Status of NHTSA’s Ejection Mitigation Research

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Ejection Mitigation

Problem Definition

- **51,700 Annual Ejections** (1997-2002)
  - 1% of all crash-involved occupants
- **10,600 Annual Ejected Fatalities**
  - 32% of all fatalities
  - 6,200 through side windows
- **10,900 Annual Rollover Fatalities**
  - 3,900 ejected through side windows
Ejection Mitigation
Research Program Goals

• Demonstrate Countermeasure Feasibility
  – Evaluate ejection mitigation capability
  – Evaluate injury-causing potential

• Develop Occupant Retention Test
  – Full-scale rollover tests not repeatable

• Develop Rollover Sensor Performance Test
Ejection Mitigation
Dynamic Rollover Fixture (DRF)

- Research Tool to Evaluate Countermeasures
- Produces Repeatable Full-Dummy Ejections
  - Allows dummy response measurements
- Produces Realistic Roll Rates
  - Up to 360 deg/sec
- Variable Occupant-to-Window Speeds
  - 15 to 30 kmph
- Variable Occupant Trajectories and Impact Locations
- Does Not Simulate Lateral Vehicle Accelerations
Ejection Mitigation
Countermeasure Candidates

- **Inflatable Systems**
  - Advanced Head Protection System (AHPS): Original & Beltline Systems
    - Zodiac Automotive US
  - Prototype Window Curtain
    - TRW Automotive

- **Advanced Side Glazings**
  - Bi-laminate
  - Tri-laminate
  - Modified door frame

- **Inflatable/Glazing Combination**
  - Less door frame modifications
Ejection Mitigation
DRF Testing

- **Window Treatments**
  - Open window
  - Inflatable, glazings, combination

- **Dummy Sizes**
  - 50th male
  - 5th female
  - 6 year-old

- **Seated Positions**
  - Behind steering wheel
  - Inboard
• **Open Window**
  – Complete ejection in every case

• **TRW and Original AHPS Inflatable Systems**
  – Prevented complete ejections
  – Shoulders & arms escaped below bag

• **Beltline AHPS Inflatable System**
  – Prevented complete and partial ejections

• **Advanced Glazing**
  – Prevented complete and partial ejections

• **Combination Systems**
  – Prevented complete and partial ejections
Ejection Mitigation
DRF Testing Results – AHPS Systems

Original

Beltline
• **Low Head Injury Potential**
  – Maximum $HIC_{36} = 121$

• **Low Neck Tension**
  – Maximum - 33% IARV (per FMVSS 208)

• **Generally Low Neck Compression**
  – Maximum - 82% IARV (per FMVSS 208)
  – All the rest below 60%
  – Higher values from contact with side roof rail while engaged with countermeasure
Ejection Mitigation
DRF Testing Results – Dummy Responses

Lateral Neck Loading

- **Maximum Shear Loads**
  - 50th male – 1020 N
  - 5th female – 754 N

- **Maximum Bending Moments**
  - 50th male – 68 N-m
  - 5th female – 42 N-m

- **No Established Injury Criteria**
Ejection Mitigation
Guided Impactor

- **18 kg Mass**
- **Featureless Headform**
  - Average of front & side of head geometries
  - Better approximation of head/shoulder loading area
- **Measures Displacement**
- **Positioned Inside Vehicle**
- **Impact a Variety of Locations**
## Ejection Mitigation

**Guided Impactor Test Matrix**

### Impact Location on Side Window Area

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16 kmph 6 sec</td>
<td>20 kmph 1.5 sec</td>
<td>24 kmph 1.5 sec</td>
<td>16 kmph 6 sec</td>
</tr>
<tr>
<td>Advanced Glazing Systems Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflatable Systems Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflatable Systems With Glazing (pre-broken)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflatable Systems With Glazing (unbroken)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ejection Mitigation
Side Window Impact Locations
• **TRW**
  – 1.5 seconds = 62 kPa
  – 6 seconds = 28 kPa

• **Zodiac**
  – 1.5 seconds = 79 kPa
  – 6 seconds = 49 kPa
Ejection Mitigation
Pre-Broken Glazing
## Ejection Mitigation
Guided Impactor Test Results

<table>
<thead>
<tr>
<th>Impactor Deflection Beyond Window Plane (mm)</th>
<th>Impact Location on Side Window Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>16 kmph</td>
</tr>
<tr>
<td>TRW Inflatable Curtain No Glazing</td>
<td>No Data*</td>
</tr>
<tr>
<td>TRW Inflatable Curtain With HP Laminate (pre-broken)</td>
<td>80</td>
</tr>
<tr>
<td>TRW Inflatable Curtain With HP Laminate (unbroken)</td>
<td>-42</td>
</tr>
<tr>
<td>Zodiac Beltline AHPS No Glazing</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

* Bag Provides No Coverage
Ejection Mitigation
Impactor Results

Maximum Excursion Beyond Window Plane
TRW - No Glazing

Impact Position

Displacement (mm)

No Coverage

16 kmph/0 sec
20 kmph/1.5 sec
24 kmph/1.5 sec

1 2 3 4
Ejection Mitigation Impactor Results

Maximum Excursion Beyond Window Plane
Zodiac AHPS(beltline) - No Glazing

Impact Position

Displacement (mm)

-15 -10 -5 0 5 10 15 20 25

16 kmph/6 sec
20 kmph/1.5 sec
24 kmph/1.5 sec
NO TEST
NO TEST
Ejection Mitigation
Impactor Test Repeatability

Impactor Test Excursion Repeatability

Displacement (mm)

Test 1  Test 2

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</tr>
</thead>
<tbody>
<tr>
<td>HP Laminate</td>
<td>No Glass</td>
<td>No Glass</td>
<td>No Glass</td>
<td>HP Laminate</td>
<td>HP Laminate</td>
<td>HP Laminate</td>
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Ejection Mitigation
Ongoing Research

• **Evaluate Countermeasures and Continue Test Procedure Development**
  – Continue DRF testing, especially with 6YO
  – Expand to rear side windows
  – Develop/adopt method to pre-break glazing

• **Develop Rollover Sensor Performance Test**
We wish to thank

TRW Automotive
and
Zodiac Automotive US

for their cooperation in this research
THE END