Aviation Child Safety Device Performance Standards Review

Presented to: The Sixth Triennial International Aviation Fire and Cabin Safety Research Conference

By: Rick DeWeese
    FAA Civil Aerospace Medical Institute

Date: October 26, 2010
Introduction

• Child Restraint Systems (CRS) meeting the auto safety standards (FMVSS-213) have been permitted on aircraft since 1985.
• Research revealed that forward facing CRS could provide poor performance when installed in some aircraft seat configurations.
Introduction

Good interface with seat (belt anchor aft-ward)  
Bad interface with seat (belt anchor forward)
Introduction

• As a result, SAE AS5276/1 “Performance Standard for Child Restraint Systems in Transport Category Airplanes” was developed to ensure proper restraint of infants and small children in the aircraft environment.

• TSO C-100b was issued in 2002 which referenced this document as a Minimum Performance Standard.
Introduction

• Prototypes were developed to meet draft aviation CRS requirements. Optimized design improved performance.
Implementation Challenges

• Development of CRS to meet aviation specifications has proven technically challenging. So far, no systems have been granted TSO approval.

• AS5276/1 requirements were based on FMVSS-213 and an aircraft seat configuration reflecting a near worst-case combination of parameters affecting CRS performance.
Implementation Challenges

- CRS manufacturers identified specific test requirements as hindering their ability to meet the specifications:
  - Belt Anchor Location. Most seat designs now have an anchor further aft than the location specified.
  - Seat Cushion Dimensions and Properties. Width and depth reflect average values, but the thickness and stiffness reflects the thickest and softest cushions in service.
  - Installation Method. Reflects an worst-case in-service installation scenario that could produce a loose fit of the CRS in the seat.
Seat Design Evolution

- New aircraft seat designs with a better CRS interface (further aft belt anchor point) have entered service and are gradually replacing the older seat designs.
- This means that AS5276/1 tests are based on aircraft seat geometry that may no longer be representative of the majority of seats currently in service.
Testing Technology Advances

• A major revision to FMVSS-213 was adopted in 2005.
  – Test fixtures revised to reflect current automotive seat geometry and the new LATCH anchorage systems.
  – Improved test dummies and test methods increased the level of safety provided.
Rule Changes

- Aviation regulations were revised to accommodate certification of innovative CRS optimized for aviation use.
- These revisions removed the requirement that TSO-C100 CRS and other Aviation Child Safety Devices (ACSD) also have FMVSS-213 approval.
- This action may have removed some useful requirements since AS5276/1 had been developed to complement rather than replace FMVSS-213.
Addressing Challenges and Changes

• **FMVSS-213** was reviewed to:
  - Identify requirements that are applicable to CRS intended for aviation use that are not currently addressed in the aviation standards.
  - Identify requirements that offer an improvement over similar requirements currently cited in the aviation standards.

• **AS 5276/1 test requirements** were reviewed to determine if they are still appropriate considering current seating configurations.
FMVSS-213 Review
– Potential Additions to Aviation Standards

- Design specifications for occupant support surfaces
- Belt and buckle strength and durability
- Defined restraint configuration, geometry and adjustment range
FMVSS-213 Review
– Potential Improvements to Aviation Standards

• Advanced Test Dummies
  CRABI 12-month-old          Hybrid-III 3-year-old

• Test Dummy preparation and positioning procedures
  – Dummy specific rather than generic
FMVSS-213 Review
– Potential Improvements to Aviation Standards

• Head injury assessment procedure
  – HIC36 evaluates injury potential due to both contact and non-contact (inertial) head acceleration.

• CRS installation procedures
  – Provides a repeatable installation method since it requires a specific lap belt tension (15 lb.).
AS5276/1 Review
– Belt Anchor

• Belt anchor location is a major factor affecting CRS performance.
  – head excursion increases as the belt anchor is moved further forward.

• Original selection based on 1996 survey of transport fleet.

SRP
Range of Belt Anchor Locations

3.8
5.4
AS5276/1 Review
– Belt Anchor

• Estimates of anchor point distribution in the current fleet were made by combining:
  – Fleet size and makeup from the FAA’s Safety Performance Analysis System
  – Seating requirements defined in each aircraft’s Type Data Sheet
  – Defined belt geometry (16 G seats have a belt anchor located no more than 2 inches forward of the CRP)
  – The 1996 survey results (primarily 9 G seats)
  – Assumptions about belt anchor locations on seats in aircraft that were retired / replaced since 1996
AS5276/1 Review
– Belt Anchor

CRP-to-Lap Belt Anchor Horizontal Distance
Cumulative Percentile Distribution
Comparison of Most and Least Conservative Estimates
AS5276/1 Review
– Belt Anchor

• Both estimation methods are conservative due to:
  – 16 G compatible seats may have been installed on many aircraft delivered after 1992 or installed on older aircraft during refurbishments.
  – The continued retirement and refurbishment of older aircraft, plus the requirement to install 16 G seats on all newly built aircraft, will tend to move the typical anchor location further aft over time.
AS5276/1 Review
– Belt Anchor

• Analysis results indicate that a belt anchor location 3.7 inches forward of the CRP is the most appropriate location for a minimum performance standard test procedure.

<table>
<thead>
<tr>
<th>Lap Belt Anchor X Location Estimated Distribution</th>
<th>50%tile Location</th>
<th>75%tile Location</th>
<th>95%tile Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Analysis</td>
<td>3.6</td>
<td>3.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Most Conservative Analysis</td>
<td>2.4</td>
<td>3.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Least Conservative Analysis</td>
<td>2.3</td>
<td>3.0</td>
<td>3.7</td>
</tr>
</tbody>
</table>
AS5276/1 Review
– Seat Cushion

• Size and Stiffness bounded by conflicting design goals of accommodating a range of occupant sizes while being compact.
• Review of new economy class seats indicated that current seat cushions are still similar to AS5276/1 specifications.
# AS5276/1 Review

## – Seat Cushion

### Seat Cushion Parameter Comparison

<table>
<thead>
<tr>
<th>Bottom Cushion Parameter</th>
<th>AS 5276 Specifications</th>
<th>Review Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Surface Angle</td>
<td>5.5 Degrees</td>
<td>4.5 - 7.5 Degrees</td>
</tr>
<tr>
<td>Cushion Depth</td>
<td>16.2 Inches</td>
<td>17 – 18 Inches</td>
</tr>
<tr>
<td>Support Structure Depth</td>
<td>14.8 Inches</td>
<td>15 – 16 Inches</td>
</tr>
<tr>
<td>Thickness above forward support</td>
<td>3.5 Inches polyurethane + 0.5 Inches polyethylene</td>
<td>3 – 4.75 Inches</td>
</tr>
<tr>
<td>Foam/Cushion Stiffness</td>
<td>21-27 ILD for the polyurethane layer</td>
<td>44 – 81 IFD</td>
</tr>
</tbody>
</table>
AS5276/1 Review
– Seat Cushion

• Computer modeling results indicate that cushion stiffness has little affect on CRS performance.
AS5276/1 Review
– Seat Cushion

• Seat Pan specified in test procedures is somewhat shorter than typical.

• A one inch diameter cylindrical extension to pan would improve realism.

1 Inch Dia Seat Pan Extension (Bottom of extension flush with bottom of Seat Pan)

Current Test Seat Pan
AS5276/1 Review
– Installation Method

• Current AS 5276 method can result in widely varying pre-test lap belt tension due to variations in belt adjuster friction

• FMVSS-213 method produces consistent pre-test tension values since tension is measured directly.
AS5276/1 Review
– Installation Method

• Following CRS manufacturer’s instructions will likely result in tension values similar to the FMVSS-213 test specifications.
Conclusions

• Incorporating applicable FMVSS-213 requirements into the aviation standards should provide a safety benefits for ACSD.

• Utilizing applicable automotive requirements would also allow ACSD users to benefit from the extensive research that went into the development of those requirements.
Conclusions

• Revising test requirements to be more representative of the current aircraft environment should advance the development of ACSD while maintaining or improving the current level of safety.
Acknowledgment

Co-authors:

David Moorcroft          Amanda Taylor

Civil Aerospace Medical Institute
Federal Aviation Administration

Compilation of Fleet Statistics from the Safety Performance Analysis System

John Petrakis
FAA Headquarters
Reference

A report containing the details of this project will be published as an Office of Aviation Medicine Report available at: www.faa.gov