U.S. Department of Transportation
Federal Aviation Administration

Policy Statement

Subject: Technical Criteria for Approving Oblique Seats

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Initiated By:
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Summary

This policy statement communicates the Federal Aviation Administration (FAA) certification policy on title 14, Code of Federal Regulations (14 CFR) 25.562 and 25.785, amendment 25-64 or later, for side-facing seats installed at angles greater than 18° up to and including 45° from the centerline of the airplane as measured from the forward direction (oblique seats). This policy addresses both the technical criteria for certifying oblique seat designs and the implementation of those criteria. Current FAA research has only been conducted up to the 45° angle; therefore, seats installed at more than a 45° angle are beyond the scope of this policy.

Definition of Key Terms

In this policy, the terms "must," "should," and "recommend" have specific meanings:

- The term "must" refers to a regulatory requirement that is mandatory for design approval. The functional impact of the term "must" is that the requirement has to be met to achieve design approval.

- The term "should" refers to instructions for a particular acceptable means of compliance (MOC). The functional impact of the term "should" is that any alternative MOC has to be approved by issue paper.

- The term "recommendation" refers to a recommended practice that is optional. There is no functional impact of the term "recommend" because it is optional.

In addition, for the purposes of this policy, the following terms are defined as follows:

1. Side-facing seat - Any seat that is installed with the occupant facing at more than an 18° angle (as measured from the airplane forward direction) from the vertical plane containing the airplane centerline.

2. Oblique seat - A side-facing seat that is installed with the occupant facing at an angle greater than 18° up to and including a 45° angle (as measured from the airplane forward direction) from the vertical plane containing the airplane centerline.

Current Regulatory and Advisory Material

The following 14 CFR regulations, amendment 25-64 or later, apply to the certification of oblique seats:

- Section 25.562, *Emergency landing dynamic conditions*.
- Section 25.785, *Seats, berths, safety belts, and harnesses*.

Section 25.562(a), amendment 25-64, requires that the seat and restraint system be designed to protect each occupant when (1) proper use is made of the seats, safety belts, and shoulder harnesses; and (2) the occupant is exposed to loads resulting from the conditions prescribed in § 25.562(b).

Section 25.785(b), amendment 25-72 and later, requires occupants of seats that are occupied during takeoff and landing not suffer serious injury as a result of the inertia forces specified in §§ 25.561 and 25.562. This requirement was previously in § 25.785(a) at amendment 25-64.

The FAA has not issued any previous advisory material on oblique seats.

For basic dynamic testing and set-up principles and addressing range of occupants, refer to Advisory Circular (AC) 25.562-1B, *Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes*, dated January 10, 2006; including Change 1, dated September 30, 2015.

Relevant Past Practice

Amendment 25-15 to part 25, dated October 24, 1967, introduced the subject of side-facing seats and a requirement that each occupant in a side-facing seat must be protected from head injury by a safety belt and a cushioned rest that will support the arms, shoulders, head, and spine.

Subsequently, amendment 25-20, dated April 23, 1969, clarified the definition of side-facing seats to require that each occupant of a seat that is positioned at more than an 18° angle to the vertical plane containing the airplane centerline must be protected from head injury by a safety belt and an energy-absorbing rest that supports the arms, shoulders, head, and spine; or by a safety belt and shoulder harness that prevents the head from contacting injurious objects. The FAA concluded that a maximum 18° angle would provide an adequate level of safety based on tests that were performed at the time, and thus adopted that standard.

Amendment 25-64, dated June 16, 1988, revised the emergency-landing conditions that must be considered in the design of the airplane. It revised the static-load conditions in § 25.561 and added a new § 25.562, requiring dynamic testing for all seats approved for occupancy during takeoff and landing. The intent was to provide an improved level of safety for occupants on

transport category airplanes. Because most seating on transport category airplanes is forward-facing, the pass/fail criteria developed in amendment 25-64 focused primarily on forward-facing seats. Therefore, the testing specified in the rule did not provide a complete measure of occupant injury in seats that are not forward-facing; although § 25.785 does require occupants of all seats that are occupied during taxi, takeoff, and landing not suffer serious injury as a result of the inertia forces specified in §§ 25.561 and 25.562.

To address recent research findings and accommodate commercial demand, the FAA developed a methodology to address all fully side-facing seats (i.e., seats oriented in the airplane with the occupant facing 90° to the direction of airplane travel) and has documented those requirements in a set of new special conditions. The FAA issued policy statement PS-ANM-25-03-R1 on November 12, 2012, titled, *Technical Criteria for Approving Side-Facing Seats*, which conveys the injury criteria to be used in the special conditions. Some of those criteria are applicable to oblique seats, but others are not because the motion of an occupant in an oblique seat is different from the motion of an occupant in a fully side-facing seat during emergency landing conditions.

For shallower installation angles, the FAA has granted equivalent level of safety (ELOS) findings for oblique seat installations on the premise that an occupant's kinematics in an oblique seat during a forward impact would result in the body aligning with the impact direction. We predicted that the occupant response would be similar to an occupant of a forward-facing seat, and would produce a level of safety equivalent to that of a forward-facing seat. These ELOS findings were subject to many conditions that reflected the injury-evaluation criteria and mitigation strategies available at the time of issuance of the ELOS. However, review of dynamic test results for many of these oblique seat installations raised concerns that the premise was not correct. Potential injury mechanisms exist that are unique to oblique seats and are not mitigated by the ELOS self-alignment approach even if the occupant appears to respond similarly to a forward-facing seat. Therefore, the FAA strongly recommends installation of effective upper-torso restraints, especially for oblique seats installed at angles between 30° and 45° to the vertical plane containing the airplane centerline.

The FAA has been conducting and sponsoring research on an acceptable method of compliance with §§ 25.562 and 25.785(b) for oblique seat installations. Current research has shown that even when the body is allowed to nearly align with the impact direction, neck, spine, and torso injuries can still occur. The FAA developed a set of criteria to address potential injuries due to emergency landing conditions for oblique seats. We issued these criteria in special conditions for various oblique seat projects, adding to the criteria as we learned more.

Appendix A contains some background and discussion of the criteria to address neck, torso, and spine injuries. Also included in appendix A are background and discussion of the Hybrid III anthropomorphic test dummy (ATD) and the injury criteria that are measured with the ATD. The Hybrid III ATD has improved biofidelity and instrumentation to allow a more accurate evaluation of injury potential than the ATDs previously cited in the regulation and ELOS findings.

Policy

To provide a level of safety equivalent to that afforded to occupants of forward- and aft-facing seats, additional airworthiness standards, in the form of special conditions, are necessary. Although previously issued special conditions and ELOS findings were applicable to some oblique seat installations, current research shows that those conditions and findings do not completely address the complex occupant-loading conditions from a seat installed at an angle between 18° and 45° to the centerline of the airplane as measured from the airplane forward direction. Therefore, we will no longer issue ELOS findings for obliquely-oriented seats on the basis that the occupant response is similar to a forward-facing seat, as discussed below in the Implementation section. The FAA has determined that to achieve the level of safety envisioned by amendment 25-64, additional requirements are needed. See appendix B for detailed requirements that will be issued as special conditions. However, the FAA research program is not complete and we may update these criteria as we obtain more research results.

The FAA strongly recommends installing effective upper-torso restraints, especially for oblique seats installed at angles between 30° and 45° to the vertical plane containing the airplane centerline. If airbag devices, such as inflatable lap belts or structure-mounted airbags, are used to meet the injury criteria, they need to meet the applicable airbag device special conditions for the affected airplane make and model.

The SAE International Aerospace Standard AS6316, *Performance Standards for Oblique Facing Passenger Seats in Transport Aircraft*, published June 28, 2017, is an acceptable alternate method that satisfies the intent of this policy. However, the FAA must still issue special conditions applicable to the seat installation project as noted above.

Effect of Policy

The general policy stated in this document does not constitute a new regulation. Agency employees and their designees and delegations must not depart from this policy statement without appropriate justification and concurrence from the FAA management that issued this policy statement. The authority to deviate from this policy statement is delegated to the Manager of the Transport Standards Branch. In addition, as with all guidance material, this policy statement identifies one means, but not the only means, of compliance.

Implementation

This policy discusses compliance methods that should be applied to type certificate, amended type certificate, supplemental type certificate, and amended supplemental type certificate projects. The compliance methods apply to those programs with an application date that is on or after the effective date of the final policy. If the date of application precedes the effective date of the final policy, and the methods of compliance have already been coordinated with and approved by the FAA or its designee, the applicant may choose to either follow the previously acceptable methods of compliance or follow the guidance contained in this policy.

The effective date of this policy is upon signature of final policy. In some cases, the seat design and certification process can be lengthy, so we have identified specific criteria based on the

status of the program. Implementation will be considered for three cases of certification program:

- Previously approved
- In-work
- New

1 **PREVIOUSLY APPROVED:** For oblique seat installations that were approved prior to the effective date of this policy, this policy has no effect.

2 **IN-WORK:** The FAA's intent is to implement this policy to achieve the long-term safety benefits associated with a more-comprehensive examination of safety aspects relevant to oblique seats. For oblique seat certification projects currently in-work that have a previously granted ELOS finding or approved special conditions applicable to the oblique seat installation, the applicant should use one of these two compliance methods:

2.1 The applicant follows the criteria in this policy and the FAA issues the criteria as special conditions applicable to the project. The FAA prefers this method.

2.2 The applicant follows the criteria in the previously granted ELOS or special conditions.

Note: Meeting the ELOS criteria includes demonstrating that the occupant of the seat experiences no injury mechanisms other than those that an occupant of a forward-facing seat would experience.

3 **NEW:** This policy applies to all oblique seat installations in new type certificate, amended type certificate, supplemental type certificate, and amended supplemental type certificate projects applied for after the effective date of the policy statement.

Note: The FAA will amend existing special conditions if necessary to address new research findings. Amended special conditions are not retroactively applied to previously approved projects. Amended special conditions would be applicable only to projects for which the amended special conditions are listed in the certification basis of the project.

Conclusion

The FAA has concluded that it is necessary to issue special conditions for oblique seat installations to ensure the safety of occupants in emergency landing conditions. If the FAA obtains additional data demonstrating that revisions to the criteria are necessary to prevent

serious injury to occupants of oblique seats in emergency landing conditions, the content of this policy would be revised to provide the updated criteria.

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Appendix A. Background and Discussion of Neck, Torso, and Spine Injury Criteria Limits

The new special conditions use the FAA Hybrid III (HIII) anthropomorphic test dummy (ATD). This ATD has improved biofidelity and instrumentation that allow more accurate evaluations of injury potential than the Hybrid II ATD. The FAA has evaluated and documented the FAA HIII ATD performance in several seating configurations and impact vectors in SAE International Technical Paper 1999-01-1609, *A Lumbar Spine Modification to the Hybrid III ATD for Aircraft Seat Tests*, V. Gowdy, et al (1999). This ATD is appropriate for measuring all injury criteria cited in the special conditions and § 25.562(c). Either the FAA HIII or the ATD currently specified in § 25.562 may be used in tests showing the structural integrity of the seat and restraint system.

Neck and spine injuries have been a concern in oblique seat installations, but no data was available to establish injury criteria when early oblique seat projects were certified. Neck and spine injury evaluation methods applicable to the most common oblique seat configurations were identified during the recent FAA research. A soon-to-be-published report, *Preliminary FAA Hybrid III Spinal Injury Criteria for Oblique Aviation Seats*, John Humm, et al, Technical Paper IMECE2015-52059 (2015), is summarized in a published abstract available from the American Society of Mechanical Engineers (ASME). This report contains data supporting the cited spine injury criteria. FAA research on this topic, however, is not complete. Therefore, specific injury criteria for all possible loading scenarios that could affect occupants of oblique seats are not currently available. To limit the injury risk in those cases, these special conditions provide conservative injury-evaluation means that are derived from the latest research data, past practice, and applicable scientific literature as outlined below.

1 **HEAD INJURY CRITERIA (HIC):**

HIC evaluation of head impacts with low acceleration of gravity (g) levels at long duration can result in values that overestimate the actual risk of injury. This type of loading often occurs when the head impacts an airbag. To address this issue, Federal Motor Vehicle Safety Standards (FMVSS) No. 208 (49 CFR 571.208) limits the duration of impact considered in the HIC evaluation to 15 milliseconds (HIC_{15}). The FAA has included HIC_{15} of 700 as a pass/fail score in the special conditions to address airbag interactions that produce long impact durations.

2 **NECK INJURY CRITERIA (Nij):**

Observed occupant kinematics in research and seat development tests led to concerns about neck loading that differed significantly from what occurs in typical forward-facing seats. The special conditions include the same neck injury criteria used in 49 CFR 571.208 to evaluate neck injury risk. Significant twisting of the neck was also observed in some research and development tests. Since the automotive neck injury criteria do not address this type of loading, the special conditions include a limit on the amount of head rotation about the neck Z axis. The limit was based on human neck torsional strength data reported in SAE International Technical Paper No. 892437, *Responses of the Human Cervical Spine to Torsion*, B. Myers, et al (1989). The special conditions also prohibit concentrated loading on the neck.

3 SPINE AND TORSO INJURY CRITERIA:

3.1 The spine's tolerance to loading decreases if the spine is twisted (e.g., due to torso and pelvis misalignment). FAA-sponsored research has found that unrestrained flailing of the upper torso, even when the pelvis and torso are nearly aligned, can produce serious spinal and torso injuries. However, the same research found that at lower impact severities, even with significant misalignment between the torso and pelvis, the injuries did not occur. Tests with an FAA HIII ATD have identified a level of lumbar spinal tension corresponding to the no-injury impact severity. This level of tension is included as a limit in the special conditions. Since this limit does not represent a direct correlation between misalignment and tolerance to injury, it is meant to be conservative.

Significant contact between the occupant's back and surrounding hard structure was observed during rebound in some development tests. Concentrated loading on the spine resulting in high shear forces has been observed to create serious injuries. Research sponsored by the National Aeronautics and Space Administration (NASA) indicates that concentrated loads in excess of 820 pound-force (lb_f) applied to the lower back can cause spinal injuries. Current ATD technology does not support direct measurement of spine contact loads; however, linear acceleration near the torso center of gravity can be measured. The 50^{th} percentile-sized ATD used to test aircraft seats has a torso weight specification of 41.5 pounds (lb) ± 1.6 lb. One means of estimating the force resulting from contact between the torso and a seat item is to multiply the torso mass by the peak torso acceleration during the contact. Limiting the torso rearward acceleration to 20g would in-turn keep the contact forces below the level observed to cause significant injury in current studies.

3.2 The special conditions also include a prohibition on occupant interaction with the armrest or other seat components in any manner significantly different than would be expected for a forward-facing seat installed at 0 degrees relative to the airplane centerline. This limitation is necessary, in part, to reduce injury risk from chest contact with surrounding structure during flailing. FAA-sponsored research findings indicate that significant torso contact with surrounding structure, such as armrests, can produce serious thoracic injuries.

4 PELVIS AND SPINE INJURY CRITERIA:

4.1 The criteria are the same as previously included in policy statement PS-ANM-25-03-R1, *Technical Criteria for Approving Side-Facing Seats*, dated November 12, 2012, and are intended to limit the same injury risks in oblique seats.

4.2 One factor in determining if a dynamic test is successful is whether the primary load path between the occupant and the seat attachments is maintained (see Advisory Circular (AC) 25.562-1B, *Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes*, dated September 30, 2015). Since the bottom seat cushion supporting structure is a primary load path, the load-bearing portion of the occupant's pelvis must be supported by it throughout the impact event. The area of the cushion under the ATD having the greatest effect on performance is defined in AC 25.562-1B, appendix 3, paragraph 9b. This means the corresponding area on the

bottom of the pelvis is the principal load-bearing area, and can be used when determining whether the load path between the ATD and seat pan is maintained.

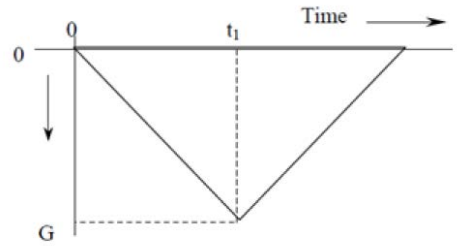
5 FEMUR INJURY CRITERIA:

5.1 Serious leg injuries, such as femur fracture, can occur in aviation side-facing seats that could threaten the occupant's life directly or prevent the occupant's ability to evacuate. Femur fractures of the leading leg were seen in post-mortem human subject (PMHS) tests using an aviation seating configuration that produced torque in the femur (see report no. DOT/FAA/AR-09/41, *Neck Injury Criteria for Side-Facing Aircraft Seats*, February 2011). The test protocol for that project (which was focused on neck injury) did not allow for a determination of PMHS femur torque or the specific angle that causes injury. However, if the upper-leg's axial rotation, with respect to the pelvis, is limited to the normal static range of motion, then the risk of injury should be low. That range of motion for a seated occupant's internal and external rotation ranges from 18° for the least flexible persons (the male population's 5^{th} percentile rotation value) to 45° for the most flexible persons (the female population's 95^{th} percentile rotation value) (see *The Measure of Man and Woman: Human Factors in Design*, Henry Dreyfuss Associates, 2002). ATD tests in the same seat configuration as the PMHS tests showed that the ES-2re model ATD leg will rotate at least 60° in this loading scenario (see report no. DOT/FAA/AM-07/13, *Assessment of Injury Potential in Aircraft Side-Facing Seats Using the ES-2 Anthropomorphic Test Dummy*, May 2007). Therefore, limiting upper-leg axial rotation with respect to the pelvis to 35° from the nominal seated position (approximately the 50^{th} percentile range of motion for both genders) should also limit the risk of serious leg injury. One means of determining the amount of relative upper-leg rotation is by observing lower-leg flailing in typical high-speed video of the dynamic tests. Since the lap belt tends to prevent significant lateral rotation of the pelvis, the motion of the lower leg with respect to its initial position is sufficient to derive the upper-leg relative rotation with respect to the pelvis. This requirement complies with the intent of the § 25.562(c)(6) injury criteria in preventing serious leg injury.

5.2 To protect the occupants of oblique seats from serious injuries, airbags are frequently incorporated into the seat system design. Because this type of protection system may or may not activate during various crash conditions, we further clarify that the applicant must demonstrate that the injury criteria in appendix B are not exceeded in an event which is at or slightly above the activation level of the system using a deactivated airbag system.

5.3 If testing is used for this demonstration, an acceptable pulse shape is shown in figure below. The pulse onset rate must be the same as the 16g pulse defined in AC 25.562-1B Change 1. The pulse parameters (G, t_1, velocity change) must be selected based on the sensor parameters that activate the airbag.

5.4 The magnitude of the required pulse must not deviate below the ideal pulse by more than 0.5g until 1.33 t_1 is reached.



The ideal pulse is a symmetrical isosceles triangle

5.5 Airbag systems should be shown to not affect the main aisle, cross-aisle, and passageway emergency egress capabilities.

Appendix B. Criteria for Oblique Seats in Addition to the Requirements of § 25.562

1 **HEAD INJURY CRITERIA:**

Compliance with § 25.562(c)(5) is required, except that, if the anthropomorphic test dummy (ATD) has no apparent contact with the seat/structure but has contact with an airbag, a head injury criterion (HIC)[1] score in excess of 1000 is acceptable, provided the HIC_{15} score (calculated in accordance with 49 CFR 571.208) for that contact is less than 700.

2 **BODY-TO-WALL/FURNISHING CONTACT:**

If a seat is installed aft of a structure (e.g., the back side of another seat, an interior wall or furnishing) that does not provide a homogenous contact surface for the expected range of occupants and yaw angles, then additional analysis, or tests, or both may be required to demonstrate that the injury criteria are met for the area which an occupant could contact. For example, if different yaw angles could result in different airbag device performance, then additional analysis or separate test(s) may be necessary to evaluate performance.

3 **NECK INJURY CRITERIA:**

3.1 The seating system must protect the occupant from experiencing serious neck injury. The assessment of neck injury must be conducted with the airbag device activated The applicant must also demonstrate that the neck injury criteria are not exceeded in an event which is at or slightly above the activation level of the system.

3.2 The N_{ij} (calculated in accordance with 49 CFR 571.208) must be below 1.0, where $N_{ij} = (F_z/F_{zc}) + (M_{ocy}/M_{yc})$, and N_{ij} critical values are:

3.2.1 $F_{zc} = 1530$ lb_f for tension

3.2.2 $F_{zc} = 1385$ lb_f for compression

3.2.3 $M_{yc} = 229$ lb_f ft in flexion

3.2.4 $M_{yc} = 100$ lb_f ft in extension

3.3 In addition, peak upper neck F_z must be below 937 lb_f in tension and 899 lb_f in compression.

3.4 Rotation of the head about its vertical axis, relative to the torso, is limited to 105° in either direction from forward-facing.

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[1] In the context of § 25.562, "HIC" means HIC with an unlimited calculation interval, sometimes known as HIC unlimited, and is calculated as shown in § 25.562(c)(5).

3.5 The neck must not impact any surface that would produce significant concentrated loading on the neck.

4 **SPINE AND TORSO INJURY CRITERIA:**

4.1 The lumbar spine tension (F_z) must not exceed 1200 lb_f.

4.2 Significant concentrated loading on the occupant's spine, in the area between the pelvis and shoulders, is not acceptable during ATD impact and rebound. During this type of contact, the interval for any rearward (X direction) acceleration exceeding 20g must be less than 3 milliseconds as measured by the thoracic instrumentation specified in 49 CFR part 572, subpart E, and filtered in accordance with SAE Recommended Practice J211/1.

4.3 Occupant must not interact with the armrest or other seat components in any manner significantly different than would be expected for a forward-facing seat installed at 0 degrees relative to the airplane centerline.

5 **PELVIS CRITERIA:**

Any part of the load-bearing portion of the bottom of the ATD pelvis must not translate beyond the edges of the bottom seat cushion supporting structure.

6 **FEMUR CRITERIA:**

Axial rotation of the upper leg (about the z-axis of the femur per SAE International Recommended Practice J211/1) must be limited to 35° from the nominal seated position. Evaluation during rebound does not need to be considered.

7 **ATD AND TEST CONDITIONS:**

Longitudinal test(s) conducted to measure the injury criteria above must be performed with the FAA Hybrid III ATD, as described in SAE International Technical Paper 1999-01-1609. This longitudinal test(s) is as defined in § 25.562(b)(2), except it must be conducted with an undeformed floor, at the most critical yaw case(s) for injury and with all lateral structural supports (e.g., armrests and walls) installed.