Injury Potential and Regulatory Compliance for
Passenger Seats with Install Angle Above 18 Degrees

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Objective

• Premium “Herringbone” seats
  • Side Facing Seats (install angle > 18 deg.)
  • Impact Vector predominantly forward

• Compliance is Complex and Confusing
• Airbags used to help satisfy Injury Compliance

OBJECTIVE: Share Experience (Lend some Historical Perspective)
  Identify Considerations and Issues
Background: Seatbelt Airbag

Introduced in 2001, Revised and Expanded in 2002

- First BAE J-41, then Airbus A340, and A330, A320, B777, CRJ
- Front Row Economy and special economy (life raft bustle, etc.)

**Solution for FAR 25.562 Head Injury Criteria (HIC)**

- 2003: Premium Seats
- 2004: Introduced onto General Aviation
- Since 2005: Several Business / Premium Interiors and full economy class
- Over 50k Seat Placements and over 50 Commercial Airlines
Side Facing Seat – Existing Guidance

Seat angle > 18 degree: Side Facing Seat “Herringbone Interior”

• Issue Paper / Special Conditions

Support Wall: Full Body Head, Chest, Pelvis

• HIC < 1000
• Thoracic Trauma Index (TTI) < 85G

\[ TTI = \frac{1}{2}(RIBG + T12G) \]
• Pelvic Acceleration < 135 G
• May require reporting of neck loads

...and Airbag Special Conditions
Considerations

- Impact Vector toward monument
  - Monument part of seat structure or Interior
  - Row to Row vs Front Row and Seat TSO

- Side Facing Anthropomorphic Test Dummy (ATD) for TTI and Pelvic Acceleration Data
  - EuroSid II recommended by FAA CAMI,
- Hybrid II and/or FAA Hybrid III for HIC and Neck

- No recent programs with side wall…..evolution of SFS…… new questions?? (standardized process still applicable?)
Side Facing Seat – No Support Wall

Considerations

- Impact Vector away from monument into free space
  - No flailing over armrest
  - Footwell affect flailing?

- TTI, Pelvic Acceleration Data Don’t Apply if not striking wall
- ATD: Hybrid II and/or FAA Hybrid III for HIC and Neck
Scope of Compliance Discussion

- Process confusing and will have variations depending...
  - if FAA or EASA originated program (Boeing / Airbus)
  - Airline, Applicant, and Seat Supplier
- Compliance Approach is Variable
  - ELOS (Equivalent Level of Safety) is used
  - Injury compliance is Key

- Injury Compliance
  - No universally accepted ATD’s for *predominantly forward* SFS
  - No universally accepted injury measures or criteria for open flailing
  …IS Therefore SUBJECTIVE
Comparison Point (example 25° install angle)

- SFS, no support wall, Equivalent Level of Safety (ELOS)
  Option A (Past): max seat angle per FAR 25.785 = 18°

A: 18° vs 25° (+10° yaw)

Demonstrate Similarity to a certifiable interior

Limit: - Existing Certifiable Forward Facing Seat Configurations
(some angle would be too large, 35°?, 40°?)

Concern: May not capture all potential injury
(allowable 18° seats may have injury mechanisms not taken into account)
Comparison Point (example 25 ° install angle)

- SFS, no support wall, Equivalent Level of Safety (ELOS)
  Option B (Current): most common forward facing seat = 0°

B: 0° vs 25° (+10° yaw)

Demonstrate no potential injury

Limits: None

Concerns:
- Two very different angles (injury mechanisms may differ)
- Undefined injury measures and criteria
- Non 25.562 Furnishings don’t apply
Paper Abstract for this conference was submitted based on data evaluating injury comparisons using Option A. Compliance has evolved since that time. The paper was modified to reflect current status.

**Current Status:** (Option B) – Comparison is 0° standard seat

- Satisfy HIC for real interior using typical guidance
- Account for undefined / subjective injury
- Allowances
  - TTI and Pelvic Accel. Not Mandatory (unless needed)
  - Side Facing ATD Not Mandatory (unless needed)
  - Flail Comparison can be done with Structural Tests
HIC Considerations

- All Interior Combinations at + or - 10° yaw

- Representative Monuments allowed (at least as stiff as real)

- Airbag typically used to mitigate HIC
  - If monument is just within strike zone…
    
    Bag may only interact with head…
    
    Can raise concern for Neck or other injury mechanisms
    
    (that would not be considered for a normal forward facing seat)

Head can twist if airbag contacts mostly head.

More torso support is needed.
Subjective Injury Considerations

• Best Tool Today: Occupant Kinematics from High Speed Video

• Six Axis Spine Load Cell used in past, but meaning poorly understood

• Neck Load criteria beginning to take shape, but lateral vs forward impact vectors add complexity

• Current Subjective Injury Status
  • Seat must allow Free Flailing (like a no-strike forward seat)

• Free Flailing: (no armrest or other structure in the way)
  • No obstructions impinging body
  • ATD should adopt “forward” vector (recognizing that belt anchor points will not allow perfectly forward alignment)
FAA CAMI Research and other sources establish that misalignment of spine drastically reduces injury threshold.

- Severe flailing with complex (combined) motion can cause misalignment

- Objective:
  - Neck: Avoid bending with tension
    (others will be researched in future)
  - Spine: Avoid bending with rotation or tension or shear
  - Avoid intrusion into soft tissue
Automotive Research analogous to Angled Side Facing Seats

Far Side Impacts

• Center Console is a significant source of trauma from far side impacts.
• Head flailing, chest and organ injuries are all of concern.
• Inboard restraints and shoulder and thorax plates helped in some ways, but not others. The specific design must be evaluated.

Bottom Line Objective:
Must mitigate head flail and Local chest deflections.

Injury Measures:
• THOR-NT better for restraint evaluations
• WorldSID better for shoulder/chest support evaluations.

How to Certify Interior efficiently (no support wall)

1. Mitigate HIC
   • Associated benefit for head flailing and neck loads
     (limited head accel. mitigates injury, even if undefined)

2. Move lateral obstructions out of the way
   • Mitigates local chest trauma in a practical manner

3. Compare Flailing to “Normal” Forward (0 degree install angle)

4. Save Some Effort: Avoid Side Facing ATD Tests

5. But Extra Effort is Needed to evaluate Subjective Injury:
   Structure program to evaluate realistic flailing early
   Coordinate Occupant Kinematics Response with authorities
Thank You For Your Time!

Questions?
Comments?

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