) must appear at the top of each page containing information claimed to be confidential, and the information must be clearly identified in accordance with 49 CFR 512.6. If you submit a request for confidentiality for all or part of your response to this IR, that is in an electronic format (e.g., CD-ROM), your request and associated submission must conform to the new requirements in NHTSA's Confidential Business Information Rule regarding submissions in electronic formats. See 49 CFR 512.6(c) (as amended by 72 Fed. Reg. 59434 (October 19, 2007)).

If you have any questions regarding submission of a request for confidential treatment, contact Otto Matheke, Senior Attorney, Office of Chief Counsel at otto.matheke@dot.gov or (202) 366-5253.

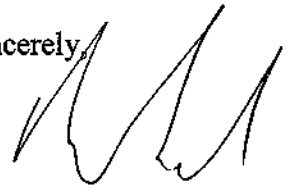
Due Date

RDTI's response to this letter, in duplicate, together with a copy of any confidentiality request, must be submitted to this office by **March 28, 2016**. If RDTI finds that it is unable to provide all of the information requested within the time allotted, RDTI must request an extension from me at (202) 366-6938 no later than five business days before the response due date. If RDTI is unable to provide all of the information requested by the original deadline, it must submit a partial response by the original deadline with whatever information RDTI then has available, even if an extension has been granted.

Please send email notification to me at bruce.york@dot.gov and to ODI_IRresponse@dot.gov when RDTI sends its response to this office and indicate whether there is confidential information as part of RDTI's response.

Prior to starting you response please call me at (202) 366-6938, to discuss this information request or if you have any technical questions concerning this matter.

Sincerely,



Bruce B. York, Chief
Medium/Heavy Duty Vehicle Division
Office of Defects Investigation

Supporting Documents: Please contact me at the above email address to receive attachments containing two Excel spreadsheet template files.

WILLIAMS KASTNER™

OFFICE OF CHIEF COUNSEL
RECEIVED

2016 APR 25 A

April 21, 2016

30341.0101

VIA U.S. MAIL

Office of Chief Counsel (NCC-111)
National Highway Traffic Safety Administration
Room W41-227
1200 New Jersey Avenue, S.E.
Washington, DC 20590

Re: Ride the Ducks International, LLC's ("RTDI") responses to information requests related to September 24, 2015 accident of DUKW #6, owned and operated by Ride the Ducks of Seattle, LLC ("RTDS")

To the Office of Chief Counsel:

Enclosed please find RTDI's responses to the Office of Defects Investigation's information requests. Pursuant to the instructions in the letter from the Office of Defects Investigation, RTDI is submitting two copies of responses that include confidential information. RTDI has labeled the entire answers and/or documents as confidential, rather than redacting each piece of confidential information contained in these answers and documents, as doing so would be unduly burdensome. Finally, the third copy of responses is not labeled as confidential, and the answers and documents designated as "confidential" in the first two copies of responses are omitted in this third copy. Please do not hesitate to give me a call should you have any questions or concerns.

Williams, Kastner & Gibbs PLLC
Two Union Square
601 Union Street, Suite 4100
Seattle, Washington 98101
mail 206.628.6600 fax 206.628.6611
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SEATTLE | PORTLAND

Very truly yours,

WILLIAMS, KASTNER & GIBBS PLLC

Rodney L. Umberger, Jr.
Attorney at Law
(206) 628-2421
rumberger@williamskastner.com

Enclosure

cc: bruce.york@dot.gov; ODI_IRresponse@dot.gov
Robby Hultz, Managing Partner, Ride the Ducks International, LLC (w/encl.)

A. DiMarsico

JAN 1 0 2017

Rodney Umberger
Williams, Kastner & Gibbs PLLC
Two Union Square
601 Union Street, Suite 4100
Seattle, WA 98101

Re: Confidentiality Determination/RTDI Responses to NHTSA's Information Request

Dear Mr. Umberger:

This responds to your letter of April 21, 2016 submitting confidential information within Ride the Ducks International, LLC's (RTDI) response to an Information Request.

For the reasons discussed below, I deny giving confidential treatment to RTDI's submission.

As a preliminary matter, we note that RTDI's response was required to the Agency's Information Request. *See* 49 U.S.C. § 30166. Consequently, to protect commercial information from disclosure under the Freedom of Information Act, 5 U.S.C. § 552(b)(4), it must meet the Exemption 4 test from *National Parks & Conservation Ass'n v. Morton*, 498 F.2d 765 (D.C. Cir. 1974). Under this test, Exemption 4 requires a showing that the disclosure of commercial or financial information would be likely to cause substantial competitive harm to the information submitter or that it is likely to impair the Agency's ability to obtain similar data in the future.

Under the National Highway Traffic Safety Administration's regulations, when a person claims submitted information is confidential and that its disclosure will result in substantial competitive harm, that person must, among other things, justify the basis for that claim by describing what the harmful effects of disclosure would be and why the effects should be viewed as substantial. *See* 49 CFR 512.8. RTDI's submission does not meet the requirements for claims of confidentiality established by 49 CFR Part 512. Labeling information as confidential in your submission is not sufficient to meet the regulatory requirements. I note also that you did not include a certificate in support of RTDI's request for confidential treatment. As a result, I cannot conclude that RTDI's information is entitled to confidential treatment.

If you disagree with this determination, you may request reconsideration. If you seek reconsideration, your request must be addressed to NHTSA's Chief Counsel and filed within 20 working days after the receipt of this letter (49 CFR § 512.19(a)). Any such request must fully conform with 49 CFR Part 512 and contain sufficient justification supporting your claims for confidential treatment consistent with 49 CFR Part 512 and applicable case law.

Sincerely,

Original Signed By

Otto G. Matheke, III
Senior Trial Attorney

cc: Jacqueline Glassman
King & Spalding, LLP
1700 Pennsylvania Avenue NW, Suite 200
Washington, DC 20006

NCC-100: JStephens:cyb:1/5/17
NCC-100: om, js **NCC16-002004**
NCC-300 A. DiMarsico
Confidentiality\Misc17\RTDI002004js

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

WILLIAMS KASTNER™

April 21, 2016

30341.0101

VIA U.S. MAIL

Office of Chief Counsel (NCC-111)
National Highway Traffic Safety Administration
Room W41-227
1200 New Jersey Avenue, S.E.
Washington, DC 20590

Re: Ride the Ducks International, LLC's ("RTDI") responses to information requests related to September 24, 2015 accident of DUKW #6, owned and operated by Ride the Ducks of Seattle, LLC ("RTDS")

To the Office of Chief Counsel:

RTDI has responded to the Office of Defects Investigation's information requests. As mentioned in the cover letter attached to this document, RTDI has labeled its answers and attached documents as confidential, rather than redact each piece of confidential information contained in the answers and/or documents, because it would be unduly burdensome to do so.

1. *State, by make, model and model year, the number of subject vehicles RDTI has manufactured for sale or lease in the United States. Separately, for each subject vehicle manufactured to date by RTDI, state the following:*

   a. VIN;
   b. Make;
   c. Model;
   d. Model Year;
   e. Vehicle date of manufacture:
   f. Vehicle date of refurbishment / re-manufacture for use as an amphibious tour vehicle
   g. Model number of axle installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   i. Model number of transmission installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
   j. Origin of transmission installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;

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k. Model number of engine installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
l. Origin of engine installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
m. Origin of hull installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle;
n. Origin of chassis installed at time of refurbishment / re-manufacture for use as an amphibious tour vehicle.

Response:

Please see the attached Excel table, entitled "PRODUCTION DATA" [Bates stamp nos. RTDI-USDOT000001-3].

Source of information: Robby Hultz, Managing Partner, Ride the Ducks International, LLC
Last date the information was gathered: March 25, 2016

2. *State the number of each of the following, received by RDTI, or of which RDTI is otherwise aware, which relate to, or may relate to, the alleged defect in the subject vehicles:*

a. Consumer complaints;
b. Field reports, including dealer field reports;
c. Reports involving a crash, fire, injury or fatality;
d. Property damage claims;
e. Third-party arbitration proceedings where RDTI is or was a party to the arbitration; and
f. Lawsuits, both pending and closed, in which RDTI is or was a defendant or codefendant.

For subparts "a" through "f," state the total number of each item (e.g., consumer complaints, field reports, etc.) separately. Multiple incidents involving the same vehicle are to be counted separately. Multiple reports of the same incident are also to be counted separately (i.e., a consumer complaint and a field report involving the same incident in which a crash occurred are to be counted as a crash report, a field report and a consumer complaint).

In addition, for items "c" through "f," provide a summary description of the alleged problem and causal and contributing factors and RDTI's assessment of the problem, with a summary of the significant underlying facts and evidence. For items "d" through "f," identify the parties to the action, as well as the caption, court, docket number, and date on which the complaint or other document initiating the action was filed.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Response:

RTDI objects to this request to the extent said request is overly broad and vague. Moreover, RTDI objects to the characterization of "alleged defect" as used in said request. Without waiving its objection, RTDI has attached a chart [Bates stamp nos. RTDI-USDOT000025-37] which includes responses concerning "reports involving a crash, fire, injury or fatality" and "lawsuits, both pending and closed, in which RDTI is or was a defendant or codefendant ."

RTDI has not received and is not otherwise aware of any "consumer complaints," "field reports, including dealer field reports," "property damage claims," or "third-party arbitration proceedings where RDTI is or was a party to the arbitration" which relate to, or may relate to, the "alleged defect", as characterized and/or defined in the request.

Source of information: Public court dockets; Robby Hultz, Ride the Ducks International, LLC
Last date the information was gathered: April 12, 2016

3. *Separately, for each item (complaint, report, claim, notice, or matter) within the scope of your response to Request No. 2, state the following information:*

a. RDTI's file number or other identifier used;
b. The category of the item, as identified in Request No. 2 (i.e., consumer complaint, field report, etc.);
c. Vehicle owner's name, mailing address, email address, and telephone number;
d. VIN;
e. Mileage at time or incident, if known;
f. Time in service at time of incident, if known;
g. Date of original retail sale;
h. Incident date;
i. Report or claim date;
j. Whether a crash is alleged;
k. Whether property damage is alleged;
1. Number of alleged injuries, if any; and
m. Number of alleged fatalities, if any.

Provide this information in Excel, or a compatible format, entitled "REQUEST NUMBER TWO DATA." A pre-formatted Data Collection File, which provides further details regarding this submission, will be emailed to you.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Response:

Please see RTDI's objections to Request No. 2. Without waiving said objections, RTDI produces the attached Excel table, entitled "REQUEST NUMBER TWO DATA" [Bates stamp no. RTDI - USDOT000219]. All complaints listed in RTDI's response to Request No. 2 arise from the same incident, the September 24, 2015 accident involving DUKW #6 (Seattle).

Source of information: Public court dockets; Robby Hultz, Ride the Ducks International, LLC
Last date the information was gathered: April 12, 2016

4. *Produce copies of all documents related to each item within the scope of Request No. 2. Organize the documents separately by category (i.e., consumer complaints, field reports, etc.) and describe the method RDTI used for organizing the documents.*

Response:

Please see the attached complaints, all of which arise out of the September 24, 2015 accident that occurred when a 1945 GMC DUKW amphibious vehicle ("DUKW 6"), owned and operated by Ride The Ducks of Seattle ("RTDS"), was involved in an accident with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South, while both vehicles were traveling over the George Washington Memorial Bridge (also known as the Aurora Bridge) in Seattle, Washington. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT):

Bates stamp nos. for each complaint are included below:
RTDI-USDOT000038-45
RTDI-USDOT000046-57
RTDI-USDOT000058-72
RTDI-USDOT000073-85
RTDI-USDOT000086-98
RTDI-USDOT000099-112
RTDI-USDOT000113-127
RTDI-USDOT000128-142
RTDI-USDOT000143-156
RTDI-USDOT000157-165
RTDI-USDOT000166-180
RTDI-USDOT000181-195
RTDI-USDOT000196-218

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Source of information: Public court dockets
Last date the information was gathered: April 12, 2016

5. *State, by make, model and model year, a total count for all of the following categories of claims, collectively, that have been paid by RDTI to date that relate to, or may relate to, the alleged defect in the subject vehicles: warranty claims; extended warranty claims; claims for good will services that were provided; field, zone, or similar adjustments and reimbursements; and warranty claims or repairs made in accordance with a procedure specified in a technical service bulletin or customer satisfaction campaign.*

Separately, for each such claim, state the following information:

a. RDTI's claim number;
b. Vehicle owner's name, mailing address, email address, and telephone number;
c. VIN;
d. Repair date;
e. Vehicle warranty start date;
f. Mileage at time of repair;
g. Time in service at time of repair;
h. Repairing dealer's or facility's name, telephone number, city and state or ZIP code;
i. Labor operation number;
j. Problem code;
k. Replacement part number(s) and description(s);
1. Concern stated by customer; and
m. Comment, if any, by dealer/technician relating to claim and/or repair.

Provide this information in Excel, or a compatible format, entitled "WARRANTY DATA." A pre-formatted Data Collection File, which provides further details regarding this submission, will be emailed to you.

Response:

RDTI objects to the characterization used in the request of "alleged defect." Without waiving said objection or adopting said characterization, RTDI has not paid any claims relating to the "alleged defect" in the subject vehicles.

Source of information: Robby Hultz, Ride the Ducks International, LLC
Last date the information was gathered: N/A

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

6. *Describe in detail the search criteria used by RDTI to identify the claims identified in response to Request No. 5, including the labor operations, problem codes, part numbers and any other pertinent parameters used. Provide a list of all labor operations, labor operation descriptions, problem codes, and problem code descriptions applicable to the alleged defect in the subject vehicle. State, by make, model, and model year, the terms of the new warranty coverage offered by RDTI covering the subject and peer vehicles (i.e., the number of months and mileage for which coverage is provided and the component systems that are covered). Describe any extended warranty coverage option(s) that RDTI offered for the subject and peer vehicles and state by option, make, model, and model year, the number of subject and peer vehicles that are covered under each such extended warranty.*

Response:

RTDI objects to the characterization used in the request of "alleged defect." Without waiving said objection, RTDI has not paid any claims relating to the "alleged defect" in the subject vehicles, and therefore has not used search criteria to identify any such claims. The only pending claims involving RTDI all arise out of the September 24, 2015 accident that occurred when a 1945 GMC DUKW amphibious vehicle ("DUKW 6"), owned and operated by Ride The Ducks of Seattle ("RTDS"), was involved in an accident with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South, while both vehicles were traveling over the George Washington Memorial Bridge (also known as the Aurora Bridge) in Seattle, Washington. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).

Source of information: Robby Hultz, Ride the Ducks International, LLC
Last date the information was gathered: N/A

7. *Produce copies of all service, warranty, and other documents that relate to, or may relate to, the alleged defect in the subject vehicles or subject component, that RDTI has issued to any dealers, regional or zone offices, field offices, fleet purchasers, or other entities. This includes, but is not limited to, bulletins, advisories, informational documents, training documents, or other documents or communications, with the exception of standard shop manuals. Also include the latest draft copy of any communication that RDTI is planning to issue within the next 120 days.*

Response:

RTDI objects to the characterization used in the request of "alleged defect." Without waiving said objection, please see the two service bulletins (No. SB-11-14-13 and No. SB-00-01-16) attached hereto [Bates stamp nos. RTDI-USDOT000004-10 and RTDI-USDOT000011-19, respectively]. Additionally, please see 2013 email correspondence between RTDI and RTDS, concerning Service Bulletin No. SB-11-14-13 [Bates stamp nos. RTDI -USDOT000219].

Source of information: Robby Hultz, Managing Partner, Ride the Ducks International, LLC
Last date the information was gathered: March 25, 2016

8. *Describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations (collectively, "actions") that relate to, or may relate to, the alleged defect in the subject vehicles or subject component that have been conducted, are being conducted, are planned, or are being planned by, or for, RDTI. For each such action, provide the following information:*

a. Action title or identifier;
b. The actual or planned start date;
c. The actual or expected end date;
d. Brief summary of the subject and objective of the action;
e. Engineering group(s)/supplier(s) responsible for designing and for conducting the action; and
f. A brief summary of the findings and/or conclusions resulting from the action.

For each action identified, provide copies of all documents related to the action, regardless of whether the documents are in interim, draft, or final form. Organize the documents chronologically by action.

Response:

RTDI objects to the characterization used in the request of "alleged defect." Without waiving said objection, please see the two tables below. For copies of the service bulletins referenced below, please see RTDI's response to Request No. 7, above [Bates stamp nos. RTDI-USDOT000004-10 and RTDI-USDOT000011-19, respectively].

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

a.	2004 Axle Assessment
b.	Unknown
c.	Fall 2004
d.	Evaluate axle knuckle ball fracture
e.	Staff of Ozark Scenic Tours, the predecessor to RTDI
f.	RTDI is not privy to the findings and/or conclusions resulting from the action because no final report was saved to a file, and none of the Ozark Scenic Tours staff involved with the assessment are still employed by RTDI. Notwithstanding the above, from the period following the conclusion of the axle assessment (Fall 2004) until October 1, 2013, the date that RTDI released Service Bulletin SB-00-14-13, all Stretch Ducks refurbished by RTDI implemented the process of welding a small section of pipe to the bottom of the steering knuckle ball, which served to bridge the gap between the ball and housing on Stretch Duck steer axles.

a.	SB-11-14-13: Stretch Duck Steering Axle Mods
b.	August 10, 2013
c.	October 1, 2013
d.	Evaluate axle knuckle ball fracture
e.	RTDI staff
f.	The original axle housing tapers down to a smaller diameter as it approaches the knuckle ball. Adding an additional reinforcing collar bridges the gap between the knuckle ball and the axle housing and increases the diameter of the connecting material, thereby increasing its strength. These findings were summarized in Service Bulletin SB-00-14-13, which was distributed across the company and was applicable to all Stretch Ducks.

a.	SB-00-01-16: Non-Destructive Testing
b.	January 8, 2016
c.	Ongoing
d.	To enhance the inspection of safety critical components beyond visual examination.
e.	RTDI Staff; Anderson Engineering, John Cook.
f.	Based on testing conducted on operating vehicles and multiple axles from inventory there have been no fractures found in the suspect area of the axle.

Source of information: Robby Hultz, Managing Partner, Ride the Ducks International, LLC
Last date the information was gathered: April 14, 2016

9. *Describe all modifications or changes made by, or on behalf of, RDTI in the design, material composition, manufacture, quality control, supply, or installation of the axles installed on the subject vehicles, from the start of production to date, which relate to, or may relate to, the alleged defect. For each such modification or change, provide the following information:*

a. The date or approximate date on which the modification or change was incorporated into production;
b. A detailed description of the modification or change;
c. The reason(s) for the modification or change;
d. The part number(s) (service and engineering) of the original component;
e. The part number(s) (service and engineering) of the modified component;
f. Whether the original unmodified component was withdrawn from production and/or sale, and if so, when;
g. When the modified component was made available as a service component; and
h. Whether the modified component can be interchanged with earlier production components.

Also, provide the above information for any modification or change that RDTI is aware of which may be incorporated into vehicle production within the next 120 days.

Response:

RTDI objects to the characterization used in the request of "alleged defect." Without waiving said objection, please see the two tables below. For copies of the service bulletins referenced below, please see RTDI's response to Request No. 7, above [Bates stamp nos. RTDI-USDOT000004-10 and RTDI-USDOT000011-19, respectively]. For information relating to any modification or change that RTDI is aware of which may be incorporated into vehicle production within the next 120 days, please see Service Bulletin No. SB-00-01-16, attached to RTDI's response to Request No. 7, above [Bates stamp no. RTDI-USDOT000011-19].

a.	**Fall 2004**
b.	**The process entailed welding a small section of pipe to the bottom of the steering knuckle ball, which service to bridge the gap between the ball and housing on all Stretch Ducks.**
c.	**Based on the recollection of an RTDI staff member, inspections of two parked stretch ducks in Branson, Missouri, on two separate occasions in 2003-2004, revealed that the left front wheel on both Stretch Ducks was canted in at the top. The identifying Stretch Duck numbers and the precise 2003-2004 dates involved are unknown. Upon**

	further inspection and examination, it was determined that the axle housings were fractured along the bottom of the housing between the knuckle ball and where the axle ends were pressed into and welded to the housing.
d.	HOUSING, ASSY – 7411299; Original unmodified axle housing produced by General Motors.
e.	No part number(s) (service or engineering) exist for the modified component.
f.	The original unmodified axle housing was no longer used on any Stretch Duck refurbished by RTDI from Fall 2004 forward.
g.	Fall 2004.
h.	Yes, the component is interchangeable with earlier production components.

a.	October 1, 2013
b.	RTDI issued Service Bulletin No. SB-00-14-13 for the purpose of avoiding axle fractures and to strengthen the connection where the knuckle housing ball connects to the axle housing of the Duck wheels. In that service bulletin, RTDI recommended certain modifications that were to be implemented prior to operating the vehicles in 2014. Between the date the service bulletin was issued and operating the vehicles in 2014, RTDI recommended that all Stretch Ducks be inspected daily for vertically canted wheels. In the event that a vertically canted wheel is detected, RTDI recommended that the Duck be taken out of active service and that the damaged axle housing be removed and replaced with an axle housing that has been modified in accordance with the service bulletin.
c.	On July 27, 2013, the driver of Stretch Duck 14 ("SD14") in Branson, Missouri, observed that the left front axle housing on SD14 had broken at the knuckle ball. Based on the recollection of multiple RTDI staff members, as well as available photographs, SD14 had been turned onto its left side during a 2012 tornado. A crane was required to lift SD14 back onto its wheels. RTDI later suspected that a fracture may have occurred due to the pressure being placed on the wheel while the Duck was being lifted back onto its wheels by the crane. There was no accident on July 27th, 2013, the date that the Stretch Duck 14 driver noticed the broken left front axle housing, and no injuries were associated with the fracture. As a result of its inspections and examinations, RTDI replaced the axle housing on SD14. On August 10, 2013, RTDI inspected Stretch Duck 12 ("SD12") in Branson, Missouri and determined that the left front wheel was canted in at the top. Upon further inspections and examinations, RTDI determined that the axle housing was fractured between the knuckle ball and where the axle end is pressed into and welded to the housing. In addition, it was observed that this stretch duck had previously undergone

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

	the axle repair associated with the axle housing item observed in 2003-2004. There was no accident on August 10, 2013, and no injuries were associated with the fracture/break in the duck's left front axle housing.
d.	No part number(s) (service or engineering) exist for the modified component.
e.	S.D. WELD ON COLLAR FOR STEERING AXLE REINFORCEMENT MOD. – 007342-1.
f.	From October 1, 2013, and onward, the axle housing modified with the small section of pipe was no longer used on any stretch duck refurbished by RTDI, and modifications were ordered to be performed on all existing steering axles by SB-00-14-13 Stretch Duck Steering Axle Mods.
g.	October 1, 2013.
h.	The component is interchangeable with earlier production components.

a.	January 8, 2016
b.	Please see Service Bulletin No. SB-00-01-16, attached to RTDI's response to Request No. 7, above. [Bates stamp no. RTDI-USDOT000011-19].
c.	To enhance the inspection of safety critical components beyond visual examination.
d.	HOUSING, ASSY – 7411299; Original unmodified axle (Front) housing produced by General Motors HOUSING, ASSY – 7411297; Original unmodified axle (Forward rear) housing produced by General Motors HOUSING, ASSY – 7411298; Original unmodified axle (Rear rear) housing produced by General Motors
e.	SD STEER AXLE HOUSING – 005250-1 SD TAG AXLE HOUSING – 002793-1 SD TAG AXLE HOUSING – 006978-1
f.	This change only reflects a test procedure, so the component would only be removed from service if test failed.
g.	Testing procedure was implemented on January 8, 2016.
h.	This change is a test procedure and should be utilized on earlier production components.

Source of information: Robby Hultz, Managing Partner, Ride the Ducks International, LLC
Last date the information was gathered: April 14, 2016

10. *Furnish RDTI's assessment of the alleged defect in the subject vehicle, including:*

a. The causal or contributory factor(s);
b. The failure mechanism(s);
c. The failure mode(s);
d. The risk to motor vehicle safety that it poses;
e. What warnings, if any, the operator and the other persons both inside and outside the vehicle would have that the alleged defect was occurring or subject component was malfunctioning; and
f. The reports included with this inquiry.

Response:

RTDI objects to the characterization used in the request of "alleged defect." Without waiving said objection, RTDI has not performed an independent assessment of the "alleged defect" in Duck #6, which is owned and operated by RTDS. The extent of RTDI's knowledge of the alleged defect in Duck #6 is solely as a party to the ongoing NTSB investigation and the related lawsuits that have been filed. Furthermore, RTDI cannot possibly assess the "alleged defect" in Duck #6 because it is currently in NTSB's custody.

Source of information: Robby Hultz, Managing Partner, Ride the Ducks International, LLC
Last date the information was gathered: N/A

* * * *

RTDI will supplement these responses to the extent it is able to locate additional responsive material. In the meantime, please let us know if you have any questions or concerns.

Very truly yours,

WILLIAMS, KASTNER & GIBBS PLLC

Rodney L. Umberger, Jr.
Attorney at Law
(206) 628-2421
rumberger@williamskastner.com

cc: Robby Hultz, Managing Partner, Ride the Ducks International, LLC

From: Matheke, Otto (NHTSA)
Sent: 28 Oct 2016 14:37:47 +0000
To: Glassman, Jacqueline
Subject: Any Duck news?

Thanks

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Cc:	Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA); Kolodziej, Kerry (NHTSA)
Subject:	Draft Proposed Consent Order
Date:	Wednesday, October 05, 2016 4:49:00 PM
Attachments:	DRAFTOct5RTDI Consent Order.pdf

Jackie:

Attached please find a proposed consent order for the Ducks. The structure calls for a penalty up front and a deferred amount contingent upon completion of the Consent order terms. Of course, the document calls for your client to bring the vehicles into compliance, comply with EWR, file a 573 and do all the things it should have done to comply with the Safety Act. In addition, we are requesting that RTDI retain an independent consultant, complete a compliance and training plan and dedicate 20k to an industry outreach program dedicated to informing similarly situated businesses about the requirements of the Safety Act. The document also calls for RTDI to perform an engineering analysis of the remedy applied to the axle as well as an assessment of the carrying capacity of the axle.

I recognize that the dollar amounts are not acceptable to you and point out that they reflect the extent of my authority as of today. We know that your client wishes to pay any penalty amounts over time. Within limits, this is not an issue that should be difficult to resolve.

Please review and let me know what you think. I would like to be in a position to have the document fairly well wrapped up by early next week.

I will call.

Thanks

Otto

From: Matheke, Otto (NHTSA)
Sent: 13 Oct 2016 15:22:57 +0000
To: Jacqueline Glassman
Cc: Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA)
Subject: Conference call today Ducks

Jackie - I would like to discuss Ducks today. Please send me some times we could do this.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Matheke, Otto (NHTSA)
Sent: 4 Nov 2016 16:14:08 +0000
To: Jacqueline Glassman (jglassman@kslaw.com)
Subject: DUCK dinero

Ms. G:

The Administrator has blessed the financial terms we discussed. 250 up front, 250 over time, 500 deferred contingent.

Let me know ASAP if this is not consistent with your view of the terms.

Otherwise, I look forward to your proposed language.

Thanks,

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Matheke, Otto (NHTSA)
Sent: 30 Sep 2016 14:00:58 +0000
To: Jacqueline Glassman
Cc: Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA)
Subject: Ducks

Jackie

I would like to chat briefly this afternoon and perhaps set up a meeting for next week to discuss penalties and consent order terms. When would be a good time to call?

Thanks

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Matheke, Otto (NHTSA)
Sent: 5 Oct 2016 20:00:33 +0000
To: Jacqueline Glassman
Subject: Ducks

Jackie:

I got stuck in meetings this afternoon. I am going to send a draft consent order and try to call before COB today.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Matheke, Otto (NHTSA)
Sent: 11 Oct 2016 18:41:31 +0000
To: Jacqueline Glassman
Subject: Ducks

Just checking in because I recall you will be out tomorrow. Let me know when you can share your version of the consent order.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Matheke, Otto (NHTSA)
Sent: 20 Oct 2016 22:18:16 +0000
To: Jacqueline Glassman (jglassman@kslaw.com)
Subject: DUCKS

Ms. Glassman:

Is the ball in your court or mine? Having enjoyed my midweek vacation and sent my older brother off to spend the winter in the tropics on his sailboat, I would like to maintain momentum on the DUCKS.

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
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From: Glassman, Jacqueline
Sent: 8 Nov 2016 17:10:42 -0500
To: Matheke, Otto (NHTSA)
Subject: Ducks
Attachments: DUCKSDRAFTConsent OrderNov8.docx

Otto – Here is a draft with some comments. I may have more (or slightly different) comments still, but we can start here. One big picture issue is that the draft you sent me had various confirmations and reports that are overkill here and unnecessary. They make this very hard to work with and don't seem to serve any additional safety purpose. This is not a huge company – they don't need to have executives signing declarations that their underlings took care of business. I've suggested deleting some of those.

Also the Attachments aren't necessary here. The Industry Outreach plan is basically asking you what you would like and with whom as it relates to companies outside of the small APV industry. If you skip the extra declarations and reports, the chronology is pretty simple and not hard to follow. And there's no need here for another certificate that the Consent Order was followed – it was or it wasn't, and if we have a dispute we'll deal with it.

There's some language changes either to make it better conform to the regs or to the facts. On the "admissions," I am fine stating the facts but don't think we need to make this company, which did nothing willfully and tried to do the right thing throughout, have to characterize their conduct. I don't see any safety benefit to that.

There aren't many changes, and I tried to go mostly lightly. But these are important.

Thanks, Jackie

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UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
	)
Ride the Ducks International, LLC	)
	)
	)

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's failure to notify NHTSA of a safety-related defect, 49 U.S.C. § 30118(c) and 49 C.F.R. Part 573; failure to notify owners of a safety-related defect in accordance with NHTSA's regulations, 49 U.S.C. § 30119 and 49 C.F.R. Part 577; failure to issue a recall for a safety-related defect in accordance with NHTSA's processes, 49 U.S.C. § 301118(c) and 49 C.F.R. 578.6; failure to provide a remedy without charge, 49 U.S.C. § 30120 and 49 C.F.R. Part 573; violations of its reporting requirements, 49 U.S.C. § 30166(f) and 49 C.F.R. Part 579.5; violations of its TREAD Act reporting requirements, 49 U.S.C. § 30166(m) and 49 C.F.R. Part 579.27; manufacturing for sale motor vehicles that do not comply and/or are not certified as complying with all applicable federal motor vehicle safety standards ("FMVSS"); under the following terms and conditions, as well as all attachments, which are hereby incorporated by reference.

I. NATURE OF THE ACTION

1. The National Traffic and Motor Vehicle Safety Act of 1966 as amended and recodified (the "Safety Act"), 49 U.S.C. § 30101, *et seq.*, provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation, including the promulgation of federal motor vehicle safety standards (FMVSS). 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an

inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins when "whether it actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. §

577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. A person who violates the notification requirements or remedy requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A separate violation occurs for each motor vehicle or

item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a).

Comment [ ]: Why multiple civll penalty paragraphs? Suggest only having one.

10. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

11. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make,

model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are now required to submit to the Agency an index for each communications to dealers, owners, or purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

12. Specifically, NHTSA's regulations require all manufacturers of motor vehicles and motor vehicle equipment to furnish to NHTSA "a copy of all notices, bulletins, and other communications (including those transmitted by computer, telefax, or other electronic means and including warranty and policy extension communiqués and product improvement bulletins) . . . , sent to more than one manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser, in the United States, regarding any defect in its vehicles or items of equipment (including any failure or malfunction beyond normal deterioration in use, or any failure of performance, or any flaw or unintended deviation from design specifications), whether or not such defect is safety-related." 49 C.F.R. § 579.5(a). Additionally, all manufacturers of motor vehicles and motor vehicle equipment are required to "furnish to NHTSA a copy of each communication relating to a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment that the manufacturer issued to, or made available to, more than one dealer, distributor, lessor, lessee, other manufacturer, owner, or purchaser, in the United States." 49 C.F.R. § 579.5(b). "Customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment" is further defined as including "any communication by a manufacturer to, or made available to, more than one dealer, distributor, lessor, lessee, other manufacturer, or owner, whether in writing or by electronic means, relating to repair, replacement, or modification

Comment [ ]: Duplicative of the prior paragraph?

of a vehicle, item of equipment, or a component thereof, . . . ; or advice or direction to a dealer or distributor to cease the delivery or sale of specified models of vehicles or equipment." 49 C.F.R. § 579.4. Copies of such documents are to be submitted to NHTSA "not later than five working days after the end of the month in which [they are] issued." 49 C.F.R. § 579.5(d).

13. A person who violates the Safety Act's reporting requirements, or a regulation prescribed thereunder, is liable to the United States Government for daily civil penalties. *See* 49 U.S.C. §§ 30166(m), 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

14. In general, only new motor vehicles that comply with applicable FMVSS and are so certified can be sold for use on the public roads. 49 U.S.C. §§ 30112(a), 30115. Motor vehicles must bear a label certifying such compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

15. A person who violates the certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty was $7,000 per violation. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A separate violation occurs for each motor vehicle or item of motor vehicle

Comment [ ]: Duplicative

Comment [ ]: duplicative

equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a).

16. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

17. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers (VINs) in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 565.

18. A person who violates 49 U.S.C. § 30166(e), 49 C.F.R. Part 565, and 49 C.F.R. Part 566 is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

19. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) ~~for this purpose~~ and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

Comment [ ]: duplicative

20. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

21. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

22. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses. RTDI further represents that it and/or its licensees have registered the amphibious vehicles with the Federal Motor Carrier Safety Administration, obtained DOT numbers, and utilized only drivers with proper Commercial Driver Licenses.

23. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

24. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

25. After learning of the Aurora Bridge crash, NHTSA issued an information request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015. .

26. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch

Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it ~~is a~~ manufacture~~d~~ ~~r of~~ motor vehicles under the Safety Act ~~or that the amphibious vehicles it manufactured are motor vehicles under the Safety Act~~.

27. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

28. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. Terms and Conditions of Consent Order

A. ~~Admission of~~ Noncompliance with the Safety Act

29. RTDI ~~admits that it~~ did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that ~~only~~ Coast Guard marine safety regulations were those applicable ~~ed~~ to its amphibious vehicles. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. ~~Therefore,~~ RTDI admits that it ~~violated the Safety Act by~~ manufacture~~ding~~ vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 30112. RTDI also failed ~~admits that it~~

~~violated the Safety Act's reporting requirements by failing~~ to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and by failing to report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. RTDI also failed ~~admits it violated the Safety Act by failing~~ to notify NHTSA of the safety-related defect (axle fracture) in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, failing to notify owners of the safety-related defect in accordance with 49 C.F.R. § 577.5, including, but not limited to, making clear ~~declaring~~ that the axle failure could result in a loss of control that could cause death or injury, and did ~~by~~ not provid~~e~~ing the remedy for the axle without charge as directed by 49 U.S.C. §30120.

B. Civil Penalty

30. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

31. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand ($ 480,000.00) in accordance with the instructions provided in Paragraph 32 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 54 through 57 and Attachment A (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order

during the term of this Consent Order, RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand (~~_____~~) ($ 500,000.00 (~~_____~~)), in accordance with the terms and conditions set forth below (the "Deferred Amount").

32. RTDI shall pay the ~~Non-Deferred Amount in _____ installments by electronic funds transfer, in accordance with the instructions provided by NHTSA, with the first such installment payable no later than 180 calendar days following execution of this Consent Order. The~~ first installment of two hundred fifty thousand ($250,000.00) ~~shall be second installment shall be due~~ no later than 180 days after the date of execution of this Consent Order. The remaining two hundred fifty thousand ($250,000.00) shall be due in three equal annual increments from the date of the first installment. At its option, RTDI may pay any remaining amounts prior to their respective due dates.

33. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 34 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (3~~en (1~~0) calendar days following a determination that they are due and owing.

34. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (3~~en (1~~0) calendar days, in accordance with instructions provided by

NHTSA,.. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (3~~en (1~~0) calendar days, in accordance with instructions provided by NHTSA. Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remainder~~ing two hundred eighty thousand dollars ($280,000)~~ of the Deferred Amount will become due and owing within thirty (3~~en (1~~0) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

35. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. Performance Obligations

36. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 39 through 59 below.

37. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

~~***1.*** RTDI agrees to undertake its reasonable best efforts to comply with all aspects of the Safety Act. If any material violation of the Safety Act, not expressly identified in this Consent Order or otherwise brought to NHTSA's attention in accordance with Paragraphs 44 through 45 below, occurs after the execution date of this Consent Order and during the pendency of this Consent Order, then the Deferred Amount shall become immediately due and owing to NHTSA, unless RTDI demonstrates that it acted in good faith and exercised reasonable best efforts to comply.~~

1. Remedying Past Noncompliance with the Safety Act

38. No later than 10 ~~53~~ working days after the execution of this Consent Order,[1] RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and any required reports with regard to claims or notices received by RTDI in 2015 relating to ~~of~~ the September 2015 crash involving deaths as referenced in Paragraph 29 above.

[1] ~~A schedule of RTDI's performance obligations under this Consent Order is attached as Attachment B.~~

Comment [ ]: Repetitive

Comment [ ]: What is a report of a crash?

39. No later than 30 calendar days after the execution of the Consent Order, RTDI will send current owners of the 57 Stretch Ducks formal customer notification in conformance with NHTSA regulations and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge. ~~shall take all necessary steps to recall all 57 Stretch Ducks regardless of whether they are already remedied, including notifying owners of the safety-related defect as referenced in Paragraph 29 above.~~

Comment [ ]: This is a vague and undefined reference.

40. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a compliance plan to NHTSA. The plan will state whether, and if so, when and how, RTDI intends to bring the vehicles into compliance with certain FMVSS. The plan will also state whether RTDI will file a petition for inconsequential treatment or a petition for an exemption with regard to certain of the FMVSS. RTDI states that, with regard to many of the FMVSS at issue, RTDI believes it has either previously addressed the safety considerations reflected through the standard or that the standard is not, as a practical matter, applicable to amphibious vehicles. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA that affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan) and have been certified as such by the application of certification labels. NHTSA agrees and understands that

RTDI has entered into this Consent Order in the expectation that, after appropriate review, NHTSA will grant its petitions ~~for inconsequential treatment~~. If NHTSA should not grant any part of RTDI's inconsequentiality petition, the parties agree to consult in good faith with regard to determining next steps and a reasonable time period to address the issue. - ~~No later than 90 calendar days after the execution of the Consent Order, RTDI shall submit to NHTSA a confirmation signed under oath that all Stretch Ducks comply with all applicable FMVSS and have been certified as such by the application of certification labels as referenced in Paragraph 29 above.~~

41. RTDI shall submit all manufacturer identification information required under 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

42. RTDI shall consult with NHTSA with regard to the need for any new VIN information and potential discrepancies with marine identification numbers and/or state registration requirements. The parties agree to cooperate in good faith to resolve whether new VINs are necessary, as well as the structure and implementation of any motor vehicle VINs and the potential for discrepancy between the structure of vehicle identification numbers and marine vessel information numbers and/or state registration requirements. ~~submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order or provide NHTSA with a plan on how to resolve any uncertainties arising in how to develop such VIN information with regard to the vehicles~~

43. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with Part 579.5~~report~~ any~~all previously unreported~~ notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to Part 579.5, regardless of whether RTDI has already provided those service

Comment [ ]: Since we know where all these vehicles are, there does not appear to be real significance to having a road VIN in addition to the original chassis VIN and/or the marine VIN. But we can figure that out.

bulletins in response to NHTSA's Information Request. ~~required to be submitted under 49 C.F.R. § 579.5.~~ RTDI shall also include indexes for each document ~~required to submit to the Agency at any time~~ that was issued since October 1, 2012.~~, required to be submitted under 49 U.S.C. § 30166(f)(2) and 49 C.F.R. § 579.5. [No later than 90 calendar days after execution of this Consent Order, RTDI shall submit a report to NHTSA, confirming that it has submitted any all previously unreported service bulletins as set forth above from the past five years, required to be submitted under 49 C.F.R. §§ 579.5(a)-(b), by submitting a schedule listing each such service bulletin and the date on which it was issued. The report shall also include indexes for each communications since October 1, 2012. RTDI shall promptly notify NHTSA if it discovers any previously unreported service bulletins or indexes that have not been reported in accordance with this Paragraph.]~~

Comment [ ]: There is no need, particularly for this small company, to overwhelm this Consent Order with multitudes of reports and confirmations. They are agreeing to do this. All this extra documentation creates a lot of confusion and does not necessary for this Consent Order.

Comment [ ]: Again, unnecessary.

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA and provide any Death and Injury reports from the last five years that would have been required. [~~report all previously unreported incidents involving a death identified in a claim or notice from the past five (5) years, required to be submitted under 49 C.F.R. § 579.27. No later than 90 calendar days after execution of this Consent Order, RTDI shall submit a report to NHTSA, confirming that it has submitted all previously unreported information on incidents involving death from the past five years, required to be submitted under 49 C.F.R. §§ 579.5(a)-(b), by submitting a schedule listing each such incident alphabetically by make, within each make alphabetically by model, and within each model chronologically by model year. RTDI shall promptly notify NHTSA if it discovers any previously unreported incidents involving a death that have not been reported in accordance with this Paragraph.]~~

2. Retention of Outside Consultant

45. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 51 and 52. The Consultant shall review for sufficiency technical service bulletins (TSBs), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

46. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 46, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

47. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

48. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

49. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 2013 TSB is effective and report the results to NHTSA. RTDI may comply with this obligation by providing NHTSA with a previously conducted engineering analysis.

50. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle ~~dealers,~~ owners or licensees~~, and purchasers~~ of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) ~~comprehensive~~ reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring any new vehicles manufactured by RTDI comply with applicable FMVSS ~~and all regulatory requirements~~ (collectively, "Compliance Plan"). ~~No later than 120 calendar days after execution of this Consent Order, RTDI shall provide a copy of such Compliance Plan to NHTSA.~~ If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such

Comment [ ]: We're not covering other agencies here.

feedback from NHTSA. ~~RTDI agrees that the Compliance Plan required in this Paragraph shall be publicly available.~~

51. ~~RTDI shall not claim any portion of the Compliance Plan is (i) subject to attorney-client privilege or attorney work product, or (ii) confidential business information, not subject to public disclosure by NHTSA.~~

51. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

52. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 51 and the Training Plan specified in Paragraph 52.

4. The Industry Outreach Performance Obligations

53. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The

performance obligations will be satisfied through the activities as set forth in Paragraphs 55 through 57 below and described in Attachment A to this Consent Order.

54. RTDI will consult with NHTSA to prepare a plan for the industry outreach that serves the agency's objectives as set forth above. The parties agree that RTDI will expend approximately $20,000.00 in execution of the industry outreach and will provide NHTSA with an itemized report of its expenditures. If RTDI has completed the industry outreach within one year, then RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA.~~report that includes a plan and procedures for addressing the targeted performance obligations set forth in Attachment A and will submit this report to NHTSA no later than 120 calendar days after the execution of this Consent Order. NHTSA, at its option, may accept, reject, or revise any part of the proposed report at any time during the pendency of this Consent Order, including on the basis that the proposed report does not include a sufficient number or variety of performance obligations, and may submit it back to RTDI for further revision, if necessary. The proposed report shall include metrics of success for the performance obligations specified in the report. NHTSA must give its approval, which will not be unreasonably withheld, to the proposed report before work on any of the performance obligations may begin.~~

~~The parties to this Consent Order agree that the cost of RTDI's execution of the performance obligations set forth in Paragraphs 54 and 55 and Attachment A shall not be less than twenty thousand dollars ($20,000), to be expended over a one year period of time (the "Industry Outreach Amount"). In documenting the Industry Outreach Amount, RTDI shall provide NHTSA a report no later than _____ days after the execution of this Consent Order, detailing the amount of dollars that RTDI actually expended during the prior year in furtherance~~

Comment [ ]: This is not a typical industry outreach since you're adding an industry outside of RTDI's scope. The company will need to work with the agency to identify what steps are appropriate for the $20K. In this context, the Appendix and a big plan from RTDI is not warranted or feasible.

Comment [ ]: Unnecessary

~~of its obligations under Paragraphs 54 and 55 and Attachment A. NHTSA may consider the reasonable continuing and future costs to RTDI associated with RTDI carrying out the performance obligations beyond the term of this Consent Order. At NHTSA's sole discretion, a reasonable amount of RTDI's future costs of implementing the performance obligations may be counted towards the calculation of the Industry Outreach Amount.~~

~~In accordance with this Consent Order, RTDI is responsible for the satisfactory completion of the performance obligations set forth in Paragraphs 54 through 56 and Attachment A. Subject to NHTSA's discretion to extend the term of this Consent Order under Paragraph 62 below, if RTDI has reasonably completed the performance obligations in Paragraphs 54 through 56 and Attachment A and has expended the full Industry Outreach Amount, then on the one year from the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out in Paragraphs 54 through 56 and Attachment A, then the balance of the Industry Outreach Amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 62 below, RTDI's obligations under this Consent Order and this Paragraph to pay the balance of the Industry Outreach Amount shall also be extended for the term of one year.~~

5. Completion of Performance

55. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

Comment [ ]: Not needed. We'll just work together and figure out how to spend the $20K to get to the folks you want to reach.

Comment [ ]: Unnecessary and duplicative

56. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

57. ~~shall provide to NHTSA, no later than ____ calendar days after execution of this Consent Order, a declaration from an officer of the company documenting the completion of its obligations, as defined in Attachment C, since the execution of this Consent Order. The declaration shall be submitted to NHTSA pursuant to 28 U.S.C. § 1746.~~

57. ~~In accordance with this Consent Order, RTDI is responsible for the satisfactory completion of the performance obligations set forth in Paragraphs 39 through 57. No later than _____ calendar days after the execution of this Consent Order, RTDI shall submit a Completion Report to NHTSA and, at NHTSA's election, RTDI will make a presentation of its performance obligations under the Consent Order. The Completion Report shall address the metrics of success for each of the targeted performance obligations and objectives, included in Attachment C. NHTSA will use this report to determine whether RTDI has reasonably completed the performance obligations and should be released from the Consent Order under Paragraph 62 or whether this Consent Order should be extended for an additional year as set forth herein. In the event obligations remain to be performed by RTDI notwithstanding RTDI's best efforts to complete same, NHTSA will not unreasonably deny a request by RTDI to extend the time to complete the performance obligations.~~

D. Compliance

58. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts

Comment [ ]: We either complete or we don't. No need for such certification.

Comment [ ]: Does not make sense as to this Consent Order

shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

59. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

III. TERM OF CONSENT ORDER

60. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraphs 39 through 59 shall survive the term of this Consent Order until the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

IV. AMENDMENT

61. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

V. MISCELLANEOUS

62. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

63. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 31 and 32, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 39 through 59, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order or identified in any schedules and reports submitted pursuant to Paragraphs 44 and 45, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraphs 44 and 45, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraphs 44 and 45, NHTSA may pursue any and all enforcement action or

claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

64. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

65. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

66. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 35 above.

67. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

68. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

69. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

70. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set

forth in Paragraphs 31 and 32, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

71. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

72. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

73. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

74. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

75. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order and the attachments thereto.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

DRAFT – FOR SETTLEMENT PURPOSES ONLY
NOT ADMISSIBLE
FED. R. EVID. 408

ATTACHMENT A

Comment [ ]: Delete

Industry Education and Outreach

A. Purpose of the Industry Outreach Performance Obligations.

NHTSA and RTDI agree that the performance obligations included below are intended to secure a significant benefit to the interests of public safety by mitigating the risks of harm associated with non-compliance with the National Traffic and Motor Vehicle Safety Act of 1966 as amended and recodified (the "Safety Act"), 49 U.S.C. § 30101, *et seq.*, and that the following performance obligations are consistent with the purpose of the Safety Act.

B. Targeted Performance Obligations.

In executing the terms of the Consent Order, RTDI must file certain reports related to its plan for industry and consumer outreach, which will include the following and which are to be completed over the next year:

(1) Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

(2) Develop Safety Act educational materials for distribution to manufacturers.

(3) Assist other manufacturers in developing their own safety outreach programs.

(4) Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

(5) Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

C. Development of Written Plan and Procedures for Industry Outreach.

As set forth in Paragraph 55 of the Consent Order, RTDI will prepare a report which includes a plan and procedures for fulfilling the targeted performance obligations set forth in Section B above. This report shall be submitted to NHTSA no later than 120 calendar days after the execution of the Consent Order, and shall include metrics of success for the targeted performance obligations contained in Section B above. NHTSA, at its option, may accept, reject or revise any part of the proposed report at any time during the pendency of this Consent Order and submit it back to RTDI for further revision, if necessary. NHTSA must give its approval, which will not be unreasonably withheld, to the proposed report before work on any of the targeted performance obligations may begin.

The targeted performance obligations outlined in Section B may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations outlined in Section B may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

D. Costs Associated With the Industry Outreach Performance Obligations.

Consistent with Paragraphs 31 and 56 of the Consent Order, the total expenditure of the performance obligations described above shall not be less than twenty thousand dollars ($20,000), and shall be documented in accordance with those paragraphs.

In the event of a dispute as to whether RTDI has incurred any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have fifteen working days to respond. Upon receipt of RTDI's response, should NHTSA still dispute any contested amount, NHTSA shall advise RTDI in writing within fifteen working days, and RTDI shall hire, at its sole expense, a third-party, independent public accounting firm to assess RTDI's costs incurred. The independent public accounting firm will evaluate whether or not the costs identified are accurate, whether they reached the cost of the Industry Outreach Amount, and whether they are reasonably tailored to the exercise of the targeted performance obligations. The independent public accounting firm will advise NHTSA of its findings by submitting a declaration to NHTSA regarding these points pursuant to 28 U.S.C. § 1746.

E. Completion of Targeted Performance Obligations.

Consistent with Paragraph 62 of the Consent Order, the timeline for the satisfactory completion of the targeted performance obligations listed in Section B above is one year. No later than 335 days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations.

RTDI is responsible for the satisfactory completion of the targeted performance obligations in Section B above in accordance with the Consent Order. Subject to the provisions for extending the term of this Consent Order in Paragraph 62, if RTDI has reasonably achieved all of the targeted performance obligations on or before the one year anniversary of the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out in Section B

above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 62, RTDI's responsibility for the satisfactory completion of the targeted performance obligations listed in Section B shall also be extended for the term of one year.

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ATTACHMENT B

Comment [ ]: Delete. Unnecessary and confusing. And would need to be conformed to revised language.

Schedule of Performance Obligations
(for the Consent Order term)

Due Date	Description	Consent Order
3 working days	Submit outstanding October 1, 2013 TSB and corresponding Part 573 Defect Information Report and report of the September 2015 crash involving deaths	Paragraph 39
30 days	Take all necessary steps to recall all 57 Stretch Ducks, including notifying Stretch Duck owners of safety defect in axles	Paragraph 40
30 days	Provide NHTSA name and resume of proposed Consultant	Paragraph 47
30 days	Perform engineering analysis of Stretch Duck axle and provide NHTSA with results	Paragraph 50
60 days	Retain Consultant	Paragraph 46
90 days	Submit report under oath confirming all vehicles comply with FMVSS	Paragraph 41
90 days	Submit all manufacturer identification information required by 49 C.F.R. Part 566	Paragraph 42
90 days	Submit VIN information required by 49 C.F.R. Part 565 or report why do not conform with requirements	Paragraph 43
90 days	Submit all previously unreported service bulletins from past 5 years and required corresponding indexes AND submit report confirming that all unreported service bulletins and indexes have been submitted	Paragraph 44
90 days	Submit all previously unreported incidents involving a death AND submit report confirming that all unreported incidents involving a death from the past 5 years have been submitted	Paragraph 45
90 days	Submit report identifying all safety-related defects and noncompliances with FMVSS currently under review	Paragraph 49
120 days	Compliance Plan	Paragraph 51
120 days	Training Plan	Paragraph 52

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120 days	Industry outreach plan	Paragraph 55 and Attachment A
180 days	First Payment of Non-Deferred Amount	Paragraph 32
180 days	Submit report detailing efforts to implement Compliance Plan and Training Plan	Paragraph 53
335 days	Report on Industry Outreach Amount	Paragraph 56
335 days	Declaration regarding completion of performance obligations and Completion Report	Paragraphs 58 and 59
____ days	Second Payment of Non-Deferred Amount	Paragraph 32

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NOT ADMISSIBLE
FED. R. EVID. 408

ATTACHMENT C

Comment [ ]: Delete. This is unnecessary as applied to this Consent Order and would need to be conformed to any changes. This is over bureaucracy.

Declaration of Performance Obligation Completion

In accordance with Paragraphs 58 and 59 of the Consent Order, RTDI shall provide to NHTSA, no later than _____ days after execution of this Consent Order, a declaration from an officer of the company pursuant to 28 U.S.C. § 1746, documenting the completion of its performance obligations during the prior year. RTDI's performance obligations include the following:

Submit materials to remedy past noncompliance

High Level Summary:

Within the agreed upon time period, RTDI will:

- Submit the October 1, 2013 service bulletin, a Part 573 for the axle safety-related defect, and a report of the September 2015 crash involving deaths;
- Take all steps necessary to recall the Stretch Ducks, including notifying owners of the safety-related defect;
- Submit a report under oath confirming all vehicles comply with all applicable FMVSS;
- Submit all manufacturer identification information required by 49 C.F.R. Part 566; and
- Submit all VIN information required under 49 C.F.R. Part 565. If the VINs assigned the vehicles are not in compliance with part 565, provide a detailed report.

Measurement of Completion:

- Information submitted; and
- Owners notified of safety-defect and remedy program is underway.

Submit information required by reporting requirements
High Level Summary:

Within the agreed upon time period, RTDI will:

- Submit all previously unreported "service bulletins" from past five years and corresponding indexes for service bulletins since October 1, 2012;

- Provide a report to NHTSA confirming that all unreported service bulletins from the past five years and indexes for service bulletins since October 1, 2012 have been reported;

- Submit all previously unreported incidents involving death from past 5 years;

- Provide a report to NHTSA confirming that all unreported incidents involving death from the past five years have been reported; and

- Notify the agency of all safety-related defects or noncompliances of which it has actual knowledge or that are currently under review by RTDI.

Measurement of Completion:

- Information submitted to NHTSA within the defined time periods.

Hire outside consultant

High Level Summary:

Within the agreed upon time period RTDI will:

- Select outside consultant with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations;

- Submit the name and detailed resume of the individual whom RTDI intends to retain;

- Notify the agency when hire Consultant; and

- Allow Consultant to review all reports required under the Consent Order and advise RTDI on compliance with Safety Act and regulations.

Measurement of Completion:

- Submit proposed Consultant's name and resume to NHTSA and gain acceptance of proposed individual from the agency;

- Hire Consultant and report hiring to NHTSA; and

- Work with Consultant to comply with Consent Order and Safety Act and regulations.

Perform engineering analysis of Stretch Duck axle

High Level Summary:

Within the agreed upon time period, RTDI will:

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NOT ADMISSIBLE
FED. R. EVID. 408

- Perform an engineering analysis of the Stretch Duck axle and provide results to NHTSA.

Measurement of Completion:

- Complete the engineering analysis on Stretch Duck axle; and
- Submit results to NHTSA within the defined time period.

Develop new written procedures

High Level Summary:

- Develop a new "Compliance Plan" written procedures, with assistance from Consultant.

Measurement of Completion:

- Submit a copy of the Compliance Plan to NHTSA and gain acceptance of proposal from the agency.

Train appropriate RTDI personnel

High Level Summary:

Within the agreed upon time period, RTDI will:

- Prepare a "Training Plan," with assistance from Consultant; and
- Annually train personnel on Safety Act reporting requirements and Compliance Plan written procedures.

Measurement of Completion:

- Training Plan submitted and approved by NHTSA; and
- Training log detailing what individuals were trained and what training was received.

Report on Compliance Plan and Training Plan

High Level Summary:

Within the agreed upon time period, RTDI will:

- Submit a report detailing its efforts to implement the Compliance Plan and train its personnel.

Measurement of Completion:

- Report submitted to NHTSA within the defined time period.

Industry Outreach
High Level Summary:

Within the agreed upon time period, RTDI will:

- Perform industry outreach, educating manufacturers with similar business models of their obligations under the Safety Act and reporting regulations.

Measurement of Completion:

- Report submitted to NHTSA that details the plan and procedures for addressing the obligations set forth in Attachment A.

Educate customers and licensees

High Level Summary:

Within the agreed upon time period, RTDI will:

- Undertake a good faith attempt to reach and train RTDI's customer base (which includes its licensees).

Measurement of Completion:

- Evidence of completions/attempts to perform training.

Develop Safety Act education materials

High Level Summary:

Within the agreed upon time period, RTDI will:

- Prepare educational materials regarding NHTSA, the Safety Act, and manufacturer reporting responsibilities to be shared with other members of the industry.

Measurement of completion:

- Approval from NHTSA of materials.

Assist other manufacturers in developing their own safety outreach program

High Level Summary:

Within the agreed upon time period, RTDI will:

- Share educational materials, such as the Compliance Plan and Training Plan, with other members of the industry.

Measurement of completion:

- Submit to NHTSA a list of manufacturers with whom RTDI has shared its educational materials and/or Compliance Plan and Training Plan.

Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA

High Level Summary:

Within the agreed upon time period, RTDI will:

- Prepare educational materials regarding NHTSA, the Safety Act, and manufacturer reporting responsibilities to be shared with other members of the industry.

Measurement of completion:

- Submit to NHTSA evidence of presentations made by RTDI.

Work with partners to enhance recall effectiveness

High Level Summary:

Within the agreed upon time period, RTDI will:

- Share educational materials, such as the Compliance Plan and Training Plan, with other members of the industry.

Measurement of completion:

- Submit to NHTSA a list of partners and suppliers with whom RTDI has shared its educational materials and/or Compliance Plan and Training Plan.

Completion Report

High Level Summary:

Within the agreed upon time period, RTDI will:

- Submit a Completion Report to NHTSA and may give a presentation to the agency of its performance under the Consent Order.

Measurement of Completion:

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- Report submitted to NHTSA within the defined time period.

From: Glassman, Jacqueline
Sent: 9 Nov 2016 14:26:29 -0500
To: Matheke, Otto (NHTSA)
Cc: Torres, Justin
Subject: Ducks

Otto – There were a couple of items the RTDI team caught.

It's not clear that all of the Ducks have DOT numbers. It may have depended on whether or not the states had the Ducks registered as marine vessels. Best to remove that sentence:

22. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

[RTDI further represents that it and/or its licensees have registered the amphibious vehicles with the Federal Motor Carrier Safety Administration, obtained DOT numbers, and utilized only drivers with proper Commercial Driver Licenses.] – delete.

It is possible that RTDI will want to re-engineer to comply but can't feasibly make that happen within the 120 day time period. I am thinking mostly of that possibility with regard to lifts. We would like to reserve the option of explaining that plan to you and having you approve the good faith timetable to re-engineer the vehicles:

40. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a compliance plan to NHTSA. The plan will state whether, and if so, when and how, RTDI intends to bring the vehicles into compliance with certain FMVSS. The plan will also state whether RTDI will file a petition for inconsequential treatment or a petition for an exemption with regard to certain of the FMVSS. RTDI states that, with regard to many of the FMVSS at issue, RTDI believes it has either previously addressed the safety considerations reflected through the standard or that the standard is not, as a practical matter, applicable to amphibious vehicles. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA that affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan or are subject to ongoing design and/or engineering efforts which NHTSA has approved) and have been certified as such by the application of certification labels. NHTSA agrees and understands that RTDI has entered into this Consent Order in the expectation that, after appropriate review, NHTSA will grant its petitions for inconsequential treatment. If NHTSA should not grant any part of RTDI's inconsequentiality petition, the parties agree to consult in good faith with regard to determining next steps and a reasonable time period to address the issue.

Thanks, Jackie

Jacqueline Glassman
King & Spalding LLP
1700 Pennsylvania Avenue, NW
Washington DC 20006
Jglassman@kslaw.com
202-626-9228

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From: Glassman, Jacqueline
Sent: 11 Nov 2016 15:52:20 -0500
To: Matheke, Otto (NHTSA)
Subject: Ducks
Attachments: DUCKSDRAFTConsent OrderNov10 CLEAN.docx

Otto – We have a few, relatively small language requests, which are inserted.

As discussed, we again ask the agency to consider foregoing the admission language. This is an easy mechanical fix – just the removal of the list in the first paragraph and paragraph 25. The document still stands on its own and remains very strong.

The company has agreed to the various performance obligations, including industry outreach and a substantial civil penalty. This additional language may actually detract from the agency's effort to gain the attention of other companies that are refurbishing vehicles. They may read the laundry list of violations and the admission as an indication that there was a more knowing effort to avoid the regulations and simply conclude that they are following what they believe to be the rules in good faith and would not be subject to this kind of enforcement action. You may send your message more clearly by keeping the language clean and more concise.

Chris has reached out to the Administrator to touch base before we finalize this on Monday. He has let the Administrator know that we've been working successfully with you and others, and are very close to an agreement, but would appreciate an opportunity to touch base before finalizing a document of such importance to the future of the company.

Thanks, Jackie

Jacqueline Glassman
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UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
	)
Ride the Ducks International, LLC	)
	)
	)

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. [It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's failure to notify NHTSA of a safety-related defect, 49 U.S.C. § 30118(c) and 49 C.F.R. Part 573; failure to notify owners of a safety-related defect in accordance with the National Traffic and Motor Vehicle Safety Act ("Safety Act") and NHTSA's regulations, 49 U.S.C. § 30119 and 49 C.F.R. Part 577; failure to issue a recall for a safety-related defect in accordance with the Safety Act and NHTSA's regulations, 49 U.S.C. § 301118(c) and 49 C.F.R. 578.6; failure to provide a remedy without charge, 49 U.S.C. § 30120 and 49 C.F.R. Part 573; violations of its reporting requirements, 49 U.S.C. § 30166(f) and 49 C.F.R. Part 579.5; violations of its TREAD Act reporting requirements, 49 U.S.C. § 30166(m) and 49 C.F.R. Part 579.27; manufacturing for sale motor vehicles that do not comply and/or are not certified as complying with all applicable federal motor vehicle safety standards ("FMVSS"); under the following terms and conditions.]

I. NATURE OF THE ACTION

1. The Safety Act provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated

Comment [ ]: We again ask that the agency to consider foregoing this language and paragraph 25. RTDI is agreeing to rectifying the oversight and to a substantial penalty.

This language is likely to dissuade those in the broader industry because it makes it appear that the conduct was more knowing and few small business owners are likely to read through the whole document to see this was all the result of a mistake that they may also be making. You are more likely to reach your intended audience by keeping the language cleaner and more concise.

his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins when "whether it actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. § 577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the

Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

10. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign,

consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make, model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are required to submit to the Agency an index for each communications to dealers, owners, or purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

11. In general, motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery. 49 U.S.C. §§ 30112(a), 30115. This certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

12. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

13. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers (VINs) in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 565.

14. A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). A separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A person who violates 49 U.S.C. § 30166, 49 C.F.R. Part 565, 49 C.F.R. Part 566, and 49 C.F.R. Part 579 is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

15. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

16. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles

were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

17. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

18. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

19. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was

released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

20. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

21. After learning of the Aurora Bridge crash, NHTSA issued an information request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015.

22. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it manufactured motor vehicles under the Safety Act.

23. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the October 1, 2013 Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

24. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. Terms and Conditions of Consent Order

[A. Admission of RTDI's Safety Act Violations

25. RTDI did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that only Coast Guard marine safety regulations were applicable to the amphibious vehicles it manufactured. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. RTDI admits that it manufactured vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 301152. RTDI also failed to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and did not ~~by failing to~~ report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. ~~RTDI also failed to notify NHTSA of the safety-related defect (axle fracture) in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, failed to notify owners of the safety-related defect in accordance with 49 C.F.R. § 577.5, including, but not limited to, making clear that the axle failure could result in a~~

~~loss of control that could cause death or injury, and did not provide the remedy for the axle without charge as directed by 49 U.S.C. §30120.~~ RTDI also admits that its notifications, service bulletins and other communications to owners regarding a safety-related defect in 57 stretch duck axles did not fully comply with 49 CFR Part 573 (notifying NHTSA), 49 CFR Part 577.5 (clarity of potential consequences of inaction by owners), and 49 USC 30120 (offering to pay for the remedy).]

B. Civil Penalty

26. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

27. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand dollars ($480,000.00) in accordance with the instructions provided in Paragraph 28 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 49 through 52 (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order during the term of this Consent Order, RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand dollars ($500,000.00), in accordance with the terms and conditions set forth below (the "Deferred Amount").

28. RTDI shall make a payment of two hundred forty thousand dollars ($240,000.00) no later than May 14, 2017. The remaining two hundred forty thousand dollars ($240,000.00) shall be due in three equal annual increments due not later than May 14, 2018, May 14, 2019, and May 14, 2020 respectively. At its option, RTDI may pay any remaining amounts prior to their respective due dates. RTDI expressly agrees that the obligation to pay the foregoing sums as specified above shall survive the termination of this Consent Order.

29. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 30 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (30) calendar days following a determination that they are due and owing.

30. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining three hundred thousand dollars ($300,000) of the Deferred Amount will become due and owing within thirty

(30) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

31. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. Performance Obligations

32. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 34 through 54 below.

33. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

1. Remedying Past Noncompliance with the Safety Act

34. No later than 5 working days after the execution of this Consent Order, RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and a report of a claim alleging that a death resulted from a safety defect related to the September 2015 crash involving deaths as referenced in Paragraph 20 above.

35. No later than 30 calendar days after the execution of the Consent Order, RTDI will send owners of the 57 Stretch Ducks formal customer notification as directed by 49 CFR Part 577 and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge.

36. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a FMVSS compliance plan to NHTSA. The plan will identify those FMVSS for which RTDI has made a good faith determination are applicable to the vehicles it has manufactured. For each such FMVSS, RTDI shall state when and how RTDI intends to bring the vehicles into compliance with a particular standard by following the statutory recall process or filing a petition for inconsequential noncompliance under 49 CFR Part 556 or a petition for exemption under 49 CFR Part 555. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to

RTDI's plan or are subject to ongoing design and/or engineering efforts which, subject to NHTSA's consent, require further extension of the 120 day deadline) and have been certified as such by the application of certification labels. If NHTSA should not grant any part of RTDI's inconsequentiality petition or exemption petition, the parties agree to consult in good faith with regard to determining next steps to address the issue.

37. RTDI shall submit all manufacturer identification information required by 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

38. RTDI shall submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order. If vehicles have been assigned VINs that are not in compliance with the requirements of 49 CFR Part 565, RTDI will provide a detailed report to NHTSA no later than 90 days after the execution of this Consent Order, with each vehicle's assigned VIN and a description of why the VIN does not conform to the requirements of Part 565.

39. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with 49 U.S.C. §30166(f) and 49 CFR § 579.5 any notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to 49 CFR § 579.5, regardless of whether RTDI has already provided those service bulletins in response to NHTSA's Information Request. RTDI shall also include indexes for each document that was issued since October 1, 2012.

40. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA. No later than 180 calendar days after execution of this Consent Order, RTDI shall submit any and all reports required by 49 C.F.R. § 579.27 for the five years preceding the aforementioned date of execution.

2. Retention of Outside Consultant

41. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 46 and 47. The Consultant shall review for sufficiency technical service bulletins (TSBs), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

42. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 41, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

43. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

45. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 2013 TSB is effective and report the results to NHTSA.

46. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle owners, licensees, and purchasers of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring vehicles manufactured by RTDI in the future comply with applicable FMVSS and other statutory and regulatory requirements administered by NHTSA (collectively, "Compliance Plan"). If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in the Paragraph shall be publicly available.

47. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to

be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

48. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 46 and the Training Plan specified in Paragraph 47.

4. The Industry Outreach Performance Obligations

49. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The industry outreach performance obligations will be satisfied through the activities as set forth in Paragraph 50 through 52 below.

50. The parties agree that RTDI will expend not less than $20,000.00 in execution of the industry outreach. Not less than 120 days after execution of this Consent Order, RTDI shall provide NHTSA with a plan for industry and consumer outreach, which NHTSA, at its option, may accept, reject, or revise and submit it back to RTDI for further revision, if necessary. The proposed plan ~~will~~ may include the following and which are to be completed over the next year:

a. Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety

Act obligations, such as early warning and other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

b. Develop Safety Act educational materials for distribution to manufacturers.

c. Assist other manufacturers, if requested, in developing their own safety outreach programs.

d. Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

e. Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

The outreach plan shall include metrics of success for the foregoing targeted performance obligations. The targeted performance obligations may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

51. RTDI shall expend its best efforts to complete the targeted performance obligations not less than one year after NHTSA gives its approval of the industry outreach plan. No later than 360 calendar days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations. In the event of a dispute as to whether RTDI has expended any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have fifteen working days to respond.

52. RTDI is responsible for the satisfactory completion of the targeted performance obligations described above. Subject to the provisions for extending the term of this Consent Order in Paragraph 57, if RTDI has reasonably achieved all of the targeted performance obligations on or before 365 calendar days after the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 57, RTDI's responsibility for the satisfactory completion of the targeted performance obligations shall also be extended for the term of one year.

5. Completion of Performance

53. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

54. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

D. Compliance

55. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any

requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

56. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

III. TERM OF CONSENT ORDER

57. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraph 28 and Paragraphs 34 through 54 shall survive the term of this Consent Order until the Non Deferred Amount is paid in full and the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

IV. AMENDMENT

58. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

V. MISCELLANEOUS

59. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

60. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 27 and 28, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 34 through 54, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraph 39, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraph 39, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

61. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or

any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

62. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

63. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 31 above.

64. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

65. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

66. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

67. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 27 and 28, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

68. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in

connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

69. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

70. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

71. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

72. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

From: Matheke, Otto (NHTSA)
Sent: 25 Oct 2016 17:43:44 +0000
To: Jacqueline Glassman (jglassman@kslaw.com)
Subject: DUCKS and Compliance - for settlement purposes not admissible FRE 408

Jackie:

Try this on for size for new language for Paragraph 41 in the most recent consent order I sent you.

1. RTDI has consulted with NHTSA regarding the FMVSS that apply to the vehicles it has produced. Nonetheless, RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains RTDI's sole responsibility. No later than 60 calendar days after the execution of the Consent Order, RTDI shall submit to NHTSA a plan for bringing the vehicles it has produced into compliance with all applicable FMVSS or to the extent necessary, filing petitions for inconsequential non-compliance. RDTI further agrees that it will conduct safety recalls to address any and all non-compliances with applicable FMVSS not addressed by a petition for inconsequential non-compliance. No later than 120 days after the submission of the aforementioned FMVSS compliance plan, RTDI shall submit a confirmation signed under oath to NHTSA affirming that all Stretch Ducks owned or operated by RTDI or RTDI licensees obligated to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequential non-compliance have been filed by RTDI) and have been certified as such by the application of certification labels as referenced in Paragraph 29 above.

2. RTDI has consulted with NHTSA regarding the FMVSS that apply to the vehicles it has produced. Nonetheless, RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains RTDI's sole responsibility. No later than 60 calendar days after the

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Thanks

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Subject:	DUCKS and Compliance - for settlement purposes not admissible FRE 408
Date:	Tuesday, October 25, 2016 1:43:00 PM
Attachments:	image001.png image002.png image003.png image004.png

Jackie:

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recalls to address any and all non-compliances with applicable FMVSS not addressed by a petition for inconsequential non-compliance. No later than 120 days after the submission of the aforementioned FMVSS compliance plan, RTDI shall submit a confirmation signed under oath to NHTSA affirming that all Stretch Ducks owned or operated by RTDI or RTDI licensees obligated to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequential non-compliance have been filed by RTDI) and have been certified as such by the application of certification labels as referenced in Paragraph 29 above.

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Thanks

NHTSA
Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration

1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Matheke, Otto (NHTSA)
Sent: 2 Nov 2016 15:26:56 +0000
To: Jacqueline Glassman (jglassman@kslaw.com)
Cc: Stephens, Jordan (NHTSA);Kolodziej, Kerry (NHTSA)
Subject: Ducks and EWR fatality reporting

Jackie:

Thanks for your phone call and for alerting me to your concern that RTDI may not have had any obligation to report the Seattle death claims because of the age of the crash vehicle.

I took a look at this and I think that RTDI would have had an obligation to file a fatality report if they received a claim in the 3rd or 4th quarter of 2015. RTDI did not have model years, so they would default to a calendar year of manufacture. The Seattle crash vehicle was built in 2005 and because the rule states that you have to report for the current model year and the nine previous model years, there would have been an obligation to report if the written claim hit RTDI's inbox before the beginning of calendar year 2016.

The relevant language is in 579.4 and 479.21.

Thanks

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Cc:	Stephens, Jordan (NHTSA); Kolodziej, Kerry (NHTSA)
Subject:	Ducks and EWR fatality reporting
Date:	Wednesday, November 02, 2016 11:26:00 AM
Attachments:	image001.png image002.png image003.png image004.png

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Jackie:

Thanks for your phone call and for alerting me to your concern that RTDI may not have had any obligation to report the Seattle death claims because of the age of the crash vehicle.

I took a look at this and I think that RTDI would have had an obligation to file a fatality report if they received a claim in the 3rd or 4th quarter of 2015. RTDI did not have model years, so they would default to a calendar year of manufacture. The Seattle crash vehicle was built in 2005 and because the rule states that you have to report for the current model year and the nine previous model years, there would have been an obligation to report if the written claim hit RTDI's inbox before the beginning of calendar year 2016.

The relevant language is in 579.4 and 479.21.

Thanks

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Cc:	Kolodziej, Kerry (NHTSA); Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject:	DUCKS consent order draft.
Date:	Friday, October 14, 2016 4:57:00 PM
Attachments:	image001.png image002.png image003.png image004.png

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Jackie:

I was a tad optimistic on our ability to get you a draft by COB today. We will send on Monday.

Have a good weekend.

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Torres, Justin
Sent: 15 Nov 2016 11:28:00 -0500
To: Matheke, Otto (NHTSA)
Cc: Glassman, Jacqueline
Subject: DUCKS Consent Order Final - SIGNED RTDI.PDF
Attachments: DUCKS Consent Order Final - SIGNED RTDI.PDF

Otto – please see attached the signed RTDI Consent Decree.

Best, Justin

Justin A. Torres | King & Spalding LLP
1700 Pennsylvania Ave, NW, Washington, D.C. 20006
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UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
	)
Ride the Ducks International, LLC	)
	)

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's violations of the National Traffic and Motor Vehicle Safety Act ("Safety Act") and NHTSA's regulations as detailed herein under the following terms and conditions.

I. NATURE OF THE ACTION

1. The Safety Act provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins when

"whether it actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. § 577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

10. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make, model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are required to submit to the Agency an index for each communications to dealers, owners, or

purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

11. In general, motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery. 49 U.S.C. §§ 30112(a), 30115. This certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

12. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

13. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers (VINs) in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e); 49 C.F.R. Part 565.

14. A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). A separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A person who violates 49 U.S.C. § 30166, 49 C.F.R. Part 565, 49 C.F.R. Part 566, and 49 C.F.R. Part 579

is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

15. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

16. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

17. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading

and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

18. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

19. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

20. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

21. After learning of the Aurora Bridge crash, NHTSA issued an Information Request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its

licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015.

22. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it manufactured motor vehicles under the Safety Act.

23. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the October 1, 2013 Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

24. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. Terms and Conditions of Consent Order

Admission of Safety Act Violations

25. RTDI did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules were applicable to the

amphibious vehicles it manufactured. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. RTDI admits that it manufactured vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 30112. RTDI also failed to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and did not report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. RTDI also did not notify NHTSA of the safety defect in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, did not provide a remedy for axle defect without charge as directed by 49 U.S.C. § 30120 and admits that its communication to owners regarding a safety related defect in the 57 Stretch Duck axles did not fully comply with 49 C.F.R. § 577.5 (describing potential safety consequences of a defect).

B. Civil Penalty

26. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

27. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand dollars ($480,000.00) in accordance with the instructions provided in Paragraph 28 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 49 through 52 (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order during the term of this Consent Order,

RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand dollars ($500,000), in accordance with the terms and conditions set forth below (the "Deferred Amount").

28. RTDI shall make a payment of two hundred forty thousand dollars ($240,000) no later than May 14, 2017. The remaining two hundred forty thousand dollars ($240,000) shall be due in three equal annual increments due not later than May 14, 2018, May 14, 2019, and May 14, 2020 respectively. At its option, RTDI may pay any remaining amounts prior to their respective due dates. RTDI expressly agrees that the obligation to pay the foregoing sums as specified above shall survive the termination of this Consent Order.

29. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 30 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (30) calendar days following a determination that they are due and owing.

30. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA.

Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining three hundred thousand dollars ($300,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

31. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. <u>Performance Obligations</u>

32. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 34 through 54 below.

33. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

1. Remedying Past Noncompliance with the Safety Act

34. No later than 5 working days after the execution of this Consent Order, RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and a report of a claim alleging that a death resulted from a safety defect related to the September 2015 crash involving deaths as referenced in Paragraph 20 above.

35. No later than 30 calendar days after the execution of the Consent Order, RTDI will send owners of the 57 Stretch Ducks formal customer notification as directed by 49 C.F.R. Part 577 and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge.

36. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a FMVSS compliance plan to NHTSA. The plan will identify those FMVSS for which RTDI has made a good faith determination are applicable to the vehicles it has manufactured. For each such FMVSS, RTDI shall state when and how RTDI intends to bring the vehicles into compliance with a particular standard by following the statutory recall process or filing a petition for inconsequential noncompliance under 49 C.F.R. Part 556 or a petition for exemption under 49 C.F.R. Part 555. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by

contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan or are subject to ongoing design and/or engineering efforts which, subject to NHTSA's consent, require further extension of the 120 day deadline) and have been certified as such by the application of certification labels. If NHTSA should not grant any part of RTDI's inconsequentiality petition or exemption petition, the parties agree to consult in good faith with regard to determining next steps to address the issue.

37. RTDI shall submit all manufacturer identification information required by 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

38. RTDI shall submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order. If vehicles have been assigned VINs that are not in compliance with the requirements of 49 C.F.R. Part 565, RTDI will provide a detailed report to NHTSA no later than 90 days after the execution of this Consent Order, with each vehicle's assigned VIN and a description of why the VIN does not conform to the requirements of Part 565.

39. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with 49 U.S.C. §30166(f) and 49 C.F.R. § 579.5 any notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to 49 C.F.R. § 579.5, regardless of whether RTDI has already provided those service bulletins in response to NHTSA's Information Request. RTDI shall also include indexes for each document that was issued since October 1, 2012.

40. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA. No later than 180 calendar days after execution of this Consent Order, RTDI shall submit any and all reports required by 49 C.F.R. § 579.27 for the five years preceding the aforementioned date of execution.

2. Retention of Outside Consultant

41. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 46 and 47. The Consultant shall review for sufficiency technical service bulletins (TSBs), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

42. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 41, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

43. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

45. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 1, 2013 Service Bulletin is effective and report the results to NHTSA.

46. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle owners, licensees, and purchasers of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring vehicles manufactured by RTDI in the future comply with applicable FMVSS and other statutory and regulatory requirements administered by NHTSA (collectively, "Compliance Plan"). If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in the Paragraph shall be publicly available.

47. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to

be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

48. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 46 and the Training Plan specified in Paragraph 47.

4. The Industry Outreach Performance Obligations

49. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The industry outreach performance obligations will be satisfied through the activities as set forth in Paragraph 50 through 52 below.

50. The parties agree that RTDI will expend not less than $20,000 in execution of the industry outreach. Not less than 120 days after execution of this Consent Order, RTDI shall provide NHTSA with a plan for industry and consumer outreach, which NHTSA, at its option, may accept, reject, or revise and submit it back to RTDI for further revision, if necessary. The proposed plan shall include the following and which are to be completed over the next year:

a. Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and

other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

b. Develop Safety Act educational materials for distribution to manufacturers.

c. Offer to assist other manufacturers and, if requested, help these manufacturers in developing their own safety outreach programs.

d. Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

e. Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

The outreach plan shall include metrics of success for the foregoing targeted performance obligations. The targeted performance obligations may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

51. RTDI shall expend its best efforts to complete the targeted performance obligations not less than one year after NHTSA gives its approval of the industry outreach plan. No later than 360 calendar days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations. In the event of a dispute as to whether RTDI has expended any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have 15 working days to respond.

52. RTDI is responsible for the satisfactory completion of the targeted performance obligations described above. Subject to the provisions for extending the term of this Consent

Order in Paragraph 57, if RTDI has reasonably achieved all of the targeted performance obligations on or before 365 calendar days after the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 57, RTDI's responsibility for the satisfactory completion of the targeted performance obligations shall also be extended for the term of one year.

5. Completion of Performance

53. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

54. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

D. <u>Compliance</u>

55. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to

thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

56. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

II. TERM OF CONSENT ORDER

57. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraph 28 and Paragraphs 34 through 54 shall survive the term of this Consent Order until the Non Deferred Amount is paid in full and the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

III. AMENDMENT

58. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

IV. MISCELLANEOUS

59. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

60. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 27 and 28, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 34 through 54, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraph 39, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraph 39, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

61. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

62. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

63. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 31 above.

64. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

65. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

66. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

67. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 27 and 28, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

68. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

69. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

70. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

71. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

72. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016 11 / 15 / 2016

By: _____

Chris Herschend
President

Dated: __, 2016 11/15/2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

November
Dated: 15, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

From: Glassman, Jacqueline
Sent: 15 Nov 2016 10:43:55 -0500
To: Chris Herschend (chris@ridetheducks.com);Matheke, Otto (NHTSA);Kolodziej, Kerry (NHTSA)
Cc: Torres, Justin
Subject: DUCKS Consent Order Final.docx
Attachments: DUCKS Consent Order Final.docx

This should be the final version. We had difficulty with the formatting so please make sure it came through correctly.

Chris will give this a once over and, assuming he's okay, will send us a signed signature page and we'll send that over to you with ours.

We appreciate the opportunity for Chris to speak briefly with the Administrator.

Thanks, Jackie

King & Spalding Confidentiality Notice:

This message is being sent by or on behalf of a lawyer. It is intended exclusively for the individual or entity to which it is addressed. This communication may contain information that is proprietary, privileged or confidential or otherwise legally exempt from disclosure. If you are not the named addressee, you are not authorized to read, print, retain, copy or disseminate this message or any part of it. If you have received this message in error, please notify the sender immediately by e-mail and delete all copies of the message.

UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
	)
Ride the Ducks International, LLC	)
	)

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's violations of the National Traffic and Motor Vehicle Safety Act ("Safety Act") and NHTSA's regulations as detailed herein under the following terms and conditions.

I. NATURE OF THE ACTION

1. The Safety Act provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins when

"whether it actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. § 577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

10. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make, model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are required to submit to the Agency an index for each communications to dealers, owners, or

purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

11. In general, motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery. 49 U.S.C. §§ 30112(a), 30115. This certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

12. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e) and 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

13. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers (VINs) in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e); 49 C.F.R. Part 565.

14. A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). A separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A person who violates 49 U.S.C. § 30166, 49 C.F.R. Part 565, 49 C.F.R. Part 566, and 49 C.F.R. Part 579

is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

15. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

16. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

17. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading

and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

18. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

19. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

20. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

21. After learning of the Aurora Bridge crash, NHTSA issued an Information Request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its

licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015.

22. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it manufactured motor vehicles under the Safety Act.

23. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the October 1, 2013 Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

24. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. Terms and Conditions of Consent Order

Admission of Safety Act Violations

25. RTDI did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules were applicable to the

amphibious vehicles it manufactured. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. RTDI admits that it manufactured vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 30112. RTDI also failed to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and did not report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. RTDI also did not notify NHTSA of the safety defect in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, did not provide a remedy for axle defect without charge as directed by 49 U.S.C. § 30120 and admits that its communication to owners regarding a safety related defect in the 57 Stretch Duck axles did not fully comply with 49 C.F.R. § 577.5 (describing potential safety consequences of a defect).

B. Civil Penalty

26. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

27. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand dollars ($480,000.00) in accordance with the instructions provided in Paragraph 28 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 49 through 52 (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order during the term of this Consent Order,

RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand dollars ($500,000), in accordance with the terms and conditions set forth below (the "Deferred Amount").

28. RTDI shall make a payment of two hundred forty thousand dollars ($240,000) no later than May 14, 2017. The remaining two hundred forty thousand dollars ($240,000) shall be due in three equal annual increments due not later than May 14, 2018, May 14, 2019, and May 14, 2020 respectively. At its option, RTDI may pay any remaining amounts prior to their respective due dates. RTDI expressly agrees that the obligation to pay the foregoing sums as specified above shall survive the termination of this Consent Order.

29. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 30 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (30) calendar days following a determination that they are due and owing.

30. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA.

Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining three hundred thousand dollars ($300,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

31. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. <u>Performance Obligations</u>

32. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 34 through 54 below.

33. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

1. Remedying Past Noncompliance with the Safety Act

34. No later than 5 working days after the execution of this Consent Order, RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and a report of a claim alleging that a death resulted from a safety defect related to the September 2015 crash involving deaths as referenced in Paragraph 20 above.

35. No later than 30 calendar days after the execution of the Consent Order, RTDI will send owners of the 57 Stretch Ducks formal customer notification as directed by 49 C.F.R. Part 577 and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge.

36. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a FMVSS compliance plan to NHTSA. The plan will identify those FMVSS for which RTDI has made a good faith determination are applicable to the vehicles it has manufactured. For each such FMVSS, RTDI shall state when and how RTDI intends to bring the vehicles into compliance with a particular standard by following the statutory recall process or filing a petition for inconsequential noncompliance under 49 C.F.R. Part 556 or a petition for exemption under 49 C.F.R. Part 555. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by

contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan or are subject to ongoing design and/or engineering efforts which, subject to NHTSA's consent, require further extension of the 120 day deadline) and have been certified as such by the application of certification labels. If NHTSA should not grant any part of RTDI's inconsequentiality petition or exemption petition, the parties agree to consult in good faith with regard to determining next steps to address the issue.

37. RTDI shall submit all manufacturer identification information required by 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

38. RTDI shall submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order. If vehicles have been assigned VINs that are not in compliance with the requirements of 49 C.F.R. Part 565, RTDI will provide a detailed report to NHTSA no later than 90 days after the execution of this Consent Order, with each vehicle's assigned VIN and a description of why the VIN does not conform to the requirements of Part 565.

39. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with 49 U.S.C. §30166(f) and 49 C.F.R. § 579.5 any notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to 49 C.F.R. § 579.5, regardless of whether RTDI has already provided those service bulletins in response to NHTSA's Information Request. RTDI shall also include indexes for each document that was issued since October 1, 2012.

40. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA. No later than 180 calendar days after execution of this Consent Order, RTDI shall submit any and all reports required by 49 C.F.R. § 579.27 for the five years preceding the aforementioned date of execution.

2. Retention of Outside Consultant

41. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 46 and 47. The Consultant shall review for sufficiency technical service bulletins (TSBs), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

42. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 41, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

43. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

45. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 1, 2013 Service Bulletin is effective and report the results to NHTSA.

46. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle owners, licensees, and purchasers of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring vehicles manufactured by RTDI in the future comply with applicable FMVSS and other statutory and regulatory requirements administered by NHTSA (collectively, "Compliance Plan"). If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in the Paragraph shall be publicly available.

47. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to

be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

48. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 46 and the Training Plan specified in Paragraph 47.

4. The Industry Outreach Performance Obligations

49. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The industry outreach performance obligations will be satisfied through the activities as set forth in Paragraph 50 through 52 below.

50. The parties agree that RTDI will expend not less than $20,000 in execution of the industry outreach. Not less than 120 days after execution of this Consent Order, RTDI shall provide NHTSA with a plan for industry and consumer outreach, which NHTSA, at its option, may accept, reject, or revise and submit it back to RTDI for further revision, if necessary. The proposed plan shall include the following and which are to be completed over the next year:

a. Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and

other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

b. Develop Safety Act educational materials for distribution to manufacturers.

c. Offer to assist other manufacturers and, if requested, help these manufacturers in developing their own safety outreach programs.

d. Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

e. Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

The outreach plan shall include metrics of success for the foregoing targeted performance obligations. The targeted performance obligations may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

51. RTDI shall expend its best efforts to complete the targeted performance obligations not less than one year after NHTSA gives its approval of the industry outreach plan. No later than 360 calendar days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations. In the event of a dispute as to whether RTDI has expended any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have 15 working days to respond.

52. RTDI is responsible for the satisfactory completion of the targeted performance obligations described above. Subject to the provisions for extending the term of this Consent

Order in Paragraph 57, if RTDI has reasonably achieved all of the targeted performance obligations on or before 365 calendar days after the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 57, RTDI's responsibility for the satisfactory completion of the targeted performance obligations shall also be extended for the term of one year.

5. Completion of Performance

53. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

54. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

D. <u>Compliance</u>

55. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to

thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

56. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

II. TERM OF CONSENT ORDER

57. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraph 28 and Paragraphs 34 through 54 shall survive the term of this Consent Order until the Non Deferred Amount is paid in full and the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

III. AMENDMENT

58. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

IV. MISCELLANEOUS

59. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

60. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 27 and 28, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 34 through 54, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraph 39, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraph 39, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

61. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

62. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

63. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 31 above.

64. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

65. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

66. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

67. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 27 and 28, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

68. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

69. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

70. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

71. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

72. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

From: Matheke, Otto (NHTSA)
Sent: 15 Nov 2016 17:34:20 +0000
To: Jacqueline Glassman (jglassman@kslaw.com);Torres, Justin;Kolodziej, Kerry (NHTSA);Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA)
Cc: Hemmersbaugh, Paul (NHTSA)
Subject: DUCKS Consent Order Final NOV 15.docx
Attachments: DUCKS Consent Order Final NOV 15.docx

Jackie, Justin:

This should be the final version. We fixed a few minor formatting issues.

Otto

UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:	)
	)
Ride the Ducks International, LLC	)
	)

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI"), in connection with RTDI's violations of the National Traffic and Motor Vehicle Safety Act ("Safety Act") and NHTSA's regulations as detailed herein under the following terms and conditions.

I. NATURE OF THE ACTION

1. The Safety Act provides for regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to "manufacturers." 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to "motor vehicles," defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7).

4. Under 49 C.F.R. § 571.7(e), certain vehicles built with a combination of new and used components are not considered to be new vehicles whose rebuilders must comply with the Safety Act. The "glider" exemption applies when a new cab or body is put on a truck when the engine, transmission, and axles are not new and at least two of those components are from the same vehicle. 49 C.F.R. § 571.7(e). The rule mainly applies to truck "glider" kits, as well as buses, that use new cabs with old parts.

5. Under 49 C.F.R. § 571.7(c), vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS. This exception to the Safety Act's applicability does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle. In a November 30, 1987 NHTSA interpretation letter responding to an inquiry from D.F. Landers, President of Mobile Products, Inc., asking, among other things, if surplus military vehicles were subject to NHTSA's jurisdiction, the Agency stated that surplus military "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in . . . the intended or actual use, design or sale . . . ." of the vehicle. *See* NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

6. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicable FMVSS. 49 U.S.C. § 30118(c)(1); 49 C.F.R. Part 573. The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report." 49 C.F.R. Part 573. NHTSA's regulations require a manufacturer to notify NHTSA not more than five working days after a defect in a vehicle or an item of equipment has been determined to be safety-related or noncompliant with an applicable FMVSS. 49 C.F.R. § 573.6(b). However, the manufacturer's duty to notify and remedy begins "whether it

actually determined, *or it should have determined*, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988) (emphasis added).

7. A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS. *See* 49 U.S.C. §§ 30118(c), 30119; 49 C.F.R. Part 577. The notification to owners or purchasers must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573." *See* 49 U.S.C. § 30119; 49 C.F.R. § 577.7(a)(1). The duty to notify and remedy arises when the manufacturer determined or should have determined that there was a safety-related defect or noncompliance. *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988).

8. When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a duty to remedy the motor vehicle. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573. The manufacturer is responsible for remedying the safety-related defect within a reasonable time. *See* 49 U.S.C. § 30120; 49 C.F.R. § 573.5. According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related." *United States v. General Motors Corp.*, 656 F. Supp. 1555, 1559 n. 5 (D.C. 1987), *aff'd on other grounds*, 841 F.2d 400 (D.C. Cir. 1988). The manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fail to comply with applicable FMVSS under these same procedures. *See* 49 U.S.C. § 30120; 49 C.F.R. Part 573.

9. As required by the Transportation, Recall Enhancement, Accountability, and Documentation ("TREAD") Act, NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer. *See* 67 Fed. Reg. 45,822 (July 10, 2002). The first group consists of larger manufacturers of motor vehicles and all manufacturers of child restraint systems and tires. *See* 49 C.F.R. §§ 579.21-579.26. These manufacturers are required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports. *See* 49 C.F.R. §§ 579.21-579.26. The second group consists of all other manufacturers of motor vehicles and motor vehicle equipment, including manufacturers of fewer than 100 buses annually. *See* 49 C.F.R. § 579.27. This second group of manufacturers must report the same information about incidents involving deaths as the first group, but is not required to report any other "Early Warning Information." *Id.*

10. Manufacturers of motor vehicles and motor vehicle equipment are required to submit to NHTSA copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment (collectively, "service bulletins"), sent to more than one manufacturer, distributor, dealer, owner or purchaser. *See* 49 U.S.C. § 30166(m)(3)(A)(ii); 49 C.F.R. §§ 579.5(a)-(b). A copy of each communication shall be submitted to NHTSA not later than five working days after the end of the month in which it was issued. 49 C.F.R. § 579.5(d). All manufacturers must also submit an index to the communications that "identifies the make, model, and model year of the affected vehicles" and "includes a concise summary of the subject matter of the communication." 49 U.S.C. § 30166(f)(2); 49 C.F.R. § 579.5. Manufacturers are required to submit to the Agency an index for each communications to dealers, owners, or

purchasers about a defect or noncompliance they were required to submit at any time since October 1, 2012. *See* 49 U.S.C. § 30166(f)(2); 81 Fed. Reg. 16,270 (March 25, 2016).

11. In general, motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery. 49 U.S.C. §§ 30112(a), 30115. This certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer. 49 U.S.C. § 30115; 49 C.F.R. Part 567. Manufacturers of motor vehicles are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale. *See* 49 U.S.C. §§ 30112, 30115.

12. Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA. 49 U.S.C. § 30166(e); 49 C.F.R. Part 566. Manufacturers must report this information no later than 30 days after manufacturing begins. 49 C.F.R. § 566.6.

13. Manufacturers of motor vehicles are also required to assign Vehicle Identification Numbers ("VINs") in accordance with 49 C.F.R. Part 565. 49 U.S.C. § 30166(e); 49 C.F.R. Part 565.

14. A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). A separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act. 49 U.S.C. § 30165(a)(1); 49 C.F.R. § 578.6(a). As of December 27, 2012, the maximum penalty per violation was $7,000. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). That penalty increased from $7,000 to $21,000 per violation effective March 17, 2016. 81 Fed. Reg. 15,413 (Mar. 22, 2016). The maximum penalty for a related series of violations is currently $105 million. *See id.* A person who violates 49 U.S.C. § 30166, 49 C.F.R. Part 565, 49 C.F.R. Part 566, and 49 C.F.R. Part 579

is liable to the United States for a civil penalty. *See* 49 U.S.C. § 30165(a)(3). As of December 27, 2012, the maximum penalty was $7,000 per day. 77 Fed. Reg. 70,710, 70,713 (Nov. 27, 2012) (codified at 49 C.F.R. § 578.6). Effective March 17, 2016, the maximum civil penalty was increased from $7,000 to $21,000 per day. *See* 81 Fed. Reg. 15,413 (Mar. 22, 2016) (codified at 49 C.F.R. § 578.6(a)(3)). The maximum penalty for a related series of daily violations is currently $105 million. *See id.*

15. RTDI is the current owner, operator, and licensor of certain amphibious vehicles and amphibious vehicle tour bus operations. RTDI operates tour operations which run amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations manufactured amphibious vehicles (either directly or through a contract manufacturer) and sold the vehicles to a limited number of independent licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

16. According to RTDI, RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

17. RTDI also states it began manufacturing "Stretch" Duck amphibious vehicles in 1996. The "Stretch" Duck construction process began by stripping down an original DUKW to its frame and then renewing and lengthening the hull, replacing the engine, transmission and axles with new components or components sourced from other vehicles, changing the number of driven wheels and upgrading the brakes to all-wheel disc brakes. There are currently 57 "Stretch" Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the "Truck" Duck with a patented RTDI design. The "Truck" Duck is based on a M-Series 2 1/2 ton military cargo vehicle and its construction also involved substantial upgrading

and replacement of original components and the complete fabrication of a hull on the existing frame. There are currently 49 "Truck" Ducks either in operation or ready for use in the United States. Both the "Stretch" and the "Truck" Ducks are under 26,000 lbs. loaded weight.

18. RTDI represents that all amphibious vehicles that it operated or produced were appropriately registered within the state or territories in which they have operated. RTDI further represents that throughout its history, RTDI worked closely with the Coast Guard to meet and/or exceed all applicable marine standards. RTDI also represents that it has sponsored industry efforts to discuss and disseminate best safety practices for the operation of amphibious tour buses.

19. On October 1, 2013, RTDI issued a Service Bulletin (SB-00-14-13) to its licensees with regard to the potential for the front axle on the Stretch Ducks to fail. RTDI represents that all affected vehicles under its control were properly repaired in accordance with the Service Bulletin, and that it repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. The Service Bulletin stated it was released to "avoid axle fractures" and further stated that the axles should be repaired as soon as it was practical to do so and prior to operating in 2014. The Service Bulletin further stated that until the axle was repaired, the axles should be inspected on a daily basis.

20. On September 24, 2015, a Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. Although the Stretch Duck involved in the crash had a front axle with the defect addressed by the October 1, 2013 Service Bulletin, it had not been repaired as directed by that bulletin.

21. After learning of the Aurora Bridge crash, NHTSA issued an Information Request to RTDI. In April 2016, RTDI submitted a timely response, which included the October 2013 Service Bulletin and all other Service Bulletins issued by RTDI to its operations and its

licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash, some of which were received by RTDI during 2015.

22. Review of RTDI's submissions led NHTSA to conclude that RTDI is a "manufacturer" of "motor vehicles" under the Safety Act. The RTDI Stretch Duck vehicles used the frame, some hull sections, and miscellaneous other parts from donor WWII vintage DUKWs while a new hull, new engine, new transmission, refurbished axles from donor vehicles, new brakes, and new drive configuration were incorporated into the final product. The Stretch Ducks are not rebuilt vehicles under NHTSA regulations because three requisite components (engine, transmission, and axles) were changed and no two are from the same vehicle. 49 C.F.R. § 571.7(e). RTDI does not contest that it manufactured motor vehicles under the Safety Act.

23. RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles affected by the October 1, 2013 Service Bulletin other than those at Ride the Ducks Seattle (which are currently out of service) have had the axle repair conducted.

24. NHTSA issues this Consent Order pursuant to its authority under the Safety Act, 49 U.S.C. § 30101, et seq., as delegated by the Secretary of Transportation, 49 C.F.R. §§ 1.95, 501.2(a)(1), to compromise the amount of civil penalties for violations of the Safety Act and regulation thereunder, 49 U.S.C. § 30165(b), to inspect and investigate, 49 U.S.C. § 30166(b)(1), to ensure that defective vehicles are recalled, 49 U.S.C. §§ 30118-30119, and to require any person to file reports or answers to specific questions, 49 U.S.C. § 30166(g). It is AGREED by RTDI and ORDERED by NHTSA as follows:

II. TERMS AND CONDITIONS OF CONSENT ORDER

A. Admission of Safety Act Violations

25. RTDI did not comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and represents that it acted on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules were applicable to the

amphibious vehicles it manufactured. Nonetheless, RTDI agrees that as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense. RTDI admits that it manufactured vehicles for sale that do not comply and/or are not certified as complying with applicable FMVSS, in accordance with 49 U.S.C. § 30112. RTDI also failed to submit service bulletins and other communications to NHTSA, including its October 1, 2013 service bulletin, in accordance with 49 C.F.R. § 579.5, and did not report claims that a defect in its products caused a death, including the September 2015 crash, in accordance with 49 C.F.R. § 579.27. RTDI also did not notify NHTSA of the safety defect in its 57 Stretch Ducks in accordance with 49 C.F.R. Part 573, did not provide a remedy for axle defect without charge as directed by 49 U.S.C. § 30120 and admits that its communication to owners regarding a safety related defect in the 57 Stretch Duck axles did not fully comply with 49 C.F.R. § 577.5 (describing potential safety consequences of a defect).

B. Civil Penalty

26. RTDI agrees that the United States is entitled to a civil penalty of up to one million dollars ($1,000,000) for the violations set forth above, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, *et seq.* (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

27. To satisfy its obligations to pay a civil penalty, as authorized by 49 U.S.C. § 30165(b), RTDI shall pay the sum of four hundred eighty thousand dollars ($480,000.00) in accordance with the instructions provided in Paragraph 28 below (the "Non-Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs 49 through 52 (the "Industry Outreach Amount"). In the event RTDI commits further violations of the Safety Act or this Consent Order during the term of this Consent Order,

RTDI may, in addition to any civil penalties that would otherwise accrue, be potentially obligated to pay additional sums totaling up to a maximum of five hundred thousand dollars ($500,000), in accordance with the terms and conditions set forth below (the "Deferred Amount").

28. RTDI shall make a payment of two hundred forty thousand dollars ($240,000) no later than May 14, 2017. The remaining two hundred forty thousand dollars ($240,000) shall be due in three equal annual increments due not later than May 14, 2018, May 14, 2019, and May 14, 2020 respectively. At its option, RTDI may pay any remaining amounts prior to their respective due dates. RTDI expressly agrees that the obligation to pay the foregoing sums as specified above shall survive the termination of this Consent Order.

29. The Deferred Amount shall only become due and owing in accordance with and subject to the provisions set forth in Paragraph 30 below. NHTSA and RTDI expect that RTDI will comply fully with this Consent Order and the Safety Act and that the Deferred Amount accordingly will not become due and will be released at the termination of this Consent Order. In the event RTDI is required to pay any of the Deferred Amount, such payments will be made by electronic funds transfer, in accordance with the instructions provided by NHTSA, no later than thirty (30) calendar days following a determination that they are due and owing.

30. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of fifty thousand dollars ($50,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of one hundred fifty thousand dollars ($150,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with instructions provided by NHTSA.

Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining three hundred thousand dollars ($300,000) of the Deferred Amount will become due and owing within thirty (30) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

31. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. <u>Performance Obligations</u>

32. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs 34 through 54 below.

33. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

1. Remedying Past Noncompliance with the Safety Act

34. No later than 5 working days after the execution of this Consent Order, RTDI shall submit to NHTSA a copy of its October 1, 2013 service bulletin, a Part 573 Report for the safety-related defect, and a report of a claim alleging that a death resulted from a safety defect related to the September 2015 crash involving deaths as referenced in Paragraph 20 above.

35. No later than 30 calendar days after the execution of the Consent Order, RTDI will send owners of the 57 Stretch Ducks formal customer notification as directed by 49 C.F.R. Part 577 and shall notify the owners that they are entitled to reimbursement for costs incurred in having remedied the vehicles or, in the case of the Seattle licensor, that a remedy remains available and that it is free of charge.

36. RTDI has consulted with NHTSA regarding which FMVSS applied to the vehicles when they were manufactured. RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains with RTDI. Not later than 60 calendar days after the appointment of the Consultant, as set forth below, RTDI will submit a FMVSS compliance plan to NHTSA. The plan will identify those FMVSS for which RTDI has made a good faith determination are applicable to the vehicles it has manufactured. For each such FMVSS, RTDI shall state when and how RTDI intends to bring the vehicles into compliance with a particular standard by following the statutory recall process or filing a petition for inconsequential noncompliance under 49 C.F.R. Part 556 or a petition for exemption under 49 C.F.R. Part 555. No later than 120 days after the submission of the compliance plan, RTDI will submit a confirmation to NHTSA affirming that all such vehicles owned or operated by RTDI or RTDI licensees obligated by

contract to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequentiality or exemption have or are to be filed pursuant to RTDI's plan or are subject to ongoing design and/or engineering efforts which, subject to NHTSA's consent, require further extension of the 120 day deadline) and have been certified as such by the application of certification labels. If NHTSA should not grant any part of RTDI's inconsequentiality petition or exemption petition, the parties agree to consult in good faith with regard to determining next steps to address the issue.

37. RTDI shall submit all manufacturer identification information required by 49 C.F.R. Part 566 within 90 calendar days of the execution of this Consent Order.

38. RTDI shall submit VIN information required in 49 C.F.R. Part 565 within 90 calendar days of the execution of this Consent Order. If vehicles have been assigned VINs that are not in compliance with the requirements of 49 C.F.R. Part 565, RTDI will provide a detailed report to NHTSA no later than 90 days after the execution of this Consent Order, with each vehicle's assigned VIN and a description of why the VIN does not conform to the requirements of Part 565.

39. No later than 90 calendar days after the execution of this Consent Order, RTDI shall submit in accordance with 49 U.S.C. §30166(f) and 49 C.F.R. § 579.5 any notices, bulletins, and communications (collectively, "service bulletins") from the past five (5) years that would have been subject to 49 C.F.R. § 579.5, regardless of whether RTDI has already provided those service bulletins in response to NHTSA's Information Request. RTDI shall also include indexes for each document that was issued since October 1, 2012.

40. No later than 90 calendar days after the execution of this Consent Order, RTDI shall establish an early warning account with NHTSA. No later than 180 calendar days after execution of this Consent Order, RTDI shall submit any and all reports required by 49 C.F.R. § 579.27 for the five years preceding the aforementioned date of execution.

2. Retention of Outside Consultant

41. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in connection with this Consent Order. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs 46 and 47. The Consultant shall review for sufficiency technical service bulletins ("TSBs"), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

42. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant as referenced in Paragraph 41, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval, which will not be unreasonably withheld. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

43. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

3. General Performance Obligations

44. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all potential safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

45. No later than 30 calendar days after the execution of this Consent Order, RTDI shall perform an engineering analysis of the Stretch Duck axle to determine if the remedy included in the October 1, 2013 Service Bulletin is effective and report the results to NHTSA.

46. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying vehicle owners, licensees, and purchasers of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with those sections of 49 C.F.R. Part 579 applicable to RTDI; and (d) ensuring vehicles manufactured by RTDI in the future comply with applicable FMVSS and other statutory and regulatory requirements administered by NHTSA (collectively, "Compliance Plan"). If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in the Paragraph shall be publicly available.

47. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to

be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

48. No later than 180 calendar days after the execution of this Consent Order, RTDI shall submit a report detailing its efforts to implement the Compliance Plan specified in Paragraph 46 and the Training Plan specified in Paragraph 47.

4. The Industry Outreach Performance Obligations

49. In addition to RTDI's performance obligations described above, this Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The industry outreach performance obligations will be satisfied through the activities as set forth in Paragraph 50 through 52 below.

50. The parties agree that RTDI will expend not less than $20,000 in execution of the industry outreach. Not less than 120 days after execution of this Consent Order, RTDI shall provide NHTSA with a plan for industry and consumer outreach, which NHTSA, at its option, may accept, reject, or revise and submit it back to RTDI for further revision, if necessary. The proposed plan shall include the following and which are to be completed over the next year:

a. Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufacturers and small, independent manufacturers of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and

other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

b. Develop Safety Act educational materials for distribution to manufacturers.

c. Offer to assist other manufacturers and, if requested, help these manufacturers in developing their own safety outreach programs.

d. Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

e. Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

The outreach plan shall include metrics of success for the foregoing targeted performance obligations. The targeted performance obligations may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

51. RTDI shall expend its best efforts to complete the targeted performance obligations not less than one year after NHTSA gives its approval of the industry outreach plan. No later than 360 calendar days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations. In the event of a dispute as to whether RTDI has expended any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have 15 working days to respond.

52. RTDI is responsible for the satisfactory completion of the targeted performance obligations described above. Subject to the provisions for extending the term of this Consent

Order in Paragraph 57, if RTDI has reasonably achieved all of the targeted performance obligations on or before 365 calendar days after the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 57, RTDI's responsibility for the satisfactory completion of the targeted performance obligations shall also be extended for the term of one year.

5. Completion of Performance

53. RTDI will meet with NHTSA one year after the execution of the Consent Order to review the current status of RTDI's obligations under the Consent Order and to discuss any open items. Neither RTDI nor NHTSA anticipate open items as of that juncture, with the exception of the payment of the additional non-deferred payments as set forth above.

54. If there are unfulfilled items as of that meeting, RTDI will provide a plan for completing those items within a reasonable time, which is to be determined in consultation with NHTSA.

D. <u>Compliance</u>

55. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to

thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

56. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

III. TERM OF CONSENT ORDER

57. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraph 28 and Paragraphs 34 through 54 shall survive the term of this Consent Order until the Non-Deferred Amount is paid in full and the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

IV. AMENDMENT

58. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

V. MISCELLANEOUS

59. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

60. Upon receipt of the Non-Deferred Amount set forth in Paragraphs 27 and 28, and NHTSA's determination that RTDI has reasonably achieved all of the performance obligations, set forth in Paragraphs 34 through 54, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all violations of RTDI's Safety Act reporting obligations, including those expressly identified in this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order included in Paragraph 39, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report under Paragraph 39, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

61. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

62. None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

63. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 31 above.

64. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

65. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

66. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

67. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 27 and 28, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

68. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

69. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

70. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

71. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

72. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding
Counsel for Ride the Ducks International, LLC

From: Matheke, Otto (NHTSA)
To: Jacqueline Glassman
Subject: Ducks
Date: Wednesday, October 05, 2016 4:00:34 PM

Jackie:

I got stuck in meetings this afternoon. I am going to send a draft consent order and try to call before COB today.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman
Cc:	Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject:	Ducks
Date:	Friday, September 30, 2016 10:00:58 AM

Jackie

I would like to chat briefly this afternoon and perhaps set up a meeting for next week to discuss penalties and consent order terms. When would be a good time to call?

Thanks

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Matheke, Otto (NHTSA)
To: Jacqueline Glassman (jglassman@kslaw.com)
Subject: Ducks
Date: Tuesday, August 23, 2016 4:57:00 PM

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Matheke, Otto (NHTSA)
To: Jacqueline Glassman
Subject: Ducks
Date: Tuesday, October 11, 2016 2:41:31 PM

Just checking in because I recall you will be out tomorrow. Let me know when you can share your version of the consent order.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Cc:	Kolodziej, Kerry (NHTSA); Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA); O"Donnell, Melanie (NHTSA)
Subject:	DUCKSDRAFTConsent OrderNov10 CLEAN.docx
Date:	Thursday, November 10, 2016 4:24:00 PM
Attachments:	DUCKSDRAFTConsent OrderNov10 CLEAN.docx

Jackie:

Our responses to your suggestions to the last draft are incorporated in this document. From our perspective, there is very little in this version that we consider to be negotiable.

You will see that Paragraph 36 contains language addressing your concern that some compliance issues may require additional time to resolve. In regard to your concerns about VIN issues, I know you now understand our position regarding the importance of complying with the VIN requirements. You will also note that we are not agreeing to your suggestion that the compliance plan not be made public. I don't see any basis for us not making the document public even if we were inclined to do so. We have also deleted your suggested language about the existing engineering analysis of the axles being sufficient. You will note that the document explicitly states that credit will be given for work already done when considering the compliance plan and other requirements.

I will be out of the office tomorrow but will be checking my email and can be reached either on my personal cel phone at 202-236-2958 or my work cel number below.

I expect that Mr. Herschend and Mr. Hultz will be coming to town for the NTSB hearing on Tuesday. If they have not done so already, I strongly suggest that their travel plans include arriving early on Monday to either execute an agreement or come in with you in on Monday morning to hammer out a deal and sign an agreement.

From:	Matheke, Otto (NHTSA)
To:	Jacqueline Glassman (jglassman@kslaw.com)
Cc:	Kolodziej, Kerry (NHTSA); Stephens, Jordan (NHTSA); Hemmersbaugh, Paul (NHTSA); Sorg, Sarah (NHTSA); Rosekind, Mark (NHTSA)
Subject:	DUCKSDRAFTConsent OrderNov14NHTSAPropose.docx
Date:	Monday, November 14, 2016 1:55:00 PM
Attachments:	BMW-Consent-Order-12182015.pdf FCA_Consent_Order.pdf GM May-16-2014-TQ14-001-Consent-Order.pdf Honda-consent-order-12292014.pdf NHTSA-ConsentOrder-Takata.pdf Ricon-NHTSA-Consent-Order-02-2015.pdf DUCKSDRAFTConsent OrderNov14NHTSAPropose.docx

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Jackie:

Attached please find my responses to your latest draft. The header language has been modified in accordance with your wishes.

Paragraph 25 has been changed directionally but does not adopt all of your suggestions. As you and I have discussed, intent is not an element of the provisions of the Safety Act at play here. Moreover, all of the various consent orders we have entered into contain language in which the manufacturer involved has admitted they violated the Safety Act. At least 5 examples can be obtained by doing a Google search of "NHTSA Consent Order." Some samples are also attached.

Your substation of "may" for "will" in paragraph 50 addressing the contents of the outreach program would leave us in a position where we could not enforce that provision. We will not accept this. However, subparagraph c of that paragraph has been modified to address your concern that it would be unseemly for your clients to force other manufacturers to adopt a safety outreach program at gunpoint .

There are other changes that address punctuation and typos and they are not material.

We have discussed your concerns with Administrator Rosekind and he is agreement with Chief Counsel's position on the issues discussed above. If your client still wants to discuss the matter with the Administrator, we can check on his availability.

While I do not doubt the sincerity of your client's motives, our view is that the tragedy in Seattle may have been averted if your client has sent us the service bulletin in October 2013. Another opportunity was missed when that service bulletin did not contain the language required by Part 577, including the risk of injury or death, which may have prompted the Seattle operation to put the axle repair at the top of the list and not the bottom of the pile.

Please let me know your thoughts and your availability for wrapping this up.

Thanks

From: Matheke, Otto (NHTSA)
To: Jacqueline Glassman (jglassman@kslaw.com)
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA); Kolodziej, Kerry (NHTSA)
Subject: DUCKSDRAFTConsent OrderSENTOCT17.docx
Date: Monday, October 17, 2016 4:51:00 PM
Attachments: DUCKSDRAFTConsent OrderSENTOCT17.docx

Jackie:

Attached please find a redrafted version of our proposed Consent Order.

I will be out of the office tomorrow and Wednesday and back in Thursday.

Jordan will be available both days I am out and I will be checking my emails both days that I am out.

Thanks

From:	Matheke, Otto (NHTSA)
To:	Iannetta, Christie (CIannetta@KSLAW.com)
Cc:	DiMarsico, Andrew (NHTSA) (Andrew.DiMarsico@dot.gov); Stephens, Jordan (NHTSA); Skinner, Monica (NHTSA)
Subject:	FOIA request from Williams Kastner
Date:	Tuesday, September 13, 2016 5:03:00 PM
Attachments:	image009.png image010.png image011.png image012.png

Ms. Iannetta:

We have a pending FOIA request from Williams, Kastner seeking every scrap of paper we have on Ride The Ducks International as well as any and all information relating to our determination that RTDI is a manufacturer under the Safety Act. Putting aside the fact that this request establishes that they spent more time fashioning the inquiry than they expended in response to my honest efforts to have a dialogue (i.e. actually returning phone calls), I would think that this request is moot and overtaken by events. Acting on the supposition that you will be more diplomatic than I, that you have had some communication with the Seattleites and perhaps be more persuasive, I was wondering if you would be willing to give them a call and ask if they would like to withdraw this request.

If you believe this is a task it would not be appropriate to undertake, please let me know and I will contact them directly.

Thanks for your help.

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline
Sent: 18 Jan 2017 09:07:02 -0500
To: Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA);Matheke, Otto (NHTSA)
Subject: FW: DRAFT - Amphibious Passenger Vessel Industry Education Meeting Communication

Guys – We would like to send this invitation out today. Can you let me know this morning if you have any changes. If I don't hear from you, I'm going to assume it's okay with you due to the short time frame.

Thanks, Jackie

From: Glassman, Jacqueline
Sent: Thursday, January 12, 2017 5:07 PM
To: Matheke, Otto (NHTSA)
Cc: York, Bruce (NHTSA); Christopher Bonanti
Subject: DRAFT - Amphibious Passenger Vessel Industry Education Meeting Communication

Otto – Below is a draft invitation to an industry outreach effort in mid-February. We are focused on February because if we miss that month we will enter into the busy season and will not likely get much responsiveness until much later in the year. My understanding is that Chris and Bruce have discussed the below in general terms. Please let us know if you approve the below message.

Thanks, Jackie

DRAFT Email Invitation - Includes edits from Chris Bonanti

Please review and provide feedback.

Pursuant to a Consent Order with the National Highway Traffic Safety Administration (NHTSA), Ride The Ducks International will host an industry education meeting on Thursday, February 16, 2017 at the Atlanta Evergreen Marriott Conference Center, Stone Mountain Park, Georgia. Invited attendees include all US based amphibious passenger vessel manufacturers, licensees of Ride The Ducks International and other amphibious passenger vessel operators.

The scope of this meeting is to educate the industry on NHTSA's role, the importance of meeting the National Traffic and Motor Vehicle Safety Act (Safety Act) obligations and reporting requirements. The education session will be led by Christopher J. Bonanti, Senior

Managing Consultant with Engineering Systems Inc. (ESI) and former NHTSA Associate Administrator for Rulemaking. Mr. Bonanti has been retained as an outside consultant pursuant to a Consent Order with NHTSA and has more than 20 years of experience and expertise in motor vehicle safety, requirements of the Safety Act and regulations thereunder.

According to NHTSA's jurisdiction determination regarding surplus military vehicles, these "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in ... the intended or actual use, design or sale ..." It is important that representatives within our industry have a comprehensive understanding of regulations that apply to them. For instance, each violation of 49 CFR §579.5 is subject to civil penalties of up to $21,000 per day.

A detailed agenda for this full-day meeting will follow in separate communication. Attendees should plan to arrive on Wednesday evening, February 15 and a group dinner is planned for that evening at 6:00 PM in the Waterside Restaurant at the Atlanta Evergreen Marriott at Stone Mountain Park. A block of rooms is being held for this meeting. Please contact the hotel directly at 770-879-9900 for lodging accommodations and indicate that you will be part of the Ride The Ducks Industry Education Meeting. We encourage you to attend this education meeting. By requirement, a list of invited attendees will be provided to NHTSA as well as an attendance roster of those who attended the session. We look forward to seeing you next month.

Sincerely,

Chris Herschend
Ride The Ducks International, LLC

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From: Matheke, Otto (NHTSA)
To: Kolodziej, Kerry (NHTSA); Stephens, Jordan (NHTSA)
Subject: FW: Ducks
Date: Tuesday, November 08, 2016 5:47:00 PM
Attachments: DUCKSDRAFTConsent OrderNov8.docx
image001.png
image002.png
image003.png
image004.png

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, November 08, 2016 5:11 PM
To: Matheke, Otto (NHTSA)
Subject: Ducks

Otto – Here is a draft with some comments. I may have more (or slightly different) comments still, but we can start here. One big picture issue is that the draft you sent me had various confirmations and reports that are overkill here and unnecessary. They make this very hard to work with and don't seem to serve any additional safety purpose. This is not a huge company – they don't need to have executives signing declarations that their underlings took care of business. I've suggested deleting some of those.

Also the Attachments aren't necessary here. The Industry Outreach plan is basically asking you what you would like and with whom as it relates to companies outside of the small APV industry. If you skip the extra declarations and reports, the chronology is pretty simple and not hard to follow. And there's no need here for another certificate that the Consent Order was followed – it was or it wasn't, and if we have a dispute we'll deal with it.

There's some language changes either to make it better conform to the regs or to the facts. On the "admissions," I am fine stating the facts but don't think we need to make this company, which did nothing willfully and tried to do the right thing throughout, have to characterize their conduct. I don't see any safety benefit to that.

There aren't many changes, and I tried to go mostly lightly. But these are important.

Thanks, Jackie

Jacqueline Glassman
King & Spalding LLP
1700 Pennsylvania Avenue, NW

Washington DC 20006
Jglassman@kslaw.com
202-626-9228

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From: Matheke, Otto (NHTSA)
Sent: 15 Nov 2016 20:48:34 +0000
To: 'Chris Herschend'
Cc: Jacqueline Glassman (jglassman@kslaw.com)
Subject: RE: 1:30 call with Chris Herschend today

Based on the information NHTSA has at this time, we are not adopting a "do not drive" recommendation.

I am copying Jackie on this as I am obligated to communicate with you through her and she can advise you on what your legal obligations are if you know something we don't.

Bryan Thomas' contact info is:

Bryan.thomas@dot.gov

202-366-5789

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Chris Herschend [mailto:chris@ridetheducks.com]
Sent: Tuesday, November 15, 2016 2:05 PM
To: Matheke, Otto (NHTSA)
Cc: Jacqueline Glassman (jglassman@kslaw.com)
Subject: Re: 1:30 call with Chris Herschend today

Otto, one other point I forgot to raise in the call. NTSB is telling us one of the staff recommendations is to ground all stretch ducks until the axle repair can be independently confirmed as sufficient. Our position and public statement will be that every axle has been inspected, the history of the axle has been reviewed and no other similar failures have occurred, etc. Also that we are already conducting this independent examination (which we agreed to as part of the consent order as you know)...so grounding is unwarranted.

It seems so odd to require it 12 months after the accident, anyway, in addition to the fact set above.

If this is indeed recommended by the Board, would it be fair to say that NHTSA is not requiring or proposing this grounding?

cph

On Tue, Nov 15, 2016 at 10:57 AM, Matheke, Otto (NHTSA) <Otto.Matheke@dot.gov> wrote:
The call is with NHTSA's Administrator.

His Admin's info is below:

Dana Douglas
Executive Assistant to Administrator Rosekind
Office of the Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
Washington, DC 20590
Dana.Douglas@dot.gov
Tel: 202-366-0361/1836

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Sara Schmidt [mailto:sara.schmidt@herschendfamily.com]
Sent: Tuesday, November 15, 2016 10:54 AM
To: Matheke, Otto (NHTSA)
Subject: 1:30 call with Chris Herschend today

Hello Otto, I hope that you are well?

Chris asked me to populate his calendar with the call at 1:30. I just wanted to check if there are dial in details for this or if it's a 1:1 with you?

Also just checking that it's Eastern time

Thanks
Sara

Sara Schmidt
Stockholder Relations
Herschend Enterprises

Office: 678 379 2793
Cell: 770 883 9844

sara.schmidt@herschendfamily.com

--

_____

Chris Herschend
President, Ride The Ducks
chris@ridetheducks.com
678 466 7090 office
404 272 6460 mobile
@chris_herschend

From: Glassman, Jacqueline
Sent: 28 Oct 2016 11:07:30 -0400
To: Matheke, Otto (NHTSA)
Subject: RE: Any Duck news?

Not yet. We are reviewing. Thanks.

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Friday, October 28, 2016 10:38 AM
To: Glassman, Jacqueline
Subject: Any Duck news?

Thanks

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From: Matheke, Otto (NHTSA)
Sent: 13 Oct 2016 16:18:12 +0000
To: 'Glassman, Jacqueline'
Cc: Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA)
Subject: RE: Conference call today Ducks

Yes. 4 PM. We will call you.

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, October 13, 2016 11:26 AM
To: Matheke, Otto (NHTSA)
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: RE: Conference call today Ducks

Yes, you're on my list for today! Can you talk at 4 today?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Thursday, October 13, 2016 11:23 AM
To: Glassman, Jacqueline
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: Conference call today Ducks

Jackie - I would like to discuss Ducks today. Please send me some times we could do this.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

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From: Glassman, Jacqueline
Sent: 11 Oct 2016 15:57:08 -0400
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks
Attachments: RTDI Oct 11.docx

Hi Otto. Yes, thanks for reaching out. Here is our draft. Our draft may look very different, but mostly reflects the same structure, albeit in a simplified form. We did change the recitation of facts considerably to convey what we believe the circumstances to have been. We also simplified the section on remediating past shortcomings since, as we've discussed, all vehicles subject to the 2013 Service Bulletin (except those out of service in Seattle) have already been remediated and we believe the Consent Order should reflect the discussions we've had about the FMVSS. My understanding is that RTDI has already provided to NHTSA all past Service Campaigns as part of the IR response so some of those provisions seemed unnecessary. Obviously we are going to need to discuss the financial obligations. This draft incorporates our preferred structure – which would be to defer the penalty pending completion of the Consent Order. Much of the original draft still remains in this one.

Let's discuss further later this week and see if there's a reasonable path forward here.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, October 11, 2016 2:42 PM
To: Glassman, Jacqueline
Subject: Ducks

Just checking in because I recall you will be out tomorrow. Let me know when you can share your version of the consent order.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

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UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:

Ride the Ducks International, LLC

CONSENT ORDER

This Consent Order is issued pursuant to the authority of the National Highway Traffic Safety Administration ("NHTSA"), an operating administration of the U.S. Department of Transportation, administratively to resolve a NHTSA enforcement action, mitigate and control risks of harm, and promote safety. It sets forth the requirements and performance obligations of Ride the Ducks International, LLC ("RTDI") with regard to its obligations as the manufacturer of certain amphibious vehicles produced and sold in the United States. This Consent Order resolves issues regarding RTDI's failure to comply with certain requirements of the National Traffic and Motor Vehicle Safety Act of 1966 as amended and recodified (the "Safety Act"), 49 U.S.C. § 30101, et seq.

I. Nature of the Action

1. The Safety Act provides for the regulation of motor vehicles and motor vehicle equipment by the Secretary of Transportation. 49 U.S.C. § 30111. The Secretary has delegated his authorities under the Safety Act to the NHTSA Administrator. 49 C.F.R. §§ 1.95(a), 501.2(a)(1).

2. The Safety Act applies to manufacturers. 49 U.S.C. § 30102(a)(6). A manufacturer is defined as a person "manufacturing or assembling motor vehicles or motor vehicle equipment." *Id.*

3. The Safety Act applies to motor vehicles, defined as vehicles "driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but

does not include a vehicle operated only on a rail line." 49 U.S.C. § 30102(a)(7). The Safety Act applies to new motor vehicles, and contains an exception for vehicles that are at least 25 years old. 49 U.S.C. § 30112(b)(9).

4. Under the Safety Act and implementing regulations, a manufacturer of motor vehicles or equipment has certain obligations to notify NHTSA with regard to safety related defects and to report certain information with regard to service bulletins and certain claims received by the manufacturer. A manufacturer of new motor vehicles must additionally certify that any new motor vehicle complies with federal motor vehicle safety standards applicable as of the date of the vehicle's manufacturer prior to placing the vehicle into interstate commerce for the purpose of sale. 49 U.S.C. §§ 30118-30120; 30112, 30115. The Safety Act provides for certain civil penalties for violations of these obligations, and authorizes NHTSA to compromise civil penalties. In doing so, the agency must take into consideration certain statutory factors, including "knowledge by the person charged of its obligations" under the Safety Act, and actions taken by the person charged to identify, investigate, or mitigate the condition." 49 U.S.C. § 30165(c).

5. RTDI is the current owner, operator and licensor of certain amphibious vehicles. RTDI operates tour operations which operate amphibious vehicles on both the public roads and the public waterways. RTDI or its predecessor corporations produced amphibious vehicles (either directly or through a contract manufacturer) for this purpose and sold the vehicles to a limited number of licensees who operate similar tour services. In total, there are currently 106 amphibious vehicles produced by RTDI either in operation or ready for use in the United States.

6. RTDI's predecessor corporation began to produce and operate amphibious vehicles in 1977 in Branson, Missouri. The original amphibious vehicles were reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. These amphibious vehicles were retired in 2006.

7. In 1996, RTDI introduced the "Stretch" Duck amphibious vehicle. The "Stretch" Duck included standard all-wheel disc brakes and new anti-corrosion steel fittings. The hull was renewed and DUKW components were replaced with modern equipment, refurbished over the

original DUKW chassis frame. There are currently 57 “Stretch” Ducks either in operation or ready for use in the United States. In 2005, RTDI introduced the “Truck” Duck with a patented RTDI design. The “Truck” Duck is based on a M-Series 2 1/2 ton military cargo vehicle. There are currently 49 “Truck” Ducks either in operation or ready for use in the United States. Both the “Stretch” and the “Truck” Ducks are under 26,000 lbs. loaded weight.

8. All RTDI amphibious vehicles were appropriately registered within the state or territories in which they have operated. Throughout its history, RTDI has worked closely with the Coast Guard to meet and/or exceed all applicable marine standards and has sponsored industry efforts to discuss and disseminate best safety practices. RTDI and/or its licensees have additionally registered the amphibious vehicles with the Federal Motor Carrier Safety Administration, obtained DOT numbers and utilized only drivers with proper Commercial Driver Licenses.

9. RTDI has throughout its history made considerable good faith efforts to maintain and enhance the safety of the amphibious vehicles it produced and operates. In furtherance of its safety efforts, in October, 2013, RTDI issued a Service Bulletin to its licensees with regard to the potential for the axle on the Stretch Ducks to fail (SB-00-14-13). RTDI ensured that all affected vehicles under its control were properly repaired, and repeatedly reminded its licensees of the importance of conducting the repair on the vehicles within their fleets. RTDI has provided NHTSA with confirmation that, other than the Stretch Ducks currently under the control of the independent licensee in Seattle (Ride the Ducks Seattle) and currently out of service, all affected Stretch Ducks have been repaired per the Service Bulletin.

10. On September 24, 2015, an Stretch Duck owned and operated by Ride the Ducks of Seattle was involved in a crash with a 2009 MCI motor coach while both vehicles were traveling over the George Washington Memorial Bridge (a.k.a. the Aurora Bridge), resulting in fatalities. The Stretch Duck involved in the crash had not been subject to the repair procedure set forth in the SB-00-14-13.

11. After learning of the Aurora Bridge crash, NHTSA issued an information request to RTDI. In April, 2016, RTDI submitted a timely response, which included the October, 2013 Service

Bulletin and all other Service Bulletins issued by RTDI to its operations and its licensees. RTDI's response also included a number of lawsuits filed against RTDI related to the Aurora Bridge crash.

12. Upon reviewing RTDI's submission, NHTSA has concluded that the level of refurbishment of the vehicles and the use of the public roads is substantial enough to render RTDI's amphibious vehicles new "motor vehicles" under the Safety Act. As such, NHTSA has concluded that the amphibious vehicles should be, and should have been, certified to applicable federal motor vehicle safety standards. NHTSA has also concluded that RTDI, as the manufacturer of new motor vehicles, should be, and should have been subject to the various requirements of the Safety Act and implementing regulations, including certain obligations under the TREAD regulations and the requirement to conduct a formal safety recall rather than having issued a Service Bulletin with less formal follow up.

13. RTDI is not contesting NHTSA's conclusions, although its noncompliance with the Safety Act requirements was due solely to a misunderstanding that the amphibious vehicles were subject only to Coast Guard marine regulations and were not subject additionally to NHTSA motor vehicle regulations. RTDI has cooperated with NHTSA since coming to an understanding the NHTSA regulations comply and hereby agrees to comply with all applicable NHTSA regulations as set forth in this Consent Order.

II. Terms and Conditions of Consent Order

A. <u>Admission of Noncompliance with the Safety Act</u>

14. RTDI admits that it did not follow the strictures of the Safety Act based on a good faith belief that those obligations did not apply to the amphibious vehicles refurbished by RTDI and placed into service by RTDI or a RTDI licensee. RTDI conscientiously complied with all federal and state requirements which it understood at the time to apply to the amphibious vehicles and has taken proactive steps to monitor and address safety and quality issues concerning the vehicles.

15. RTDI has cooperated with NHTSA's investigation and has undertaken to work with the agency to identify and address the federal motor vehicle safety standards, as appropriate. RTDI admits that it did not certify its amphibious vehicles to the federal motor vehicle safety standards because it did not understand at the time that those standards were applicable to the amphibious vehicles is manufactured.

16. RTDI admits that, had it understood that NHTSA regulations were applicable to the axle service campaign, under those regulations the campaign should have been conducted as a safety recall. While RTDI did not conduct a formal recall, RTDI has provided NHTSA with confirmation that all RTDI produced amphibious vehicles other than those at Ride the Ducks Seattle (and currently out of service) have had the axle repair conducted. RTDI and NHTSA therefore agree that no further documentation is necessary with regard to that campaign.

B. Civil Penalty

17. RTDI agrees that the United States is entitled to a civil penalty of up to one million five hundred thousand dollars ($1,500,000) for the shortcomings in not complying with the Safety Act, subject to the provisions of this Consent Order and applicable law, including the Federal Claims Collection Act of 1966, as amended and codified at 31 U.S.C. § 3701, et seq. (hereinafter the "Debt Collection Act") (the "Total Civil Penalty").

18. In light of RTDI's good faith approach to safety considerations and its cooperation with the agency with regard to this investigation, the civil penalty set forth above shall be held in abeyance pending RTDI's completion of the requirements of this Consent Order. In the event RTDI violates the Safety Act or this Consent Order during the term of this Consent Order, RTDI may be potentially obligated to pay additional sums totaling up to a maximum one million four hundred and eighty thousand dollars ($1,480,000), in accordance with the terms and conditions set forth below (the "Deferred Amount"). RTDI shall use the remaining twenty thousand dollars ($20,000) to ensure satisfactory completion, as determined by NHTSA, of certain performance obligations described below in Paragraphs __ through __ and Attachment A (the "Industry Outreach Amount").

19. Should NHTSA receive notice or make its own determination that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, a lump-sum payment of two hundred fifty thousand dollars ($250,000) of the Deferred Amount will become due and owing to the U.S. Treasury within ten (10) calendar days, in accordance with instructions provided by NHTSA. Upon a second notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, an additional lump-sum payment of two hundred fifty thousand dollars ($250,000) of the Deferred Amount will become due and owing to the U.S. Treasury within ten (10) calendar days, in accordance with instructions provided by NHTSA. Upon a third notice or determination by NHTSA that RTDI has materially violated the Safety Act, regulations thereunder, or the terms of this Consent Order, the remaining Deferred Amount will become due and owing to the U.S. Treasury within ten (10) calendar days, in accordance with the instructions provided by NHTSA. RTDI will not be liable for the above amounts if RTDI demonstrates to NHTSA's reasonable satisfaction that it acted in good faith and exercised reasonable best efforts to comply.

20. If RTDI fails to make any of the payments set forth above, RTDI shall be in default of this Consent Order and the balance of the Total Civil Penalty shall become immediately due and owing. In such event: (i) RTDI agrees not to contest any collection action undertaken by NHTSA or the United States pursuant to the Debt Collection Act and the U.S. Department of Transportation's regulations, 49 C.F.R. Part 89, either administratively or in any court, and (ii) RTDI affirmatively waives any and all defenses or rights that would otherwise be available to it in any such proceeding. In addition, in such a proceeding, RTDI shall pay the United States all reasonable costs of collection and enforcement, including attorneys' fees and expenses. NHTSA in its sole discretion may waive or reduce any stipulated penalties owing under this Consent Order.

C. Performance Obligations Relating to Prior Conduct

21. This Consent Order requires RTDI to execute certain performance obligations, the objectives of which are to assist NHTSA in its mission to, among other things, carry out safety programs under the Safety Act and to improve RTDI's processes and procedures for making safety-related

defects and noncompliance determinations, reporting defects and noncompliances to NHTSA in a timely manner, and complying with reporting requirements. These performance obligations will be satisfied through the activities set forth in Paragraphs __ through __ below.

22. NHTSA will consider any and all remedial actions that RTDI has undertaken prior to the execution of this Consent Order in determining whether RTDI has carried out the performance requirements of this Consent Order.

23. RTDI agrees to undertake its reasonable best efforts to comply with all aspects of the Safety Act. If any material violation of the Safety Act, not expressly identified in this Consent Order or otherwise brought to NHTSA's attention in accordance with Paragraphs __ through __ below, occurs after the execution date of this Consent Order and during the pendency of this Consent Order, then the Deferred Amount shall become immediately due and owing to NHTSA, unless RTDI demonstrates that it acted in good faith and exercised reasonable best efforts to comply.

24. Within 60 calendar days after execution of the Consent Order, RTDI will confirm that NHTSA has been made aware through RTDI's response to the agency's Information Request of any defect-related communications (Service Bulletins), deaths alleged in claims made against the company or notices received by the company, and/or any other safety-related defect. RTDI will confirm in writing that it has made a good faith search for any additional records and either that it has found none or that it is supplying NHTSA with a copy of the additional records subject to this requirement.

25. With regard to Service Bulletins, RTDI will submit a schedule listing each such Service Bulletin and the date on which it was issued. The report shall also include indexes for each communications since October 1, 2012. RTDI will provide the index regardless of whether RTDI has already provided the Service Bulletins or communications to NHTSA in response to the Information Request.

26. Within 60 days after execution of the Consent Order, RTDI will provide NHTSA with manufacturer information pursuant to 49 CFR Part 566.

27. RTDI and NHTSA have in good faith reviewed the federal motor vehicle safety standards potentially applicable to RTDI's amphibious vehicles. RTDI and NHTSA's consideration of the potentially applicable FMVSS is set forth in Appendix A. Within 60 days after consultation with the Outside Consultant as set forth below, RTDI will provide NHTSA with a plan to address those FMVSS identified in Appendix as "requiring further action." NHTSA may require modifications to the plan if needed to ensure compliance with the FMVSS identified as "requiring further action."

D. Retention of Outside Consultant

28. No later than 60 calendar days after the execution of this Consent Order, RTDI shall retain an outside consultant ("Consultant") with experience and expertise in motor vehicle safety and the requirements of the Safety Act and regulations thereunder. The Consultant position shall be held by a separate individual from the individual(s) representing RTDI in settlement negotiations. The Consultant shall advise and assist RTDI in developing a Compliance Plan and the Training Plan as referenced in Paragraphs __ and __. The Consultant shall review for sufficiency technical service bulletins (TSBs), other communications, and all reports required under the terms of the Consent Order, that RTDI is required to submit to NHTSA and/or owners during the term of the Consent Order. The Consultant shall advise and assist RTDI on all aspects of RTDI's compliance with the Safety Act and regulations thereunder.

29. Within 30 days calendar days after the execution of this Consent Order and prior to retaining the Consultant referred to above, RTDI shall submit the name and detailed resume of the individual whom RTDI intends to retain to NHTSA for approval. RTDI agrees to ensure NHTSA has the ability to interview the individual prior to granting or denying approval. NHTSA will notify RTDI within 10 working days if it does not accept the proposed Consultant. RTDI will then have an additional 15 working days to submit a second proposed Consultant to NHTSA. The same procedures will apply to NHTSA's review of the name and resume of RTDI's subsequent proposed Consultant.

30. RTDI will report to NHTSA in writing when it has retained the Consultant, including the identity of the Consultant and the date upon which the individual was officially retained. RTDI shall retain the Consultant at its sole expense as needed during the term of the Consent Order.

E. General Performance Obligations

31. No later than 90 calendar days after the execution of this Consent Order, RTDI shall also submit a report to NHTSA, notifying the agency of all safety-related defects or noncompliances with applicable FMVSS that are currently under review by RTDI, for which notice has not previously been given to NHTSA.

32. No later than 30 calendar days after the execution of this Consent Order, RTDI shall provide to NHTSA an engineering analysis of the Stretch Duck axle to confirm the effectiveness of the remedy referenced in the October 2013 TSB, including analyzing if the axle has sufficient load capacity for use in the Stretch Duck vehicles and report the results to NHTSA.

33. RTDI shall develop new written procedures for: (a) making safety-related defect and noncompliance determinations and notifying NHTSA of such safety-related defects or noncompliances with FMVSS in accordance with 49 C.F.R. Part 573; (b) notifying licensees of safety-related defects and noncompliances in accordance with 49 C.F.R. Part 577; (c) reporting in compliance with 49 C.F.R. Part 579; and (d) ensuring vehicles comply with applicable FMVSS and all regulatory requirements (collectively, "Compliance Plan"). No later than 120 calendar days after execution of this Consent Order, RTDI shall provide a copy of such Compliance Plan to NHTSA. If NHTSA reasonably determines that any changes to the written procedures are warranted, RTDI shall revise its written procedures to incorporate NHTSA's feedback. RTDI shall provide a revised copy of the Compliance Plan to NHTSA no later than 30 calendar days after receiving any such feedback from NHTSA. RTDI agrees that the Compliance Plan required in this Paragraph shall be publicly available. RTDI shall not claim any portion of the Compliance Plan is (i) subject to attorney- client privilege or attorney work product, or (ii) confidential business information, not subject to public disclosure by NHTSA.

34. RTDI shall train appropriate personnel on its Safety Act reporting requirements and Compliance Plan. RTDI's training shall be recurrent on at least an annual basis. No later than 120 calendar days after the execution date of this Consent Order, RTDI shall submit a report describing RTDI's training plan, including details on the subjects to be taught and individuals to be trained (the "Training Plan"). NHTSA may, at its option, accept, reject or revise any part of the proposed Training Plan and may submit it back to RTDI for further revision, if necessary.

F. Industry Outreach Performance Obligations

35. This Consent Order requires RTDI to execute certain performance obligations directed at industry education and outreach, the objectives of which are to further the goals of the Safety Act, particularly with regard to educating manufacturers with similar business models, including other amphibious vehicle manufacturers and small, independent manufacturers, of their obligations under the Safety Act and regulations thereunder for reporting information to NHTSA, manufacturing vehicles that comply with applicable FMVSS, and making safety-related defect determinations. The performance obligations will be satisfied through the activities as set forth in Paragraphs __ through __ below and described in Attachment A to this Consent Order.

36. RTDI will prepare a report that includes a plan and procedures for addressing the targeted performance obligations set forth in Attachment A and will submit this report to NHTSA no later than 120 calendar days after the execution of this Consent Order. NHTSA, at its option, may accept, reject, or revise any part of the proposed report at any time during the pendency of this Consent Order, including on the basis that the proposed report does not include a sufficient number or variety of performance obligations, and may submit it back to RTDI for further revision, if necessary. The proposed report shall include metrics of success for the performance obligations specified in the report. NHTSA must give its approval, which will not be unreasonably withheld, to the proposed report before work on any of the performance obligations may begin.

37. The parties to this Consent Order agree that the cost of RTDI's execution of the performance obligations set forth in Paragraphs __ and __ and Attachment B shall not be less than twenty

thousand dollars ($20,000), to be expended over a one year period of time (the "Industry Outreach Amount"). In documenting the Industry Outreach Amount, RTDI shall provide NHTSA a report no later than 335 days after the execution of this Consent Order, detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations under Paragraphs 73 and 74 and Attachment B. NHTSA may consider the reasonable continuing and future costs to RTDI associated with RTDI carrying out the performance obligations beyond the term of this Consent Order. At NHTSA's sole discretion, a reasonable amount of RTDI's future costs of implementing the performance obligations may be counted towards the calculation of the Industry Outreach Amount.

38. In accordance with this Consent Order, RTDI is responsible for the satisfactory completion of the performance obligations set forth in Paragraphs __ through __ and Attachment B. Subject to NHTSA's discretion to extend the term of this Consent Order under Paragraph __ below, if RTDI has reasonably completed the performance obligations in Paragraphs __ through __ and Attachment B and has expended the full Industry Outreach Amount, then on the one year from the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out in Paragraphs __ through __ and Attachment B, then the balance of the Industry Outreach Amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph __ below, RTDI's obligations under this Consent Order and this Paragraph to pay the balance of the Industry Outreach Amount shall also be extended for the term of one year.

G. Completion of Performance Obligations

39. RTDI shall provide to NHTSA, no later than 335 calendar days after execution of this Consent Order, a declaration from an officer of the company documenting the completion of its obligations, as defined in Attachment C, since the execution of this Consent Order. The declaration shall be submitted to NHTSA pursuant to 28 U.S.C. § 1746.

40. In accordance with this Consent Order, RTDI is responsible for the satisfactory completion of the performance obligations set forth herein. No later than 335 calendar days after the execution of this Consent Order, RTDI shall submit a Completion Report to NHTSA and, at NHTSA's election, RTDI will make a presentation of its performance obligations under the Consent Order. The Completion Report shall address the metrics of success for each of the targeted performance obligations and objectives, included in Attachment C. NHTSA will use this report to determine whether RTDI has reasonably completed the performance obligations and should be released from the Consent Order under Paragraph __ or whether this Consent Order should be extended for an additional year as set forth herein. In the event obligations remain to be performed by RTDI notwithstanding RTDI's best efforts to complete same, NHTSA will not unreasonably deny a request by RTDI to extend the time to complete the performance obligations.

III. Compliance with Consent Order

41. RTDI shall comply with its obligations under the Safety Act and regulations thereunder to take all actions necessary to comply with this Consent Order and to cooperate with NHTSA in carrying out the requirements of this Consent Order. RTDI's reasonable best efforts shall include, but shall not be limited to: (i) providing prompt notice to NHTSA in the event any requirement of this Consent Order cannot be met or timely met, and (ii) ensuring that employees involved with implementation of the performance requirements of this Consent Order are kept well-informed and are allocated sufficient time during their working hours to enable them to thoroughly and effectively perform actions to carry out or implement the performance requirements of this Consent Order.

42. RTDI shall provide written notice of each required submission under this Consent Order by electronic mail to NHTSA's Medium & Heavy Duty Vehicle Division Chief (currently Bruce York, Bruce.York@dot.gov), and with copies to NHTSA's Associate Administrator for Enforcement (currently Jeffrey Giuseppe, Jeffrey.Giuseppe@dot.gov) and NHTSA's Assistant Chief Counsel for Litigation and Enforcement (currently Kerry Kolodziej, Kerry.Kolodziej@dot.gov).

IV. Term of Consent Order

43. Unless otherwise specified, the term of this Consent Order and RTDI's performance obligations thereunder is one year from the date of execution, provided, however, that the commitments in Paragraphs 57 through 78 shall survive the term of this Consent Order until the performance obligations with respect to the Deferred Amount and Industry Outreach Amount are reasonably satisfied. NHTSA may, at its option, extend the period for one year.

IV. Amendment

44. This Consent Order cannot be modified, amended, or waived except by an instrument in writing signed by all parties, and no provision may be modified, amended, or waived other than by a writing setting forth such modification, amendment, or waiver and signed by the party making the modification, amendment, or waiver.

V. Miscellaneous

45. Nothing in this Consent Order shall be interpreted or construed in a manner inconsistent with, or contravening, any federal law, rule, or regulation at the time of the execution of this Consent Order, or as amended thereafter.

46. Upon NHTSA's determination that RTDI has reasonably achieved all of the performance obligations set forth herein, at a date agreed upon by the parties, but at no time before the first anniversary of this Consent Order, RTDI, including its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns will be released from liability for civil penalties pursuant to 49 U.S.C. § 30165 in connection with any and all Safety Act reporting obligations, including those expressly identified in this Consent Order or identified in any schedules and reports submitted pursuant to this Consent Order, from the inception of the Safety Act through the execution date of this Consent Order. Additionally, the Secretary of Transportation, by and through the Administrator of NHTSA, hereby waives any and all enforcement action or claims against RTDI (including its current

and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns) for civil penalties solely with respect to potential violations of the Safety Act or its implementing regulations that are disclosed pursuant to the Terms and Conditions of the Consent Order, and subject to RTDI's satisfactory fulfillment of its other obligations under this Consent Order. Should RTDI fail to satisfactorily disclose the service bulletins, incidents involving death, or safety-related defects it is required to report, NHTSA may pursue any and all enforcement action or claims for civil penalties with respect to potential violations of the Safety Act or its implementing regulations that are disclosed.

47. This Consent Order does not release RTDI from civil or criminal liabilities, if any, that may be asserted by the United States, the Department of Transportation, NHTSA, or any other governmental entity, other than its civil penalty liabilities under 49 U.S.C. §§ 30165 and 30166 as described in this Consent Order.

48, None of the specific reporting obligations described in this Consent Order relieve RTDI of its obligation to submit any other reports required by the Safety Act or its corresponding regulations.

48. The parties shall each bear their own respective attorneys' fees, costs, and expenses, except as provided in Paragraph 53 above.

49. This Consent Order shall be effective following its execution. Any breach of the obligations under this Consent Order may, at NHTSA's option, be immediately enforceable in any United States District Court. RTDI agrees that it will not raise any objection as to venue.

50. In the event of RTDI's breach of, or failure to perform, any term of this Consent Order NHTSA reserves the right to pursue any and all appropriate administrative and/or judicial remedies, including, but not limited to, assessing interest for untimely settlement payments and/or commencing litigation to enforce this Consent Order in any United States District Court.

51. The parties who are the signatories to this Consent Order have the legal authority to enter into this Consent Order, and each party has authorized its undersigned to execute this Consent Order on its behalf.

52. RTDI expressly waives any and all defenses and agrees not to plead, argue, or otherwise raise any defenses other than (i) that the payment of the Non-Deferred Amount, set forth in Paragraphs 49 and 50, was made to NHTSA, if applicable, and (ii) that RTDI has substantially complied with the terms of this Consent Order.

53. This Consent Order shall be binding upon, and inure to the benefit of, RTDI and its current and former directors, officers, employees, agents, parents, subsidiaries, affiliates, successors, and assigns. RTDI agrees to waive any and all defenses that may exist or arise in connection with any person or entity succeeding to the interests or obligations herein, including as a result of any changes to the corporate structure or relationships among or between RTDI and any of its parents, subsidiaries, or affiliates.

54. Should any condition or other provision contained herein be held invalid, void, or illegal by any court of competent jurisdiction, it shall be deemed severable from the remainder of this Consent Order and shall in no way affect, impair, or invalidate any other provision of this Consent Order.

55. This Consent Order shall not be construed to create rights in, or grant any cause of action to, any third party not party to this Consent Order.

56. This Consent Order may be executed in counterparts, each of which shall be considered effective as an original signature.

57. This Consent Order is a fully integrated agreement and shall in all respects be interpreted, enforced, and governed under the federal law of the United States. This Consent Order which are fully incorporated by reference, sets forth the entire agreement between the parties with

regard to the subject matter hereof. There are no promises, agreements, or conditions, express or implied, other than those set forth in this Consent Order and the attachments thereto.

APPROVED AND SO ORDERED:

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION

Dated: __, 2016

By: **// ORIGINAL SIGNED BY //**_____

Mark R. Rosekind, Ph.D.
Administrator

Dated: __, 2016

By: _____

Paul A. Hemmersbaugh
Acting Chief Counsel

Dated: __, 2016

By: _____

Kerry E. Kolodziej
Acting Assistant Chief Counsel
for Litigation and Enforcement

Dated: __, 2016

By: _____

Otto G. Matheke, III
Senior Trial Attorney

Dated: __, 2016

By: _____

Sarah E. Sorg
Senior Trial Attorney

Dated: __, 2016

By: _____

Jordan E. Stephens
Trial Attorney

AGREED:

RIDE THE DUCKS INTERNATIONAL, LLC

Dated: __, 2016

By: _____

Chris Herschend
President

Dated: __, 2016

By: _____

Robby Hultz
Managing Partner

Dated: __, 2016

By: _____

Jacqueline S. Glassman
King & Spalding LLC
Counsel for Ride the Ducks International, LLC

ATTACHMENT B

Industry Education and Outreach

A. Purpose of the Industry Outreach Performance Obligations.

NHTSA and RTDI agree that the performance obligations included below are intended to secure a significant benefit to the interests of public safety by mitigating the risks of harm associated with non-compliance with the National Traffic and Motor Vehicle Safety Act of 1966 as amended and recodified (the "Safety Act"), 49 U.S.C. § 30101, *et seq.*, and that the following performance obligations are consistent with the purpose of the Safety Act.

B. Targeted Performance Obligations.

In executing the terms of the Consent Order, RTDI must file certain reports related to its plan for industry and consumer outreach, which will include the following and which are to be completed over the next year:

(1) Educate manufacturers with similar business models, including other amphibious vehicle manufacturers and small, independent manufacturers, on the importance of meeting their Safety Act obligations, such as early warning and other reporting requirements under 49 C.F.R. Part 579 and recall requirements under 49 C.F.R. Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

(2) Develop Safety Act educational materials for distribution to manufacturers.

(3) Assist other manufacturers in developing their own safety outreach programs.

(4) Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

(5) Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

C. Development of Written Plan and Procedures for Industry Outreach.

As set forth in Paragraph 74 of the Consent Order, RTDI will prepare a report which includes a plan and procedures for fulfilling the targeted performance obligations set forth in Section B above. This report shall be submitted to NHTSA no later than 120 calendar days after the execution of the Consent Order, and shall include metrics of success for the targeted performance obligations contained in Section B above. NHTSA, at its option, may accept, reject or revise any part of the proposed report at any time during the pendency of this Consent Order and submit it back to RTDI for further revision, if necessary. NHTSA must give its approval, which will not be unreasonably withheld, to the proposed report before work on any of the targeted performance obligations may begin.

The targeted performance obligations outlined in Section B may be carried out, at RTDI's discretion, with the assistance and participation of other designers, engineers and manufacturers of amphibious vehicles, specialty vehicles, and tourism markets. At RTDI's discretion, the targeted performance obligations outlined in Section B may also be carried out with the assistance and participation of industry trade associations. Any non-RTDI assistance and participation shall be done in a manner consistent with antitrust guidelines.

D. Costs Associated With the Industry Outreach Performance Obligations.

Consistent with Paragraphs 49 and 75 of the Consent Order, the total expenditure of the performance obligations described above shall not be less than twenty thousand dollars ($20,000), and shall be documented in accordance with those paragraphs.

In the event of a dispute as to whether RTDI has incurred any part or all of twenty thousand dollars ($20,000), NHTSA shall advise RTDI of such in writing, to which RTDI shall have fifteen working days to respond. Upon receipt of RTDI's response, should NHTSA still

dispute any contested amount, NHTSA shall advise RTDI in writing within fifteen working days, and RTDI shall hire, at its sole expense, a third-party, independent public accounting firm to assess RTDI's costs incurred. The independent public accounting firm will evaluate whether or not the costs identified are accurate, whether they reached the cost of the Industry Outreach Amount, and whether they are reasonably tailored to the exercise of the targeted performance obligations. The independent public accounting firm will advise NHTSA of its findings by submitting a declaration to NHTSA regarding these points pursuant to 28 U.S.C. § 1746.

E. Completion of Targeted Performance Obligations.

Consistent with Paragraph 76 of the Consent Order, the timeline for the satisfactory completion of the targeted performance obligations listed in Section B above is one year. No later than 335 days after the execution of this Consent Order, RTDI will submit a report to NHTSA detailing the amount of dollars that RTDI actually expended during the prior year in furtherance of its obligations.

RTDI is responsible for the satisfactory completion of the targeted performance obligations in Section B above in accordance with the Consent Order. Subject to the provisions for extending the term of this Consent Order in Paragraph 81, if RTDI has reasonably achieved all of the targeted performance obligations on or before the one year anniversary of the execution date of this Consent Order, RTDI will be released from any and all obligations to pay the Industry Outreach Amount, or any remaining portion thereof, to NHTSA. If, however, RTDI has not reasonably achieved the requirements of the performance obligations set out in Section B above by the end of the term of the Consent Order, the balance of the Industry Outreach amount shall become immediately due and owing. Should NHTSA extend the term of this Consent Order as set forth in Paragraph 81, RTDI's responsibility for the satisfactory completion of the targeted performance obligations listed in Section B shall also be extended for the term of one year.

From: Matheke, Otto (NHTSA)
Sent: 11 Oct 2016 20:35:38 +0000
To: Glassman, Jacqueline
Subject: RE: Ducks

Thanks

Talk to you on Thursday?

I don't want to drive new RTDI under but I have to reiterate that the old RTDI was owned completely by a flush parent People died. I can work in your direction on money but there will have to be cash up front. I assume that you have had to talk to the parent's counsel and wonder if it would help if we contacted them ourselves.

Thanks

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Glassman, Jacqueline <JGlassman@KSLAW.com>
Sent: Tuesday, October 11, 2016 3:57:08 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Hi Otto. Yes, thanks for reaching out. Here is our draft. Our draft may look very different, but mostly reflects the same structure, albeit in a simplified form. We did change the recitation of facts considerably to convey what we believe the circumstances to have been. We also simplified the section on remediating past shortcomings since, as we've discussed, all vehicles subject to the 2013 Service Bulletin (except those out of service in Seattle) have already been remediated and we believe the Consent Order should reflect the discussions we've had about the FMVSS. My understanding is that RTDI has already provided to NHTSA all past Service Campaigns as part of the IR response so some of those provisions seemed unnecessary. Obviously we are going to need to discuss the financial obligations. This draft incorporates our preferred structure – which would be to defer the penalty pending completion of the Consent Order. Much of the original draft still remains in this one.

Let's discuss further later this week and see if there's a reasonable path forward here.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, October 11, 2016 2:42 PM
To: Glassman, Jacqueline
Subject: Ducks

Just checking in because I recall you will be out tomorrow. Let me know when you can share your version of the consent order.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

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From: Glassman, Jacqueline
Sent: 11 Oct 2016 16:52:39 -0400
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Let's talk and see if there's a path forward.

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, October 11, 2016 4:36 PM
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Subject: RE: Ducks

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Sent with Good (www.good.com)

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From: Glassman, Jacqueline
Sent: 20 Oct 2016 19:09:23 -0400
To: Matheke, Otto (NHTSA)
Subject: Re: DUCKS

Ha! Just waiting for you to re-emerge!

I am on travel tomorrow but can call you in the morning.

Sent from my iPhone

On Oct 20, 2016, at 6:18 PM, Matheke, Otto (NHTSA)
<Otto.Matheke@dot.gov<mailto:Otto.Matheke@dot.gov>> wrote:

Ms. Glassman:

Is the ball in your court or mine? Having enjoyed my midweek vacation and sent my older brother off to spend the winter in the tropics on his sailboat, I would like to maintain momentum on the DUCKS.

<image001.png><http://www.nhtsa.gov/>

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

<image002.png><https://www.facebook.com/NHTSA>
<image003.png><https://twitter.com/@nhtsagov>
<image004.png><https://www.youtube.com/user/usdotnhtsa>

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From: Kolodziej, Kerry (NHTSA)
Sent: 9 Nov 2016 15:36:41 +0000
To: Matheke, Otto (NHTSA);Stephens, Jordan (NHTSA)
Cc: Sorg, Sarah (NHTSA)
Subject: RE: Ducks
Attachments: DUCKSDRAFTConsent OrderNov8 - kek.docx

My thoughts. I don't think we're too far off.

From: Matheke, Otto (NHTSA)
Sent: Tuesday, November 08, 2016 5:47 PM
To: Kolodziej, Kerry (NHTSA); Stephens, Jordan (NHTSA)
Subject: FW: Ducks

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, November 08, 2016 5:11 PM
To: Matheke, Otto (NHTSA)
Subject: Ducks

Otto – Here is a draft with some comments. I may have more (or slightly different) comments still, but we can start here. One big picture issue is that the draft you sent me had various confirmations and reports that are overkill here and unnecessary. They make this very hard to work with and don't seem to serve any additional safety purpose. This is not a huge company – they don't need to have executives signing declarations that their underlings took care of business. I've suggested deleting some of those.

Also the Attachments aren't necessary here. The Industry Outreach plan is basically asking you what you would like and with whom as it relates to companies outside of the small APV industry. If you skip the extra declarations and reports, the chronology is pretty simple and not hard to follow. And there's no need here for another certificate that the Consent Order was followed – it was or it wasn't, and if we have a dispute we'll deal with it.

There's some language changes either to make it better conform to the regs or to the facts. On the "admissions," I am fine stating the facts but don't think we need to make this company, which did nothing willfully and tried to do the right thing throughout, have to characterize their conduct. I don't see any safety benefit to that.

There aren't many changes, and I tried to go mostly lightly. But these are important.

Thanks, Jackie

Jacqueline Glassman
King & Spalding LLP
1700 Pennsylvania Avenue, NW
Washington DC 20006
Jglassman@kslaw.com
202-626-9228

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NOT ADMISSIBLE
FED. R. EVID. 408

- Report submitted to NHTSA within the defined time period.

Industry Outreach
High Level Summary:

Within the agreed upon time period, RTDI will:

- Perform industry outreach, educating manufacturers with similar business models of their obligations under the Safety Act and reporting regulations.

Measurement of Completion:

- Report submitted to NHTSA that details the plan and procedures for addressing the obligations set forth in Attachment A.

Educate customers and licensees

High Level Summary:

Within the agreed upon time period, RTDI will:

- Undertake a good faith attempt to reach and train RTDI's customer base (which includes its licensees).

Measurement of Completion:

- Evidence of completions/attempts to perform training.

Develop Safety Act education materials

High Level Summary:

Within the agreed upon time period, RTDI will:

- Prepare educational materials regarding NHTSA, the Safety Act, and manufacturer reporting responsibilities to be shared with other members of the industry.

Measurement of completion:

- Approval from NHTSA of materials.

Assist other manufacturers in developing their own safety outreach program

High Level Summary:

Within the agreed upon time period, RTDI will:

- Share educational materials, such as the Compliance Plan and Training Plan, with other members of the industry.

Measurement of completion:

- Submit to NHTSA a list of manufacturers with whom RTDI has shared its educational materials and/or Compliance Plan and Training Plan.

Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA

High Level Summary:

Within the agreed upon time period, RTDI will:

- Prepare educational materials regarding NHTSA, the Safety Act, and manufacturer reporting responsibilities to be shared with other members of the industry.

Measurement of completion:

- Submit to NHTSA evidence of presentations made by RTDI.

Work with partners to enhance recall effectiveness

High Level Summary:

Within the agreed upon time period, RTDI will:

- Share educational materials, such as the Compliance Plan and Training Plan, with other members of the industry.

Measurement of completion:

- Submit to NHTSA a list of partners and suppliers with whom RTDI has shared its educational materials and/or Compliance Plan and Training Plan.

Completion Report

High Level Summary:

Within the agreed upon time period, RTDI will:

- Submit a Completion Report to NHTSA and may give a presentation to the agency of its performance under the Consent Order.

Measurement of Completion:

DRAFT – FOR SETTLEMENT PURPOSES ONLY
NOT ADMISSIBLE
FED. R. EVID. 408

- Report submitted to NHTSA within the defined time period.

From: Glassman, Jacqueline
Sent: 30 Sep 2016 10:04:22 -0400
To: Matheke, Otto (NHTSA)
Cc: Sorg, Sarah (NHTSA);Stephens, Jordan (NHTSA)
Subject: Re: Ducks

I am at a law firm retreat. Just pick a time between 11-2 and I can give you a call.

Sent from my iPhone

> On Sep 30, 2016, at 10:01 AM, Matheke, Otto (NHTSA) <Otto.Matheke@dot.gov> wrote:
>
> Jackie
>
> I would like to chat briefly this afternoon and perhaps set up a meeting for next week to discuss penalties and consent order terms. When would be a good time to call?
>
> Thanks
>
>
>
>
>
> Otto Matheke
> Senior Attorney
> National Highway Traffic Safety Administration
>
> Sent with Good (www.good.com)

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From: Glassman, Jacqueline
Sent: 18 Jan 2017 11:50:21 -0500
To: Matheke, Otto (NHTSA);Stephens, Jordan (NHTSA)
Subject: RE: RDTI powerpoint from September meeting
Attachments: SKM_C364e17011810310.pdf, RTDI Confidentiality Request.docx, Ride The Ducks International CBI.PPTX, Ride The Ducks International Redacted.pptx

Here you go. The first page of the request is blank due to some IT glitch I am too old to figure out, but the letter appears on the second page.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Monday, January 09, 2017 4:10 PM
To: Glassman, Jacqueline
Subject: RDTI powerpoint from September meeting

Jackie:

We have a powerpoint from our September meeting with you and the officers of RDTI containing a little information about the company and your views about the applicable safety standards and RTDI's compliance with the same.

Did you file a request for confidential treatment for this powerpoint?
We have no record of receiving one.

Thanks

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

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Certificate in Support of Request for Confidentiality

I, Brian Deckard, pursuant to the provisions of 49 C.F.R. Part 512, state as follows:

1. I am Brian Deckard, and I am a senior official at Ride The Ducks International (RTDI) and I am authorized to execute this certificate on its behalf;

2. I certify that the information contained in the enclosed attachments and marked as Confidential Business Information is confidential and proprietary data, in the form of confidential business information, and is being submitted with the claim that it is entitled to confidential treatment under 5 U.S.C. § 552(b)(4) (as incorporated by reference in and modified by 49 C.F.R. Part 512);

3. I hereby request that the information contained in the enclosed documents be protected permanently or until such time as the information is no longer held confidential by the company;

4. This certification is based on the information provided by the responsible RTDI personnel who have authority in the normal course of business to release the information for which a claim of confidentiality has been made to ascertain whether such information has ever been released outside RTDI;

5. Based upon that information, to the best of my knowledge, information and belief, the information for which has claimed confidential treatment has never been released or become available outside RTDI;

6. I make no representations beyond those contained in this Certificate and, in particular, I make no representations as to whether this information may become available outside RTDI because of unauthorized or inadvertent disclosure, except as noted in paragraph 5 above; and

I certify under penalty of perjury that the foregoing is true and correct.

Executed on this 18 day of Jan, 2017.

Brian Deckard

From: Matheke, Otto (NHTSA)
Sent: 13 Feb 2017 21:31:50 +0000
To: 'Iannetta, Christie'
Subject: RE: Ride the Ducks International

Ms. Iannetta:

Your request for an extension of time to submit the compliance plan is granted.

Thank you.

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Iannetta, Christie [mailto:CIannetta@KSLAW.com]
Sent: Monday, February 13, 2017 3:47 PM
To: Matheke, Otto (NHTSA) <Otto.Matheke@dot.gov>
Subject: Ride the Ducks International

Otto –

Ride the Ducks International (RTDI) is requesting a short extension of time to submit its FMVSS Compliance Plan to NHTSA pursuant to paragraph 36 of the Consent Order. RTDI is currently in the process of reviewing the issues raised in the Consultant's draft report. The company is evaluating the technical merits of those issues as well as how it may address any potential compliance related issues. In order to provide the agency with the most accurate and complete plan possible, RTDI requests that the deadline to submit its FMVSS Compliance Plan be extended up to and including March 6, 2017. RTDI does not anticipate that this brief extension of time will have any impact on any other dates in the Consent Order.

Thank you for your consideration. Christie.

Christie L. Iannetta
KING & SPALDING LLP
1700 Pennsylvania Ave, N.W.
Washington D.C. 20006
Direct: (202) 626-9229
E-mail: ciannetta@kslaw.com

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From: Matheke, Otto (NHTSA)
Sent: 29 Mar 2017 20:49:14 +0000
To: 'Iannetta, Christie'
Cc: York, Bruce (NHTSA)
Subject: RE: RTDI Industry Outreach Plan

Ms. Iannetta:

Two comments on the plan.

The training plan is just an outline of what they intend to do. The training materials are not included.

On the outreach program, they included materials, but not how, when or how frequently they will distribute them. There should be a plan for the distribution of the materials.

I also need to discuss the recall remedy with you. Please give me a call.

Thanks

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 ? Cell: 202-713-7883

-----Original Message-----
From: Iannetta, Christie [mailto:CIannetta@KSLAW.com]
Sent: Wednesday, March 15, 2017 4:29 PM
To: Matheke, Otto (NHTSA) <Otto.Matheke@dot.gov>; Stephens, Jordan (NHTSA) <jordan.stephens@dot.gov>; York, Bruce (NHTSA) <Bruce.York@dot.gov>
Cc: Glassman, Jacqueline <JGlassman@KSLAW.com>
Subject: RTDI Industry Outreach Plan

All -

In accordance with the Consent Order, attached please find Ride the Ducks International's Industry Outreach Plan, Training Plan and supporting materials.

Please let me know if you have any questions.

Thank you. Christie.

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From: Matheke, Otto (NHTSA)
To: "Glassman, Jacqueline"
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: RE: Conference call today Ducks
Date: Thursday, October 13, 2016 12:18:00 PM
Attachments: image001.png
image002.png
image003.png
image004.png

Yes. 4 PM. We will call you.

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, October 13, 2016 11:26 AM
To: Matheke, Otto (NHTSA)
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: RE: Conference call today Ducks

Yes, you're on my list for today! Can you talk at 4 today?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Thursday, October 13, 2016 11:23 AM
To: Glassman, Jacqueline
Cc: Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: Conference call today Ducks

Jackie - I would like to discuss Ducks today. Please send me some times we could do this.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

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From: Matheke, Otto (NHTSA)
To: "Glassman, Jacqueline"
Cc: Torres, Justin
Subject: RE: DUCKS and Compliance - for settlement purposes not admissible FRE 408
Date: Tuesday, October 25, 2016 4:22:00 PM
Attachments: image005.png
image006.png
image007.png
image008.png
image009.png
image010.png
image011.png
image012.png

The last one is the one I intended to send. I thought I had mastered cut and paste.

The last of the three is a rework of the old paragraph 41.

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, October 25, 2016 4:20 PM
To: Matheke, Otto (NHTSA)
Cc: Torres, Justin
Subject: RE: DUCKS and Compliance - for settlement purposes not admissible FRE 408

Did you intend for these 3 paragraphs to be the same?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, October 25, 2016 1:44 PM
To: Glassman, Jacqueline
Subject: DUCKS and Compliance - for settlement purposes not admissible FRE 408

Jackie:

Try this on for size for new language for Paragraph 41 in the most recent consent order I sent you.

1. RTDI has consulted with NHTSA regarding the FMVSS that apply to the vehicles it has produced. Nonetheless, RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains RTDI's sole responsibility. No later than 60 calendar days after the execution of the Consent Order, RTDI shall submit to NHTSA a plan for bringing the vehicles it has produced into compliance with all applicable FMVSS or to the extent necessary, filing

petitions for inconsequential non-compliance. RDTI further agrees that it will conduct safety recalls to address any and all non-compliances with applicable FMVSS not addressed by a petition for inconsequential non-compliance. No later than 120 days after the submission of the aforementioned FMVSS compliance plan, RTDI shall submit a confirmation signed under oath to NHTSA affirming that all Stretch Ducks owned or operated by RTDI or RTDI licensees obligated to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequential non-compliance have been filed by RTDI) and have been certified as such by the application of certification labels as referenced in Paragraph 29 above.

2. RTDI has consulted with NHTSA regarding the FMVSS that apply to the vehicles it has produced. Nonetheless, RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains RTDI's sole responsibility. No later than 60 calendar days after the execution of the Consent Order, RTDI shall submit to NHTSA a plan for bringing the vehicles it has produced into compliance with all applicable FMVSS or to the extent necessary, filing petitions for inconsequential non-compliance. RDTI further agrees that it will conduct safety recalls to address any and all non-compliances with applicable FMVSS not addressed by a petition for inconsequential non-compliance. No later than 120 days after the submission of the aforementioned FMVSS compliance plan, RTDI shall submit a confirmation signed under oath to NHTSA affirming that all Stretch Ducks owned or operated by RTDI or RTDI licensees obligated to perform repairs as directed by RTDI comply with all applicable FMVSS (other than those for which petitions for inconsequential non-compliance have been filed by RTDI) and have been certified as such by the application of certification labels as referenced in Paragraph 29 above.

3. RTDI has consulted with NHTSA regarding the FMVSS that apply to the vehicles it has produced. Nonetheless, RTDI acknowledges that NHTSA does not "approve" or endorse manufacturer certifications and that the duty to determine which FMVSS apply to RTDI's vehicles remains RTDI's sole responsibility. No later than 60 calendar days after the

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Thanks

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

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From:	Matheke, Otto (NHTSA)
To:	"Glassman, Jacqueline"; Chris Herschend (chris@ridetheducks.com); Kolodziej, Kerry (NHTSA)
Subject:	RE: DUCKS Consent Order Final.docx
Date:	Tuesday, November 15, 2016 10:48:00 AM
Attachments:	image001.png image002.png image003.png image004.png

Are we confirmed for 1:30 call?

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, November 15, 2016 10:44 AM
To: Chris Herschend (chris@ridetheducks.com); Matheke, Otto (NHTSA); Kolodziej, Kerry (NHTSA)
Cc: Torres, Justin
Subject: DUCKS Consent Order Final.docx

This should be the final version. We had difficulty with the formatting so please make sure it came through correctly.

Chris will give this a once over and, assuming he's okay, will send us a signed signature page and we'll send that over to you with ours.

We appreciate the opportunity for Chris to speak briefly with the Administrator.

Thanks, Jackie

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From:	Matheke, Otto (NHTSA)
To:	"Chris Herschend"
Cc:	Glassman, Jacqueline; Kolodziej, Kerry (NHTSA)
Subject:	RE: DUCKS Consent Order Final.docx
Date:	Tuesday, November 15, 2016 10:51:00 AM
Attachments:	image005.png image006.png image007.png image008.png image009.png image010.png image011.png image012.png

---

OK.

Mark's Admin is Dana Douglas

Dana.Douglas@dot.gov
Tel: 202-366-0361/1836

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Chris Herschend [mailto:chris@ridetheducks.com]
Sent: Tuesday, November 15, 2016 10:49 AM
To: Matheke, Otto (NHTSA)
Cc: Glassman, Jacqueline; Kolodziej, Kerry (NHTSA)
Subject: Re: DUCKS Consent Order Final.docx

sure!

On Tue, Nov 15, 2016 at 10:48 AM, Matheke, Otto (NHTSA) <Otto.Matheke@dot.gov> wrote:
Are we confirmed for 1:30 call?

NHTSA

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, November 15, 2016 10:44 AM
To: Chris Herschend (chris@ridetheducks.com); Matheke, Otto (NHTSA); Kolodziej, Kerry (NHTSA)
Cc: Torres, Justin
Subject: DUCKS Consent Order Final.docx

This should be the final version. We had difficulty with the formatting so please make sure it came through correctly.

Chris will give this a once over and, assuming he's okay, will send us a signed signature page and we'll send that over to you with ours.

We appreciate the opportunity for Chris to speak briefly with the Administrator.

Thanks, Jackie

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--

Chris Herschend
President, Ride The Ducks
chris@ridetheducks.com
678 466 7090 office
404 272 6460 mobile
@chris_herschend

From: Matheke, Otto (NHTSA)
To: "Glassman, Jacqueline"
Subject: RE: Ducks
Date: Monday, August 29, 2016 5:24:00 PM

Thanks for the information.

What is your client's position regarding filing a 573 for the front axle issue?

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Thursday, August 25, 2016 5:56 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Amphibious vehicle manufacturers are:

Advanced Amphibious Design (Hawaii) – which also uses older military vehicles
Cool Amphibious Manufacturing International (Bluffton, SC) – which uses modern chassis
Salamander (Northern Ireland) is not selling into the US as of yet – also uses modern chassis

---

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 5:12 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Yes. I am in a meeting from 2 until 4 but free all day otherwise. Pick a time and let me know.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 23, 2016 5:09 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Can we talk on Thursday?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 4:57 PM
To: Glassman, Jacqueline
Subject: Ducks

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

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From: Matheke, Otto (NHTSA)
To: "Glassman, Jacqueline"
Subject: RE: Ducks
Date: Tuesday, August 23, 2016 5:12:00 PM

Yes. I am in a meeting from 2 until 4 but free all day otherwise. Pick a time and let me know.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Glassman, Jacqueline [mailto:JGlassman@KSLAW.com]
Sent: Tuesday, August 23, 2016 5:09 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Can we talk on Thursday?

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 4:57 PM
To: Glassman, Jacqueline
Subject: Ducks

Jackie:

Let me know when you are up to speed on the above and we can talk further.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

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From: Matheke, Otto (NHTSA)
To: JGlassman@KSLAW.com
Subject: RE: Ducks
Date: Tuesday, August 23, 2016 7:28:33 PM

Ok. 4 it is

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

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From: Glassman, Jacqueline <JGlassman@KSLAW.com>
Sent: Tuesday, August 23, 2016 5:20:28 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Let's talk after your meeting at 4. Thanks!

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, August 23, 2016 5:12 PM
To: Glassman, Jacqueline
Subject: RE: Ducks

Yes. I am in a meeting from 2 until 4 but free all day otherwise. Pick a time and let me know.

Thanks

Otto G. Matheke, III
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To: Matheke, Otto (NHTSA)
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Let me know when you are up to speed on the above and we can talk further.

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Otto G. Matheke, III
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From: Matheke, Otto (NHTSA)
To: Glassman, Jacqueline
Subject: RE: Ducks
Date: Tuesday, October 11, 2016 4:35:39 PM

Thanks

Talk to you on Thursday?

I don't want to drive new RTDI under but I have to reiterate that the old RTDI was owned completely by a flush parent People died. I can work in your direction on money but there will have to be cash up front. I assume that you have had to talk to the parent's counsel and wonder if it would help if we contacted them ourselves.

Thanks

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Glassman, Jacqueline <JGlassman@KSLAW.com>
Sent: Tuesday, October 11, 2016 3:57:08 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ducks

Hi Otto. Yes, thanks for reaching out. Here is our draft. Our draft may look very different, but mostly reflects the same structure, albeit in a simplified form. We did change the recitation of facts considerably to convey what we believe the circumstances to have been. We also simplified the section on remediating past shortcomings since, as we've discussed, all vehicles subject to the 2013 Service Bulletin (except those out of service in Seattle) have already been remediated and we believe the Consent Order should reflect the discussions we've had about the FMVSS. My understanding is that RTDI has already provided to NHTSA all past Service Campaigns as part of the IR response so some of those provisions seemed unnecessary. Obviously we are going to need to discuss the financial obligations. This draft incorporates our preferred structure – which would be to defer the penalty pending completion of the Consent Order. Much of the original draft still remains in this one.

Let's discuss further later this week and see if there's a reasonable path forward here.

Thanks, Jackie

From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]
Sent: Tuesday, October 11, 2016 2:42 PM

To: Glassman, Jacqueline
Subject: Ducks

Just checking in because I recall you will be out tomorrow. Let me know when you can share your version of the consent order.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

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From:	Matheke, Otto (NHTSA)
To:	Umberger, Rodney
Subject:	RE: Ride the Ducks International
Date:	Monday, June 06, 2016 8:42:48 AM

Assumed this was the issue. Talk to you on Friday.

Otto Matheke
Senior Attorney
National Highway Traffic Safety Administration

Sent with Good (www.good.com)

From: Umberger, Rodney <rumberger@williamskastner.com>
Sent: Sunday, June 5, 2016 8:20:36 PM
To: Matheke, Otto (NHTSA)
Subject: RE: Ride the Ducks International

Mr. Matheke –

Thank you for your email and telephone call last week. I apologize for my belated reply, but unfortunately, I was and continue to be out of town for a jury trial that is going to last another couple of weeks. That said, it appears that we are not going to be in trial on Friday of this coming week (June 10) and I will call you back then.

Regards,

- Rod

Rodney L. Umberger
Williams Kastner | Attorney at Law
601 Union Street, Suite 4100
Seattle, WA 98101-2380
P: 206-628-2421 | M: 206-755-6369
www.williamskastner.com | Bio | V-Card

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From: Matheke, Otto (NHTSA) [mailto:Otto.Matheke@dot.gov]

Sent: Wednesday, June 1, 2016 11:30 AM
To: Umberger, Rodney <rumberger@williamskastner.com>
Subject: Ride the Ducks International

Mr. Umberger:

Based on the information provided in Ride the Ducks International's (RTDI) April 21, 2016 response to NHTSA's information request, the agency believes that your client's modifications of the vehicle involved in the September2015 collision were so extensive that RTDI should be considered the manufacturer of the vehicle under our statute and regulations.

I would like to discuss our concerns with you at your first convenience and ask that you call me at the number provided below.

Thank you.

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Matheke, Otto (NHTSA)
To: "Iannetta, Christie"
Cc: Glassman, Jacqueline; Sorg, Sarah (NHTSA); Stephens, Jordan (NHTSA)
Subject: RE: Ride the Ducks
Date: Monday, September 12, 2016 5:52:00 PM
Attachments: image001.png
image002.png
image003.png
image004.png

Thanks

I had to move the meeting for the 22nd back to 3:30 as there is an ODI/OVSC all hands meeting from 2- 3:30.

I will be in touch.

Otto Matheke
Senior Attorney for Defects Investigation
Department of Transportation
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE., Washington, DC 20590
Office: 202-366-5253 • Cell: 202-713-7883

From: Iannetta, Christie [mailto:CIannetta@KSLAW.com]
Sent: Monday, September 12, 2016 5:49 PM
To: Matheke, Otto (NHTSA)
Cc: Glassman, Jacqueline
Subject: Ride the Ducks

Otto –

As discussed, here is the RTDI 2014 and 2015 audited financial statement as well as a preliminary financial forecast for 2016.

Thanks. Christie.

Christie L. Iannetta
King & Spalding LLP
1700 Pennsylvania Ave, N.W.
Washington D.C. 20006
Direct: (202) 626-9229
E-mail: ciannetta@kslaw.com

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From: Matheke, Otto (NHTSA)
To: "Iannetta, Christie"
Subject: RE: The Ducks
Date: Wednesday, September 07, 2016 4:52:00 PM

Thanks.

Another ask that I have is documentation establishing that the Ducks with defective axles were repaired. Jackie sent me a timeline, but I need more than that or a 573.

In regard to your certification question, I would suggest you talk to Coleman Sachs. 202-366-3151.

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Iannetta, Christie [mailto:CIannetta@KSLAW.com]
Sent: Wednesday, September 07, 2016 3:19 PM
To: Matheke, Otto (NHTSA)
Subject: The Ducks

Otto –

I passed the message along to Jackie and she is working on organizing meeting dates. She'll also get you financial statements and is working through the FMVSSs with the company.

Thanks. Christie.

Christie L. Iannetta
King & Spalding LLP
1700 Pennsylvania Ave, N.W.
Washington D.C. 20006
Direct: (202) 626-9229
E-mail: ciannetta@kslaw.com

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From: Matheke, Otto (NHTSA)
To: "rumberger@williamskastner.com"
Subject: Ride the Ducks - Find Another Partner or an Associate
Date: Thursday, June 16, 2016 1:58:00 PM

Rod:

I have empathy for your situation due to past lives in private practice and as an Assistant US Attorney.

For a variety of reasons, not the least of which is the interest of NHTSA's Administrator (formerly with the NTSB), I have to move this matter forward.

While I realize that getting someone to cover for you is going to take time you don't have, I would like to have a dialogue with someone before taking other steps.

Thanks

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Matheke, Otto (NHTSA)
To: "rumberger@williamskastner.com"
Subject: Ride the Ducks International
Date: Wednesday, June 01, 2016 2:29:00 PM

Mr. Umberger:

Based on the information provided in Ride the Ducks International's (RTDI) April 21, 2016 response to NHTSA's information request, the agency believes that your client's modifications of the vehicle involved in the September2015 collision were so extensive that RTDI should be considered the manufacturer of the vehicle under our statute and regulations.

I would like to discuss our concerns with you at your first convenience and ask that you call me at the number provided below.

Thank you.

Otto G. Matheke, III
Senior Attorney for Defects Investigation
National Highway Traffic Safety Administration

(202) 366-5253

From: Iannetta, Christie
Sent: 15 Mar 2017 20:29:01 +0000
To: Matheke, Otto (NHTSA);Stephens, Jordan (NHTSA);York, Bruce (NHTSA)
Cc: Glassman, Jacqueline
Subject: RTDI Industry Outreach Plan
Attachments: RTDI Training Plan.pdf, RTDI Industry Outreach Plan.doc.pdf, Manufacturer_Handbook_20161019.pdf, 12523-NHTSA_CFR_FlowChart2_082416_v1.pdf, 11878-Manfufacturer Defect Reporting QandA_062116_v4_tag.pdf, RTDI Training presentation 2-16-2017.pdf

All -

In accordance with the Consent Order, attached please find Ride the Ducks International's Industry Outreach Plan, Training Plan and supporting materials.

Please let me know if you have any questions.

Thank you. Christie.

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RIDE THE DUCKS INTERNATIONAL

TRAINING PLAN

Pursuant to paragraph 47 of the November 15, 2016 Consent Order, Ride the Ducks International (RTDI) submits this Training Plan.

This plan provides a summary of the subject areas that will be included in RTDI's annual training.

The titles of the personnel that will be trained annually are:

- Director of Fleet Operations
- Fleet Operations/Safety Manager
- Director of Operations
- Operations Manager

As summarized below, the Training Plan is intended to complement RTDI's written procedures for Safety Act Compliance and includes the following main areas: (1) Identifying key Definitions under the Safety Act, (2) Making Safety-Related Defect and Noncompliance Determinations, (3) Notifying NHTSA and Vehicle Owners, Licensees and Purchasers of Safety-Related Defects and Noncompliances, and (4) Identifying the Process for Submission of Technical Service Bulletins, Notices and Communications, and (5) Review of FMVSS Applicable to APVs

Annual training will consist of in-person training of the referenced subject areas, with appropriate regulatory updates integrated into the training presentation. The training presentation provided during the industry outreach session will be modified to cover the five referenced subject areas and will be fully integrated with the "Written Procedures for Safety Act Compliance" provided to NHTSA pursuant to paragraph 46.

The training presentation will consist of the following:

(1) Identifying definitions under the Safety Act
(2) Making Safety-Related Defect and Noncompliance Determinations
    a. Detection of Potential Safety Issues
    b. Investigations of Potential Safety-related Issues
(3) Notifying NHTSA and Vehicle Owners, Licensees and Purchasers of Safety-Related Defects and Noncompliance
    a. Reporting Defects and Noncompliance to NHTSA
    b. Process for Issuing Notification Letters to Owners, Licensees and Purchasers
    c. Recall Completion
(4) Identifying the Process for Submission of Technical Service Bulletins, Notices and Communications
    a. Determining What Type of Communication is Appropriate
    b. Tracking Technical Service Bulletins
    c. Early Warning Reporting
        i. Information on Incidents Involving Deaths
(5) Review of FMVSS Applicable to APVs

As stated in RTDI's "Written Procedures for Safety Act Compliance" submission to NHTSA, RTDI does not anticipate manufacturing any additional vehicles. If this situation changes, RTDI will ensure that all applicable FMVSS regulations are integrated into the company's annual training and any changes to the FMVSS requirements are also included in the training.

RIDE THE DUCKS INTERNATIONAL

INDUSTRY & CONSUMER OUTREACH PLAN

Pursuant to paragraphs 49-52 of the November 15, 2016 Consent Order, Ride the Ducks International (RTDI) submits this Industry & Consumer Outreach Plan (the "Plan").

This Plan provides a summary of both the actions that RTDI has taken under this provision of the Consent Order, as well as the outreach/educational materials presented to the APV industry in February 2017.

Paragraph 50 of the Consent Order identifies five areas that the Industry & Consumer Outreach Plan must include:

(1) Educate manufacturers building vehicles using combinations of donor and new components to produce complete vehicles, including other amphibious vehicle manufactures and small, independent manufactures of heavy trucks, on the importance of meeting their Safety Act obligations, such as early warning and other reporting requirements under 49 C.F.R Part 579 and recall requirements under 49 C.F.R Parts 30118 through 30120 and 49 C.F.R. Parts 573 and 577.

(2) Develop Safety Act educational materials for distribution to manufacturers.

(3) Offer to assist other manufacturers and, if requested, help these manufacturers in developing their own safety outreach programs.

(4) Educate licensees and other manufacturers on the importance of reporting potential defects directly to NHTSA, through VOQ complaints and otherwise.

(5) Work with licensees to enhance recall effectiveness and mitigate the impact of recalls on consumers.

During a live presentation on February 16, 2017, RTDI presented the attached comprehensive PowerPoint, to members of the APV industry. As contained in the Power Point, the presentation addressed each of the five areas addressed in paragraph 50 described above. RTDI also plans to also distribute copies of several NHTSA documents which include: "NHTSA Manufacturer Requirements Guide for Applicable Laws and Regulations," "Q&A Guide for Defect Communication," and NHTSA's "New Manufacturer's Handbook." A copy of these documents are attached to the Plan.

Targeted Metrics of Success

RTDI considered the following performance metrics when developing its industry outreach plan:

(1) RTDI identified all manufacturers and operators of APVs in the United States and invited them to the industry outreach training program that took place on February 16, 2017. RTDI invited all manufacturers and operators of APVs in the United States known to it, including those entities specifically requested by the agency.

(2) RTDI assessed the number of companies which attended the industry outreach training program (whether in-person or by remote access). RTDI strived to have at least 25% of the total

APV industry attend. RTDI's records indicate that a total of 40% of the APV industry (12 companies) attended the training event.

The following table summarizes the companies that were invited to the February 16, 2017 industry outreach training session and those which attended.

Name of Company	Attended
Chattanooga Ducks	Yes
Land And Sea Tours	
Miami Ducks	Yes
Boston Super Tours	
Ride The Ducks International	Yes
Ride the Ducks Branson	Yes
Ride The Ducks of Seattle	Yes
Just Ducky Tours	Yes
Stone Mountain Park	
DC Ducks	Yes
Boston Duck Tours	Yes
Wisconsin Duck Tours	Yes
Historic Tours	
Duck Tours South Beach	
Dells Ducks	
Down East Duck Adventures	
Camillc	
AK Ducks	
Cape Cod Ducks	
Diva Duck	
Ride The Ducks Guam	
Oahu Duck	
Austin Ducks	
Mobile Ducks	Yes
National Park Duck Tours	Yes
Galveston Duck Tours	Yes
Hawaii Duck Tours	
Fitzgerald	
ABC Companies	
Coach Crafters	
Total Attendees	12

RTDI's Outreach Actions

As described above and in accordance with Paragraph 50, RTDI plans to distribute to all companies identified above, a copy of the following: "NHTSA Manufacturer Requirements Guide for Applicable Laws and Regulations" a "Q&A Guide for Defect Communication," and NHTSA's "New Manufacturer's Handbook."

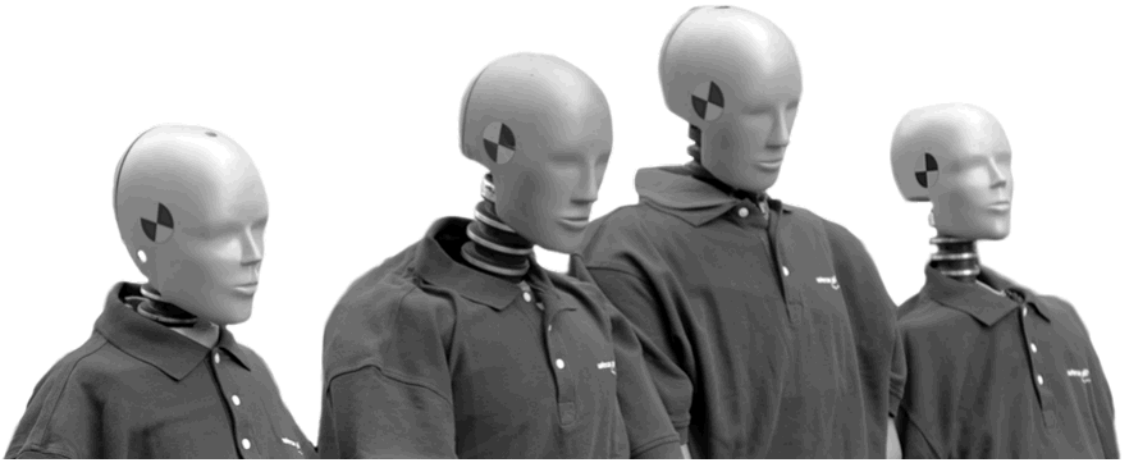
In addition, as requested in the Consent Order, RTDI will work with its own licensees to enhance recall effectiveness and mitigate any impact of recalls on the RTDI vehicles to consumers and will offer to assist other APV manufacturers in developing their own safety programs.

ES17-001728 276

National Highway Traffic Safety Administration

Safer cars. Safer Drivers. Safer roads.

Requirements for Manufacturers of Motor Vehicles and Motor Vehicle Equipment



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Requirements for Manufacturers of Motor Vehicles and Motor Vehicle Equipment Items

Disclaimer – This document is a simplified description of the requirements for manufacturers of motor vehicles and motor vehicle equipment and does not supersede any requirements contained in the statutes and regulations administered by The National Highway Traffic Safety Administration. Please refer to the statutes and regulations cited herein for a more detailed description of such requirements.

Chapter 1. Background

Federal Statutes and Regulations

The National Highway Traffic Safety Administration (NHTSA) is the U.S. government agency responsible for implementing and enforcing the National Traffic and Motor Vehicle Safety Act of 1966, as amended, 49 U.S.C. Chapter 301 (the Vehicle Safety Act), and certain other laws relating to motor vehicle safety. Under that authority, NHTSA issues and enforces Federal motor vehicle safety standards (FMVSS) that apply to motor vehicles and to certain items of motor vehicle equipment. Implementing regulations are found in Title 49 of the Code of Federal Regulations (CFR), Parts 500-599.[1] Most CFR citations in this document are to specific sections of the regulations. For example, FMVSS No. 101 *Controls and Displays* can be found at 49 CFR 571.101.

How and Why Were the Federal Motor Vehicle Safety Standards Developed?

The Vehicle Safety Act was enacted to reduce traffic crashes and deaths and injuries resulting from traffic crashes. Under that authority, NHTSA issues and enforces FMVSS that apply to motor vehicles and certain items of motor vehicle equipment. The Vehicle Safety Act requires that each FMVSS be practicable, meet the need for motor vehicle safety, and be stated in objective terms.[2] On February 3, 1967, NHTSA published a final rule establishing the first FMVSS. [3]

Motor Vehicle and Motor Vehicle Equipment Certification

The Vehicle Safety Act requires that motor vehicles and regulated items of motor vehicle equipment manufactured for sale in the United States be certified to comply with all applicable FMVSS.[4] Type approval is not required for motor vehicles and motor vehicle equipment sold in the United States. NHTSA does not issue type approval certifications and does not certify any motor vehicles or motor vehicle equipment as complying with applicable FMVSS. Instead, in accordance with 49 U.S.C. 30115, a "self-certification" process is in place, which requires the manufacturer to certify the vehicle or equipment item as complying with the applicable FMVSS. The Vehicle Safety Act requires the exercise of "reasonable care" in issuing a certification of compliance with safety standards.[5]

---

[1] The CFR may be browsed or searched at the link http://www.ecfr.gov/cgi-bin/text-idx?SID=48fa9e537b7babef583a42e23e4555c5&mc=true&tpl=/ecfrbrowse/Title49/4 9tab_02.tpl

[2] See 49 U.S.C. 30111

[3] See 32 FR 2408

[4] See 49 U.S.C. 30115

[5] Ibid.

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Penalties for Violations of the Vehicle Safety Act and Implementing Regulations

Manufacturers may be subject to substantial civil penalties for failure to meet the requirements of the statutes and regulations that NHTSA administers.[6] Currently, those penalties can be as high as $21,000 for each violation with a maximum civil penalty of $105,000,000 for a related series of violations.[7] For example, the failure of a manufacturer to furnish notification of a noncompliance or defect to owners or to NHTSA may subject the fabricating manufacturer to substantial civil penalties.

Chapter 2. What does NHTSA Regulate?

Motor Vehicles

Motor vehicles are defined by statute as vehicles that are driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, or highways.[8] In regulating the manufacture of motor vehicles, NHTSA has established the type classifications identified and defined in Table 1.[9]

Table 1 – Motor Vehicle Type Classifications

Classification	Definition
Passenger car	A motor vehicle with motive power, except a low-speed vehicle, multipurpose passenger vehicle, motorcycle, or trailer, designed for carrying 10 persons or less.
Multipurpose passenger vehicle	A motor vehicle with motive power, except a low-speed vehicle or trailer, designed to carry 10 persons or less which is constructed either on a truck chassis or with special features for occasional off-road operation.
Truck	A motor vehicle with motive power, except a trailer, designed primarily for the transportation of property or special purpose equipment.
Bus	A motor vehicle with motive power, except a trailer, designed for carrying more than 10 persons.
Motorcycle	A motor vehicle with motive power having a seat or saddle for the use of the rider and designed to travel on not more than three wheels in contact with the ground.
Trailer	A motor vehicle with or without motive power, designed for carrying persons or property and for being drawn by another motor vehicle.
Low-speed vehicle	A motor vehicle, that is 4-wheeled, whose speed attainable in 1 mile (1.6 km) is more than 20 miles per hour (32 kilometers per hour) and not more than 25 miles per hour (40 kilometers per hour) on a paved level surface, and whose GVWR is less than 3,000 pounds (1,361 kilograms).
Pole Trailer	A motor vehicle without motive power designed to be drawn by another motor vehicle and attached to the towing vehicle by means of a reach or pole, or by being boomed or otherwise secured to the towing vehicle, for transporting long or irregularly shaped loads such as poles, pipes, or structural members capable generally of sustaining themselves

All motor vehicles must be classified in the manner set forth in Table 1. For example, school buses are classified as buses, motor driven cycles are classified as motorcycles, and motor homes are classified as multipurpose passenger vehicles. Vehicles such as race cars, dirt bikes, or all-terrain vehicles that are not primarily manufactured for on-road use do not qualify as motor vehicles and are therefore not regulated by NHTSA. Instead, such vehicles may be regulated by the Consumer Product Safety Commission (CPSC).[10]

[6] See 49 U.S.C. 30165
[7] See 49 CFR Part 578
[8] See 49 U.S.C. 30102
[9] See 49 CFR § 571.3 Definitions
[10] See www.cpsc.gov

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Motor Vehicle Equipment

The Vehicle Safety Act defines motor vehicle equipment as:

- Any system, part, or component of a motor vehicle as originally manufactured;
- Any similar part or component manufactured or sold for replacement or improvement of a system, part, or component, or as an accessory or addition to a motor vehicle; or
- Any device or an article of apparel (except medicine or eyeglasses prescribed by a licensed practitioner) that is not a system, part, or component of a motor vehicle and is manufactured, sold, delivered, offered, or intended to be used only to safeguard motor vehicles and highway users against risk of accident, injury, or death.[11]

The Vehicle Safety Act requires that regulated items of motor vehicle equipment manufactured for sale in the United States be certified to comply with all applicable FMVSS.[12] Motor vehicle equipment items that are not subject to the FMVSS do not require certification; however, such items may be found (by either NHTSA or the manufacturer) to have a safety-related defect, and if so, the manufacturer will have an obligation to furnish owners of the equipment with notification of, and a remedy for, the defect, usually at no charge to the consumer. Motor vehicle equipment items that are subject to the FMVSS are identified in Table 2.

Table 2 – Motor Vehicle Equipment Items Subject to the FMVSS

Motor Vehicle Equipment Description	See FMVSS Number(s)
Tires	109/110/117/119/120/129/139
Rims	110/120
Brake Hoses	106
Brake Fluid	116
Seat Belt Assemblies	209
Lamps, Reflective Devices, and Associated Equipment	108
Glazing (Automotive Glass and Plastics)	205
Motorcycle Helmets	218
Child Restraint Systems (Child Safety Seats)	213
Platform Lift Systems For The Mobility Impaired	404
Rear Impact Guards For Trailers	223
Triangular Reflective Warning Devices	125
Compressed Natural Gas Containers	304

[11] See 49 U.S.C. 30102(a)(7)
[12] See 49 U.S.C. 30115

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Chapter 3. Procedural Requirements for Fabricating Manufacturers

Introduction

Before offering a motor vehicle or motor vehicle equipment item for sale in the United States, the fabricating manufacturer must: 1) designate a permanent resident of the United States as its agent for service of process if the fabricating manufacturer is not located in the United States (49 CFR Part 551, Subpart D *Service of Process on Foreign Manufacturers and Importers*) and 2) submit to NHTSA identifying information on itself and on the products it manufactures to the FMVSS, not later than 30 days after the manufacturing process begins (49 CFR Part 566 *Manufacturer Identification*).[13] Forms Part 565 & Part 566, as well as Equipment and Tire forms must be submitted to the NHTSA Manufacturer Portal. Information about the Portal can be found in Appendix 7.

Part 551 - Designate a Permanent Resident of the United States as its Agent for Service of Process

All foreign manufacturers, assemblers, and importers of motor vehicles or motor vehicle equipment must comply with this regulation before offering a motor vehicle or item of motor vehicle equipment for importation into the United States. The purpose of this regulation is to ensure that NHTSA is able to serve the manufacturer's agent with administrative or judicial notice or process. A detailed explanation of this regulation may be found in 49 CFR Part 551, Subpart D.

To expedite NHTSA's processing of submissions received under Part 551, Subpart D, foreign manufacturers may submit designation information online at: http://vpic.nhtsa.dot.gov/MfrPortal/. After a manufacturer submits designation information online, NHTSA's database will email a confirmation of the form. **The manufacturer must print, sign and mail the designation form to NHTSA's at this address:**

U.S. Department of Transportation
NHTSA Correspondence Unit
1200 New Jersey Avenue, SE
Room W41-306
Washington, D.C. 20590

To comply with Part 551, Subpart D, the manufacturer must mail to NHTSA an original printout of the Adobe PDF with original ink signatures by both the manufacturer and agent. Submitting your designation information online, without mailing the original form with ink signatures to NHTSA, will not satisfy the requirements of Part 551, Subpart D.

See Appendix 1 for a Part 551 submission form.

Part 566 - Manufacturer Identification

Manufacturers of motor vehicles and of motor vehicle equipment to which a FMVSS applies (except tires), must submit to NHTSA identifying information and a description of the items they produce not later than 30 days after manufacturing begins.[14] Not later than 30 days after any relevant business information changes, manufacturers must notify NHTSA to ensure that their records remain current, accurate, and complete.[15]

An individual business such as a corporation or limited liability company may want to operate multiple businesses without creating a new legal entity for each business. In the United States, these names are generally registered with the Office of the Secretary of State for the State in which the company is domiciled. Business laws may

[13] NHTSA maintains on its web site a list of manufacturers that have made Part 566 submissions. See http://vpic.nhtsa.dot.gov/mid/

[14] See 49 CFR Part 566

[15] NHTSA obtains tire manufacturer identification information when the agency assigns a plant code to the tire manufacturer. See 49 CFR 574.5

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be different from State to State and even more diverse from country to country; however, it is important for manufacturers to furnish NHTSA with all versions of its company's legal business name, including trade names, assumed names, fictitious business names, and brand or label names that are associated with the business. Unregistered manufacturers' names on vehicle certification labels, importation documents, or vehicle ownership documents may cause confusion or delays when processing vehicles at the ports or during titling and registration of the vehicles for on-road use. Several examples of business names are shown in Table 3.

Table 3 - Examples of Assumed / Fictitious Business Names

Acme Company, Inc.	Trading As or T/A	Smith Productions
Jones Manufacturing	Doing business as or DBA or d/b/a	Acme Company, Inc.
Smith and Sons	A Division of	Acme Company, Inc.
Jones Manufacturing	A Subsidiary of	Acme Company, Inc.
Brown Quality Motors, Ltd.	Operating as or o/a	BQM Associates
China ABC Group Co. Ltd.	Doing business as or DBA or d/b/a	Qinghai Wu Industries

See Appendix 6 for instructions on how to search NHTSA's Manufacturers' Information database and Appendix 7 for instructions on how to submit 566 submittals to NHTSA Manufacturer Portal at: http://vpic.nhtsa.dot.gov/MfrPortal/.

Part 566 information submitted by manufacturers is searchable on the Manufacturer's Information Database web site is: http://vpic.nhtsa.dot.gov/mid/.

Chapter 4. Vehicle Identification Numbers

Vehicle Identification Number or VIN

Under regulations administered by NHTSA, a vehicle identification number or VIN is "a series of Arabic numbers and Roman letters that is assigned to a motor vehicle for identification purposes."[16] Among other things, NHTSA's regulations at 49 CFR Part 565 require a motor vehicle manufacturer to assign to each motor vehicle manufactured for sale in the United States a 17-character VIN that uniquely identifies the vehicle. The VIN must be correctly formatted and include a check digit in Position 9 that is mathematically correct under a formula that is included in the regulation. VINS are required to have 17 characters that do not include the letters I, O, or Q. Beginning with the 1980 model year, the VINs of any two vehicles manufactured within a 60-year period must not be identical. All spaces provided for in the VIN must be occupied by a character specified in Part 565 and the type face used for each VIN must be in capitals and use san serif characters. This means that the characters will not have fine lines or "serifs" finishing off the main strokes of the letters. The VIN of each vehicle must appear clearly and indelibly upon either a part of the vehicle, other than the glazing, that is not designed to be removed except for repair or upon a separate plate or label that is permanently affixed to such a part.[17]

VIN Location on Vehicles

The VIN for passenger cars, multipurpose passenger vehicles, low-speed vehicles, and trucks of 10,000 lbs. or less gross vehicle weight rating (GVWR) must be located inside the passenger compartment and readable, without moving any part of the vehicle, through the vehicle glazing (windshield) from outside the vehicle adjacent

[16] See 49 CFR 565.12(r)
[17] See 49 CFR 565.13(e)

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to the left windshield pillar.[18] This is commonly called the "public VIN." NHTSA regulations require that a motorcycle's VIN need only appear on the label certifying compliance with all applicable FMVSS that the manufacturer must affix to a permanent member of the motorcycle as close as practicable to the intersection of the steering post with the handle bars in such a location that it can be easily readable without moving any part of the vehicle except for the steering mechanism.[19] The VIN for a trailer must appear on the label certifying the vehicle's compliance with all applicable FMVSS that the manufacturer must affix to a location on the forward half of the trailer's left side, such that it is easily readable from outside the trailer without moving any part of the vehicle.[20]

VIN Content

On April 30, 2008, NHTSA issued amended VIN regulations.[21] These amendments were necessary to make certain that the VIN system would remain viable for the next 30 years. All motor vehicles that are manufactured on or after April 30, 2009 are subject to the amended regulation.

Chart 1 identifies how a VIN is formatted, the general contents of a VIN, and specifications for the characters to be used in certain positions of the VIN.

Chart 1 - General VIN Format

<table>
<tr><th colspan="3">1st Section</th><th colspan="5">2nd Section</th><th>3rd</th><th colspan="2">4th Section</th><th colspan="6"></th></tr>
<tr><td colspan="3">Identifies Manu-facturer and Type of Vehicle</td><td colspan="5">Identifies Vehicle Attributes (Now includes Vehicle Make)</td><td>Check Digit</td><td>MY</td><td>Plant</td><td colspan="6">Number sequentially assigned in Positions 12-17 if a High-Vol. Manu. or in Positions 15-17 if a Low-Vol. Manu.</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td></tr>
<tr><td></td><td></td><td>"9" if low-vol. manu.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">WMI if low-vol. manufacturer (<1,000 of a given type each year)</td></tr>
<tr><td colspan="6"></td><td>@@</td><td></td><td></td><td></td><td>##</td><td>##</td><td>##</td><td>##</td><td>##</td></tr>
<tr><td colspan="6"></td><td colspan="2">if car, and MPV and truck ≤ 10,000 lbs.</td><td colspan="5">if car, and MPV and truck ≤ 10,000 lbs.</td></tr>
<tr><td colspan="11"></td><td>##</td><td>##</td><td>##</td><td>##</td></tr>
<tr><td colspan="11">@@ means that VIN Characters are: A,B,C,D,E,F,G,H,J,K,L,M,N,P,R,S,T,U,V,W,X,Y,or Z
means that VIN Characters are: 0,1,2,3,4,5,6,7,8, or 9</td><td colspan="4">For vehicle not a car, and MPV and truck ≤ 10,000 lbs.</td></tr>
</table>

The VIN is comprised of four sections. Each section is described in detail below.

First Section of the VIN

The first section of a VIN consists of three characters. These first three characters of a VIN uniquely identify a motor vehicle manufacturer using the "World Manufacturer Identifier" or WMI code, if the manufacturer produces 1,000 or more vehicles of a given type each year (i.e., a "high-volume" manufacturer[22]). A "low-volume" manufacturer that produces fewer than 1,000 vehicles of a given type each year uses the numeral "9" as the third character and Positions 12, 13, and 14 of the VIN for the remainder of the WMI. The placement of the WMI

[18] See 49 CFR 565.13(f)
[19] See 49 CFR 567.4(e)
[20] See 49 CFR 567.4(d)
[21] See 73 Federal Register 23367, Published April 30, 2008
[22] See 49 CFR 565.12(e)

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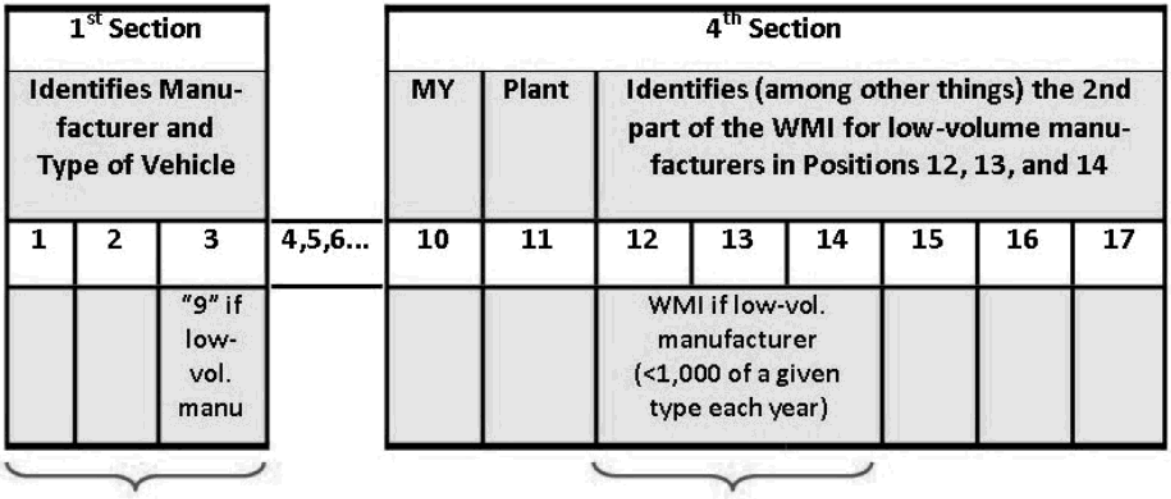
within a 17-character VIN is identified in Chart 2.

Chart 2 - Placement of the World Manufacturer Identifier in the VIN



Obtaining a World Manufacturer Identifier

A manufacturer that intends to assemble motor vehicles in the United States must obtain a WMI from the SAE International (Previously known as the Society of Automotive Engineers). NHTSA has a contract with that organization to assign WMIs to manufacturers that assemble motor vehicles in the United States. Manufacturers must contact the SAE directly (and not NHTSA) to request the assignment of a WMI. They may do so by telephoning 724-772-8511 or by writing to: SAE International, 400 Commonwealth Avenue, Warrendale, PA 15096, Attention: WMI Coordinator.

Second Section of the VIN

The second section of the VIN, known as the "Vehicle Descriptor Section," consists of Positions 4 through 8. This second is used to identify "vehicle attributes" for each vehicle type as identified by 49 CFR 565.15, Table I, entitled "*Type of Vehicle and Information Decipherable*." There are two special rules for passenger cars, and for multi-purpose passenger vehicles (MPVs) and trucks with a gross vehicle weight rating (GVWR) of 10,000 lbs. or less. First, manufacturers of such vehicles must report all restraint devices and their locations in the vehicles. Second, Position 7 of the VIN of such a vehicle must be alphabetic. Therefore, for passenger cars, and MPVs and trucks with a GVWR of 10,000 lbs. or less, if Position 7 of the VIN is alphabetic, the model year identified in Position 10 of the VIN refers to a year in the range of 2010-2039. Position 7 of VINs assigned to other vehicle types (e.g., motorcycles, buses, trailers) may be either alphabetic or numeric.

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Part 565 requires that manufacturers identify in the second section of the VIN, the vehicle attributes for each vehicle type as summarized in Chart 3.

Chart 3 - Vehicle Attributes for Each Vehicle Type that must be Identified in VIN Positions 4 through 8

Required Information for:	Passenger	Multipurpose	Truck*	Bus	Trailer	Motorcycle	Incomplete	Low Speed
Make	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Line or Model	Yes	Yes	Yes	Yes		Yes	Yes	
Series	Yes	Yes	Yes	Yes			Yes	
Body Type	Yes	Yes		Yes				Yes
Engine Type	Yes	Yes	Yes	Yes		Yes	Yes	Yes
GVWR@		Yes	Yes					Yes
All Restraint Devices & Location*	Yes	Yes	Yes					Yes
Chassis			Yes					
Cab Type			Yes				Yes	
Brake System			Yes	Yes			Yes	Yes
Trailer Connection Type					Yes			
Trailer Body Type					Yes			
Length					Yes			
Axle Configuration					Yes			
Type of Motorcycle						Yes		
Net Brake Horsepower@@						Yes		

Footnotes to Chart 3:
@The GVWR designations in "Table II – Gross Vehicle Weight Rating Classes" must be used. The use of these designations within the VIN itself is not required.
@@Engine net brake horsepower when encoded in the VIN cannot differ by more than 10% from the actual net brake horsepower. In the case of a motorcycle with an actual net brake horsepower of 2 or less, the net brake horsepower must be not more than 2, and must be greater than 2 in the case of a motorcycle with an actual brake hp greater than 2. (The purpose of this exception is to preserve the distinction in the VIN between motorcycles and motor driven cycles.)
*Trucks and Multipurpose Passenger Vehicles of GVWR≤10,000 lbs. are required to have all restraint devices and locations available -- Trucks and MPVs of GVWR>10,000 lbs. are not required to have this information.

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The terms used in Chart 3 are defined in 49 CFR 565.12. These definitions, and examples of the vehicle characteristics they cover, are identified in Chart 4.

Chart 4 – Definitions and Examples of Vehicle Attributes

Term	Definition	Examples
Type	means a class of vehicle distinguished by common traits including design and purpose	Passenger cars, Multipurpose Passenger Vehicles (MPVs), Trucks, Buses, Trailers, Incomplete Vehicles, Low Speed Vehicles (LSVs), and Motorcycles are separate types
Make	means a name that a manufacturer applies to a group of vehicles or engines	Chevrolet, Buick, Pontiac, Cadillac
Model	means the name that a manufacturer applies to a family of vehicles of the same type, make, line, series, and body type	Monte Carlo, Malibu, Lucerne, CTS
Line	means a name that a manufacturer applies to a family of vehicles within a make that have a degree of commonality in construction, such as body, chassis, or cab type	Super Sport, LT Classic, GXP, CX, CXL
Series	means a name that a manufacturer applies to a subdivision of a "line" denoting price, size or weight identification, and that is used by the manufacturer for marketing purposes	3500, 4500, 5500, 6500 Series
Body Type	means the general configuration or shape of a vehicle distinguished by such characteristics as the number of doors or windows, cargo carrying features and the roofline	4-door Sedan, 2-door, 2-door Fastback, 3-door Hatchback, 2-door Convertible, 5-door Liftback, 4-door Station Wagon
Engine Type	means a power source with defined characteristics. The specific manufacturer and make shall be represented if the engine powers a passenger car, and a MPV or truck with a GVWR ≤ 10,000 lbs.	Fuel utilized, number of cylinders, displacement, and net brake horsepower.

Trucks and other vehicle types have as many as nine reportable vehicle attributes and only five VIN positions in which to report these. This causes NHTSA to be frequently asked: "How do I fit all this information into the second section of the VIN?"

Part 565 gives manufacturers the flexibility to determine how they wish to structure or "encode" the contents of this section. One way a manufacturer may encode the information is to employ a "lookup table." For example, the manufacturer's five VIN characters "ABCDE" may be decoded using a lookup table to identify more than five vehicle attributes. It is important to remember that the manufacturer's coding must be decipherable to NHTSA so that the agency may carry out its safety mission. The following examples for a passenger car may help clarify this.

Passenger Car Manufacturer's Sample VIN for the Second Section of the VIN (Positions 4-8)

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Example				R	P	1	A	3									

Note: Please remember VINs cannot contain the characters I, O or Q and that Position 7 must be alphabetic for passenger cars, and MPVs and trucks with a GVWR of 10,000 lbs. or less manufactured on or after April 30, 2009.

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Sample Passenger Car Manufacturer's Lookup Table for the Second Section of the VIN (Positions 4-8)

Passenger Car Vehicle Attributes That Must Be Identified							
VIN 4-8 Code	Make	Line or Model	Series	Body Type	Engine Type	GVWR Class @	Restraint System @@
RP1A3	USA Car Co.	Super	LV	3 Dr. Coupe	2.4L 4 cyl. 180hp gas	A	A
RP1B3	USA Car Co.	Super	DV	4 Dr. Sedan	2.4L 4 cyl. 180hp Gas	B	B

Manufacturer's Notes to Lookup Table:
@GVWR Class is from 49 CFR 565.15 "Table II - Gross Vehicle Weight Rating Classes"
A= Not greater than 1360 kg. (3,000 lbs.)
B=Greater than 1360 kg. to 1814 kg. (3,001–4,000 lbs.)
@@Restraint System
A= Front: Seat Belt, Air Bag, Side Air Bag, and Side Curtain Air Bag (Driver and Passenger) and
Rear: Seat Belt and Side Curtain Air Bag.

Motorcycle VINs

Part 565 requires only five vehicle attributes of a motorcycle to be reported in the second section of a VIN. Because there are five positions available in the second section, a manufacturer may use each position for one of the five attributes. A motorcycle example will show how the second section of the VIN may be encoded.

Motorcycle Manufacturer's Sample VIN for the Second Section of the VIN (Positions 4-8)

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Example				U	2	A	D	G									

Sample Motorcycle Manufacturer's Lookup Table for the Second Section of the VIN (Positions 4-8)

VIN Position	Vehicle Attribute	Coding
4	Make	U=USA Motorcycle Co.
5	Line or Model	2=Winner
6	Type of Motorcycle	A= Scooter B=Sport Bike C=Cruiser
7	Engine Type	D=V-2, 200cc, gas E= V-4, 400cc, gas F=V-8, 1000cc, gas
8	Net Brake HP	G=V-2 - 15hp H=V-4 - 36hp J=V-8 - 75hp

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Trailer VINs

The vehicle attributes "length" and "axle configuration" are applicable only to trailers. Although the term "length" is not defined in Part 565, the agency has interpreted it to mean the length of a trailer as measured from one extremity to the other. For a trailer, this would include the equipment that is part of the vehicle and by which it is towed (i.e., the tongue or equivalent connector to the towing vehicle). Axle configuration means the number of axles, e.g., 1-axle, 2-axle, 3-axle, etc. A trailer example will show how VIN Positions 4 through 8 of the second section may be encoded.

Trailer Manufacturer's Sample VIN for the Second Section of the VIN (Positions 4-8)

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Example				U	1	M	6	1									

Sample Trailer Manufacturer's Lookup Table for the Second Section of the VIN (Positions 4-8)

VIN Position	Vehicle Attribute	Coding
4	Trailer Make	U=USA Trailer Co.
5	Trailer to Towing Vehicle Connection Type	1=Ball Type Pull 2=Pintle Hitch 3=Gooseneck 4=Straight Semi 5=Fifth Wheel 6=Kingpin 7=Bumper Pull 8=Others
6	Trailer Body Type	A=Flatbed B=Tank C=Utility D=Livestock E=Enclosed
7	Trailer Length	6=6 feet long 9=9 feet long A=26 feet long
8	Trailer Axle configuration	1=Single Axle 2=2 Axles 3=3 Axles

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Sample Tank Trailer Manufacturer's Lookup Table for the Second Section of the VIN (Positions 4-8)

VIN Position	Vehicle Attribute	Coding
4	Type of Trailer	A=NON-CODE B=NON-CODE ETM C=Reserved D=DRY BULK E=DOT 406 F=DOT 407 G=DOT 412 V=CONTAINER CHASSIS
5	Type of Material	A=Aluminum B=Stainless Steel C=Carbon Steel D=Fiberglass/Composite
6	Gallonage	0=Container Chassis 1=1000 > Gallons 2=1000 ≤ Gallons < 2000 3=2000 ≤ Gallons < 3000 4=3000 ≤ Gallons < 4000 5=4000 ≤ Gallons < 5000 … 9=9000 ≤ Gallons < 10000 B=10000 ≥ Gallons
7	Trailer Length	6=6 feet long 9=9 feet long A=26 feet long
8	Trailer Axle configuration	1=Single Axle 2=2 Axles 3=3 Axles

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Second Section VIN Character Restrictions

The amended VIN regulations no longer restrict Positions 4, 5, 6, or 8 to either alphabetic or numeric characters. This gives manufacturers more permutations for their vehicle attribute coding. However, as stated above, for passenger cars, and MPVs and trucks with a GVWR of 10,000 lbs. or less manufactured on or after April 30 2009, Position 7 of the VIN must be alphabetic, which designates that the model year in Position 10 of the VIN refers to a year in the range of 2010-2039.

Third Section of the VIN

The third section of the VIN consists of one character, called the "check digit", which occupies Position 9 in the VIN. The check digit's purpose is to provide a means for verifying the accuracy of any VIN transcription. NHTSA regulations establish a mathematical formula for calculating the check digit.

After all other characters in VIN have been determined by the manufacturer, the check digit is calculated by carrying out the mathematical computation specified in the regulation.[23] First, each character in the VIN is assigned a "numerical value" as shown in Table III of the regulation, entitled "*Assigned Values*".

49 CFR 565.15(c)(1) Table III – Values Assigned to Characters of VIN

A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	1	2	3	4	5	7	9	2	3	4	5	6	7	8	9

Each position of the VIN (except Position 9, the check digit) is assigned a "weight value" as shown in Table IV of the regulation, entitled "*VIN Position and Weight Factor*".

49 CFR 565.15(c)(2) Table IV – Weight Factors Assigned to VIN Positions 1-8 and 10-17

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Weight	8	7	6	5	4	3	2	10	N/A	9	8	7	6	5	4	3	2

Next, each character's numeric value is multiplied by the position's weight value. After you compute several, the check digit mathematical calculations are not very difficult. Below is an example.

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sample VIN	1	J	9	R	P	1	A	3		A	1	6	4	4	3	4	5
Assigned Value	1	1	9	9	7	1	1	3		1	1	6	4	4	3	4	5
VIN Position Weight	8	7	6	5	4	3	2	10	N/A	9	8	7	6	5	4	3	2
Multiply Value by Weight	= 8	+ 7	+ 54	+ 45	+ 28	+ 3	+ 2	+ 30		+ 9	+ 8	+ 42	+ 24	+ 20	+ 12	+ 12	+ 10 = 314

X X etc

[23] See 49 CFR 565.15, paragraphs (c) (1) through (4)

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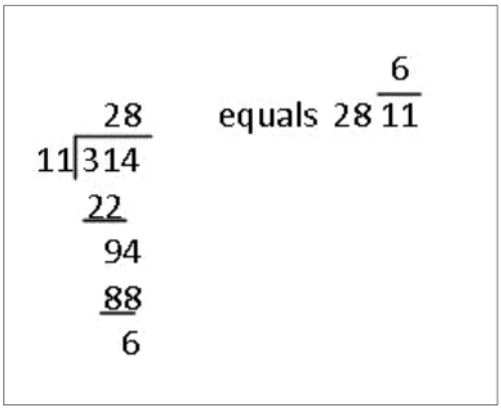
The results are now added together and the total "314" is then divided by 11.

8 + 7 + 54 + 45 + 28 + 3 + 2 + 30 + 9 + 8 + 42 + 24 + 20 + 12 + 12 + 10 = 314



The total 314 is then divided by 11 = 28 6/11 or 28.545454

The check digit is based on either the Fractional Remainder or the Decimal Equivalent Remainder as reflected in Table V of the regulation, entitled "*Ninth Position Check Digit Values*".

49 CFR 565.15(c)(4) Table V – 9th Position Check Digit Values

6/11 or .545

Fractional Remainder	0	1/11	2/11	3/11	4/11	5/11	6/11	7/11	8/11	9/11	10/11
Decimal Equivalent Remainder	0	.091	.182	.273	.364	.455	.545	.636	.727	.818	.909
Check Digit	0	1	2	3	4	5	6	7	8	9	X

Check Digit "6"

All decimal equivalent remainders in Table V are rounded to the nearest thousandth (i.e., the 3rd digit to the right of the decimal point). If the 4th digit to the right of the decimal point is 5 or greater, round up; if 4 or less, round down.

In our total, 28.545<u>4</u>, the 4th digit to the right of the decimal point is 4, so round to 28.54<u>5</u>. Table V shows that our decimal equivalent remainder ".545" equates to the check digit "6".

A check digit, which can be zero through nine (0–9) or the letter "X", appears in Position 9 of the VIN. Our computed check digit "6" will appear in Position 9 of our completed VIN: 1J9RP1A3<u>6</u>A1644345. While the mathematical computations can be completed by hand, the agency recommends that new manufacturers develop a simple spreadsheet program to assist with calculating check digits and thereby reduce VIN errors. See Appendix 2 for a sample spreadsheet format to calculate VIN check digits.

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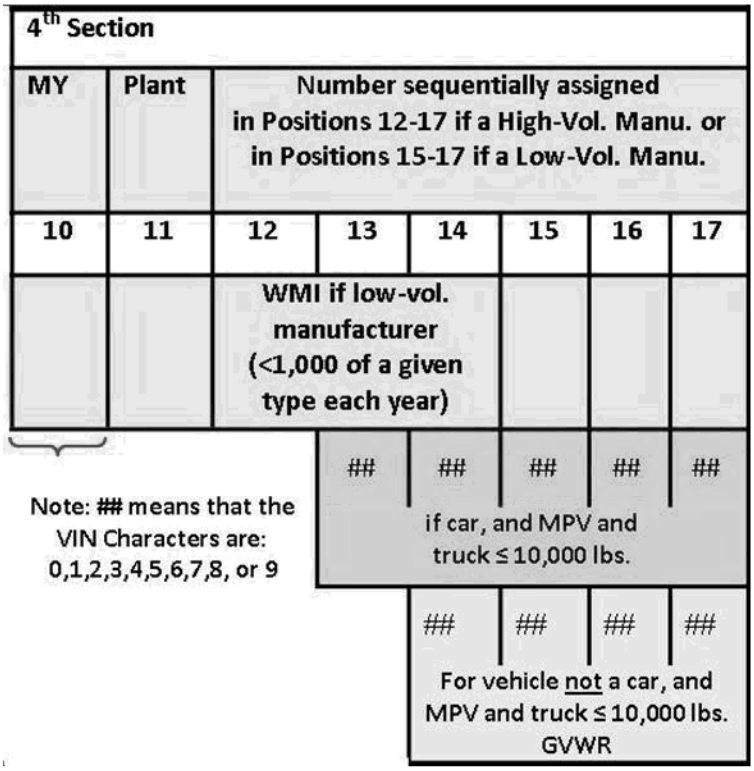
Fourth Section

The fourth section of the VIN consists of Positions 10 through 17. Position 10 is reserved to encode the model year of the vehicle.

Fourth Section of the VIN - Model Year Placement



Besides the three letters that are not allowed in the VIN itself (I, O, and Q), the letters U and Z and the number 0 are not used for the year code. The model year is the year that a manufacturer uses to designate a discrete vehicle model, irrespective of the calendar year in which the vehicle was actually produced, provided that the production period does not exceed 24 months.[24] The year codes that must be used in the manufacturer's VIN are found in Table VII of the regulation, entitled "*Year Codes for VIN*".

49 CFR 565.15(d)(1) - Table VII – Required Year Codes for VIN

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Code	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	V	W

Position 11 of a VIN is used to encode the vehicle's plant of manufacture. This term is defined by the regulation as "the plant where the manufacturer affixes the VIN."[25] Manufacturers may assign their own plant codes, but should report to NHTSA, in their VIN deciphering information, the city, state, and country in which the plant of manufacture is located, as well as the name of the Plant (e.g., Lansing, Michigan, USA - GMNA). Plant Name is only a required field where applicable. If the manufacturer has no plant name, then it may be left off the submission. An example will show how VIN Positions 10 and 11 of the fourth section may be encoded.

[24] See 49 CFR 565.12(m)
[25] See 49 CFR 565.12(n)

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Manufacturer's Sample VIN for the Fourth Section of the VIN (Positions 10-11)

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Example										A	B						

Manufacturer's Lookup Table for the Fourth Section of the VIN (Positions 10 and 11)

VIN Position	Vehicle Attribute	Coding
10	Model Year	H=2017 J=2018 K=2019 (From Table VII of 49 CFR 565.15(d)(1))
11	Plant of Manufacture	B=Baltimore, MD USA – Main Plant F=Flint, MI USA – Flint Plant L=Lansing, MI USA - GMNA M=Lordstown, OH USA K=Bowling Green, KY USA R=Ramos Arizpe, Coahuila, Mexico

Positions 12 through 17 of the VIN represent the number sequentially assigned by the manufacturer in the production process if the manufacturer is a high-volume manufacturer. If the manufacturer is a low-volume manufacturer, Positions 12, 13, and 14 combined with Positions 1, 2, and 3 of the VIN uniquely identify the manufacturer. Please note that Positions 13 through 17 must be numeric, if the VINs are for passenger cars, and MPVs and trucks with a GVWR of 10,000 lbs. or less. For any other type of vehicle, Positions 14 through 17 must be numeric.

4th Section							
MY	Plant	Number sequentially assigned in Positions 12-17 if a High-Vol. Manu. or in Positions 15-17 if a Low-Vol. Manu.					
10	11	12	13	14	15	16	17
		WMI if low-vol. manufacturer (<1,000 of a given type each year)					
			##	##	##	##	##
			if car, and MPV and truck ≤ 10,000 lbs.				
				##	##	##	##
				For vehicle not a car, and MPV and truck ≤ 10,000 lbs. GVWR			

Note: ## means that the VIN Characters are: 0,1,2,3,4,5,6,7,8, or 9

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Manufacturer's Requirement to Furnish NHTSA with VIN Deciphering Information

It is very important that each manufacturer report to NHTSA its complete VIN deciphering information so that the agency may simplify vehicle identification information retrieval and increase the accuracy and efficiency of the vehicle recall campaigns. The VIN has become the key identifier in data systems that track compliance with Federal and state safety programs and that manage and analyze information on vehicle manufacturing processes, registrations, insurance programs, crash investigations, and safety research. Organizations that use VINs in data systems include NHTSA, manufacturers, state motor vehicle departments, law enforcement agencies, insurance companies, and motor vehicle safety researchers.

Under 49 CFR 565.26, a motor vehicle manufacturer must submit to NHTSA, either directly or through an agent, information the agency will need to decipher the manufacturer's VIN characters not later than 60 days before the manufacturer offers for sale the first vehicle identified by that VIN or if information concerning vehicle characteristics sufficient to specify the VIN code is unavailable to the manufacturer by that date, then within one week after that information first becomes available. The purpose of the 60-day requirement is to permit users of the VIN, such as State motor vehicle agencies, to obtain the necessary deciphering information before vehicle purchasers begin registering their vehicles. The VIN deciphering information must be submitted through the NHTSA Manufacturer Portal or by email at manufacturerinfo@dot.gov. See Appendix 3 for sample VIN deciphering letters.

Chapter 5. Certification to all Applicable FMVSS

Introduction

Vehicles manufactured for sale in the United States be certified to comply with all applicable FMVSS. NHTSA's regulations on motor vehicle certification are found at 49 CFR Part 567, while the regulations on the certification As noted above, the Vehicle Safety Act requires that regulated items of motor vehicle equipment and motor of motor vehicle equipment subject to the FMVSS are found within the standards that pertain to each such item of equipment, as published in 49 CFR Part 571, Subpart B.

Motor Vehicle Equipment Certification and NHTSA Assigned Codes

Motor vehicle equipment that is subject to an FMVSS must, as originally manufactured, conform to the standard and be so certified. In most instances, certification of compliance with the applicable FMVSS for regulated items of motor vehicle equipment is evidenced by the symbol "DOT" either inscribed on the equipment in a prescribed location, or placed on the outside of the container in which the equipment is shipped.[26]

Along with a marking that indicates certification of compliance with an applicable FMVSS, the fabricating manufacturer of certain regulated equipment items such as brake hoses, glazing (automotive glass and plastics), and tires must label its products with code marks or identification numbers assigned to the manufacturer by NHTSA.[27] NHTSA assigns an identification number to a manufacturer of tires or glazing (automotive glass and plastics) and accepts the designation of a brake hose manufacturer after the manufacturer submits an application to the National Highway Traffic Safety Administration through the Manufacturer Portal. See Appendix 7 for a description on how to use the NHTSA Manufacturer Portal[28]. To avoid a delay in the issuance of NHTSA assigned code marks or identification numbers, it is wise to comply with the requirements to designate a U.S. resident as agent for service of process if the fabricating manufacturer is not located in the United States.

This is accomplished by submitting the appropriate form to the NHTSA Office of Chief Counsel. See Chapter 3, Paragraph B and Appendix 1 of this document for the Part 551 requirements and form.

Requirements for certification markings on equipment items are found in the individual standards that apply to

[26] See 49 U.S.C. §§ 30112 and 30115

[27] See 49 CFR 571.106, paragraph S5.2.2(b), relating to brake hoses; 49 CFR 571.205, paragraph S6.2, relating to glazing; and 49 CFR 574.5, relating to tires

[28] See http://vpic.nhtsa.dot.gov/MfrPortal/

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those items, as published in 49 CFR Part 571. For example, FMVSS No. 205 requires a glazing manufacturer to certify its glazing by adding to the marks required by section 7 of ANSI/SAE Z26.1–1996,[29] in letters and numerals of the same size, the symbol "DOT" and a manufacturer's code mark that NHTSA assigned to the glazing manufacturer.

Motor Vehicle Certification

A motor vehicle must be manufactured to comply with all applicable FMVSS and bear a label certifying such compliance that is permanently affixed (riveted or affixed in such a manner that it cannot be removed without destroying or defacing it) by the vehicle's manufacturer (i.e., the actual assembler of the vehicle).[30] Certification labeling requirements are necessary to establish that the vehicle was manufactured to comply with all applicable FMVSS. Because the label also identifies the type classification of the vehicle, it also helps to identify which of the FMVSS, Bumper Standards (49 CFR Part 581), and Federal Theft Prevention Standards (49 CFR Part 541) apply to the vehicle.

Motor Vehicle Certification Labels

Placement of the Certification Label[31]

For vehicles other than trailers and motorcycles, the manufacturer's certification label must be affixed to either the hinge pillar, door-latch post, or the door edge that meets the door-latch post, next to the driver's seating position, or if none of these locations is practicable, to the left side of the instrument panel. If that location is also not practicable, the label must be affixed to the inward-facing surface of the door next to the driver's seating position.[32] The location of the label must be such that it is easily readable without moving any part of the vehicle except an outer door.

The manufacturer's certification label for trailers must be affixed to a location on the forward half of the left side, such that it is easily readable from outside the vehicle without moving any part of the vehicle. The certification label for motorcycles must be affixed to a permanent member of the vehicle as close as is practicable to the intersection of the steering post with the handle bars, in a location such that it is easily readable without moving any part of the vehicle except for the steering system. This label is the only location on a motorcycle that must show the VIN.

Motor Vehicle Certification Label Content

The motor vehicle certification label, among other things, identifies the vehicle's manufacturer (i.e., the actual assembler of the vehicle), states the vehicle's date of manufacture (month and year), Gross Vehicle Weight Rating or GVWR, Gross Axle Weight Rating or GAWR of each axle, vehicle type classification (e.g., MPV, truck), and VIN. For multipurpose passenger vehicles and trucks with a GVWR of 6,000 pounds or less, the label must contain the statement: *"This vehicle conforms to all applicable Federal motor vehicle safety and theft prevention standards in effect on the date of manufacture shown above."* For passenger cars, the label must contain the statement *"This vehicle conforms to all applicable Federal motor vehicle safety, bumper, and theft prevention standards in effect on the date of manufacture shown above."* For all other vehicles, the label must contain the statement: *"This vehicle conforms to all applicable Federal motor vehicle safety standards in effect on the date of manufacture shown above."*

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[29] See 49 CFR 571.205 S3.2, entitled "Incorporation by Reference" wherein it states: (a) "American National Standard for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways-Safety Standard" ANSI/SAE Z26.1–1996, Approved by American National Standards Institute August 11, 1997 (ANSI/SAE Z26.1– 1996) is incorporated by reference in Section 5.1 and is hereby made part of this Standard

[30] See 49 U.S.C. §§ 30112 and 30115, and 49 CFR part 567

[31] See 49 CFR 567.4(c), (d), and (e)

[32] If none of the preceding locations is practicable, notification of that fact, together with drawings or photographs showing a suggested alternate location in the same general area, shall be submitted for approval to the Administrator, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, D.C. 20590

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Certification Requirements for Vehicles Manufactured in Two or More Stages

A "completed" vehicle is one that requires no further manufacturing operations to perform its intended function. An "incomplete" vehicle is an assemblage consisting, at a minimum, of chassis (including the frame) structure, power train, steering system, suspension system, and braking system, in the state that those systems are to be part of the completed vehicle, but requires further manufacturing operations to become a completed vehicle. An incomplete trailer is also an incomplete vehicle.[33] Manufacturers of incomplete vehicles must furnish at or before the time of delivery an incomplete vehicle document or "IVD" that contains, among other things, a list of each FMVSS applicable to the incomplete vehicle's type classification and a statement whether the vehicle will or will not conform to each applicable FMVSS, or that FMVSS conformance cannot be determined.[34]

Additionally, incomplete vehicle manufacturers must generally affix to their vehicles a label that identifies the incomplete manufacturer, the vehicle's date of manufacture (month and year), its GVWR, GAWR, and VIN.

A final-stage manufacturer is a person who performs such manufacturing operations on an incomplete vehicle that it becomes a completed vehicle. An intermediate manufacturer is a person, other than the incomplete vehicle manufacturer or the final-stage manufacturer, who performs manufacturing operations on a vehicle manufactured in two or more stages.[35] Both the final-stage and intermediate manufacturers assume legal responsibility for all certification-related duties and liabilities under the Vehicle Safety Act with respect to components and systems they install or supply for installation on the incomplete vehicle, unless changed by a subsequent manufacturer. Both have responsibility to further manufacture or complete the vehicle in accordance with the IVD furnished by the incomplete vehicle manufacturer.

The intermediate manufacturer must affix a label that identifies that manufacturer, states the vehicle's GVWR, GAWR, and VIN, and identifies the month and year in which the intermediate manufacturer performed its last manufacturing operation on the incomplete vehicle.

The final-stage manufacturer must affix a label that identifies that manufacturer, states the vehicle's GVWR, GAWR, vehicle type classification, and VIN, and identifies the vehicle's date of manufacture (month and year). The date selected must be the date of manufacture of the incomplete vehicle, the date of final completion, or a date between those two dates. The label must also contain one of the following three alternative certification statements:[36]

1. *"This vehicle conforms to all applicable Federal Motor Vehicle Safety Standards*, [and Bumper and Theft Prevention Standards, if applicable] *in effect in (month, year)."*

2. *"This vehicle has been completed in accordance with the prior manufacturers' IVD, where applicable. This vehicle conforms to all applicable Federal Motor Vehicle Safety Standards,* [and Bumper and Theft Prevention Standards, if applicable] *in effect in (month, year)."*

3. *"This vehicle has been completed in accordance with the prior manufacturers' IVD, where applicable, except for* [insert FMVSS]. *This vehicle conforms to all applicable Federal Motor Vehicle Safety Standards*, [and Bumper and Theft Prevention Standards if applicable] *in effect in (month, year)."*

[33] See 49 CFR 567.3
[34] See 49 CFR 568.4(a) and (b)
[35] See 49 CFR 567.3
[36] See 49 CFR 567.5(d)

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Certification label content requirements for each manufacturer are summarized in Table 4.

Table 4 - Certification Label Content Requirements by Manufacturer Type

Manufacturer Type	Company's Name	Date of Manufact -ure	GVWR	GAWR	Vehicle Type	VIN	Certification Statement Source
Completed Vehicle	Yes	Yes	Yes	Yes	Yes	Yes	Yes, 1 of 3 567.4(g)
Incomplete Vehicle	Yes	Yes	Yes	Yes	No	Yes	No, IVD 567.5(b)(2)
Intermediate	Yes	Yes	Yes	Yes	No	Yes	No 567.5(c)(2)
Final-stage	Yes	Yes	Yes	Yes	Yes	Yes	Yes, 1 of 3 567.5(d)(2)

Sample manufacturers' certification labels covering a motorcycle, trailer, low-speed vehicle, multipurpose passenger vehicle, truck, and passenger car are provided in Appendix 3.

Certification Label Suppliers

NHTSA does not endorse any certification label suppliers or their products; however, companies known to the agency that supply such products to motor vehicle manufacturers are identified in Appendix 5.

Chapter 6. The Federal Motor Vehicle Safety Standards

FMVSS Issuance

NHTSA is authorized by the Vehicle Safety Act to issue safety standards that set minimum performance requirements for new motor vehicles and for certain items of motor vehicle equipment. Such standards must be practicable, meet the need for motor vehicle safety, and be stated in objective terms. The FMVSS specify the minimum performance requirements and, in general terms, the objective tests required to demonstrate product compliance.

FMVSS Organization under 49 CFR Part 571

The FMVSS are generally organized under Vehicle Crash Avoidance (Series 100), Crashworthiness (Series 200)[37], Post-Crash Protection (Series 300), Miscellaneous (Series 400), Low-Speed Vehicles (Series 500), or Equipment standards. All FMVSS are found in 49 CFR Part 571, Subpart B, and are numbered to correspond to the FMVSS number. For example FMVSS No. 101 *Controls and Displays* is found in 49 CFR 571.101.

Because manufacturers are responsible for "self-certifying" that their products meet all applicable FMVSS before those products can be offered for sale, it is important for a manufacturer to be knowledgeable about the performance requirements of each FMVSS applicable to its products. NHTSA encourages manufacturers to conduct tests as specified in certain of the FMVSS. Manufacturers should also be familiar with the laboratory test procedures that NHTSA uses to evaluate the compliance of their products with each FMVSS. These may be found on the NHTSA web site.[38]

[37] Crashworthiness means the protection a passenger motor vehicle gives its passengers against personal injury or death from a motor vehicle crash

[38] See http://www.nhtsa.gov/Vehicle+Safety/Test+Procedures

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FMVSS Applicability

A paragraph within each FMVSS identifies the types of vehicles or equipment items to which the standard applies. For example, Paragraph S3 of 49 CFR 571.101 states that FMVSS No. 101 *Controls and Displays* applies to passenger cars, multipurpose passenger vehicles, trucks, and buses. Certain FMVSS requirements apply only to vehicles above or below a specified GVWR. For example, FMVSS No. 201 *Occupant Protection in Interior Impact* applies to passenger cars, multipurpose passenger vehicles, trucks, and buses with a GVWR of 10,000 pounds (4,536 kilograms) or less.[39] Other FMVSS requirements may not apply to certain specialty vehicles. For example, FMVSS No. 225 *Child Restraint Anchorage Systems* does not apply to walk-in van-type vehicles, vehicles manufactured to be sold exclusively to the U.S. Postal Service, shuttle buses, and funeral coaches.[40]

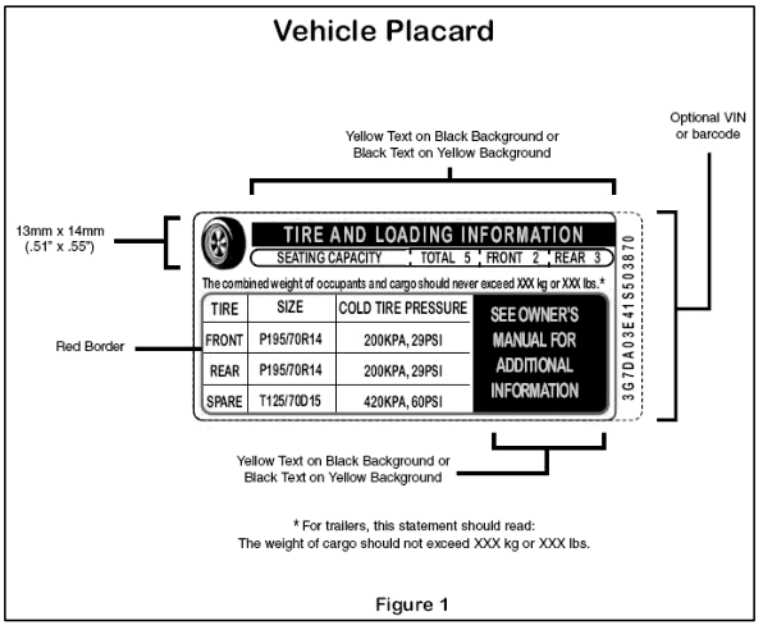
Reference Table Identifying FMVSS Applicability by Vehicle Type and Equipment Items

To assist manufacturers, NHTSA has created a ready reference table to show FMVSS applicability by motor vehicle type classification and motor vehicle equipment item. See Appendix 8. As FMVSS are adopted or amended, they are assigned effective dates. It is therefore wise to check the most up-to-date version of 49 CFR Part 571, Subpart B for regulatory amendments.

Chapter 7. Tire Information Labeling Requirements

FMVSS No. 110 specifies, among other things, requirements for tire selection to prevent tire overloading. The standard applies to vehicles with a GVWR of 10,000 pounds (4,536 kilograms) or less, except for motorcycles, low-speed vehicles, and incomplete vehicles.[41] Manufacturers are required to permanently affix a tire placard in a specified location on the vehicle. The placard provides consumers with tire and loading information, including the vehicle's seating capacity and weight. An example of the required placard is shown in Figure 1.

Figure 1 – Tire Placard



[39] See 49 CFR 571.201 paragraph S2
[40] See 49 CFR 571.225 paragraph S2
[41] See 49 CFR 571.110 paragraph S4.3

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Chapter 8. Duty to Notify NHTSA of a Noncompliance with an FMVSS or a Safety-Related Defect

Notwithstanding its certification of a product, a manufacturer may subsequently determine that a noncompliance with an FMVSS or a safety-related defect exists in a motor vehicle or a motor vehicle equipment item it has produced. Manufacturers have a duty to notify NHTSA if they learn the vehicle or equipment contains a defect and in good faith they decide that the defect is related to motor vehicle safety, or in good faith they decide that the vehicle or equipment does not comply with an applicable FMVSS.[42] The manufacturer must notify NHTSA within five working days after determining the existence of a noncompliance or a safety-related defect.[43] Alternately, NHTSA may determine the existence of a noncompliance or a safety-related defect in a particular motor vehicle or motor vehicle equipment item and order the responsible manufacturer to recall the product.[44]

Chapter 9. Duty to Notify Owners and Dealers and Provide a Remedy for a Noncompliance or a Safety-Related Defect

Regardless of whether the noncompliance with an FMVSS or a safety-related defect is determined to exist by the manufacturer or by NHTSA, the manufacturer must provide owners and dealers of the affected products with notification of the noncompliance or defect and must remedy the noncompliance or defect, usually without charge.[45] The notification and remedy process is commonly referred to as a "safety recall campaign" or more simply as a "recall." NHTSA monitors the remedy program to ensure its successful completion. The agency is not authorized to expend its funds on recalls; the expense of notifying owners and providing a remedy must be borne by the fabricating manufacturer and/or importer of the products found to contain the noncompliance or defect.[46] Manufacturers are encouraged to contact NHTSA at 202-366-5210 or review the agency's web site for more comprehensive information. See http://www-odi.nhtsa.dot.gov/.

Chapter 10. Record Keeping for Manufacturers

Tires

A new tire manufacturer is required by NHTSA regulations to permanently mold into each tire intended for use on a motor vehicle a "tire identification number" or "TIN."[47] Tire distributors and dealers that are owned or controlled by tire manufacturers are required to send to the tire manufacturers, records of any new tires they sell, including the TINs of the tires and the name and address of the tire purchasers. Independent tire distributors or dealers are required to furnish tire registration forms that identify the TIN and the tire distributor or dealer's name and address to the purchasers of new tires, who may then mail the forms to the tire manufacturer. See Appendix 9 for a sample tire registration form. Instead of furnishing the tire purchaser with a registration form, independent tire distributors or dealers may electronically transmit tire purchaser and tire registration information to the tire manufacturer by secure means, as identified or authorized by the manufacturer.

Tire manufacturers must maintain information from the registration forms for a period of not less than 5 years from the date on which the information is recorded. Motor vehicle manufacturers are required to maintain records of the TINs for the tires installed on their vehicles and the name and address of the first purchasers of their vehicles for 5 years from the date that the vehicles are sold. These requirements are intended to ensure that purchasers receive proper notification in the event that a tire is recalled to remedy a noncompliance or

[42] See 49 U.S.C. 30118(c)
[43] See 49 CFR 573.6
[44] See 49 U.S.C. 30118(b)
[45] See 49 CFR Part 577
[46] See 49 U.S.C. §§ 30118 - 30120
[47] See 49 CFR Part 574.5

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safety-related defect.[48]

Child Restraints

In like manner, the manufacturer of a child restraint system (i.e., a child safety seat), other than one installed on a vehicle as newly manufactured, must furnish a registration form to be completed by the owners of those seats and retain information from the form for a period of not less than 6 years to ensure that the owners receive proper notification of a recall campaign.[49]

Motor Vehicles and Equipment

NHTSA regulations also require manufacturers of motor vehicles and motor vehicle equipment to retain claims, complaints, reports, and other records concerning alleged and proven defects and malfunctions that may be related to motor vehicle safety for a period of five calendar years from the date on which they were generated or acquired by the manufacturer.[50] Under this regulation, "malfunctions that may be related to motor vehicle safety" are defined as including any failure or malfunction beyond normal deterioration in use, or any failure of performance, or any flaw or unintended deviation from design specifications, that could in any reasonably foreseeable manner be a causative factor in, or aggravate, a crash or an injury to a person. This regulation also describes the records that manufacturers must maintain, including all documentary materials, films, tapes, and other information-storing media that contain information concerning malfunctions that may be related to motor vehicle safety. The section describes such records as including, but not being limited to, reports and other documents, including material generated or communicated by computer, telefax or other electronic means, that are related to work performed under warranties; and any lists, compilations, analyses, or discussions of such malfunctions contained in internal or external correspondence of the manufacturer, including communications transmitted electronically.

Chapter 11. Early Warning Reporting

Manufacturers must submit quarterly reports to NHTSA under the agency's Early Warning Reporting (EWR) regulations that implement the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000. These regulations require manufacturers to submit information that could assist the agency in determining whether a safety-related defect exists in a vehicle or equipment item used in the United States.[51] The regulations divide manufacturers of motor vehicles and motor vehicle equipment into two groups with different responsibilities for reporting information that could indicate the existence of potential safety-related defects.

The first group comprises motor vehicle manufacturers that meet certain production thresholds, tire manufacturers that produce more than a certain number of tires by tire line, and all manufacturers of child restraint systems. Manufacturers of light vehicles, motorcycles, trailers, and medium-heavy vehicles (except buses and emergency vehicles) that produced, imported, offered for sale, or sold 5,000 or more vehicles of a category annually in the United States are required to furnish NHTSA with comprehensive reports every calendar quarter. Emergency vehicle manufacturers must report if they produced, imported, offered for sale, or sold 500 or more vehicles annually, and bus manufacturers must report if they produced, imported or offered for sale, or sold 100 or more buses annually in the United States. Manufacturers of passenger car, light truck, and motorcycle tires are also required to provide comprehensive quarterly reports if they produced, imported, offered for sale, or sold 15,000 or more tires in a tire line. This group of manufacturers must generally report to NHTSA production-related information, incidents related to a death or injury, consumer complaints, warranty claims (warranty adjustments for tires), property damage claims, and field reports.

The second group comprises all other manufacturers of motor vehicles and motor vehicle equipment (i.e., vehicle manufacturers that produce, import, or sell annually in the United States fewer than 5,000 light vehicles,

[48] See 49 CFR Part 574
[49] See 49 CFR Part 588
[50] See 49 CFR Part 576
[51] See 49 CFR Part 579, Subpart C

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motorcycles, trailers, and medium-heavy vehicles (excluding emergency vehicles and buses); manufacturers that produce, import, or sell annually in the United States fewer than 500 emergency vehicles; manufacturers that produce, import, or sell annually in the United States fewer than 100 buses; manufacturers of original motor vehicle equipment; and manufacturers of replacement motor vehicle equipment other than child restraint systems and tires). These manufacturers must submit a report if they receive a claim or notice related to an incident involving a death, but are not required to report any other information under the EWR rule. Manufacturers are encouraged to contact NHTSA at 202-366-4238 or review the agency's web site for more comprehensive EWR information. See http://www-odi.nhtsa.dot.gov/ewr/ewr.cfm.

Under other NHTSA regulations, all vehicle and equipment manufacturers in both groups must provide copies of all documents sent or made available to more than one dealer, distributor, owner, purchaser, lessor or lessee, in the United States concerning customer satisfaction campaigns, consumer advisories, recalls, or other activities involving the repair or replacement of vehicles or equipment.[52] A manufacturer must also report safety recalls and other safety campaigns it conducts in a foreign country that cover a motor vehicle, an item of motor vehicle equipment, or a tire that is identical or substantially similar to such a product offered for sale or sold in the United States.[53]

Chapter 12. Other Statutory/Regulatory Requirements

Manufacturers should be aware that NHTSA administers additional statutes and regulations related to motor vehicles and motor vehicle equipment. These include:

Theft Prevention

This statute and implementing regulations require motor vehicle manufacturers to affix or inscribe anti-theft identification markings to major parts and replacement parts for certain lines of passenger cars, light trucks and MPVs designated as high theft lines. See 49 U.S.C. Chapter 331 and 49 CFR Parts 541-543.

Bumper Standards

This statute and implementing regulations establish standards to reduce physical damage to the front and rear of passenger motor vehicles from low speed collisions. See 49 U.S.C. Chapter 325 and 49 CFR Part 581.

Fuel Economy

This statute and implementing regulations require manufacturers to comply with the applicable average fuel economy standards. See 49 U.S.C. Chapter 329 and 49 CFR Parts 525, 526, 529, 531, 533, 535, 537, and 538.

Domestic Content Labeling

This statute and implementing regulations establish requirements for the disclosure of information relating to the countries of origin of the equipment on new passenger motor vehicles. See 49 U.S.C. Chapter 323 and 49 CFR Part 583.

Consumer Information

This statute and implementing regulations establish requirements for the disclosure of information in the owner's manual of a motor vehicle relating to tires and the Uniform Tire Quality Grading program and the reporting of possible safety defects to NHTSA. Owner's manuals of special vehicles such as slide-in campers and trucks that are capable of accommodating slide-in campers must also contain certain consumer information.[54] For certain

[52] See 49 CFR 579.5 and 579
[53] See 49 CFR Part 579, Subpart B
[54] See 49 CFR 575.103

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vehicles, manufacturers are required to affix a Rollover Warning label[55] and to label the vehicle with New Car Assessment Program Safety Rating information.[56] See 49 U.S.C. Chapter 323 and 49 CFR Part 575.

Chapter 13. NHTSA Contacts

Table 5 provides NHTSA contact numbers and Internet resources to help answer questions about the information presented in the previous sections.

Table 5 – NHTSA Contacts

Office of Vehicle Safety Compliance		
Topic	***NHTSA Office/Internet***	***Telephone No./ Link***
General questions about importing vehicles and equipment items	Import and Certification Division	(202) 366-5291
General Importation Information	http://www.nhtsa.gov/cars/rules/import	
Questions about how a manufacturer informs NHTSA about its company and the products it manufactures	Import and Certification Division	(202) 366-5291
Questions about how to provide NHTSA with the manufacturer's vehicle identification number deciphering information	NHTSA Manufacturer Help Desk	1- (888) 399-3277
Questions about NHTSA ID numbers that are assigned to equipment manufacturers of brake hoses, glazing (glass), and tires	Equipment Division	(202) 366-5317
Information to Assist New Manufacturers	https://vpic.nhtsa.dot.gov/	
Questions about how to submit Manufacturer Information (49 CFR 566), VIN deciphering info (49 CFR 565), and Equipment forms to NHTSA	https://vpic.nhtsa.dot.gov/	
Questions about FMVSS as they relate to equipment items (i.e., tires, rims, brake hoses, brake fluid, seat belt assemblies, lighting equipment, glazing (automotive glass and plastics), motorcycle helmets, child restraint systems (child safety seats), platform lift systems for the mobility impaired, rear impact guards for trailers, triangular reflective warning devices, and compressed natural gas containers)	Equipment Division	(202) 366-5317
Federal motor vehicle safety standards (FMVSS)	http://www.nhtsa.gov/cars/rules/	
NHTSA's Manufacturer Databases	http://vpic.nhtsa.dot.gov/mid/	
Government Vehicle Safety Information	http://www.safercar.gov/	

[55] See 49 CFR 575.105
[56] See 49 CFR 575.301

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Office of Defects Investigation		
Topic	***NHTSA Office/Internet***	***Telephone No./Link***
Questions about Early Warning Reporting (EWR)	Early Warning Division	(202) 366-4238
Early Warning Reporting	http://www-odi.nhtsa.dot.gov/ewr/ewr.cfm	
Questions about Defects and Recalls	Office of Defects Investigation	(202) 366-5210
Defects Investigations	http://www-odi.nhtsa.dot.gov/	

Office of Chief Counsel		
Topic	***NHTSA Office/Internet***	***Telephone No./Link***
Requests for interpretation of the statutes and regulations administered by NHTSA	Office of Chief Counsel	Requests should be made in writing.
NHTSA Chief Counsel interpretive letters	http://isearch.nhtsa.gov/	
NHTSA Statutory Authorities	http://www.nhtsa.gov/Laws-Regs	
NHTSA Regulations	http://www.nhtsa.gov/cars/rules/	
Questions about how to designate a U.S. resident as an agent for service of process	Office of Chief Counsel	(202) 366-1834
Suggested Designation of Agent for Service of Process 49 CFR Part 551, Subpart D	http://vpic.nhtsa.dot.gov/MfrPortal/	

Chapter 14. Additional Resources

Other than those noted before, manufacturers may find helpful the resources identified in Table 6.

Table 6 – Additional Resources

Resource	Contact
Environmental Protection Agency	www.epa.gov
Motorcycle Industry Council	www.mic.org
National Association of Trailer Manufacturers	www.natm.com
Truck Trailer Manufacturers Association	www.ttmanet.org
Recreational Vehicle Industry Association	www.rvia.org
Tire and Rim Association, Inc.	www.us-tra.org
National Truck Equipment Association	www.ntea.com

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Chapter 15. Helpful Hints

Manufacturer's Statements of Origin or Certificates of Origin

NHTSA is not responsible for titling or registering motor vehicles or for regulating the operation of motor vehicles on public roads in the United States. That is instead the responsibility of the individual States. Some States may require a manufacturer's certificate of origin (MCO) or manufacturer's statement of origin (MSO) to register a new motor vehicle. These are not federally required documents. NHTSA, therefore, is not in a position to offer guidance to prospective vehicle manufacturers or vehicle purchasers on obtaining a needed MCO or MSO. For assistance, please contact your State's Department of Motor Vehicles (DMV).

Search the United States Code

To search the United States Code, follow this link: http://uscode.house.gov/

Search the Code of Federal Regulations

To search the Code of Federal Regulations, follow this link: http://www.ecfr.gov/cgi-bin/text-idx?SID=7d86ffa476c2d4b7414acbd1b7e9b0d1&mc=true&tpl=/ecfrbrowse/Title49/49tab_02.tpl

Search the Federal Register

To search the Federal Register, follow this link: http://www.gpo.gov/fdsys/search/home.action

Search NHTSA Interpretations

To search NHTSA Interpretation letters, follow this link: http://isearch.nhtsa.gov

FMVSS Compliance Test Procedures

For FMVSS Compliance Test Procedures, follow this link: http://www.nhtsa.gov/Vehicle-Safety/Test-Procedures

Motorcycle and motorcycle frame engineering reports

Engineering reports for motorcycles and motorcycle frames are available on a fee basis through the SAE. See that organization's web site at www.sae.org

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Appendices

Appendix 1 - Part 551 - Designate a permanent resident of the United States as its agent for service of process.

OMB No. 2127-0040
Expiration Date: 07/31/2009

Paperwork Reduction Act Burden Statement

A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a current valid OMB Control Number. The OMB Control Number for this information collection is 2127-0040. Public reporting for this collection of information is estimated to be approximately 30 minutes per response, including the time for reviewing instructions, completing and reviewing the collection of information. All responses to this collection of information are mandatory. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, National Highway Traffic Safety Administration, 1200 New Jersey Avenue, SE, Washington, D.C. 20590.

SUGGESTED DESIGNATION OF AGENT FOR SERVICE OF PROCESS
UNDER 49 U.S.C. § 30164 and 49 C.F.R. Part 551, Subpart D

PART A: DESIGNATION BY FOREIGN MANUFACTURER

Pursuant to 49 U.S.C. § 30164 and 49 C.F.R. Part 551, Subpart D, the Foreign Manufacturer listed below hereby designates the following Agent on whom service of all administrative and judicial processes and notices may be made. This designation is for service of process only and for no other purpose. It shall remain in effect until it is withdrawn or another Agent is designated in accordance with the requirements of 49 U.S.C. § 30164 and 49 C.F.R. Part 551, Subpart D.

The Manufacturer identified below hereby certifies:

1. This designation is in valid form and binding on the Manufacturer under the laws, corporate bylaws or other requirements governing the making of designations at the place and time where it is made.

2. The full legal name, principal place of business and mailing address of the Manufacturer are:
   _____
   _____
   _____

3. The Manufacturer's products will be sold under the following trade or brand names, marks, logos or other designations of origin (**List all names, marks, logos or designations**):_____
   _____
   _____

4. The full legal name, principal place of business, mailing address and telephone number of the Agent are:_____
   _____
   _____

By: _____ / / _____
Signature of Manufacturer's Authorized Representative — Month / Day / Year

_____ _____
Printed Name — Title

[Note: Part B of the form continues on the next page]

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PART B: ACCEPTANCE BY AGENT

The undersigned hereby accepts appointment as Agent solely for the purpose of service of process on the Manufacturer under 49 U.S.C. § 30164 and 49 C.F.R. Part 551, Subpart D. I understand that this appointment shall remain in effect until withdrawn or replaced by the Manufacturer in accordance with the requirements of 49 U.S.C. § 30164 and 49 C.F.R. Part 551, Subpart D. I understand also that I may not assign performance of my functions under this Designation to another person.

By: _____ / / _____

Signature of Agent — Month / Day / Year

(Date of acceptance must be *on or after* date of designation)

_____ _____

Printed Name — Title

Mail original documents with ink signatures only to: U.S. Department of Transportation, NHTSA Correspondence Unit, 1200 New Jersey Avenue, SE, Room W41-306, Washington, D.C. 20590

Please note that:

- Manufacturers must submit to NHTSA **original**, fully executed designation forms with **ink signatures**. NHTSA will not accept copies of designation forms, facsimiles, emails, emailed PDF files, or forms that do not contain original ink signatures.
- The date of acceptance by an agent must be **on or after** the date of designation by a foreign manufacturer.
- Designation forms must be submitted to U.S. Department of Transportation, NHTSA Correspondence Unit, 1200 New Jersey Avenue, SE, Room W41-306, Washington, D.C. 20590. No other NHTSA office is authorized to accept designation documents. To avoid delays, the agency suggests using express mail services.

Questions?

For further assistance or with questions about the requirements of Part 551, Subpart D, please email Ms. Jin Kim at Jin.Kim@dot.gov.

A fillable PART 551 form is available here:
http://vpic.nhtsa.dot.gov/SUGGESTED%20DESIGNATION%20OF%20AGENT%20FOR%20SERVICE%20OF%20PROCESS.PDF

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Appendix 2 - Sample spreadsheet format to calculate a VIN check digit

POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
CURRENT VIN	1	z	9	p	e	5	5	0	6	9	s	3	5	5	0	0	1	Your VIN
CONVERT TO NUMBER	1	9	9	7	5	5	5	0		9	2	3	5	5	0	0	1	
MULTIPLIER	8	7	6	5	4	3	2	10		9	8	7	6	5	4	3	2	
RESULT	8	63	54	35	20	15	10	0		81	16	21	30	25	0	0	2	380
DIVIDE																		11
TRUNCATED																		34
REMAINDER																		6

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Appendix 3 – Part 565 Vehicle Identification Number - Trailers

Sample VIN Deciphering Submission – USA Trailer Company

Date: July 4, 20XX

Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE W43-488
Washington, DC 20590
Attention: VIN Coordinator

RE: Vehicle Identification Number Deciphering Information

In accordance with 49 CFR Part 565, *Vehicle Identification Number Requirements*, USA Trailer Company, Inc. is submitting information necessary to decipher the characters contained in its Vehicle Identification Numbers. Please see the attachment.

USA Trailer Company, Inc. is a low-volume trailer manufacturer assigned WMI: 1ZZ/400. If you have any questions, please contact me at (555) 555-0000.

Sincerely,

John Doe
USA Trailer Company, Inc.
345 Main St.
Anywhere, USA

Attachment

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number - Trailers

Sample VIN Deciphering Submission – USA Trailer Company

VIN Deciphering		
1st Section		
Position 1	WMI	1-Assigned by SAE
Position 2	WMI	Z-Assigned by SAE
Position 3	WMI	Z-Assigned by SAE
2nd Section		
Position 4	Trailer Make	U=USA Trailer Co.
Position 5	Trailer to Towing Vehicle Connection Type	1= Ball Type Pull 2= Pintle Hitch 3=Gooseneck 4= Straight Semi 5= Fifth Wheel 6=Kingpin 7=Bumper Pull 8=Others
Position 6	Trailer Body Type	A=Flatbed B=Tank C=Utility D=Livestock E=Enclosed
Position 7	Length	6=6 feet long 9=9 feet long A=26 feet long
Position 8	Axle configuration	1=Single Axle 2=2 Axles 3=3 Axles
3rd Section		
Position 9	Check Digit	Calculated See 49 CFR 565.15(c)
4th Section		
Position 10	Model Year	H=2017 J=2018 K=2019
Position 11	Plant of Manufacture	A=Baltimore, MD, USA – Main Plant B=Flint, MI, USA – Flint Plant L=Landing, MI, USA ,GMNA M=Lordstown, OH, USA
Position 12	WMI	4-Assigned by SAE
Position 13	WMI	0-Assigned by SAE
Position 14	WMI	0-Assigned by SAE
Position 15	Sequentially Assigned	
Position 16		
Position 17		

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number - Motorcycles

Sample VIN deciphering submission – USA Motorcycle Company

Date: July 4, 20XX

Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE W43-488
Washington, DC 20590
Attention: VIN Coordinator

RE: Vehicle Identification Number Deciphering Information

In accordance with 49 CFR Part 565, *Vehicle Identification Number Requirements*, USA Motorcycle Company, Inc. is submitting information necessary to decipher the characters contained in its Vehicle Identification Numbers. Please see the attachment.

USA Motorcycle Company, Inc. is a low-volume MPV manufacturer assigned WMI: 1ZZ/401. If you have any questions, please contact me at (555) 555-0000.

Sincerely,

John Doe
USA Motorcycle Company, Inc.
345 Main St.
Anywhere, USA

Attachment

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number - Motorcycles

Sample VIN deciphering submission – USA Motorcycle Company

VIN Deciphering		
1st Section		
Position 1	WMI	1- Assigned by SAE
Position 2	WMI	Z- Assigned by SAE
Position 3	WMI	Z- Assigned by SAE
2nd Section		
Position 4	Make	R=USA MOTORCYCLE COMPANY
Position 5	Line or Model	A=Winner A B=Winner B C=Winner C
Position 6	Type of Motorcycle	1=Scooter 2=Sport Bike 3=Cruiser
Position 7	Engine Type	A=V-2, 200 cc, gas B=V-4, 400 cc, gas C=V-8, 1,000 cc, gas
Position 8	Net Brake HP	1= 5hp 2=36hp 3=75hp
3rd Section		
Position 9	Check Digit	Calculated See 49 CFR 565.15(c)
4th Section		
Position 10	Model Year	H=2017 J=2018 K=2019
Position 11	Plant of Manufacture	A=Baltimore, MD, USA – Main Plant B=Flint, MI, USA – Flint Plant
Position 12	WMI	4- Assigned by SAE
Position 13	WMI	0- Assigned by SAE
Position 14	WMI	1- Assigned by SAE
Position 15	Sequentially Assigned	
Position 16		
Position 17		

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number – Multipurpose Passenger Vehicles

Sample VIN deciphering submission – USA MPV Company

Date: July 4, 20XX

Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE W43-488
Washington, DC 20590
Attention: VIN Coordinator

RE: Vehicle Identification Number Deciphering Information

In accordance with 49 CFR Part 565, *Vehicle Identification Number Requirements*, USA MPV Company, Inc. is submitting information necessary to decipher the characters contained in its Vehicle Identification Numbers. Please see the attachment.

USA MPV Company, Inc. is a low-volume MPV manufacturer assigned WMI: 1ZZ/400. If you have any questions, please contact me at (555) 555-0000.

Sincerely,

John Doe
USA MPV Company, Inc.
345 Main St.
Anywhere, USA

Attachment

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number - Multipurpose Passenger Vehicles

Sample VIN deciphering submission – USA MPV Company

VIN Deciphering		
1st Section		
Position 1	WMI	1- Assigned by SAE
Position 2	WMI	Z- Assigned by SAE
Position 3	WMI	Z- Assigned by SAE
2nd Section		
Positions 4 -8	See Chart 1	
3rd Section		
Position 9	Check Digit	Calculated See 49 CFR 565.15(c)
4th Section		
Position 10	Model Year	H=2017 J=2018 K=2019
Position 11	Plant of Manufacture	A=Baltimore, MD, USA – Main Plant B=Flint, MI, USA – Flint
Position 12	WMI	4- Assigned by SAE
Position 13	WMI	0- Assigned by SAE
Position 14	WMI	0- Assigned by SAE
Position 15	Sequentially Assigned	
Position 16		
Position 17		

Chart 1			
Positions 4-8	RP1A3	RP1B3	RP1C3
Make	USA MPV Co	USA MPV Co	USA MPV Co
Line or Model	Craggy	Craggy	Craggy
Series	3200	3250	3275
Body Type	5-Dr. Liftback	5-Dr. Liftback	5-Dr. Liftback
Engine Type	3.8L 6-cyl. 280 hp gas	3.8L 6-cyl. 280 hp gas	3.8L 6-cyl. 280 hp gas
GVWR Class	C	C	C
C = Greater than 1814 kg. to 2268 kg. (4,001–5,000 lbs.)			
Restraint Front	1	1	1
1 = Seat Belt, Air Bag, Side Air Bag, and Side Curtain Air Bag (Driver and Passenger)			
Restraint Mid	2	2	2
Restraint Rear	2	2	2
2 = Seat Belt and Side Curtain Air Bag			

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number – Passenger Cars

Sample VIN Deciphering Submission – USA Passenger Car Company

Date: July 4, 20XX

Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE W43-488
Washington, DC 20590
Attention: VIN Coordinator

RE: Vehicle Identification Number Deciphering Information

In accordance with 49 CFR Part 565, *Vehicle Identification Number Requirements*, USA Passenger Car Company, Inc. is submitting information necessary to decipher the characters contained in its Vehicle Identification Numbers. Please see the attachment.

USA Passenger Car Company, Inc. is a low-volume passenger car manufacturer assigned WMI: 1J9/640. If you have any questions, please contact me at (555) 555-0000.

Sincerely,

John Doe
USA Passenger Car Company, Inc.
345 Main St.
Anywhere, USA

Attachment

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Appendix 3 (Continued) – Part 565 Vehicle Identification Number – Passenger Cars

Sample VIN Deciphering Submission – USA Passenger Car Company

VIN Deciphering		
1st Section		
Position 1	WMI	1- Assigned by SAE
Position 2	WMI	J- Assigned by SAE
Position 3	WMI	9- Assigned by SAE
2nd Section		
Positions 4 to 8	See Chart 1	
3rd Section		
Position 9	Check Digit	Calculated See 49 CFR 565.15(c)
4th Section		
Position 10	Model Year	H=2017 J=2018 K=2019
Position 11	Plant of Manufacture	A=Baltimore, MD, USA – Main Plant B=Flint, MI, USA – Flint Plant
Position 12	WMI	6- Assigned by SAE
Position 13	WMI	4- Assigned by SAE
Position 14	WMI	0- Assigned by SAE
Position 15	Sequentially Assigned	
Position 16		
Position 17		

Chart 1			
Positions 4-8	RP1A3	RP1B3	RP1C3
Make	USA Car Co	USA Car Co	USA Car Co
Line or Model	Super	Super	Super
Series	LV	MV	HV
Body Type	3 Dr Coupe	3 Dr Coupe	3 Dr Coupe
Engine Type	2.4L 4-cyl. 180 hp gas	2.4L 4-cyl. 180 hp gas	2.4L 4-cyl. 180 hp gas
GVWR Class	A	A	A
A = Not greater than 1360 kg. (3,000 lbs.)			
Restraint Front	1	1	1
1 = Seat Belt, Air Bag, Side Air Bag, and Side Curtain Air Bag (Driver and Passenger)			
Restraint Mid	N/A	N/A	N/A
Restraint Rear	2	2	2
2 = Seat Belt and Side Curtain Air Bag			

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Appendix 4 – Part 567 Certification Labels

Sample manufacturer's certification label for a motorcycle/motor-driven cycle

MFD BY: USA MOTORCYCLE MANUFACTURERS, INC. DATE OF MFG: 03/09 GVWR: 271 KG (598 LB)

FRONT GAWR	WITH TIRES	RIMS AT	COLD
110 KG (243 LB)	120/70R18 59V	18XMT3.00	290 KPA (42 PSI)
REAR GAWR	WITH TIRES	RIMS AT	COLD
161 KG (355 LB)	160/60R17 69V	17XMT4.00	290 KPA (42 PSI)

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN XXXXXXXXXXXXXXXXX TYPE: MOTORCYCLE

Sample manufacturer's certification label for a trailer

MFD BY: USA TRAILER MANUFACTURERS, CO. DATE OF MFG: 03/09 GVWR: 8,164 KG (18,000 LB)

FRONT GAWR	WITH TIRES	RIMS AT	COLD
4,354 KG (9,600 LB)	11R17.5HC(H)	17.5X8.25HC	827 KPA (120PSI) SINGLE
REAR GAWR	WITH TIRES	RIMS AT	COLD
4,354 KG (9,600 LB)	11R17.5HC(H)	17.5X8.25HC	827 KPA (120 PSI) SINGLE

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN: XXXXXXXXXXXXXXXXX TYPE: TRAILER

Sample manufacturer's certification label for a low-speed vehicle

MANUFACTURED BY: USA LOW SPEED VEHICLES, INC. DATE OF MFD: 03/09 GVWR: 1260 KG (2778 LB)

FRONT GAWR	WITH TIRES	RIMS AT	COLD
630 KG (1389 LB)	20.5 X 8.0 – 10 B	10 x 6JA	240 KPA (35 PSI) SINGLE
REAR GAWR	WITH TIRES	RIMS AT	COLD
630 KG (1389 LB)	20.5 X 8.0 – 10 B	10 x 6JA	240 KPA (35 PSI) SINGLE

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN XXXXXXXXXXXXXXXXX TYPE: LOW-SPEED VEHICLE

Sample manufacturer's certification label for a multipurpose passenger vehicle

MFD BY: USA MPV MANUFACTURERS, INC. DATE OF MFG: 03/09

GVWR: 2,745 KG (6,052 LB)

FRONT GAWR	WITH TIRES	RIMS AT	COLD
1,339 KG (2,952 LB)	225/65R16	16X6.5	250 KPA (36 PSI)
REAR GAWR	WITH TIRES	RIMS AT	COLD
1,407 KG (3,102 LB)	225/65R16	16X6.5	250 KPA (36 PSI)

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN: XXXXXXXXXXXXXXXXX TYPE: MPV

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Appendix 4 (Continued) – Part 567 Certification Labels

Sample manufacturer's certification label for a truck (GVWR < 6,000 lbs.)

MFD BY: USA TRUCK MANUFACTURERS, INC. DATE OF MFG: 03/16 GVWR: 2541 KG (5602 LB)

FRONT GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
1293 KG (2850 LB)	**215/70R15**	**15X6**	**250 KPA (36 PSI) SINGLE**
REAR GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
1339 KG (2950 LB)	**215/70R15**	**15X6**	**250 KPA (36 PSI) SINGLE**

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN: XXXXXXXXXXXXXXXXX TYPE: TRUCK

Sample manufacturer's certification label for a truck (GVWR ≥ 6,000 lbs.)

MFD BY: USA TRUCK MANUFACTURERS, INC. DATE OF MFG: 03/16 GVWR: 4083 KG (9000 LB)

FRONT GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
2359 KG (5200 LB)	**LT265/70R17E**	**17X8.0**	**410 KPA (60 PSI) SINGLE**
REAR GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
2727 KG (6010 LB)	**LT265/70R17E**	**17X8.0**	**485 KPA (70 PSI) DUAL**

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN: XXXXXXXXXXXXXXXXX TYPE: TRUCK

Sample manufacturer's information label for an incomplete vehicle

INCOMPLETE VEHICLE MFD BY: USA TRUCK MANUFACTURERS, INC. 03/16

GVWR: 2650 KG (5842 LB)

FRONT GAWR: 1350 KG (2976 LB)

REAR GAWR: 1300 KG (2866 LB)

VIN: XXXXXXXXXXXXXXXXX

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Appendix 4 (Continued) – Part 567 Certification Labels

Sample alterer's certification label for an MPV

THIS VEHICLE WAS ALTERED BY: USA TRUCK MANUFACTURERS, INC. DATE ALTERED: 03/16

GVWR: 5003 KG (11030 LB)

FRONT GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
2000 KG (4409 LB)	**LT215/85R16**	**16X5.5J**	**420 KPA (61 PSI) SINGLE**
REAR GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
3502 KG (7721 LB)	**LT215/85R16**	**16X5.5J**	**420 KPA (61 PSI) SINGLE**

THIS VEHICLE WAS ALTERED BY USA TRUCK MANUFACTURERS INC IN 03/16 AND AS ALTERED IT CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS AFFECTED BY THE ALTERATION AND IN EFFECT IN 03/16.

VIN: XXXXXXXXXXXXXXXXX TYPE: MPV

Final-stage manufacturer's label for a truck

MFD BY: USA TRUCK MANUFACTURERS, INC. 03/16

GVWR: 4083 KG (9000 LB)

FRONT GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
2359 KG (5200 LB)	**LT265/70R17E**	**17X8.0**	**410 KPA (60 PSI) SINGLE**
REAR GAWR	**WITH TIRES**	**RIMS AT**	**COLD**
2727 KG (6010 LB)	**LT265/70R17E**	**17X8.0**	**485 KPA (70 PSI) DUAL**

[*one of three alternative certification statements:***]**

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS IN EFFECT IN 3/16.

[*OR***]**

THIS VEHICLE HAS BEEN COMPLETED IN ACCORDANCE WITH THE PRIOR MANUFACTURERS' IVD, WHERE APPLICABLE. THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDS IN EFFECT IN 3/16.

[*OR***]**

THIS VEHICLE HAS BEEN COMPLETED IN ACCORDANCE WITH THE PRIOR MANUFACTURERS' IVD, WHERE APPLICABLE, EXCEPT FOR [*insert FMVSS(S)***]. THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY STANDARDSIN EFFECT IN 3/16.**

VIN: XXXXXXXXXXXXXXXXX TYPE: TRUCK

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Appendix 4 (Continued) – Part 567 Certification Labels

Sample manufacturer's certification label for a passenger car[57]

MFD BY: PASSENGER CAR COMPANY, INC. DATE OF MFD: 03/16

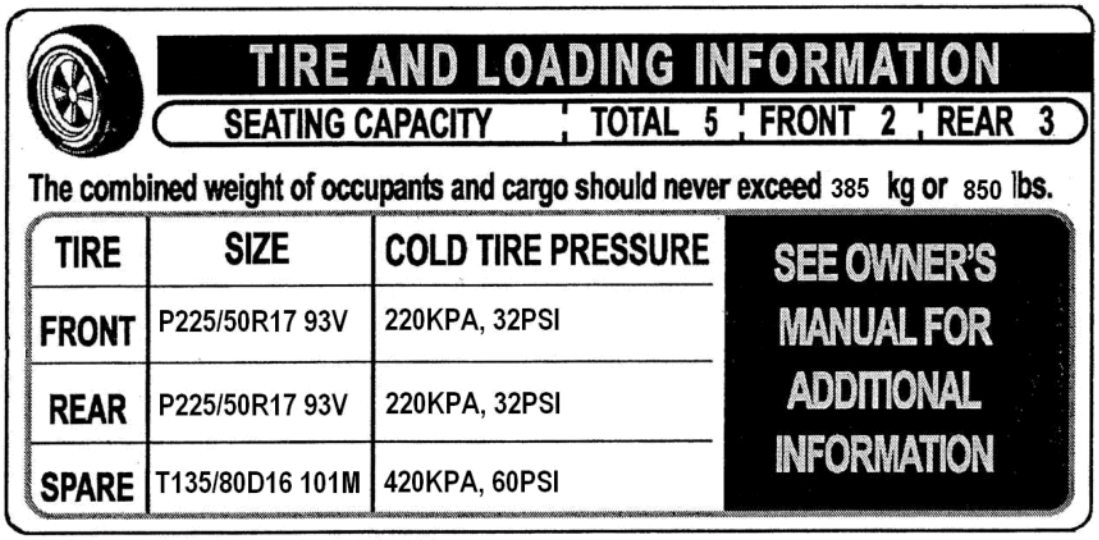
GVWR: 1918 KG (4228 LB)

FRONT GAWR 1026 KG (2262 LB)
REAR GAWR 921 KG (2030 LB)

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY, BUMPER, AND THEFT STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

VIN: XXXXXXXXXXXXXXXXX TYPE: PASSENGER

Associated passenger car tire placard



[57] Note that tire information is omitted and is moved to the Tire Placard. See 49 CFR 571.110 paragraph S4.3

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Appendix 5 – Certification Label Suppliers

NHTSA does not endorse any of the listed suppliers.

Name	Telephone	Internet
Vin-Eze/PMCS 2525 Honolulu Ave Montrose, CA 91020	888-247-7627	www.vineze.com
Dec-O-Art, Inc. 3914 Lexington Park Dr Elkhart, IN 46514	800-225-6879	www.dec-o-art.com
Cadillac Sign & Decal 4646 Poplar Level Rd Louisville, KY 40213	800-793-1618	www.cadillacsign.com
Moll Printing Co. 1012 Linn St Sikeston, MO 63801	573-472-1848	www.mollprinting.com
Proven Graphics, Inc. 2914 Highway 2 East Kalispell, MT 59901	800-477-7265	www.provengraphics.com

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Appendix 6 – How to Search NHTSA's Manufacturers' Information Database

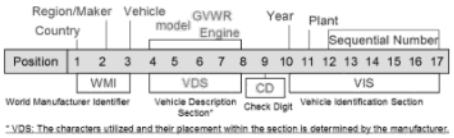
The Manufacturer's Information Database (MID) can be found through the NHTSA Product Information and Catalog Listing (vPIC). This page has a list of resource links pointing toward the Federal Regulations, as well as this Handbook and other forms shown below. When searching MID, first select the light blue vPIC MID button on the right side of the screen. Once the button has been selected, the Manufacturer's Information Database will open.

Welcome to vPIC

The NHTSA Product Information Catalog and Vehicle Listing (vPIC) is a consolidated platform that presents data collected within the manufacturer reported data from CFR 49 Parts 551 – 574 for use in a variety of modern tools. NHTSA's vPIC platform is intended to serve as a centralized source for basic Vehicle Identification Number (VIN) decoding, Manufacturer Information Database (MID), Manufacturer Equipment Plant Identification and associated data.

More Info >

Data within vPIC is primarily focused on Model Years 1995 and forward.
vPIC Patterns are based on Vehicle Identification Number (VIN) specifications received from the manufacturers following the 565 standard.



For any additional information and questions: Contact NHTSA Manufacturer Helpdesk at manufacturerinfo@dot.gov or 1-888-399-3277

Resource Links:

- NHTSA New Manufacturers Handbook (PDF) and Manufacturer Identification Form
- CFR 49 Part 551 (Foreign manufacturers and importers – designation of an agent for service of process)
- CFR 49 Part 565 (Vehicle Identification Number Guidance)
- CFR 49 Part 566 (Manufacturer Identification – Reporting Requirements)
- CFR 49 Part 574 (Tire Identification Number (TIN) Guidance)
- Suggested Designation of Agent for Service of Process Form (under 49 U.S.C A30164 and 49 C.F.R. Part 551, Subpart D)

Manufacturer Portal : a place to electronically submit required forms

- ✔ Submit new form for:
  VIN Requirements (49 CFR Part 565),
  Manufacturer Identification (49 CFR Part 566),
  Designation of U.S. Agent (49 CFR Part 551, Subpart D),
  Equipment Plant Code Request (for Brake Hose, Glazing, New Tires, or Tire Retread).
- ✔ Check status for already submitted requests.

Manufacturer's Portal

MID : Manufacturer Information Database

- ✔ View manufacturer information (Address, Products Manufactured, Makes, etc.).
- ✔ View or download documents submitted to NHTSA by Manufacturers as it relates to CFR 49 Part 566, CFR 49 Part 565 and CFR 49 Part 574).
- ✔ Obtain World Manufacturer Identifiers (WMIs) assigned to a manufacturer assigned by SAE and referenced in vPIC.

vPIC MID

VIN Decoder

- ✔ Decode a Vehicle Identification Number (VIN) for regulated vehicle types.
- ✔ Obtain manufacturer data describing the vehicle basic information.
- ✔ Print or obtain an extract of data from vPIC on a vehicle and/or trailer VIN.

vPIC Decoder

API : Application Programing Interface

- ✔ 15 APIs for use by developers, programmers or researchers interested in obtaining raw Vehicle or Manufacturer data from vPIC.
- ✔ Supports multiple data output formats like XML, CSV, JSV and JSON.
- ✔ Ability to batch decode a set of VINs.

vPIC API

Data within vPIC represents vehicles intended for sale or importation into the United States. Attempting to search on vehicles not intended for sale or importation into the US will result in a limited data result.

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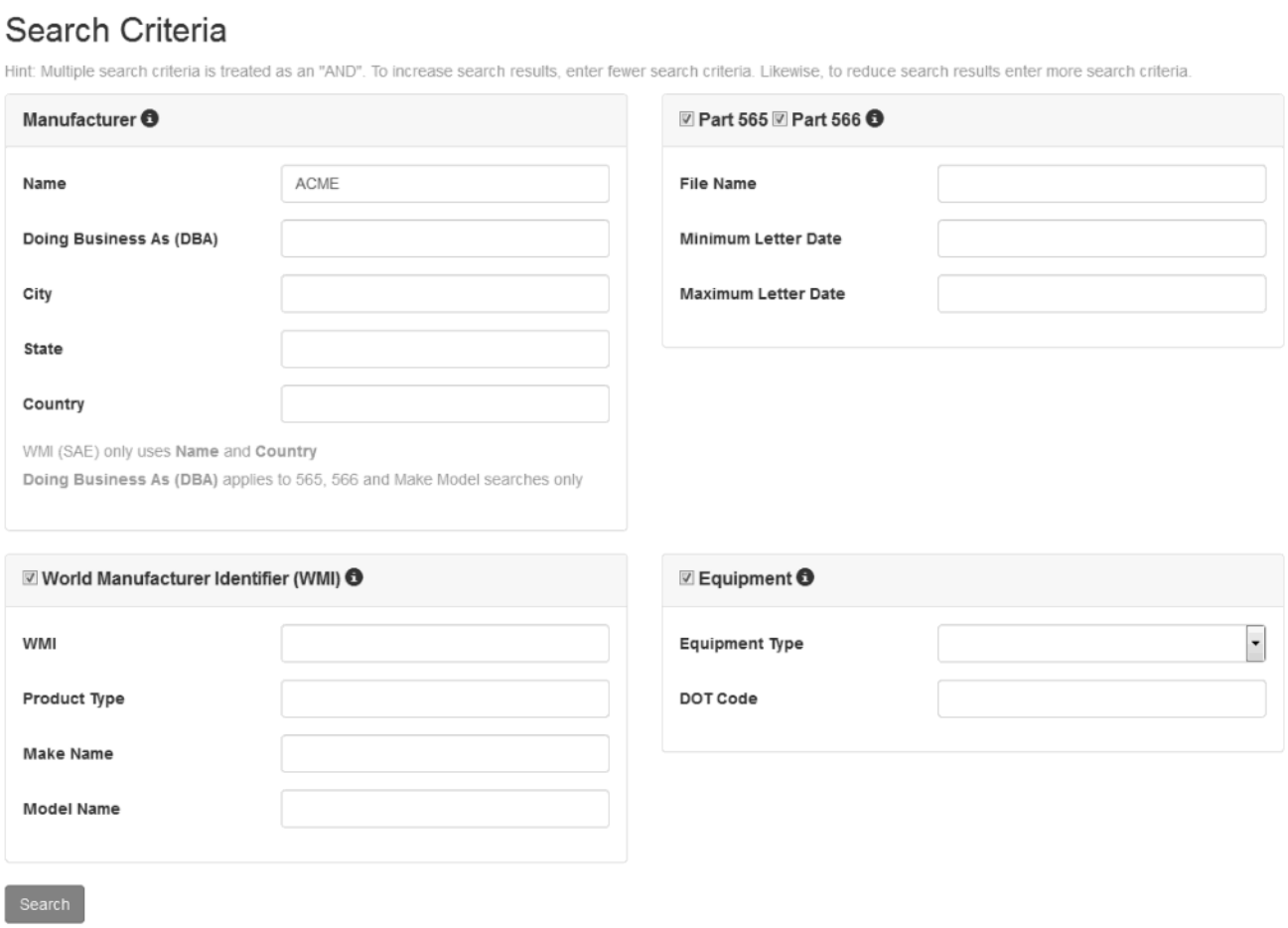
Appendix 6 (Continued) - How to Search NHTSA's Manufacturers' Information Database

Sample Search Screen

Please note that manufacturers often have assumed or fictitious business names, or in some countries such as China, province names are often part of the business names. This page is the Manufacturer's Information Database where any NHTSA registered manufacturer can be searched by name, WMI, and Equipment as well as Part 565 and 566. To search different criteria, simply select the appropriate checkbox in the title of the section. For example, the small check mark in the box to the left of, "Part 565" will assure that 565 results will appear. ACME Group LLC is used as an example.



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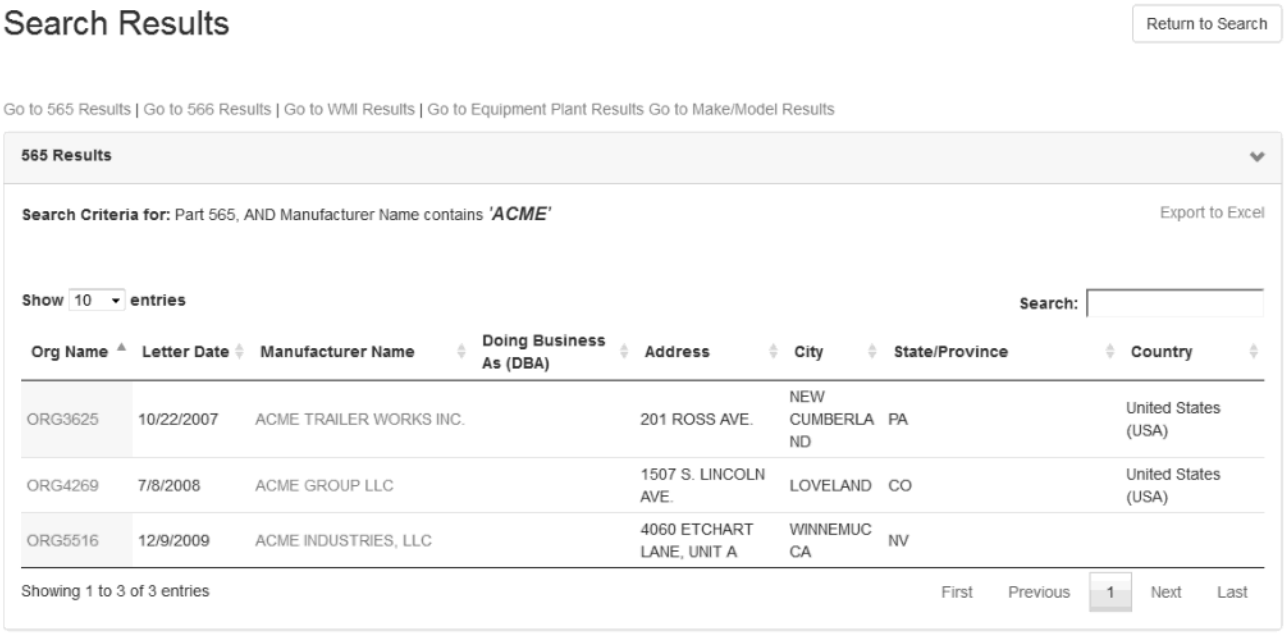
Appendix 6 (Continued) - How to Search NHTSA's Manufacturers' Information Database

When searching for a 565 submittal using MID it is most helpful to search by name. In this example, "ACME" was the only search term. This brought up all registered manufacturers that have submitted a 565 with "ACME" somewhere in the name. To narrow the results, select "Return to Search" and add in more information specific to the manufacturer. Once the correct search result is found, then by selecting the blue ORG link on the left hand side, the full submittal can be viewed. Each manufacturer name can be clicked as well in order to view details pertaining to the company. Each result; 565, 566, WMI and Equipment, can be searched for by name using the same process if the correct boxes are checked.



Search Results

Return to Search

Go to 565 Results | Go to 566 Results | Go to WMI Results | Go to Equipment Plant Results Go to Make/Model Results

565 Results

Search Criteria for: Part 565, AND Manufacturer Name contains ***'ACME'***

Export to Excel

Show 10 entries

Search:

Org Name	Letter Date	Manufacturer Name	Doing Business As (DBA)	Address	City	State/Province	Country
ORG3625	10/22/2007	ACME TRAILER WORKS INC.		201 ROSS AVE.	NEW CUMBERLAND	PA	United States (USA)
ORG4269	7/8/2008	ACME GROUP LLC		1507 S. LINCOLN AVE.	LOVELAND	CO	United States (USA)
ORG5516	12/9/2009	ACME INDUSTRIES, LLC		4060 ETCHART LANE, UNIT A	WINNEMUCCA	NV	

Showing 1 to 3 of 3 entries

First Previous 1 Next Last

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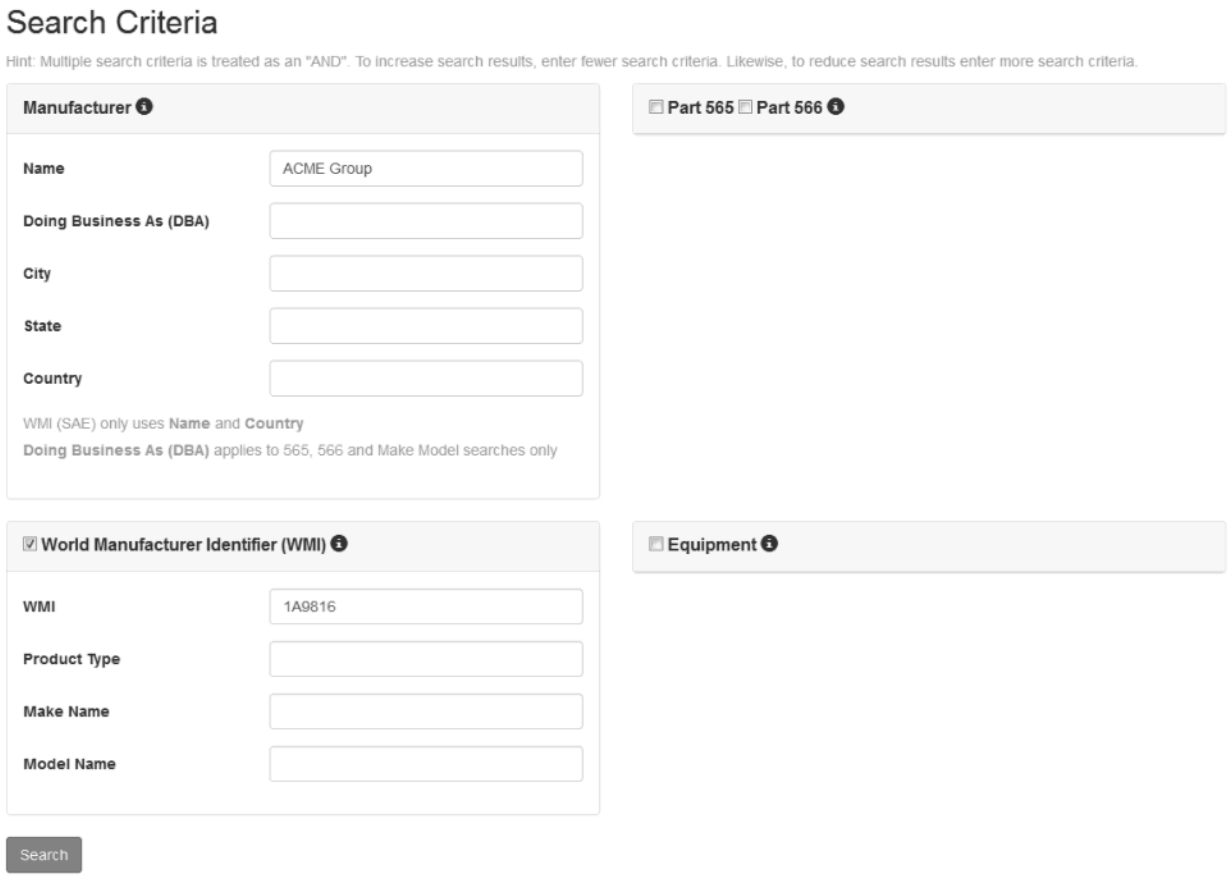
Appendix 6 (Continued) - How to Search NHTSA's Manufacturers' Information Database

World Manufacturer Identifiers (WMI) can be searched directly through typing the code into the proper section as shown below. Entering the name above is not necessary, but will help if the WMI being searched is not complete.



Scroll down for more results, including any applicable WMI assignment, etc.

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Appendix 6 (Continued) - How to Search NHTSA's Manufacturers' Information Database

The WMI search results page is much the same as the previous page, but lists specifically WMI. There is no submission to select, such as the blue ORG links above, but the information is readily available on the results page itself.

Search Results

Return to Search

Go to WMI Results | Go to Make/Model Results

WMI (SAE) Results

Search Criteria for: WMI contains *'1A9816'*

Export to Excel

Show 10 **entries** **Search:**

WMI	Manufacturer	Address Line 1	Address Line 2	Address Line 3	Postal Code	Country	Phone	Vehicle Type
1A9816	Acme Industries LLC	4060 Etchart Ln Apt A	Winnemucca NV 89445-2853		89445-2853	United States	(775)621-5870	Trailer

Showing 1 to 1 of 1 entries First Previous 1 Next Last

Go to WMI Results | Go to Make/Model Results

Make Model Results (this is partial results only based on 565 submittal)

Search Criteria for: WMI contains *'1A9816'*

Export to Excel

Show 10 **entries** **Search:**

WMI	Manufacturer Name	Doing Business As (DBA)	Make	Model	Address	Address 2	City	State/Province	Postal Code	Country	Product Type
1A9816	ACME GROUP LLC		Acme Group	Acme Group	1507 S. LINCOLN AVE.		LOVELAND	CO	80537	United States (USA)	Trailer

Showing 1 to 1 of 1 entries First Previous 1 Next Last

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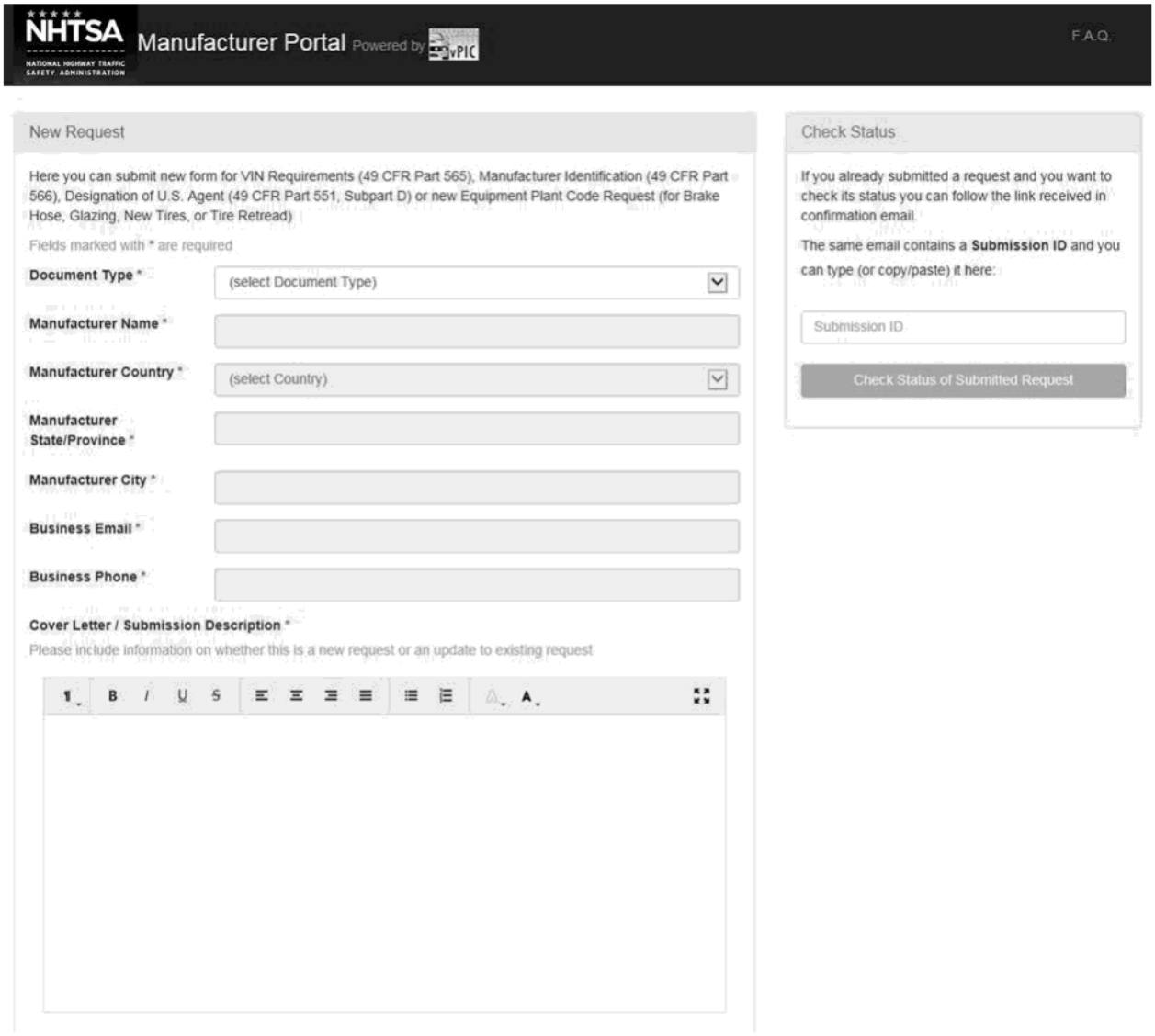
Appendix 7 - How to Enter Submittals Using NHTSA's Manufacturers Portal

NHTSA Manufacturer Portal is a system for entering information into NHTSA's database and registering as a NHTSA compliant manufacturer. To enter information into the Portal, first the document type must be selected. Document types can be seen in a drop down list and once selected will allow the remainder of the fillable form to be completed. Each section with a red asterisk (*) must be entered or the form will not allow the user to move forward. The first page of the submittal process is held constant, as shown above. Once that page has been filled out, information requirements change based on which form type is being submitted (i.e. 551, 565, 566, or various equipment, etc.).



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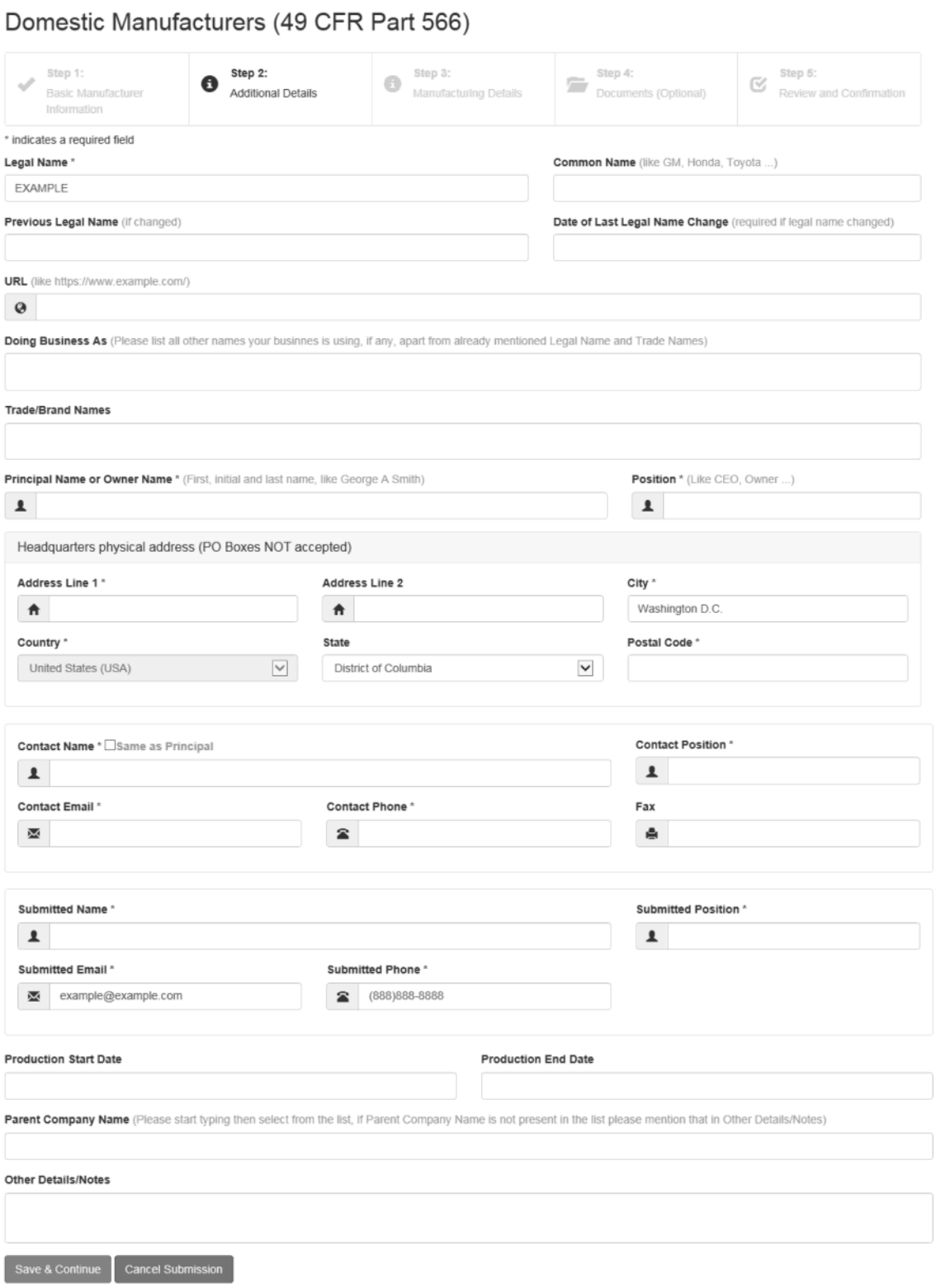
Appendix 7 (Continued) - How to Enter 566 Submittals Using NHTSA's Manufacturer Portal

A 566 form submittal covers the manufacturer and product information and proceeds as is shown below. On the top of the page is a guide following the progress of the submission as it is completed. A manufacturer will have to fill out the form below with as much information as possible before moving onto the next section titled, "Manufacturing Details".



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Appendix 7 (Continued) - How to Enter 566 Submittals Using NHTSA's Manufacturer Portal

At this stage the manufacturer must select all applicable Manufacturer Type, Vehicle Type, and Equipment. GVWR of each Vehicle Type that is produced by the manufacturer must be listed, but do not mark any items on the form that are not manufactured.

Domestic Manufacturers (49 CFR Part 566)

Step 1: Basic Manufacturer Information | Step 2: Additional Details | **Step 3: Manufacturing Details** | Step 4: Documents (Optional) | Step 5: Review and Confirmation

Manufacturer Type Please select all that apply

- ☐ **Completed Vehicle Manufacturer** - a manufacturer of vehicles that require no further manufacturing operations to perform their intended function
- ☐ **Incomplete Vehicle Manufacturer** - a manufacturer of incomplete vehicles, as defined above
- ☐ **Intermediate Manufacturer** - a manufacturer (other than the incomplete vehicle manufacturer or final-stage manufacturer) who performs manufacturing operations on a vehicle manufactured in two or more stages.
- ☐ **Final-Stage Manufacturer** - a manufacturer who performs such manufacturing operations on an incomplete vehicle that it becomes a completed vehicle
- ☐ **Alterer** - a person who alters by addition, substitution, or removal of components (other than readily attachable components), a certified vehicle before the first purchase of the vehicle other than for resale

Vehicle Type Please select all that apply

Remove Primary

Select Vehicle Type	Primary	GVWR From	GVWR To
☐ Motorcycle	○		
☐ Passenger Car	○		
☐ Truck / Chassis Cab	○		
☐ Scooter	○		
☐ Bus	○		
☐ Trailer	○		
☐ Multipurpose Passenger Vehicle (MPV)	○		
☐ Cargo Van	○		
☐ Low Speed Vehicle (LSV)	○		
☐ Incomplete Vehicle	○		

Equipment Please select all that apply

☐ Tires	☐ Rims	☐ Brake Hoses
☐ Brake Fluid	☐ Seat Belts	☐ Lamps, Reflectors and Assoc. Equipment
☐ CNG Containers	☐ Motorcycle Helmets	☐ Child Restraint Systems
☐ Platform Lifts	☐ Rear Impact Guards	☐ Triangular Warning Devices
☐ Glazing	☐ Retread	

Save & Continue | Cancel Submission

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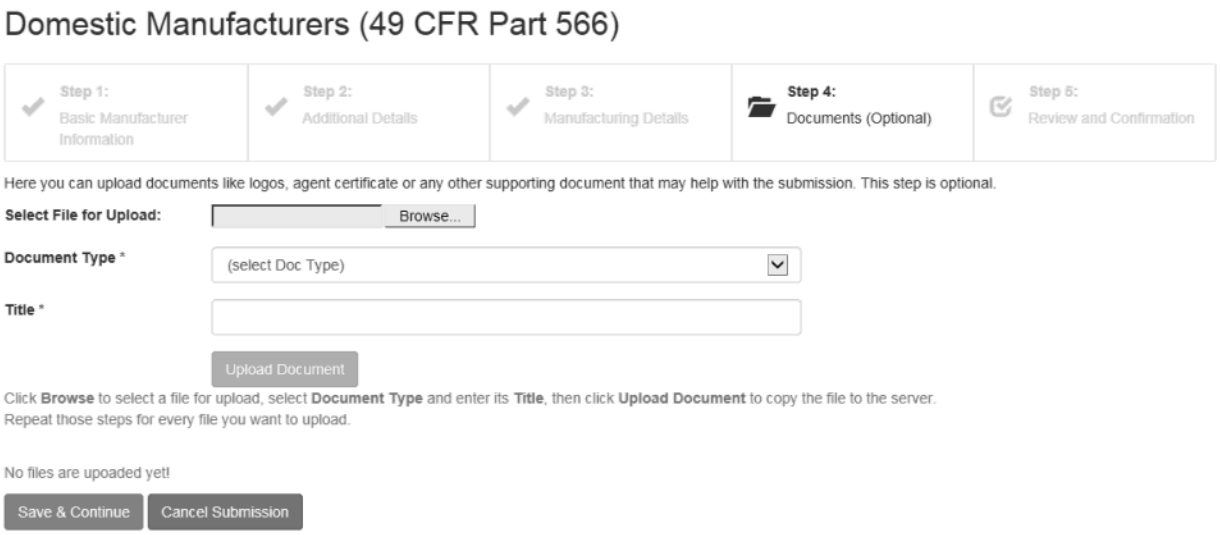
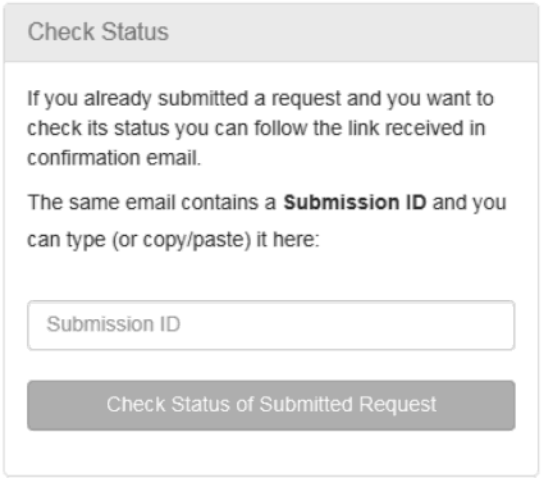
Appendix 7 (Continued) - How to Enter 566 Submittals Using NHTSA's Manufacturer Portal

Upload any necessary documents that will benefit a submission to NHTSA. After submitting any relevant documents, move onto the last step. Step 5 is simply to review and confirm that all information is correct and complete in order to pursue registration with NHTSA.



Once the process is complete, the submission can be reviewed and the progress can be checked at any time via a Submission ID. The Submission ID will be assigned to the submission after Step 5 is complete and will be visible at the completion page on Portal, as well as sent to the provided email. Simply type the ID into the Check Status box on the right side of the Manufacturer Portal home page. A confirmation email will be sent to provide notice of any acceptance or rejection of the submittal.



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Appendix 7 (Continued) - How to Enter Equipment Plant Code Requests Using NHTSA's Manufacturer Portal

Equipment Plant code requests can be submitted through the Manufacturer Portal and this Handbook has chosen to use a New Tire Plant code request as an example. Other equipment plant code requests are similar enough to New Tire Plant requests that one example should serve for all. If there are any questions about the different submissions, then please contact the NHTSA Manufacturer Helpdesk at manufacturerinfo@dot.gov or 1-888-399-3277. The second step in the filing process, shown below, requires a manufacturer to enter information with red asterisks (*) as a marking for required fields.

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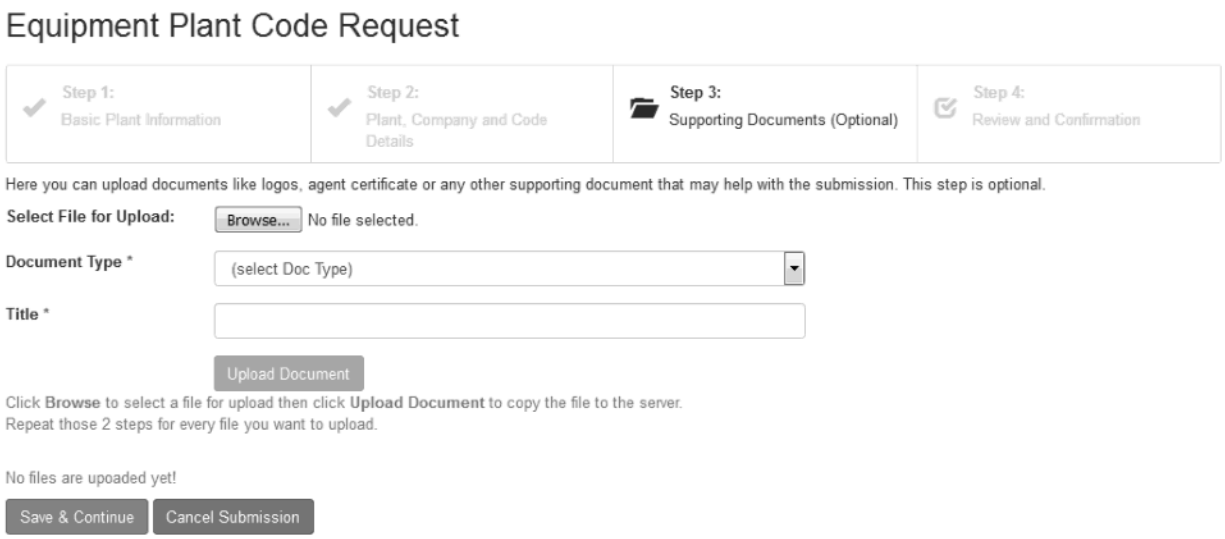
Appendix 7 (Continued) - How to Enter Equipment Plant Code Requests Using NHTSA's Manufacturer Portal

Step 3 in the Equipment plant code request requires any additional documents to be submitted, such as Agent Certificates, Logos, and other relevant documents. If there are no additional relevant documents for a manufacturer to submit, then the section can be skipped.



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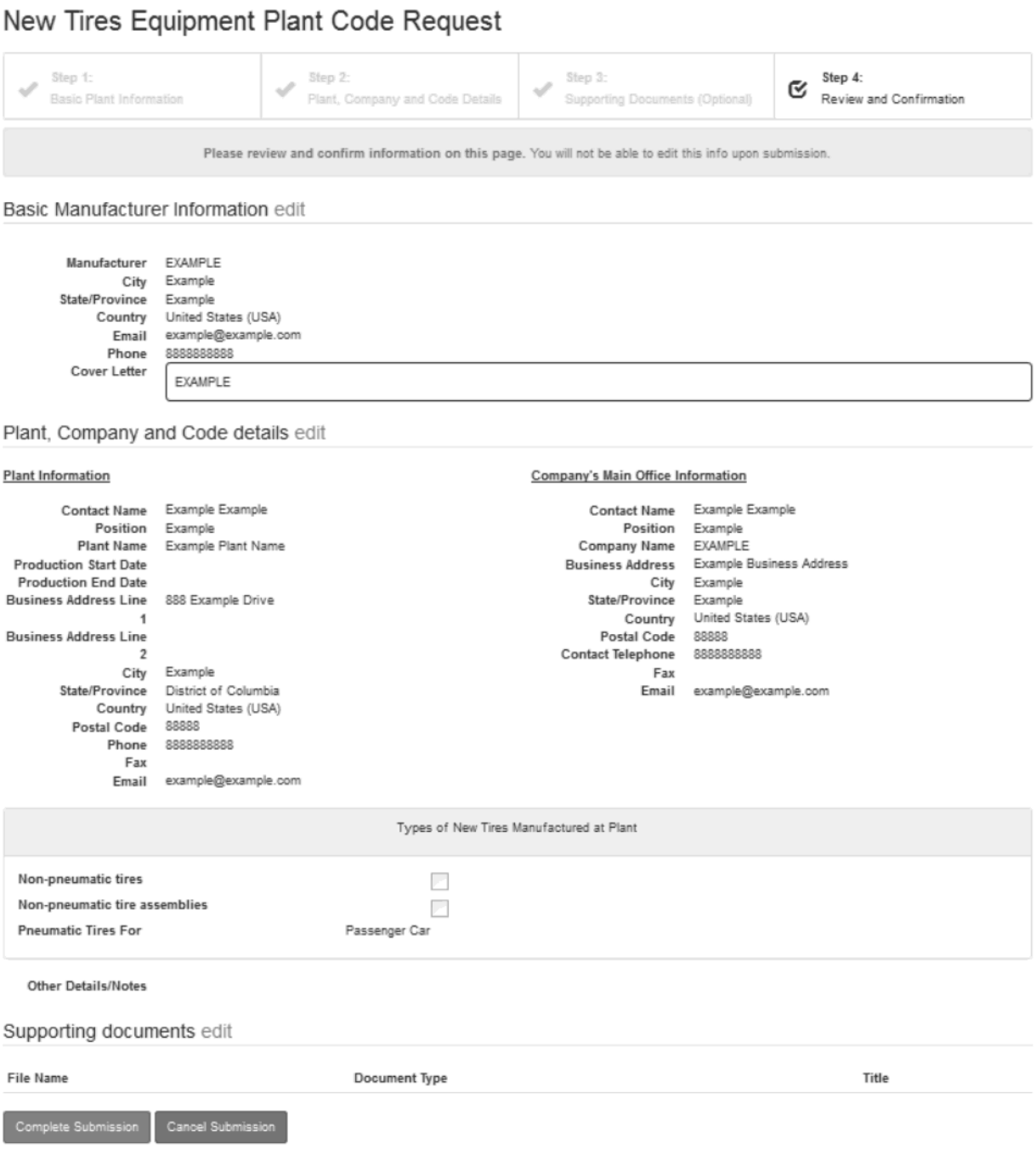
Appendix 7 (Continued) - How to Enter Equipment Plant Code Requests Using NHTSA's Manufacturer Portal

The fourth and final step in the equipment plant code request process is to review and confirm the information the manufacturer has entered into NHTSA Manufacturer Portal. If all the information is correct upon review, then click on the blue, "Complete Submission". Once the submission has been completed, a confirmation number will be available through the Manufacturer Portal itself, as well as sent to the email provided on the form. This number is the Submission ID, which can be used to check on the progress of the submission at any time by entering it into the "Check Status" box on the Manufacturer Portal homepage.



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Appendix 8 - FMVSS Applicability to Vehicle Type and Equipment Items

FMVSS Applicability		Passenger Car	Bus		MPV		Truck		School Bus		Trailer		Motorcycle	LSV	Equipment
FMVSS No.	FMVSS Description		GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg			
101	Controls and Displays	●	●	●	●	●	●	●	●	●					
102	Transmission shift lever sequence	●	●	●	●	●	●	●	●	●					
103	Windshield defrosting and defogging systems	●	●	●	●	●	●	●	●	●					
104	Windshield wiping and washing systems	●	●	●	●	●	●	●	●	●					
105	Hydraulic and electric brake systems	●	1	●	1	●	1	●	1	●					
106	Brake hoses	●	●	●	●	●	●	●	●	●	●	●	●		●
108	Lamps, reflective devices and associated equipment	●	●	●	●	●	●	●	●	●	●	●	●		●
109	New pneumatic and certain specialty tires	2	2		2		2		2		2				●
110	Tire selection & rims for vehicles with GVWR<4536 kg	●	●		●		●		●		●				●
111	Rearview mirrors	●	●	●	●	●	●	●	●	●			●		
113	Hood latch systems	●	●	●	●	●	●	●	●	●					
114	Theft protection	●	3		●		●		3						
116	Motor vehicle brake fluids	●	●	●	●	●	●	●	●	●	●	●	●		●
117	Retreaded pneumatic tires (for use on passenger cars)														●
118	Power-operated window, partition and roof panel systems	●			●		●								
119	New pneumatic tires for vehicles with GVWR>4536 kg & MC		4a	4	4a	4	4a	4	4a	4	4a	4	●		●
120	Tire selection & rims for vehicles with GVWR>4536 kg & MC			●		●		●		●		●	●		●
121	Air brake systems 5		●	●			●	●	●	●	●	●			
122	Motorcycle brake systems												●		

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Appendix 8 (Continued) - FMVSS Applicability to Vehicle Type and Equipment Items

FMVSS Applicability		Passenger Car	Bus		MPV		Truck		School Bus		Trailer		Motorcycle	LSV	Equipment
FMVSS No.	FMVSS Description		GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg			
123	Motorcycle controls and displays												●		
124	Accelerator control systems	●	●	●	●	●	●	●	●	●					
125	Warning devices														●
126	Electronic stability control systems	●	●		●		●		●						
129	New non-pneumatic tires for passenger cars	2													●
131	School bus pedestrian safety devices								6	6					
135	Light vehicle brake systems	●	7		7		7		7						
138	Tire pressure monitoring systems	●	8		8		8		8						
139	New pneumatic radial tires for light vehicles	2	2		2		2		2						●
201	Occupant protection in interior impact	●	9		●		●		9						
202a	Head restraints	●	●		●		●		10						
203	Impact protection for driver from steering control system	●	●		●		●		●						
204	Steering control rearward displacement	●	11		11		11		11						
205	Glazing materials	●	●	●	●	●	●	●	●	●			●	●	●
206	Door locks and door retention components	●			●	●	●	●							
207	Seating systems	●	●	●	●	●	●	●	●	●					
208	Occupant crash protection	●	●	●	●	●	●	●	●	●					
209	Seat belt assemblies														●

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Appendix 8 (Continued) - FMVSS Applicability to Vehicle Type and Equipment Items

FMVSS Applicability		Passenger Car	Bus		MPV		Truck		School Bus		Trailer		Motorcycle	LSV	Equipment
FMVSS No.	FMVSS Description		GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg			
210	Seat belt assembly anchorages	●	●	●	●	●	●	●	●	●					
212	Windshield mounting	●	●		●		●		●						
213	Child restraint systems	●	●	●	●	●	●	●	●	●					●
214	Side impact protection	12	12		12		12		12						
216	Roof crush resistance	●	13		13		13								
216a	Roof crush resistance (Upgraded Standard) 14	●	●		●		●		●						
217	Bus emergency exits and window retention and release		●	●					●	●					
218	Motorcycle helmets														●
219	Windshield zone intrusion	●	●		●		●		●						
220	School bus rollover protection								●	●					
221	School bus body joint strength								●	●					
222	School bus passenger seating and crash protection								●	●					
223	Rear impact guards														●
224	Rear impact protection											15			
225	Child restraint anchorage systems	●			16		16		●						
226	Ejection Mitigation	17	17		17		17		17						
301	Fuel system integrity	●	●		●		●		●	●					
302	Flammability of interior materials	●	●	●	●	●	●	●	●	●					
303	Fuel systems of compressed natural gas vehicles	●	●		●		●		●	●					
304	Compressed natural gas fuel system integrity														●

Appendix 8 (Continued)- FMVSS Applicability to Vehicle Type and Equipment Items

FMVSS Applicability		Passenger Car	Bus		MPV		Truck		School Bus		Trailer		Motorcycle	LSV	Equipment
FMVSS No.	FMVSS Description		GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg	GVWR ≤ 4,536 kg	GVWR > 4,536 kg			
305	Electric-powered vehicles; electrolyte spillage and shock protection	●	●		●		●		●						
401	Interior trunk release	18													
403	Platform lift systems for motor vehicles 19														●
404	Platform lift installations in motor vehicles 19	●	●	●	●	●	●	●	●	●	●	●			
500	Low-speed vehicles 20													●	21

Endnotes:

1	GVWR > 3,500 kg (7,716 pounds)
2	See FMVSS 110, S4.1
3	Applicable to a bus with an automatic transmission and a "park" position (brake transmission shift interlock) See FMVSS 114, S5.3
4	See FMVSS 120, S5.1.1
4a	New pneumatic light truck tires with a tread depth of 18/32 inch or greater, for use on motor vehicles with a GVWR of 4,536 kilograms (10,000 pounds) or less and bias ply light truck tires
5	Except certain vehicles -- See FMVSS 121 for list
6	Except multifunction school activity buses
7	GVWR < 3,500 kg (7,716 pounds)
8	Except vehicles with dual rear wheels
9	Upper head impacts (S6) limited to buses with GVWR ≤ 3,860 kg (8,509 pounds)
10	Driver's seat only
11	Unloaded vehicle weight < 2,495 kg (4,000 pounds)
12	For crash test, Bus, MPV, Truck GVWR < 2,722 kg (6,000 pounds); adv dummies & pole test phase-in begins 9/1/2010
13	GVWR < 2,722 kg (6,000 pounds); See FMVSS No. 216 for phase-out schedule
14	See FMVSS 216a for phase-in schedule
15	Certain trailer types are exempt
16	GVWR < 3,855 kg (8,500 pounds)
17	Except walk-in vans, modified roof vehicles, convertibles, or certain law enforcement vehicles, correctional institution vehicles, taxis and limousines. Phase-in began 9/1/2013
18	Passenger cars with a trunk, not a back door
19	Platform lifts designed to carry passengers into and out of a vehicle
20	GVWR < 1,361 kg (3,000 pounds); Max. Speed 40km/h (25mph); Min. Speed 32.2km/h (20 mph)
21	See list in S5(b) of FMVSS 500

Appendix 9 – Sample Tire Registration Form – Independent Distributors and Dealers

IMPORTANT

In case of a recall, we can reach you only if we have your name and address. You **MUST** send in this card to be on our recall list.

Do it today.

SHADED AREAS MUST BE FILLED IN BY SELLER

	QTY	TIRE IDENTIFICATION NUMBERS
CUSTOMER'S NAME (Please Print)		
CUSTOMER'S Address		
CITY STATE ZIP CODE		
NAME OF DEALER WHICH SOLD TIRE		
DEALER'S ADDRESS		
CITY STATE ZIP CODE		

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

NHTSA Manufacturer Requirements Guide for Applicable Laws and Regulations

For manufacturers of motor vehicles or motor vehicle equipment (as defined in 49 U.S.C. §30102) it is recommended that you seek professional legal counsel to ensure you are meeting the requirements of Chapter 301 of Title 49 of the U.S. Code (U.S.C.) and Title 49 of the Code of Federal Regulations (C.F.R.) Parts 500 – 599. The information provided below is incomplete and is simply a guide to **some** of the laws and regulations that manufacturers must meet.

49 U.S.C. §30102 Definitions
(a)(5) "manufacturer" means a person—
(A) manufacturing or assembling motor vehicles or motor vehicle equipment; or
(B) importing motor vehicles or motor vehicle equipment for resale.
(a)(6) "motor vehicle" means a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line.
(a)(7) "motor vehicle equipment" means—
(A) any system, part, or component of a motor vehicle as originally manufactured;
(B) any similar part or component manufactured or sold for replacement or improvement of a system, part, or component, or as an accessory or addition to a motor vehicle; or
(C) any device or an article or apparel (except medicine or eyeglasses prescribed by a licensed practitioner) that is not a system, part, or component of a motor vehicle and is manufactured, sold, delivered, offered, or intended to be used only to safeguard motor vehicles and highway users against risk of accident, injury, or death.

To view the full requirements of 49 U.S.C. Ch. 301, visit https://www.gpo.gov/fdsys/browse/collectionUScode.action and select the most recent year available. From the next screen, select Title 49, then Subtitle VI, then Part A, and then then click the PDF link to the right of Chapter 301. From this point, headings for each provision can be reviewed to determine which ones apply to your situation as a manufacturer.

To review the full requirements of 49 C.F.R. Parts 500-599, visit http://www.ecfr.gov and select Title 49 "Transportation". Then select parts 500-571 or 572-599 "National Highway Traffic Safety Administration, Department of Transportation". From this point, headings for each part can be reviewed to determine which ones apply to your situation as a manufacturer.

The **repeating regular monthly and quarterly reporting requirements** are described in 49 C.F.R. Part 579 -Reporting of Information and Communications about Potential Defects.

As a high-level, quick-reference guide, the following question tree can assist in determining some of the statutory and regulatory requirements manufacturers must meet.

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

Am I a "Manufacturer" ?

Yes, I am an vehicle mfr.

At a minimum you must meet the following requirements of 49 U.S.C. Ch. 301 and Title 49 of the C.F.R.
30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicles
30120 Remedies for defects and noncompliance
30122 Making safety devices and elements inoperative
30170 Criminal penalties
551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
563 Event data recorders *
565 Vehicle Identification Number (VIN)
567 Certification
568 Vehicles manufactured in two or more stages - All incomplete, intermediate, and final stage manufacturers of vehicles manufactured in two or mor stages
566 Manufacturer identification
571 Federal Motor Vehicle Safety Standards (FMVSS)
573 Defect and noncompliance responsibility and reports
576 Record retention
577 Defect and noncompliance notification
578 Civil and criminal penalties
579.5 Communications
579.11 Foriegn campaign reporting responsibilities
579.28 Due date of reports and other miscellaneous provisions
579.29 Manner of reporting
541-543 Theft prevention *
581 Bumper standards *
525, 526, 529, 531, 533, 535, 537, 538 Fuel economy *
583 Domestic content labeling *
575 Consumer information *
* (only apply to certain motor vehicles types)

What type of vehicle do I manufacture and what is my annual production?

579.21 - 5,000 or more light vehicles
579.22 - 100 or more buses, 500 or more emergency vehicles, 5,000 or more medium-heavy vehicles
579.23 - 5,000 or more motorcycles annually
579.24 - 5,000 or more trailers annually
579.27 - Fewer than 100 buses, 500 emergency vehicles, or 5,000 light vehicles

No

Stop here. You likley do not have any requirements for 49 U.S.C. Ch. 301 or 49 C.F.R. 500-599

Yes, I am an equpment mfr.

a minimum you must meet the following requirements of 49 U.S.C. Ch. 301 and Title 49 of the C.F.R.
30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicle equipment
30120 Remedies for defects and noncompliance
30122 Making safety devices and elements inoperative
30170 Criminal penalties
551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
573 Defect and noncompliance responsibility and reports
576 Record retention
577 Defect and noncompliance notification
578 Civil and criminal penalties
579.5 Communications
579.11 Foriegn campaign reporting responsibilities
579.27 Reporting requirements for manufacturers of equipment
579.28 Due date of reports and other miscellaneous provisions
579.29 Manner of reporting

There are 14 pieces of equipment covered by FMVSS: tires, rims, brake hoses, brake fluid, seat belt assemblies, lighting equipment, glazing, motorcycle helmets, child seats, CNG containers, platform lift systems for the mobility impaired, rear impact guards for trailers, triangular reflective warning devices, and pressure vessels / explosive devices.

Do I manufacture equipment covered by FMVSS?

No

Stop here. You likley do not have any additional requirements

Yes

30115 Certification of compliance
566 Manufacturer identification
571 Federal Motor Vehicle Safety Standards (FMVSS)
574 Tire identification and recordkeeping
575.103 Truck-camper loading
579.25 - Child restraint systems
579.26 - Tires
588 Child restraint systems recordkeeping requirements

NHTSA

Q&A: Defect Communications Reporting Requirements for Vehicle and Equipment Manufacturers Pursuant to 49 CFR § 579.5

Why is it important to submit defect communications to NHTSA?

Because it's the law. Under 49 CFR § 579.5, vehicle and equipment manufacturers are legally obligated to submit a copy of **all notices, bulletins, and other communications** issued by the manufacturer in regard to any defect, **whether or not it is safety-related**, to the National Highway Traffic Safety Administration so that NHTSA can determine whether a safety issue is involved and to engage in proactive communications with manufacturers where NHTSA believes there is a misunderstanding or misidentification of the risk or particular issue. Each violation of this requirement is subject to civil penalties of up to $21,000 per day.

Who must submit defect communications?

Regardless of the number of vehicles or pieces of equipment manufactured or assembled, the following entities must submit defect communications:

- Motor vehicle manufacturers
- Motor vehicle assemblers
- Motor vehicle equipment manufacturers
- Motor vehicle equipment assemblers
- Importers of motor vehicles for resale
- Importers of motor vehicle equipment for resale
- Any subsidiary or affiliate, and any subsidiary or affiliate of a parent corporation, of any of the above

How should defect communications be submitted?

Manufacturers must submit to NHTSA a readable copy (PDF files are recommended) of all notices, bulletins, and other communications that are sent to more than one manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser in the United States, regarding any defect in its vehicles or items of equipment (including any failure or malfunction beyond normal deterioration in use, or any failure of performance, or any flaw or unintended deviation from design specifications), whether or not such defect is safety-related. These communications must be accompanied by an index (see sample) that includes a concise summary of the subject matter of each communication and identifies the make, model, and model year of the affected vehicles (or, if this information is not available, identifying information for the affected equipment).

Defect communications must be submitted no later than **five working days** after the end of the month in which they are issued; in other words, this is a monthly submission requirement. If you do not have any submissions to make in a given month, it is recommended that you submit a letter stating so. Submit all defect communications via e-mail to mailto:tsb@dot.gov. Attachments cannot exceed 20 MB in size, per e-mail. Please be aware that for security reasons zip files are blocked and cannot be sent to NHTSA.

Note: Manufacturers must submit *safety recall-related* documents to NHTSA's Recall Management Division as required by 49 CFR Part 573. Please be aware that the deadline and submission requirements differ for *safety recall-related* documents.

Amphibious Passenger Vehicle Requirements under the National Highway Traffic Safety Administration (NHTSA)

Marriott Evergreen Conference Resort

February 16, 2017

By:

Christopher J. Bonanti

Senior Managing Consultant

Engineering Systems, Inc.

Agenda

- Why Are We Here?
- NHTSA Overview
- Vehicle Safety Enforcement Program
- Armed Forces Vehicles
- Federal Motor Vehicle Safety Standards (FMVSS)
- Part 556: Vehicle Identification Number (VIN) Requirements
- Part 567: Certification
- Part 573: Defect and Noncompliance Responsibility and Reports
- Part 577: Defect and Noncompliance Notification
- Part 579: Reporting of Information and Communications about Potential Defects
- Part 580: Odometer Disclosure Requirements

Why Are We Here?

Accident Investigated by NTSB

- Amphibious Passenger Vehicle (APV)
- DUCK 6 of Ride the Ducks Seattle
- Lane Crossover Collision With Motorcoach on State Route 99, Aurora Bridge, Seattle, Washington
- Occurred on September 24, 2015
- 5 Fatalities and 71 individuals injured

National Highway Traffic Safety Administration Overview

NHTSA's Mission

- To save lives, prevent injuries, and reduce traffic-related healthcare and other economic costs.

Rulemaking Authority from Congress

- Congress generally delegates rulemaking authority to a regulatory agency by enacting an "enabling" statute that:
  - Includes a provision delegating rulemaking authority to the agency with respect to a specified policy goal, e.g., vehicle safety; and
  - Specifies the factors that the agency must consider in deciding what rule to adopt.
- The Administrative Procedure Act (APA) generally establishes the process the agency must follow to establish a rule.
- NHTSA's main enabling statute is the National Traffic and Motor Vehicle Safety Act ("Vehicle Safety Act").

Vehicle Safety Act Requirements

- One of NHTSA's enabling statutes.
- To establish a Federal Motor Vehicle Safety Standard (FMVSS), must show that the FMVSS:
  - meets a safety need;
  - is practicable (technologically and economically); and
  - states its requirements in a way that permits compliance to be determined in an objective fashion.
- FMVSSs must be performance-oriented.
- FMVSSs must be appropriate for each vehicle type to which they apply.

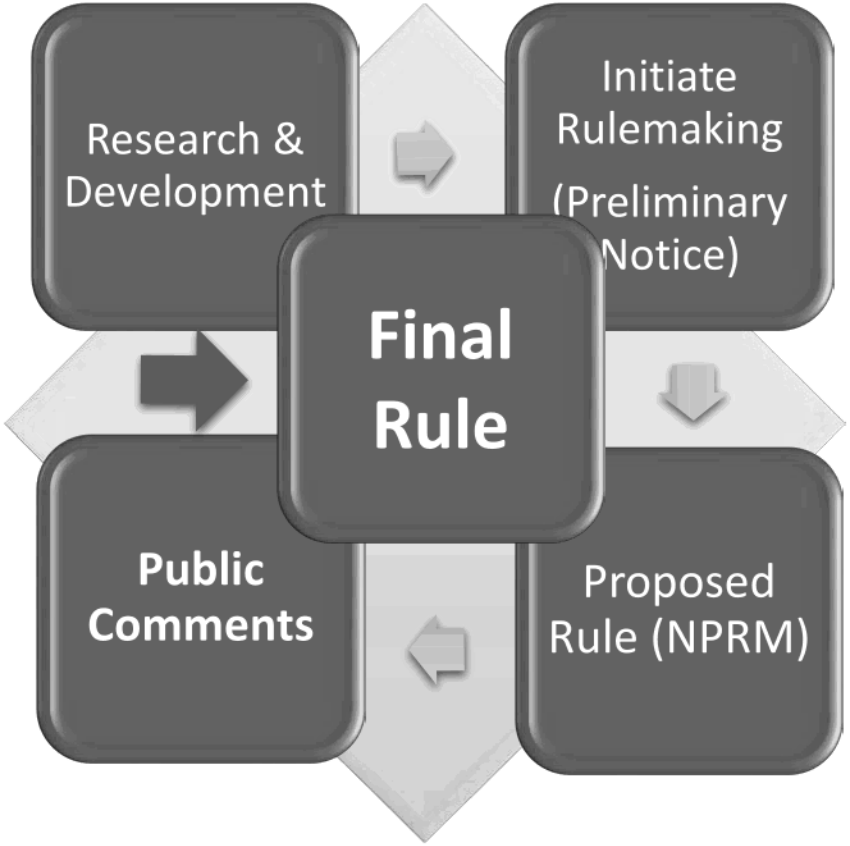
Meeting the Need for Safety

- NHTSA generally uses crash data and research to show that there is a safety need and that the regulation will address that need.
- Examples of NHTSA's crash information sources:
  - Fatality Analysis Reporting System (FARS)
    - Data on all fatal traffic crashes in the U.S.
  - National Automotive Sampling System (NASS)
    - More detailed, nationally representative data from police reports on fatal and nonfatal traffic crashes.
- Research to identify countermeasures and develop performance requirements and test procedures to evaluate their effectiveness.

Practicability

- Relates to the technical and economic feasibility of the standard.
- Establishes the outer boundary of what reasonable burdens can be imposed on the industry.
- Also considers whether or not the public is likely to accept and use the likely methods of compliance with the FMVSS.

Typical NHTSA Rulemaking Steps



Medium- and Heavy-Duty (MD/HD) Vehicle Fuel Efficiency and GHG Stds MYs 2014 – 2018/19+

BACKGROUND

- The Energy Independence and Security Act of 2007 requires that NHTSA establish a fuel efficiency program for on-road medium- and heavy-duty vehicles.

SUMMARY

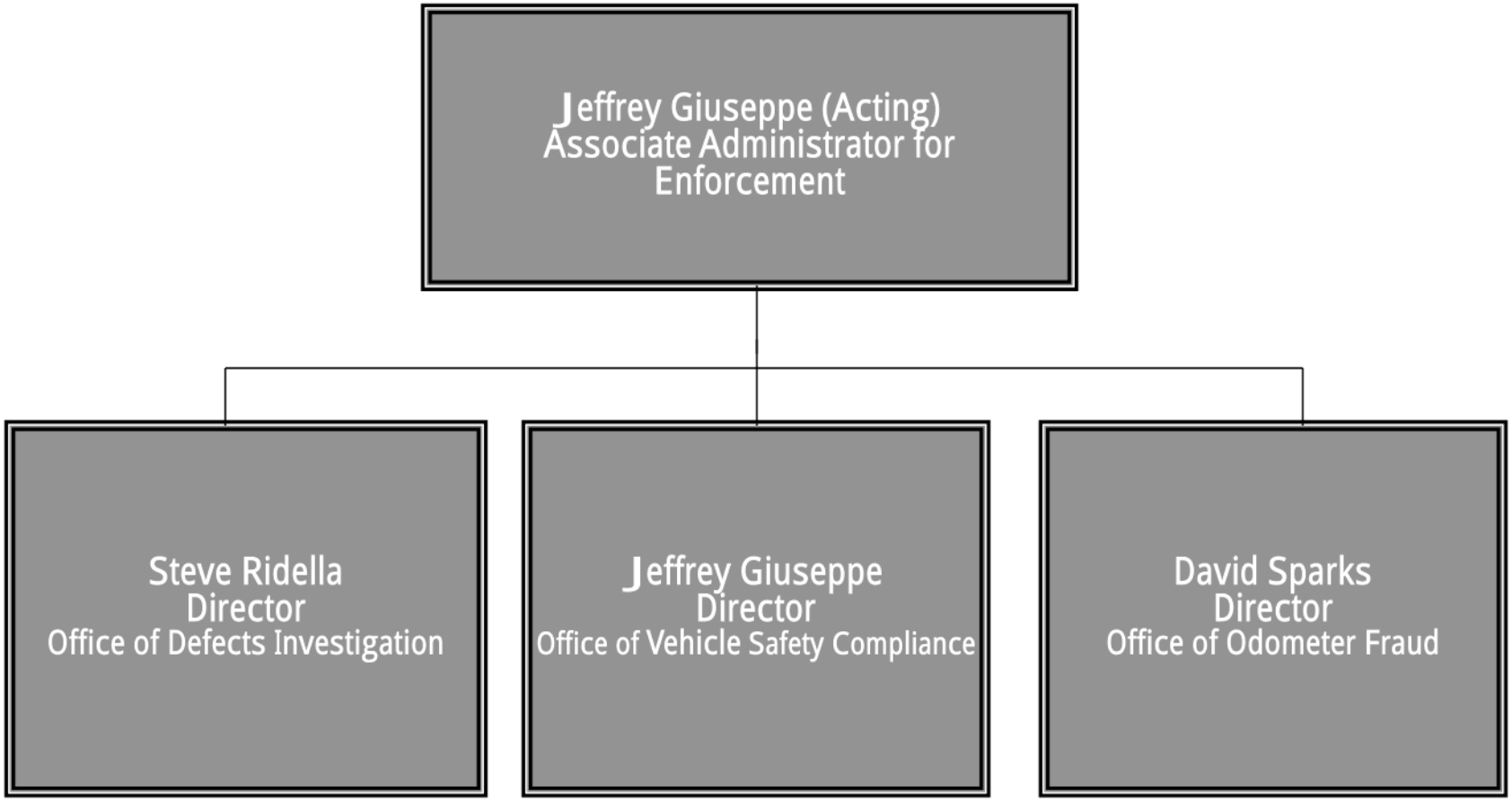
- NHTSA developed fuel efficiency standards and EPA developed GHG emissions standards in joint rulemaking.

STATUS

- Final rule was published September 15, 2011 (76 FR 57105).

Vehicle Safety Enforcement Program

Enforcement Program at NHTSA



Enforcement Responsibilities

Three primary types of enforcement:

- **Vehicle safety**: recalls for **defective** or **noncompliant** vehicles or equipment
- **Fuel economy**: civil penalties for violations of CAFE standards by manufacturers
- **Odometer fraud**: criminal prosecution of offenders

Vehicle Safety Enforcement

- Basic principles:
  - **Self-certification:** manufacturers must certify that their vehicles and equipment comply with the Federal Motor Vehicle Safety Standards (FMVSS).
  - **Prohibition:** a person may not manufacture for sale, offer for sale, introduce into commerce, or import a noncompliant vehicle or equipment.
  - **Importers <u>are</u> manufacturers:** Statutory definition of "manufacturer" states this, so importers share duties of manufacturers.

Vehicle Safety Enforcement

- Basic principles (continued):
  - **Duty to recall:** a manufacturer must do a recall (i.e., notify owner and provide remedy for the entire population of affected vehicles or equipment) if it learns of a safety defect or noncompliance or if NHTSA decides there is a defect or noncompliance.
  - **NHTSA may order a recall.**
  - **Defect** that creates an unreasonable risk to safety warrants a recall.
  - **Fully compliant vehicles or equipment may contain safety defects.**

Other Enforcement Tools

- **Civil penalties**
  - Current limits**: $21,000** per violation with a maximum of **$105,000,000** for a related series of violations
  - Chief Counsel issues penalty demand letter, negotiates with respondent, and considers statutory criteria (gravity of violation, size of business) and litigation risk in determining amounts
- **Injunctive relief** for violations of statute is available, but statute encourages NHTSA to provide notice and an opportunity to remedy the defect or noncompliance before seeking relief
- **Criminal penalties** are available for false reporting with intent to mislead NHTSA about defects that have caused death or serious injury (supplements basic false statement statute, 18 USC 1001)

Office of Defects Investigation

- "Defect related to motor vehicle safety" is a problem in performance, construction, a component, or material that creates an unreasonable risk to safety
- Nearly all recalls are voluntary: manufacturer either initiates recall on its own or is influenced to do so by NHTSA's investigation.
- NHTSA can order manufacturer to conduct recall after an opportunity for a hearing.
- NHTSA can seek enforcement of its order in court, where NHTSA must prove existence of a defect that creates an unreasonable safety risk.

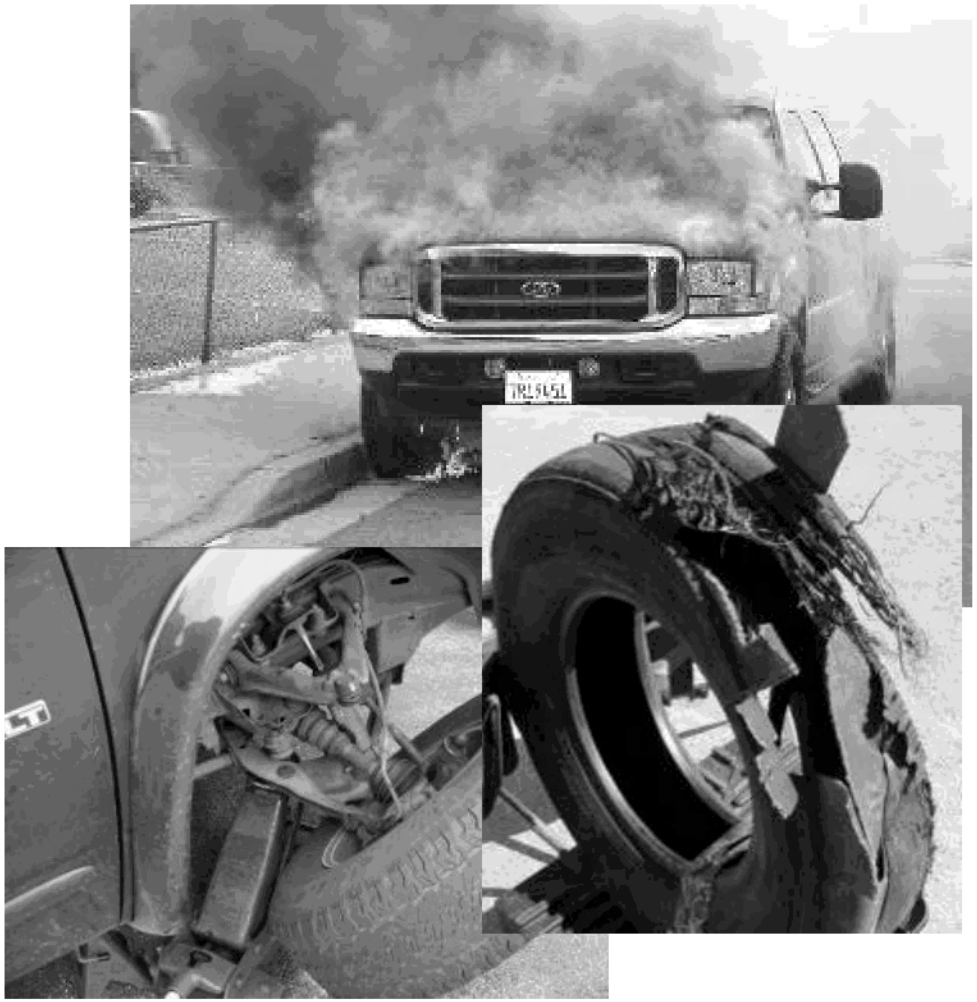
Defects Enforcement

- Office of Defects Investigation screens many sources of information about possible defects to identify likely candidates for investigation:
  - Complaints (nearly 50,000 per year): Auto Safety Hotline, letters, e-mail, vehicle owner questionnaire on Internet
  - Manufacturer notices, bulletins, advisories
  - Foreign recall reports
  - Early warning reports (death or injury incidents, damage claims, warranty claims, consumer complaints, field reports): huge volume of data
  - Petitions from public

Defects Enforcement

- Mechanical or electronic failures posing a safety risk

- Examples:
  - Stalling
  - Brake light switch
  - Fires
  - Tire failures
  - Fuel leaks
  - Ball joint fracture



Office of Vehicle Safety Compliance

- Manufacturers must comply with nearly 60 motor vehicle and equipment standards covering subjects such as crashworthiness (air bags, roof crush, etc.) and crash avoidance (brakes, ESC)
- OVSC purchases new vehicles and equipment and tests them for compliance with the FMVSS
- Requests and reviews manufacturer's certification data (manufacturers have duty to certify that their vehicles or equipment comply with standards)
- In the event of an apparent noncompliance, OVSC conducts investigations that may lead to a safety recall campaign and could result in the collection of civil penalties from the manufacturer
- OVSC also plays a vital role in rulemaking by developing compliance test procedures for inclusion in safety standards

Fuel Economy Enforcement

- OVSC administers CAFÉ fuel economy enforcement program
- Energy Policy and Conservation Act of 1975 (49 USC Chapter 329) authorizes NHTSA to collect civil penalties for violations of CAFE standards
- Penalty formula: [$5.50] X [each 1/10 of a mile per gallon by which the fuel economy standard exceeds the mileage achieved by the manufacturer's fleet] X [the number of vehicles in that fleet]
- Penalties can be offset by credits earned for exceeding the standard
- NHTSA bases penalty and credit determinations on final reports submitted by EPA
- Limited bases for compromising penalties: prevent insolvency; act of God, strike, or fire; FTC makes finding on effect on competitiveness
- Collect CAFE civil penalties (about $13 million each year)

- **Medium & Heavy Duty Fuel Efficiency Standards**

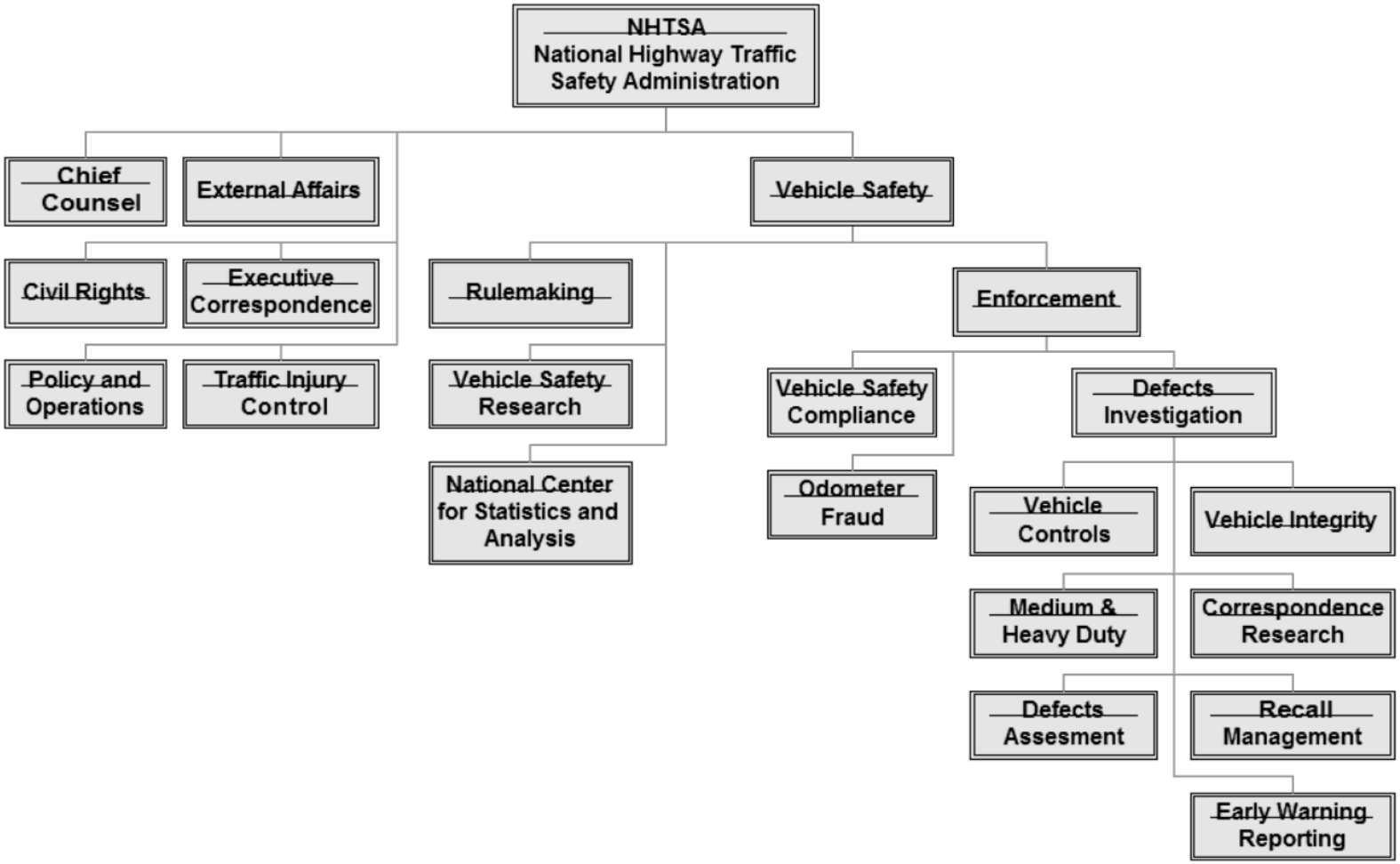
Office of Odometer Fraud Investigation

- Conduct criminal investigations concerning possible violations of odometer fraud laws
- Investigators are law enforcement officers who work closely with Department of Justice prosecutors
- Investigations have resulted in more than 250 convictions, plus millions of dollars in court ordered restitution

NHTSA Org Chart

Locating the

Office of Defects Investigation (ODI)

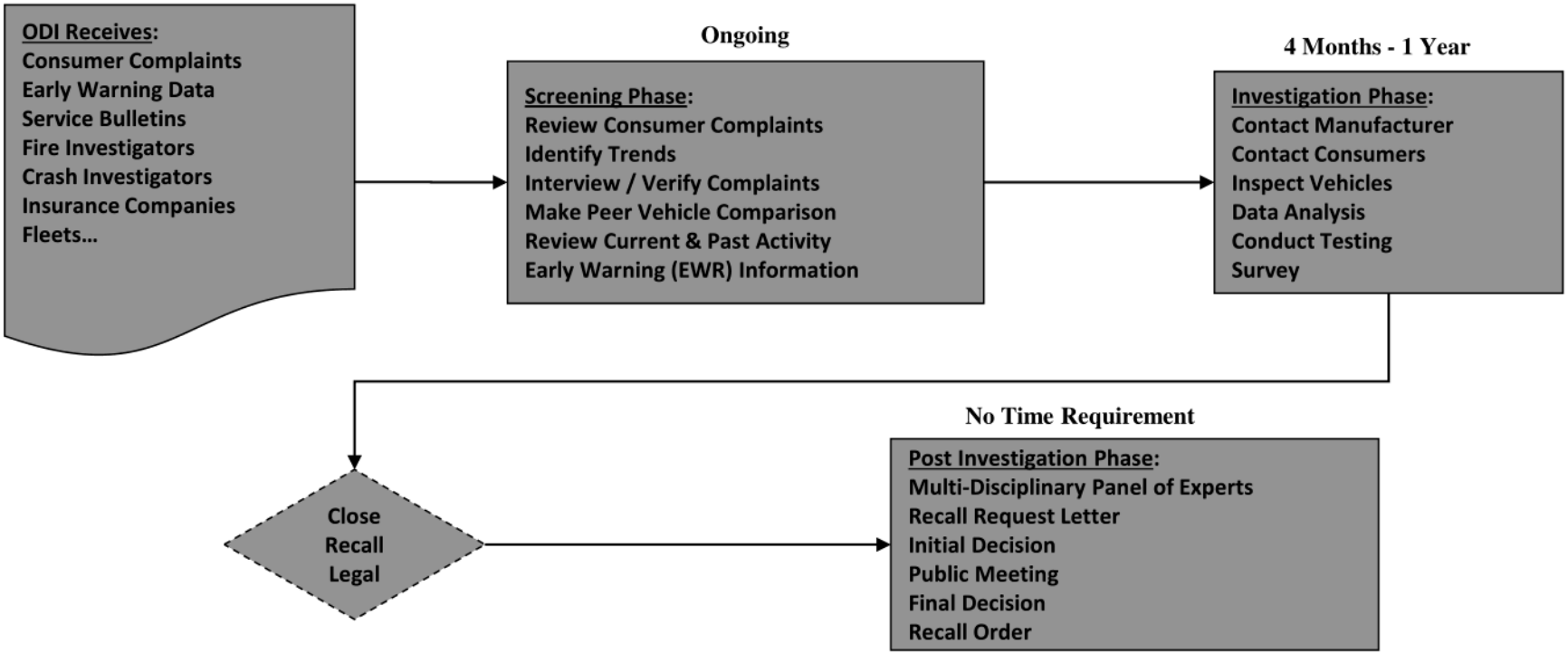


ESI

Safety vs. Compliance Defects

- **Non-Compliance Defect**: defect where a motor vehicle or covered motor vehicle equipment fails to meet one or more Federal Motor Vehicle Safety Standards (FMVSS) contained in 49 CFR Part 571.
- **Safety-Related Defect**: any defect in performance, construction, a component, or material that results in an unreasonable risk of accident or an unreasonable risk of death or injury in an accident.
  - A safety-related defect may exist on a vehicle even though it meets all FMVSS requirements.
  - A safety-related defect includes nonoperational safety.

Investigative Process



Code of Federal Regulations, Title 49

- Title 49 CFR - Transportation is one of fifty titles comprising the United States Code of Federal Regulations (CFR).
- Title 49 contains the regulations that vehicle manufacturers must meet.
- Parts relating to NHTSA's mission include:
  - 49 CFR Part 571, contains FMVSS
  - 49 CFR Part 573, defect and non-compliance reporting
  - 49 CFR Part 576, record retention
  - 49 CFR Part 577, defect and non-compliance notification
  - 49 CFR Part 578, civil penalties
  - 49 CFR Part 579, (TREAD Act) reporting requirements
    - Subpart A – General (Includes 579.5) Independent of production volume
    - Subpart B – Safety Recalls & Campaigns in Foreign Countries
    - Subpart C – Reporting of Early Warning Information (EWR) Dependent on production volume

Safety Act & Implementing Regulations

- A manufacturer of motor vehicles or equipment has a duty to notify NHTSA if the manufacturer learns or determines in good faith that there is a defect related to motor vehicle safety or a noncompliance with an applicabile
- The manufacturer's notice to NHTSA must be in the form specified by regulation, and is known as a "Defect Information Report" or "Part 573 Report”

49 CFR 573.6 – Defect and noncompliance information report. (Recall notice)

- Each manufacturer shall furnish a report to the NHTSA for each defect in his vehicles or in his items of original or replacement equipment that he or the Administrator determines to be related to motor vehicle safety, and for each noncompliance with a motor vehicle safety standard in such vehicles **or items of equipment** which either he or the Administrator determines to exist.

- Each report shall be submitted not more than **5 working days** after a defect in a vehicle or item of equipment has been determined to be safety related, or a noncompliance with a motor vehicle safety standard has been determined to exist.

Duty to Notify

- A manufacturer of motor vehicles or equipment also has a duty to notify owners, purchasers, and dealers when it determines that any motor vehicle or equipment contains a defect that relates to motor vehicle safety or a noncompliance with an applicable FMVSS
- Notification must have been "furnished no later than 60 days from the date the manufacturer files its defect or noncompliance information report under part 573

Duty to Remedy

- When a manufacturer learns that a motor vehicle or motor vehicle equipment contains a defect and it decides in good faith that the defect is related to motor vehicle safety, the Safety Act imposes a **duty to remedy** the motor vehicle
  - Within a “reasonable time”
  - According to case law, "a manufacturer incurs its duties to notify and remedy whether it actually determined, or it should have determined, that its vehicles are defective and the defect is safety-related
- Manufacturer also has a duty to recall any motor vehicles or motor vehicle equipment that fails to comply with applicable FMVSS

Identifying Information

- Manufacturers of motor vehicles are required to submit identifying information and a description of the items they produce to NHTSA
- Manufacturers must report this information no later than 30 days after manufacturing begins

Violations

- A person who violates the notification requirements, remedy requirements, or certification requirements of the Safety Act, or a regulation thereunder, is liable to the United States Government for a civil penalty
- Separate violation occurs for each motor vehicle or item of motor vehicle equipment and for each failure or refusal to allow or perform a required act

49 CFR Part 576 – Record Retention OEM and Component Suppliers

- Scope: Part 576 establishes requirements for the retention by manufacturers of motor vehicles **and of motor vehicle equipment**, of claims, complaints, reports, and other records concerning alleged and proven motor vehicle or motor vehicle equipment defects and malfunctions that may be related to motor vehicle safety.

- Purpose: The purpose of Part 576 is to preserve records that are needed for the proper investigation, and adjudication or other disposition, of possible defects related to motor vehicle safety and instances of nonconformity to the motor vehicle safety standards and associated regulations.

- Basic Requirement: Retain records for a period of five calendar years from the date on which they were generated or acquired by the manufacturer.

RS17-001728-377

49 CFR 579.5 (Subpart A) – Notices, bulletins, customer satisfaction campaigns, consumer advisories, and other communications

- Independent of production volume
- Manufacturers must submit to NHTSA a copy of all notices, bulletins, and other communications sent to more than one manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser regarding any defect in its vehicles or items of equipment.
  - Defects here mean any failure or malfunction beyond normal deterioration in use, or any failure of performance, **or any flaw or unintended deviation from design specification**s, whether or not such defect is safety-related.
- **Manufacturers** must also submit furnish to NHTSA a copy of each communication relating to a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment, that the manufacturer issued to, or made available to, more than one dealer, distributor, lessor, lessee, other manufacturer, owner, or purchaser, in the United States.
- Information and sample index: http://www-odi.nhtsa.dot.gov/mc/

49 CFR 579 (Subpart C) – Reporting of Early Warning Information (EWR)

- Dependent on production volume
- Possible Reporting Categories
  - Production Information
  - Death and Injury
  - Aggregate Data
    - Warranty Claims, Field Reports, Property Damage, Consumer Complaints
  - **Field Reports**
- 579.21 Reporting requirements for MFRs > 5,000 light vehicles annually.
- 579.22 Reporting requirements for MFRs > 5,000 heavy, > 500 Emergency, **>100 Buses annually**.
- 579.23 Reporting requirements for MFRs > 5,000 motorcycles annually.
- 579.24 Reporting requirements for MFRs > 5,000 trailers annually.
- 579.25 Reporting requirements for MFRs > 0 child restraint systems annually.
- 579.26 Reporting requirements for MFRs of tires.
- **579.27 Reporting requirements for MFRs of Low Volume or Equipment**
- 579.28 Due dates for reports and other miscellaneous provisions.
- 579.29 Manner of reporting.

Early Warning Information

- NHTSA requires reporting of "Early Warning Information" based on the type of manufacturer
- Also required to report, on a quarterly basis, production information, information on incidents involving death or injury, and data regarding property damage claims, consumer complaints, warranty claims, and field reports

Field report

- **Field report** means a communication in writing, including communications in electronic form, from an employee or representative of a manufacturer of motor vehicles or motor vehicle equipment, a dealer or authorized service facility of such manufacturer, or an entity known to the manufacturer as **owning or operating a fleet**, to the manufacturer regarding the ***failure, malfunction, lack of durability, or other performance problem of a motor vehicle or motor vehicle equipment***, or any part thereof, produced for sale by that manufacturer and transported beyond the direct control of the manufacturer, regardless of whether verified or assessed to be lacking in merit, but does not include any document covered by the attorney-client privilege or the work product exclusion.

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- § 579.27 Reporting requirements for manufacturers of fewer than 100 buses annually, for manufacturers of fewer than 500 emergency vehicles annually, for manufacturers of fewer than 5,000 light vehicles, medium-heavy vehicles (other than buses and emergency vehicles), motorcycles or trailers annually, for manufacturers of original equipment, and for manufacturers of replacement equipment other than child restraint systems and tires.
- (a)Applicability. This section applies to all manufacturers of vehicles with respect to vehicles that are not covered by reports on light vehicles, medium-heavy vehicles and buses, motorcycles, or trailers submitted pursuant to §§ 579.21 through 579.24 of this part, to all manufacturers of original equipment, to all manufacturers of replacement equipment other than manufacturers of tires and child restraint systems, and to registered importers registered under 49 U.S.C. 30141(c).

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- (b)Information on incidents involving deaths. For each reporting period, a manufacturer to which this section applies shall submit a report, pertaining to vehicles and/or equipment manufactured or sold during the calendar year of the reporting period and the nine calendar years prior to the reporting period (four calendar years for equipment), including models no longer in production, on each incident involving one or more deaths occurring in the United States that is identified in a claim against and received by the manufacturer or in a notice received by the manufacturer which notice alleges or proves that the death was caused by a possible defect in the manufacturer's vehicle or equipment, together with each incident involving one or more deaths occurring in a foreign country that is identified in a claim against and received by the manufacturer involving the manufacturer's vehicle or equipment, if it is identical or substantially similar to a vehicle or item of equipment that the manufacturer has offered for sale in the United States. The report shall be organized such that incidents are reported alphabetically by make, within each make alphabetically by model, and within each model chronologically by model year. If a manufacturer has not received such a claim or notice during a reporting period, the manufacturer need not submit a report to NHTSA for that reporting period.
- (c) For each incident described in paragraph (b) of this section, the manufacturer shall separately report the make, model, and model year of the vehicle or equipment, the VIN (for vehicles only), the incident date, the number of deaths, the number of injuries for incidents occurring in the United States, the State or foreign country where the incident occurred, each system or component of the vehicle or equipment that allegedly contributed to the incident, and whether the incident involved a fire or rollover, as follows:

579.27 Reporting requirements for MFRs of Low Volume or Equipment.

- (1) For light vehicles, the system or component involved, and the existence of a fire or rollover, shall be identified and coded as specified in § 579.21(b)(2) of this part.
- (2) For medium-heavy vehicles and buses, the system or component involved, and the existence of a fire or rollover, shall be identified and coded as specified in § 579.22(b)(2) of this part.
- (5) For original and replacement equipment, a written identification of each component of the equipment that was allegedly involved, and whether there was a fire, in the manufacturer's own words.
- (6) For original and replacement equipment, if the production year of the equipment is unknown, the manufacturer shall specify the number “9999” in the field for model or production year.

Service Bulletins to NHTSA

- Manufacturers are required to submit copies of all notices, bulletins, and other communications, including those related to any defect in its vehicles or items of equipment, a customer satisfaction campaign, consumer advisory, recall, or other safety activity involving the repair or replacement of motor vehicles or equipment sent to more than one manufacturer, distributor, dealer, owner or purchaser

Best Practice Ideas

- Submit 579.5 reports stating you have nothing to report.
  - Manufacturers should submit a negative report to the TSB portal for those months in which a TSB was not published. This allows an examiner reviewing the data to be aware that someone took the time to report “No TSB’s” for a given month, rather than remaining silent, which after several months may create concerns that TSB’s are not being submitted. While this suggestion is not required by NHTSA, it is a quality control mechanism which manufacturers may want to consider.
- Supplier / OEM warranty relationships.
  - Suppliers and OEMs should have a working relationship or agreement where identifying potential safety defects is possible. Manufacturers are responsible for meeting the requirements of Part 576. In order to do this, either or both the OEM and suppliers should maintain and have access to the required records.
- Manufacturers should be monitoring their own data for signs of potential defect.

Best Practice Ideas (Cont)

- There should be an easy, clearly advertised method for employees to report potential safety issues.
- There should be a process for periodically reviewing issues identified by all means and deciding if a defect exists. This process should include getting back to the defect identifier and informing them of the review outcome.
- The review panel should be multi disciplinary.
- The decisions made by the review panel should be documented and records retained for future reference.
- The processes developed for meeting the tread act requirements should be documented and appropriate personnel trained in their use.

Armed Forces Vehicles

49 C.F.R. § 571.7(c)

- Vehicles "manufactured for and sold directly to, the Armed Forces of the United States in conformity with contractual specifications" do not need to meet the FMVSS
- This does not apply in instances where a military vehicle has been extensively modified or otherwise serves as a donor for what is essentially a new vehicle
- "vehicles might become subject to Federal motor vehicle safety standards if there is a material change in ... the intended or actual use, design or sale . ... " of the vehicle. See NHTSA Interpretation Letter to D.F. Landers, President of Mobile Products, Inc. (Nov. 30, 1987).

Not Knowing the Regulations Is Not a Defense

- APV manufacturers must comply with the legal obligations imposed on vehicle manufacturers by the Safety Act and even if they act on a good faith belief that only Coast Guard marine safety regulations and state level road safety rules are applicable to the amphibious vehicles it manufactured.
- Nonetheless, as a matter of law, ignorance of its legal obligations under the Safety Act is not a defense for an APV manufacturer

NHTSA Manufacturer Requirements Guide for Applicable Laws & Regulations

49 U.S.C. sec. 30102 Definitions

(a)(5) **"manufacturer"** means a person –

(A) Manufacturing or assembling motor vehicles or motor vehicle equipment; or

(B) Importing motor vehicles or motor vehicle equipment for resale

49 U.S.C. sec. 30102 Definitions

(a)(6) **“motor vehicle”** means –

a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line

49 U.S.C. sec. 30102 Definitions

(a)(7) **"motor vehicle equipment"** means –

(A) Any system, part, or component of a motor vehicle as originally manufactured;

(B) Any similar part or component manufactured or sold for replacement or improvement of a system, part, or component, or as an accessory or addition to a motor vehicle; or

(C) Any device or an article or apparel (except medicine or eyeglasses prescribed by a licensed practitioner) that is not a system, part, or component of a motor vehicle and is manufactured, sold, delivered, offered, or intended to be used only to safeguard motor vehicles and highway users against risk of accident, injury, or death

Full Requirements of 49 USC Ch. 301

https://www.gpo.gov/fdsys/browse/collectionUScode.action

- Select most recent year available
- Select Title 49, Subtitle VI, Part A
- Click PDF link to Chapter 301

49 C.F.R. Parts 500-599

http://www.ecfr.gov

- Select Title 49 “Transportation”
- Select parts 500-571 or 572-599 “National Highway Traffic Safety Administration, Department of Transportation”

49 C.F.R. Part 579 – Reporting of information & Communications about Potential Defects

- repeating regular monthly and quarterly reporting requirements

NHTSA Defect Communications Reporting Requirements

49 CFR sec. 579.5

- Vehicle & equipment manufacturers required to submit a copy of **all notices, bulletins, and other communications** issued by manufacturer in regard to any defect, **whether or not it is safety-related,** to NHTSA […]
- Each violation – civil penalties of up to $21,000 / day

Who must Submit Defect Communications?

- Motor vehicle **manufacturers**
- Motor vehicle **assemblers**
- Motor vehicle **equipment manufacturers**
- Motor vehicle **equipment assemblers**
- Importers of motor vehicles for **resale**
- **Any subsidiary or affiliate**, and any subsidiary or affiliate of a parent corporation, of any of the above

How Should Defect Be Submitted?

- A readable copy of ***all notices, bulletins, and other communications***
  - that are sent to more than one ***manufacturer, distributor, dealer, lessor, lessee, owner, or purchaser*** in the United States,
  - regarding **any defect in its vehicles or items of equipment** (including any failure to malfunction beyond normal deterioration in use, or any failure of performance, or any flaw or unintended deviation from design specifications), whether or not such defect is safety-related.
- Must be accompanied by an **index**
- **5 working days** after the end of the month in which they are issued

How Should Defect Be Submitted?

- Must be accompanied by an **index**
- **5 working days** after the end of the month in which they are issued
- **Submit** to: mailto:tsb@dot.gov

Am I a "Manufacturer"? A Decision Tree.

YES, I am a **"Vehicle Manufacturer"**

Must meet the following requirements of 49 USC Ch. 301 & Title 49 of CFR

49 USC Ch. 301 & Title 49 of CFR

- 30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicles
- 30120 Remedies for defects and noncompliance
- 30122 Making safety devices and elements inoperative
- 30170 Criminal penalties
- 551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
- 563 Event data recorders*
- 565 Vehicle Identification Number (VIN)
- 567 Certification
- 568 Vehicles manufactured in two or more stages – All incomplete, intermediate, and final state manufacturers of vehicles manufactured in two or more stages
- 566 Manufacturer identification
- 571 Federal Motor Vehicle Safety Standards (FMVSS)
- 573 Defect and noncompliance responsibility and reports
- 576 Record retention

49 USC Ch. 301 & Title 49 of CFR

- 577 Defect and noncompliance notification
- 578 Civil and criminal penalties
- 579.5 Communications
- 579.11 Foreign campaign reporting responsibilities
- 579.28 Due date of reports and other miscellaneous provisions
- 579.29 Manner of reporting
- 541-543 Theft prevention*
- 581 Bumper standards*
- 525, 526, 529, 531, 533, 535, 537, 538 Fuel economy*
- 583 Domestic content labeling
- 575 Consumer information
- * (only apply to certain motor vehicles types)

What type of Vehicle do I manufacture & What is my annual production?

- 579.21 – 5,000 or more light vehicles
- 579.22 – 100 or more buses, 500 or more emergency vehicles, 5,000 or more medium-heavy vehicles
- 579.23 – 5,000 or more motorcycles annually
- 579.24 – 5,000 or more trailers annually
- 579.27 – Fewer than 100 buses, 500 emergency vehicles, or 5,000 light vehicles

Am I a “Manufacturer”?

YES, I am a **“Equipment Manufacturer”**

Must meet the following requirements of 49 USC Ch. 301 & Title 49 of CFR

49 USC Ch. 301 & Title 49 of CFR

- 30112 Prohibition on manufacturing, selling, and importing noncomplying motor vehicle equipment
- 30120 Remedies for defects and noncompliance
- 30122 Making safety devices and elements inoperative
- 30170 Criminal penalties
- 551 If you are a foreign manufacturer then designate a permanent resident of the United States as its agent for service of process
- 573 Defect and noncompliance responsibility and reports
- 576 Record retention
- 577 Defect and noncompliance notification
- 578 Civil and criminal penalties
- 579,5 Communications
- 579.11 Foreign campaign reporting responsibilities
- 579.27 Reporting requirements for manufacturers of equipment
- 579.28 Due date of reports and other miscellaneous provisions
- 579.29 Manner of reporting

14 pieces of equipment covered by FMVSS

- tires
- rims
- brake hoses
- brake fluid
- seat belt assemblies
- lighting equipment
- glazing
- motorcycle helmets
- child seats
- CNG containers
- platform lift systems for the mobility impaired
- rear impact guards for trailers
- triangular reflective warning devices
- pressure vessels / explosive devices

Do I manufacturer equipment covered by FMVSS?

- 30115 Certification of compliance
- 566 Manufacturer identification
- 571 Federal Motor Vehicle Safety Standards (FMVSS)
- 574 Tire identification and recordkeeping
- 575.103 Truck-camper loading
- 579.25 Child restraint system
- 579.26 Tires
- 588 Child restraint systems recordkeeping requirements

Federal Motor Vehicle Safety Standards

FMVSS

- Motor vehicles must comply with applicable FMVSS and must be certified as such at the time of delivery
- Certification must take the form of a label certifying compliance with applicable FMVSS that is permanently affixed by the manufacturer
- Manufacturers are responsible for "self-certifying" that their products meet all applicable FMVSS before they are offered for sale

FMVSS Std. 101: Controls and Displays – Passenger Cars (eff. 1-1-68)

- Requires that essential controls be located within reach of the driver when the driver is restrained by a lap belt and upper torso restraint, and that certain controls mounted on the instrument panel be identified

FMVSS Std. 101: Controls and Displays – Buses (APV)

- Passenger Cars (eff. 1-1-72), Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-72)
  - All manually operated controls must be identified by words.
- Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-72)
  - Except for foot-operated controls or manually operated controls mounted on steering column, the identification of essential controls and displays must be illuminated whenever the headlamps are lit.
- Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 9-1-80)
  - Certain essential hand-operated controls and certain displays must be identified by a symbol, and such identification be illuminated.

Identification and Illumination of Controls

Column 1	Column 2	Column 3	Column 4
Hand Operated Controls	Identifying Words or Abbreviation	Identifying Symbol	Illumination
Master Lighting Switch	Lights	[5]	—
Headlamps and Tail lamps	(Mfr. Option)[2]	(Mfr. Option)[2]	—
Horn	Horn	[4]	—
Turn Signal	—	[3] [5]	—
Hazard Warning Signal	Hazard	[5]	Yes
Windshield Wiping System	Wiper or Wipe		Yes
Windshield Washing System	Washer or Wash		Yes
Windshield Washing and Wiping Combined	Wash-Wipe or Washer–Wiper		Yes
Heating and or Air Conditioning Fan	Fan		Yes
Windshield Defrosting and Defogging System	Defrost, Defog or Def.		Yes
Rear Window Defrosting and Defogging System	Rear Defrost, Rear Defog, Rear Def., or R-Def		Yes
Identification, Side Marker and or Clearance Lamps	Marker Lamps or MK Lps	[2] [5]	Yes
Manual Choke	Choke	—	—
Engine Start	Engine Start[1]	—	—
Engine Stop	Engine Stop[1]	—	Yes
Hand Throttle	Throttle	—	—
Automatic Vehicle Speed	(Mfr. Option)	—	Yes
Heating and Air Conditioning System	(Mfr. Option)	(Mfr. Option)	Yes

[1] Use when engine control is separate from the key locking system.
[2] Separate identification not required if controlled by master lighting switch.
[3] The pair of arrows is a single symbol. When the controls for left and right turn operate independently, however, the two arrows may be considered separate symbols and be spaced accordingly.
[4] Identification not required for vehicles with a GVWR greater than 10,000 lbs., or for narrow ring-type controls.
[5] Framed areas may be filled.

FMVSS Std. 102

FMVSS Std. 102: Transmission Shift Position Sequence, Starter, Interlock, and Transmission Braking Effect (eff. 1-1-68)

- Specifies the requirements for the transmission shift lever sequence, a starter interlock, and for a braking effect of automatic transmissions, to reduce the likelihood of shifting errors, starter engagement with vehicle in drive position, and to provide supplemental braking at speeds below 40 km/h (25 mph)

FS17-001726-414

FMVSS Std. 103: Windshield Defrosting and Defogging Systems

(eff. 1-1-88)

- Specifies requirements for windshield defrosting and defogging systems

ES17-001728.416

FMVSS Std. 104: Windshield Wiping and Washing Systems

(eff. 1-1-88)

- Specifies requirements for windshield wiping and washing systems

FMVSS Std. 105: Hydraulic and Electric Brake Systems

(eff. 1-1-68)

- Specifies requirements for vehicles equipped with hydraulic and electric service brake systems and associated parking brake systems to ensure safe braking performance under normal conditions and emergency conditions
- **Multipurpose Passenger Vehicles, Trucks and Buses (eff. 3-1-99) Multipurpose passenger vehicles, trucks and buses with a GVWR greater than 4,536 kg (10,000 lbs.)**
  - must be equipped with an antilock brake system and meet additional stopping distance requirements.

FMVSS Std. 106: Brake Hoses

(eff. 1-1-68)

- Establishes performance and labeling requirements for hydraulic, air, and vacuum brake hoses, brake hose assemblies, and brake hose fitting for all motor vehicles.
- Purpose is to reduce brake system failure from pressure or vacuum loss due to hose or hose assembly rupture

FMVSS Std. 108: Lamps, Reflective Devices, and Associated Equipment

(eff. 1-1-68 for vehicles 2,032 mm (80 or more inches) in width and eff. 1-1-69 for all other vehicles)

- Specifies requirements for original and replacement lamps, reflective devices, and associated equipment.
- Purpose is to reduce traffic crashes and deaths and injuries resulting from traffic crashes, by providing adequate illumination of the roadway, and by enhancing the conspicuity of motor vehicles on the public roads so that their presence is perceived and their signals understood, both in daylight and in darkness or other conditions of reduced visibility

FMVSS Std. 111: Rearview Mirrors

(eff. 1-1-68)

- Specifies requirements for the performance and location of inside and outside rearview mirrors
- Purpose is to reduce the number of deaths and injuries that occur when the driver of a motor vehicle does not have a clear and reasonably unobstructed view to the rear

FMVSS Std. 113: Hood Latch System

(eff. 1-1-69)

- Establishes the requirement for providing a hood latch system or hood latch systems

FMVSS Std. 116: Motor Vehicle Brake Fluids

(eff. 1-1-68, amended 3-1-72)

- Specifies requirements for fluids for use in hydraulic brake systems of motor vehicles, containers for these fluids, and labeling of the containers.
- Purpose is to reduce failures in the hydraulic braking systems of motor vehicles which may occur because of the manufacture or use of improper or contaminated brake fluid

FMVSS Std. 119: New Pneumatic Tires for Motor Vehicles with a GWVR of More than 4,536 Kilograms (10,000 pounds) and Motorcycles

(eff. 3-1-75)

- Establishes performance and marking requirements for tires for use on motor vehicles with a GVWR of more than 10,000 pounds and motorcycles
- Purpose is to provide safe operational performance levels for tires used on motor vehicles other than passenger cars, and to place sufficient information on the tires to permit their proper selection and use

FMVSS Std. 120:

FMVSS Std. 120: Tire Selection & Rims & Motor Home/Recreation Vehicle Trailer Load Carrying Capacity (eff. 8-1-76)

- Specifies tire and rim selection requirements, rim marking requirements and motor home/recreation vehicle trailer load carrying capacity information
- Purpose is to provide safe operational performance by ensuring that vehicles to which it applies are equipped with tires of adequate size and load rating and with rims of appropriate size and type designation, and by ensuring that consumers are informed of motor home/recreation vehicle trailer load carrying capacity

FMVSS Std. 121: Air Brake Systems

(eff. 1-1-75)

- Establishes performance and equipment requirements for braking systems on vehicles equipped with air brake systems
- Purpose is to insure safe braking performance under normal and emergency conditions.

FMVSS Std. 124: Accelerator Control Systems

(eff. 9-1-73)

- Establishes requirements for the return of a vehicle's throttle to the idle position when the driver removes the actuating force from the accelerator control, or in the event of a severance or disconnection in the accelerator control system
- Purpose is to reduce deaths and injuries resulting from engine over speed caused by malfunctions in the accelerator control system

FMVSS Std. 125: Warning Devices

(eff. 1-1-74)

- Establishes requirements for devices, without self contained energy sources, that are designed to be carried in motor vehicles and used to warn approaching traffic of the presence of a stopped vehicle, except for devices designed to be permanently affixed to the vehicle
- Purpose is to reduce deaths and injuries due to rear end collisions between moving traffic and disabled vehicles

FMVSS Std. 205: Glazing Materials

(eff. 1-1-68)

- Specifies requirements for glazing materials for use in motor vehicles and motor vehicle equipment
- Purpose is to reduce injuries resulting from impact to glazing surfaces, to ensure a necessary degree of transparency in motor vehicle windows for driver visibility, and to minimize the possibility of occupants being thrown through the vehicle windows in collisions

FMVSS Std. 207: Seating Systems

Passenger Cars (eff. 1-1-68); Multipurpose Passenger Vehicles, Trucks, and Buses (eff. 1-1-72)

- Establishes requirements for seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact

FMVSS Std. 208: Occupant Crash Protection

- Specifies performance requirements for the protection of vehicle occupants in crashes
- Purpose is to reduce the number of deaths of vehicle occupants, and the severity of injuries, by specifying vehicle crashworthiness requirements in terms of forces and accelerations measured on anthropomorphic dummies in test crashes, and by specifying equipment requirements for active and passive restraint systems

FMVSS Std. 209: Seat Belt Assemblies

(eff. 3-1-67)

- Specifies requirements for seat belt assemblies
- Requirements apply to straps, webbing or similar material, as well as to all necessary buckles and other fasteners and all hardware designed for installing the assembly in a motor vehicle, and to the installation, usage, and maintenance instructions for the assembly

FMVSS Std. 210: Seat Belt Assembly Anchorages

- Establishes requirements for seat belt assembly anchorages to insure their proper location for effective occupant restraint and to reduce the likelihood of their failure
- Requirements apply to any component, other than the webbing or straps, involved in transferring seat belt loads to the vehicle structure

FMVSS Std. 213: Child Restraint Systems

(eff. 4-1-71, amended 1-1-81)

- Specifies requirements for child restraint systems used in motor vehicles and aircraft
- Purpose is to reduce the number of children killed or injured in motor vehicle crashes and in aircraft

FMVSS Std. 217: Bus Emergency Exits and Window Retention and Release

(eff. 9-1-73)

- Establishes requirements for the retention of windows other than windshields in buses, and establishes operating forces, opening dimensions, and markings for bus emergency exits
- Purpose is to minimize the likelihood of occupants being thrown from the bus and to provide a means of readily accessible emergency egress

FMVSS Std. 302: Flammability of Interior Materials

(eff. 9-1-72)

- Specifies burn resistance requirements for materials used in the occupant compartments of motor vehicles
- Purpose is to reduce deaths and injuries to motor vehicle occupants cause by vehicle fires, especially those originating in the interior of the vehicle from sources such as matches or cigarettes

FMVSS Std. 403: Platform Lift Systems for Motor Vehicles

- Specifies requirements for platform lifts used to assist persons with limited mobility in entering or leaving a vehicle
- Purpose is to prevent injuries and fatalities to passengers and bystanders during the operation of platform lifts installed in motor vehicles

ES17-001728 436

FMVSS Std. 404: Platform Lift Installations in Motor Vehicles

- Specifies requirements for vehicles equipped with platform lifts used to assist persons with limited mobility in entering or leaving a vehicle
- Purpose is to prevent injuries and fatalities to passengers and bystanders during the operation of platform lifts installed in motor vehicles

Part 554: Standards Enforcement and Defects Investigation

Part 554: Standards Enforcement and Defects Investigation

- Establishes procedures for enforcing Federal motor vehicle safety standards and associated regulations, investigating possible safety-related defects, and making non-compliance and defect determinations
- Purpose is to inform interested persons of the procedures followed by the National Highway Traffic Safety Administration in order more fairly and effectively to implement 49 U.S.C. Chapter 301

Part 556: Vehicle Identification Number (VIN) Requirements

ES17-001726440

Part 556: Vehicle Identification Number (VIN) Requirements

- Sets forth procedures, pursuant to section 157 of the Act, for exempting manufacturers of motor vehicles and replacement equipment from the Act's notice and remedy requirements when a defect or noncompliance is determined to be inconsequential as it relates to motor vehicle safety
- Purpose of this part is to enable manufacturers of motor vehicles and replacement equipment to petition the NHTSA for exemption from the notification and remedy requirements of the Act due to the inconsequentiality of the defect or noncompliance as it relates to motor vehicle safety, and to give all interested persons an opportunity for presentation of data, views, and arguments on the issues of inconsequentiality

Chart 1 - General VIN Format

1st Section			2nd Section					3rd	4th Section							
Identifies Manufacturer and Type of Vehicle			Identifies Vehicle Attributes (Now includes Vehicle Make)					Check Digit	MY	Plant	Number sequentially assigned in Positions 12-17 if a High-Vol. Manu. or in Positions 15-17 if a Low-Vol. Manu.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		"9" if low-vol. manu.									WMI if low-vol. manufacturer (<1,000 of a given type each year)					
						@@						##	##	##	##	##
						if car, and MPV and truck ≤ 10,000 lbs.						if car, and MPV and truck ≤ 10,000 lbs.				
													##	##	##	##
@@ means that VIN Characters are: A,B,C,D,E,F,G,H,J,K,L,M,N,P,R,S,T,U,V,W,X,Y,or Z ## means that VIN Characters are: 0,1,2,3,4,5,6,7,8, or 9													For vehicle not a car, and MPV and truck ≤ 10,000 lbs.			

Part 566: Manufacturer Identification

- Requires manufacturers of motor vehicles, and of motor vehicle equipment to which a motor vehicle safety standard applies, to submit identifying information and a description of the items they produce
- Purpose is to facilitate the regulation of manufacturers under the National Traffic and Motor Vehicle Safety Act, and to aid in establishing a code numbering system for all regulated manufacturers

Obtaining a World Manufacturer Identifier

- A manufacturer that intends to assemble motor vehicles in the United States must obtain a WMI from the Society of Automotive Engineers (SAE).
- NHTSA has a contract with that organization to assign WMIs to manufacturers that assemble motor vehicles in the United States.
- Manufacturers must contact the SAE directly (and not NHTSA) to request the assignment of a WMI.

An Example of the Establishment of VIN numbers

RTDI VIN Numbers

Updated: 2/13/2017

				Identifies Manufacturer and Type of Vehicle			Identifies Vehicle Attributes (Now includes Vehicle Make)					Check Digit	MY	Plant	Number sequentially assigned in Positions 15-17 if a Low-Vol. Manu.					
Production Number	**APV Design**	**Location**	**Build Year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
SD-01	Stretch Duck	Branson MO	1996	1	R	9	R	S	0	A	H	0	T	B	8	3	4	S	0	1
SD-02	Stretch Duck	Branson MO	1997	1	R	9	R	S	0	A	H	9	V	B	8	3	4	S	0	2
SD-08	Stretch Duck	Branson MO	1999	1	R	9	R	S	0	A	H	8	X	B	8	3	4	S	0	8
SD-03	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	5	Y	B	8	3	4	S	0	3
SD-04	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	7	Y	B	8	3	4	S	0	4
SD-12	Stretch Duck	Branson MO	2000	1	R	9	R	S	0	A	H	6	Y	B	8	3	4	S	1	2

Part 567: Certification

Part 567: Certification

(eff. 8-31-69)

- Specifies the content and location of and other requirements for the label or tag to be affixed to motor vehicles and items of motor vehicle equipment manufactured after August 31,1969. The certificate will provide the consumer with information to assist him or her in determining which of the FMVSS are applicable to the vehicle or item of vehicle equipment, and its date manufacture
- An amendment effective Jan. 1, 1973, required gross vehicle weight (GVWR) information on the certification label

Part 573: Defect and Noncompliance Responsibility and Reports

Part 573: Defect and Noncompliance Responsibility and Reports

(eff. 10-1-71)

- Specifies manufacturer requirements for reporting safety-related defects to the National Highway Traffic Safety Administration; for providing quarterly reports on defect notification campaigns; for providing copies of communications with dealers and purchasers concerning defects; and for maintaining owner lists

Part 576: Record Retention

Part 576: Record Retention

- Establishes requirements for the retention by manufacturers of motor vehicles and of motor vehicle equipment, of claims, complaints, reports, and other records concerning alleged and proven motor vehicle or motor vehicle equipment defects and malfunctions that may be related to motor vehicle safety
- Purpose is to preserve records that are needed for the proper investigation, and adjudication or other disposition, of possible defects related to motor vehicle safety and instances of nonconformity to the motor vehicle safety standards and associated regulations

Part 577: Defect and Noncompliance Notification

Part 577: Defect and Noncompliance Notification

(eff. 3-26-73)

- Sets forth requirements for manufacturer notification to owners, dealers, and distributors of motor vehicles and items of replacement equipment about a defect that relates to motor vehicle safety or a noncompliance with a Federal motor vehicle safety standard

Part 579: Reporting of Information and Communications about Potential Defects

ES17-001728 454

Part 579: Reporting of Information and Communications about Potential Defects

(eff. 9-30-78)

- Allocates between motor vehicle and equipment manufacturers the responsibilities under the 1974 Motor Vehicle and School Bus Safety Amendments for recalling and remedying defective motor vehicles and equipment or motor vehicles and equipment not built in compliance with the law

Example of Index of Manufacturer (MFR) Communications

Index of Manufacturer (MFR) Communications

Manufacturer:	Sample Auto Company
Date Range:	01/01/2014 - 10/31/2014
Date Submitted:	01/01/2017

[The effect of the defect or noncompliance should be described below.]

No.	MFR Communication ID	MFR Communication Date	Make	Model	Model Year	Concise Summary (2000 character limit)
1	14-AC-002-1	06/01/2014	Sample	Super	2010	This Technical Service Bulletin provides a diagnostic troubleshooting guide and list of replacement service parts for the Remote Engine Start (RES) accessory.
					2011	
					2012	
				X-500	2010	
					2011	
		06/19/2014		Megacar	2012	
			Example	Presidential	2013	
					2014	
2	WMI-RZX7Q-10	10/24/2014	Sample	X-500	2008	This communication is informing all general, sales, service and parts managers and warranty administrators that SAC will begin mailing final Customer Notification Letters for Recall Campaign 124: Front coil spring fractures, starting October 24, 2014.
					2009	

Part 580: Odometer Disclosure Requirements

Part 580: Odometer Disclosure Requirements

(eff. 3-1-73 and 4-29-89)

- Requires a person who transfers ownership of a motor vehicle to give the transferee a written disclosure of the mileage the vehicle has traveled

Production Data

1. State, by make, model and model year, the number of subject vehicles RTDI has manufactured for sale or lease in the United States. Separately, for each subject vehicle manufactured to date

a	b	c.	d.	e	f.	g	h.	i.	j.	k	l.	m.	n.
VIN	Make	Model	Model Year	Vehicle Date of Manufacture	Vehicle Date of Refurbish/Re-manufacture	Model Number of Axle Installed	Origin of Axle Installed	Model Number of Transmission Installed	Origin of Transmission Installed	Model Number of Engine Installed	Origin of Engine Installed	Origin of Hub Installed	Origin of Chassis Installed
353-19536	GMC	DUKW	1945	1945		May-96 M211	SURPLUS/AUCTION	M-465	SALVAGE	GM 366	SALVAGE	GMC/AVM	GMC
353-18845	GMC	DUKW	1945	1945		Apr-97 M211	SURPLUS/AUCTION	M-465	SALVAGE	GM 366	SALVAGE	GMC/AVM	GMC
353-18903	GMC	DUKW	1945	1945		May-97 M211	SURPLUS/AUCTION	M-465	SALVAGE	GM 366	SALVAGE	GMC/AVM	GMC
353-18850	GMC	DUKW	1945	1945		Aug-97 M211	SURPLUS/AUCTION	M-465	SALVAGE	GM 366	SALVAGE	GMC/AVM	GMC
353-15148	GMC	DUKW	1944	1944		Nov-97 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-15190	GMC	DUKW	1945	1945		Mar-98 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-11427	GMC	DUKW	1944	1944		May-98 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-19375	GMC	DUKW	1945	1945		Jun-98 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20552	GMC	DUKW	1945	1945		Sep-98 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-10733	GMC	DUKW	1945	1945		Dec-98 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-18291	GMC	DUKW	1945	1945		Feb-99 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-15008	GMC	DUKW	1945	1945		Apr-99 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-13582	GMC	DUKW	1945	1945		Jun-99 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-14106	GMC	DUKW	1945	1945		Oct-99 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20606	GMC	DUKW	1945	1945		May-00 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-19590	GMC	DUKW	1945	1945		Nov-00 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20052	GMC	DUKW	1945	1945		Jun-01 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20585	GMC	DUKW	1944	1944		Jan-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-19475	GMC	DUKW	1943	1943		May-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-14889	GMC	DUKW	1945	1945		Jul-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-22056	GMC	DUKW	1946	1946		Aug-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-2850	GMC	DUKW	1944	1944		Oct-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-15084	GMC	DUKW	1944	1944		Dec-02 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-15086	GMC	DUKW	1945	1945		Jan-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20683	GMC	DUKW	1945	1945		Dec-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20683	GMC	DUKW	1945	1945		Feb-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-17998	GMC	DUKW	1945	1945		Mar-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-20292	GMC	DUKW	1945	1945		Apr-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-4808	GMC	DUKW	1944	1944		Apr-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-19728	GMC	DUKW	1945	1945		Jun-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 366	SALVAGE	GMC/AVM	GMC
353-16753	GMC	DUKW	1945	1945		Aug-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-11383	GMC	DUKW	1945	1945		Feb-04 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-19487	GMC	DUKW	1945	1945		Jul-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-13520	GMC	DUKW	1945	1945		Oct-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-14899	GMC	DUKW	1944	1944		Sep-03 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-11262	GMC	DUKW				Feb-04 M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC

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a.	b.	c.	d.	e.	f.	g.	h.	i.	j.	k.	l.	m.	n.
VIN	Make	Model	Model Year	Vehicle Date of Manufacture	Vehicle Date of Refurbish/Re-manufacture	Model Number of Axle Installed	Origin of Axle Installed	Model Number of Transmission Installed	Origin of Transmission Installed	Model Number of Engine Installed	Origin of Engine Installed	Origin of Hull Installed	Origin of Chassis Installed
353-16386	GMC	DUKW	1945	1945	Feb-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-18659	GMC	DUKW			May-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-21978	GMC	DUKW			Apr-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-19388	GMC	DUKW			Jul-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-15698	GMC	DUKW			Jul-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-11380	GMC	DUKW	1945	1945	Aug-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-19860	GMC	DUKW	1945	1945	Oct-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-10908	GMC	DUKW			Oct-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-6116	GMC	DUKW	1945	1945	Dec-04	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-15140	GMC	DUKW			Jan-05	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-20674	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-15266	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-11566	GMC	DUKW							ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-22056	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-22076	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-12330	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-8533	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-20605	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-18658	GMC	DUKW	1945	1945					ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
353-18940	GMC	DUKW	1945	1945	IN PROCESS	M211	SURPLUS/AUCTION	AT-545	ALLISON DEALER	GM 427	GM DEALER	AVM	GMC
325-17595	AMC		1971	1971	Oct-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMC
MOZA920 16879	KAISE		1971	1971	May-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	KAISE
5401 1637	AMGE		1972	1972	Feb-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
4261581B	KAISE		1970	1970	Apr-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	KAISE
334-10250	KAISE		1973	1973	Jun-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	KAISE
225-22138	AMGE		1972	1972	Sep-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
5251792					Oct-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	
M23509	STUDE		1958	1958	Dec-06	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	STUDE
M30331					Jan-07	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	
122662	REO		1953	1953	Mar-07	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	REO
24031	KAISE		1968	1968	Jul-07	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	KAISE
4L0520					Apr-07	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	
M26656	REO		1953	1953	Aug-07	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	REO
M35A2	AMGE		1972	1972	Jan-08	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
4M1425	JEEP		1968	1968	Jan-08	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	JEEP
4L9789	KAISE		1967	1967	Jan-08	M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	KAISE

Seattle Duck 6
VIN 353-15140

Production Date:
Jan 2005

1 State, by make, model and model year, the number of subject vehicles RTDI has manufactured for sale or lease in the United States Separately, for each subject vehicle manufactured to date

a.	b.	c.	d.	e.	f.	g	h.	i.	j.	k.	l.	m	n.
VIN	Make	Model	Model Year	Vehicle Date of Manufacture	Vehicle Date of Refurbish/Re-manufacture	Model Number of Axle installed	Origin of Axle Installed	Model Number of Transmission Installed	Origin of Transmission Installed	Model Number of Engine Installed	Origin of Engine Installed	Origin of Hull Installed	Origin of Chassis Installed
M23060						Apr-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	
M21142						Apr-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	
054011916	AMGE		1972	1972		Feb-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
52519584	AMGE		1972	1972		Mar-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
M3649#	REO		1952	1952		May-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	REO
127531	REO		1953	1953		Mar-08 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	REO
M25863	AMGE		1972	1972		Jan-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	AVM	AMGE
52524847	AMGE		1972	1972		Jan-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
12523927	AMGE		1972	1972		Jan-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
M32051	REO		1972	1972		Jan-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	REO
22513849	JEEP		1972	1972		Apr-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	JEEP
52515842	CHANCE		1972	1972		Apr-09 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	CHANCE
22519145						M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	
M51251						M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	
52520750	AMGE		1972	1972		Mar-10 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
4M2138	KAISE		1968	1968		Apr-10 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
22518165	AMGE		1972	1972		Jan-11 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
M45329	STUDE		1972	1972		Jan-11 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	STUDE
4M3256	AMGE		1972	1972		Feb-11 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
4M2209	KAISE		1968	1968		M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
6M0429	KAISE		1967	1967		Apr-12 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
0K472B1053912 989	JEEP		1970	1970		May-12 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	JEEP
85951033402	AMGE		1972	1972		Mar-13 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
04F3897053911 223	JEEP		1971	1971		Jun-13 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	JEEP
4G8727105252I 546	AMGE		1970	1970		Jul-13 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
11037	AMGE		1973	1973		Feb-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
04BP867105253 5552	JEEP		1971	1971		Feb-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	JEEP
M50031	KAISE		1972	1972		Mar-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
32513535	KAISE		1968	1968		Apr-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
53515340	AMGE		1971	1971		May-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
52523212	AMGE		1972	1972		Jun-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE
12527475	KAISE		1967	1967		Jul-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	KAISE
4M01869032910 482	AMGE		1970	1970		Dec-14 M35	SURPLUS/AUCTION	AT-545	ALLISON DEALER	7.3L FORD	FORD DEALER	CHANCE RIDES	AMGE

ES17-001728 460

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

No.	Caption; Docket No.; Court; Date of filing	Parties	Alleged problem; Causal & contributing factors	RTDI's assessment of the problem	Summary of underlying facts and evidence
1	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) United States District Court for the Western District of Washington October 5, 2015	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	Discovery in the lawsuit is temporarily stayed pending possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

2	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County December 2, 2015	Plaintiff(s): (b)(6) Defendants: RTDI RTDS Washington State City of Seattle (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	Discovery in the lawsuit is temporarily stayed pending possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

3	*Estate of* (b)(6) *v. Ride the Ducks International, LLC and Ride the Ducks of Seattle, LLC,* (b)(6) United States District Court for the Western District of Washington December 8, 2015	Plaintiff(s): Estate of (b)(6) (b)(6) Defendants: RTDI RTDS	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	Discovery in the lawsuit is temporarily stayed pending possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

4	(b)(6) *v. Ride the Ducks International, LLC et al*. No. (b)(6) Superior Court of Washington for King County December 21, 2015	Plaintiff(s): (b)(6) Defendants: RTDI RTDS Washington State City of Seattle (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	Discovery in the lawsuit is temporarily stayed pending possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

5	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County December 21, 2015	Plaintiff(s): (b)(6) Defendants: RTDI RTDS Washington State City of Seattle (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	Discovery in the lawsuit is temporarily stayed pending possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

6	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County February 23, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

7	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County February 23, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

8	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County March 3, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

9	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County March 4, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

10	(b)(*v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County March 17, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

11	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County March 30, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

12	(b)(6) *v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County March 30, 2016	Plaintiff(s): (b)(6) Defendants: RTDI RTDS (b)(6)	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

13	*Estate of* (b)(*v. Ride the Ducks International, LLC et al.*, No. (b)(6) Superior Court of Washington for King County April 6, 2016	Plaintiff(s): Estate of (b)(6 (b)(6) Defendants: RTDI RTDS Washington State City of Seattle	The axle housing of a modified and remanufactured 1945 GMC DUKW amphibious military vehicle owned and operated by RTDS failed while traveling over the George Washington Memorial Bridge, resulting in a collision with a 2009 MCI motor coach operated by CWA Inc. dba Bellair Charters Hesselgrave South. The subject bridge is maintained by the Washington State Department of Transportation (WSDOT) and Seattle Department of Transportation (SDOT).	RTDS failed to implement a front axle housing repair for the subject vehicle as recommended by RTDI in an October 1, 2013 service bulletin regarding 57 similar DUKW vehicles.	A temporary stay in discovery is anticipated to permit possible coordination of other federal and state cases regarding the subject incident. NTSB has custody of the subject vehicle and its component parts.

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

a. Identifier	b. Category	c. Vehicle Owners' Information	d. VIN	e. Mileage	f. Time in Service	g. Date of Original Sale	h. Incident Date	i. Report or Claim Date	j. Whether a Crash Is Alleged	k. Whether Property Damage is Alleged	l. Number of Alleged Injuries	m. Number of Alleged Fatalities
Seattle, WA 9/24/2015	Report involving a crash, injury or fatality	Ride the Ducks of Seattle, 516 Broad St, Seattle, WA 98109; ducks@ridetheducksofseattle.com; (206) 441.3825	353-15140	Unknown	Unknown	2005 (month and day unknown)	9/24/2015	9/24/2015	yes	unknown	unknown	5

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

RIDE THE DUCKS INTERNATIONAL
Fleet Operations & Safety
2320 West Highway 76
Branson MO 65616

Bulletin No. SB-00-14-13
Release Date: 10/01/13
Effective Date: 10/01/13
Supersedes: N/A
Completion Date: Prior 2014
Applicable to: All Stretch Ducks
Total Pages: 7

SERVICE BULLETIN

REASON FOR RELEASE: To avoid axle fractures and to strengthen the connection where the knuckle housing ball connects to the axle housing. See Fig 1

Urgency: As soon as practical and prior to operating 2014. Until such time this bulletin is reconciled, all maintainers are to add the daily visual inspection of the front wheels.

Daily Inspection: Due to the axle knuckle boots covering the connection in question, the visual detection of a failing axle housing is not possible. However, during visual examination, with the (front wheels straight) you identify a wheel or wheels as being (vertically canted) the Duck should be removed from service, the damaged axle housing removed (scrapped) and replaced with an axle housing that has been modified in accordance with this Service Bulletin.

Directions: Provide below are instructions of the modification that once completed will reconcile this Bulletin.

1. Parts required for modification Fig 2
2. Preparations for modification Fig 3
3. Example of parts fit-up Fig 4
4. Welding Fig 5
5. View of mods complete Fig 6

EXAMPLE
CANTED FRONT WHEEL

NOTE: All work must be performed by qualified personnel. Use only authorized components, specified or provided by Ride The Ducks. All applicable OSHA safety standards and safe industry practices must be observed. Observe all safety information contained in the manufacturers manuals. Make available this bulletin and all related technical information to personnel using the equipment.

CONTACT US VIA EMAIL
RTDI FLEET OPS HOTLINE: 417 266 7676
RTDI PARTS: 417 266 7626

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

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Fleet Operations & Safety
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Branson MO 65616

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Fig 1

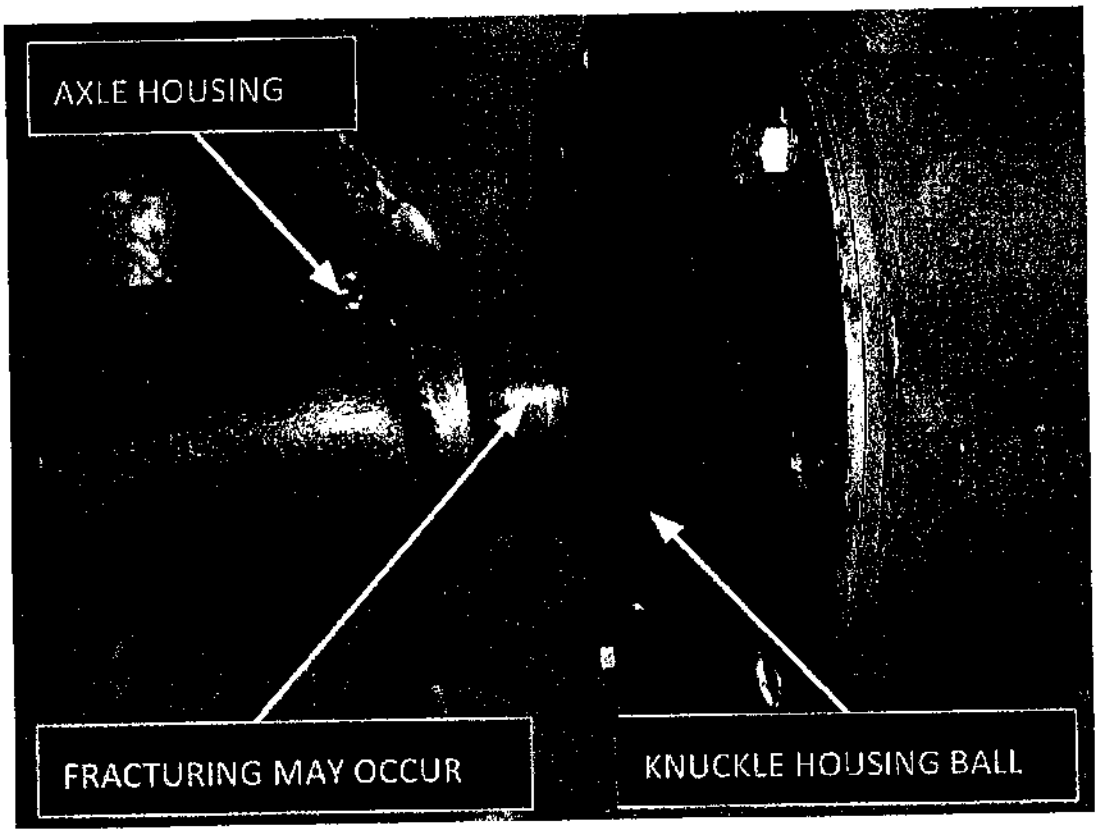

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Fig 2

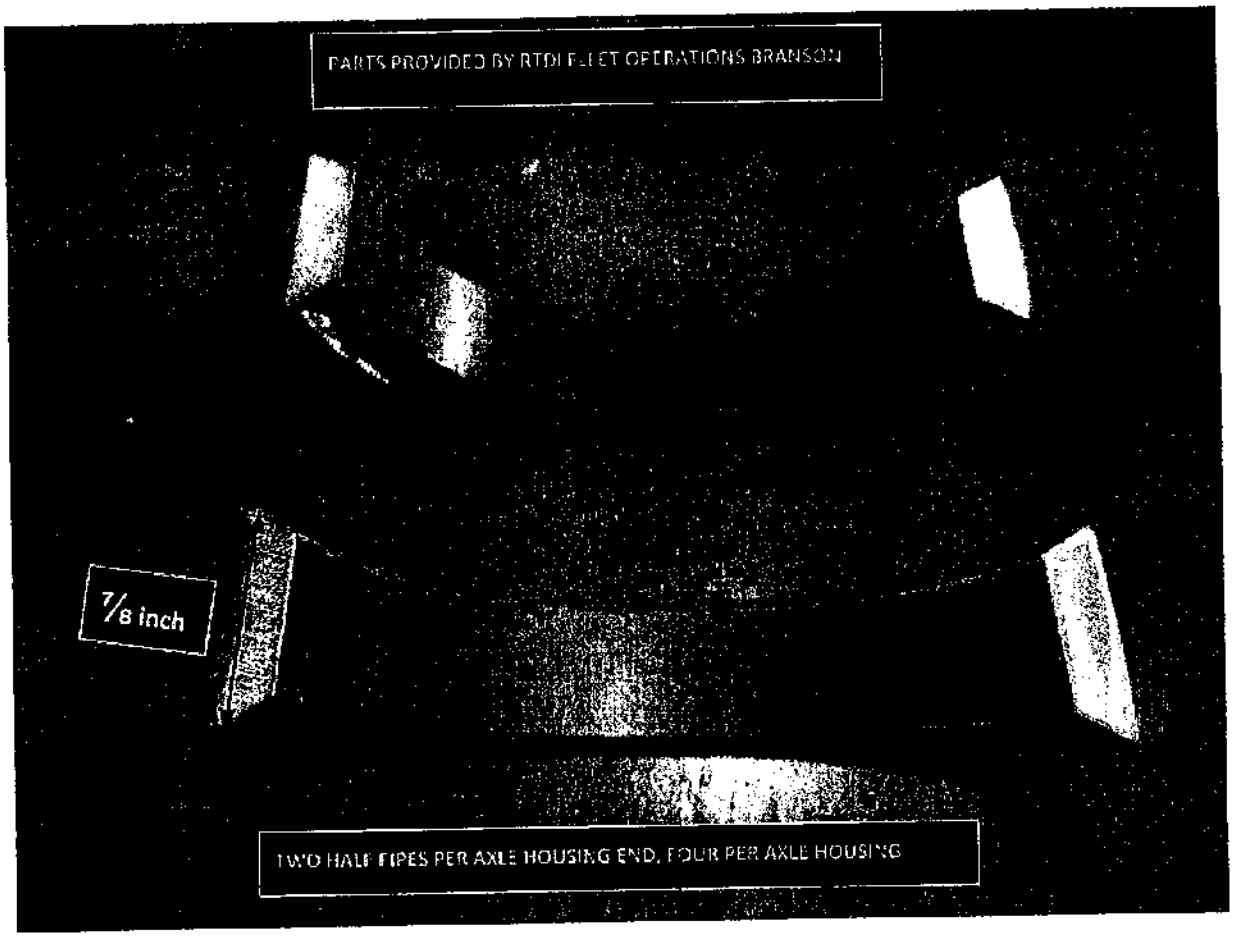

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Fig 3

1. Remove axle from the Duck
2. Set axle housing on a secure stand
3. Remove Boot and hardware
4. Thoroughly clean (remove all grease)
5. Examine axle housing for fractures

Note: Bent or fractured axle housings are not to be modified.

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Fig 4

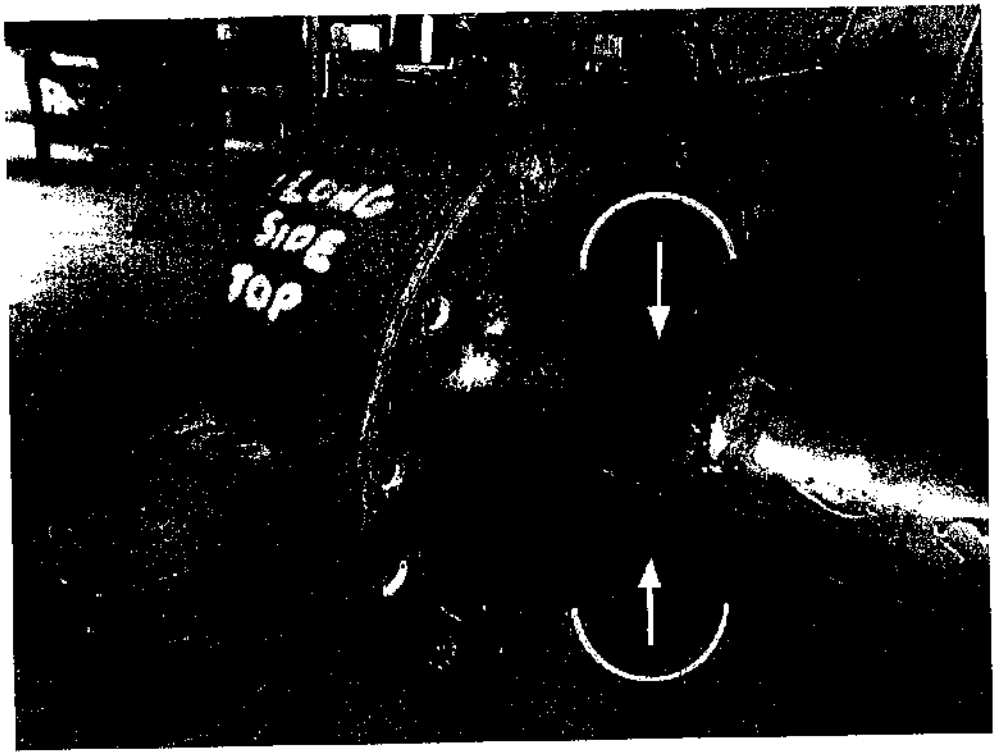

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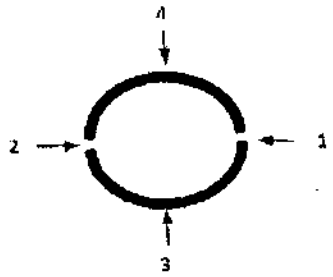
Fig 5

Tack weld half pipes in place as shown in photo

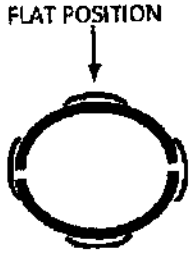
1. Center half pipe in detent gap between ball end and axle housing
2. Secure pipes in place with (vise grip) finger clamp
3. Tack weld in the sequence provided below
4. Ensure the axle housing stand is capable to allow the axle housing to rotate
5. All welds must be done in a flat position
6. Welder setting (spray arc)
   - .035 Steel hard wire
   - 75% Argon 25% Carbon Dioxide or 90% - 10%
   - Gas flow setting 30

Pending on your machine
- Volts 30-32 / Amps 200-210



TACK WELDING

FLAT POSITION



WELDING

1. Apply 2 inches of weld in flat position then rotate axle housing 180 degrees.
2. Continue step (1) until all weld joints are filled

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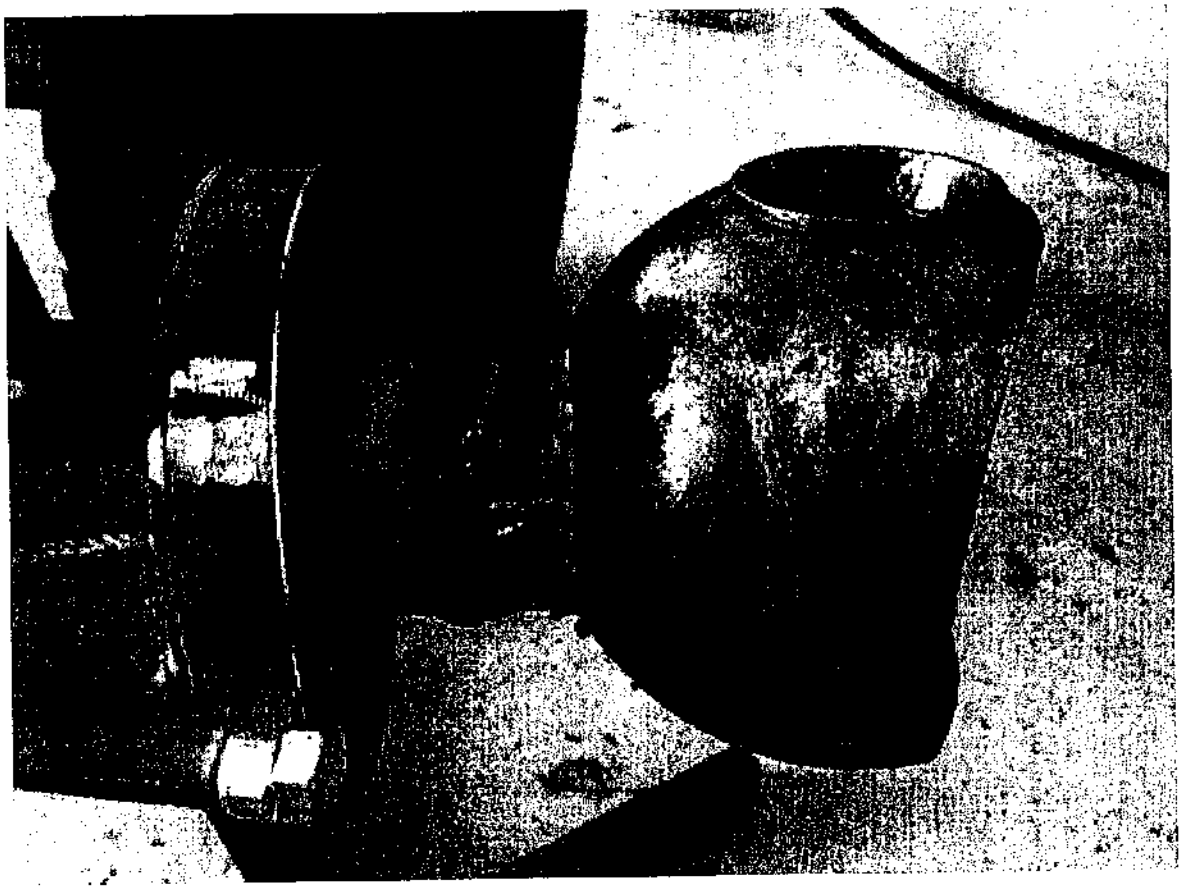
Fig 6



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Total Pages: 9

SERVICE BULLETIN

REASON FOR RELEASE: To enhance the inspection of safety critical components beyond visual examination, RTDI is releasing this Service Bulletin in order to provide guidance with regards to an annual Non-Destructive Testing Program (NDT), RTDI highly recommends you establish this program for the 2016 operating season. To initiate this program, RTDI has identified key components that require NDT testing. Moving forward RTDI additionally recommends all components listed below be required to provide for positive identification notifying the user the components have been NDT tested. Documentation and notification requirements are as follows:

1. All newly received components require a numerical tag notifying the user the component has been tested.
2. All numerically tagged components must be documented (via spreadsheet) the following information must be provided:
   - The components numerical number (tag ID) Example: SD-107 or TD-107
   - The official number of the duck (O.N.) the component is installed on.
   - Dates of annual testing of that particular component.
   - Components "NOT" in service shall be documented in the same manner and listed as "Inventory"
   - Any component that fails annual testing must be removed from service and destroyed.
   - Any component that fails annual testing must be documented (Removed from Service) and dated.

DIRECTIONS:

1. Inform and review this Service Bulletin with your staff.
2. Contact a local company qualified to perform and familiarized with the procedures listed on pg. 2
3. It is recommended you request documented proof (certifications) from the tester and keep on file.
4. Establish a means to identify tested components. Numerically engraved tags are preferred. See example pg. 3
5. It is recommended to conduct NDT testing during off season (heavy rebuild period) when the areas that require testing are already exposed due to maintenance. Depending on the set up time and the condition of the components, the testing takes approximately 1-2 hours per duck. Most testing companies encourage you to provide for a 10 hour day. Testing can be conducted while axle housing are installed on the duck.
6. Ensure the testing company provides you a written report. See example pg. 4 - 6
7. Ensure tester understands the locations that require testing. See examples pg. 7 - 9
8. Acknowledge receiving this Service Bulletin via email to fenglish@ridetheducks.com
9. Maintain awareness of this Service Bulletin and resulting action for an appropriate period to ensure effectiveness of the corrective action.

COMPONENTS AFFECTED BY THIS SERVICE BULLETIN:

TRUCK DUCKS (See pg. 7 areas to be inspected - photos)

A. Front - Axle Spindles
   It is advised to replace damaged front axle spindles with:
   - Part Number 4316SP - Forged Rockwell 2.5 Ton 4340 Front Spindle (STOCK)
   - Contact Ouverson Engineering and Machine, phone number (320 -983 - 3030) ask for Steve Ouverson
B. Rear - Intermediate Axle Housing Spindles
C. Rear - Tag Axle Housing Spindles

STRETCH DUCKS (See pg. 8 - 9 areas to be inspected - photos)

A. Front - Axle Housing Spindles "Weld Collar"
B. Front - Axle Spindles
C. Rear - Intermediate Axle Housing Spindles "Weld Collar"
D. Rear - Tag Axle Housing Spindles "Weld Collar"

NOTE: All work must be performed by qualified personnel. Use only authorized components, specified or provided by Ride The Ducks. All applicable OSHA safety standards and safe industry practices must be observed. Observe all safety information contained in the manufacturer's manuals. Make available this bulletin and all related technical information to personnel using the equipment.

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Bulletin No. SB-00-01-16
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Effective Date: 1/8/16
Supersedes: N/A

Applicable to: All Ducks
Total Pages: 9

NON-DESTRUCTIVE TESTING EXAMINATION PROCEDURE:

MAGNETIC PARTICLE TEST REPORT

CLIENT: RIDE THE DUCKS **PROJECT: STRETCH DUCK AXLE HOUSING SURVEY**

PROJECT #: 20142-15 **DATE OF EXAMINATION: 12/9/2015**

COMPONENT ID: DUCK UNIT # SD #9

COMPONENT MATERIAL: CARBON STEEL **MATERIAL THICKNESS: VARIED**

EXAMINATION PROCESS

EQUIPMENT MFR: Parker Probes MODEL & SERIAL NO.: B310/ SN: 3037 - 11-8-15
PARTICLE TYPE: Mel-L-Chek Suspended Wet Fluorescent MAGNETIZATION TECHNIQUES: Yoke
TYPE OF CURRENT: AC QUALITY REQUIREMENTS: ASTM E-709
ACCEPTANCE CRITERIA: ASTM E-709 PROCEDURE USED: ASTM E-709/ AE-MT-01
LIGHTING EQUIPMENT: High Intensity UV LED Flashlight PARTICLE COLOR: 1400B Yellow

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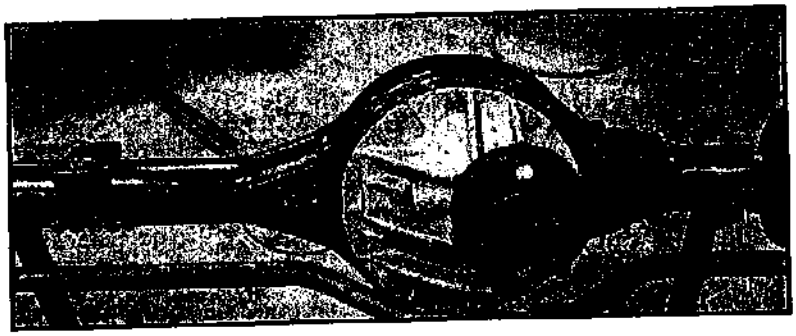

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ANDERSON ENGINEERING, INC
EMPLOYEE OWNED

306481
PAGE 1 of 3

MAGNETIC PARTICLE TEST REPORT

CLIENT: RIDE THE DUCKS — PROJECT: STRETCH DUCK AXLE HOUSING SURVEY

PROJECT #: 20142-15 — DATE OF EXAMINATION: 12/9/2015

COMPONENT ID: DUCK UNIT # SD #9

COMPONENT MATERIAL: CARBON STEEL — MATERIAL THICKNESS: VARIED

EXAMINATION PROCESS

EQUIPMENT MFR: Parker Probes — MODEL & SERIAL NO.: B310I SN: 3037 - 11-8-15
PARTICLE TYPE: Met-L-Chek Suspended Wet Fluorescent — MAGNETIZATION TECHNIQUES: Yoke
TYPE OF CURRENT: AC — QUALITY REQUIREMENTS: ASTM E-709
ACCEPTANCE CRITERIA: ASTM E-709 — PROCEDURE USED: ASTM E-709/ AE-MT-01
LIGHTING EQUIPMENT: High Intensity UV LED Fleshlight — PARTICLE COLOR: 1400B Yellow

EXAMINATION RESULTS

COMPONENT ID	ACCEPT	REJECT	INDICATION	REMARKS
Rear Intermediate (Drive) Axle Spindles – Drivers Side	X		No Relevant Indications @ Time of Inspection	
Rear Intermediate (Drive) Axle Spindles – Passengers Side	X		No Relevant Indications @ Time of Inspection	
Rear Tag Axle Spindles – Drivers Side	X		No Relevant Indications @ Time of Inspection	
Rear Tag Axle Spindles – Passengers Side	X		No Relevant Indications @ Time of Inspection	

JOHN E. COOK - CWI # 09051871 / LEVEL II NDE TECHNICIAN

John Cook
CWI 09051871
QC1 EXP. 5/1/2016

12-14-15

SIGNATURE: John E Cook — DATE: 12/14/2015

2045 W. WOODLAND SPRINGFIELD, MO 65807 PH: 417.866.2142 FX: 417.866.2775 WWW.AENGLTD.COM E-MAIL: ACINC@AENGLTD.COM
ENGINEERS * SURVEYORS * LABORATORIES * DRILLING

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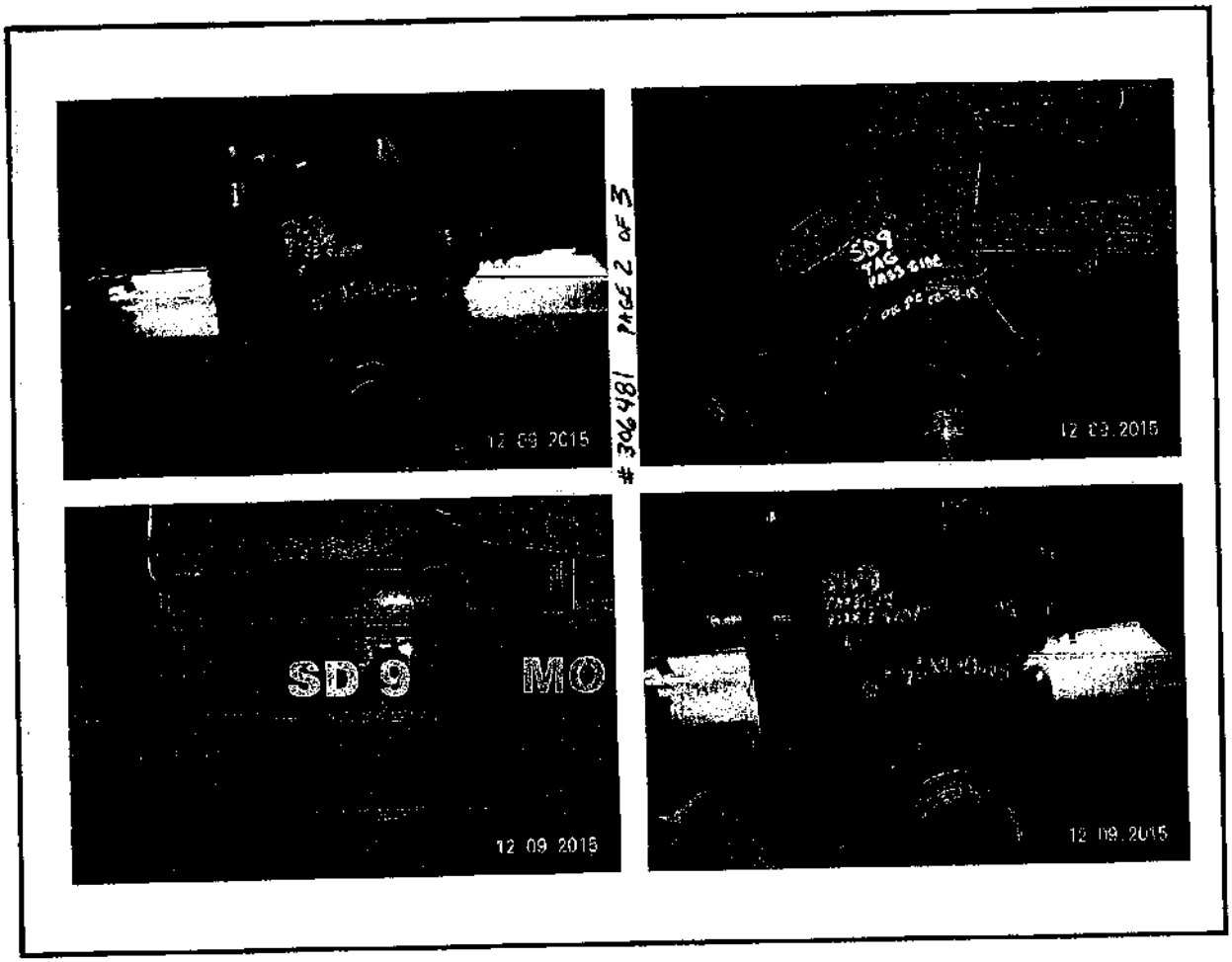

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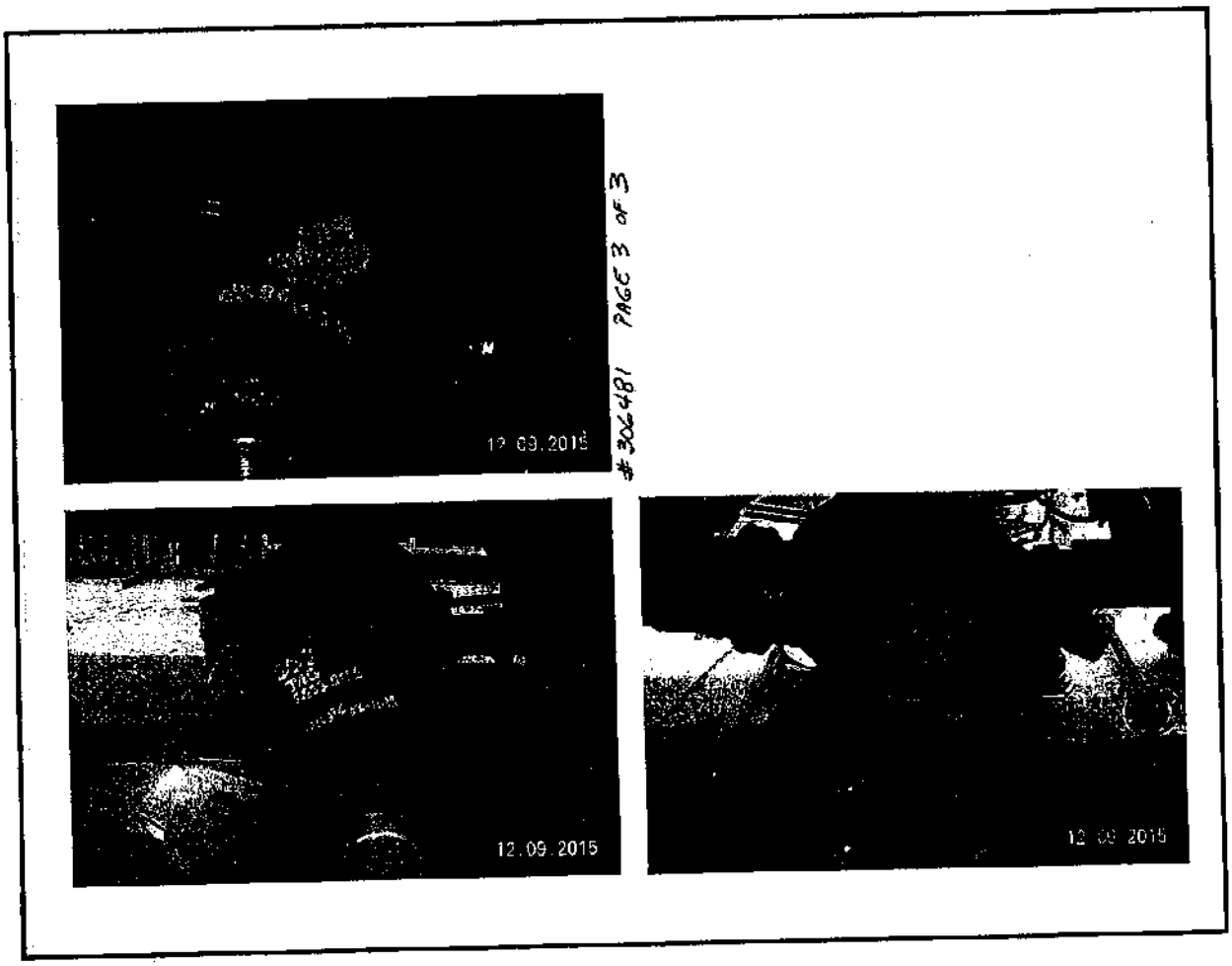

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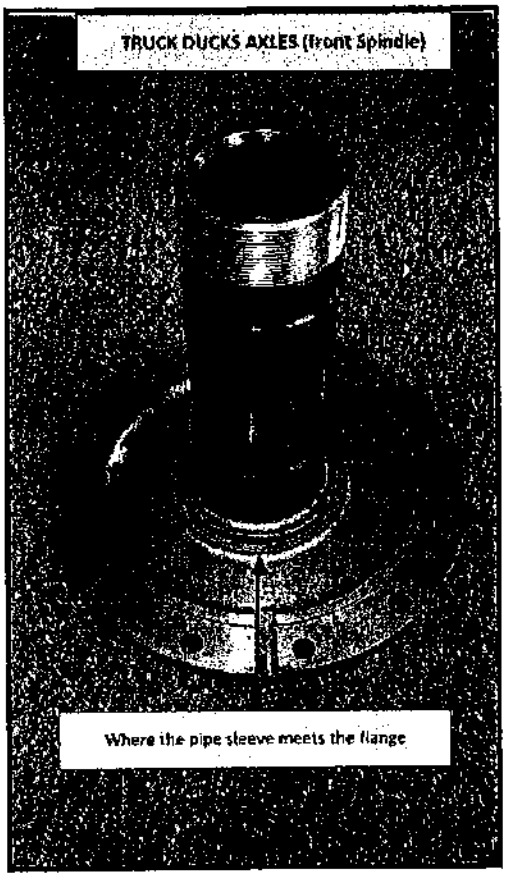


NOTE: All work must be performed by qualified personnel. Use only authorized components, specified or provided by Ride The Ducks. All applicable OSHA safely standards and safe industry practices must be observed. Observe all safety information contained in the manufacturer's manuals. Make available this bulletin and all related technical information to personnel using the equipment.

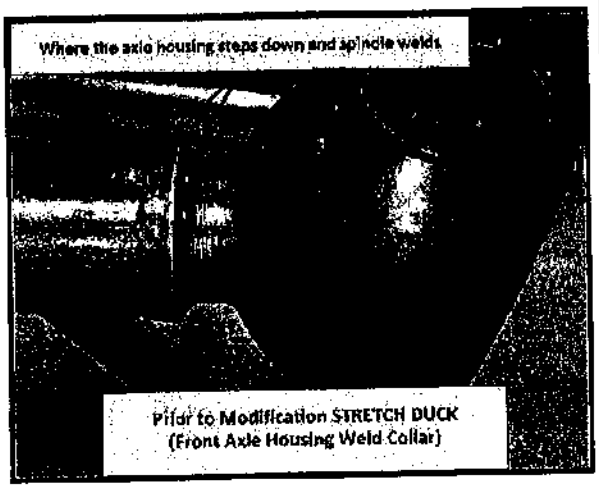
CONTACT US VIA EMAIL
RTDI FLEET OPS HOTLINE: 417 266 7676
RTDI PARTS: 417 266 7626

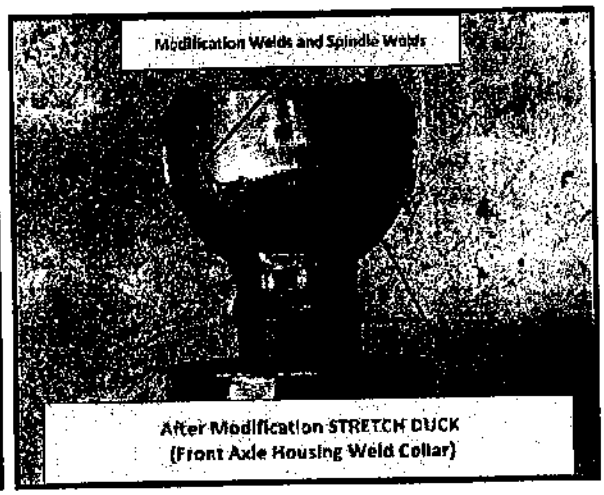
CONTAINS CONFIDENTIAL BUSINESS INFORMATION

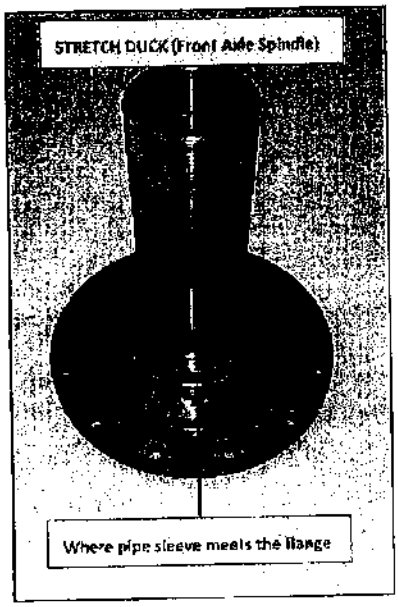
RIDE THE DUCKS INTERNATIONAL
Fleet Operations & Safety
2320 West Highway 76
Branson MO 65616

Bulletin No. SB-00-01-16
Release Date: 1/8/16
Effective Date: 1/8/16
Supersedes: N/A

Applicable to: All Ducks
Total Pages: 9







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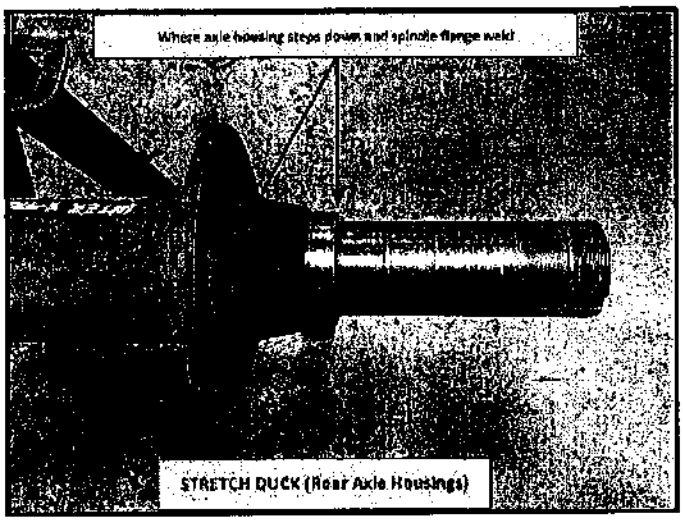

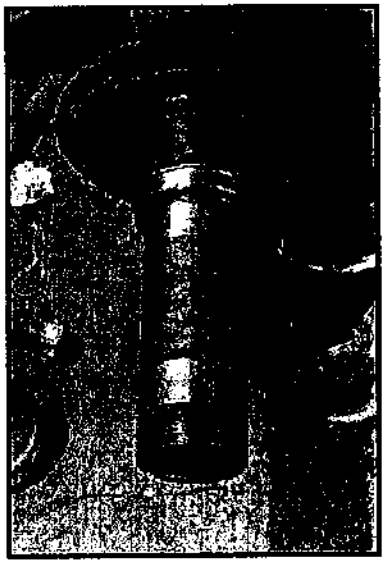

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CONTACT US VIA EMAIL
RTDI FLEET OPS HOTLINE: 417 266 7676
RTDI PARTS: 417 266 7626

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Re: Duck Central Updates

1 message

Frank English <fenglish@ridetheducks.com> Thu, Dec 12, 2013 at 4:52 PM
To: Ryan Johnson <ryan@ridetheducksofseattle.com>

That document will grow over time. Eventually I will include all life saving appliances. Inspector broke about 20 of our PFDs because his method of checking them was to twist, pull, turn tug and tear!! CG has no criteria for the inspection of PFDs.

NOW THEY DO!

If you see any mistakes in that doc let me know. Its a quick fix on my end.

Thanks
Frank

On Thu, Dec 12, 2013 at 4:31 PM, Ryan Johnson <ryan@ridetheducksofseattle.com> wrote:

> Wow how did I not see that. Thanks
>
> Ryan Johnson
>
> Director of Operations
>
> Ride the Ducks of Seattle
>
> Cell: (b)(6)
>
> Corporate Office: 206-441-4687
>
> Fax: (206)441-4697
>
> www.ridetheducksofseattle.com

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

From: Frank English [mailto:fenglish@ridetheducks.com]
Sent: Thursday, December 12, 2013 2:40 PM
To: Ryan Johnson
Subject: Re: Duck Central Updates

On the HOME page you will see it listed just under "Latest notices & bulletins" just click on Life Preserver Inspection Guide and it will link you to it.

Frank

On Thu, Dec 12, 2013 at 4:21 PM, Ryan Johnson <ryan@ridetheducksofseattle.com> wrote:

I found all the SB's but I can't locate the PFD thing in Duck Central.

Ryan Johnson

Director of Operations

Ride the Ducks of Seattle

Cell: (b)(6)

Corporate Office: 206-441-4687

Fax: (206)441-4697

www.ridetheducksofseattle.com

From: Frank English [mailto:fenglish@ridetheducks.com]
Sent: Monday, December 02, 2013 9:40 AM
To: (b)(6)

(b)(6)

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

Subject: Duck Central Updates

Everyone,

For those who do not frequently visit Duck Central, we have recently added a few Service Bulletins and a training document. If you have any questions let me know.

Thanks,

Frank

Latest notices & bulletins

Life Preserver Inspection Guide
SB-00-16-2013 Duck Emergencies & Lifesaving Equipment
SB-00-15-2013 Stairway Release Placard
SB-00-14-2013 Stretch Duck Front Axle
SB-00-06-2013 Revision - Wheelchair Lift

CONTAINS CONFIDENTIAL BUSINESS INFORMATION

SB-00-14-13 Stretch Duck Steering Axle Mods

1 message

Frank English <fenglish@ridetheducks.com> Tue, Oct 1, 2013 at 1:01 PM
To: fleet.maintenance@ridetheducks.com
Cc: Frank English <fenglish@ridetheducks.com>

Everyone,

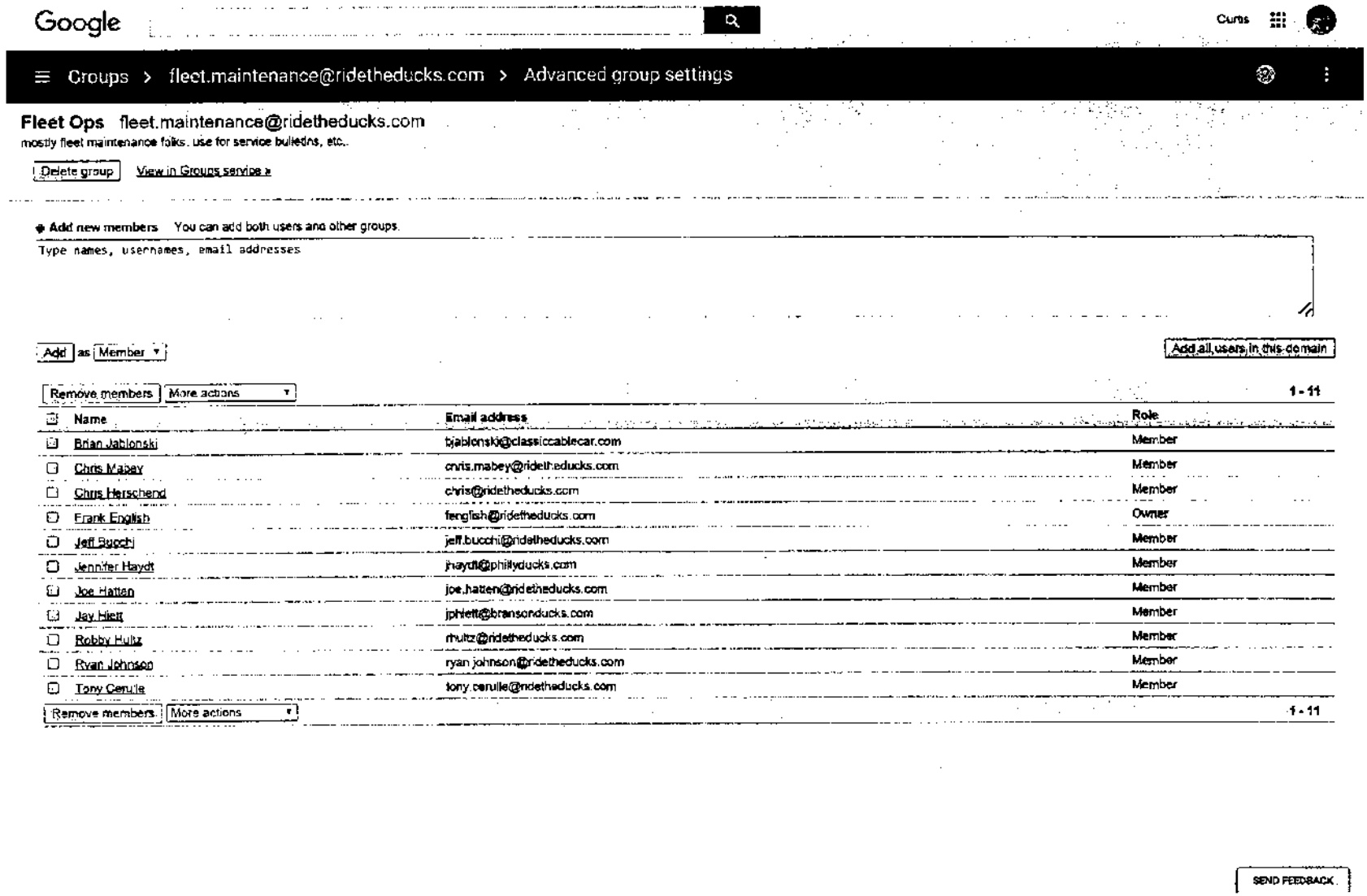
A newly posted Service Bulletin has been added to Duck Central. https://sites.google.com/a/splashducks.com/new-intranet/

Some of you I have visited recently to set up your welding machines for this modification. Those of you who have not had your welding machines calibrated please give me a call and I will talk you through it.

If you have other questions regarding this Service Bulletin please do not hesitate to contact Brian, myself or call the RTDI Fleet Operations HOTLINE number.

Thanks,
Frank

Manager of Fleet Operations & Safety
Ride The Ducks International, LLC
Branson MO 65616
417.266.7605 (O)
417.239.4417 (C)
417.266.7676 (Fleet Ops Hotline)



CONTAINS CONFIDENTIAL BUSINESS INFORMATION

FILED
15 OCT 05 AM 9:00

KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

IN THE SUPERIOR COURT OF THE STATE OF WASHINGTON
IN AND FOR THE COUNTY OF KING

(b)(6) an individual, Plaintiff, v. **RIDE THE DUCKS INTERNATIONAL, LLC,** a Missouri Corporation; **RIDE THE DUCKS OF SEATTLE, LLC,** a Washington Corporation; **"JOHN DOE DRIVER"** and **"JANE DOE DRIVER,"** both individuals, and the marital community comprised thereof, Defendants	**No.** **COMPLAINT FOR PERSONAL INJURY AND DAMAGES**

I. NATURE OF ACTIONS

1. These causes of action are brought to recover just compensation for personal injuries and damages sustained by Plaintiff (b)(6) as a result of a motor vehicle accident that occurred on the George Washington Memorial Bridge (commonly: *"Aurora Bridge"*) on SR 99 in Seattle, King County, Washington shortly after 11:00 a.m., Thursday, September 24, 2015. Plaintiff (b)(6) was a passenger on a tour bus owned and operated by Bellair Charters. The tour bus in which Plaintiff (b)(6) was riding was struck by an amphibious vehicle, originally a military model DUKW, which in 2005 was converted by Defendant Ride the Ducks International ("RTDI") into a civilian "Duck Boat." ~~which~~ Defendant RTDI sold the Duck Boat to Defendant Ride the Ducks of

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505 5th Ave So., Ste. 630
Seattle, WA 98104
V: 206.625.9104
F: 206.682.6710

Seattle ("RTDS") who owned and operated it as "Duck 6." At the time of the accident, Duck 6 was being driven by RTDS' employee, Defendant "John Doe Driver."

II. PARTIES

2. Plaintiff (b)(6) (b)(6) year-old single female. A citizen of the Republic of Korea, she arrived in the USA for the first time on September 16, 2015, in order to attend college at North Seattle College in Shoreline, Washington. She currently resides in King County.

3. Defendant RTDI is a Missouri corporation with its headquarters/principal place of business in the State of Georgia.

4. Defendant RTDS is a Washington corporation.

5. Defendant "John Doe Driver" is an individual who was employed by RTDS at the time of the accident to drive Duck 6 while entertaining the customer tourists. His true name has not been released to the public and is as of yet unknown to Plaintiff.

6. The true name of John Doe Driver's wife is likewise unknown. Therefore, she has been designated Defendant "Jane Doe Driver" and is named herein as a defendant solely in order to secure jurisdiction over John Doe Driver's marital community.

III. JURISDICTION & VENUE

7. This is an action for personal injury and damages arising out of an accident that occurred in King County.

8. Plaintiff (b)(6) resides, and Defendant RTDS has its principal place of business, in King County. While Defendant RTDI is a foreign corporation, its relevant business activities and contacts within the State of Washington were conducted in King County.

9. Accordingly, this Court has jurisdiction over the subject matter and the parties in this action and venue is proper in King County.

IV. FACTS

10. The scene of this horrific accident is located on SR 99 where it traverses the Aurora Bridge in Seattle, Washington. The bridge was originally built 83 years ago in 1932, when traffic was far lighter than the daily average of 86,000 cars crossing it now.

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11. The bridge has six 6 lanes of travel, three northbound and three southbound. The lanes are notoriously narrow, in point of fact the narrowest on any 6-lane bridge in the state. While the modern standard lane width is 11-12 feet, on the Aurora Bridge, the center northbound lane is 9 feet, 3 inches wide. The other lanes on the bridge are 9 feet, 6 inches wide to 9 feet, 8 inches wide. The width of Duck 6 is 8 feet, 2.4 inches, leaving just over a mere 6 inches of room within these lanes on either side of the vehicle. The posted speed limit is 40 mph, which the flow of traffic regularly exceeds. There is no median barrier on the bridge to prevent vehicles from crossing over into opposing traffic.

12. The Washington State Department of Transportation (WDOT) years ago recognized that this stretch of highway crossing the Aurora Bridge has one of the highest rates of accidents in the state. In 2003, WDOT proposed that the sidewalks be placed under the bridge roadway allowing the lanes of vehicle travel to be widened and that a median barrier be installed to prevent this kind of cross-over accident. It was not done, leaving dangerous traffic conditions on the bridge.

13. RTDI boasts on its website that it is the nation's largest amphibious tour operator and amphibious vehicle manufacturer.

14. RTDI has a franchisor/franchisee relationship with Defendant RTDS here in Washington. In 2005, RTDI performed the manufacturing necessary to convert Duck 6 from its original (1945) military model DUKW into what is known within the industry by its current moniker - a "Duck Boat." RTDI sold it to Defendant RTDS that same year.

15. Duck 6 was deployed by RTDS as an amphibious tourist vehicle providing tours both on land/streets and in waterways of Seattle.

16. In 2013, RTDI became aware that the axle housings on Duck Boats such as Duck 6 could be dangerously defective; they needed to be thoroughly checked and repaired. RTDI published a warning to its own operators in the form of a service bulletin, but it failed to successfully inform its franchisee – RTDS.

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17. RTDS' maintenance records reflect that the axles and housings passed 3 inspections without any negative findings whatsoever in both 2013 and 2014. RTDS failed to examine the defective housing properly and no repairs or modifications were accomplished. The RTDS mechanic who performed the first two inspections was not informed of the service bulletin regarding the dangerous defects in the axle housing.

18. The route John Doe Driver was following on the day of the accident, September 24, 2015, took DUCK 6 northbound on SR 99 over the Aurora Bridge just after 11:00 a.m. PDT. Just prior to the accident, John Doe Driver drove Duck 6 northbound on the Aurora Bridge in the middle lane. He signaled his intention to change into the left inside lane. At that moment, Duck 6 apparently had a mechanical failure involving the left front wheel assembly. Eyewitnesses describe an apparent "blowout," "lockup" or the wheel actually coming off. In the aftermath, investigators would find the left front wheel detached from Duck 6 with its axle sheared off completely either just prior to, or as a result of, the impact with the Bellair tour bus.

19. In any event, John Doe Driver failed to maintain control of Duck 6 as it crossed over the barrier-less centerline where it violently impacted with the Bellair tour bus traveling southbound across the bridge.

20. Plaintiff (b)(6) was a passenger on the Bellair tour bus, sitting on a right-most seat in roughly the middle of the bus. She and fellow students at North Seattle College were on a school sponsored orientation tour of Seattle headed to a tour of Safeco Field.

21. Ms. (b)(6) has no memory of the impact in the accident. She was knocked unconscious. Her last recollection was looking at her cell phone. The next thing she remembers is waking up sitting on the sidewalk, covered in dust, bleeding, badly bruised over her left eye and her left shoulder/arm, and experiencing extreme pain. Both her hands suffered fractures. Other students were attending her. She was taken by ambulance to the Group Health Hospital on Capitol Hill, where she was examined, treated, and released later that evening with her hands in cast and splint.

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22. Ms. (b) (6) continues to suffer from both physical and psychological injuries for which she is being treated.

V. RESPONDEAT SUPERIOR

23. All acts and/or omissions on the part of John Doe Driver and all other employees and/or agents of Defendants RTDI and RTDS that contributed to this accident, were performed within the scope of their employment and/or agency for said defendants. Thus, under the doctrine of *Respondeat Superior,* defendants are liable for any of the acts or omissions of their employees and/or agents.

VI. FIRST CAUSE OF ACTION AGAINST DEFENDANT RTDI

PRODUCTS LIABILITY - NEGLIGENCE

24. All of the above paragraphs are incorporated herein by reference.

25. RTDI not only remanufactured Duck 6 in 2005, but also sold it to RTDS in that same year.

26. Duck 6 was not reasonably safe at the time of RTSI's remanufacture and sale to RTDS. Failure of defective parts in the left front wheel assembly contributed to the accident. At the time of this accident, Duck 6 was still within its presumed period of "useful safe life" as provided for in RCW 7.72.060 Length of Time Product Sellers Are Subject to Liability.

27. Further in 2013, RTDI became aware of the defective condition of the parts that failed in this accident. While they issued warnings to their own operators in other cities, they failed to adequately warn and instruct its franchisee, RTDS.

28. RTDI was negligent in that it failed to use care that a reasonable manufacturer and/or seller would have used in like and similar circumstances to remanufacture Duck 6 correctly and to provide adequate warnings of safety hazards and/or sufficient instruction or training.

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29. As a result, Defendant RTDI is liable in negligence under Washington's *Products Liability Statutes* (RCW 7.72 et seq.) for all of Plaintiff (b)(6) personal injuries and damages proximately caused by this accident.

VII. SECOND CAUSE OF ACTION AGAINST

DEFENDANT RTDI - PRODUCTS LIABILITY - STRICT

30. All of the above paragraphs are incorporated herein by reference.

31. Duck 6 was not reasonably safe in its remanufactured condition when RTDI sold and delivered it to RTDS. Duck 6 did not conform to the implied warranties of merchantability and fitness for particular purpose as provided for in RCW 62A et seq. - Washington State's *Uniform Commercial Code*.

32. As a result, RTDI is strictly liable under Washington's Products Liability Statutes (RCW 7.72 et seq.) for all of Plaintiff (b)(6) personal injuries and damages proximately caused by this accident.

VIII. THIRD CAUSE OF ACTION AGAINST

DEFENDANTS JOHN DOE DRIVER & RTDS - NEGLIGENCE

33. All of the above paragraphs are incorporated herein by reference.

34. John Doe Driver was negligent for failing to use the ordinary care of a reasonably prudent driver to maintain control of Duck 6 to prevent it from crossing the double yellow center line and colliding with opposing traffic - expressly in violation of RCW 46.61.150 *Driving on Divided Highways*.

35. Further, RTDS negligently failed to properly train, instruct, and supervise John Doe Driver in the performance of his duties as an employee/agent of RTDS.

36. At all times relevant hereto, John Doe Driver was acting within the scope of his employment/agency on behalf of his employer/principal RTDS. Accordingly, under the doctrine of *Respondeat Superior,* RTDS is equally liable for his actions.

37. As a result, RTDS is liable for its own negligence. RTDS and John Doe Driver are both liable for the negligence of John Doe Driver and for all of Plaintiff Yoon's personal injuries and damages proximately caused by this accident.

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IX. FOURTH CAUSE OF ACTION AGAINST DEFENDANT RTDS - NEGLIGENCE

38. All of the above paragraphs are incorporated herein by reference.

39. Agents of RTDS, whose names are currently unknown to Plaintiff (b)(6) were negligent in failing to use the care reasonably prudent inspectors would have in like and similar circumstances to inspect Duck 6 and to discover the defective parts that were a proximate cause of this accident.

40. Said inspections are required in the Code of Federal Regulations under 49 CFR 396 et seq. as further required by WAC 480-30-221 concerning inspection, repair, and maintenance.

41. Further, RTDS negligently failed to properly train, instruct, and supervise these unnamed agents in the performance of their duties as employees/agents of RTDS.

42. At all times relevant hereto, the unnamed agents referred to above were acting within the scope of their employment/agency on behalf of their employer/principal RTDS. Accordingly, under the doctrine of *Respondeat Superior,* RTDS is equally liable for their negligence.

43. As a result, RTDS is liable for its own negligence as well as the negligence of these unnamed agents and for all of Plaintiff (b)(6) personal injuries and damages proximately caused by this accident.

X. JOINT AND SEVERAL LIABILITY

44. Inasmuch as Plaintiff (b)(6 was completely negligence free in this accident, pursuant to RCW 4.22 et seq., the liability of all defendants is joint and several.

XI. DAMAGES

45. Plaintiff (b)(6) suffered serious general damages including, but not limited to, physical injury, disability, disfigurement, pain and suffering, and emotional trauma, the full nature and extent of which will be proven at the time of trial.

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46. Plaintiff (b)(6) also suffered special damages including, but not limited to, costs of medical treatment, prescriptions, other medical supplies, and transportation, the exact nature and full extent of which will be proven at the time of trial.

47. The special damages suffered by Plaintiff (b)(are liquidated and ascertainable by computation. To the extent said amounts remain unpaid by defendants, Ms. (b)(6) is entitled to prejudgment interest at the statutory rate on these amounts until paid.

XII. RESERVATION

48. Plaintiff's investigation is ongoing. Further discovery should reveal the names of agents of the defendants. It may also reveal additional acts of negligence on the part of the referenced agents our other agents of these defendants and/or establish that other, so far unnamed, persons or entities may also be at fault and another cause contributing to this accident.

49. Further, the exact nature and full extent of Ms. (b)(6) personal injuries and damages are not yet known; she may have additional causes of action.

50. Plaintiff reserves the right to subsequently amend her complaint accordingly.

XIII. PRAYER FOR RELIEF

50. **WHEREFORE**, plaintiff prays for judgment against the defendants in such sum as will fully and fairly compensate plaintiff for her injuries, general damages, and special damages, including prejudgment interest as appropriate, other damages the exact nature and full extent of all of which to be proven at trial, together with attorney fees, costs and disbursements herein, as well as such other relief as the Court deems just and equitable in the premises.

DATED this 5th day of October, 2015.

HERRMANN SCHOLBE

Charles Herrmann, WSBA #6173
John Scholbe, WSBA #29433
Crystal R. Lloyd, WSBA #46072
Attorneys for Plaintiff

HERRMANN SCHOLBE
505 5th Ave So., Ste. 630
Seattle, WA 98104
V: 206.625.9104
F: 206.682.6710

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)

Plaintiff,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

(b)(6)

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiff alleges:

I. Parties

1.1 (b)(6) is an 18 year old single woman residing in Seattle, King County, Washington.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER
200 2nd Ave West Seattle, WA 98119-4204
Tel: 206-448-1777

1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State. The

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER
200 2nd Ave West Seattle, WA 98119-4204
Tel. 206-448-1777

State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a (b) year old driver and approximately 45 to 50 passengers.

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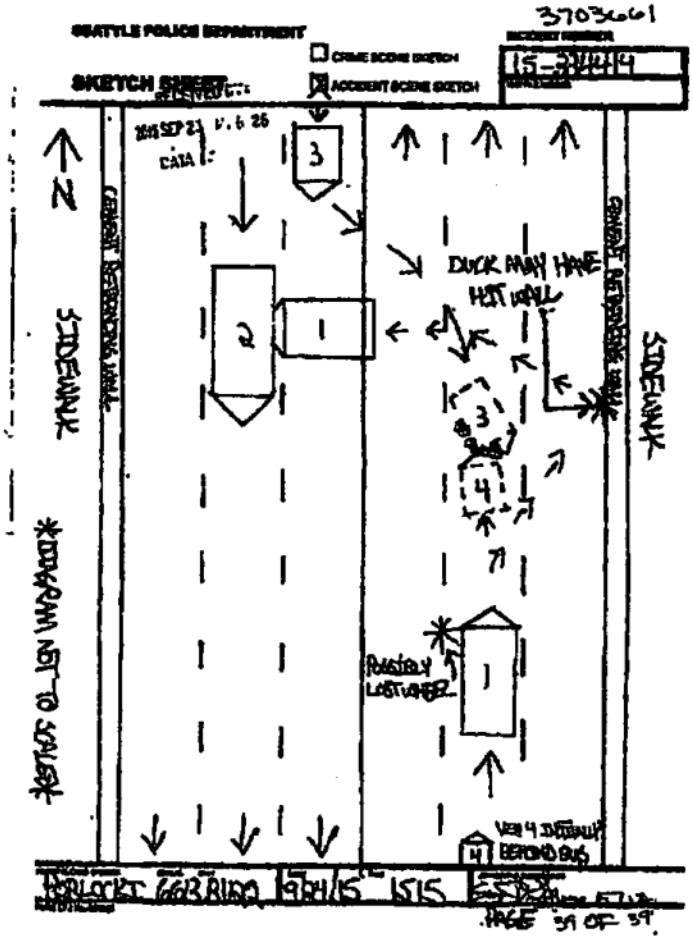
200 2nd Ave West Seattle, WA 98119-4204
Tel: 206-448-1777

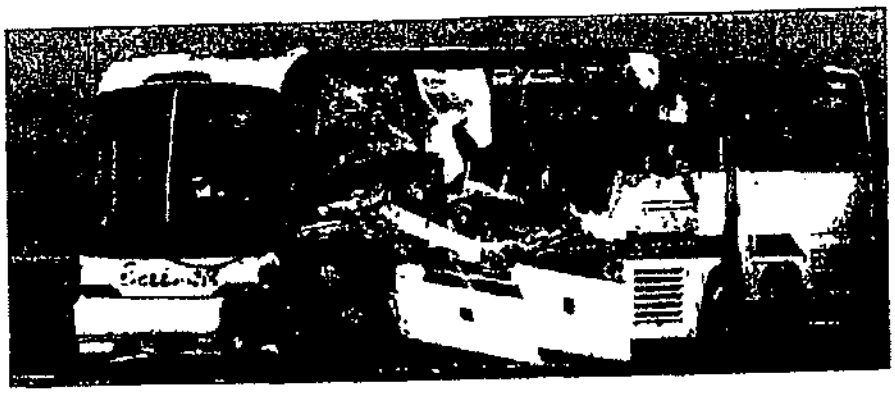
3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER
200 2nd Ave West Seattle, WA 98119-4204
Tel: 206-448-1777

3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:



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3.9 RTD International manufactured, refurbished and modified DUKW No. 6 which was originally a 1945 military model. In approximately 2005, RTD International sold the DUKW to RTD Seattle.

3.10 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.11 On or about October 2013, RTD International issued a notice to purchasers of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures.

3.12 RTD International took no further action to ensure that purchasers of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.13 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.14 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.15 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.16 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic Dominick Anderson stated he had never seen the October 13, 2013 service bulletin.

3.17 RTD International issued a statement after the collision stating that it warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country, and that it recommended specific inspections and repairs to reinforce the housing.

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3.18 The NTBS has possession of the DUKW vehicle and its component parts. It is currently performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and other investigatory acts.

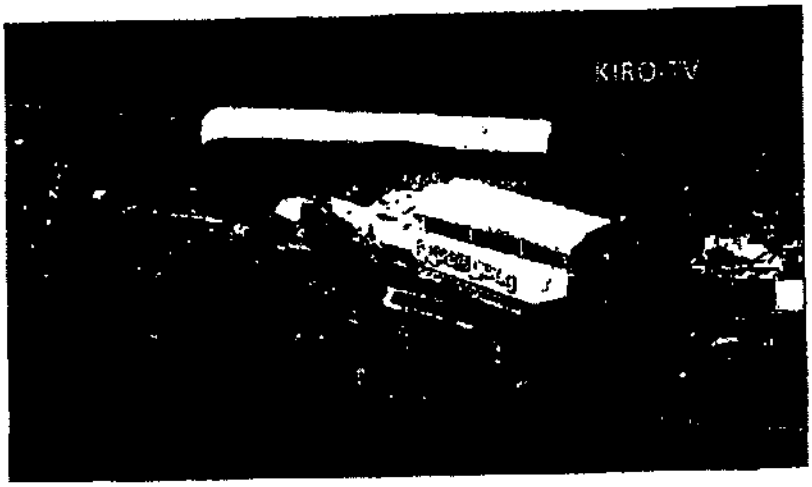
3.19 Following the Crash, the Washington Utilities and Transportation Commission suspended RTD Seattle's operations pending a full examination into its fleet. The state's investigation team is still analyzing maintenance records and conducting physical inspections of the DUKW vehicles.

3.20 RTD Seattle has implored the State to act with "urgency" so that the vehicles can be placed back in service and the company's 130 employees sent back to work.

3.21 RTD Seattle has informed the State that it will no longer use the SR 99 Aurora Bridge.

3.22 RTD Seattle has informed the State that it will now use a separate driver and tour guide instead of combining the two functions in one employee.

3.23 As a result of the collision, approximately 64 people were injured, five of whom were killed.



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3.24 A total of 45 to 50 students and staff from North Seattle College were on the motor coach when it was struck. The College had organized an excursion for students in its international program.

3.25 (b)(6) a new entering freshman, was seated in the window seat, on the left side just forward of the middle of the motor coach.

3.26 (b)(6) suffered numerous orthopedic injuries, complex facial lacerations and other injuries. She was transported to Harborview.

3.27 As of the date of this complaint, (b)(6) is still recovering at Keiro Nursing Home in Seattle.

IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq*.

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left control of RTD International, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical

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units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiff's harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72 030.

4.5 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe because adequate warnings of instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiff's harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and

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injuries, of which RTD International was aware or reasonably should have been aware.

4.7 (b)(6) was negligent, including but not limited to. a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.8 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) under the doctrine of *respondeat superior*.

4.9 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; and i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the

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physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has suffered and continues to suffer permanent physical injuries, disability, disfigurement, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has been required to seek various medical treatments and will continue to require medical treatments in the future, as well as other special damages including delay of education, increased educational expenses, wage loss, caregiver expenses, including but not limited to her parents' need to leave the family's two minor children and business in order to care for (b)(6) increased housing expenses, all in an amount to be proven at the time of trial.

5.3 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiff in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

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5.4 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.5 Plaintiff has incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiff prays for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

DATED this 2nd day of December, 2015.

/s/ Karen K. Koehler
Karen K. Koehler, WSBA#15325
Andrew N. Ackley, WSBA#41752
Counsel for Plaintiff

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UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF WASHINGTON

ESTATE OF (b)(6) through personal representative his representative capacity for the Estate; (b)(6) in his individual capacity and as the father of (b)(6) in her individual capacity and as mother of (b)(6) Plaintiffs, vs. RIDE THE DUCKS OF SEATTLE, LLC, a Washington Limited Liability Corporation; RIDE THE DUCKS INTERNATIONAL, LLC, a Missouri Limited Liability Corporation, Defendants	No **COMPLAINT FOR WRONGFUL DEATH, COMPENSATORY DAMAGES, AND PUNITIVE DAMAGES UNDER FOREIGN LAW** **JURY DEMAND**

Plaintiffs, by and through their attorneys, William J. Schroeder and Paine Hamblen LLP, by way of Complaint against the above-named Defendants, allege and claim as follows:

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I. PARTIES

A. Plaintiffs.

1. Plaintiffs' Decedent, (b)(6) was a resident of Namyangju, Gyeonggi Province, Korea. She was in Washington State about to begin a term at North Seattle College, at the time of the September 24, 2015 accident which caused her death

2 Probate was initiated in the State of Washington, County of King, Cause No. 15-4-06551-1 SEA, with her father, (b)(6) acting as personal representative Mr (b)(6) is a resident of Namyangju, Gyeonggi Province, Korea Pursuant to RCW 11.36.010(6), since Mr. (b)(6) resides outside of the state, a Resident Agent has also been appointed.

3. Plaintiff (b)(6) (b)(6) mother, is a resident of Namyangju, Gyeonggi Province, Korea.

B. Defendants.

4 Ride the Ducks of Seattle, LLC. ("Seattle Duck") is a Washington limited liability corporation, with its headquarters located in the State of Washington

5 Ride the Ducks International, LLC, ("International Duck") is a Missouri limited liability corporation, with its headquarters located in the State of Georgia.

C. Other Relevant Non-Party Persons and Entities.

6. John Doe 1, employee of Defendant Seattle Duck and driver of the 1945 DUKW ("Duck 6") at the time of the September 24, 2015 incident, upon information and belief, is a resident of the State of Washington.

7. CWA, Inc.. doing business as Bellair Charters Hesselgrave South ("Bellair"). is a Washington corporation, and owned the Motorcoach upon which Ha Ram was riding.

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8 John Doe 2, employee of Bellair and driver of the Bellair Motorcoach, upon information and belief, is a resident of the State of Washington.

9 John Doe 3, driver of the 2011 Dodge Ram involved in the incident, upon information and belief, is a resident of the State of Washington

10. John Doe 4, driver of the 2006 Toyota Highlander involved in the incident, upon information and belief, is a resident of the State of Washington

11 John Doe 5, driver of the 2007 Toyota Tundra involved in the incident, upon information and belief, is a resident of the State of Washington

II. JURISDICTION

12 This Court has jurisdiction pursuant to 28 USC 1332, as there is complete diversity among the parties and the amount in controversy exceeds the jurisdictional minimum of $75,000

III. VENUE

13 The incident in question occurred in the State of Washington; venue is proper in the Western District of Washington pursuant to 28 USC 1391.

IV. CONFLICT OF LAWS

14. "To determine the applicable substantive law, a federal court sitting in diversity applies the choice-of-law rules of the forum " *Narayan v EGL, Inc.*, 616 F.3d 895, 898 (9th Cir. 2010)

15. Washington courts follow the 'most significant relationship test' set forth in the Restatement (Second) of Conflict of Laws to resolve conflict of law tort questions. *Singh v. Edwards Lifesciences*, 151 Wn App 137, 143, 210 P.3d 337 (2009) Under Washington law, a

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jury may consider awarding punitive damages under another state's laws *Id.* at 143-48

V. PERTINENT FACTS

A. (b)(6)

16 (b)(6) was born on (b)(6). She is the eldest of three siblings. Her family resides in the city of Namyangju, which is located in Gyeonggi Province, Korea

17. After receiving top marks at Dong Hwa High School, (b)(6) was accepted at Hallym University, in the city of Chuncheon, Gangwan Province, Korea

18. On the urging of one of her professors, (b)(6) applied for and was accepted to North Seattle College for the Fall Quarter of 2015

19 (b)(6) arrived in the United States in early September, 2015, and was given a student dormitory room at North Seattle College in Shoreline, Washington.

20. On September 24, 2015, (b)(6) participated in a college-sponsored excursion to Pike Place Market and Safeco Field. Riding on a Bellair Motorcoach ("Motorcoach") driven by John Doe 2 travelling southbound in the inside lane on SR 99 crossing the George Washington Bridge /Aurora Bridge in Seattle, Washington The Motorcoach was occupied by a driver and fifty passengers.

B. 1945 DUKW.

Based upon information and belief, the following is alleged

21. A DUKW is a six wheel drive amphibious assault vehicle used by the U.S. military in World War II and the Korean War. The DUKW was originally manufactured by GMC

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22 In 2005, International Duck remanufactured a particular 1945 DUKW, known as "Duck 6", into an amphibious tourist vehicle. Duck 6 was subsequently sold by International Duck to Seattle Duck the same year.

23. Since 2005, Seattle Duck has operated Duck 6 under a license granted it by the Washington State Utilities and Transportation Commission as a tour and excursion operator

24 In 2013, International Duck became aware that certain parts on the 1945 DUKW, including Duck 6, could be dangerously defective, and needed to be repaired or replaced. From its headquarters in Georgia, International Duck published a warning to its own operators in the form of a service bulletin, but failed to adequately inform its franchisee Seattle Duck

25 In addition or in the alternative, Seattle Duck failed to examine the defective parts properly and no repairs or modifications were accomplished.

C. The Incident.

Based upon information and belief, the following is alleged

26 On September 24, 2015 at approximately 11:11 am, Duck 6 was occupied by driver John Doe 1 and 36 passengers.

27. Duck 6 was traveling northbound in the inside lane on the SR99 Aurora Bridge

28 As Duck 6 and the Bellair Motorcoach approached each other. Duck 6's driver heard a loud "bang" and then lost control of the vehicle

29. There being no median barrier or cables on that particular stretch of highway, Duck 6 crossed the center line into oncoming traffic in the southbound lanes

30 Witnesses saw red fluid shooting from the front end of Duck 6 moments before John Doe 1 lost control and crossed the center line, slamming into the center of the Motorcoach

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31. The front of Duck 6 struck the left side of the Motorcoach near the driver's compartment. Figures 1 and 2, below, depicting some of the damage done to each vehicle, are taken from a preliminary report by the National Transportation and Safety Board.

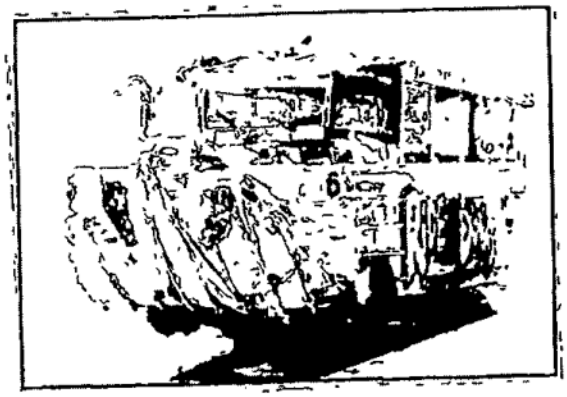

Figure 1: Linked 3D laser scans depicting frontal damage on the accident DUKW vehicle.

Figure 2: Linked 3D laser scans depicting the damaged left side of the motorcoach.

32. Duck 6 penetrated the left side passenger compartment of the Motorcoach.

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33 During the impact, Duck 6 rolled toward its left side and a number of passengers were ejected.

34 A 2011 Dodge Ram pickup truck was also traveling southbound adjacent to the Motorcoach The 2011 Dodge Ram pickup truck subsequently struck the right side of Duck 6

35 The 2011 Dodge Ram pickup truck struck a 2006 Toyota Highlander sport utility vehicle, which had been traveling in the northbound left lane behind Duck 6 and had struck the left side of Duck 6. A 2007 Toyota Tundra pickup truck, also traveling in the northbound lane, struck the left front of the 2011 Dodge Ram pickup truck

36. As a result of the accident, five occupants of the Motorcoach died. Sixty-two occupants of the Motorcoach, Duck 6, and the crash-involved passenger vehicles reported injuries.

37 (b)(6) was seated on the driver's side of the Motorcoach.

38. (b)(6) was transferred to Harborview Hospital in Seattle, Washington, shortly after the incident

39. (b)(6) experienced pain, suffering, and the fear and apprehension of death

40 Upon learning of their daughter's injuries, (b)(6) parents immediately traveled to Seattle from Korea to be with her.

41 (b)(6)'s parents were at her bedside holding her hand when she died

42 (b)(6) died on (b)(6)

43. (b)(6) body was transported back to her home in Korea, so she could be buried near her ancestors.

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VI. CAUSES OF ACTION

A. First Cause Of Action – Estate of (b)(6) ("Estate") Against Seattle Duck – Negligent Maintenance Or Repair – Washington Law.

44 Plaintiffs re-allege each preceding paragraph as if fully set forth herein.

45 Seattle Duck owes statutory and common law duties to its customers and members of the public to reasonably maintain the former military equipment it operates on city streets

46 Seattle Duck breached its duties by permitting a critical component of Duck 6 to fail through its negligent acts or omissions

47 Seattle Duck's breach of the aforementioned duties was a proximate cause of the September 24, 2015 accident which caused (b)(6) death.

48 The Estate has been damaged in an amount to be proven at trial.

B. Second Cause Of Action – Estate Against Seattle Duck – Negligent Operation – Washington Law.

49. Plaintiffs re-allege each preceding paragraph as if fully set forth herein

50. Seattle Duck has statutory and common law duties to operate its former military equipment in a reasonably safe fashion

51. John Doe 1, the driver of Duck 6, was an employee of Seattle Duck, and all acts or omissions undertaken by John Doe 1 in his operation of Duck 6 on September 24, 2015, were in the scope of his employment

52 Seattle Duck is vicariously liable for any actions or omissions of John Doe 1 undertaken while within the scope of his employment

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53 John Doe 1 negligently operated Duck 6 on September 24, 2015, causing it to strike the Motorcoach.

54 John Doe 1's negligent acts or omissions are a proximate cause of the September 24, 2015 accident which resulted in (b)(6) death

55. The Estate has been damaged in an amount to be proven at trial

C. Third Cause Of Action – (b)(6) and (b)(6) ("Parents") Against Seattle Duck – Outrage – Washington Law.

56 Plaintiffs re-allege each preceding paragraph as if fully set forth herein

57 Seattle Duck's conduct was extreme and outrageous.

58. The extreme or outrageous conduct of Seattle Duck recklessly inflicted emotional distress upon the Parents.

59. Parents have actually suffered severe emotional distress, causing them damages in an amount to be proven at trial.

D. Fourth Cause Of Action – Estate Against International Duck – Washington Product Liability And Georgia Or Missouri Punitive Damages.

60. Plaintiffs re-allege each preceding paragraph as if fully set forth herein

61 Duck 6 is a product for the purposes of the Washington Product Liability Act RCW 7.72.010 (3).

62 International Duck is a manufacturer, pursuant to RCW 7.72.010 (2).

63. The Estate is a claimant who has suffered harm, and therefore has a product liability claim, pursuant to 7.72.010 (3) – (5).

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64 International Duck breached its duties as a manufacturer concerning the design, accompanying warnings, subsequent warnings, reasonably safe construction, express warranties, and/or implied warranties. See RCW 7 72 030.

65 International Duck's breach of its duties was a proximate cause of the September 24, 2015 accident and (b)(6) death.

66 The Estate has suffered damages to be proven at trial.

67 Additionally, punitive damages should be assessed against International Duck under either Georgia or Missouri law, as is consistent with Washington decisional law See *Singh v. Edwards Lifesciences*, 151 Wn. App. 137, 143, 210 P.3d 337 (2009). Under Washington law, a jury may consider awarding punitive damages under another state's laws. *Id.* at 143-48.

68 ***Georgia punitive damages pursuant to OCG 51-12-5.1*** International Duck's actions show recklessness, wantonness, or an entire want of care which would raise the presumption of conscious indifference to consequences.

69 Upon information and belief, no award of product liability punitive damages has previously been recovered in a court of record in the state of Georgia on this subject matter. Consequently, "there shall be no limitation regarding the amount which may be awarded as punitive damages " OCG 51-12-5 1(e)(1)

70 The Estate requests an award of punitive damages against International Duck in an amount to be determined by a jury, with no limitation, pursuant to Georgia law.

71 ***Pleading in the alternative, Missouri punitive damages pursuant to Missouri Law.*** It was highly probable that International Duck's conduct was outrageous because of reckless indifference

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72. The Estate requests an award of punitive damages against International Duck pursuant to RSMo 510 263 1, RSMo 510.265.1.

E. Fifth Cause Of Action – Parents Against International Duck – Washington Outrage And Georgia Or Missouri Punitive Damages.

73. Plaintiffs re-allege each preceding paragraph as if fully set forth herein

74 International Duck's conduct was extreme and outrageous

75. The extreme or outrageous conduct of International Duck recklessly inflicted emotional distress upon the Parents.

76 Parents have actually suffered severe emotional distress, causing them damages in an amount to be proven at trial

77. Additionally, punitive damages should be assessed against International Duck under either Georgia or Missouri law, as is consistent with Washington decisional law See *Singh v. Edwards Lifesciences*, 151 Wn. App. 137, 143, 210 P.3d 337 (2009).

78 ***Georgia punitive damages pursuant to OCG 51-12-5.1.*** International Duck's actions show recklessness. wantonness, or an entire want of care which would raise the presumption of conscious indifference to consequences.

79.. Parents request an award of punitive damages against International Duck pursuant to OCG 51-12-5.1(d)(1) and OCG 51-12-5.1(g).

80. ***Pleading in the alternative, punitive damages pursuant to Missouri Law.*** It was highly probable that International Duck's conduct was outrageous because of reckless indifference

81 Parents request an award of punitive damages against International Duck pursuant to RSMo 510 263 1 and RSMo 510 265.1

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F. Sixth Cause Of Action – All Plaintiffs Against International Duck – Georgia Product Liability And Punitive Damages.

82. Plaintiffs re-allege each preceding paragraph as if fully set forth herein

83 Under Georgia law, Plaintiffs are permitted to recover for the "full value of the life of the decedent, as shown by the evidence " OCG 51-4-1; OCG 51-4-5.

84 Duck 6 was defective in its manufacture, design, and/or warnings.

85 Said defects in Duck 6 are the responsibility of International Duck, and were a proximate cause of the September 24, 2015 accident.

86. As a result of said defects, Plaintiffs have been damaged in an amount to be proven at trial

87 Moreover, International Duck's actions show recklessness, wantonness, or an entire want of care which would raise the presumption of conscious indifference to consequences

88 Upon information and belief, no award of product liability punitive damages has previously been recovered in a court of record in the state of Georgia on this subject matter. Consequently, "there shall be no limitation regarding the amount which may be awarded as punitive damages." OCG 51-12-5 1(c)(1).

89. The Estate requests an award of punitive damages against International Duck in an amount to be determined by a jury, with no limitation, pursuant to Georgia law.

G. Seventh Cause Of Action – Parents Against International Duck – Georgia Outrage And Punitive Damages.

90. Plaintiffs re-allege each preceding paragraph as if fully set forth herein

91 International Duck's conduct was extreme and outrageous.

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92 The extreme or outrageous conduct of International Duck recklessly inflicted emotional distress upon the Parents

93 Parents have actually suffered severe emotional distress, causing them damages in an amount to be proven at trial.

94 Moreover, International Duck's actions show recklessness, wantonness, or an entire want of care which would raise the presumption of conscious indifference to consequences

95 Parents request an award of punitive damages against International Duck pursuant to OCG 51-12-5 1(d)(1) and OCG 51-12-5.1(g).

H. Eighth Cause Of Action – All Plaintiffs Against International Duck – Missouri Product Liability And Punitive Damages.

96 Plaintiffs re-allege each preceding paragraph as if fully set forth herein

97 Plaintiffs are entitled to maintain suit pursuant to RSMo 537.080 and RSMo 537 090

98 Pursuant to Missouri law, International Duck is strictly liable for transferring Duck 6 in the course of its business, as the product was used in a manner reasonably anticipated; and either Duck 6 was in a defective condition unreasonably dangerous when put to a reasonably anticipated use, or as a result of lack of an adequate warning. See RSMo 537 760.

99. The aforementioned defective condition or lack of warning was a proximate cause of the September 24, 2015 accident and (b)(6) subsequent death

100 Plaintiffs have been damaged as a proximate result in an amount to be proven at trial.

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101 Moreover, it was highly probable that International Duck's conduct was outrageous because of reckless indifference.

102 Plaintiffs request an award of punitive damages against International Duck pursuant to RSMo 510.263.1 and RSMo 510.265 1.

I. Ninth Cause Of Action – Parents Against International Duck – Missouri Outrage And Punitive Damages.

103 Plaintiffs re-allege each preceding paragraph as if fully set forth herein

104 International Duck's conduct was extreme and outrageous

105 The extreme or outrageous conduct of International Duck recklessly inflicted emotional distress upon the Parents.

106 Parents have actually suffered severe emotional distress, causing them damages in an amount to be proven at trial

107 Moreover, it was highly probable that International Duck's conduct was outrageous because of reckless indifference.

108 Parents request an award of punitive damages against International Duck pursuant to RSMo 510 263 1 and RSMo 510 265.1

VII. JURY DEMAND

109. Plaintiffs hereby demand that their claims be heard before a jury.

VIII. PRAYERS FOR RELIEF

A. Against Seattle Duck:

1. Compensatory damages. in an amount to be proven at trial,

2 Costs and attorney's fees, as allowed by law; and

3 For such other and further relief as the Court deems just and equitable.

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B. Against International Duck:

1 Compensatory damages, under either Washington, Georgia, or Missouri law, in an amount to be proven at trial;

2 Punitive damages under Georgia law,

3 Alternatively, punitive damages under Missouri law;

4 Costs and attorney's fees, as allowed by law; and

5 For such other and further relief as the Court deems just and equitable

DATED this 8th day of December, 2015.

s/ William J. Schroeder
William J Schroeder, WSBA #7942
Attorney for Plaintiffs

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KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)

Plaintiff,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiff alleges:

I. Parties

1.1 (b)(6) is an 18 year-old single female residing in Seattle, King County, Washington.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State. The

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State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a (b)(6) year old driver and approximately 45 to 50 passengers.

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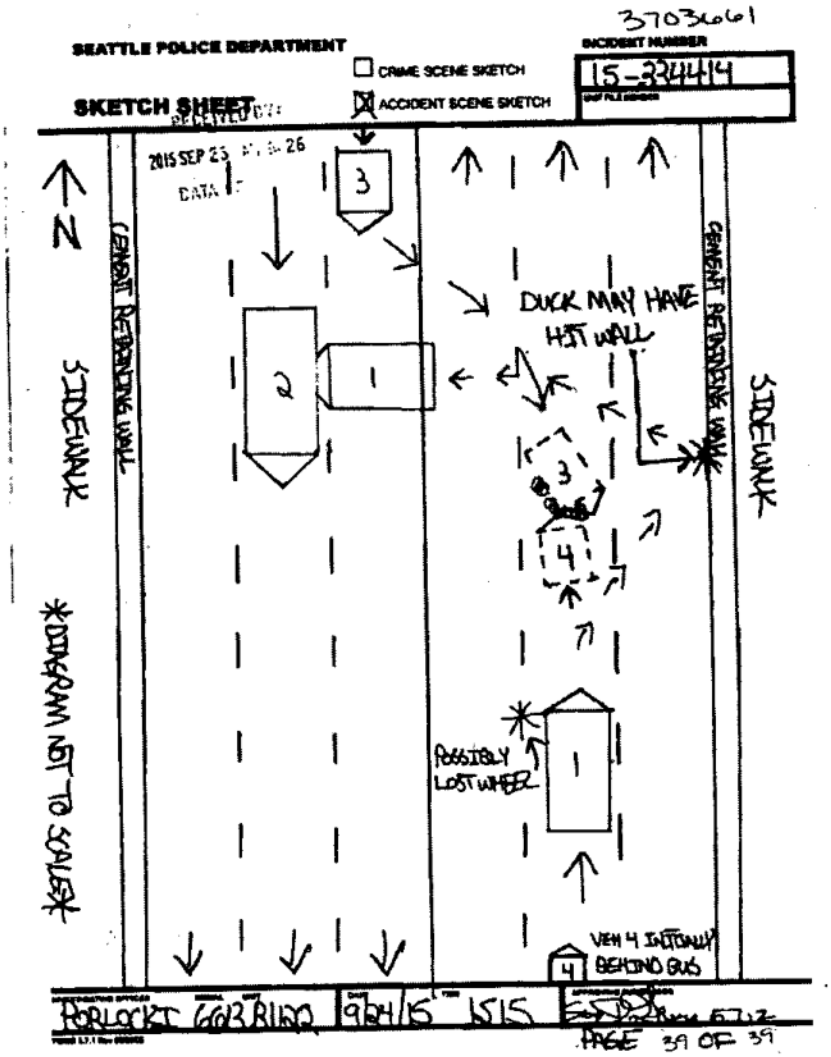
3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



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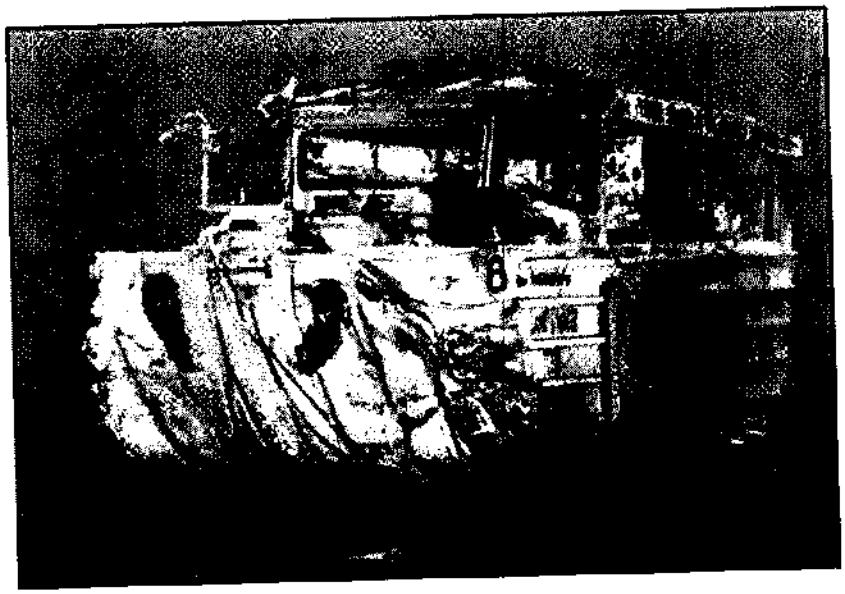
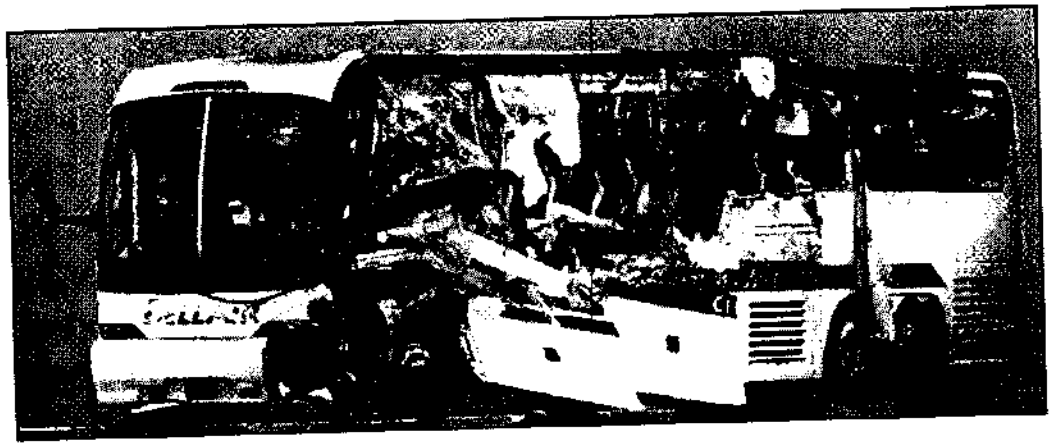
3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:





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3.9 RTD International manufactured, refurbished and modified DUKW No. 6 which was originally a 1945 military model. In approximately 2005, RTD International sold the DUKW to RTD Seattle.

3.10 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.11 On or about October 2013, RTD International issued a notice to purchasers of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures.

3.12 RTD International took no further action to ensure that purchasers of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.13 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.14 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.15 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.16 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic (b)(6) stated he had never seen the October 13, 2013 service bulletin.

3.17 RTD International issued a statement after the collision stating that it warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country, and that it recommended specific inspections and repairs to reinforce the housing.

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3.18 The NTBS has possession of the DUKW vehicle and its component parts. It is currently performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and other investigatory acts.

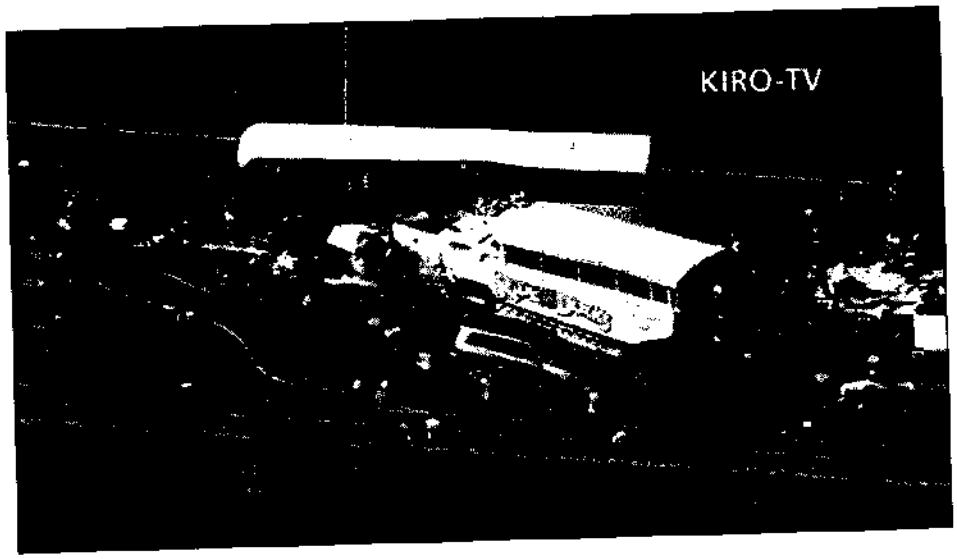
3.19 Following the Crash, the Washington Utilities and Transportation Commission suspended RTD Seattle's operations pending a full examination into its fleet. The state's investigation team is still analyzing maintenance records and conducting physical inspections of the DUKW vehicles.

3.20 RTD Seattle has implored the State to act with "urgency" so that the vehicles can be placed back in service and the company's 130 employees sent back to work.

3.21 RTD Seattle has informed the State that it will no longer use the SR 99 Aurora Bridge.

3.22 RTD Seattle has informed the State that it will now use a separate driver and tour guide instead of combining the two functions in one employee.

3.23 As a result of the collision, approximately 64 people were injured, five of whom were killed.



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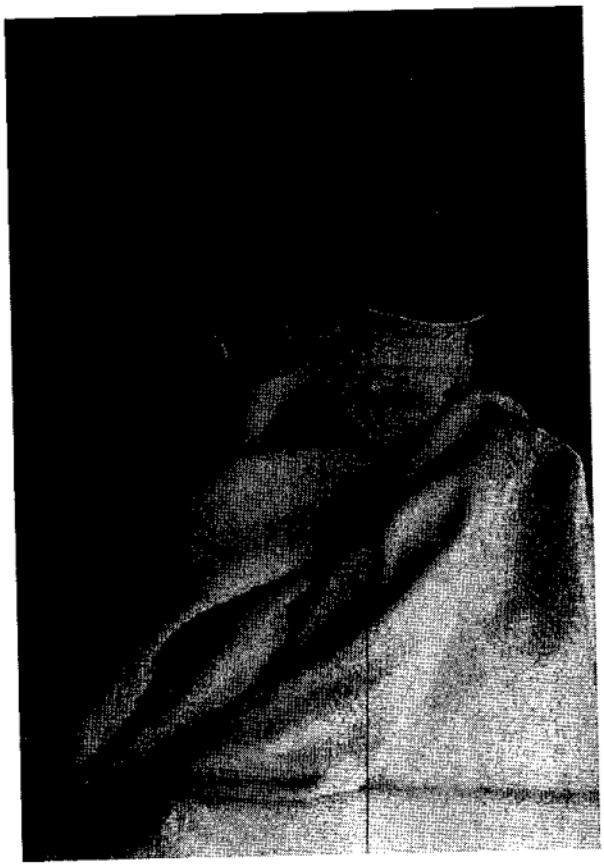
3.24 A total of 45 to 50 students and staff from North Seattle College were on the motor coach when it was struck. The College had organized an excursion for students in its international program.

3.25 (b)(6), a sophomore, was seated above and directly behind the driver on the motor coach. Upon impact she was thrown down into the stairwell of the motor coach, landing on her teacher near the entry door.

3.26 (b)(6) suffered numerous injuries including pelvic and tailbone fractures, three broken ribs, a concussion and other injuries. She was transported to Harborview.



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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left control of RTD International, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiff's harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.5 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe because adequate warnings of instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiff's harm or similar harms, and the seriousness of those

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harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.8 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) under the doctrine of *respondeat superior*.

4.9 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International;

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e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; and i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has suffered and continues to suffer permanent physical injuries, disability, disfigurement, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has been required to seek various medical treatments and will continue to require medical treatments in the future, as well as other special damages including delay of education, increased educational expenses, wage loss, caregiver expenses, increased housing expenses, all in an amount to be proven at the time of trial.

5.3 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's

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reckless indifference to the rights of others, including the plaintiff in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.4 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.5 Plaintiff has incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiff prays for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

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DATED this 21st day of December, 2015.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER

/s/ Karen Koehler
Karen Koehler, WSBA#15325
Andrew N. Ackley, WSBA#41752
Co-counsel for Plaintiff

PHILLIPS HERRON, PLLC

/s/ Douglas Phillips
Douglas Phillips, WSBA#18145
Co-counsel for Plaintiff

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FILED
15 DEC 21 PM 1:04

KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)

Plaintiff,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and (b)(6) their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiff alleges:

I. Parties

1.1 (b)(6) year-old single man residing in Seattle, King County, Washington.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

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2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a (b) year old driver and approximately 45 to 50 passengers.

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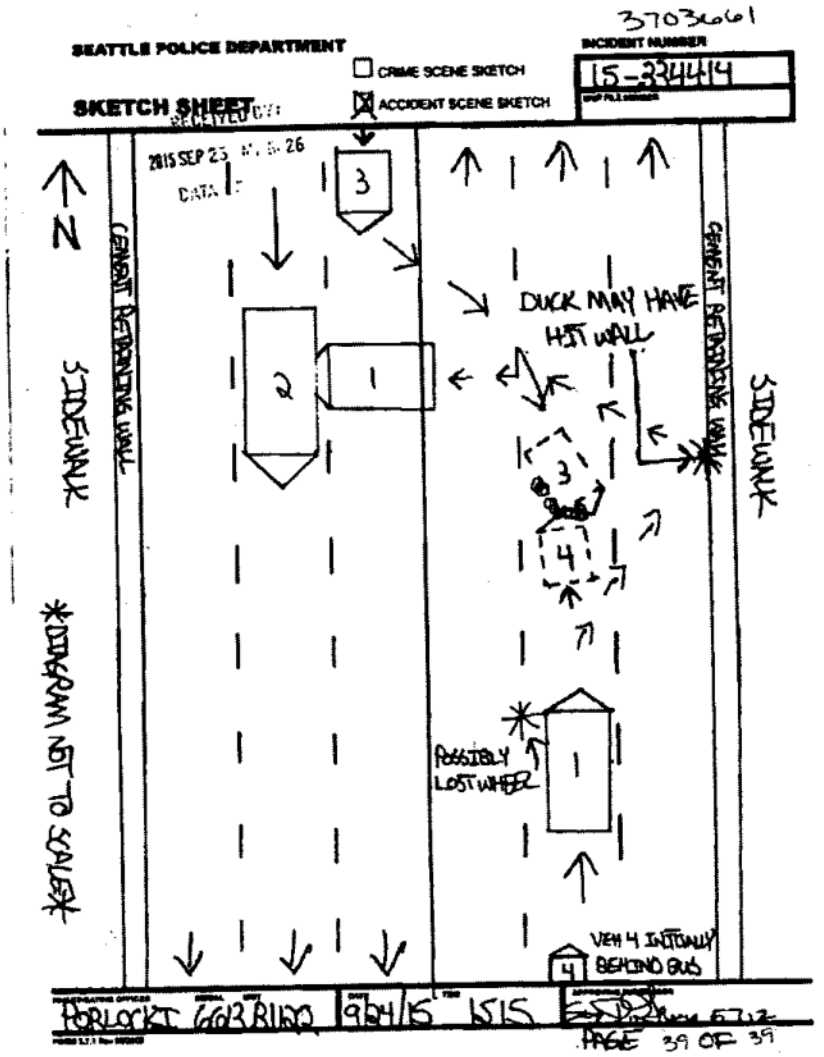
3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



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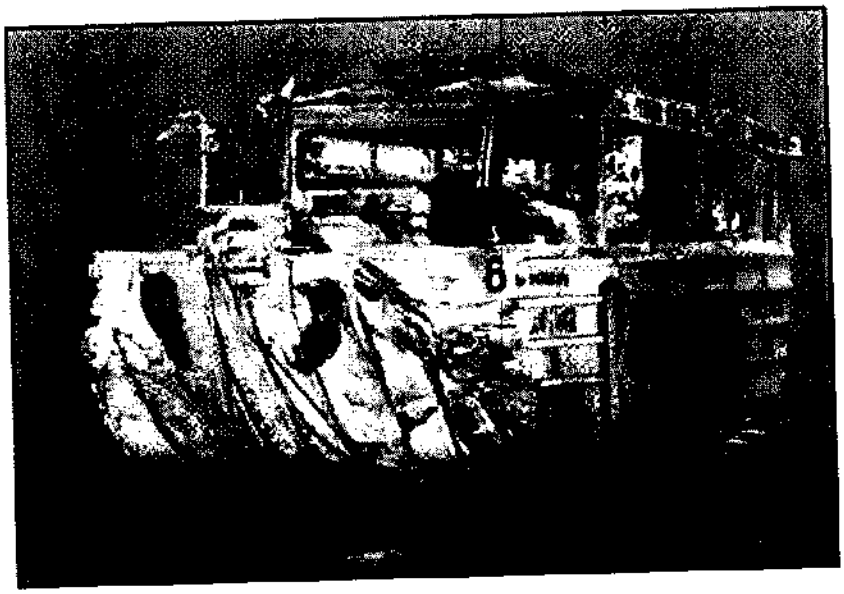
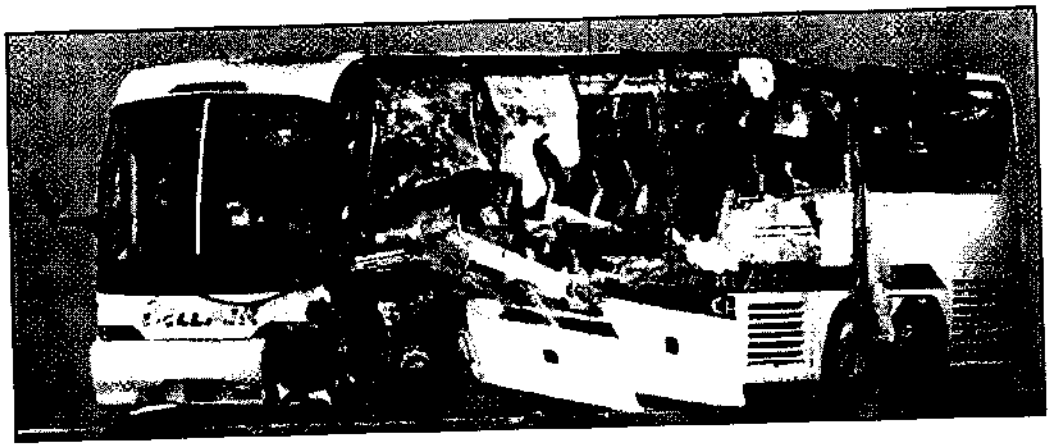
3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:





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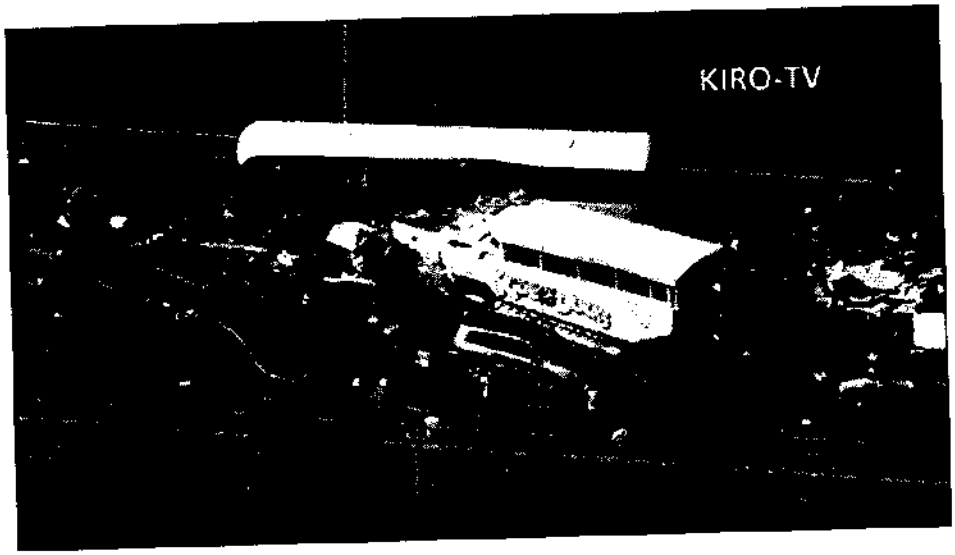

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3.24 A total of 45 to 50 students and staff from North Seattle College were on the motor coach when it was struck. The College had organized an excursion for students in its international program.

3.25 (b)(6), a new entering freshman from Japan, was seated in the window seat in the third row from the front on the left side of the motor coach. It is believed that he was seated in the seat directly in front of (b)(6)

3.26 (b)(6) sustained multiple fractures to the pelvis, hip, leg, a lacerated spleen, and other injuries. He was transported to Harborview.

3.27 (b)(6) was released from Park Ridge Care Center in Shoreline on the date of the filing of this complaint on December 21, 2015.

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harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.8 RTD Seattle is vicariously liable for the negligent acts and omissions of Eric Bishop under the doctrine of *respondeat superior*.

4.9 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International;

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e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; and i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has suffered and continues to suffer permanent physical injuries, disability, disfigurement, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has been required to seek various medical treatments and will continue to require medical treatments in the future, as well as other special damages including delay of education, increased educational expenses, wage loss, caregiver expenses, increased housing expenses, all in an amount to be proven at the time of trial.

5.3 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's

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reckless indifference to the rights of others, including the plaintiff in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.4 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.5 Plaintiff has incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiff prays for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

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DATED this 21st day of December, 2015.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER

/s/ Karen Koehler
Karen Koehler, WSBA#15325
Andrew N. Ackley, WSBA#41752
Co-counsel for Plaintiff

PHILLIPS HERRON, PLLC

/s/ Douglas Phillips
Douglas Phillips, WSBA#18145
Co-counsel for Plaintiff

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KING COUNTY
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E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)

Plaintiff,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiff alleges:

I. Parties

1.1 (b)(6) year old single man residing in Seattle, King County, Washington.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State, and

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by engaging in a licensing agreement with RTD Seattle, under which RTD International was entitled to and received five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. The State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

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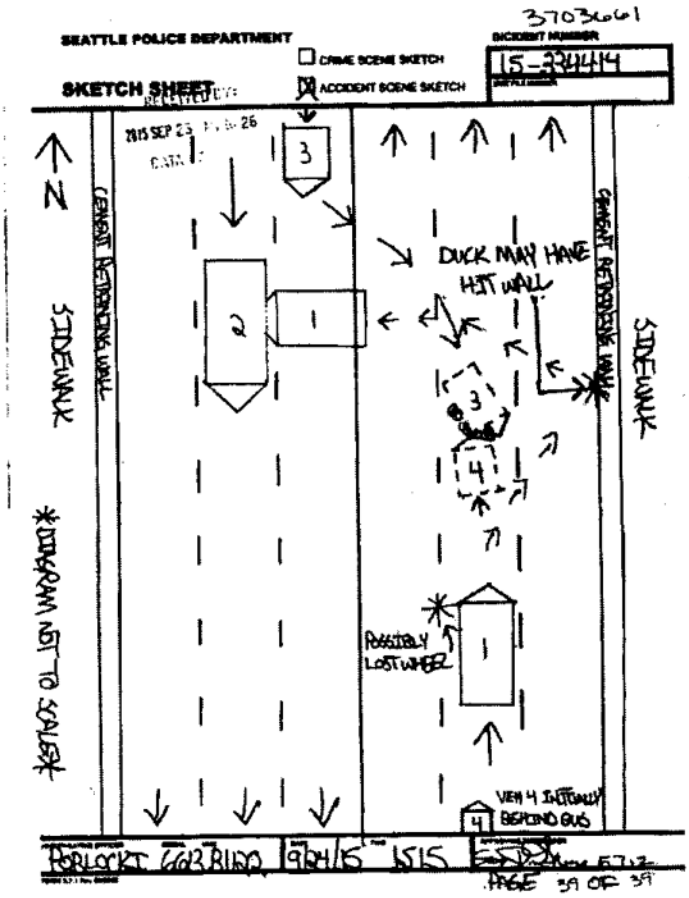
3.5 The motor coach was occupied by a (b)(6) year old driver and approximately 45 to 50 passengers.

3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



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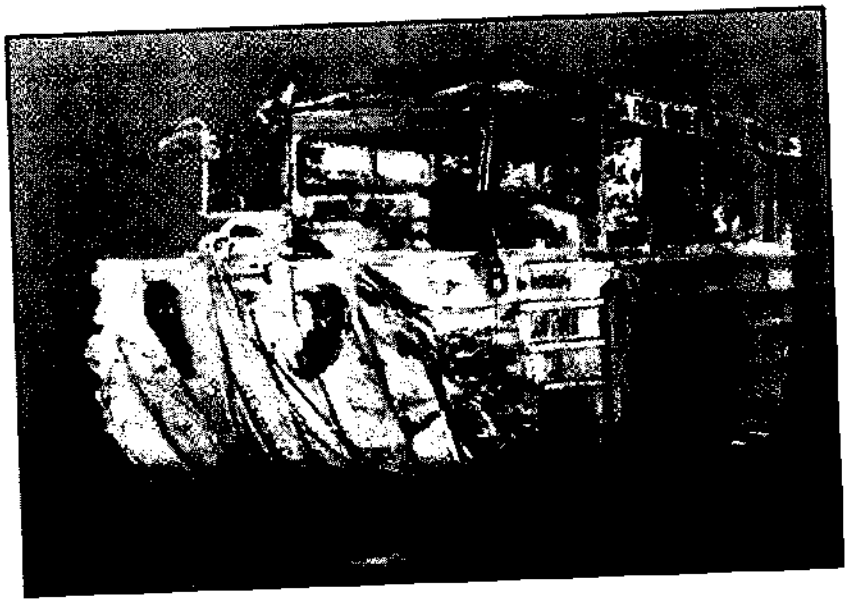
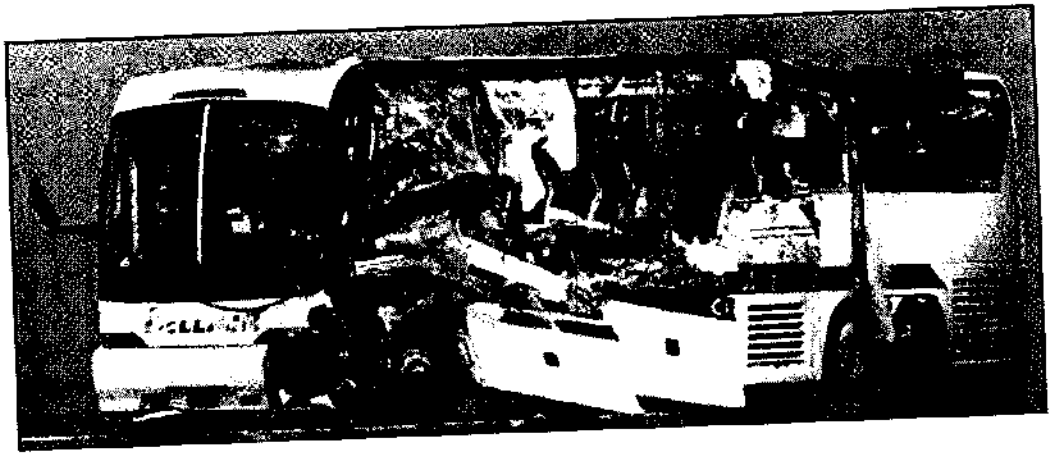
3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:





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3.9 DUKW No. 6 was originally a 1945 military model. RTD International remanufactured, refurbished, and modified DUKW No. 6 and similar military vehicles to perform the new and unusual function of transporting large numbers of tourists on guided tours by road, highway, and also by water.

3.10 RTD Seattle advertises that the "DUKWs are likely the most unique craft you'll see on the road or in the water." This is true, as DUKWs are novelty vehicles.

3.11 In approximately 2005, RTD International sold DUKW No. 6 to RTD Seattle and retained licensing rights.

3.12 As a licensor, RTD International was entitled to, and received, five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. RTD Seattle and RTD International formed an express and/or implied contract for the common purpose of manufacturing, selling, and using the DUKW vehicles for guided tours in the City of Seattle, and therefore were engaged in a joint venture with respect to the incident, claims, and damages alleged.

3.13 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.14 On or about October 2013, RTD International issued a notice to purchasers, licensees and/or joint venture/enterprise partners of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers, licensees, and/or joint venture/enterprise partners to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures. The notice also recommended daily inspection, while acknowledging that "the visual detection of a failing axle housing is not possible."

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3.15 RTD International took no further action to ensure that purchasers, licensees and/or joint venture/enterprise partners, of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.16 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.17 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.18 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.19 At the time of the incident, RTD International and RTD Seattle were consciously acting together in a tortious manner, creating and allowing a foreseeable and unreasonable risk of harm to Plaintiff and others. RTD International and RTD Seattle were therefore acting in concert at the time of Plaintiff's injuries.

3.20 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic (b)(6) stated he had never seen the October 13, 2013 service bulletin.

3.21 RTD International issued a statement after the incident stating that it warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country, and that it recommended specific inspections and repairs to reinforce the housing.

3.22 The NTBS has possession of the DUKW vehicle and its component parts. It is currently performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and other investigatory acts.

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3.23 Following the Crash, the Washington Utilities and Transportation Commission ("WUTC") suspended RTD Seattle's operations pending a full examination into its fleet.

3.24 On December 15, 2015, the WUTC released its report identifying 442 safety-related violations, stating, "All of the violations discovered were avoidable and must be corrected immediately."

3.25 RTD Seattle had implored the State to act with "urgency" so that the vehicles can be placed back in service and the company's 130 employees sent back to work.

3.26 On December 21, 2015, WUTC allowed RTD Seattle to resume limited operation of non-stretch DUKW vehicles, provided that the extensive safety violations were addressed and remedied.

3.27 Following the release of the WUTC recommendations, the Mayor of Seattle issued a letter requesting the WUTC continue the full suspension of RTD Seattle operations until such time as the safety violations had been cured and other concerns were addressed.

3.28 RTD Seattle has informed the State that it will no longer use the SR 99 Aurora Bridge.

3.29 RTD Seattle informed the State it would be using the Fremont Bridge. This drew an objection from the City of Seattle.

3.30 RTD Seattle has informed the State that it will now use a separate driver and tour guide instead of combining the two functions in one employee.

3.31 As a result of the collision, approximately 64 people were injured, five of whom were killed.

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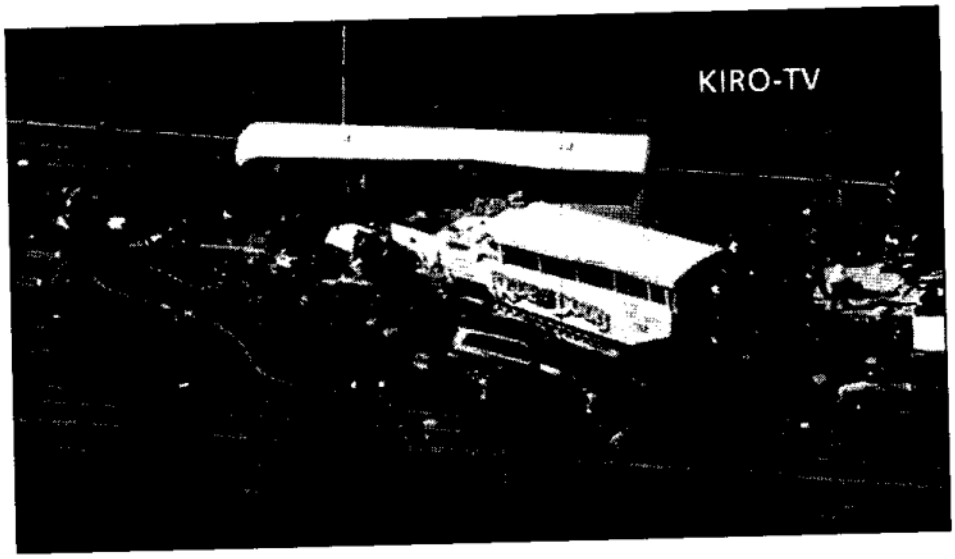
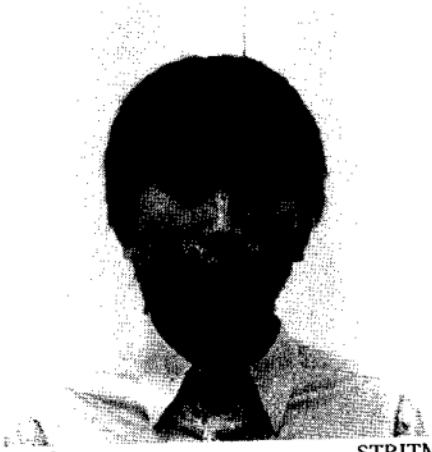


3.32 A total of 45 to 50 students and staff from North Seattle College were on the motor coach when it was struck. The College had organized an excursion for students in its international program.

3.33 (b)(6) a freshman in his second term, was seated in the first row on the right side of the motor coach.

3.34 (b)(6) suffered physical injuries to his chest, abdomen and ankle. He was transported to Northwest Hospital where he was treated.



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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left the RTD International manufacturing plant, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiff's harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

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4.5 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe because adequate warnings of instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiff's harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.8 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities,

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and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.9 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) under the doctrine of *respondeat superior*.

4.10 RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.11 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge, and j) violating relevant provisions of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

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4.12 Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiff's damages.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has suffered and continues to suffer physical injuries, disability, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has been required to seek various medical treatments and may continue to require medical treatments in the future, as well as other special damages, all in an amount to be proven at the time of trial.

5.3 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiff in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.4 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

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5.5 In addition because RTD Seattle as a joint venture in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and Georgia law.

5.6 Plaintiff has incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiff prays for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

DATED this 23rd day of February, 2016.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER

/s/ Karen K. Koehler
Karen K. Koehler, WSBA #15325
Andrew Ackley, WSBA #41752
Counsel for Plaintiff

THE JACKMAN LAW FIRM, PLLC

/s/ Chris Jackman
Chris Jackman, WSBA #46182
Counsel for Plaintiff

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FILED
16 FEB 23 PM 4:07

KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)
(b)(6) husband and wife,

Plaintiffs,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) (b)(6), and their marital community,

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiffs allege:

I. Parties

1.1 (b)(6) are each over the age of 18 years and are a married couple residing in Emmeloord, Holland.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

1.5 For ease of reference, when the term "Ride the Ducks Defendants" is used, it refers to RTD Seattle, RTD International, and Mr. (b)(6)

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

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2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State, and by engaging in a licensing agreement with RTD Seattle, under which RTD International was entitled to and received five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. The State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers, including Plaintiffs (b)(6) who were seated directly behind the driver, Mr. (b)(6)

3.3 RDT Seattle created the route driven by Defendant (b)(6), despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median barrier, and posted speed limit.

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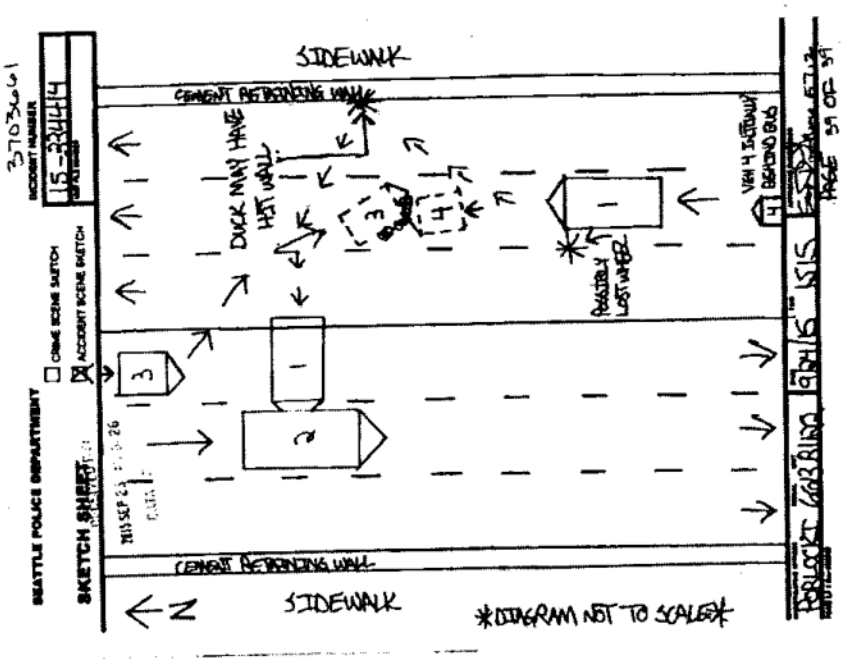
3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a (b) year old driver and approximately 45 to 50 passengers.

3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



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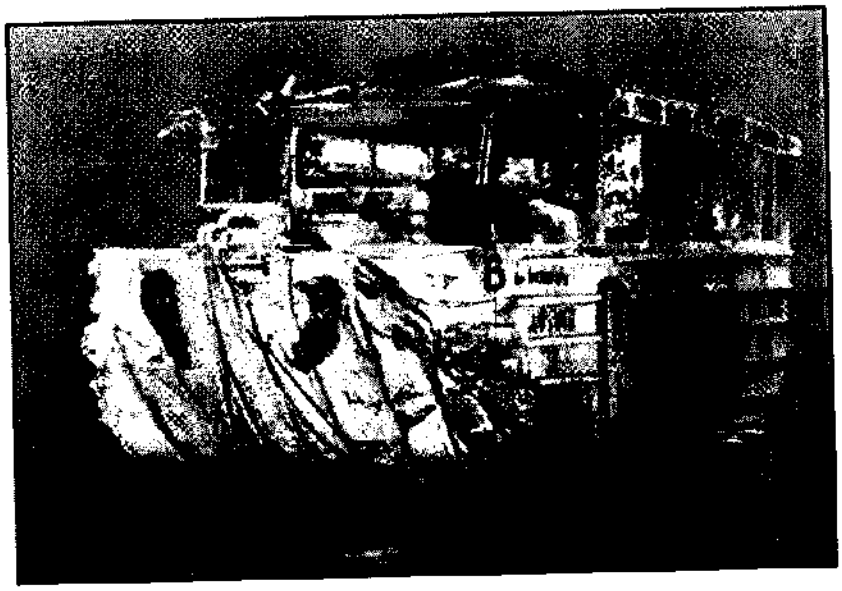
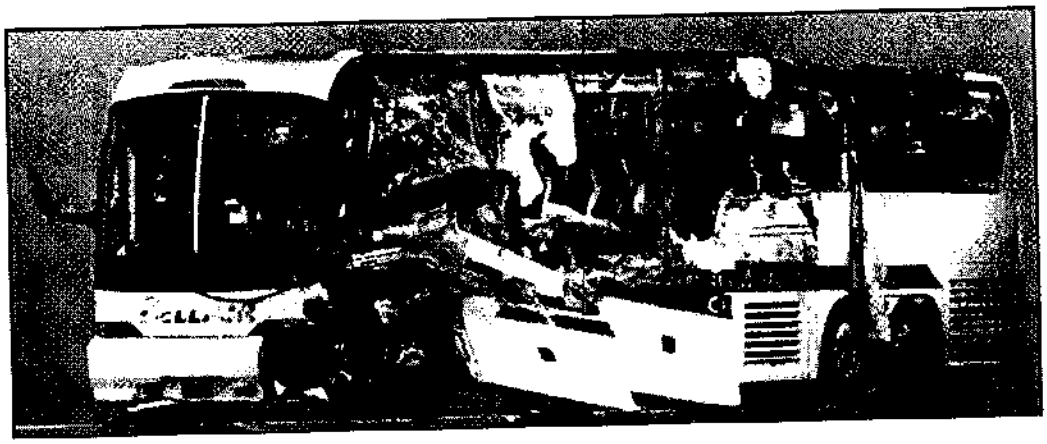
3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:





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3.10 RTD Seattle advertises that the "DUKWs are likely the most unique craft you'll see on the road or in the water." This is true, as DUKWs are novelty vehicles.

3.11 In approximately 2005, RTD International sold DUKW No. 6 to RTD Seattle and retained licensing rights.

3.12 As a licensor, RTD International was entitled to, and received, five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. RTD Seattle and RTD International formed an express and/or implied contract for the common purpose of manufacturing, selling, and using the DUKW vehicles for guided tours in the City of Seattle, and therefore were engaged in a joint venture with respect to the incident, claims, and damages alleged.

3.13 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.14 On or about October 2013, RTD International issued a notice to purchasers, licensees and/or joint venture/enterprise partners of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers, licensees, and/or joint venture/enterprise partners to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures. The notice also recommended daily inspection, while acknowledging that "the visual detection of a failing axle housing is not possible."

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3.15 RTD International took no further action to ensure that purchasers, licensees and/or joint venture/enterprise partners, of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.16 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.17 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.18 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.19 At the time of the incident, RTD International and RTD Seattle were consciously acting together in a tortious manner, creating and allowing a foreseeable and unreasonable risk of harm to Plaintiffs and others. RTD International and RTD Seattle were therefore acting in concert at the time of Plaintiffs' injuries.

3.20 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic (b)(6) stated he had never seen the October 13, 2013 service bulletin.

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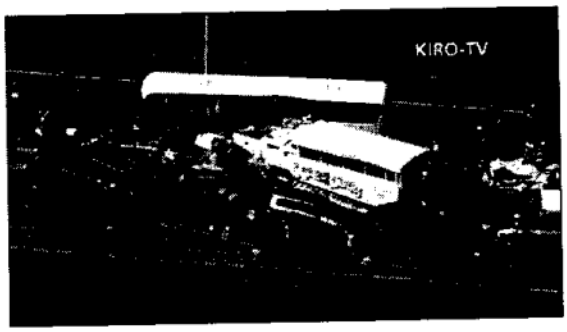

3.32 Plaintiffs (b)(6) were seated on DUKW No. 6 in the moments before the crash.

3.33 DUKW No. 6 did not have seatbelts for available use by either of the Plaintiffs.

3.34 The Plaintiffs paid a fee to the defendants to ride DUKW No. 6 on the day of the crash.

3.35 As a result of the crash, Plaintiff (b)(6) suffered numerous injuries, including a traumatic brain injury, neck and back injuries, double vision, fatigue and cognitive impairments. He was transported to Harborview Medical Center (HMC) after the crash.

3.36 As a result of the crash, Plaintiff (b)(6) suffered multiple injuries, including, 11 rib fractures, two fractured vertebrae, a fractured collar bone, a left hip fracture, a pelvic fracture and a fractured coccyx. She was transported to HMC after the crash.

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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left the RTD International manufacturing plant, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.5 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe because adequate warnings of instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiffs' harm or similar harms, and the seriousness of those

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harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.8 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median barrier; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.9 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) under the doctrine of *respondeat superior*.

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4.10 RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.11 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median barrier; h) failing to properly train and supervise its mechanics and drivers; i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge, and j) violating relevant provisions of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.12 The tortious conduct of all Defendants, as described above, was the proximate cause of the subject incident, the injuries to plaintiffs, and their resulting losses.

4.13 The Ride the Duck Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiffs' damages.

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4.14 The Plaintiffs were passengers on DUKW No. 6 at the time of the crash.

4.15 RTD Seattle is a common carrier as that term is defined pursuant to Washington law.

4.16 A common carrier in Washington is held to the highest degree of care for the safety of its passengers.

4.17 RTD Seattle failed to provide to the Plaintiffs the highest degree of care for the Plaintiffs' safety.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, the Plaintiffs have suffered and continue to suffer permanent physical injuries, disability, disfigurement, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, the Plaintiffs have been required to seek various medical treatments and will continue to require medical treatments in the future, as well as other special damages, including wage loss, caregiver expenses, and household services, all in an amount to be proven at the time of trial.

5.3 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiffs in this case, and Missouri possesses an interest in punishing and deterring such conduct. Accordingly,

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RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.4 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses an interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.5 In addition because RTD Seattle as a joint venture in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and/or Georgia law.

5.6 Plaintiffs have incurred other damages to be proven at the time of trial.

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VI. Prayer for Relief

WHEREFORE, Plaintiffs pray for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages against Defendant Ride the Duck International under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendants bring any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

DATED this 23rd day of February, 2016.

STRITMATTER KESSLER WHELAN
KOEHLER MOORE KAHLER

/s/ Brad J. Moore
Brad J. Moore, WSBA #21802
Karen K. Koehler, WSBA#15325
Andrew N. Ackley, WSBA#41752
Counsel for Plaintiffs

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FILED
16 MAR 03 PM 4:16

KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: 1 (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6) a married couple,

Plaintiffs,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiffs allege:

I. Parties

1.1 (b)(6) are each over the age of 18 years and are a married couple residing in Madison, Wisconsin.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State, and

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by engaging in a licensing agreement with RTD Seattle, under which RTD International was entitled to and received five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. The State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

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3.5 The motor coach was occupied by a [(b)(6)] year old driver and approximately 45 to 50 passengers.

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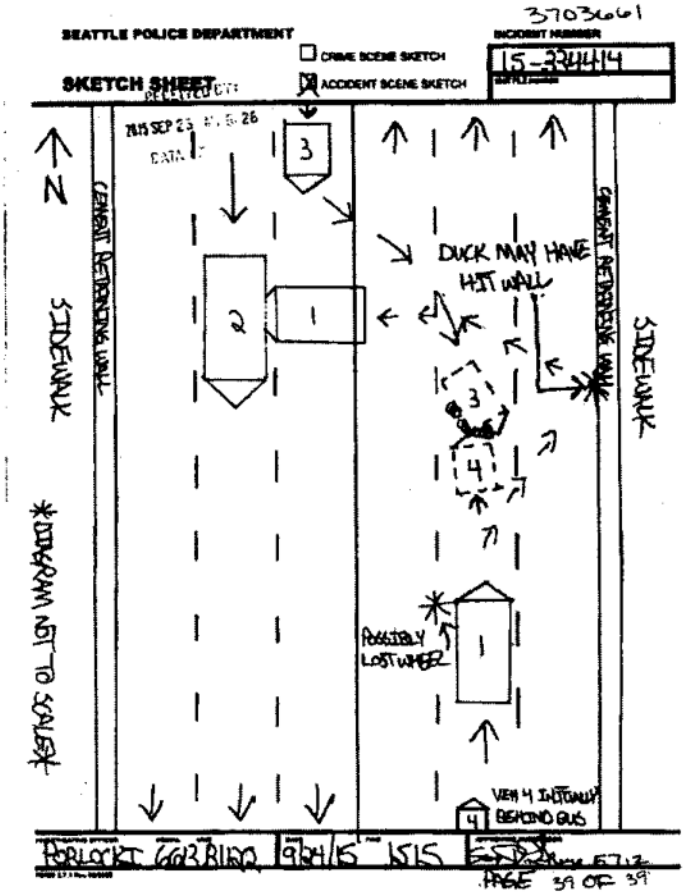
3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



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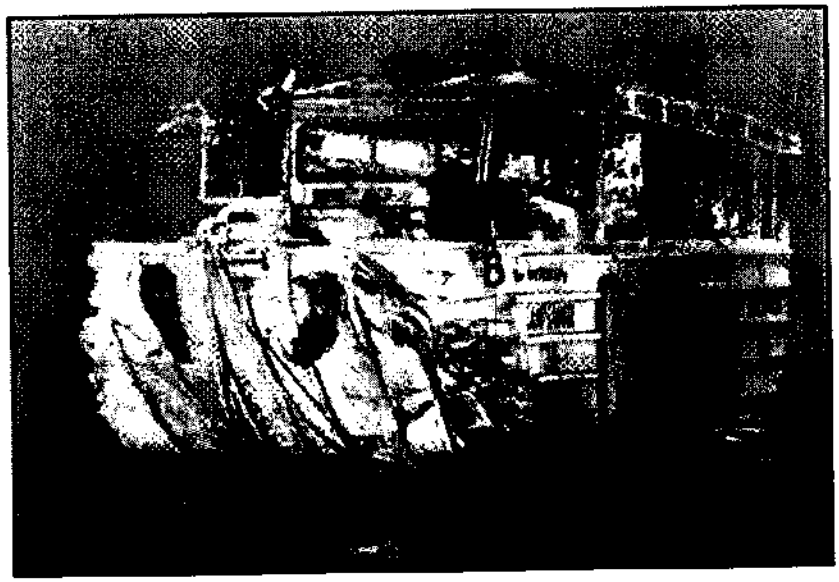

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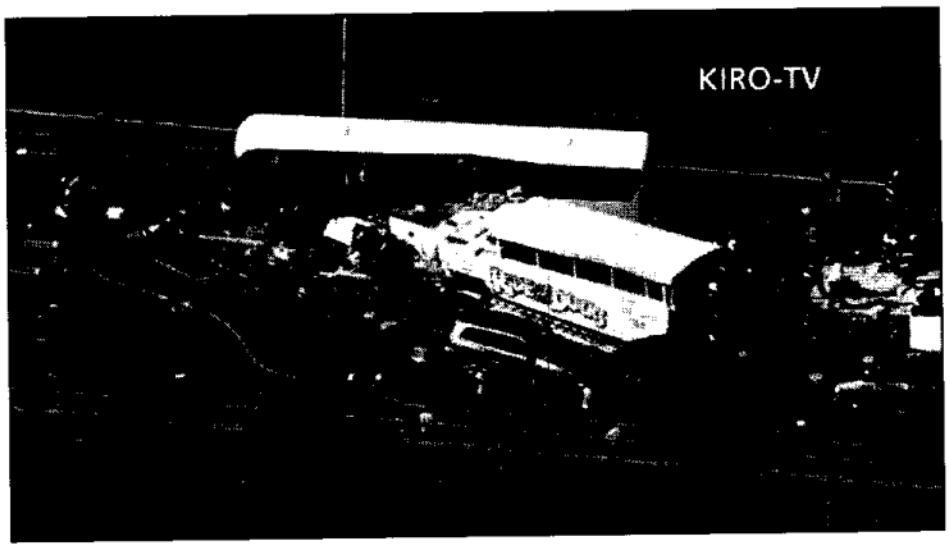

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3.33 DUKW No. 6 did not have seatbelts for available use by either of the Plaintiffs.

3.34 The Plaintiffs paid a fee to the defendants to ride DUKW No. 6 on the day of the crash.

3.35 As a result of the crash, Plaintiff (b)(6) suffered numerous injuries, including a left hip acetabular fracture, rib fracture and left shoulder injury. She was transported to Swedish Hospital after the crash.

3.36 As a result of the crash, Plaintiff (b)(6) was ejected from the Duck, and suffered multiple injuries, including fractured left tibia, right lumbar transverse process fractures and a right hip injury. She was transported to Harborview Medical Center after the crash.

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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left the RTD International manufacturing plant, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

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4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.5 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe because adequate warnings or instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiffs' harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure

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that vehicles are free of defects likely to result in an accident or breakdown."

4.8 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.9 RTD Seattle is vicariously liable for the negligent acts and omissions of Eric Bishop under the doctrine of *respondeat superior*.

4.10 RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.11 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane

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width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge, and j) violating relevant provisions of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.12 Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiffs' damages.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have suffered and continue to suffer physical injuries, disability, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have been required to seek various medical treatments and will continue to require medical treatment in the future, as well as other special damages, including wage loss, caregiver expenses, and household services, all in an amount to be proven at the time of trial.

5.3 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff (b)(6) suffered loss of spousal consortium, entitling her to recover general damages.

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5.4 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff (b)(6) suffered loss of spousal consortium, entitling her to recover general damages.

5.5 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiffs in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.6 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.7 In addition because RTD Seattle as a joint venture in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and Georgia law.

5.8 Plaintiffs have incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiffs pray for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;

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4. For statutory attorney fees;

5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;

6. For statutory interest on the judgment from the date judgment is entered until paid in full;

7. For prejudgment interest on the special damages;

8. For prejudgment interest on liquidated damages;

9. For such other and further relief as the Court may deem just and equitable.

DATED this 3rd day of March, 2016.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER

/s/ Karen K. Koehler
Karen K. Koehler, WSBA #15325
Andrew Ackley, WSBA #41752
Counsel for Plaintiffs

LAW OFFICES OF MATTHEW D. DUBIN

/s/ Matthew D. Dubin
Matthew D. Dubin, WSBA # 25378
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KING COUNTY
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CASE NUMBER: (b)(6)

**IN THE SUPERIOR COURT OF WASHINGTON
FOR KING COUNTY**

(b)(6) Husband and Wife Plaintiffs, v. RIDE THE DUCKS INTERNATIONAL, LLC, a Foreign Company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington Company; (b)(6) AND (b)(6) (b)(6), and their marital community Defendants.	No. COMPLAINT FOR PERSONAL INJURIES, DAMAGES AND PUNITIVE RELIEF

Plaintiffs allege:

I. PARTIES

1.1 (b)(6) and (b)(6) are wife and husband residing in Seattle, King County, Washington. They have two daughters, age 5 and 9.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of Missouri with its principal place of business in Georgia.

1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

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1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged in this Complaint. Mr. (b)(6) was driving Ride the Duck Boat No. 6 the vehicle involved in the collision described in this complaint. Mr. (b)(6) is a citizen of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and for his marital community.

II. JURISDICTION AND VENUE

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action under RCW 2.08.010. Jurisdiction is proper in Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within the State, and the commission of a tortious act within this State.

2.2 Venue is proper in King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged resulted in personal injury in King County, Washington.

2.3 RTD International was conducting substantial and continuous business in the State of Washington by selling products to entities within the State, and by engaging in a licensing agreement with Defendant RTD Seattle, under which Defendant RTD International was entitled to and received a percentage of all gross ticket sales from all tours operated by Defendant RTD Seattle. The State of Washington has jurisdiction over RTD International for the claims that are described in this Complaint. In addition to the extent RTD International defectively manufactured products in Missouri or Georgia sold by them and transported to Washington this court has the authority and jurisdiction to apply the punitive damages laws of those states.

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III. FACTS

3.1 On or about September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified or remanufactured for tour operations by RTD International, and operated by RTD Seattle – was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately Block No. 2900.00 1000 feet from Ray Street.

3.2 DUKW No. 6 is a six-wheel amphibious truck used during amphibious operations in World War II by the U.S. Army and Marine Corp. Its primary use was to ferry ammunition, supplies and equipment, from supply ships and transport areas offshore to supply dumps and fighting units at the beach.

3.3 The United States produced approximately 20,000 DUKWs during World War II.

3.4 After the war RTD International and its predecessors converted DUKWs into an amphibious vehicle they advertised could be used on land and in water for the tourist trade. DUKW No. 6 was one of these WW II converted amphibious vehicles.

3.5 DUKW No. 6 was one of several amphibious passenger vessels owned and operated by RTD Seattle.

3.6 Plaintiffs believe and therefore allege that DUKW No. 6 was rebuilt in early 2000 with the chassis and other parts being taken from the original 1940s vintage DUKW. It was one of a series of amphibious passenger vehicles termed "stretch Ducks" by their builder AVM, which merged into RTD International in 2005.

3.7 Plaintiffs believe and therefore allege that the decision to use the chassis from the 1940s amphibious vehicles was to avoid modern safety and emissions standards.

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3.8 In 2006, the predecessor to RTD International produced a patented "truck duck" with a new and modern design which was a safer amphibious passenger vehicle than the converted 1940s vehicles. The RTD Seattle fleet included both types of vehicles. DUKW No. 6 did not have the new and modern design.

3.9 In approximately 2005 RTD International sold DUKW No. 6 to RTD Seattle and retained licensing rights.

3.10 As a licensor, RTD International was entitled to, and received a percentage of all gross ticket sales from all tours operated by RTD Seattle. These defendants formed an express and/or implied contract for the common purpose of manufacturing, selling, and using the DUKW vehicles for guided tours in the City of Seattle, and therefore were engaged in a joint venture regarding the incident, claims and damages alleged.

3.11 On September 24, 2015 DUKW No. 6 was being operated by (b)(6) and was occupied by 36 passengers.

3.12 RTD Seattle created the route driven by Defendant (b)(6) That route included travel over the Aurora Bridge. Despite knowing the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of center median, and posted speed limit.

3.13 (b)(6) year-old driver was directed by his employer RDT Seattle to ferry the 36 passengers over the Aurora Bridge.

3.14 At the same time, that Mr. (b)(6) was traveling across the bridge, a 2009 MCI Motor Coach, operated by CWA, Inc. d/b/a Bellair Charters Hesselgrave South, was traveling southbound in the center lane on Washington State Route 99 (SR 99) also known as the Aurora

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Bridge. The motor coach with its driver was occupied by approximately 45 to 50 passengers, including Plaintiff (b)(6)

3.15 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when Defendant (b)(6) reported hearing a loud "bang" after which he claims he lost control of DUKW No. 6.

3.16 The DUKW crossed the centerline of SR 99 Aurora Bridge into the oncoming southbound lane of traffic, then struck and penetrated into the left side of the motor coach.

3.11 Though SR 99 has median barriers both north and south of the Aurora Bridge there are no median barriers on the bridge itself.

3.12 State Route 99 at the location of the Aurora Bridge has a long history of crossover collisions, warranting the installation of a medium barrier that would reduce or eliminate these crossover collisions. Lacking a medium barrier the Aurora Bridge is not reasonably safe place to operate the DUKW No. 6. Plaintiffs believe and therefore allege Defendant RTD Seattle knew of the history of crossover collisions and the lack of medium barriers on the bridge and despite that knowledge included traveling over the Aurora Bridge as part of its regular route for the DUKWs.

3.13 The National Transportation Safety Board conducted an investigation of the collision and documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The DUKW penetrated the left side of the motor coach causing extensive damage to the vehicle and injuries to most of most of its passengers.

3.15 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

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3.16 On or about October 2013 RTD International issued a notice to purchasers, licensees, and/or joint venture/enterprise partners of approximately 57 of its refurbished, manufactured, and modified DUKW vehicles. The notice alerted the purchasers, licensees, and/or joint venture/enterprise partners to dangerous defects in the axle housing. The notice also provided some guidance on a suggested modification to strengthen the axle housing to prevent fractures to that housing. The notice also recommended daily inspection, while acknowledging that "the visual detection of a failing axle housing is not possible."

3.17 RTD International made no further efforts and took no further action to ensure that the purchasers, licensees, and/or joint venture/enterprise partners, of its manufactured, refurbished, and modified DUKW products had done anything to remedy the dangerous defects noted in their report and noted by them on or before October, 2013.

3.18 RTD International failed to issue a recall of its defective and dangerous DUKW products.

3.19 According to reports issued by the NTSB: the left front axle that failed on the accident vehicle had an earlier modification to the axle housing recommended by RTD International, but did not have an associated service bulletin.

3.20 The "earlier modification" to the axle housing was not the same recommendation outlined in the October, 2013 service bulletin as a recommended fix for the DUKW."

3.21 On the date of the accident, RTD International and RTD Seattle were consciously acting together in a tortious manner, creating and allowing a foreseeable and unreasonable risk of harm to Plaintiffs and others. These Defendants were therefore acting in concert when Plaintiffs suffered their injuries.

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3.21 Plaintiffs believe and therefore allege that the person or persons responsible for doing any modification to the axle housing, who were employed by Defendant RTD Seattle, contend they have never seen the October 13, 2013 service bulletin which RTD International claims it had sent to RTD Seattle.

3.22 Following the collision, RTD International issued a statement claiming it had warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country and that it had recommended specific inspections and repairs to reinforce that housing.

3.23 At the present time the NTSB has possession of the DUKW vehicle and the charter bus. It also has possession of all the component parts. Plaintiffs believe and therefore allege the NTSB is conducting and performing metallurgical examination of the axle components and is also reviewing the motor coach companies' onboard video systems and is performing other investigatory acts. The NTSB has not yet completed its investigation and the physical evidence collected by them is unavailable to Plaintiffs for their inspection.

3.24 Following the crash, the Washington Utilities and Transportation Commission ("WUTC") suspended RTD Seattle's operations pending a full examination into its fleet. The state investigator analyzed maintenance records and conducted physical inspection of the DUKW vehicles. Recently the license to operate DUKWs other than the converted 1945 amphibious vehicles has been reinstated. The reinstatement is subject to various conditions.

3.26 The WUTC prior to the reinstatement released a report on December 15, 2015 identifying 442 safety-related violations and concluded they were all avoidable and had to be corrected immediately.

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3.25 Plaintiffs believe and therefore allege that included amongst the recommendations made for the reinstatement of RTD Seattle's license to operate its DUKW vehicles, was an agreement by RTD Seattle to no longer use the Aurora Bridge on its routes.

3.26 In addition the WUTC and other Seattle City agencies recommended and RTD Seattle agreed it will now use a separate driver and a tour guide instead of combining the two functions into one employee.

3.27 Because of the collision on the Aurora Bridge approximately 64 people were injured, including five fatalities.

3.28 45 to 50 students and staff from the North Seattle College were on the motor coach when it was struck. The college had organized an excursion for the students in its international program as part of their orientation.

3.29 Plaintiff (b)(6) is an employee of the North Seattle College. She is the Assistant Director of International Programs and was acting in that capacity on the day of the accident.

3.30 Plaintiff (b)(6) was seated directly behind the driver. Upon impact by DUKW No. 6, she was thrown forward violently and landed at the bottom of the entry/exit stairs of the motor coach.

3.31 Plaintiff (b)(6) suffered numerous injuries, including multiple fractures to her pelvis, sacrum, and ribs. Prior to this collision, she was a marathon runner and avid bicyclist who ran and rode in numerous competitive events. Now she cannot walk for any extended period without the use of a cane. She was transported from the accident site to Swedish Hospital where she remained for several days. She continues to recuperate at her home

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with the aid of her husband. Her injuries have prevented her from been able to return to her job at the College.

3.32 As of filing of this Complaint, Plaintiff (b)(6) is still recovering from her injuries. It is likely that she has suffered a permanent partial disability as a result of the crash.

IV. LIABILITY

4.1 RTD International is a product manufacturer and a product seller within the meaning of RCW 7.72 *et seq*.

4.2 RTD International manufactured or remanufactured DUKW No. 6, the product, which was not reasonably safe in construction. When the product left control of RTD International, it deviated in material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing resulting in fractures and other hazardous defects, that deviated from specification, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused because DUKW No. 6 was not reasonably safe in construction and was unreasonably dangerous for its intended use. RCW 7.72.030, section 402(A) Restatement of the Law of Torts (Second).

4.4 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe as designed. At the time of the manufacture or remanufacture, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have

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prevented those harms and the adverse effect that an alternate design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.5 RTD International is liable for Plaintiff's damages because DUKW No. 6 was not reasonably safe because adequate warnings or instruction were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6 and the likelihood that the product would cause Plaintiff's harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6 is liable for negligence, including but not limited to failing to maintain or ensure the maintenance and proper repair of DUKW No. 6 and failing to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the crash described and the injuries to Plaintiffs, of which RTD International was aware or reasonably should have been aware.

4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.8 (b)(6) was negligent, including but not limited to:

a) Operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington;

b) Acting as a tour guide while also operating a vehicle;

c) Failing to maintain proper control of the DUKW No. 6;

d) Failing to stay in his lane of travel;

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c) Traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely;

f) Traveling upon a bridge known to be unsafe due to lack of a center median; and

g) Traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge.

4.8 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) (b)(6) under the doctrine of respondeat superior. RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.9 RTD Seattle was negligent in several respects, including but not limited to:

a) Failing to properly inspect, maintain, and repair DUKW No. 6;

b) Failing to use reasonable care to detect hazardous defects in the DUKW No. 6;

c) Failing to use reasonable care to warn and remedy those defects;

d) Failing to address the 2013 notice issued by RTD International;

e) Operating an unsafe, dangerous and defective vehicle on a State roadway;

f) Requiring its drivers to operate the vehicle while entertaining the passengers;

g) Creating a travel route that included utilization of SR 99 Aurora Bridge despite having actual or constructive knowledge that the bridge had inadequate lane width to accommodate a DUKW safely, had no center median and had a history of crossover collisions;

h) Failing to properly train and supervise its mechanics and drivers; and

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i) Endangering the public safety by operating a modified World War II vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of DUKW and the SR 99 Aurora Bridge.

4.10 Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiffs injuries and damages.

V. DAMAGES

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has suffered and continues to suffer permanent physical injuries, disability, disfigurement, pain and suffering, emotional trauma, loss of enjoyment of life and other general damages in the amount to be proven at the time of trial.

5.2 As a direct result and proximate result of the above acts, omissions, and other conduct of Defendants (b)(6) has suffered a loss of consortium.

5.3 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) has had to seek various health care treatments and will continue to require treatments for the physical and emotional injuries she has suffered in the future, and other special damages including wage loss, loss of earnings, and other special damages in an amount to be proven at the time of trial.

5.4 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in the state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the Plaintiffs , and Missouri possesses an interest in punishing and deterring such conduct. Accordingly RTD International is liable for

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punitive damages under Missouri Law Singh v. Edwards Lifesciences Corp., 151 Wn. App. 137, 210 P.3d 337 (2009).

5.5 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD Internationals liable for punitive damages under Georgia law. Singh v. Edwards Lifesciences Corp., 151 Wn. App. 137, 210 P.3d 337 (2009). Because RTD Seattle is a joint venturer in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and Georgia Law.

5.6 Plaintiffs have also incurred other damages in an amount to be proven at the time of trial.

WHEREFORE, Plaintiffs pray for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and other disbursement;
4. For statutory attorney's fees;
5. For statutory interest on the judgment from the date judgment was entered until paid in full;
6. For prejudgment interest on the special damages;
7. For prejudgment interest on any liquidated damages;
8. For such other and further relief as to the Court may deem just and equitable.

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RESPECTFULLY submitted this 3 day of March, 2016.

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SUPERIOR COURT OF THE STATE OF WASHINGTON
FOR KING COUNTY

(b)(6) an individual; (b)(6) an individual; (b)(6) an individual,

Plaintiffs,

vs.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATLTE, LLC, a Washington Company; (b)(6) and (b)(6) and their marital community,

Defendants.

No.

COMPLAINT FOR DAMAGES

Demand for Jury Trial

COMES NOW Plaintiffs, by and through their attorneys Darrell L. Cochran and Kevin M. Hastings, and the law firm of Pfau Cochran Vertetis Amala PLLC, to bring a cause of action against the defendants, and allege the following:

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I. PARTIES

1. Plaintiff (b)(6) Plaintiff (b)(6) at all relevant times was a resident of King County, Washington.

2. Plaintiff (b)(6) Plaintiff (b)(6) at all relevant times was a resident of Billings, Montana.

3. Plaintiff (b)(6) Plaintiff (b)(6) at all relevant times was a resident of King County, Washington.

4. Ride the Ducks International, LLC. Defendant Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

5. Ride the Ducks of Seattle, LLC. Defendant Ride the Ducks of Seattle ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

6. (b)(6) Defendant (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. JURISDICTION AND VENUE

7. Jurisdiction. This court has proper jurisdiction over Defendants because the acts and omissions alleged in this complaint arose out of activities and business within Washington. This court also has proper universal original subject matter jurisdiction under the Washington State Constitution and RCW 2.08.010.

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8. Venue. Venue is proper under RCW 4.12.025 because Defendant RTD Seattle has its principal place of business and transacts business in King County, Washington. Venue is also proper under RCW 4.12.020 because the acts and omissions alleged in this complaint also resulted in personal injury in King County, Washington.

III. FACTS

9. Facts; RTD Seattle Duck Vehicle Driver Loses Control and Crashes Into Oncoming Traffic. On September 24, 2015, at approximately 1111 hours, (b)(6) was driving a retrofitted and remanufactured WWII amphibious military vehicle, identified by RTD Seattle as DUKW No. 6, across the George Washington Memorial Bridge ("Aurora Bridge") on the SR 99 highway in Seattle, Washington. (b)(6) suddenly lost control of DUKW No. 6, veered into oncoming traffic and smashed into a motor coach operated by CWA Inc., d/b/a Bellair Charters Hesselgrave South.

10. Facts; the crash injured dozens and killed 5 individuals. The massive crash that resulted injured approximately 64 individuals and killed 5. Victims of this horrible crash were both on the DUCK No. 6 as well as the motor coach.

11. Facts; RTD International Retrofitted and Remanufactured DUKW No. 6 to RTD Seattle. RTD International is in the business of retrofitting and remanufacturing old WWII amphibious military vehicles for use as tour vehicles in various cities across the United States. In or around 2005, RTD International had completed retrofitting and remanufacturing DUKW NO. 6 and then sold the vehicle to RTD Seattle. RTD International retained licensing rights, allowing it to collect five percent of all gross ticket sales from RTD Seattle tours. The resulting business relationship created is best described as a joint venture: RTD International builds and distributes the amphibious vehicles to various local businesses and reserves a portion of the daily tour profit generated by the vehicle.

12. Facts; RTD International Knew that DUKW No. 6 Had a Dangerously Defective Axle Housings. RTD International knew that its retrofitted and remanufactured WWII

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amphibious military vehicles had dangerously defective axle housings, and in or around October 2013, RTD International sent a notice regarding the defects to the operators of approximately 57 of its amphibious vehicles. The notice explained how to modify and strengthen the axle housing to prevent fractures, as well as acknowledged that "the visual detection of a failing axle housing is not possible. Other than sending this notice, RTD International took no further action, including but not limited to a recall, to ensure that the defects it identified were remedied.

13. Facts; RTD International retrofitted, manufactured, and remanufactured DUKW No. 6 so as to render it unsafe. RTD International retrofitted, manufactured, and remanufactured DUKW No. 6 here by deviating in material ways from the design specifications and /or performance standards of the manufacturer, and / or by deviating in material ways from otherwise identical WWII amphibious military vehicles. As a result, RTD International caused DUKW No. 6 to have dangerous defects in the axle housing, resulting in factures or other defects that materially deviated from the specifications and standards of other similar products manufactured or remanufactured by RTD International.

14. Facts; the burden on RTD International to design a safe product that would have prevented the harms alleged in this complaint is substantially outweighed by the likelihood of serious injuries and harms. RTD International's practice of retrofitting, manufacturing, and remanufacturing the WWII amphibious military vehicles was a profit source. The extra steps needed to make the vehicles safe, such as by ensuring that the axles did not suffer from dangerous product defects, was small compared to the likelihood that allowing defective units to be operated on city streets would cause catastrophic injuries.

15. Facts; RTD International failed to provide adequate warnings or instructions to RTD Seattle regarding maintenance and repair of DUKW No. 6 and the likelihood of a catastrophic crash for failing to properly fix defective parts. The notice that RTD International provided to RTD Seattle was inadequate and failed to provide sufficient instructions on how to

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repair known defects in the WWII amphibious military vehicles. The notice was equally defective for failing to sufficiently warn and guard against the dangers that would foreseeably follow from operating amphibious vehicles with defective parts on city streets and in city traffic.

16. Facts; DUKW No. 6 had a failure to the left axle that was a proximate cause of the crash. One of the factors that caused the crash was a catastrophic failure to the left axle of DUKW No. 6. According to the National Traffic Safety Board, this axle had an "earlier modification" that was at some point recommended by RTD International; however, there was never an associated service bulletin that documented the modification. Upon information and belief, the "earlier modification" to the axle housing was not the same recommendation that RTD International outlined in its October 2013 notice regarding the defective axle housing.

17. Facts; Washington Utilities and Transportation Commission ("WUTC") suspended RTD Seattle's operations. Following the massive crash that is at the center of this lawsuit, the WUTC suspended RTD Seattle from operating the retrofitted and remanufactured WWII amphibious military vehicles in Washington. On December 15, 2015, WUTC released a report that identified hundreds of safety-related violations, stating, "All of the violations discovered were avoidable and must be corrected immediately."

18. Facts; RTD Seattle admitted to 463 safety violations and agreed to pay $222,000 in penalties. WUTC announced that its investigators found 159 acute and critical safety violations and another 304 violations related to record-keeping. RTD Seattle agreed to pay $222,000 in penalties related to these violations.

19. Facts; RTD Seattle's actions fell below the ordinary care in many regards. As operator of DUKW No. 6, RTD Seattle owed a duty of care to its passengers and others using the streets and thoroughfares. This defendant breached its duty of ordinary care in many regards, including but not limited to (1) failing to properly inspect, maintain, and repair DUKW No. 6; (2) failing to use reasonable care to warn against and remedy those defects; (3) failing to address the 2013 notice that RTD International issued; (4) knowingly operating a dangerous

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and defective and unsafe vehicle on roadways in a busy city; (5) knowingly requiring its drivers to serve as tour guides while also operating a large vehicle; (6) knowingly utilizing SR 99 despite earlier warnings that this roadway was dangerous for its narrow lanes and lack of a center median; (7) failing to properly train and supervise its mechanics and drivers; (8) failing to properly inspect its fleet of amphibious military vehicles; (9) knowingly operating the amphibious military vehicles in a busy city at highway speeds; and (10) violating WAC 480-30-221.

20. Facts; RTD Seattle announced changes in routes and practices in the wake of the crash. Since the crash, RTD Seattle announced that it would no longer use the SR 99 Aurora Bridge. RTD Seattle has also stated that it will now use a separate drive and tour guide instead of combining these two functions into one employee.

21. Facts; Defendants knew that the SR 99 Aurora Bridge had dangerously narrow lanes. Lane width on the Aurora Bridge from west to east is 10 feet, 9 feet, 9.5 feet, 9 feet, and 10 feet. The speed limit is 40 miles per hour, but traffic regularly flows much faster across the bridge than the posted limit. In 2002, the Washington State Department of Transportation released a news bulletin commissioning a safety study of the Aurora Bridge because it "ranks third among all high-accident corridors in the state." Study data between 1999 and 2001 showed that there was more than 1,500 accidents in an eight-mile stretch of SR 99. The study was completed in March 2003, and it recommended widening the lanes by moving the pedestrian walkways to underneath the bridge.

22. Facts; Plaintiffs suffered damages as a direct and proximate result of RTD International and RTD Seattle's negligence. RTD International and RTD Seattle knew about the dangerously defective axles on its WWII amphibious vehicles before the crash in question. Their negligent, or alternatively, grossly negligent, failure to fix the axle's defects was a proximate cause to the crash and the resultant injuries that Plaintiffs suffered.

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23. Facts; Plaintiffs suffered damages as a direct and proximate result of RTD International and RTD Seattle's negligence. RTD International and RTD Seattle engaged in a joint business venture that provided a driver who would both drive and give a tour guide at the same time. This practice and procedure was inherently dangerous because it created a situation, like here, where the drivers were distracted. A bad accident flowing from the distractions was foreseeable. These negligent, or alternatively grossly negligent, practices proximately caused the crash and the resultant injuries that Plaintiffs suffered.

24. Facts; Plaintiffs suffered damages as a direct and proximate result of RTD International and RTD Seattle's negligence. RTD International and RTD Seattle knew or should have known that the Aurora Bridge had lanes that were too narrow and that were extremely dangerous for wide vehicles, like the retrofitted and remodeled WWII amphibious vehicles that they operated. Despite this knowledge, RTD International and RTD Seattle maintained a joint business venture that permitted its fleet of amphibious vehicles to use the Aurora Bridge, disregarding the dangers at hand. These negligent, or alternatively grossly negligent, practices proximately caused the crash and the resultant injuries that Plaintiffs suffered.

25. Facts; Plaintiffs suffered damages as a direct and proximate result of Bishop's negligence. Bishop was an agent of RTD International and RTD Seattle, responsible for the safety and wellbeing of his passengers as well as others on the roads. He knowingly drove a retrofitted and remanufactured WWII amphibious vehicle across a narrow bridge while he was distracted with giving a tour at the same time. Bishop's negligent, or alternatively grossly negligent, conduct was a proximate cause of the crash and the resultant injuries that Plaintiffs suffered.

26. Damages. As the proximate result of the negligence, or alternatively, gross negligence, as set forth above, Plaintiffs suffered economic and noneconomic damages in an amount to be proved at trial.

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27. Punitive Damages. Defendant RTD International is liable for punitive damages under Washington's choice of law.

IV. CAUSES OF ACTION

COUNT I
PRODUCT LIABILITY
AS TO RTD INTERNATIONAL

28. Product liability. Based on the paragraphs set forth and alleged above, Defendant RTD International is a product manufacturer and seller under RCW 7.72 et seq., and is liable under this chapter for all damages proximately caused by DUKW No. 6 not being of reasonably safe design or construction.

COUNT II
NEGLIGENCE
AS TO DEFENDANTS RTD INTERNATIONAL, RTD SEATTLE, AND BISHOP

29. Negligence. Based on the paragraphs set forth and alleged above, Defendant RTD International, RTD Seattle, and (b)(6), acting as an agent of RTD Seattle and RTD International, owed a duty of care under law, breached the duty owed, and proximately caused Plaintiffs to suffer damages. These Defendants were either ordinarily negligent, or alternatively, grossly negligent.

V. RESERVATION OF RIGHTS

30. Reservation of Rights. Plaintiffs reserve the right to assert additional claims as may be appropriate following further investigation and discovery.

VI. JURY DEMAND

31. Jury Demand. Plaintiffs demand that this action be tried before a jury.

VII. PRAYER FOR RELIEF

32. Relief. Plaintiff respectfully requests that the Court award the following relief:

A. All special and general damages established at trial;

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B. Punitive damages under any provision of law under which such damages may be imposed given Washington's choice of law;

C. Costs, reasonable attorneys' fees, and statutory interest under any applicable law or ground in equity;

D. Pre-judgment interest on special damages and liquidated damages;

E. Statutory interest on the judgment from the date judgment is entered until paid in full;

F. Such other, favorable relief as may be available and appropriate under law or at equity; and

G. Such other and further relief as the Court may deem just and proper.

Respectfully submitted,

Dated: March 17, 2016

By: /s/ Darrell L. Cochran
One of Plaintiffs' Attorneys

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4842-5889-7711, v. 2

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KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)
(b)(6) a married couple,

Plaintiffs,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiffs allege:

I. Parties

1.1 (b)(6) are each over the age of 18 years and are a married couple residing in Riverside, California.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State, and

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by engaging in a licensing agreement with RTD Seattle, under which RTD International was entitled to and received five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. The State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a (b) year old driver and approximately 45 to 50 passengers.

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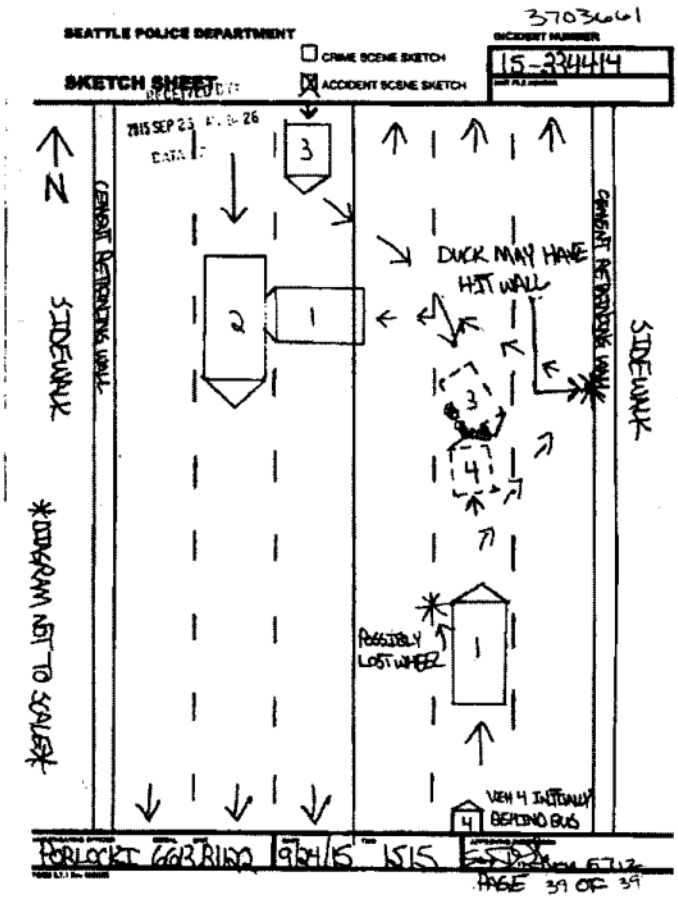
3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The

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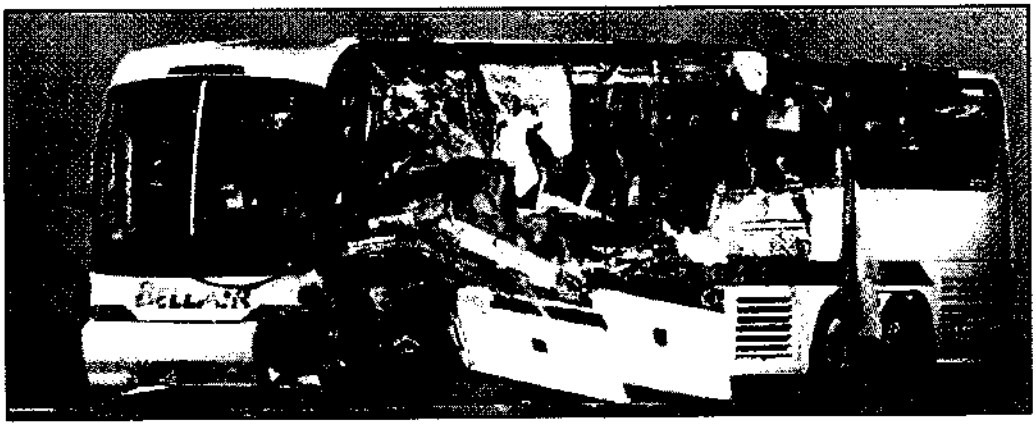
following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:



3.9 DUKW No. 6 was originally a 1945 military model. RTD International remanufactured, refurbished, and modified DUKW No. 6 and similar military vehicles to perform the new

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and unusual function of transporting large numbers of tourists on guided tours by road, highway, and also by water.

3.10 RTD Seattle advertises that the "DUKWs are likely the most unique craft you'll see on the road or in the water." This is true, as DUKWs are novelty vehicles.

3.11 In approximately 2005, RTD International sold DUKW No. 6 to RTD Seattle and retained licensing rights.

3.12 As a licensor, RTD International was entitled to, and received, five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. RTD Seattle and RTD International formed an express and/or implied contract for the common purpose of manufacturing, selling, and using the DUKW vehicles for guided tours in the City of Seattle, and therefore were engaged in a joint venture with respect to the incident, claims, and damages alleged.

3.13 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.14 On or about October 2013, RTD International issued a notice to purchasers, licensees and/or joint venture/enterprise partners of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers, licensees, and/or joint venture/enterprise partners to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures. The notice also recommended daily inspection, while acknowledging that "the visual detection of a failing axle housing is not possible."

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3.15 RTD International took no further action to ensure that purchasers, licensees and/or joint venture/enterprise partners, of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.16 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.17 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.18 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.19 At the time of the incident, RTD International and RTD Seattle were consciously acting together in a tortious manner, creating and allowing a foreseeable and unreasonable risk of harm to Plaintiffs and others. RTD International and RTD Seattle were therefore acting in concert at the time of Plaintiffs' injuries.

3.20 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic (b)(6) stated he had never seen the October 13, 2013 service bulletin.

3.21 RTD International issued a statement after the incident stating that it warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country, and that it recommended specific inspections and repairs to reinforce the housing.

3.22 The NTBS has possession of the DUKW vehicle and its component parts. It is currently performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and other investigatory acts.

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3.23 Following the Crash, the Washington Utilities and Transportation Commission ("WUTC") suspended RTD Seattle's operations pending a full examination into its fleet.

3.24 On December 15, 2015, the WUTC released its report identifying 442 safety-related violations, stating, "All of the violations discovered were avoidable and must be corrected immediately."

3.25 RTD Seattle had implored the State to act with "urgency" so that the vehicles can be placed back in service and the company's 130 employees sent back to work.

3.26 On December 21, 2015, WUTC allowed RTD Seattle to resume limited operation of non-stretch DUKW vehicles, provided that the extensive safety violations were addressed and remedied.

3.27 Following the release of the WUTC recommendations, the Mayor of Seattle issued a letter requesting the WUTC continue the full suspension of RTD Seattle operations until such time as the safety violations had been cured and other concerns were addressed.

3.28 RTD Seattle has informed the State that it will no longer use the SR 99 Aurora Bridge.

3.29 RTD Seattle informed the State it would be using the Fremont Bridge. This drew an objection from the City of Seattle.

3.30 RTD Seattle has informed the State that it will now use a separate driver and tour guide instead of combining the two functions in one employee.

3.31 As a result of the collision, approximately 64 people were injured, including (b)(6) (b)(6) five of whom were killed.

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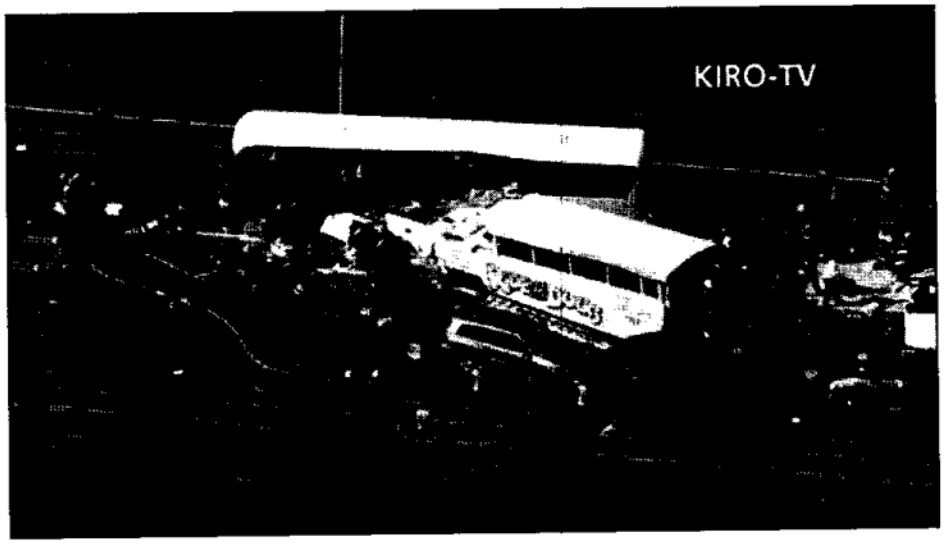

3.32 Plaintiffs (b)(6) were seated on DUKW No. 6, in the window and aisle seats respectively, of row "F" in the moments before the crash.

3.33 DUKW No. 6 did not have seatbelts for available use by either of the Plaintiffs.

3.34 The Plaintiffs paid a fee to the defendants to ride DUKW No. 6 on the day of the crash.

3.35 As a result of the crash, Plaintiff (b)(6) suffered numerous injuries, including fractures of the clavicle, left leg and ribs, lacerations to the head, ankle and foot, internal injuries, musculoskeletal injuries and contusions. He was transported to Harborview after the crash.

3.36 As a result of the crash, Plaintiff (b)(6) suffered multiple injuries, including laceration of her hand, musculoskeletal injuries and contusions. She was transported to Harborview after the crash.

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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left the RTD International manufacturing plant, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects,

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that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.5 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe because adequate warnings or instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiffs' harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

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4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.8 (b)(6) was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.9 RTD Seattle is vicariously liable for the negligent acts and omissions of (b)(6) under the doctrine of *respondeat superior*.

4.10 RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.11 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring

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its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge, and j) violating relevant provisions of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.12 Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiffs' damages.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have suffered and continue to suffer physical injuries, disability, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have been required to seek various medical treatments and will continue to require medical treatment in the future, as well as other special damages, including wage loss, all in an amount to be proven at the time of trial.

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5.3 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff [(b)(6)] suffered loss of spousal consortium, entitling him to recover general damages.

5.4 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff [(b)(6)] suffered loss of spousal consortium, entitling her to recover general damages.

5.5 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiffs in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.6 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.7 In addition because RTD Seattle as a joint venture in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and Georgia law.

5.8 Plaintiffs have incurred other damages to be proven at the time of trial.

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VI. Prayer for Relief

WHEREFORE, Plaintiffs pray for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

DATED this 30th day of March, 2016.

STRITMATTER KESSLER WHELAN KOEHLER MOORE KAHLER

/s/ Karen K. Koehler
Karen K. Koehler, WSBA #15325
Andrew Ackley, WSBA #41752
Counsel for Plaintiffs

PREMIER LAW GROUP

/s/ Patrick J. Kang
Patrick J. Kang, WSBA #30726
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KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

(b)(6)
(b)(6) a married couple,

Plaintiffs,

v.

RIDE THE DUCKS INTERNATIONAL, LLC, a foreign company; RIDE THE DUCKS OF SEATTLE, LLC, a Washington company; (b)(6) and their marital community;

Defendants.

No.

COMPLAINT FOR PERSONAL INJURIES, DAMAGES, AND PUNITIVE RELIEF

Plaintiffs allege:

I. Parties

1.1 (b)(6) are each over the age of 18 years and are a married couple residing in Appleton, Wisconsin.

1.2 Ride the Ducks International, LLC ("RTD International") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia.

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1.3 Ride the Ducks of Seattle, LLC ("RTD Seattle") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD Seattle is a citizen of the State of Washington.

1.4 (b)(6) was an employee of RTD Seattle acting within the course and scope of his employment with RTD Seattle at the time of the events alleged herein. Mr. (b)(6) was driving Ride the Duck Boat No. 6, the vehicle involved in the below-described collision. Mr. (b)(6) is a citizen of the State of Washington domiciled in Snohomish County, Washington. All acts of Mr. (b)(6) were also done individually and on behalf of his marital community.

II. Jurisdiction and Venue

2.1 The Superior Court of King County, State of Washington, has subject matter jurisdiction over this action pursuant to RCW 2.08.010.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State, and the commission of a tortious act within this State, because RTD Seattle has its principal place of business in this State, and because (b)(6) is a resident and citizen of this State. RCW 4.28.185; RCW 4.12.025.

2.3 Venue is proper in and for King County, Washington because RTD Seattle has its principal place of business and transacts business in King County, Washington, and because the acts and omissions alleged herein resulted in personal injury in King County, Washington. RCW 4.12.020-025.

2.4 RTD International was at all relevant times conducting substantial and continuous business in the State of Washington by selling products to entities within this State, and

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by engaging in a licensing agreement with RTD Seattle, under which RTD International was entitled to and received five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. The State of Washington has jurisdiction over RTD International for the below-described claims. To the extent RTD International defectively manufactured products in Missouri or Georgia, this Court has the authority and jurisdiction to apply the punitive damages laws of those states to this action.

2.5 Mr. (b)(6) and RTD Seattle are citizens of and domiciled in the State of Washington. Accordingly, this action may not be removed pursuant to 28 U.S. Code § 1441(b)(2).

III. Facts

3.1 About 11:11 a.m. local time on Thursday September 24, 2015, a 1945 GMC DUKW No. 6 – an amphibious military vehicle modified and remanufactured for tour operations by RTD International, and operated by RTD Seattle - was traveling northbound in the center lane on the SR 99 Aurora Bridge at approximately block no. 2900.00, 1000 feet from Raye Street.

3.2 DUKW No. 6 was occupied by (b)(6) year old driver, and 36 passengers.

3.3 RDT Seattle created the route driven by Defendant (b)(6) despite knowing that the SR 99 Aurora Bridge was unsafe to be traveled upon by a DUKW due to the bridge's narrow lane configuration, lack of a center median, and posted speed limit.

3.4 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound on the center lane on Washington State Route 99 (SR 99) also known as the Aurora Bridge.

3.5 The motor coach was occupied by a [redacted] year old driver and approximately 45 to 50 passengers.

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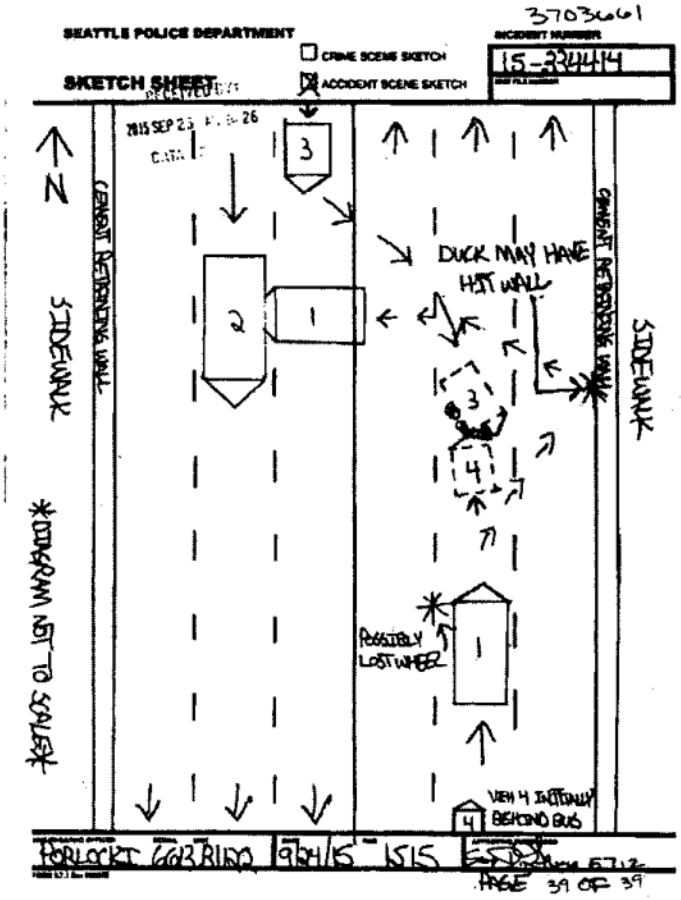
3.6 The two vehicles were traveling in their respective lanes heading in opposite directions on the southern span of the bridge when defendant (b)(6) reported hearing a loud "bang" and lost control of DUKW No. 6.

3.7 The DUKW crossed the center line of the SR 99 Aurora Bridge into the oncoming southbound lanes of traffic, then struck and penetrated into the left side of the motor coach.



3.8 The National Transportation Safety Board documented the damage to the crash scene, the DUKW vehicle and motor coach using three-dimensional laser scanning technology. The

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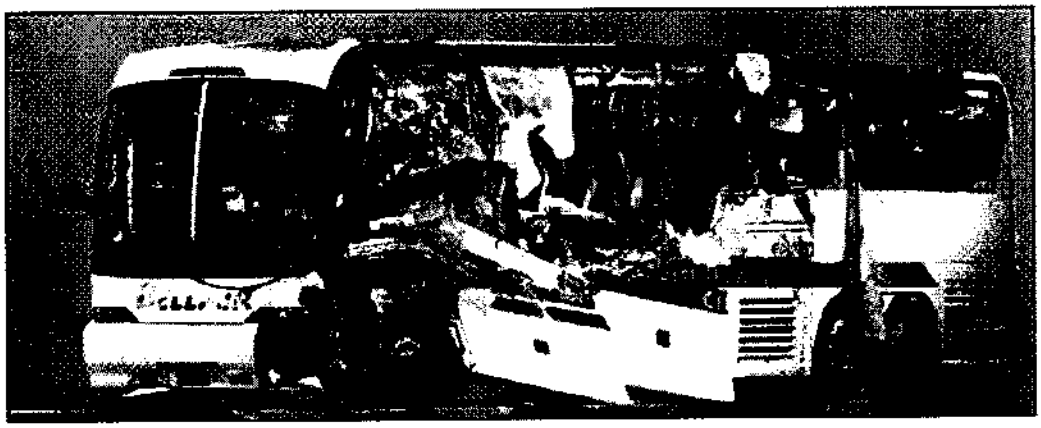
following figures show the 3D scans of the left front side of the DUKW and left side of the motor coach:



3.9 DUKW No. 6 was originally a 1945 military model. RTD International remanufactured, refurbished, and modified DUKW No. 6 and similar military vehicles to perform the new

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and unusual function of transporting large numbers of tourists on guided tours by road, highway, and also by water.

3.10 RTD Seattle advertises that the "DUKWs are likely the most unique craft you'll see on the road or in the water." This is true, as DUKWs are novelty vehicles.

3.11 In approximately 2005, RTD International sold DUKW No. 6 to RTD Seattle and retained licensing rights.

3.12 As a licensor, RTD International was entitled to, and received, five (5) percent of all gross ticket sales from all tours operated by RTD Seattle. RTD Seattle and RTD International formed an express and/or implied contract for the common purpose of manufacturing, selling, and using the DUKW vehicles for guided tours in the City of Seattle, and therefore were engaged in a joint venture with respect to the incident, claims, and damages alleged.

3.13 On or before October 2013, RTD International determined that the axle housings in their manufactured, refurbished, and modified DUKWs were dangerously defective.

3.14 On or about October 2013, RTD International issued a notice to purchasers, licensees and/or joint venture/enterprise partners of approximately 57 of its refurbished, manufactured and modified DUKW vehicles. The notice alerted the purchasers, licensees, and/or joint venture/enterprise partners to dangerous defects in the axle housing. The notice provided guidance on a modification to strengthen the axle housing to prevent fractures. The notice also recommended daily inspection, while acknowledging that "the visual detection of a failing axle housing is not possible."

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3.15 RTD International took no further action to ensure that purchasers, licensees and/or joint venture/enterprise partners, of its manufactured, refurbished, and modified DUKW products had in fact remedied the dangerous defects.

3.16 RTD International did not issue a recall of its defective and dangerous DUKW products.

3.17 According to the NTSB: The left front axle that failed on the accident vehicle had an earlier modification to the axle housing that had been recommended by RTD International but did not have an associated service bulletin.

3.18 The "earlier modification" to the axle housing was not the same recommendation outlined in the October 2013 service bulletin as a recommended fix for the DUKW.

3.19 At the time of the incident, RTD International and RTD Seattle were consciously acting together in a tortious manner, creating and allowing a foreseeable and unreasonable risk of harm to Plaintiffs and others. RTD International and RTD Seattle were therefore acting in concert at the time of Plaintiffs' injuries.

3.20 According to The Seattle Times story of September 29, 2015, RTD Seattle mechanic (b)(6) stated he had never seen the October 13, 2013 service bulletin.

3.21 RTD International issued a statement after the incident stating that it warned purchasers about potential failure of the front axle housing assembly on 57 vehicles in service throughout the country, and that it recommended specific inspections and repairs to reinforce the housing.

3.22 The NTBS has possession of the DUKW vehicle and its component parts. It is currently performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and other investigatory acts.

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3.23 Following the Crash, the Washington Utilities and Transportation Commission ("WUTC") suspended RTD Seattle's operations pending a full examination into its fleet.

3.24 On December 15, 2015, the WUTC released its report identifying 442 safety-related violations, stating, "All of the violations discovered were avoidable and must be corrected immediately."

3.25 RTD Seattle had implored the State to act with "urgency" so that the vehicles can be placed back in service and the company's 130 employees sent back to work.

3.26 On December 21, 2015, WUTC allowed RTD Seattle to resume limited operation of non-stretch DUKW vehicles, provided that the extensive safety violations were addressed and remedied.

3.27 Following the release of the WUTC recommendations, the Mayor of Seattle issued a letter requesting the WUTC continue the full suspension of RTD Seattle operations until such time as the safety violations had been cured and other concerns were addressed.

3.28 RTD Seattle has informed the State that it will no longer use the SR 99 Aurora Bridge.

3.29 RTD Seattle informed the State it would be using the Fremont Bridge. This drew an objection from the City of Seattle.

3.30 RTD Seattle has informed the State that it will now use a separate driver and tour guide instead of combining the two functions in one employee.

3.31 As a result of the collision, approximately 64 people were injured, including (b)(6) (b)(6) five of whom were killed.

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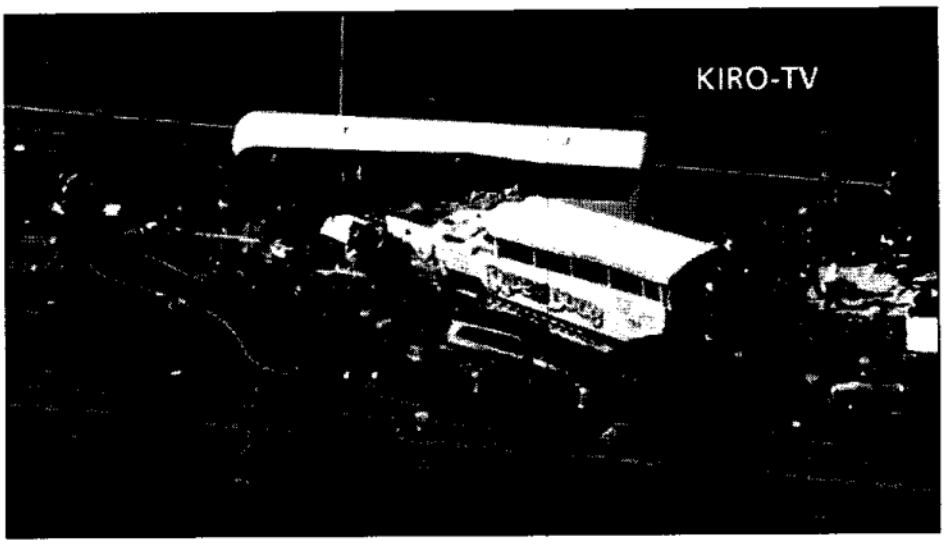

3.32 Plaintiffs (b)(6) were seated on DUKW No. 6, in the aisle and window seats respectively, of row "E" in the moments before the crash.

3.33 DUKW No. 6 did not have seatbelts for available use by either of the Plaintiffs.

3.34 The Plaintiffs paid a fee to the defendants to ride DUKW No. 6 on the day of the crash.

3.35 As a result of the crash, Plaintiff (b)(6) suffered numerous injuries, including a laceration of his left leg, musculoskeletal injuries and contusions. He was transported to Virginia Mason after the crash.

3.36 As a result of the crash, Plaintiff (b)(6) suffered multiple injuries, including a mild traumatic brain injury, head laceration, musculoskeletal injuries and contusions. She was transported to Virginia Mason after the crash.

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IV. Liability

4.1 RTD International is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.2 RTD International manufactured or remanufactured DUKW No. 6, the relevant product, which was not reasonably safe in construction. When the product left the RTD International manufacturing plant, it deviated in a material way from the design specifications or performance standards of the manufacturer, or deviated in a material way from otherwise identical units of the same product line. To wit, DUKW No. 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTD International.

4.3 RTD International is strictly liable for all damages proximately caused by the fact that DUKW No. 6 was not reasonably safe in construction. RCW 7.72.030.

4.4 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe as designed. At the time of manufacture or remanufacture, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the seriousness of those harms, outweighed the burden on RTD International to design a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

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4.5 RTD International is liable for Plaintiffs' damages because DUKW No. 6 was not reasonably safe because adequate warnings or instructions were not provided to RTD Seattle regarding maintenance and repair of DUKW No. 6, and the likelihood that the product would cause Plaintiffs' harm or similar harms, and the seriousness of those harms, rendered the warnings or instructions of the manufacturer inadequate, and RTD International could have provided the warnings or instructions which would have been adequate.

4.6 RTD International, as the product seller of DUKW No. 6, is liable for negligence, including but not limited to the failure to maintain or ensure the maintenance and proper repair of DUKW No. 6, and the failure to properly and adequately notify RTD Seattle of the dangerous defects in DUKW No. 6 that caused the above-described crash and injuries, of which RTD International was aware or reasonably should have been aware.

4.7 RTD International was negligent in failing to comply and assure compliance with the safety standards of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

4.8 Eric Bishop was negligent, including but not limited to: a) operating a motor vehicle below the standard of reasonable care required for the operation of a motor vehicle on the public roads of Washington; b) acting as a tour guide while also operating a vehicle; c) failing to maintain proper control of the DUKW No. 6; d) failing to stay in his lane of travel; e) traveling upon a bridge known to have inadequate lane width to accommodate a DUKW safely; f) traveling upon a bridge known to be unsafe due to lack of a center median; g) traveling at an unsafe rate of speed given the physical dimensions, capacities,

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and characteristics of a DUKW and the SR 99 Aurora Bridge; and h) crossing the center line of the SR 99 Aurora Bridge.

4.9 RTD Seattle is vicariously liable for the negligent acts and omissions of Eric Bishop under the doctrine of *respondeat superior*.

4.10 RTD International is vicariously liable for the negligent acts and omissions of RTD Seattle because Defendants were engaged in a joint venture, and the tortious acts and omissions described above were within the scope of the joint venture.

4.11 RTD Seattle was negligent in many respects, including but not limited to: a) failing to properly inspect, maintain, and repair DUKW No. 6; b) failing to use reasonable care to detect hazardous defects in DUKW No. 6; c) failing to use reasonable care to warn and remedy those defects; d) failing to address the 2013 notice issued by RTD International; e) operating an unsafe, dangerous and defective vehicle on a state roadway; f) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; g) creating a travel route that included utilization of SR 99 Aurora bridge despite having actual or constructive knowledge that the bridge had an inadequate lane width to accommodate a DUKW safely as well as no center median; h) failing to properly train and supervise its mechanics and drivers; i) endangering the public safety by operating a modified WWII vehicle at highway speeds that were excessive given the physical dimensions, capacities, and characteristics of a DUKW and the SR 99 Aurora Bridge, and j) violating relevant provisions of WAC 480-30-221, including but not limited to the requirement that operators must "Maintain all motor vehicles in a safe and sanitary condition" and "Ensure that vehicles are free of defects likely to result in an accident or breakdown."

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4.12 Defendants are jointly and severally liable because they were acting in concert when they caused Plaintiffs' damages.

V. Damages

5.1 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have suffered and continue to suffer physical injuries, disability, pain and suffering, emotional trauma, loss of enjoyment of life, and other general damages in an amount to be proven at the time of trial.

5.2 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, (b)(6) have been required to seek various medical treatments and will continue to require medical treatment in the future, as well as other special damages, all in an amount to be proven at the time of trial.

5.3 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff (b)(6) suffered loss of spousal consortium, entitling him to recover general damages.

5.4 As a direct and proximate result of the above acts, omissions, and other conduct of Defendants, plaintiff (b)(6) suffered loss of spousal consortium, entitling her to recover general damages.

5.5 Although Washington has the most significant relationship to the conduct underlying the negligence and products liability claims, RTD International committed conduct in its state of citizenship, Missouri, that was outrageous because of RTD International's reckless indifference to the rights of others, including the plaintiffs in this case, and Missouri possesses the interest in punishing and deterring such conduct. Accordingly,

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RTD International is liable for punitive damages under Missouri law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.6 In addition or in the alternative, RTD International committed acts of willful misconduct or wantonness in its other state of citizenship, Georgia, and Georgia possesses the interest in punishing and deterring such conduct. Accordingly, RTD International is liable for punitive damages under Georgia law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009).

5.7 In addition because RTD Seattle as a joint venture in concert with RTD International, RTD Seattle is liable for punitive damages under Missouri and Georgia law.

5.8 Plaintiffs have incurred other damages to be proven at the time of trial.

VI. Prayer for Relief

WHEREFORE, Plaintiffs pray for judgment against Defendants, jointly and severally as follows:

1. For special and general damages in amounts to be proven at trial;
2. For punitive damages under Missouri and/or Georgia law;
3. For costs and disbursements;
4. For statutory attorney fees;
5. If Defendant brings any frivolous or unfounded defenses, for attorneys' fees and costs pursuant to RCW 4.84.185 and/or Rule 11 of the Superior Court Civil Rules;
6. For statutory interest on the judgment from the date judgment is entered until paid in full;
7. For prejudgment interest on the special damages;
8. For prejudgment interest on liquidated damages;
9. For such other and further relief as the Court may deem just and equitable.

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DATED this 30th day of March, 2016.

STRITMATTER KESSLER WHELAN
KOEHLER MOORE KAHLER

/s/ Karen K. Koehler
Karen K. Koehler, WSBA #15325
Andrew Ackley, WSBA #41752
Counsel for Plaintiffs

PREMIER LAW GROUP

/s/ Patrick J. Kang
Patrick J. Kang, WSBA #30726
Counsel for Plaintiffs

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FILED
16 APR 06 AM 9:00

KING COUNTY
SUPERIOR COURT CLERK
E-FILED
CASE NUMBER: (b)(6)

IN THE SUPERIOR COURT OF THE STATE OF WASHINGTON
IN AND FOR THE COUNTY OF KING

(b)(6) the personal representative of the Estate of (b)(6) (b)(6) individually,

Plaintiffs,

vs.

RIDE THE DUCKS INTERNATIONAL, LLC, a Missouri Corporation; RIDE THE DUCKS OF SEATTLE, LLC, a Washington Corporation; STATE OF WASHINGTON; and CITY OF SEATTLE,

Defendants.

Case No.

COMPLAINT FOR DAMAGES

COME NOW the Plaintiffs, (b)(6) and allege as follows:

I. PARTIES

1.1 Plaintiff (b)(6) is the appointed Administrator/Personal Representative of the Estate of (b)(6) old daughter of Plaintiff (b)(6) and second cousin to Plaintiff (b)(6) was the shining light of and hope for her family. She excelled academically, and won awards in Beijing, China, her home city. As a result of her academic performance she was able to study in Kentucky in 2014. In September, 2015, she had just begun the next stage of her academic development in the International Program at North Seattle College. Before she had barely launched this next stage of her promising young life, on September 24, 2015, (b)(6) life came to an end when DUKW # 6 crossed the center line

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on the Aurora Bridge and speared the tour bus on which (b)(6) rode as a passenger. (b)(6) brings this action for (b)(6) claims surviving death pursuant to RCW 4.20.046.

1.2 Plaintiff (b)(6) mother. She resides in Beijing, China. Ms. (b)(brings this action under the Death of a Child statute (RCW 4.24.010) for loss of love and companionship, and destruction of the parent-child relationship.

1.3 Defendant Ride the Ducks International, LLC ("RTDI") is a limited liability company organized under the laws of the State of Missouri with its principal place of business in the State of Georgia. RTDI was acquired by Herschend Family Entertainment Corporation, a Missouri Corporation, in 2004. RTDI is a citizen of the states of Missouri and Georgia.

1.4 Defendant Ride the Ducks of Seattle, LLC ("RTD SEATTLE") is a limited liability company organized under the laws of the State of Washington with its principal place of business in King County, Washington. RTD SEATTLE maintains the registered trade name "Seattle Duck Tours." Brian Tracey is the President and CEO of RTD SEATTLE. RTD SEATTLE is a citizen of the State of Washington. RTD SEATTLE operates and maintains a fleet of 20 amphibious vehicles, including DUKW # 6. The vehicles, called "Duck Boats", provide 90-minute land and water passenger tours. Duck Boats include "Truck Duck" and "Stretch Duck" vehicle types. "Stretch Duck" vehicles were built on a World War II-era chassis. DUKW # 6 is a 1945 GMC "Stretch Duck" vehicle, model number DUKW/AMP, with a seating capacity of 36. A DUKW vehicle is a six wheel drive amphibious assault vehicle used by the U.S. military in World War II and the Korean War. DUKW # 6 is a modified military model DUKW vehicle, and was refurbished by Defendant RTDI in 2005.

1.5 Defendant State of Washington is a governmental entity. Defendant State of Washington is responsible for the design, maintenance, repair, construction and safe operation of State Route 99 along the Aurora Bridge in Seattle. On October 19, 2015 Plaintiffs filed their Claims for Damages with the Office of Risk Management for the State of Washington, more than 60 days prior to the filing of this Complaint.

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1.6 The City of Seattle is a governmental entity. Defendant City of Seattle is responsible for the design, routine maintenance, repair, construction and safe operation of the Aurora Bridge in Seattle. On October 20, 2015, Plaintiffs filed their Claims for Damages with the City of Seattle, more than 60 days prior to filing this Complaint.

II. VENUE AND JURISDICTION

2.1 The acts and omissions giving rise to this Complaint occurred in Seattle, King County, Washington. Therefore, this Court has jurisdiction and venue with respect to the parties to and subject matter of this action.

2.2 Jurisdiction is proper in the State of Washington because the alleged causes of action arose out of activities within the State of Washington, including but not limited to the transaction of business within this State and the commission of tortious acts within this state. RCW 4.28.185.

2.3 Venue is proper in this Court as to RTD SEATTLE because it resides in King County. RTD SEATTLE transacts business and has an office for the transaction of business in King County. RCW 4.12.025.

2.4 Defendant RTDI is a foreign corporation that maintains relevant business activities and contacts within the State of Washington and in King County. Venue is proper as to RTDI because an action may be brought in any county where some one of the defendants resides at the time of the commencement of the action. RCW 4.12.025.

2.5 Venue is proper as to the City because an action may be commenced against a city in the county in which it is located, and in any county where some one of the defendants resides at the time of the commencement of the action. RCW 4.12.025.

2.6 Venue is proper as to the State pursuant to RCW 4.92.010 because an action against the State may be commenced in the county where the cause of action arose.

2.7 Defendant RTD SEATTLE is a citizen of and domiciled in the State of Washington. Accordingly, this action may not be removed. 28 U.S.C. § 1441(b)(2).

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2.8 This action also must be filed in superior court because the State is a defendant. RCW 4.92.010. Under the Eleventh Amendment, the case is not removable without consent of the State.

III. FACTUAL BACKGROUND

Facts Related to the Liability of RTD SEATTLE and RTDI

3.1 About 11:11 a.m. local time on Thursday, September 24, 2015, DUKW # 6 was traveling northbound in the center lane on the Aurora Bridge. RTD SEATTLE adopted DUKW # 6's route, despite knowing that the Aurora Bridge is unreasonably unsafe for travel by a DUKW vehicle given that vehicle's width and lack of maneuverability, and the Aurora Bridge's narrow lanes and lack of a center median barrier.

3.2 At the time of the collision DUKW # 6 was driven by (b)(6) year old driver, and carried 36 passengers. Mr. (b)(6) was an employee of RTD SEATTLE acting within the course and scope of his employment with RTD SEATTLE at the time of the events alleged herein.

3.3 At the same time, a 2009 MCI motor coach, operated by CWA Inc. dba Bellair Charters Hesselgrave South, was traveling southbound in the center lane on the Aurora Bridge, carrying (b)(6) and her fellow students, who were traveling to Safeco Field as part of a new student orientation.

3.4 While the two vehicles were traveling in opposite directions on the southern span of the bridge, Mr. (b)(6) reported hearing a loud "bang" and lost control of DUKW # 6.

3.5 DUKW # 6 crossed the center line of the Aurora Bridge into the oncoming southbound lanes of traffic. It then struck and penetrated the left side of the motor coach carrying (b)(6)

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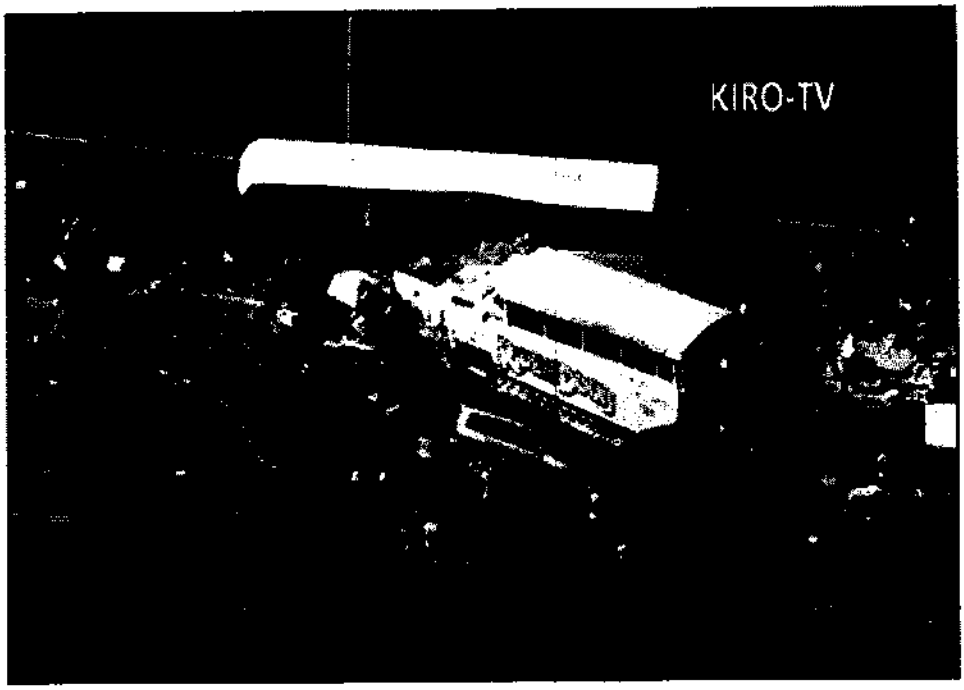

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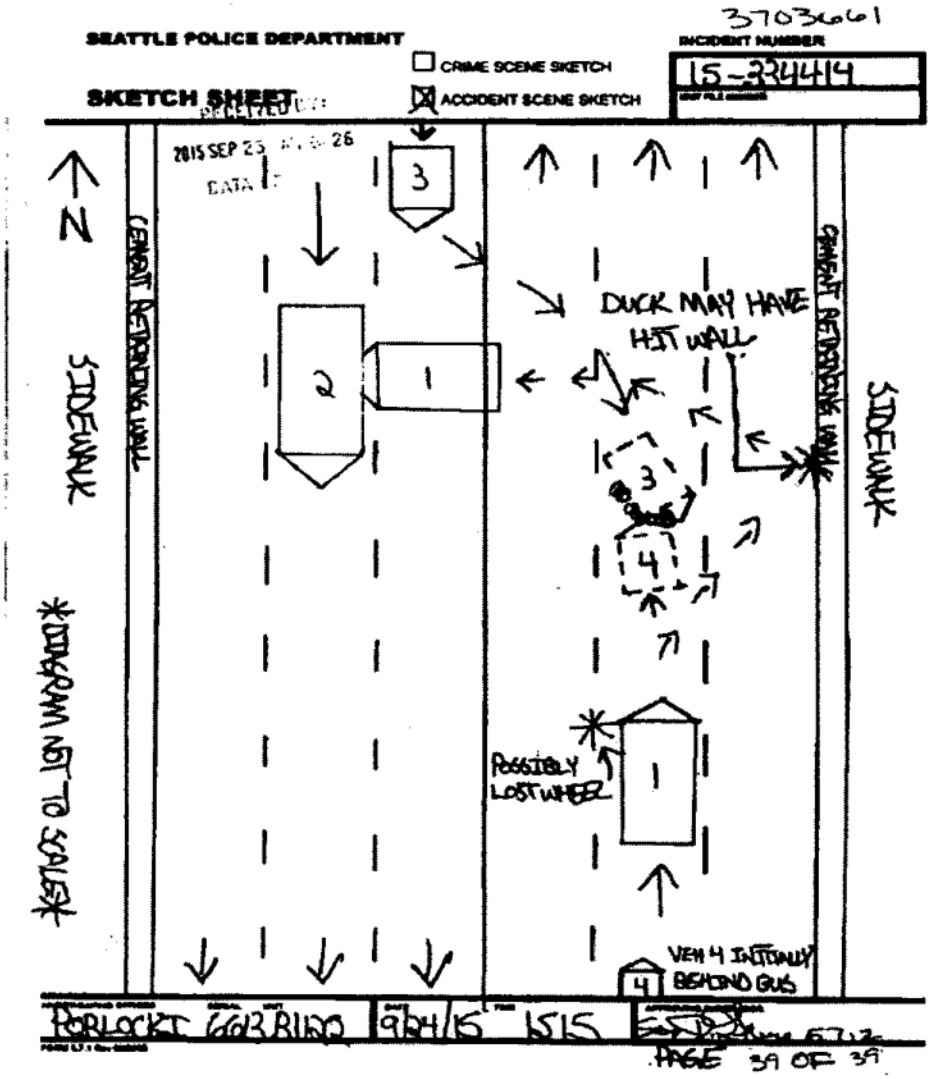

3.6 The crash injured dozens of people, and five people lost their lives. (b)(6) was one of them. She was the youngest person killed in the crash.

3.7 The National Transportation Safety Board ("NTSB") documented the damage to the crash scene, DUKW # 6 and the motor coach using three-dimensional laser scanning technology.

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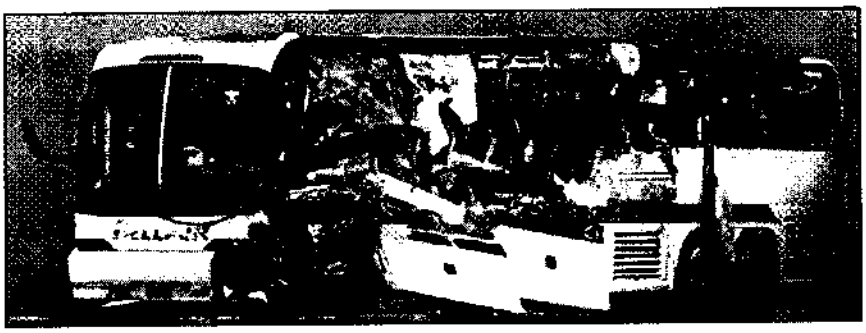
The following figures show the 3D scans of the left front side of DUKW # 6 and the left side of the motor coach:



3.8 RTDI manufactured, refurbished and modified DUKW # 6, which was originally a 1945 military model. In approximately 2005, RTDI sold DUKW # 6 to RTD SEATTLE.

3.9 On information and belief, RTDI and RTD SEATTLE formed an express and/or implied contract and entered into a licensing agreement, joint venture, or similar business relationship. As part of their business relationship, RTDI received a percentage of gross ticket sales from RTD SEATTLE.

3.10 On October 1, 2013, RTDI issued Service Bulletin No. SB-00-14-13 ("Bulletin"). The Bulletin alerted owners of DUKW vehicles of dangerous defects in the axle housing of

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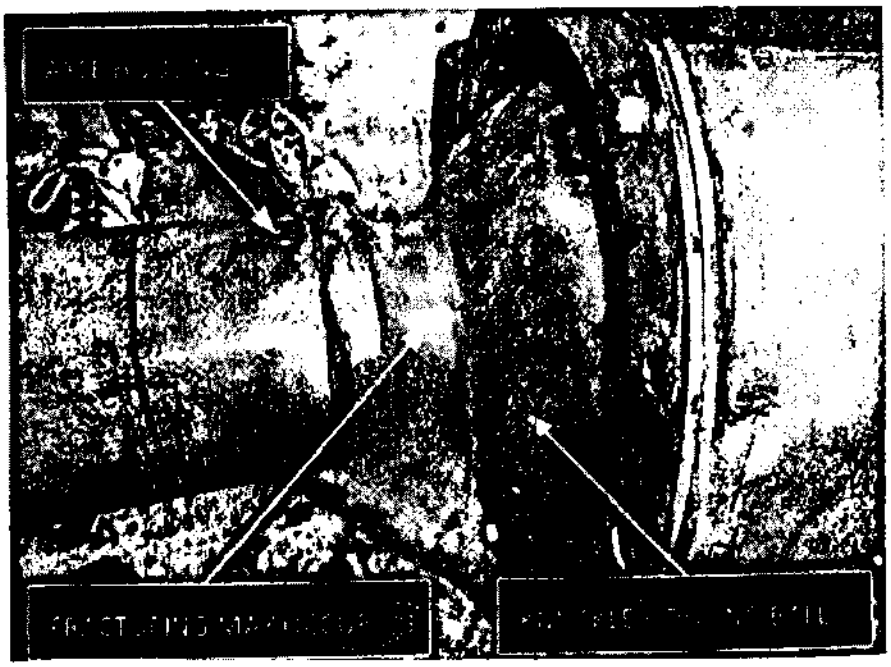
DUKW # 6 and similar vehicles and provided maintenance instructions. The Bulletin was issued "[t]o avoid axle fractures" and "strengthen the connection . . . to the axle housing." It instructed DUKW vehicle owners to complete specified modifications "[a]s soon as practical ***and prior to operating 2014***." (Emphases added). The Bulletin further directed "maintainers . . . to add . . . daily visual inspection of the front wheels."

3.11 The Bulletin identified the location where possible fracturing may occur:



3.12 The Bulletin specified that visual detection of a failing axle housing itself was not possible, and it required "maintainers" to conduct daily visual inspection of the front axles to look for signs of wheels being vertically canted. On information and belief, the Bulletin, even if followed, was inadequate to protect against catastrophic failure of the axle.

3.13 On information and belief, either the Bulletin was not received by RTD SEATTLE or RTD SEATTLE did not follow it in all particulars. According to the Seattle Times

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story of September 29, 2015, former RTD SEATTLE mechanic (b)(6) stated he had never seen the Bulletin.

3.14 RTDI took no further action to ensure that the RTD SEATTLE remedied, repaired, or otherwise addressed the dangerous defects in DUKW # 6. RTDI did not issue a recall of its defective and dangerous products.

3.15 Beginning in 2003, RTDI welded small metal plates onto the front axle housing of Stretch Duck vehicles prior to selling them to Ride the Ducks franchises, including vehicles purchased by RTD SEATTLE. RTD SEATTLE Stretch Duck vehicles ## 1, 3, 6, and 8 were purchased by RTD SEATTLE after 2003, and each had these small metal plates welded onto their front axles. In a preliminary report, the NTSB determined that "[t]he left front axle assembly that failed on [DUKW # 6] had an earlier modification to the axle housing" which had been the subject of the Bulletin. On information and belief, the earlier repair was inadequate to address the axle defect and protect against catastrophic failure.

3.16 The NTSB and/or Seattle Police Department possess the DUKW # 6 vehicle and its component parts. The NTSB is performing metallurgical examination of the axle components, review of the motor coach company's onboard video systems, and conducting further investigation.

3.17 At the time of the collision, DUKW # 6 was operated by a single driver, Mr. (b)(6) who was responsible for simultaneously driving the vehicle and providing entertainment to passengers. On October 8, 2015, RTD SEATTLE issued a statement that going forward, it would employ both a driver and tour guide instead of employing a single person to serve both functions.

3.18 On September 28, 2015, due to the "important governmental interest" concerning "the public's health, safety, and welfare" the Washington Utilities and Transportation Commission ("UTC") suspended RTD SEATTLE's certificate to operate and provide excursion services, pending a safety investigation and inspection of RTD SEATTLE's drivers and vehicles.

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3.19 On September 29, 2015, the UTC filed a Complaint for Violations of Vehicle Safety Rules against RTD SEATTLE, alleging violations of the Code of Federal Regulations, Title 49, and WAC 480-30-221.

3.20 The UTC investigative staff reviewed safety practices, vehicle maintenance, driver safety, and other operational issues, including training, policies and procedures, and filed its report in December 2015. The UTC identified hundreds of "avoidable" violations of WAC 480-30-221. The UTC report found multiple violations of "critical regulations" and recordkeeping requirements, and recommended a proposed *unsatisfactory* rating for RTD SEATTLE. Ninety-three of RTD SEATTLE's violations (requiring drivers to make a record of their duty status) consisted of repeat violations that RTD SEATTLE "knew or should have known how to comply [with.]"

3.21 During its investigation of RTD SEATTLE, the UTC examined the metal plates welded onto the front axle housings on Stretch Duck vehicles 1, 3, and 8. In the presence of UTC staff, NTSB staff cleaned the welds attaching the metal plates to the axle housings. This revealed "small cracks" on four of the welds. "The cracks did not appear to extend into the axles but ran the length of the weld."

3.22 RTD SEATTLE hired an expert to evaluate the axle housings on its Stretch Duck vehicles. The UTC report recommended that the company be required to submit the results of the expert report to the UTC staff for review.

3.23 On March 14, 2016, RTD SEATTLE settled with the UTC, agreeing to a civil penalty of $222,000. The UTC suspended $111,600 of the penalty. In reaching the settlement, RTD SEATTLE "admit[ted] the violations alleged in the Commission's First Amended Complaint." The admission covered 463 violations.

3.24 When and after RTD SEATTLE adopted the route of travel for DUKW # 6, it knew that travel on the Aurora Bridge was unreasonably unsafe for that vehicle to travel. Indeed, one former DUKW driver told the Seattle Times: "I remember being told in training that

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the Duck would fit in a lane [on the Aurora Bridge], but that if you felt safer, to go ahead and straddle over the line some[.]" The Seattle Times, *Span's narrow lanes a longtime safety concern* (Sept. 24, 2015).

Facts Related to the City's and State's Liability.

3.25 The Aurora Bridge opened in 1932 and was listed in the National Register of Historic Places in 1982. It is 2,945 feet long, 70 feet wide, 167 feet above water, and carries State Route 99 over the northwest end of Lake Union. The six lane bridge has no median barrier and no shoulders for vehicle emergencies.

3.26 The State of Washington and the City of Seattle signed the GM-20 Maintenance Agreement on July 14, 1954, obligating the City to perform "routine maintenance" on State Highway routes within the corporate limits of the City. The agreement provides that the City may only perform work classified as "new construction, betterment, replacement or extraordinary maintenance" where the work is formally agreed to and authorized by the Director of Highways (whose powers functions and duties were transferred to the Washington State Department of Transportation). GM-20 Maintenance Agreement (July 14, 1954); RCW 47.01.031(2). On information and belief, the bridge is operated and maintained by the State and City, and both are responsible for ensuring that it is reasonably safe for travel.

3.27 The bridge carries more than 80,000 vehicles daily into and out of Seattle, including local and regional bus services. It also is a significant freight corridor moving approximately 13,109,000 tons annually.

3.28 In 2007, the Federal Highway Administration National Bridge Inventory found the bridge to be "functionally obsolete."

3.29 Both the City and State knew for decades that SR 99 and the Aurora Bridge were dangerous in precisely the ways that contributed to the September 24, 2015 accident and Runjie Song's death.

3.30 As the State itself noted:

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> "[The Aurora Bridge] consists of six lanes 9.5-foot wide and minimal 5-foot curbs and sidewalks. There is no median barrier to separate opposing traffic or between the roadway and bicyclists and pedestrians. This section of SR 99 experiences high levels of traffic congestion and poor operations due to large traffic volumes and narrow lanes. These conditions also result in a high accident rate, especial[ly] head-on collisions."
>
> WSDOT, *Project Prospectus* (June 8, 1995).
>
> The existing bridge has 9.5-foot wide lanes with minimal 5-foot curb and sidewalks. There is no barrier or separation between opposing traffic or between the roadway and bicyclists and pedestrians. This creates a situation where head-on collisions have occurred and are an increasing risk, as well as other accidents, due to the high traffic volumes and narrow lanes.
>
> *Demonstration Project Evaluation Criteria* (undated, pre-1999).

3.31 The City and State were aware that traffic on the bridge typically exceeds the 40 miles per hour posted speed limit by 10 to 20 miles per hour.

3.32 As early as 1999, the City and State knew that the Aurora Bridge was subject to a substantially higher rate of opposite direction accidents than the statewide average. "Statewide average for opposite direction accidents excluding ODLT on undivided highways is 4.85 vs 17.5% on the Aurora Bridge." WSDOT TRACTS Inquiry entered by Pat Foley (March 10, 1999).

3.33 In the fall of 2002, the WSDOT explained:

> 1. The existing travel lanes are very narrow, thereby contributing to sideswipe accidents and reduced capacity. Wider lanes will significantly improve the safety and performance of the roadway.
>
> 2. Currently, the bridge doesn't have a raised median to separate opposing traffic, thereby contributing to a high severity accidents involving vehicles crossing over the centerline.
>
> SR 99 North Corridor Study Frequently Asked Questions (Fall 2002).

3.34 The WSDOT Northwest Washington Division, Planning and Policy Office published the study, "**Route Development Plan,** State Route 99 North/Aurora Avenue North,"

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("2003 Report") in March 2003, cataloging the unreasonably unsafe conditions of SR 99 and Aurora Bridge. The City of Seattle signed the 2003 Report.

3.35 The 2003 Report found:

> Over 1,500 accidents occurred on the SR 99 North study corridor between 01/01/99 and 12/31/01—53 of these were disabling injuries and eight were fatalities. The SR 99 North study corridor includes a WSDOT designated high accident corridor (with the highest number of disabling accidents in Puget Sound), six high accident locations, and 12 pedestrian accident locations [.]

2003 Report at 6.

> The majority of the existing travel lanes in this area are narrow, especially on the Aurora Bridge (George Washington Memorial Bridge), contributing to sideswipe accidents and reducing traffic capacity. Just over 17% of the traffic accidents in the South Focus Area were sideswipe accidents, with 10% of those accidents occurring on the Aurora Bridge. The Aurora Bridge also lacks a center barrier to separate opposing traffic typically traveling at speeds exceeding the speed limit. The lack of a center barrier increases the risk for crossover/head-on traffic accidents.

Id. at 33.

> ***Lane Widths***
> The existing lane widths for the SR 99 North corridor are listed in Table 1-2. A majority of existing lanes do not meet the current design standards of 12 feet or 11 feet for P-2 and P-6 roadways, respectively. The proposed lane widths with redevelopment are shown in Chapter 6, Long-Term Improvements. Not all of the proposed lane widths will meet the Design Manual criteria and will require design deviations or the approval of this Route Development Plan. These lane widths were agreed upon to improve traffic safety and mobility without significantly impacting neighboring properties.

Id. at 40.

3.36 The 2003 Report acknowledged that it was necessary to "[w]iden existing lanes, add median barrier, [and] construct new pedestrian facilities[.]" *Id.* at 50. Summarizing the safety hazards of SR 99 and the Aurora Bridge, the 2003 Report concluded:

> The Aurora Bridge area has traffic congestion and is part of a High Accident Corridor (see Chapter 3: Accidents and Safety Issues). The existing Aurora Bridge has narrow lanes (9.5 feet), no median barrier, and no barrier separating the roadway and sidewalk. The lanes are so narrow that buses and other large vehicles sometimes straddle two lanes while traveling on the bridge. The combination of narrow lanes, lack of a median barrier, and driver actions (speeding, following too close, etc) creates a risk for sideswipe, rear-end and head-on traffic accidents. Over 80% of the accidents on the bridge are either sideswipe or rear-end accidents. The narrow lanes also reduce the traffic capacity

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> of the roadway. Rear-end accidents also occur on the bridge due to congestion from the Raye Street intersection to the south and the N. 38th Street off-ramp to the north.

Id. at 62

3.37 While the modern standard lane width is 11 to 12 feet, at the collision site the width of each the northbound and southbound center lanes of the Aurora Bridge are only 9 feet 5 inches (113 inches) wide.

3.38 Stretch Duck vehicles, including DUKW # 6, have the following dimensions:

Width: 8.5 feet (102 inches)

Height: 11.2 feet (134 inches)

Length: 33 feet (396 inches)

3.39 DUKW # 6 was only eleven inches narrower than the lane in which it travelled on the Aurora Bridge.

3.40 The motor coach that DUKW # 6 crashed into also was 8 feet 5 inches wide.

3.41 Vehicles traveling on Seattle roadways may not exceed a width of 8.5 feet (102 inches). RCW 46.44; SMC 11.60.

3.42 Since 2003, State and City employees have repeatedly acknowledged the "broad agreement" that improvements to the Aurora Bridge are necessary because the road is unreasonably unsafe:

> There is broad agreement that a median barrier ***is needed*** on the Aurora Bridge. WSDOT and City of Seattle have undertaken preliminary planning efforts to develop a project that will widen the bridge deck. As currently conceived the project is meant to provide wider and safer [ ] travel lanes along with a fixed median barrier to physically separate opposing traffic.
>
> WSDOT TRACTS Inquiry entered by Darrel Whyte (July 24, 2003) (emphasis added); WSDOT TRACTS Inquiry entered by Don Sims (Sept. 11, 2003) (same); WSDOT TRACTS Inquiry entered by Darrel Whyte (Oct. 12, 2007) (same).

3.43 Despite the "broad agreement" spanning decades "that a median barrier is needed on the Aurora Bridge", the City and State failed to install one.

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3.44 The narrow lane width coupled with the absence of shoulders, effective speed limit, and lack of a median barrier increased the risk of severe lane departure and median crossover collisions on the bridge, particularly for large vehicles such as DUKW # 6.

3.45 The WSDOT classified the Aurora Bridge as a High-Accident Corridor more than a decade before the crash that killed (b)(6) The bridge is located within the third worst High-Accident Corridor in the State.

3.46 According to Seattle Police Department records, between March 30, 1998 and October 19, 2015, there were 79 accidents causing injury on the Aurora Bridge, and 18 accidents with unknown injuries.

3.47 Seattle Department of Transportation collision records from January 1, 2005 through October 13, 2015 show that 126 accidents occurred on the Aurora Bridge between Raye Street and Bridge Way North, including eight head-on collisions and 44 sideswipes.

3.48 According to the Washington State Patrol, in 2013 there were five crashes caused when a vehicle crossed the center line of the Aurora Bridge. There were four such crashes in 2014 and six in 2015, two of which occurred after the September 24, 2015 accident.

3.49 A Seattle Times analysis of federal records revealed that the bridge was the "tightest six-lane highway bridge in the state, some 4½-feet leaner than any of its peers[.]" In addition the article noted the bridge did not have a median divider like "most comparable bridges in the state." The Seattle Times, *Span's narrow lanes a longtime safety concern* (Sept. 24, 2015).

3.50 RTD SEATTLE knew that the narrow lanes and lack of a median barrier on the Aurora Bridge presented a danger to oversized vehicles. Brian Tracy, the President and CEO of RTD SEATTLE, has said that because of the palpably unsafe conditions on the bridge, extraordinary measures were supposedly employed by DUKW drivers on the bridge: "Normally when we go over the Aurora Bridge we put the flashers on and slow down..." KIRO-TV, *Should Aurora Bridge have fewer lanes and traffic barrier?* (Sept. 24, 2015).

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3.51 The City and State were aware that the route adopted by RTD SEATTLE for DUKW vehicles involved traversing the Aurora Bridge and that it was unreasonably unsafe for such vehicles to be on the bridge given the bridge's narrow lane configuration, lack of a center median barrier, lack of shoulders, and effective speed limits.

3.52 On information and belief, the City and State sanctioned RTD SEATTLE's use of the bridge as part of the company's touring operations since 1997 despite knowledge that the bridge is unreasonably unsafe, and in particular, for large vehicles, to travel.

3.53 The City and State had the power and authority to regulate the charter tour routes taken by RTD SEATTLE and DUKW vehicles on roadways within city limits.

3.54 The City and State did not discourage, place restrictions upon, or prevent RTD SEATTLE from operating its DUKW vehicles on the dangerous Aurora Bridge.

3.55 Despite knowledge of the unreasonably unsafe conditions on the Aurora Bridge, the City and State failed to use ordinary care to design and maintain the roadway in a reasonably safe condition for ordinary travel.

3.56 The Aurora Bridge presented and continues to present an inherently dangerous condition for drivers and the public, and the City and State have taken no corrective actions to protect drivers and the public from catastrophic collisions.

3.57 If the City and State had had (a) adequate lane width and a median barrier on the Aurora Bridge; (b) prohibited vehicles of a certain size, width, or weight from traveling on the bridge, including large and over-sized vehicles; or (c) taken other prudent safety measures, DUKW # 6 would not have speared the bus carrying (b)(6) ending her promising young life.

3.58 As a proximate cause of the failure of the City and State to implement necessary safety measures on the dangerous Aurora Bridge, (b)(6) life came to an end.

3.59 Both the City and the State had a duty to maintain SR 99 and the Aurora Bridge in a condition reasonably safe for travelers, such as (b)(6). The State and City had a duty

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to mitigate the hazards present on the Aurora Bridge and are liable for their failure to take simple measures to mitigate the risk faced by (b)(6) and the many others who died or were injured on September 24, 2015. Such measures would have mitigated or averted the disaster on that date. Instead, the City and State took no action in the decades that it knew SR 99 and the Aurora Bridge were unreasonably unsafe, even though a number of mitigating measures would have been easy and inexpensive, and, the City and State are liable for breaches of duty of ordinary care.

IV. LIABILITY

4.1 Plaintiffs reallege and incorporate by reference all other paragraphs of this Complaint as if fully set forth herein.

4.2 RTDI is a product manufacturer and product seller within the meaning of RCW 7.72 *et seq.*

4.3 RTDI manufactured, remanufactured, and/or refurbished DUKW # 6, the relevant product, which was not reasonably safe in construction or design. When the product left control of RTDI, it deviated in a material way from the design specifications or performance standards of the manufacturer or that are required of a common carrier, or deviated in a material way from otherwise identical units of the same product line.

4.4 DUKW # 6 had dangerous defects in the axle housing, resulting in fractures and other hazardous defects, that deviated from specifications, standards, and other products manufactured or remanufactured by RTDI or required of a common carrier.

4.5 RTDI is strictly liable for all damages proximately caused by the fact that DUKW # 6 was not reasonably safe in design or construction and RTDI did not adequately warn of its defects. RCW 7.72.030.

4.6 RTDI is liable for Plaintiffs' damages because DUKW # 6 was not reasonably safe as designed and constructed. At the time of manufacture, remanufacture, or refurbishment, the likelihood that the product would cause the Plaintiffs' harm or similar harms, and the

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seriousness of those harms, outweighed the burden on RTDI to design and construct a product that would have prevented those harms and the adverse effect that an alternative design that was practical and feasible would have on the usefulness of the product. RCW 7.72.030.

4.7 RTDI is liable for Plaintiffs' damages because DUKW # 6 was not reasonably safe. Adequate warnings or instructions were not provided to RTD SEATTLE regarding maintenance and repair of DUKW # 6, or RTDI failed adequately to follow-up and ensure that such warnings and instructions were received and followed. The likelihood that the product would cause Plaintiffs' harm or similar harms, and the seriousness of those harms, rendered any and all warnings or instructions of the manufacturer inadequate, and RTDI could have provided the warnings or instructions that would have been adequate.

4.8 RTDI is liable for Plaintiffs' damages because DUKW # 6 was not reasonably safe. RTDI failed to issue adequate warnings or instructions concerning the danger that DUKW # 6 presented. RTDI failed to exercise reasonable care to inform RTD SEATTLE of the dangers of DUKW # 6, and RTDI failed to issue warnings or instructions in such a manner as a reasonably prudent manufacturer would act under the same or similar circumstances.

4.9 RTDI is strictly liable to Plaintiffs because Plaintiffs' harm was proximately caused by the fact that DUKW # 6 was not reasonably safe in construction, including but not limited to the metal plates welded onto the front axle housing of DUKW # 6 prior to its sale to RTD SEATTLE. DUKW # 6, when it left the control of RTDI, deviated in some material way from the design specifications or performance standards of RTDI or those required of a common carrier, or deviated in some material way from otherwise identical units of the Stretch Duck product line.

4.10 RTDI is liable for negligence and its failure to properly and adequately notify and warn RTD SEATTLE after the product was manufactured about the dangerous defects in DUKW # 6 that caused the above-described collision and injuries, of which RTDI was aware or reasonably should have been aware.

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4.11 RTD SEATTLE was negligent for at least the following actions: (a) failing to properly inspect, maintain, and repair DUKW # 6; (b) certifying DUKW # 6 as "ready for operation" on or about March 2, 2015; (c) failing to use reasonable care to detect hazardous defects in DUKW # 6, including defects that were likely to result in a collision or breakdown; (d) failing to use reasonable care to remedy those defects; (e) failing to adequately address the Bulletin issued by RTDI; (f) failing to implement the maintenance and repair work specified in the Bulletin; (g) failing to implement other inspection and maintenance approaches that would have adequately monitored axles for catastrophic failure potential; (h) permitting DUKW # 6 to operate after December 31, 2013, without having performed the maintenance and repair work specified in the Bulletin; (i) operating an unsafe, dangerous, and defective vehicle on a state roadway; (j) requiring its drivers to have the dual function of both operating a vehicle and entertaining its passengers; (k) failing to properly train, instruct, and supervise its employees, mechanics, and drivers, including but not limited to (b)(6) (l) creating a travel route that included use of the Aurora Bridge despite having actual knowledge that the bridge had an inadequate lane width to accommodate Duck Boat vehicles, including but not limited to DUKW # 6; (m) requiring Duck Boat vehicles, including but not limited to DUKW # 6, to travel on a route containing a bridge with no center median barrier; (n) endangering the public safety by operating a modified World War II vehicle at speeds that were excessive given the physical dimensions, capacities, and characteristics of a Duck Boat and the Aurora Bridge; and by (o) continuing to operate, manage, and conduct Duck Boat tour operations when 463 violations of WAC 480-30-221 were ongoing and remained unaddressed.

4.12 RTD SEATTLE's negligence is also established by the fact that as a common carrier it: (a) failed "to promote the safety, health, comfort, and convenience of its patrons, employees, and the public." RCW 81.28.010; (b) failed to ensure that "[p]arts and accessories [are] in safe and proper operating condition at all times . . . including but not limited to . . . axles and attaching parts[.]" *See* WAC 480-30-221; 49 CFR § 396.3(a)(1); (c) failed to "[e]nsure that

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vehicles [were] free of defects likely to result in an accident or breakdown." *See* WAC 480-30-221; (d) failed to ensure that the front axle of DUKW # 6 was not cracked, broken, loose or missing. *See* WAC 480-30-221; 49 CFR § 393.207(a); and (e) caused or permitted a prohibited, forbidden or unlawful act to be done, and/or RTD SEATTLE omitted to do a required act. *See* RCW 81.04.440.

4.13 (b)(6) death and the losses to the Plaintiffs were proximately caused by the tortious conduct of Defendants State of Washington and City of Seattle in negligently and improperly designing, operating and maintaining State Route 99 where the tragedy occurred, including without limitation:

A. Operating a roadway that was unsafe for motorists by failing to install a median barrier on the bridge, knowing that the bridge has a long history of cross-over collisions that would be prevented by installing a median barrier;

B. Failing to consider or implement interim safety measures precluding vehicles of a certain size, width or weight from using the Aurora Bridge, reducing the number of lanes on the Bridge to accommodate a median barrier, and removing one sidewalk to accommodate wider lane widths and a median barrier.

4.14 Defendants State of Washington and City of Seattle knew or should have known of the unreasonably unsafe condition of State Route 99 at the Aurora Bridge. Nevertheless, both Defendants failed to take any preventive or corrective measure to make the road safe for travel.

4.15 The State and City had and have a duty to exercise ordinary care in the design, maintenance, construction, repair, and operation of their roadways such that they are reasonably safe for ordinary travel.

4.16 The State and City failed to design, maintain, construct, repair, and operate the Aurora Bridge in a condition that was reasonably safe for ordinary travel.

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4.17 The State and City failed to take any corrective action to protect drivers and the public from the inherently dangerous conditions on the Aurora Bridge.

4.18 In spite of extensive notice over decades of deficiencies and dangers on the Aurora Bridge, the State and City took no action to correct unreasonably unsafe conditions.

4.19 The failure of the State and City to provide a reasonably safe roadway at the Aurora Bridge constituted tortious conduct.

4.20 The tortious conduct of all Defendants, as described above, was the proximate cause of the September 24, 2015 Aurora Bridge accident, the death of (b)(6) and Plaintiffs' resulting losses.

V. DAMAGES

5.1 Plaintiffs reallege and incorporate by reference all other paragraphs of this Complaint as if fully set forth herein.

5.2 Under Washington choice of law principles, a court may permit a jury to award punitive damages under another state's law. *Singh v. Edwards Lifesciences Corp.*, 151 Wn. App. 137, 210 P.3d 337 (2009). RTDI is a citizen of Missouri and Georgia. Because RTDI committed an intentional wanton, willful, and outrageous act without justification or acted with reckless disregard for the rights and interests of others, Missouri is interested in punishing and deterring such conduct. And because RTDI committed acts of willful misconduct or wantonness, Georgia has an interest in punishing and deterring such conduct. Therefore RTDI is liable for punitive damages under both Missouri and Georgia law.

5.3 Plaintiffs are entitled to be compensated for all damages authorized under the law, including but not limited to:

A. Damages for the decedent's medical, hospital, and medication expenses; lost earning capacity; lost future earnings; interference with normal life; and past and future economic damages;

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B. Damages for the loss to Plaintiffs and all statutory beneficiaries of services and support; loss of love and companionship of the decedent; and for injury to or destruction of the parent-child relationship (including but not limited to parental grief, mental anguish, and suffering) in such amount as, under all the circumstances of the case, may be just;

C. Funeral and burial expenses;

D. For costs and disbursements;

E. For statutory attorney fees;

F. For special and general damages in amounts to be proven at trial;

G. For prejudgment interest on the special damages; and

H. For prejudgment interest on liquidated damages.

5.4 Plaintiffs seek all other rights and remedies available under the law.

5.5 All of the above damages are in an amount that will be proved at trial.

VI. PLAINTIFFS' PRAYER FOR RELIEF

Plaintiffs pray for judgment against Defendants as follows:

A. For judgment against Defendants;

B. For judgment against all Defendants for all general and special damages in amounts to be proven at the time of trial;

C. For punitive damages under Missouri and/or Georgia law against RTDI; and

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D. For such other and further relief as the Court deems just and equitable under the circumstances.

DATED this 6th day of April, 2016.

PHILLIPS LAW GROUP, PLLC

By: _____
John W. Phillips, WSBA #12185
Michael T. Madderra, WSBA #48169
Attorneys for Plaintiffs Xia and Wang

CORRIE YACKULIC LAW FIRM, PLLC

By: _____
Corrie J. Yackulic, WSBA #16063
Attorneys for Plaintiffs Xia and Wang

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KING & SPALDING

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Partner
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January 10, 2017

Mr. Paul A. Hemmersbaugh
Chief Counsel
National Highway Traffic Safety Administration
1200 New Jersey Avenue, S.E.
West Building
Room W41-227
Washington D.C. 20590

Re: Request for Confidential Treatment of Voluntary Submission

Dear Mr. Hemmersbaugh,

Ride The Ducks International (RTDI) submits this Request for Confidential Treatment for certain information that is being submitted to the agency voluntarily. On September 27, 2017, senior officials of RTDI met with agency staff to discuss a variety of matters relating to RTDI's product and services. RTDI's powerpoint presentation included certain confidential business information (CBI). The CBI included in that presentation is marked in the attached and a public version of the presentation is provided.

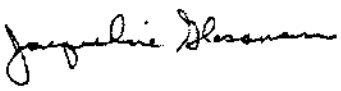
RTDI seeks confidential treatment for the identified information because that information is competitively sensitive and should be withheld from public disclosure under 49 C.F.R. Part 512 and Exemption 4 of the Freedom of Information Act (FOIA), 5 U.S.C. § 552(b)(4). The information was submitted voluntarily as part of a meeting requested by RTDI. It is therefore entitled to protection under the test announced in *Critical Mass Energy Project v. NRC, et. al.*, 975 F.2d 871 (D.C. Cir. 1992). Disclosure of this information also has the potential to discourage companies in the future from engaging in proactive discussions with the agency when issues arise, and therefore would jeopardize the government's ability to secure this and similar types of information in the future.

RTDI is additionally entitled to confidential treatment under the principles announced in *National Parks & Conservation Ass 'n v. Morton*, 498 F.2d 765 (D.C. Cir. 1974), because disclosure of the information would likely cause competitive harm to RTDI. The information reveals details about RTDI's product construction and business interests, as well as confidential settlement negotiations.

The marked information in the attached documents has been treated confidentially within the company and has not been shared publicly. As such, this information should been deemed "confidential" and is entitled to protection under Exemption 4 of FOIA for an indefinite period of time. The certificate required by Part 512 is attached.

Please feel free to contact me if you have additional concerns or questions.

Sincerely,



Jacqueline Glassman
Partner

Enclosures: 2 copies of complete submission marked Confidential
1 copy with public redacted version of submission
Certificate in Support of Request for Confidential Treatment

AuthorClosingName

Certificate in Support of Request for Confidentiality

I, Brian Deckard, pursuant to the provisions of 49 C.F.R. Part 512, state as follows:

1. I am Brian Deckard, and I am a senior official at Ride The Ducks International (RTDI) and I am authorized to execute this certificate on its behalf;

2. I certify that the information contained in the enclosed attachments and marked as Confidential Business Information is confidential and proprietary data, in the form of confidential business information, and is being submitted with the claim that it is entitled to confidential treatment under 5 U.S.C. § 552(b)(4) (as incorporated by reference in and modified by 49 C.F.R. Part 512);

3. I hereby request that the information contained in the enclosed documents be protected permanently or until such time as the information is no longer held confidential by the company;

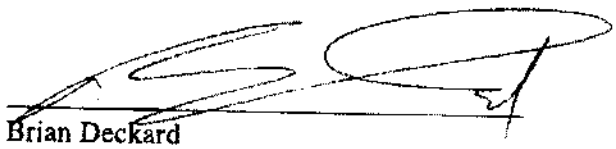
4. This certification is based on the information provided by the responsible RTDI personnel who have authority in the normal course of business to release the information for which a claim of confidentiality has been made to ascertain whether such information has ever been released outside RTDI;

5. Based upon that information, to the best of my knowledge, information and belief, the information for which has claimed confidential treatment has never been released or become available outside RTDI;

6. I make no representations beyond those contained in this Certificate and, in particular, I make no representations as to whether this information may become available outside RTDI because of unauthorized or inadvertent disclosure, except as noted in paragraph 5 above; and

I certify under penalty of perjury that the foregoing is true and correct.

Executed on this 18 day of Jan, 2017.



Brian Deckard

A. DiMarsico

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

Jacqueline Glassman
King & Spalding LLP
1700 Pennsylvania Avenue, NW
Suite 200
Washington, DC 20006-4707

JUN 28 2017

Re: Confidentiality Determination/RTDI's September 27, 2016 PowerPoint Presentation

Dear Ms. Glassman:

This responds to your letter of January 10, 2017 requesting confidential treatment for Ride The Ducks International's ("RTDI") PowerPoint presentation from a September 27, 2016 meeting with NHTSA. RTDI notes that the identified information contains details on its product construction and business interests as well as details about confidential settlement negotiations. Specifically, RTDI requests confidential treatment for the designated information indefinitely.

RTDI describes the information on slides 10, 14, 15, and 17 as its sensitive business and product construction information and settlement negotiation information that is competitively sensitive and has not been publicly disclosed. RTDI contends that disclosure of this information would harm its ability to compete.

Your request is granted.

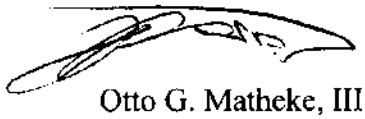
Because RTDI submitted this information voluntarily, I reviewed your claim of confidential treatment under the test announced in *Critical Mass Energy Project v. NRC*, 975 F.2d 871, 878 (D.C. Cir. 1992). Under that test, information is confidential if it was submitted voluntarily to the Agency and the information would not customarily be released to the public by the submitter.

I have reviewed your submission, including the materials that you claim are entitled to confidential treatment and the arguments that you assert in support of your claim. I have determined that the information at issue was provided voluntarily and is not customarily disclosed to the public. RTDI has taken measures to ensure that the material has been treated confidentially and has not been publicly released. Further, releasing such information could potentially discourage proactive discussions to address issues in the future, which may hinder the government's ability to obtain such information.

Therefore, this information is entitled to confidential treatment pursuant to Exemption 4 of FOIA, 5 U.S.C. § 552(b)(4). Subject to the conditions below, this grant of confidential treatment will remain in effect indefinitely.

This grant of confidential treatment is subject to certain conditions. The information may be disclosed under 49 CFR § 512.22 based upon newly discovered or changed facts, and you must inform the Agency of any changed circumstances that may affect the protection of the information (49 CFR § 512.10). If necessary, you will be notified prior to the release of any information under the procedures established by our regulations (49 CFR § 512.22(b)). Furthermore, this information may be disclosed if such disclosure would be in the public interest, pursuant to the procedures established in 49 CFR § 512.23.

Sincerely,



Otto G. Matheke, III
Senior Trial Attorney

Ride The Ducks International

Meeting with NHTSA

September 27, 2016

Confidential Business Information Redacted

History

- 1977: Ride the Ducks launched in Branson, Missouri using reconstructed WWII DUKW vehicles. Per Missouri law, titled and registered as marine vessels.
- 1994-1998: RTD licenses to Boston and Seattle
- 1996: Coast Guard approves “Stretch Duck” design
- 2005: Coast Guard approves “Truck Duck” design

Original Design

- Reconstructed WWII-era DUKW amphibious vehicles used for transport over land and water without harbors. Retired in 2006.

- Safety equipment, fire protection, canopy with emergency egress system and other required devices installed per Coast Guard requirements.

- All-wheel disc brakes retrofitted on later vehicles.

“Stretch” Ducks

- Introduced in 1996 with same Coast Guard safety features, standard all-wheel disc brakes, and new anti-corrosion steel fittings.

- Hulls renewed and DUKW components replaced with modern equipment, refurbished over the original DUKW chassis frame. Hull “stretched” to add buoyancy, provide better driver visibility and increase carrying capacity.

- Under 26,000 lbs loaded weight.

- 56 Stretch Ducks in operation/ready for use.

Ride
the
Ducks

“Truck” Ducks

- Introduced in 2005 with a patented RTDI design.
- Based on “M-Series” 2 ½ ton military cargo vehicle.
- Under 26,000 lbs loaded weight (well within loaded weight rating for M-Series vehicles).
- 49 in operation/ready for use.

M-Series military cargo vehicle provides the chassis design

Confidential Business Information Redacted

Repair and Maintenance

- RTDI provides service bulletins to its field locations and to licensees for safety, maintenance and repair issues
  - RTDI has provided past Service Bulletins to NTSB and to NHTSA
  - RTDI will provide all future Service Bulletins to NHTSA per Part 579.5
  - RTDI will conduct safety recalls, as necessary, per NHTSA regulations

Service Bulletin No. SB-00-14-13

- 56 Stretch APVs Affected by Service Bulletin
  - 43 Active Stretch APVs, service bulletin remedy completed
    - 19 Stretch APVs owned by RTDI in Branson
    - 12 Stretch APVs owned by RTDI in Philadelphia
    - 5 APVs in Stone Mountain, Georgia (licensee)
    - 4 APVs in Newport, KY (licensee)
    - 3 APVs in Mobile, AL (licensee)
  - 13 Inactive APVs
    - 10 at RTD Seattle (out of service)
    - 3 nonoperable, partially dismantled in Branson

- Also issued a subsequent bulletin for non-destructive testing of the axle housing modification

Compliance Considerations

- APV operation:
  - 70 minute tour on prescribed urban route, with generally about a 30 minute water element
  - Riders board at “Duck Central,” stay aboard and egress at same location
  - Separate Driver and Tour Guide since 2015
  - APVs do not travel at over 40-45 mph
- Meet all Coast Guard safety requirements

Confidential Business Information Redacted

Confidential Business Information Redacted

Transit and Sightseeing Buses

Transit

- Not an OTR bus
- Characterized by low-speed use on a regular route
- Generally safer: "fatality data for urban transit buses differ significantly from that of other buses … in part [because of] the stop-and-go manner of transit bus operation."

Sightseeing

- "Capable of [highway travel] and are used on high speed roads."
- "The sights to which they travel may be far distances apart."
- "Lengthy tours … [travelers] may ride the bus over long distances over highways."

Confidential Business Information Redacted

U.S. Department of Transportation
National Highway Traffic Safety Administration

1200 New Jersey Avenue SE
Washington, DC 20590

December 1, 2016

Mr. Brian Deckard
Director of Fleet Operations
Ride The Ducks International LLC
PO Box 1837
Branson, MO 65615

NEF-150MR
16V-859

Subject: Axle Housing may Fracture due to Fatigue

Dear Mr. Deckard:

This letter serves to acknowledge Ride The Ducks International LLC's notification to the National Highway Traffic Safety Administration (NHTSA) of a safety recall which will be conducted pursuant to Federal law for the product(s) listed below. Please review the following information to ensure that it conforms to your records as this information is being made available to the public. If the information does not agree with your records, please contact us immediately to discuss your concerns.

Makes/Models/Model Years:
RIDE THE DUCKS/AMPHIBIOUS VEHICLE/1996-2005

Mfr's Report Date: November 22, 2016

NHTSA Campaign Number: 16V-859

Components:
POWER TRAIN:AXLE ASSEMBLY

Potential Number of Units Affected: 57

Problem Description:
Ride the Ducks International LLC (RTDI) is recalling certain model year 1996-2005 "Stretch" Amphibious Passenger Vehicles. Due to excessive fatigue, the axle housing on the affected vehicles may fracture at the connection point between the knuckle ball and the housing, possibly resulting in a loss of vehicle control.

Consequence:
A loss of vehicle control can increase the risk of a crash.

Remedy:
RTDI will notify the company-owned operators and licensors and will strengthen the connection at the knuckle housing ball and the axle housing, free of charge. The manufacturer has not yet provided a notification schedule. RTDI customer service can be contacted at 1-417-266-7600.

Notes:
Owners may also contact the National Highway Traffic Safety Administration Vehicle Safety Hotline at 1-888-327-4236 (TTY 1-800-424-9153), or go to www.safercar.gov.

We have received RTDI's proposed owner notification letter and it is currently under review. You will be notified of any changes or concerns once our review is complete.

Please be reminded of the following requirements:

Copies of all notices, bulletins, dealer notifications, and other communications that relate to this recall, including a copy of the final owner notification letter and any subsequent owner follow-up notification letter(s), are required to be submitted to this office no later than 5 days after they are originally sent (if they are sent to more than one manufacturer, distributor, dealer, or purchaser/owner).

As stated in Part 573.7, submission of the first of six consecutive quarterly status reports is required within one month after the close of the calendar quarter in which notification to purchasers occurs. Therefore, the first quarterly report will be due on, or before, 30 days after the close of the calendar quarter.

Your contact for this recall will be Michelle Rice who may be reached by phone at 202-366-1060, or by email at michelle.rice@dot.gov or through the office email at rmd.odi@dot.gov. We look forward to working with you.

Sincerely,

Jennifer Timian
Chief, Recall Management Division
Office of Defects Investigations
Enforcement

OMB Control No.: 2127-0004

Recall Quarterly Report

16V-859

Manufacturer Name : Ride The Ducks International LLC
NHTSA Recall No. / MFR Recall No. : 16V-859 /
Recall Subject : Axle Housing may Fracture due to Fatigue
Owner Notification Beginning Date : DEC 14, 2016
Owner Notification End Date: DEC 14, 2016

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Report #	Submission Date	Report Quarter	Recall Population	Total Remedied	Total Unreachable	Total Removed
3	JUL 26, 2017	2017-2	57	43	0	1
2	APR 27, 2017	2017-1	57	43	0	1
1	JAN 30, 2017	2016-4	57	43	0	1

This Document Last Updated : JUL 27, 2017

Definitions :

Report Quarter : The quarter the manufacturer is reporting recall completion figures (e.g. 2012-3 means the 3rd quarter of 2012).
Recall Population : The total number of products recalled by the manufacturer.
Total Remedied : The total number of products either remedied, inspected without needing remedy, or returned to inventory.
Total Unreachable : Products deemed unreachable as owner notifications were unable to be delivered.
Total Removed : Products that have been scrapped, stolen, or exported.

OMB Control No.: 2127-0004

Recall Quarterly Report

16V-859

Manufacturer Name : Ride The Ducks International LLC
NHTSA Recall No. / MFR Recall No. : 16V-859 /
Recall Subject : Axle Housing may Fracture due to Fatigue
Owner Notification Beginning Date : DEC 14, 2016
Owner Notification End Date: DEC 14, 2016

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Report #	Submission Date	Report Quarter	Recall Population	Total Remedied	Total Unreachable	Total Removed
1	JAN 30, 2017	2016-4	57	43	0	1

This Document Last Updated : JAN 30, 2017

Definitions :

Report Quarter : The quarter the manufacturer is reporting recall completion figures (e.g. 2012-3 means the 3rd quarter of 2012).
Recall Population : The total number of products recalled by the manufacturer.
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OMB Control No.: 2127-0004

Recall Quarterly Report

16V-859

Manufacturer Name : Ride The Ducks International LLC
NHTSA Recall No. / MFR Recall No. : 16V-859 /
Recall Subject : Axle Housing may Fracture due to Fatigue
Owner Notification Beginning Date : DEC 14, 2016
Owner Notification End Date: DEC 14, 2016

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Report #	Submission Date	Report Quarter	Recall Population	Total Remedied	Total Unreachable	Total Removed
2	APR 27, 2017	2017-1	57	43	0	1
1	JAN 30, 2017	2016-4	57	43	0	1

This Document Last Updated : MAY 03, 2017

Definitions :

Report Quarter : The quarter the manufacturer is reporting recall completion figures (e.g. 2012-3 means the 3rd quarter of 2012).
Recall Population : The total number of products recalled by the manufacturer.
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Total Unreachable : Products deemed unreachable as owner notifications were unable to be delivered.
Total Removed : Products that have been scrapped, stolen, or exported.

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	NOV 22, 2016
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
Address :	2320 W Highway 76 PO BOX 1837 BRANSON MO 65616
Company phone :	417 266 7600

Population :

Number of potentially involved :	57
Estimated percentage with defect :	100 %

Vehicle Information :

Vehicle 1 :	1996-2005 RTDI "Stretch" Amphibious Passenger Vehicles
Vehicle Type :	
Body Style :	
Power Train :	NR
Descriptive Information :	Amphibious Passenger Vehicle
Production Dates :	JAN 01, 1996 - DEC 31, 2005
VIN Range 1 : Begin :	NR End : NR ☐ Not sequential

Description of Defect :

Description of the Defect :	The axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue.
FMVSS 1 :	NR
FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Part 573 Safety Recall Report 16V-859

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR
	NR
Country :	NR

Chronology :

See attached document

Description of Remedy :

Description of Remedy Program :	The remedy program applied was set forth in the Service Bulletin issued on October 1, 2013. The remedy involved strengthening the connection where the knuckle housing ball connects to the axle housing.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

Description of Recall Schedule :	RTDI will send formal customer notification letters to its company-owned operators and licensors as set forth in the Consent Order with NHTSA. To the extent that Ride the Ducks Seattle requests parts to conduct the repair, they are available. Ride the Ducks International will offer reimbursement to any licensor that has already conducted the repairs.
Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

* NR - Not Reported

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	JAN 30, 2017
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
Address :	2320 W Highway 76 PO BOX 1837 BRANSON MO 65616
Company phone :	417 266 7600

Population :

Number of potentially involved :	57
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Vehicle Information :

Vehicle 1 :	1996-2005 RTDI "Stretch" Amphibious Passenger Vehicles
Vehicle Type :	
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Power Train :	NR
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Production Dates :	JAN 01, 1996 - DEC 31, 2005
VIN Range 1 : Begin :	NR End : NR ☐ Not sequential

Description of Defect :

Description of the Defect :	The axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue.
FMVSS 1 :	NR
FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Part 573 Safety Recall Report 16V-859

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR
	NR
Country :	NR

Chronology :

See attached document amending chronology

Description of Remedy :

Description of Remedy Program :	The remedy program applied was set forth in the Service Bulletin issued on October 1, 2013. The remedy involved strengthening the connection where the knuckle housing ball connects to the axle housing.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

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Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

* NR - Not Reported

OMB Control No.: 2127-0004

Part 573 Safety Recall Report 16V-859

Manufacturer Name :	Ride The Ducks International LLC
Submission Date :	MAY 04, 2017
NHTSA Recall No. :	16V-859
Manufacturer Recall No. :	NR

Manufacturer Information :

Manufacturer Name :	Ride The Ducks International LLC
Address :	2320 W Highway 76 PO BOX 1837 BRANSON MO 65616
Company phone :	417 266 7600

Population :

Number of potentially involved :	57
Estimated percentage with defect :	100 %

Vehicle Information :

Vehicle 1 :	1996-2005 RTDI "Stretch" Amphibious Passenger Vehicles
Vehicle Type :	
Body Style :	
Power Train :	NR
Descriptive Information :	Amphibious Passenger Vehicle
Production Dates :	JAN 01, 1996 - DEC 31, 2005
VIN Range 1 : Begin :	NR End : NR ☐ Not sequential

Description of Defect :

Description of the Defect :	The axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue.
FMVSS 1 :	NR
FMVSS 2 :	NR
Description of the Safety Risk :	If the axle housing fractures, the driver may lose control of the vehicle and increase the risk of a crash.
Description of the Cause :	The axle housing can fracture due to excessive fatigue.
Identification of Any Warning that can Occur :	NR

Supplier Identification :

Component Manufacturer

Name :	NR
Address :	NR

Part 573 Safety Recall Report 16V-859

	NR
Country :	NR

Chronology :

See attached document amending chronology

Description of Remedy :

Description of Remedy Program :	RTDI will replace each of the front axles with one that has a coupler welded to the axle. Prior to the installation of the coupler, the axles will undergo magna particle testing. The axles will also be inspected on an annual basis.
How Remedy Component Differs from Recalled Component :	NR
Identify How/When Recall Condition was Corrected in Production :	RTDI is not currently building or having built new amphibious passenger vehicles.

Recall Schedule :

Description of Recall Schedule :	RTDI will send formal customer notification letters to its company-owned operators and licensors as set forth in the Consent Order with NHTSA. Ride the Ducks International will offer reimbursement to any licensor that has already conducted the repairs.
Planned Dealer Notification Date :	NR - NR
Planned Owner Notification Date :	NR - NR

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Ride The Ducks International

RTDI - TECHNICAL SERVICE BULLETIN

TSB TITLE: Steer Axle Strength Enhancement	**DATE:** 7/12/17

RTDI BULLETIN NO: TSB-01-17 **NHTSA RECALL NO.** 16V-859	**MODEL:** All STRETCH DUCKS

REASON: Steer axle enhancement, to increase the strength of the connection point between the knuckleball and the housing.

ACTION: RTDI will reinforce the strength of the connection point between the knuckleball and the axle housing and will ship reinforced steer axle housings to all affected locations for installation. The parts needed to perform this repair will be provided free of charge.

PART NUMBER	DESCRIPTION	QUANTITY per unit	TOTAL SERVICING LABOR HRS- $45.00 Per Hour
007474	Steer Axle Housing	1	
NA	NDT/MPT testing	2	
007342	Collars	2	
NA	Remove and replace existing steer axle housing	1	30hrs

SERVICE PROCEDURE:

Before Delivering the Reinforced Steer Axle Housings RTDI Will:

1. Conduct non-destructive testing at the connection point between the knuckleball and the housing..
2. Install the reinforcement collars.
3. Conduct non-destructive testing of the reinforcement collar welds.
4. Stamp numbering sequence on each axle housing.
5. Prep and paint the axle housings.
6. Ship completed axle housings to all affected locations.

RTD Licensee Will:

1. Receive one (1) reinforced steer axle per vehicle operated.
2. Transfer the drive components from existing steer axle into the reinforced axle.
3. Ship the existing (core) steer axle back to RTDI.
4. Notify RTDI when each vehicle has completed this TSB. Complete form on pg. 2.

NOTE: The reinforced steer axle housings will be delivered as bare housings (no drive gears). You will be required to remove the drive components from the existing housings and transfer them into the reinforced housings. All steer axle cores must be returned to RTDI. Contact RTDI to make shipping arrangements. Notify RTDI when this repair procedure has been completed. You will be reimbursed a 30 hour servicing fee per vehicle for the labor involved in replacing the front axle after RTDI receives the returned cores and the Notification of Completion Form.

TSB COMPLETION IS DUE BY:	Upon receiving reinforced steer axles

The information in Technical Service Bulletins is intended for use by trained technicians with the knowledge, tools and equipment to do the job properly and safely. It informs technicians of conditions that may occur on some vehicles, or provides information that could assist in proper vehicle service. The information in this Technical Service Bulletin (TSB) was current at the time of printing. Ride The Duck International reserves the right to supercede this information with updates.

Ride The Ducks International

RTDI - TECHNICAL SERVICE BULLETIN

Notification of Completion Form

DIRECTIONS: After the repair procedure described above has been fully completed, complete the form below, scan and email the completed form back to RTDI at the following email address. fleetoperations@ridetheducks.com

RTDI TSB No. 01-17 STEER AXLE SAFETY ENHANCEMENT	**NHTSA RECALL NO:** 16V-859

RTD LICENSEE NAME:

DUCK VIN#:

DUCK LOCAL NUMBER/NAME:

My signature certifies that I have followed all required Service Procedures and that the RTDI Technical Service Bulletin No. TSB-01-17 has been completed on the vehicle listed above.

PRINT NAME:

SIGNATURE:	**REPAIR COMPLETION DATE** :

IMPORTANT SAFETY RECALL

NHTSA Recall: 16V-_____

Insert Date

This notice applies to your vehicle, Duck No. _____.

Dear RTDI Stretch Duck Operator:

This notice is sent to you in accordance with the National Traffic and Motor Vehicle Safety Act.

Ride the Ducks International (RTDI) has decided that a defect relating to motor vehicle safety exists or existed in certain "Stretch" Amphibious Passenger Vehicles ("Stretch Ducks"). As a result, RTDI is conducting a safety recall.

RTDI is conducting a recall because of the possibility that over time the axle housing can fracture at the connection point between the knuckle ball and the housing due to excessive fatigue. If the axle housing fractures, this condition could cause a driver to lose control of the vehicle, increasing the risk of a crash.

In October 2013, RTDI issued a Service Bulletin (SB-00-14-13) instructing vehicle operators and licensees to repair and reinforce the connection where the knuckle housing ball connects to the axle housing. If you have already performed this repair on your vehicles, you are entitled to reimbursement for the costs associated with having done so. If you have not yet performed this repair on your vehicles, you must do so expeditiously and the service will be performed for you at **no charge.**

Pursuant to a recent agreement with the National Highway Traffic Safety Administration, RTDI is conducting an independent engineering analysis of the repair procedures in SB-00-14-13. If any further action is required, we will notify you promptly.

If after contacting RTDI, you are not satisfied we have done our best to remedy this condition without charge and within a reasonable time, you may wish to write to the following:

Administrator
National Highway Traffic Safety Administration,
1200 New Jersey Avenue, SE.,
Washington, DC 20590

You may also call the toll-free Vehicle Safety Hotline at 1.888.327.4236 (TTY 1.800.424.9153), or go to http://www.safercar.gov.

The National Highway Traffic Safety Administration Campaign ID Number for this recall is 16V___.

From: Ride the Ducks International, LLC

To: NHTSA Recall Management Division

Date: July 24, 2017

Re: Recall No. 16V-859/Quarterly Reports

On November 22, 2016, Ride the Ducks International, LLC (RTDI) submitted a recall notification pursuant to 49 C.F.R. Part 573 to address concerns relating to the potential for the axle housing to fracture at the connection point between the knuckle ball and the housing in its Amphibious Passenger Vehicles. The remedy identified in the recall notification involved strengthening the connection where the knuckle housing ball connects to the axle housing by applying a collar to the axle. For the first two quarterly reports submitted (Q4 2016 and Q1 2017), RTDI remedied 43 vehicles. (Out of the total population of 57 vehicles, 43 were repaired, 1 had been scrapped, 3 were partially dismantled and not in service and 10 vehicle in the Seattle fleet were in a "Not in Service" status).

Following subsequent communications with NHTSA and at the conclusion of an independent engineering analysis, on May 4, 2017, RTDI amended its Part 573 Report to modify the remedy. Under the revised remedy, RTDI will replace each of the front axles with one that has a coupler welded to the axle. Prior to the installation of the coupler, the axles will undergo magna particle testing and the axles will be inspected on an annual basis. On July 12, 2017, RTDI issued a bulletin to vehicle owners advising them of the axle repair. As of July 24, 2017, replacement axles have been shipped to the Seattle fleet, but the axles have not yet been installed. RTDI anticipates sending replacement axles to the remaining vehicles affected by this action in the near future.

P.O. Box 1857 • Branson, MO 65615 • 417-266-7600 • Fax: 417-266-7611 • www.bransonducks.com
a Herschend Family Entertainment company

Recall 16V-859, Supplement to Quarterly Report 2016, Q4

Total Recall Population: 57

Vehicles Remedied: 43

Vehicles Scrapped: 1

Other Vehicles:

- 3 Vehicles Partially Dismantled and Not in Service
- 10 Vehicles Located in Seattle, Washington are Not in Service

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Recall 16V-859, Supplement to Quarterly Report 2017, Q1

Total Recall Population: 57

Vehicles Remedied: 43

Vehicles Scrapped: 1

Other Vehicles:

- 3 Vehicles Partially Dismantled and Not in Service
- 10 Vehicles Located in Seattle, Washington are Not in Service

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