Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Seat Testing Harmonization Working Group

Task 1 – Certification of Flightcrew Seats

Task Assignment

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Subcommittee; Seat Testing Harmonization Working Group

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of establishment of Seat Testing Harmonization Working Group.

SUMMARY: Notice is given of the establishment of the Seat Testing Harmonization Working Group of the Transport Airplane and Engine Subcommittee. This notice informs the public of the activities of the Transport Airplane and Engine Subcommittee of the Aviation Rulemaking Advisory Committee.

FOR FURTHER INFORMATION CONTACT: Mr. William J. (Joe) Sullivan, Executive Director, Transport Airplane and Engine Subcommittee, Aircraft Certification Service (AIR-3), 800 Independence Avenue, SW., Washington, DC 20591, Telephone: (202) 267-9554; FAX: (202) 267-5364.

SUPPLEMENTARY INFORMATION: The Federal Aviation Administration (FAA) established an Aviation Rulemaking Advisory Committee (56 FR 2190, January 22, 1991) which held its first meeting on May 23, 1991 (56 FR 20492, May 3, 1991). The Transport Airplane and Engine Subcommittee was established at that meeting to provide advice and recommendations to the Director, Aircraft Certification Service, FAA, regarding the airworthiness standards for transport airplanes, engines and propellers in parts 25, 33 and 35 of the Federal Aviation Regulations (14 CFR parts 25, 33 and 35).

The FAA announced at the Joint Aviation Authorities (JAA)-Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Ontario, Canada (June 2-5, 1992), that it would consolidate within the Aviation Rulemaking Advisory Committee structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR). Coincident with that announcement, the FAA assigned to the Transport Airplane and Engine Subcommittee those projects related to JAR/FAR 25, 33 and 35 harmonization which were then in the process of being coordinated between the JAA and the FAA. The harmonization process included the intention to present the results of JAA/FAA coordination to the public in the form of either a Notice of Proposed Rulemaking or an advisory circular—an objective comparable to and compatible with that assigned to the Aviation Rulemaking Advisory Committee. The Transport Airplane and Engine Subcommittee, consequently, established the Seat Testing Harmonization Working Group.

Specifically, the Working Group's task is the following:

The Seat Testing Harmonization Working Group is charged with making recommendations to the Transport Airplane and Engine Subcommittee concerning the FAA disposition of the following subject recently coordinated between the JAA and the FAA:

Crew Seats: Make recommendations concerning the requirements and guidance material for the certification of flightcrew seats and the associated test conditions (FAR 25.562; AC 25.562A).

Reports:

A. Recommend time line(s) for completion of the task, including rationale, for Subcommittee consideration at the meeting of the subcommittee held following publication of this notice.

B. Give a detailed conceptual presentation on each task to the Subcommittee before proceeding with the work stated under items C, below.

C. Draft a Notice of Proposed Rulemaking the task proposing new or revised requirements, a supporting economic analysis, and other required analysis, with any other collateral documents (such as Advisory Circulars) the Working Group determines to be needed.

D. Give a status report on each task at each meeting of the Subcommittee.

The Seat Testing Harmonization Working Group will be comprised of experts from those organizations having an interest in the tasks assigned. A Working Group member need not necessarily be a representative of one of the organizations of the parent Transport Airplane and Engine Subcommittee or of the full Aviation Rulemaking Advisory Committee. An individual who has expertise in the subject matter and wishes to become a member of the Working Group should write the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task, and the expertise he or she would bring to the Working Group. The request will be reviewed with the Subcommittee and Working Group Chairs and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee and its subcommittees are necessary in the public interest in connection with the performance of duties of the FAA by law. Meetings of the full Committee and any subcommittees will be open to the public except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Seat Testing Harmonization Working Group will not be open to the public except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of Working Group meetings will be made.

Issued in Washington, DC, on December 4, 1992.

William J. Sullivan,

Executive Director, Transport Airplane and Engine Subcommittee, Aviation Rulemaking Advisory Committee.

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Recommendation Letter

Gerald R. Mack
Director
Airplane Certification

Boeing Commercial Airplane Group
P.O. Box 3707, #MS 67-UM
Seattle, WA 98124-2207

ARM-20

October 27, 1995
B-T000-ARAC-95-007

BOEING

Mr. Anthony J. Broderick
Associate Administrator for Regulations and Certification, (AVR-1)
Department of Transportation
Federal Aviation Administration
800 Independence Avenue, S.W.
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Dear Mr. Broderick:

The Aviation Rulemaking Advisory Committee's Transport Airplane and Engine Issues Group (TAEIG) met in Boston, Massachusetts on October 17 and 18, 1995. One of the significant items for consideration and recommended action was the draft Advisory Circular 25.562-1 on Seat Dynamic Testing. The TAEIG's Seat Test Working Group was tasked to clarify and harmonize the A.C. guidance.

The Working Group had numerous meetings before reaching an agreement. Part of their problem for the extended time period to bring the draft A.C. to the TAEIG was the current difficulty being experienced in TSO C-127 approval and FAR 25.562 installation certification. The Working Group was well aware of the peripheral issues for which a public meeting was held on October 23 and 24, 1995.

After considerable discussion at the Boston meeting, the TAEIG recommends that the draft A.C. be processed. This TAEIG agreement for recommendation was based on the provision that it be understood the A.C. reflects only the action chartered to ARAC and that it does not signify industry's satisfaction with the rule.

In consideration of the October 23 and 24 Public meeting, TAEIG strongly requests that any tasks that evolve from the meeting, in terms of guidance and/or rule change, be given to the TAEIG. Also, it is requested that if the A.C. is subsequently modified by the FAA prior to publication without the concurrence of TAEIG, the final publication not be identified as an ARAC product.

BOEING

Sincerely,

G. R. Mack

Gerald R. Mack
Assistant Chairman
Transport Airplane & Engine Issues Group
Aviation Rulemaking Advisory Committee
Tele: (206) 234-9570, Fax: 237-0192, Mailstop: 67-UM

Enclosure

Acknowledgement Letter

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

DEC 20 1995

Mr. Gerald R. Mack
Aviation Rulemaking Advisory Committee
Boeing Commercial Airplane Group
P.O. Box 3707, M/S 67-UM
Seattle, WA 98124-2207

Dear Mr. Mack:

Thank you for your October 27 letter forwarding the Aviation Rulemaking Advisory Committee's (ARAC) recommendation in the form of a draft Advisory Circular (AC) on Seat Dynamic Testing.

You stated that the recommendation reflects only the action that was chartered to ARAC; and that it does not signify industry's satisfaction with the rule. ARAC's position in this regard is noted. You also asked that any tasks involving a possible rule change or guidance on this issue, that evolve from the October 23 and 24 public meeting in Seattle, be given to ARAC, Transport Airplane and Engine issues. This request will be considered. With regard to the request not to identify ARAC products, that have been subsequently changed by the Federal Aviation Administration (FAA), as ARAC products, it is necessary that we accurately describe in our documents how we arrived at the proposed or final product; and this means citing the work done by ARAC. However, we understand your concern, and will be careful to show how the ARAC product was altered by the FAA.

I am aware that the ARAC vote on this recommendation included two dissenting votes. We have asked the organizations involved to provide us additional information so we can address their concerns in the public notice on this AC.

I would like to thank the aviation community, and particularly the Seat Testing Harmonization Working Group, for its commitment to ARAC and for its interest and effort on this project.

Sincerely,

Anthony J. Broderick
Associate Administrator for
Regulation and Certification

U.S. Department of Transportation
Federal Aviation Administration

DRAFT

9-8-95

Advisory Circular

Subject: DYNAMIC EVALUATION OF SEAT RESTRAINT SYSTEMS & OCCUPANT PROTECTION ON TRANSPORT AIRPLANES

Date:

Initiated by: ANM-110

AC No: 25.562-1

Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance regarding acceptable, but not the only, means of compliance with Part 25 of the Federal Aviation Regulations (FAR) applicable to dynamic testing of seats intended for use in transport category airplanes. The AC provides background and discussion of the reasoning behind the test procedures. It also describes the test facilities and equipment necessary to conduct the tests. Terms used in this AC, such as "shall" and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described herein is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the pertinent FAR. This advisory circular does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

2. RELATED REGULATIONS. Sections 25.562, 25.785, 25.787, and 25.789 of Part 25 of the Federal Aviation Regulations.

3. DISCUSSION.

a. Intent of Tests. The intent of the tests is to evaluate airplane seats, restraints, and related interior systems in order to demonstrate the structural strength and the ability of those systems to protect an occupant from injuries in a crash environment. For example, occupant injury potential, which is influenced, by head strike envelopes and seat pitch, should be assessed. This assessment will be essentially qualitative.

b. Standardized Test Procedures - Reason and Practicalities. The tests described are standardized procedures that are generally to be regarded as the minimum necessary to demonstrate compliance. Such standardized procedures ensure that, to the maximum extent possible, consistent results are achieved between different test facilities. These facilities may be of varying types, as described in paragraph 6. They will often not be under the direct control of the designer or manufacturer of the article under test, and they may be primarily dedicated to testing not related to the aerospace industry. For this reason many of the procedures and evaluations described are already accepted as standards by government and commercial test facilities and have been modified only as necessary for the specific testing of civil airplane systems.

c. Standardized Test Procedures - Relationship to Design Standards. As stated above, the tests are, of necessity, standardized. The most obvious examples are the one size and weight representation of the occupant and the two discrete directions specified for the test impact. This philosophy is no different than that applied to static testing but, in the dynamic case, results in a much more complex consideration of the design factors involved in ensuring that the testing performed is adequate to demonstrate compliance with the applicable regulations.

(1) Occupant size. The dynamic tests are performed with an anthropomorphic test device (ATD) approximately representing the 50th percentile male occupant. Although the basic structural capability of the seat/restraint system is not directly demonstrated for other size occupants, aspects such as energy absorbing systems, restraint system loads and anchorage locations, and seat adjustments are typical design factors which are directly influenced by occupant size.

(2) Test Conditions. Only the two minimum impact tests are described in the dynamic test procedures discussed in this AC. These procedures therefore address the tests required to demonstrate compliance for one seat and restraint system installation. A typical use of a seat model on a particular aircraft will involve variations of seat design and installation. Additional tests may be necessary to demonstrate compliance for these variations if analysis is not adequate. An example is the lateral component of the test where it is necessary to consider the effect of loads from either side.

(3) Floor Deformation. The test procedure requires that for structural evaluation the floor should be deformed. The seat and restraint system should also perform properly if the floor remains undeformed.

(4) Head Impact. Occupant head impact with the interior of the airplane, should it occur, is evaluated by using a Head Injury Criterion (HIC) that can be measured directly in the tests described in this AC, or in alternative tests of the interior. The HIC is measured on the most critical surface within the ±10 degrees yaw envelope (measurement of the HIC does not supersede the requirements of § 25.785). The HIC does not consider injuries that can occur at low impact velocities from contact with surfaces having small contact areas or sharp edges, especially if those surfaces are relatively rigid.

(5) Femur Injury. Extensive seat testing has shown that the femur loading criterion is not exceeded. For this reason, the femur loads need not be recorded in the individual test if compliance can be shown by rational comparative analysis using data from previous tests.

NOTE: There may be several other aspects of the standardized test procedure that need to be considered when determining the test program required to demonstrate compliance or interpret the test results. The extent of the test program will depend on the most critical case determination and its applicability to other configurations. Further information on this aspect of testing is provided in paragraph 4b.

4. TEST CONDITIONS.

a. General. A minimum of two dynamic tests are required to assess the performance of an airplane seat, restraints, and related interior system. The seat, the restraint, and the nearby interior are all considered to act together as a system to provide protection to the occupant during a crash. For side-facing seats, there may be additional criteria necessary to determine that these seats provide the same level of safety as is intended by the regulation. (See paragraph 9d for additional considerations regarding side- facing seats.)

(1) Test 1 (Figure 1), as a single row seat test, determines the performance of the system in a test condition where the predominant impact force component is along the spinal column of the occupant, in combination with a forward impact force component. This test evaluates the structural adequacy of the seat, critical pelvic/lumbar column forces, and permanent deformation of the structure under downward and forward combined impact loading, and may yield data on ATD head displacement, velocity, and acceleration time histories.

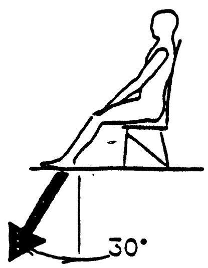
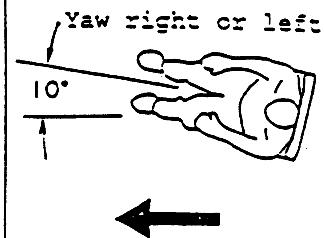
(2) Test 2 (Figure 1), as a single row seat test, determines the performance of a system in a test condition where the predominant impact force component is along the longitudinal axis of the airplane and is combined with a lateral impact force component. This test evaluates the structural adequacy of the seat, permanent deformation of the structure, and the pelvic restraint and upper torso restraint (if applicable) behavior and loads, and may yield data on ATD head displacement, velocity, and acceleration time histories, and the seat leg loads imposed on the seat tracks or attachment fittings.

This test requires simulating airplane floor deformation by deforming the test fixture, as respectively prescribed in Figures 1 and 2 for single occupant and multiple occupant seats, prior to applying the dynamic impact conditions. The purpose of providing floor deformation for the test is to demonstrate that the seat/restraint system will remain attached to the airframe and perform properly, even though the airplane and/or seat are deformed by the forces associated with a crash.

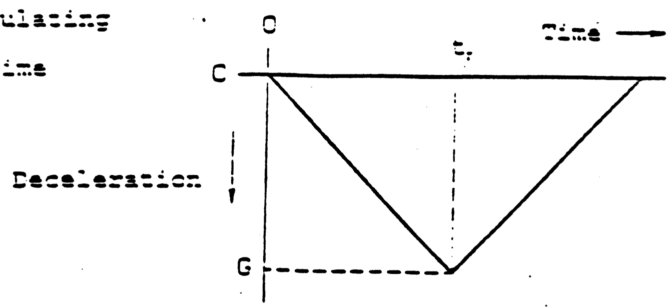
(3) For seats placed in repetitive rows, an additional test condition, using two seats in tandem placed at representative fore and aft distance between the seats (seat pitch), similar to Test 2 with or without the floor deformation directly evaluates head and femur injury criteria (the floor deformation is required if the test also demonstrates structural performance). These injury criteria are dependent on seat pitch, seat occupancy, and the effect of hard structures within the path of head

excursions in the ±10 degrees yaw attitude range of the Test 2 conditions. The test procedure using the appropriate data obtained from Test 2, as described in paragraph 12d, may be an alternative to multiple row testing.

NOTE: It may be possible to evaluate the HIC using alternative tests. Specific methodologies will require acceptance for certification.

Illustration shows a forward-facing seat Inertial load shown by arrow	TEST 1	TEST 2
		
Min V_i m/s (ft/s)	10.67 (35)	13.41 (44)
Max t_r s	0.08	0.09
Min G.	14	16
Deform floor:		
Degrees roll	0	10
Degrees pitch	0	10

Test Pulse Simulating Aircraft Floor Deceleration-Time History:



t_r = Rise time
V_i = Impact velocity

Figure 1. Type A Seat/Restraint System Dynamic Tests

b. Consideration of test criteria. The tests should be planned to achieve "most critical" conditions for the criteria that make up each test.

(1) For multiple place seats, a rational structural analysis shall be used to determine the number and seat location for the ATDs and the direction for seat yaw in Test 2 to provide the most critical seat structural test. This will usually result in unequally loaded seat legs. The floor deformation procedure shall be selected to increase the load on the highest loaded seat leg and to load the floor track or fitting in the most severe manner.

(2) If multiple-row testing is used to gather data to assess head and femur injury protection in passenger seats, the seat pitch shall be selected so that the head would be most likely to contact hard structure in the forward seat row. The effect of the 10 degree yaw in Test 2, the seat back breakover, and front seat occupancy shall be considered. Results from previous tests or rational analysis may be used to estimate the head strike path of similar seats in similar installations. The front row may be unoccupied.

(3) If non-symmetrical upper torso restraints (such as single diagonal shoulder belts) are used in a system, they shall be installed on the test fixture in a position representative of that in the airplane and which would most likely allow the ATD to move out of the restraint. For example, in a forward-facing crew seat equipped with a single diagonal shoulder belt, the seat should be yawed in Test 2 in a direction such that the belt passes over the trailing shoulder.

(4) If a seat has vertical or horizontal adjustments, it shall be tested in the position that produces the most critical loads on the seat structure (typically the highest vertical position). Positions prohibited for takeoff and landing need not be considered. Seat adjustments that do not have a significant effect on structural loading (e.g., thigh support angle, lumbar support, armrest and headrest positions) shall be tested in the design positions for the 50th-percentile male occupant, unless special requirements dictate the positions allowed for takeoff and landing.

5. TEST ARTICLES.

a. General. In all cases, the test article must be representative of the final production article in all structural elements, and shall include the seat cushions, restraints, and armrests. It must also include a functioning position adjustment mechanism and correctly adjusted breakover (if present). Food trays or any other service or accouterment that are part of the seat design must be representative of the final production item if they influence seat stiffness or head impact. Otherwise they and any other items of mass that are carried on or positioned by the seat structure e.g., weights simulating luggage carried by luggage restraint bars [90 N (20 lb) per passenger place], fire extinguishers, survival equipment, emergency equipment etc.

need only be representative masses. If these items of mass are placed in a position that could limit the function of an energy-absorbing feature in the test article, they should be of representative shape and stiffness, as well as weight. In addition, items of mass of any significance could become both an evacuation hazard, as well as dangerous projectiles. Nonetheless, detachment of certain items, such as an in-arm ashtray or decorative trim, can be considered inconsequential and should not be grounds for re-test (the means of restraint should be improved, however). In any case, the separation of an item of mass should not leave any sharp or injurious edges. Function of equipment or systems after the test is not required. Once an item of mass has been demonstrated to be retained in its critical loading case, subsequent tests may be conducted with the item secured for test purposes. This AC does not establish operational requirements for equipment attached to the seat system.

b. Selection of test articles. Many designs comprise a family of seats that have the same basic structural design but differ in detail. For example, a basic seat frame configuration can allow for several different seat leg locations to permit installation in different airplanes. If these differences are of a nature that their effect can be determined by rational analysis, then the analysis can determine the most critical configuration. As a minimum, the most highly stressed configuration shall be selected for the dynamic tests so that the other configurations could be accepted by comparison with that configuration. For Test 2, there are two factors that need to be considered in selecting the critical structural test configurations. First, the seat to airplane interface loads (undeformed seat) can be determined by rational analysis for all seat design and load configurations. The rational analysis can be based on static or dynamic seat/occupant analytical methods. That rational analysis can form the basis for selecting the most highly stressed critical configuration based on load. Additionally, the effects of seat deformation should also be considered. As noted, a family of seats typically includes seat models with varied seat leg locations. The effects of floor deformation are more critical for narrow spaced seat legs. Thus, a test or rational analysis of the seat model with the minimum seat leg spacing needs to be conducted to evaluate the most highly stressed critical configuration based on deformation.

The following additional items shall be considered in choosing test articles and the manner of loading:

(1) If a multiple-place seat incorporates energy-absorbing or load-limiting features that are necessary to meet the test criteria or other requirements, a partially occupied seat may adversely affect the performance of that seat. In such a case it shall be shown, by rational analysis or additional testing, that the seat will continue to perform as intended, even with fewer occupants.

(2) If different configurations of the same basic design incorporate load-carrying members, especially joints or fasteners, that differ in detail design, the performance of each detail design should be demonstrated in a dynamic test. Experience has shown that small details in the design often cause problems in meeting the test performance criteria.

(3) Additional dynamic impact testing may be required for a seat with features that could affect its performance, even though the test may not be the most critical case based on structural performance. For example, if in one of the design configurations the restraint system attachment points are located so that the pelvic restraint is more likely to slip above the ATD's pelvis during the impact, that configuration should also be dynamically tested, even though the structural loading might be less than the critical configuration in a family of seats.

(4) Typical dress cover materials, including synthetic and natural fabrics, and leather, can be used on a seat without testing more than one material, or substituted on an already certificated seat. Evaluation of such materials has shown the effect on test results is small, particularly considering other factors such as occupant clothing. It is possible that some unusual seat surfaces such as hard plastics, which exhibit very low friction coefficients, may require some additional substantiation.

6. TEST FACILITIES.

a. General. There are a number of test facilities that can be used to accomplish dynamic testing. These can be grouped into categories based on the method used to generate the impact pulse (i.e., accelerators, decelerators, or impact with rebound), and whether the facility is a horizontal (sled) design or a vertical (droptower) arrangement. Each of the designs has characteristics that have advantages or disadvantages with regard to the dynamic tests discussed in this AC. One concern is the rapid sequence of acceleration and deceleration that must take place in the tests. In an airplane crash, the acceleration phase is always gradual, and usually well separated in time from the deceleration (crash) phase. In a test, the deceleration always closely follows the acceleration. When assessing the utility of a facility for the specific test procedures outlined in the recommendations, it is necessary to understand the possible consequences of this rapid sequence of acceleration and deceleration.

b. Deceleration sled facilities. In an airplane crash, the impact takes place as a deceleration, so loads are applied more naturally in test facilities that create the test impact pulse as a deceleration. Since it is simpler to design test facilities to extract energy in a controlled manner than to impart energy in a controlled manner, several different deceleration sled facilities can be found. The deceleration sled facility at the Federal Aviation Administration's Civil Aeromedical Institute (CAMI) was used in developing the test procedures discussed in this AC. The acceleration phase of the test, where sufficient velocity for the test impact pulse is acquired, can distort the test results if the acceleration is so high that the test articles or ATDs are moved from their intended pre-test position. This inability to control the initial conditions of the test would directly affect the test results. This can be avoided by using a lower acceleration for a relatively long duration and by providing a coast phase (in which the acceleration or deceleration is almost zero) prior to the impact. This allows any dynamic oscillation in the test articles or the ATD, which might be caused by the acceleration, to decay. To guard against errors in data caused by pre-impact accelerations, data from the electronic test measurements (accelerations, loads) should be reviewed for the time period just before the test impact pulse to make sure all measurements are at the baseline (zero) level. Photometric film taken of the test should also be reviewed to make certain that the ATDs used in the test and the test articles were all in their proper position prior to the test impact pulse.

The horizontal test facility readily accommodates forward-facing seats in both tests discussed in this AC, but problems can exist in positioning the test ATDs in Test 1 if the seat is a rearward-facing or side- facing seat. In these cases, the ATDs tend to fall out of the seat due to the force of gravity and must be restrained in place using break-away tape, cords, or strings. Since each installation will present its own problems, there is no simple, generally applicable, guidance which can be given for doing this. Attention should be given to positioning the ATD against the seat back, and to proper positioning of the ATD's arms and legs. It will probably be necessary to build special supports for the break-away restraint so that they will not interfere with the function of the seat and restraint system during the test. Film taken of the test should be reviewed to make sure that the break-away restraint did break (or become slack) in a manner that did not influence the motion of the ATD or the test articles during the test.

c. Acceleration sled facilities. Acceleration sled facilities, usually based on the HYdraulically controlled Gas Energized (HYGE) accelerator device, provide the impact test pulse as a controlled acceleration at the beginning of the test. The test item and the ATDs are installed facing in the opposite direction from the velocity vector, (opposite from the direction used on a deceleration facility) to account for the change in direction of the impact. There should be no problem with the ATD or the test items being out of position due to pre-impact sled acceleration, since there is no sled movement prior to the impact test pulse. After the impact test pulse, when the sled is moving at the maximum test velocity, it must be safely brought to a stop. Most of the facilities of this design have limited track length available for deceleration, so that the deceleration levels can be relatively high and deceleration may begin immediately after the impact test pulse. Since the dynamic response of the system follows (in time) the impact test pulse, any sled deceleration that takes place during that response will affect the response and change the test results. The magnitude of change depends on the system being tested, so that no general "correction factor" can be specified. The affect can be minimized if the sled is allowed to coast, without significant deceleration, until the response is complete. If the seat or restraint system experiences a structural failure during the test pulse, the post-impact deceleration can increase the damage and perhaps result in failures of unrelated components. This will complicate the determination of the initial failure mode, and make product improvement more difficult. One other consideration is that the photometric film coverage of the response to impact test pulse must be accomplished when the sled is moving at near maximum velocity. On-board cameras or a series of track-side cameras are usually used to provide film coverage of the test. Since on-board cameras frequently use a wide angle lens placed close to the test items, it is necessary to account for the effects of distortion and parallax when analyzing the film. The acceleration sled facility faces the same problems in accommodating rearward facing or side-facing seats in Test 1 as the deceleration sled facility, and the corrective action is the same for both facilities.

d. Impact-with-rebound sled facilities. One other type of horizontal test facility used is the "impact-with-rebound" sled facility. On this facility, the impact takes place as the moving sled contacts a braking system, which stores the energy of the impact, and then returns the stored energy back to the sled, causing it to rebound in the opposite direction. This facility has the advantage over acceleration or deceleration facilities in that only one half of the required velocity for the impact would need to be generated by the facility (assuming 100 percent efficiency). Thus, the track length can be shortened and the method of generating velocity is simplified. The disadvantages of this facility combine the problems mentioned above for both acceleration facilities and deceleration facilities. Since one of the reasons for this type of facility is to allow short track length to be used, it may be difficult to obtain sufficiently low acceleration just before or after the impact pulse to resolve data error problems caused by significant pre-impact and post-impact accelerations.

e. Drop towers. Vertical test facilities can include both drop towers (decelerators) and vertical accelerators. Vertical accelerators that can produce the long duration/displacement impact pulse depicted in Figure 1 have not been generally available. However, drop towers are one of the easiest facilities to build and operate, and are frequently used. In these facilities, the pull of earth's gravity is used to accelerate the sled to impact velocity so that the need for a complex mechanical accelerating system is eliminated. Unfortunately, these facilities are difficult to use for conducting Test 2, particularly for typical forward-facing seats. In preparing for this test, the seat must be installed at an angle such that the ATD tends to fall from the seat due to gravity. The restraint system being tested cannot hold the ATD against the seat unless tightened excessively, and will not usually locate the head, arms, or legs in their proper position relative to the seat. Design and fabrication of an auxiliary "break-away" ATD positioning restraint system just for this test is a complex task. The auxiliary restraint must not only position the ATD against the seat (including maintaining proper seat cushion deflection) during the pre-release condition of 1g, it must also maintain the ATD in that proper position during the free fall to impact velocity when the system is exposed to 0g, and then it must release the ATD in a manner that does not interfere with the ATD response to impact. The usual sequence of 1g/0g impact, without the possibility of a useful "coast" phase, as done in horizontal facilities, causes shifts in initial conditions for the test impact pulse which can affect the response to the impact. The significance of this will depend on the dynamic characteristics of the system being tested, and these are seldom known with sufficient accuracy to enable the response to be corrected. In addition, the earth's gravity will oppose the final rebound of the ATDs into the seat back, so that an adequate test of seat back strength and support for the ATD cannot be obtained. The problems in Test 1, or with rear-facing seats in Test 2, are not as difficult because the seat will support the ATD occupant prior to the free fall. However, the 0g condition that exists prior to impact will allow the ATD to "float" in the seat restraint system, perhaps changing position and certainly changing the initial impact conditions. Again, use of an auxiliary break-away restraint system to correct these problems is difficult.

7. ANTHROPOMORPHIC TEST DEVICES.

a. General. The tests discussed in this AC were developed using modified forms of the ATDs specified by the United States Code of Federal Regulations, Title 49, Part 572 Anthropomorphic Test Dummies, Subpart B - 50th Percentile Male. These "Part 572B" ATDs have been shown to be reliable test devices that are capable of providing reproducible results in repeated testing. However, since ATD development is a continuing process, provision was made for using "equivalent" ATDs. ATD types should not be mixed when completing the tests discussed in this AC.

b. Modification to measure pelvic/lumbar load.

(1) To measure the axial compressive load between the pelvis and lumbar column due to vertical impact as well as downward loads caused by upper torso restraints, a load (force) transducer shall be inserted into the ATD pelvis just below the lumbar column. This modification is shown in Figure 2. The illustration shows a commercially available femur load cell, with end plates removed, that has been adapted to measure the compression load between the pelvis and the lumbar column of the ATD.

(2) A femur load cell is selected because of its availability in most test facilities and its ability to measure the compression forces without errors due to sensitivity to shear forces and bending or twisting moments which are also generated during the test. To maintain the correct seated height of the ATD the load cell must be fixed in a rigid cup which is inserted into a hole bored in the top surface of the ATD pelvis. The interior diameter of the cup provides clearance around the outside diameter of the load cell, so that the loads are transmitted only through the ends of the cell. If necessary, ballast shall be added to the pelvis to maintain the weight of the original (unmodified) assembly.

(3) Alternative approaches to measuring the axial force transmitted to the lumbar spinal column by the pelvis are acceptable if the method:

(i) Accurately measures the axial force but is insensitive to moments and forces other than that being measured;

(ii) Maintains the intended alignment of the spinal column and the pelvis, the correct seated height, and the correct weight distribution of the ATD; and

(iii) Does not alter the other performance characteristics of the ATD.

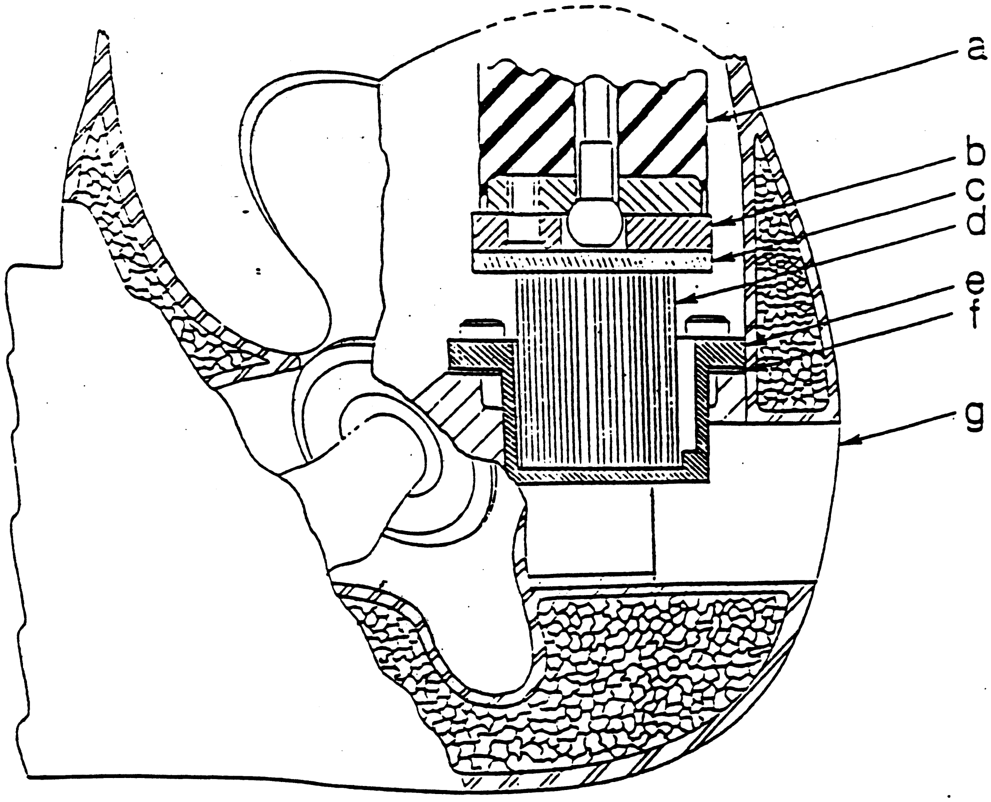


Figure 2. Installation of Pelvic–Lumbar Spine Load Cell in Part 572B ATD.

This illustration shows an acceptable adaptation of a femur load cell (d) at the base of the ATD lumbar spine (a). The load cell is in line with the centerline of the lumbar spine, and set below the top surface of the pelvis casting to maintain the seated height of the ATD. A rigid adapter cup (e) is fabricated to hold the load cell and a hole is bored in the ATD pelvis to accept the cup. Clearance must be provided between the walls of the adapter cup and the load cell for the wires leading from the cell. The bottom of the load cell is bolted to the adapter cup. Adapter plates having similar hold patterns in their periphery are fabricated for the lower surface of the lumbar spine (b) and the upper surface of the load cell (c). These plates are fastened to the lumbar spine and load cell with screws through holes matching threaded holes in those components, and are then joined together by bolts through the peripheral holes. The flange on the adapter cup has a bolt hole pattern that matches that on the pelvis. The cup is fastened to the pelvis using screws to the threaded holes in the pelvis. Spacers (f) may be placed under the flange of the cup to obtain the specified ATD seating height. Additional weight should be placed in the cavity below the adapter cup to compensate for any weight lost because of this modification. The instrument cavity plug (g) is cut to provide clearance for the adapter cup and added weight.

c. Other ATD Modifications.

(1) To prevent failure of the clavicle used in Part 572 Subpart B ATDs due to flailing, a clavicle of the same shape but of higher strength material can be substituted.

(2) Submarining indicators, such as electronic transducers, may be added on the ATD pelvis. These are located on the anterior surface of the ilium of the ATD pelvis without altering its contour, and indicate the position of the pelvic restraint as it applies loads to the pelvis. These indicators can provide a direct record that the pelvic restraint remains on the pelvis during the test, and eliminate the need for careful review of high-speed camera images to make that determination.

d. Equivalent ATDs. The continuing development of ATDs for dynamic testing of seating restraint/crash-injury-protection systems is guided by goals of improved biofidelity (human-like response to the impact environment) and reproducibility of test results. For the purposes of the tests discussed in this AC, these improved ATDs can be considered the equivalent of the Part 572B ATD if:

(1) They are fabricated in accordance with design and production specifications established and published by a regulatory agency that is responsible for crash injury protection systems;

(2) They are capable of providing data for the measurements discussed in this AC or of being readily altered to provide the data;

(3) They have been evaluated by comparison with the Part 572B ATD and are shown to generate similar response to the impact environment discussed in this AC; and

(4) Any deviations from the Part 572B ATD configuration or performance are representative of the occupant of a civil airplane in the impact environment discussed in this AC.

8. INSTRUMENTATION.

a. General.

(1) Electronic and photographic instrumentation systems shall be used to record data for qualification of seats. Electronic instrumentation shall measure the test environment, and measure and record data required for comparison of performance to pass/fail criteria.

(2) Photographic instrumentation shall be used to document the overall results of tests, confirming that the pelvic restraint remains on the ATD's pelvis, and that the upper torso restraint straps remain on the ATD's shoulder during impact,

and documenting that the seat does not deform as a result of the test in a manner that would impede rapid evacuation of the airplane by the occupants and that the seat remains attached at all points of attachment. For passenger seats with lap belt angles of btween 45 and 55 degrees, submarining is typically not a problem. For this reason, a second camera (e.g., an overhead camera) for evaluation of submarining is not necessary.

b. Electronic Instrumentation. Electronic instrumentation should be accomplished in accordance with the Society of Automotive Engineers Recommended Practice SAE J211, "Instrumentation for Impact Tests." In this practice, a data channel is considered to include all of the instrumentation components from the transducer through the final data measurement, including connecting cables and any analytical procedures that could alter the magnitude or frequency content of the data. Each dynamic data channel is assigned a nominal channel class that is equivalent to the high frequency limit for that channel, based on a constant output/input ratio versus frequency response plot which begins at 0.1 Hz (+1/2 to -1/2 dB) and extends to the high frequency limit (+1/2 to -1 dB). Frequency response characteristics beyond this high frequency limit are also specified. When digitizing data, the sample rate should be at least five times the -3 dB cutoff frequency of the presample analog filters. Since most facilities set all presample analog filters for Channel Class 1000, and since the -3 dB cutoff frequency for channel class 1000 is 1650 Hz, the minimum digital sampling rate would be about 8000 samples per second. For the dynamic tests discussed in this AC, the dynamic data channels shall comply with the following channel class characteristics:

(1) Sled or drop tower vehicle acceleration should be measured in accordance with the requirements of Channel Class 60, unless the acceleration is also integrated to obtain velocity or displacement, in which case it shall be measured in accordance with Channel Class 180 requirements.

(2) Belt-restraint system and seat attachment reaction loads (when measured) shall be measured in accordance with the requirements of Channel Class 60. Loads in restraint systems that attach directly to the test fixture can be measured by three-axis load cells fixed to the test fixture at the appropriate location. These commercially available load cells measure the forces in three orthogonal directions simultaneously, so that the direction as well as the magnitude of the force can be determined. If desired, similar load cells can be used to measure forces at other boundaries between the test fixture and the test item, such as the forces transmitted by the legs of the seat into the floor track. It is possible to use independent, single axis load cells arranged to provide similar data, but care should be taken to use load cells that can withstand significant cross axis loading or bending without causing errors in the test data.

(3) ATD head accelerations used for calculating the Head Injury Criterion (HIC) should be measured in accordance with the requirements of Channel Class 1000.

(4) ATD femur forces should be measured in accordance with Channel Class 600.

(5) ATD pelvic/lumbar column force shall be measured in accordance with the requirements of Channel Class 600.

(6) The full-scale calibration range for each channel shall provide sufficient dynamic range for the data being measured.

(7) Digital conversion of analog data shall provide sample resolution of not less than 1 percent of full-scale input.

c. Photographic Instrumentation. Photographic instrumentation shall be used for documenting the response of the ATDs and the test items to the dynamic test environment. Both high-speed and still image systems should be used.

(1) High speed cameras that provide data used to calculate displacement or velocity shall operate at a nominal speed of 500 frames per second. Photo instrumentation methods shall not be used for measurement of acceleration. The locations of the cameras and of targets or targeted measuring points within the field of view shall be measured and documented. Targets shall be at least 1/100 of the field width covered by the camera and shall be of contrasting colors or shall contrast with their background. The center of the target shall be easily discernible. Rectilinearity of the image shall be documented. If the image is not rectilinear, appropriate correction factors shall be used in the data analysis process. Photographic instrumentation should be in accordance with SAE J211, part 2.

(2) A description of photographic calibration boards or scales within the camera field of view, the camera lens focal length, and the make and model of each camera and lens shall be documented for each test. Appropriate digital or serial timing shall be provided on the image media. A description of the timing signal, the offset of timing signal to the image, and the means of correlating the time of the image with the time of electronic data shall be provided. A rigorous, verified analytical procedure shall be used for data analysis.

(3) Cameras operating at a nominal rate of 200 frames per second or greater may be used to document the response of ATDs and test items if measurements are not required. For example, actions such as movement of the pelvic restraint system webbing off of the ATD's pelvis can be observed by documentation cameras placed to obtain a "best view" of the anticipated event. These cameras shall be provided with appropriate timing and a means of correlating the image with the time of electronic data.

(4) Still image cameras shall be used to document the pre-test installation and the post-test response of the ATDs and the test items. At least four

pictures shall be obtained from different positions around the test items in pre-test and post-test conditions. Where an upper torso restraint system is installed, post-test pictures shall be obtained before moving the ATD. For additional post-test pictures, the ATD's upper torso may be rotated to its approximate upright seated position so that the condition of the restraint systems may be better documented, but no other change to the post-test response of the test item or the ATD shall be made. The pictures shall document whether the seat remained attached at all points of attachment to the test fixture.

(5) Still pictures may also be used to document post-test yielding of the seat for the purpose of showing that it would not impede the rapid evacuation of the aircraft occupants. The ATD should be removed from the seat in preparation for still pictures used for that purpose. Targets or an appropriate target grid should be included in such pictures, and the views should be selected so that potential interference with the evacuation process can be determined. For tests where the ATD's head impacts a fixture or another seat back, pictures shall be taken to document the head contact areas.

9. TEST FIXTURES.

a. General. A test fixture is required to position the test article on the sled or drop carriage of the test facility and takes the place of the airplane's floor structure. It does not need to simulate the airplane floor flexibility. It holds the attachment fittings or floor tracks for the seat and provides the floor deformation if needed for the test; it provides anchorage points if necessary for the restraint system; it provides a floor or footrest for the ATD; and it positions instrument panels, bulkheads, or a second row of seats, if required.

b. Floor Deformation.

(1) Purpose of floor deformation. The purpose of providing floor deformation for the longitudinal tests is to demonstrate that the seat system will remain attached and perform properly, even though the seat or airframe may be deformed by the forces associated with the crash. Floor deformation is not required for demonstrating compliance with injury criteria.

(2) Floor Deformation Fixture. For the typical seat with four seat legs mounted in the aircraft on two parallel tracks, the floor deformation test fixture shall consist of two parallel beams: a pitch beam that pivots about a lateral (y) axis and a roll beam that pivots about a longitudinal (x) axis (see Figure 3 for a schematic representation). The beams can be made of any rigid structural form: box, I-beam, channel, or other appropriate cross section. The pitch beam shall be capable of rotating in the x-z plane up to ±10 degrees relative to the longitudinal (x) axis. The roll beam should be capable of ±10 degrees roll about the centerline of floor tracks or fittings. A means shall be provided to fasten the beams in the deformed positions.

The beams should have provision for installing floor track or other attachment fittings on their upper surface in a manner that does not alter the above-floor strength of the track or fitting. The track or other attachment fittings must be representative in above-floor configuration and strength to that which would be used in the airplane. Structural elements below the surface of the floor that are not considered part of the floor track or seat attach fitting need not be included in the installation. Appropriate safety precautions should be taken while imposing floor deformations.

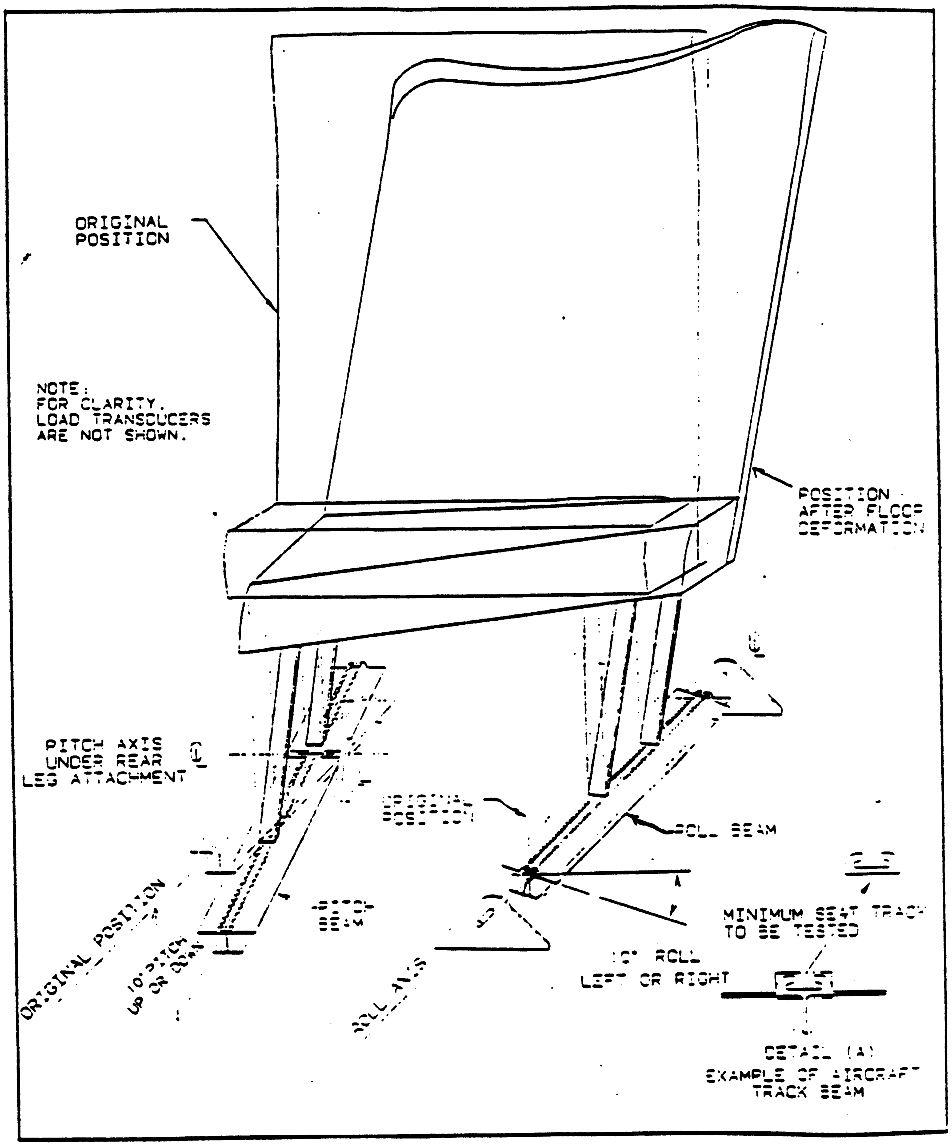


Figure 3.
Schematic Floor Deformation Fixture; Seat Legs Attached at Floor Level

(3) Airplane Floor Track or Attachment Fitting Simulation. An example of the minimum required representation of a floor track is shown in Detail A of Figure 3 for one type of seat track. The track, or other attachment fittings, must be representative of those used in the airplane. Alternatively, three components of reaction forces and three components of reaction moments may be measured during dynamic tests. These six components may be applied simultaneously, by a separate static or dynamic test, to a track or attachment fitting used on an airplane, or to a more critical track or attachment fitting than that used on an airplane, to demonstrate that the loads measured in the dynamic impact test will not fail the track or attachment fitting used on an airplane.

(4) Load Transducer Installation (Optional). The pitch and roll beams should have provisions for installing individual load transducers at each seat leg attachment point capable of measuring three reaction forces and, if necessary, three reaction moments (see paragraph 9b(3)). The load transducers should have provisions to install floor track or other attachment fittings on their upper surface in a manner that does not alter the above-floor strength of the track or fitting.

c. Other Mounting Configuration Constraints. The preceding discussion describes the fixture and floor deformation procedure that would be used for a typical seat that uses four seat legs and four attachments to the aircraft floor. These test procedures are not intended to be restricted only to those seat configurations, but shall be adapted to seats having other designs. Special test fixtures may be necessary for those different configurations. The following methods, while not covering all possible seat designs, shall be followed for the more common alternatives:

(1) Airplane seats with three legs may have one central leg at the front or back of the seat, and one leg on each side of the seat. The central leg shall be held in its undeformed position as deformation is applied to the side legs.

(2) Seats that have more than two pairs of legs should be tested with the floor warpage condition that results in the most critically stressed condition. This typically involves warping adjacent pairs of legs. Seats that employ several pairs of legs, ganged together by common cross tubes, can be distorted so that one pair (the critical pair) of legs is rolled, while the remaining legs on one side of the critical leg are pitched in unison. The legs that are pitched should be selected to increase the load on the critical leg, and stress the floor or track fitting in the most severe manner (see Figures 4 and 5).

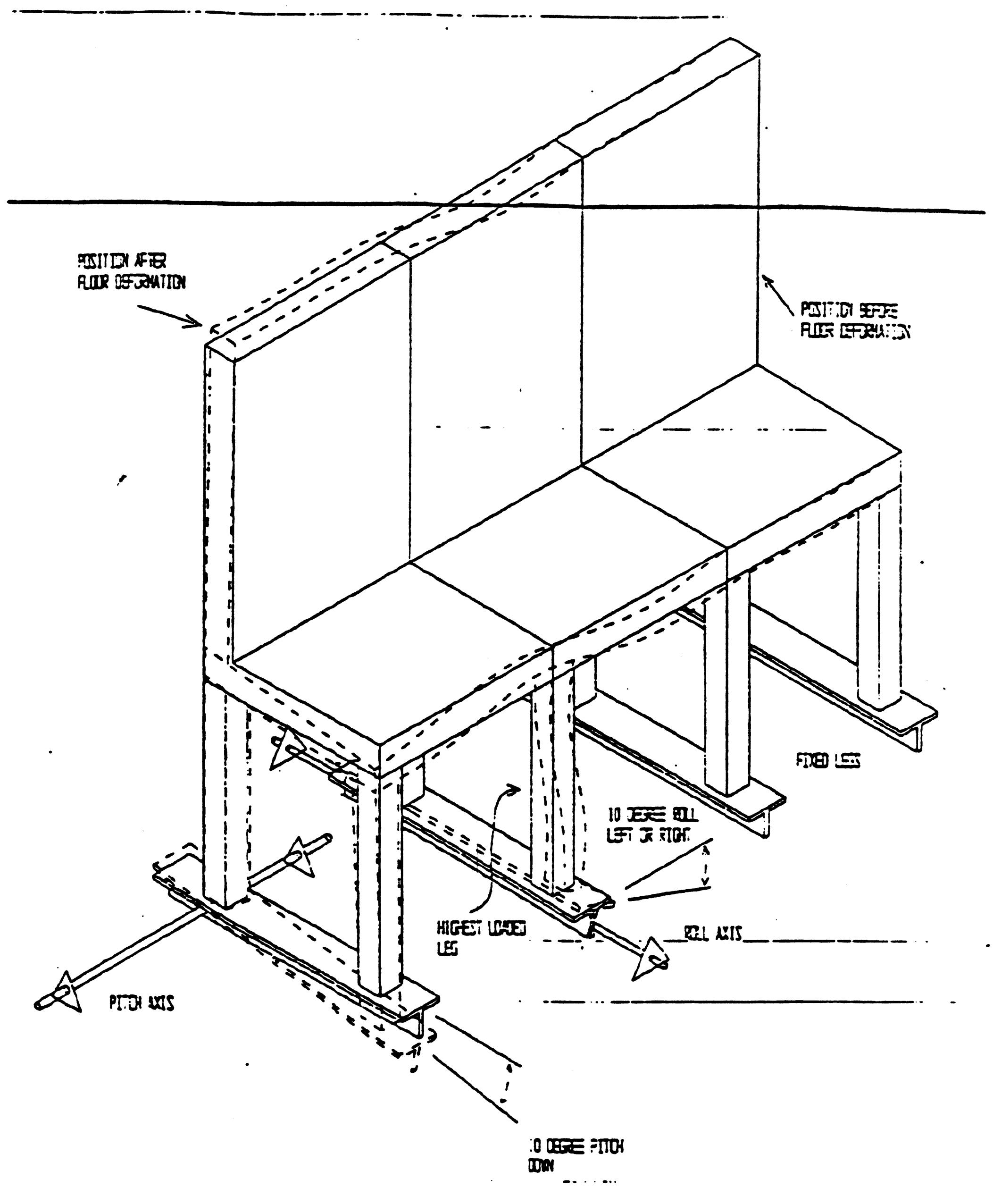

POSITION AFTER FLOOR DEFORMATION
POSITION BEFORE FLOOR DEFORMATION
FIXED LEGS
10 DEGREE ROLL LEFT OR RIGHT
HIGHEST LOADED LEG
ROLL AXIS
PITCH AXIS
10 DEGREE PITCH DOWN

Figure 4.

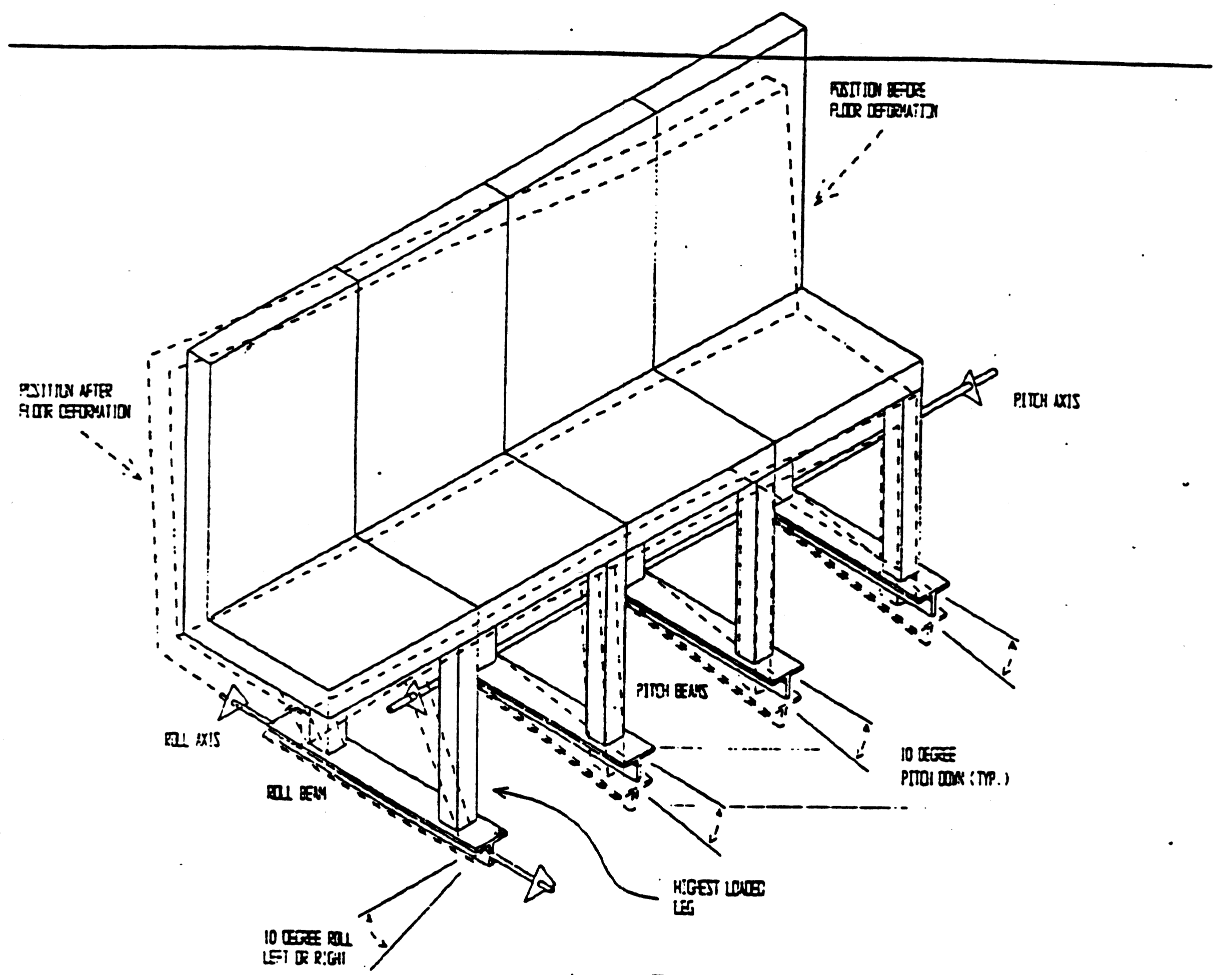

POSITION BEFORE
FLOOR DEFORMATION
POSITION AFTER
FLOOR DEFORMATION
PITCH AXIS
PITCH BEAMS
ROLL AXIS
ROLL BEAM
10 DEGREE
PITCH DOWN (TYP.)
HIGHEST LOADED
LEG
10 DEGREE ROLL
LEFT OR RIGHT

Figure 5.

(3) Seats that are wall-mounted must be evaluated individually. There are several types of mounting schemes, some of which are discussed below. As noted in the preamble to Amendment 25-64, the dynamic impact pulses defined in § 25.562 are considered compatible with existing airframe structure. The definition of the test fixture required for floor-mounted seats takes this into account, so that extensive floor structure is not necessary for test; that is, only the seat track above the floor is used. The important consideration is the retention of the seat under dynamic conditions, and the test setup should account for this in wall-mounted seats as well. The following guidance has been established with this objective in mind.

(i) Seats that are mounted to primary airplane structure, such as a pressure bulkhead, need only be tested with the attachment fitting mounted to rigid structure, in a manner equivalent to the production installation.

(ii) Seats mounted to a structure, such as a structural bulkhead, galley or lavatory, where no integral structural members are used for attachment, should be tested with the seat attached to segments of the mounting surface. These segments are typically eight inch by eight inch sections of the panel. These sections can, in turn, be mounted to a rigid structure.

(iii) Seats that are mounted to single panel furnishings, such as class dividers or windscreens, where the panel essentially fulfills the role of the legs, should be treated the same as floor mounted seats. For the purpose of conducting tests, the entire assembly, including the panel and its attachments, should be included in the test setup. In this case, floor warpage should be applied to track-mounted furnishings.

(4) Seats that are attached to both the floor and a bulkhead should be tested on a fixture that positions the bulkhead surface in a plane through the axis of rotation of the pitch beam. The bulkhead surface should be located perpendicular to the plane of the floor (the airplane floor surface, if one were present) in the undeformed condition, or in a manner appropriate to the intended installation. Either a rigid bulkhead simulation or an actual bulkhead panel can be used. If a test fixture with a rigid bulkhead simulation is used, the seat restraint system shall attach to fittings installed in a test panel equivalent to those used in the actual installation. The seat should be attached to the bulkhead and the floor in a manner representative of the airplane installation, and the floor shall then be deformed as described in paragraph 9b.

(5) Seats that are mounted between sidewalls or to the sidewall and floor of an aircraft shall be tested in a manner that simulates airplane fuselage cross-section deformation during a crash. Brackets shall be provided to attach the seat to the test fixture at the same level above the fixture floor representing the installation above the airplane floor where the inboard tracks or attachment is located. The roll axis should be approximately at the center of the outboard track.

A sidewall bracket shall be located on the roll beam. Then, as the beams are rotated to produce the most critical loading condition (sidewall rotates outward), the combined angular and transitional deformation will simulate the deformation that could take place in a crash (see Figure 6 for a schematic representation). The seat positioning pins or locks shall be fastened in the same manner as would be used in the airplane, including the adjustment of anti-rattle mechanisms, if provided.

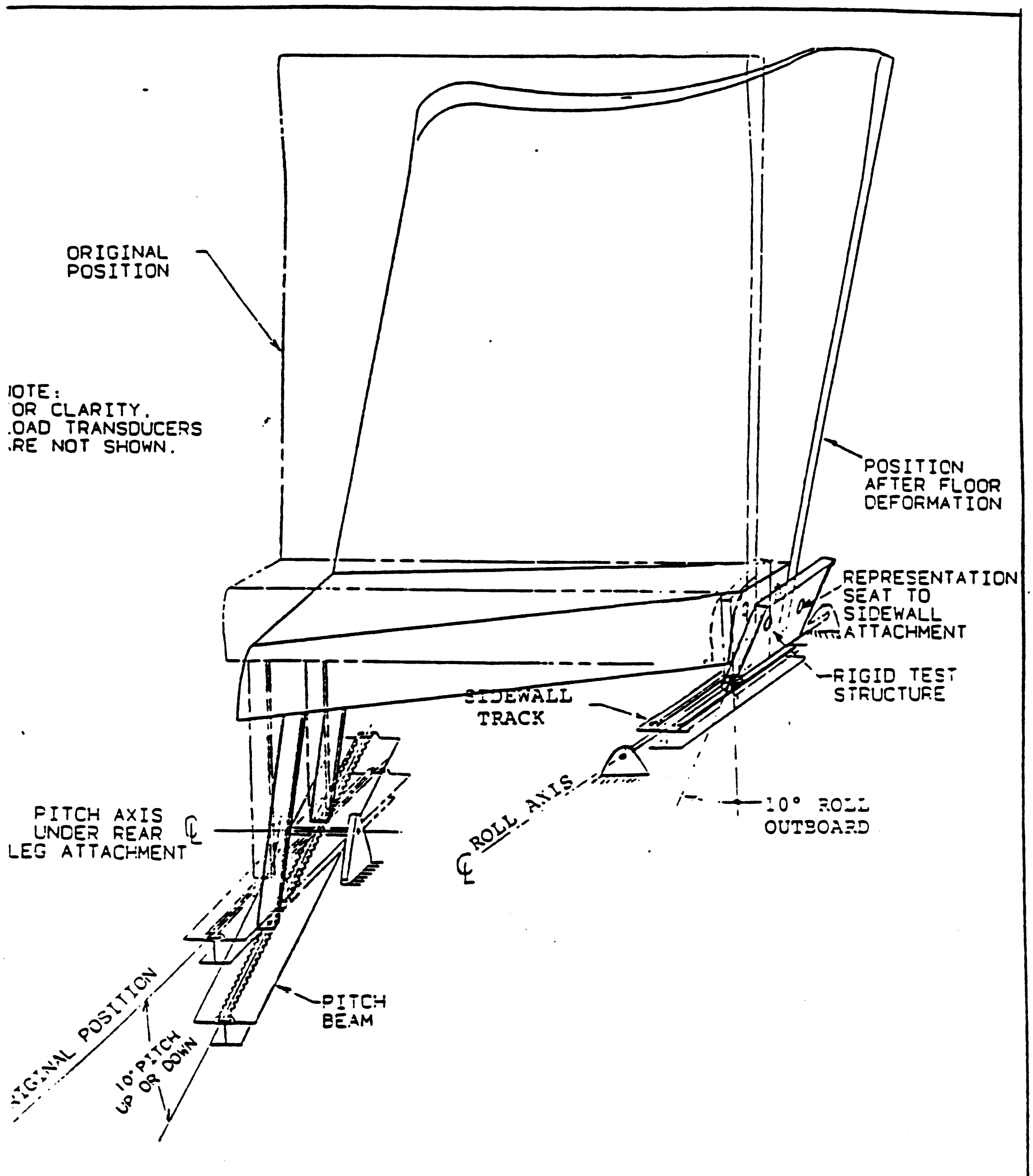


Figure 6. Schematic Test Fixture; Sidewall Mounted Seat

(6) <u>Seats that are cantilevered from one sidewall without connection to other structure</u> are not subject to floor deformation. A determination shall be made whether sidewall deformations could be expected that could generate a condition critical for seat performance in a crash. If sidewall deformation is likely, the entire sidewall attachment plane, or the attachment points, shall be deformed in a manner to represent the sidewall deformation. Either a rigid sidewall simulation or an actual sidewall panel may be used. If a test fixture with a rigid sidewall simulation is used, the seat/restraint system shall be attached to fittings installed in a test panel equivalent to those used in the actual installation.

(7) Seats that are mounted on a plinth. Where the plinth is used to mount a single seat, and the plinth is attached to the floor, the plinth should be considered as part of the seat assembly as an adaptor and should be deformed as described in paragraph 9b. Any items of mass attached to the plinth need to be represented and included in the dynamic testing.

(8) Seats that are mounted on a pallet (e.g., multiple seat rows). The pallet is considered part of the floor structure of the airplane. The seats should be attached to the pallet in a manner representative of the airplane installation. The seat legs should be deformed as described in paragraph 9b. Any items of mass attached to the pallet and not part of the seat structure do not need to be included in the dynamic testing.

d. <u>Side-Facing Seats</u>.

(1) <u>General</u>. All seats occupiable for takeoff and landing are subject to the specified dynamic test conditions, including side-facing seats, both single occupancy and multiple place (e.g. divans). Compliance with the structural requirements should be demonstrated for side-facing seats using the same conditions for the test and pass/fail criteria as for fore- and aft-facing seats. The seat should be loaded in the most critical case structurally. Means of restraining the ATDs may need to be adapted to ensure adequate retention during the test. The application of floor distortion will need to be assessed on an individual basis, depending on the design of the fixation of the seat. The injury criteria of § 25.562 are not adequate to demonstrate equivalent safety of side-facing seats when compared to fore- and aft-facing seats. To demonstrate equivalent safety fully in the absence of such specified criteria, the applicant must use other injury criteria which may be derived from the automotive industry, which uses side impact ATDs.

(2) Assessment Criteria. Research into side-facing seats is ongoing; therefore, in the absence of specific compliance guidance, the FAA is prepared to assess side-facing seats on the following basis:

(i) The seat must demonstrate compliance with the structural requirement.

(ii) If an acceptable side impact ATD has not been used with assessment of the corresponding injury criteria, it must be shown that the occupants are restrained in such a manner that prevents substantial energy absorption by body to body contact (on a multiple occupancy seat), and which, using the best available engineering judgment, minimizes injury to the occupant(s).

(iii) As research proceeds, the FAA will work toward establishing a more definitive policy with respect to the acceptance of side-facing seats.

e. Multiple Row Test Fixtures. In tests of passenger seats that are normally installed in repetitive rows in the airplane, head and knee impact conditions are best evaluated through tests that use at least two rows of seats. These conditions are usually critical only in Test 2. This test allows direct measurements of the head and femur injury data (see Figure 1).

(1) The fixture shall be capable of setting the airplane longitudinal axis at a yaw angle of -10 to +10 degrees. The fixture should also allow adjustment of the seat pitch and installation angle with respect to the airplane center line.

(2) To allow direct measurement of head acceleration for the head injury assessment of a seat installation where the head of the occupant is within striking distance of structure, a representative impact surface may be attached to the test fixture in front of the seat at the orientation and distance from the seat representing the airplane installation.

f. Other Fixture Applications. Test fixtures should provide a flat footrest for ATDs used in tests of passenger seats and crewmember seats that are not provided with special footrests or foot-operated airplane controls. The surface of the footrest shall be covered with carpet (or other appropriate material) and be at a position representative of the floor in the airplane installation. Test fixtures used for evaluating crew seats that are normally associated with special footrests or foot-operated controls shall simulate those components. Note: A footrest is optional for test 2 (see paragraph 10f). Test fixtures may also be required to provide guides or anchors for restraint systems or for holding instrument panels or bulkheads, if necessary, for the planned tests. If these provisions are required, the installation shall represent the configuration of the airplane installation and be of adequate structural strength.

10. Test Preparation.

a. Preparation for the tests will involve positioning and securing the ATD, the ATD restraint system, the seat, and the instrumentation. This will be done for the specific critical condition being tested. Preparations that pertain to the normal operation of the test facility, such as safety provisions and the actual procedures for accomplishment of the tests, are specific to the test facility and will not be addressed in this AC.

b. Use of anthropomorphic dummies. Anthropomorphic dummies used in the tests discussed in this AC should be maintained to perform in accordance with the requirements described in their specification. Periodic teardown and inspection of the ATD should be accomplished to identify and correct any worn or damaged components, and appropriate ATD calibration tests (as described in their specification) should be accomplished if major components are replaced. For the tests discussed in this AC, the following procedures have been found to be adequate:

(1) Since extremes of temperature and humidity can affect ATD performance, the ATDs should be maintained at a temperature range between 66 to 78 degrees F (19 to 26 degrees C) and at a relative humidity from 10 to 70 percent for a minimum of 4 hours prior to the test.

(2) Each ATD should be clothed in form-fitting cotton stretch garments with short sleeves, mid-calf length pants, and shoes (size 11E) weighing about 2.5 pounds. The color of the clothing should be in contrast to the color of the restraint system.

(3) For tests where the ATD's head is expected to impact a fixture or another seat back, the head and face of the ATD may be treated with a suitable material to mark head contact areas. The material used must not reduce the resulting HIC values.

(4) The friction in limb joints should be set so that they barely restrain the weight of the limb when extended horizontally.

(5) The ATD should be placed in the center of the seat, in as nearly a symmetrical position as possible. The ATD should be placed in the seat in a uniform manner so as to obtain reproducible test results.

(6) The ATD's back should be against the seat back without clearance. This condition can be achieved if the ATD's legs are lifted as it is lowered into the seat. Then, the ATD is pushed back into the seat back as it is lowered the last few inches into the seat pan. Once all lifting devices have been removed from the ATD, the ATD should be "rocked" slightly to settle it in the seat.

(7) The ATD's knees should be separated about four inches.

(8) The ATD's hands should be placed on the top of it's upper legs, just behind the knees. If tests on crew seats are conducted in a mockup that has airplane controls, the ATD's hands should be lightly tied to the controls.

(9) The feet should be in the appropriate position for the type of seat tested (flat on the floor for a passenger seat, on control pedals or on a 45 degree footrest for flightcrew systems). The feet should be placed so that the centerlines of

the lower legs are approximately parallel, unless the need for placing the feet on airplane controls dictates otherwise.

c. Seat adjustment. To the extent that they influence the injury criteria, all seat adjustments and controls should be in the design position intended for the 50th percentile male occupant. If seat restraint systems are being tested that are to be used in applications where special requirements dictate their position for landing or takeoff, those positions should be used in the tests.

d. Installation of instrumentation. Professional practice should be followed when installing instrumentation. Care should be taken when installing the transducers to prevent deformation of the transducer body that could cause errors in data. Lead-wires should be routed to avoid entanglement with the ATD or test article, and sufficient slack should be provided to allow motion of the ATD or test article without breaking the lead-wires or disconnecting the transducer. Calibration procedures should consider the effect of long transducer lead-wires. Head accelerometers and femur load cells should be installed in the ATD in accordance with the ATD specification and the instructions of the transducer manufacturer. The load cell between the pelvis and the lumbar column should be installed in accordance with the approach shown in Figure 2 of this AC, or in a manner that will provide equivalent data (see paragraph 7b).

(1) If an upper torso restraint is used, the tension load should be measured in a segment of webbing between the ATD's shoulders and the first contact of the webbing with hard structure (the anchor point or a webbing guide). Restraint webbing should not be cut to insert a load cell in series with the webbing, since that will change the characteristics of the restraint system. Load cells that can be placed over the webbing without cutting are commercially available. They should be placed on free webbing to minimize contact with hard structure, seat upholstery, or the ATD during the test. They should not be used on double-reeved webbing, multiple-layered webbing, locally stitched webbing, or folded webbing, unless it can be demonstrated that these conditions do not cause errors in the data. These load cells should be calibrated using a length of webbing of the type used in the restraint system. If the placement of the load cell on the webbing causes the restraint system to sag, the weight of the load cell can be supported by light string or tape that will break away during the test.

(2) Since load cells are sensitive to the inertial forces of their own internal mass and to the mass of fixtures located between them and the test article, as well as to forces applied by the test article, it may be necessary to compensate the test data for that inaccuracy if the error is significant. Data for such compensation will usually be obtained from an additional dynamic test that replicates the load cell installation, but does not include the test item.

e. Restraint system adjustment. The restraint system adjustment should be made as follows: The restraint system shall not be tightened beyond the level that could reasonably be expected in use, and the emergency locking device (inertia reel) shall not be locked prior to the impact. Automatic locking retractors shall be allowed to perform the webbing retraction and automatic locking function without assistance. Care shall be taken that emergency locking retractors that are sensitive to acceleration do not lock prior to the impact test because of preimpact acceleration applied by the test facility. If comfort zone retractors are used, they shall be adjusted in accordance with instructions given to the user of the restraint system.

(1) If manual adjustment of the restraint system is required, slack shall be removed, and the restraint system should be snug about the ATD. For test 2, this can normally be determined when two fingers will fit snugly between the belt and the pelvis of the ATD. The restraint system shall be checked and adjusted just prior to the floor deformation phase of the test.

(2) If the system is tested in other than a "horizontal floor" position, the restraint should be properly adjusted with the seat in the "horizontal floor" position and the webbing transducers installed (if required). After sufficient time has elapsed to allow the cushion to reach an equilibrium position, the webbing should be marked to indicate the correct adjustment point. The seat and ATD should then be installed on the fixture in the appropriate dynamic test orientation and the restraint system again adjusted to that same point.

(3) An alternate method to impose a 1-g preload is to measure the position of the ATD hip joints relative to the floor as shown in Figure 7 below. The ATD is then depressed into the cushion to reproduce this relative position after the ATD and seat have been installed on the fixture, as shown in Figure 8. The lap belt may be tightened to maintain this position. This load may make it impossible to insert two fingers between the lap belt and the pelvis of the ATD, but it should not produce a cushion displacement in excess of that measured by placing the ATD on the seat in a 1-g orientation.

STRUCTURAL TESTS,

f. A floor is not required for Test 2, but if a floor is installed, it should not influence the behavior of the seat, or unduly restrict the movement of the ATD's feet. This is a concern especially when floor distortion is applied.

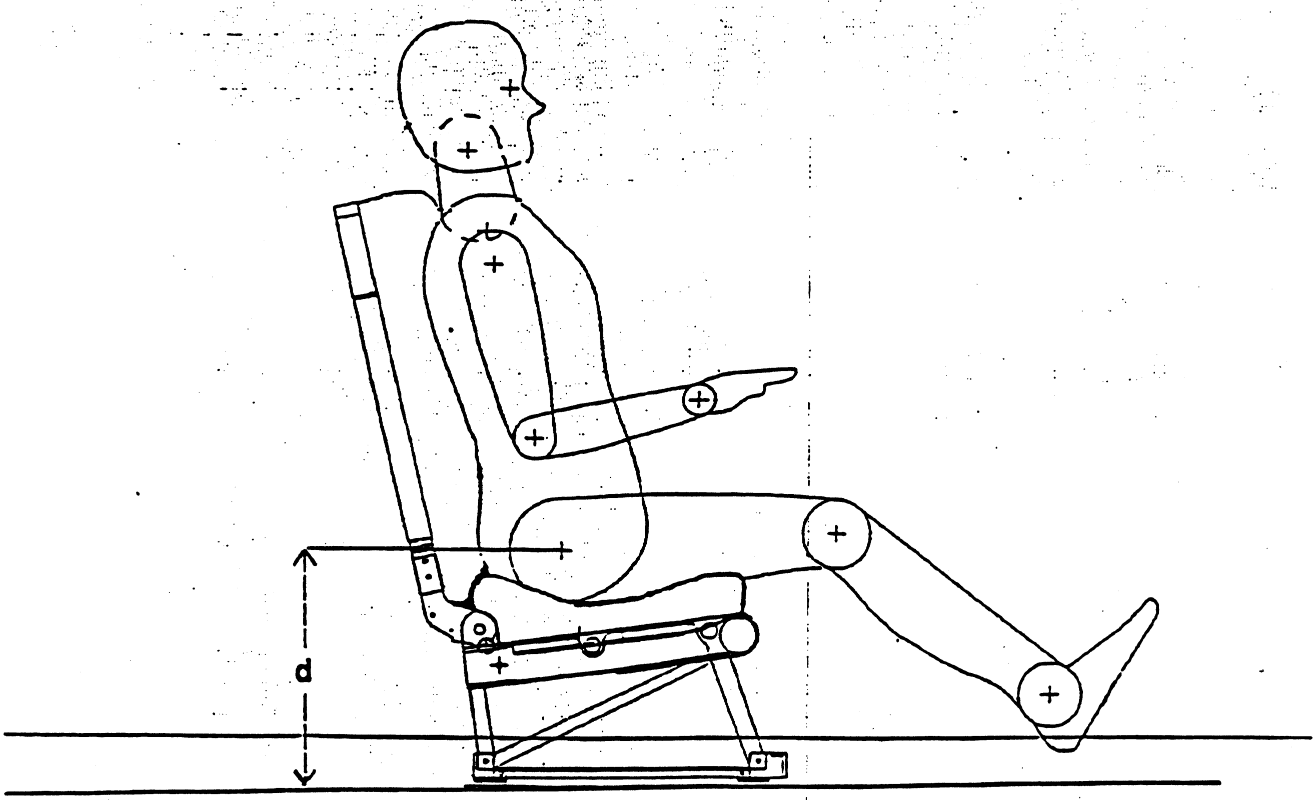


Figure 7.

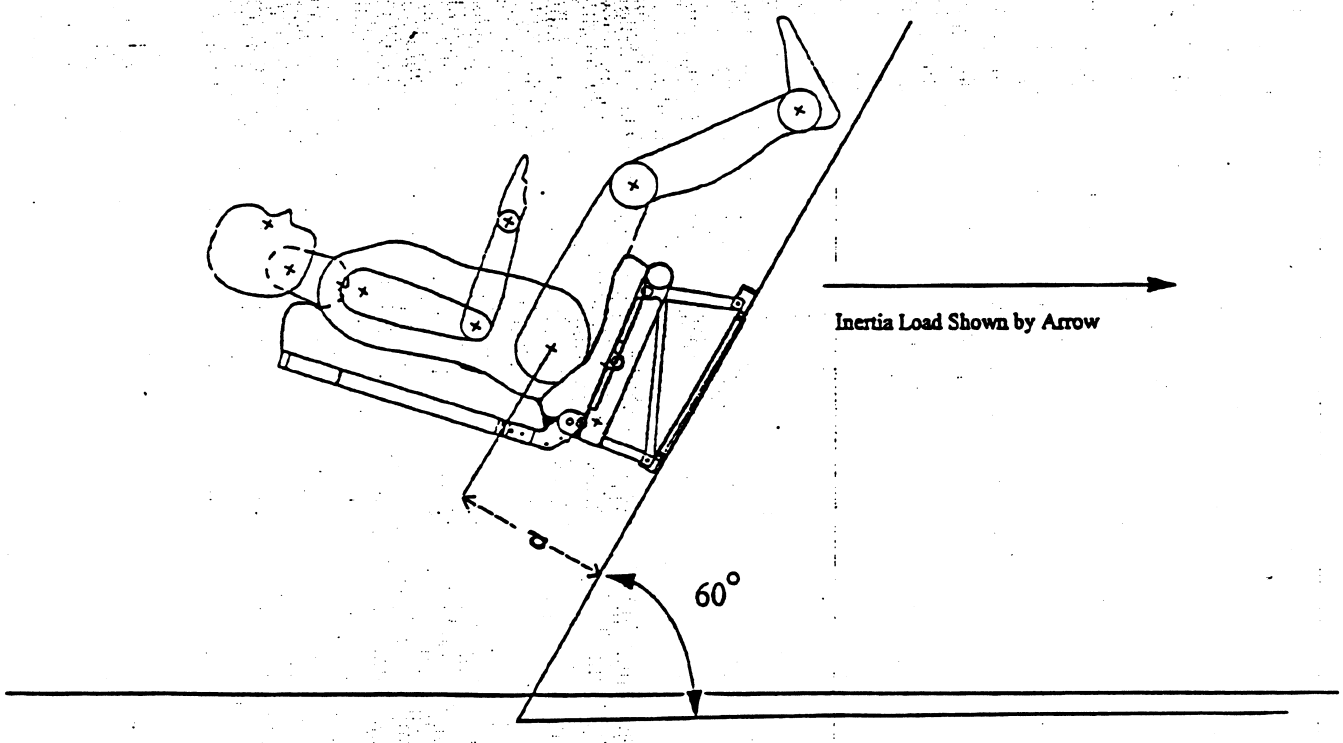


Figure 8.

11. DATA REQUIREMENTS. The data should include charts, listings, and/or tabulated results, and copies of any photo instrumentation used to support the results. The following should be recorded:

a. Impact pulse shape

b. Head Injury Criterion (HIC) results for all ATD's exposed to head impact with interior components of the airplane or head strike paths and velocities if head impact is likely but could not be evaluated by these tests

c. Total velocity change

d. Upper torso restraint system load, if applicable

e. Compressive load between the pelvis and the lumbar column

f. Retention of upper torso restraint straps, if applicable

g. Retention of pelvic restraint

h. Femur loads, if applicable

i. Seat attachment (including structural damage)

j. Seat deformation

k. Seat attachment reaction time histories

l. Retention of items of mass

m. Post test retrieval of life vest

n. Evaluation of seat egress

12. DATA ANALYSIS.

a. General. All data obtained in the dynamic tests should be reviewed for errors. Baseline drift, ringing, and other common electronic instrumentation problems should be detected and corrected before the tests. Loss of data during the test is readily observed in a plot of the data versus time and is typically indicated by sharp discontinuities in the data, often exceeding the amplitude limits of the data collection system. If these occur early in the test in essential data channels, the data should be rejected and the test repeated. If they occur late in the test after the maximum data in each channel has been recorded, the validity of the data should be carefully evaluated, and the maximum values of the data may still be acceptable for the tests described in this AC. The HIC does not represent simply a maximum data value, but an integration of data over a varying time base. The head acceleration measurements used for that computation are not acceptable if errors or loss of data are apparent in the data at any time, from the beginning of the test until the ATD and all test articles are at rest after the test.

b. Impact pulse shape. Data for evaluating the impact pulse shape is obtained from an accelerometer that measures the acceleration in the direction parallel to the inertial response shown in Figure 1 of this AC. The impact pulses intended for the tests discussed in this AC have an isosceles triangle shape. These ideal pulses are considered minimum test conditions. Since the actual acquired test pulses will differ from the ideal, it is necessary to evaluate the acquired test pulses to insure the minimum requirements are satisfied. The five properties of the ideal pulse that must be satisfied by the acquired test pulse are as follows (see Figure 1):

Pulse shape:	isosceles triangle
G_{req}:	peak deceleration required by test condition
T_{req}:	rise time required by test condition
V:	total velocity change required by test condition
V_{tr}:	velocity change required during T_{req} ($V_{tr} = V/2$)

A graphical technique can be used to evaluate pulse shapes that are not precise isosceles triangles. Appendix 1 of this AC presents the graphical method of evaluating the acquired pulse (the recorded test sled acceleration versus time). For the acquired pulse to be acceptable, the following five criteria must be met:

(1) The magnitude of the peak value for the acquired pulse, G_{pk}, must be greater than or equal to G_{req}.

(2) The actual rise time, $Tr = T_2 - T_1$, must be less than or equal to T_{req}.

(3) The result of integrating the acquired pulse during the interval from $t = T_1$ to $t = T_3$ must be equal to or greater than V_{tr}, one-half of the required velocity change for the specified test. If the magnitude of the acquired pulse is greater than the ideal pulse during the entire interval from T_1 to T_3, this requirement is automatically met.

(4) The result of integrating the acquired pulse during the interval from $t = T_1$ to $t = T_1 + 2.3\ (T_{req})$ must equal or exceed the required test velocity change, V, of the test condition. If the acquired pulse returns to zero g's at $t = T_4 < (T_1 + 2.3\ (T_{req}))$, the end of the interval of integration is reduced to $t = T_4$.

(5) If the magnitude of the acquired pulse is greater than the ideal pulse during the entire interval of $t = T_1$ to T_2, and the parameters of paragraphs (1) through (4) above are satisfied, then the acquired pulse is acceptable.

(6) If the magnitude of the acquired pulse is not greater than the ideal pulse during the entire interval $t = T_1$ to T_2, the difference between acquired pulse and the ideal must be no greater than 2.0 g's at those times when the acquired pulse is less than the ideal. The parameters of paragraphs (1), (2), and (3) above must also be satisfied for the acquired pulse to be acceptable.

c. Total Velocity Change. Impact velocity can be obtained by measurement of a time interval and a corresponding sled displacement that occurs just before or after (if appropriate) the test impact, and then dividing the displacement by the time interval. When making such a computation, the possible errors of the time and displacement measurements shall be used to calculate a possible velocity measurement error, and the test impact velocity should exceed the velocity shown in Figure 1 by at least the velocity measurement error. If the sled is not changing velocity during the immediate preimpact or postimpact interval, the impact velocity is the total velocity change. If the sled is changing velocity during the immediate pre-impact or post-impact interval, or if the facility produces significant rebound of the sled, the total velocity change can be determined by integrating the plot of sled acceleration versus time, as described in Appendix 1. If this method is used, the sled acceleration shall be measured in accordance with Channel Class 180 requirements.

d. Head Injury Criterion (HIC).

(1) Data for determining the Head Injury Criterion (HIC) need to be collected during the tests discussed in this AC only if the ATD's head is exposed to an impact on airplane interior features (not including the floor or the ATD's own leg) during the test. The HIC is calculated according to the following equation:

$$HIC = \left[(t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(t)\,dt\right]^{2.5}\right]_{max}$$

Where: t_1 and t_2 are any two points in time (in seconds) during the head impact, and a(t) is the resultant head acceleration (expressed in g's) during the head impact.

(2) The HIC is a method for defining an acceptable degree of occupant head injury. The HIC should not exceed 1000, for head impact against interior surfaces in a crash.

(3) The HIC is invariably calculated by computer based data analysis systems, and the discussion that follows outlines the basic method for computation . The HIC is based on data obtained from three mutually perpendicular accelerometers installed in the head of the ATD in accordance with the ATD specification. Data from these accelerometers are obtained using a data system conforming to Channel Class

1000, as described in SAE Recommended Practice J211. Only the data taken during head impact with the airplane interior need be considered; this is usually indicated in the data by a rapid change in the magnitude of the acceleration. Film of the test may show head impact that can be correlated with the acceleration data by using the time base common to both electronic and photographic instrumentation. Simple contact switches that do not significantly alter the surface profile could also be used to define the initial contact time.

(4) The magnitude of the resultant acceleration vector obtained from the three accelerometers is represented as a function of time. Then, beginning at the time of initial head contact (t_1), the average value of the resultant acceleration is found for each increasing increment of time (t_2-t_1), by integrating the curve between t_1 and t_2 and then dividing the integral value by the time (t_2-t_1). This calculation should use all data points provided by the minimum 8000 samples per second digital sampling rate for the integration. However, the maximizing time intervals need be no more precise than 0.001 seconds. The average values are then raised to the 2.5 power and multiplied by the corresponding increment of time (t_2-t_1).

(5) This procedure is then repeated, increasing t_1 by 0.001 seconds for each repetition. The maximum value of the set of computations obtained from this procedure is the HIC. The procedure may be simplified by noting that the maximum value will only occur in intervals where the resultant magnitude of acceleration at t_1 is equal to the resultant magnitude of acceleration at t_2, and when the average resultant acceleration in that interval is equal to 5/3 times the acceleration at t_1 or t_2. The HIC is usually reported as the maximum value, and the time interval during which the maximum value occurs is also given.

(6) In many cases, a full system sled test to evaluate specific occupant injury conditions may not be needed to evaluate a redesign of the seat system that affects only HIC. In such cases, the photometric head path data can be gathered and used to ensure no contact will occur, or to define the head angle and velocity at impact. These data can used in a component test of severity comparable to the whole system sled test. Other factors, such as the inertial response of the impact target, must be accounted for in the component test condition so that the impact condition is representative. Component testing methods must be demonstrably comparable to whole system sled tests as a HIC measure, and the specific methodology used will require approval by the FAA.

Additionally, a seat may be designed for use in multiple locations where head contact against a range on unknown bulkhead targets is anticipated (e.g., front row seats). For these seats, HIC may be measured using a representative impact target mounted in front of the seat at the installation setback, or range of setbacks. This target will represent typical fixtures such as galleys, partitions, lavatories, and closets, and its stiffness wil be representative for those monuments. If contact occurs, the HIC must be $\leq$ 1000.

e Upper torso restraint system load. The maximum load in the upper torso restraint system webbing can be obtained directly from a plot or listing of webbing load transducer output. If a three-axis load transducer, fixed to the test fixture, is used to obtain these data, the data from each axis shall be combined to provide the resultant vector magnitude. If necessary, corrections shall be made for the internal mass of the transducer and the fixture weight it supports. This correction will usually be necessary only when the inertial mass or fixture weight is high, or when the correction becomes critical to demonstrate that the measurements fall below the specified limits.

f. Compressive load between the pelvis and lumbar column. The maximum compressive load between the pelvis and the lumbar column of the ATD can be obtained directly from a plot or listing of the output of the load transducer at that location. Since most load cells will indicate tension as well as compression, care should be taken that the polarity of the data has been correctly identified.

g. Retention of upper torso restraint straps. Retention of the upper torso restraint straps on the ATD's shoulders can be verified by observation of photometric or documentary camera coverage. The straps must remain on the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. The straps must not bear on the neck or side of the head and must not slip to the upper rounded portion of the upper arm during that time period.

h. Retention of pelvic restraint. Retention of the pelvic restraint on the ATD's pelvis can be verified by observation of photometric or documentary camera coverage. The pelvic restraint shall remain on the ATD's pelvis, bearing on or below each prominence representing the anterior superior iliac spine, until the ATD rebounds after the test impact and the pelvic restraint becomes slack. Provided that the pelvic restraint remains on the ATD's pelvis, traping of the belt between the leg and the pelvis is acceptable.

Movement of the pelvic restraint above the prominence is usually indicated by an abrupt displacement of the belt onto the ATD's soft abdominal insert which can be seen by careful observation of photo data from a camera located to provide a close view of the belt as it passes over the ATD's pelvis. This movement of the belt is sometimes indicated in measurements of pelvic restraint load (if such measurement are made) by a transient decrease or plateau in the belt force, as the belt slips over the prominence, followed by a gradual increase in belt force as the abdominal insert is loaded by the belt.

i. Femur load. Data for measuring femur loads can be collected in the tests discussed in this AC if the ATD's legs contact seats or other structure. Data need not be recorded in each individual test, if rational comparitive analysis is available for showing compliance.

13. PASS/FAIL CRITERIA. The dynamic impact tests shall demonstrate that:

a. Since the test methods described in this AC are ultimate load condtions, damage to the seat and restraint is expected. The regulation specifically accounts for yielding as an acceptable form of permanent damage. In addition, the following should be considered:

(1) The seat system remains attached to the test fixture at all points of attachment, the occupant restraint system remains attached at all points of attachment and the primary load path remains intact. For the purpose of showing compliance with the structural requirements of § 25.562, acceptable damage to the load-carrying structural elements include: bending deformation, tension deformation, compression crippling, and shear buckling. Cracking of structural elements and the shearing or separation of rivets and minor delamination of composite panels is allowed provided a continuous load path remains between the occupant and the seat attachments.

(2) Damage to seat belts, such as scuffing, fraying and breakage of fibers is considered acceptable. The seat belt should not be cut, or torn by features of the seat or the belt adjuster mechanism. Cuts or tears should be investigated as to their cause, and appropriate corrective action taken, although a retest may not be necessary.

b. If the ATD's head is exposed to impact with interior features during the test, a HIC of 1,000 is not exceeded.

c. Where upper torso restraint straps are used, tension loads in individual straps do not exceed 1,750 lbs.(7.78 kN). If dual straps are used for restraining the upper torso, the total strap tension load does not exceed 2,000 lbs.(8.90 kN).

d. The maximum compressive load measured between the pelvis and the lumbar column of the ATD does not exceed 1,500 lbs. (6.67 kN).

e. The upper torso restraint straps (where installed) remain on the ATD's shoulder during impact.

f. The pelvic restraint remains on the ATD's pelvis during impact.

g. Where leg contact with seats or other structure occurs, the axial compressive load in each femur does not exceed 2,250 lbs. (10.0 kN).

h. The seat permanent deformations are within the quantitative limits of Appendix 2 of this AC and will not significantly impede an occupant from releasing his restraints, standing, and exiting the seat. In no case should deformation of the seat cause entrapment of the occupant, whether or not the defined limits referenced in Appendix 2 are exceeded.

NOTE: It is assumed that the maximum seat deformation will result from the structural evaluation (i.e., single row Type 2 test). Once this is accomplished, it would not, therefore, be considered necessary to repeat deformation measurements after the injury criteria (multiple row) tests, unless the structural and injury criteria tests were combined into one test.

i. All deployable items must remain stowed, unless it can be shown that they do not impede egress or cause serious injury (see appendix 2).

14. TEST DOCUMENTATION.

a. General. The tests should be documented in reports that describe the procedures, limitations, results, and deviations to the tests discussed in this AC. In addition to the specific data requirements specified in paragraph 11 of this AC, the documentation should include the following:

(1) Facility data.

(i) The name and address of the test facility performing the tests.

(ii) The name and telephone number of the individual at the test facility responsible for conducting the tests.

(iii) A brief description and/or photograph of each test fixture.

(iv) The date of the last instrumentation system calibration and the name and telephone number of the person responsible for instrumentation system calibration.

(v) A statement confirming that the data collection was done in accordance with the recommendations in this AC, or a detailed description of the actual calibration procedure used and technical analysis showing equivalence to the recommendations of this AC.

(vi) The manufacturer, governing specification, serial number, and test weight of the ATDs used in the tests, and a description of any modifications or repairs performed on the ATDs that could cause them to deviate from the specification.

(vii) A description of the photographic-instrumentation system used in the tests.

(2) Seat restraint system data.

(i) The manufacturer's name and identifying model numbers of the seat restraint system used in the tests, with a brief description of the system, including identification and a functional description of all major components and photographs or drawings, as applicable. Qualifying approvals, such as Technical Standard Order (TSO) authorizations, should be included.

(ii) For systems that are not symmetrical, an analysis supporting the selection of most critical conditions used in the tests.

b. Test Description. The description of the test should be documented in sufficient detail so that the tests could be reproduced simply by following the guidance given in the report. The procedures outlined in this AC can be referenced in the report, but should be supplemented by such details as are necessary to describe the unique conditions of the tests. For example:

(1) Pertinent dimensions and other details of the installation that are not included in the drawings of the test items should be provided. This can include footrests, restraint system webbing guides and restraint anchorages, "interior surface" simulations, bulkhead or sidewall attachments for seats or restraints, etc.

(2) The floor deformation procedure, guided by goals of most critical loading for the test articles, should be documented.

(3) The placement and characteristics of electronic and photographic instrumentation chosen for the test, beyond that information provided by the facility, should be documented. This can include special targets, grids, or marking used for interpretation of photo documentation, transducers, restraint system loads, floor reaction forces, or other measurements beyond those discussed in this AC.

(4) Any unusual or unique activity or event pertinent to conducting the test should be documented. This could include use of special "break away" restraints or support for the ATDs, test items or transducers, operational conditions or activities such as delayed or aborted test procedures, and failures of test fixtures, instrumentation system components, or ATDs.

(5) Any energy-absorbing features that are intended as part of the design, and the expected structural behavior that will result should be documented.

15. COMPUTER MODELS. Several computer models have been developed to represent the seat restraint/occupant system in a crash. Some of these models include representation of the vehicle interior as well. These models can vary in complexity from simple spring-mass dynamic models to exceedingly complex models, which can be of help in designing an entire work station. Validation of these models also varies, from no validation at all to complex validation efforts based on controlled testing and field experience. The use of these models during the design phase of seat restraint/interior systems for civil airplanes is encouraged. They can be of great assistance in predicting "most critical" conditions, in understanding the performance of systems when used by various sized occupants, in estimating head strike paths and velocities, and for many other uses of interest to the designer. The Federal Aviation

Administration will continue to assess the performance of dynamic computer models, and will issue appropriate advisory material should any of these techniques be found to be useful alternatives to the tests discussed in this AC.

APPENDIX 1
PROCEDURE FOR EVALUATING PULSE SHAPES

A.1

This graphical procedure may be used to evaluate the impact pulse shape acquired from a test. While this procedure is based on graphical concepts, an accurate evaluation of the pulse parameters should be obtained using the digitized data and computer algorithms that provide the analysis illustrated in the following steps:

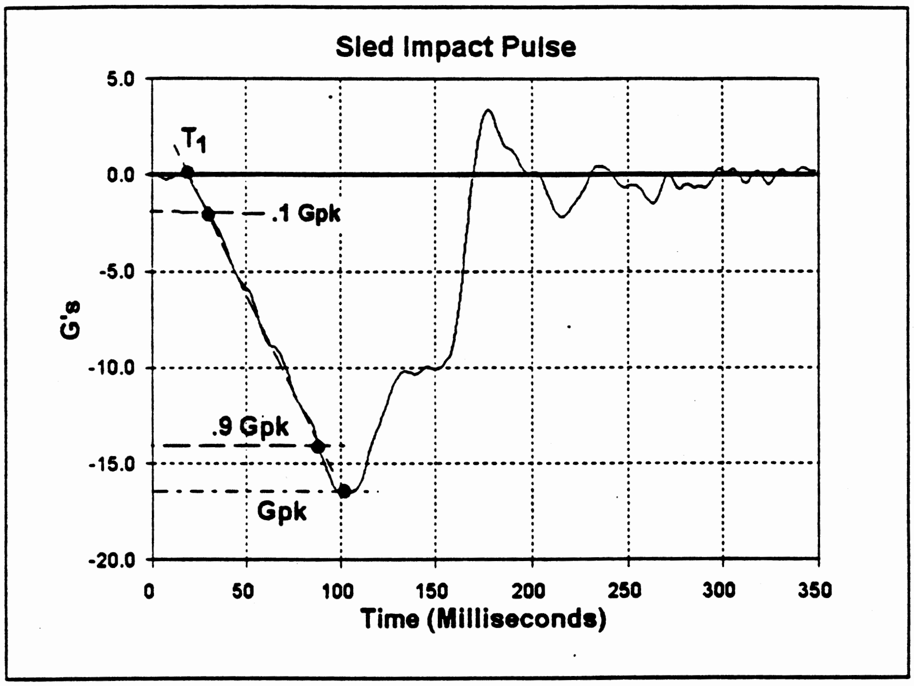


FIGURE A1

A.2 STEP 1:

On the plot of the acquire pulse, identify the peak deceleration point, Gpk, and points on the onset of the pulse equal to 0.1 Gpk and 0.9 Gpk. Construct an onset line through the points 0.1 Gpk and 0.9 Gpk. Extend the constructed onset line to the base line of the data plot, G=0. Identify the intersection of the constructed onset line and baseline as the start of the acquired pulse, T1. For the acquired pulse to be acceptable, the magnitude of Gpk must equal or exceed the minimum required pulse, Greq for the specified test condition.

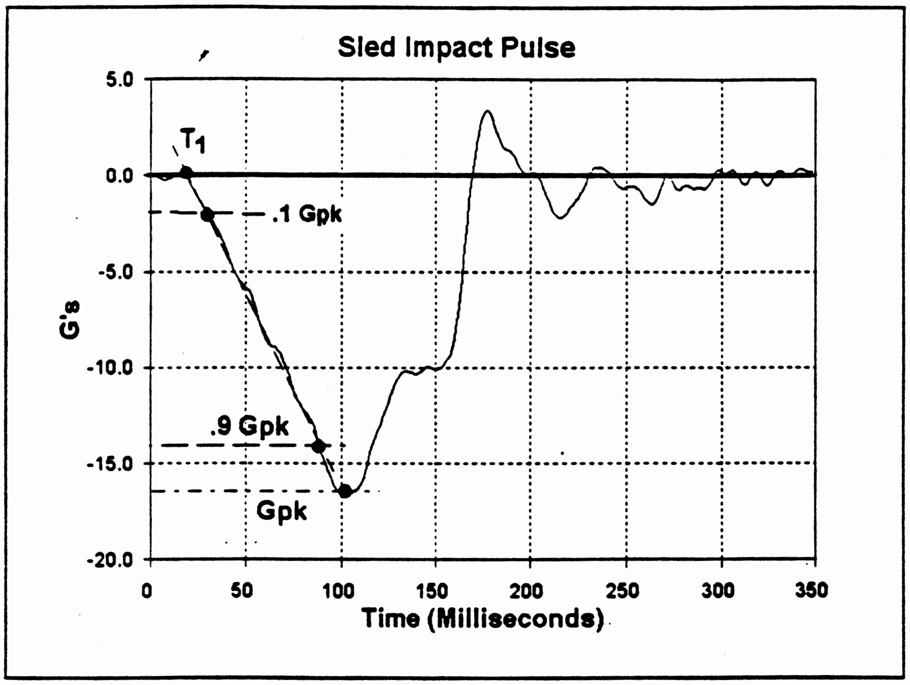


FIGURE A2

A.3 Step 2:

Using T_1 as the start time, construct the ideal pulse required for the test condition. Draw a vertical line and a horizontal line through the peak of the ideal pulse, Greq. The vertical line through Greq will intersect the time axis at the maximum allowed rise time, T_3. Draw another vertical line at the first intersection of the horizontal line through Greq and the acquired pulse after T_1. This vertical line will intersect the time axis at T_2. The actual rise time, $Tr = T_2 - T_1$, must be less than or equal to Treq for the acquired pulse to be acceptable.

A.4 Step 3:

Compute the velocity change, Vra, of the acquired pulse during the interval T_1 to T_3. Note that T_3 will usually occur after the peak, Gpk, of the acquired pulse. For the acquired pulse to be acceptable, Vra must be at least one-half the total velocity V, required for the specified test condition.

A.5 Step 4:

If the total velocity change for the test is calculated from the acquired pulse, use the interval starting at T_1 and ending:

a. at the point T4, where the acquired pulse first intersects the baseline, G = 0, after the time of Gpk or

b. at the time equal to: $T_1+2.3xTreq$ whichever occurs first.

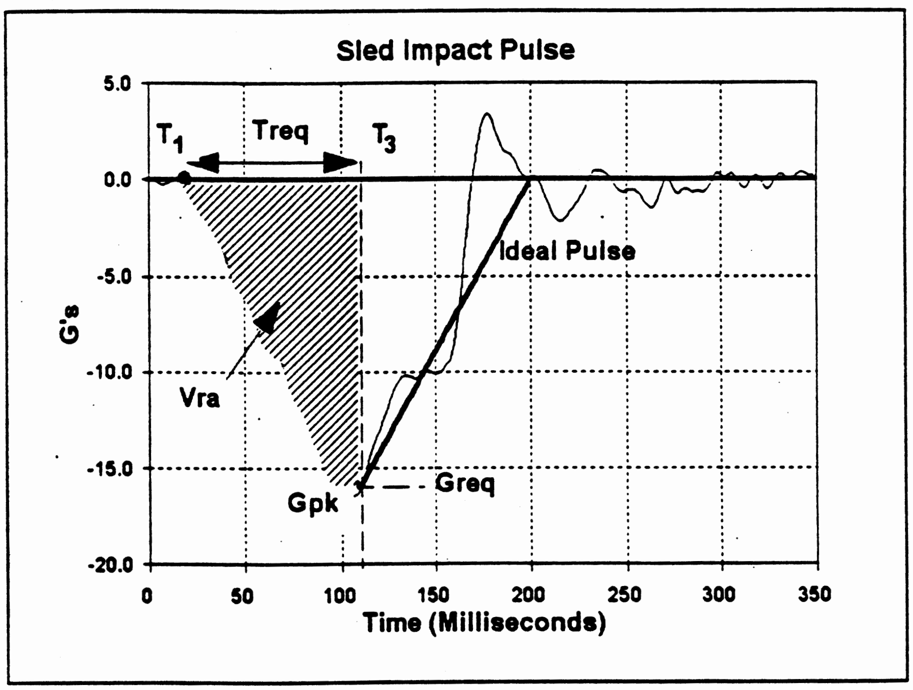


FIGURE A3

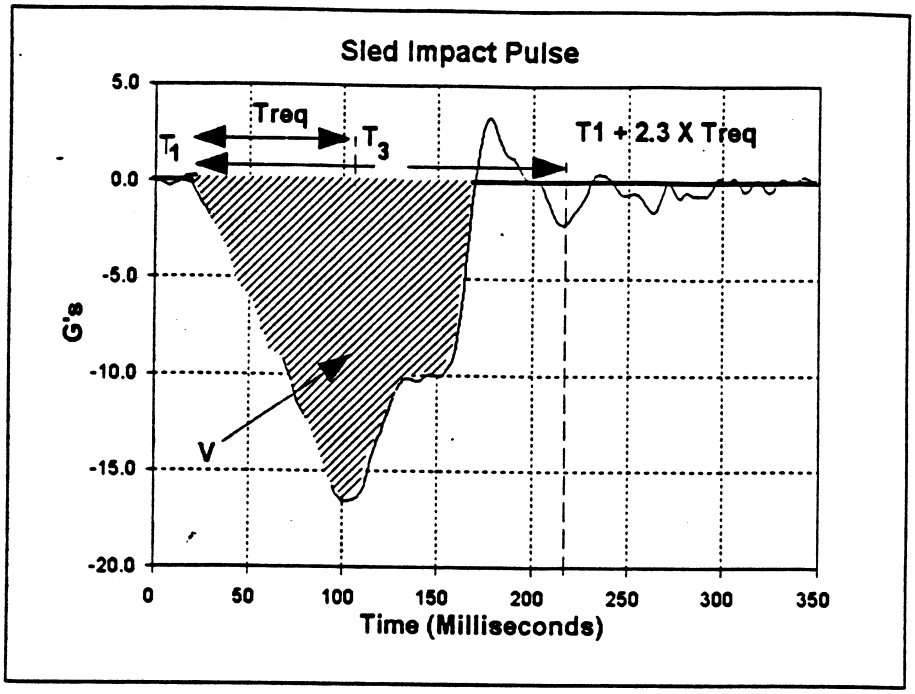

Sled Impact Pulse
Treq
T1
T3
T1 + 2.3 X Treq
V
G's
5.0
0.0
-5.0
-10.0
-15.0
-20.0
0
50
100
150
200
250
300
350
Time (Milliseconds)

FIGURE A4

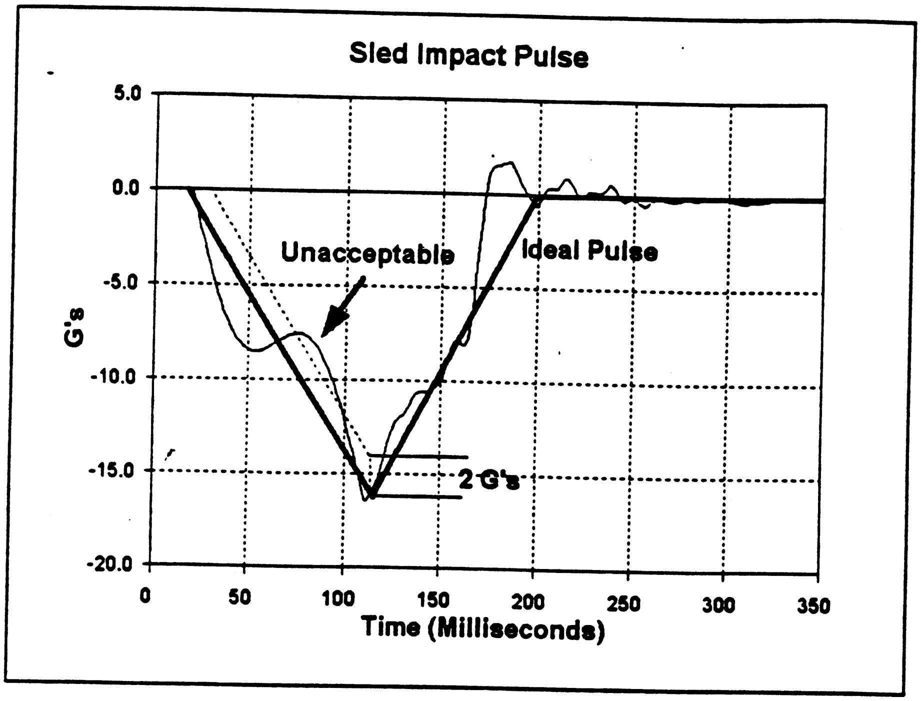


FIGURE A5

A.6 Step 5:

Construct a line parallel to the ideal pulse and offset by 2 G's in magnitude less than the ideal during the time interval between T1 and T2. If the magnitude of the acquired pulse is 2 G's less than the ideal at any point during the interval between T1 and T2, the pulse is not acceptable. Figure A2 is an example of an acceptable pulse shape. The acquired pulse shown in Figure A5 is unacceptable.

Appendix 2 - SEAT DEFORMATION

1. General. Seats that are evaluated in accordance with the tests discussed in this AC may deform either due to the action of discrete energy absorber systems included in the design or due to residual plastic deformation of their structural components. If this deformation is excessive, it could impede the airplane emergency evacuation process. Each seat design may differ in this regard and should be evaluated according to its unique deformation characteristics. If floor deformations are applicable, consistency in pre and post-test measurements shall be maintained. If the pretest measurements are made before floor deformations are applied, the post-test measurements shall be made after floor deformations have been removed. Conversely, if the pretest measurements are made after floor deformations are applied, the post-test measurements shall be made before removal of floor deformations.

2. Fixed Seats. The following post-test deformations and limitations regarding emergency exit egress may be used for showing compliance with §§ 25.561(d) and 25.562(c)(8). Dimensions specified for undeformed seat rows assume the maximum permanent deformation discussed below, and are given to enable evaluation of an installation without having to make reference to test reports. In those cases where the actual permanent deformations are less than maximum, the specified dimensions for undeformed seat rows could be correspondingly decreased.

a. Forward or Rearward Directions. Seats that exhibit forward or rearward deformations should not exceed a maximum of 3.0 inches (75 mm). In this case, the clearance between undeformed seat rows, measured as shown in Figure 1, Dimension A, of this appendix, should be 9.0 inches (228 mm) or, alternatively, 6.0 inches (150 mm), plus the actual fore/aft deformation. Seat rows that lead to Type III exits are subject to the specific access requirements for those exits. This will result in greater spacing at those seat rows in the undeformed case. For seats with deformations that exceed 3.0 inches, the undeformed clearances should be increased accordingly. In addition, at seat rows leading to Type III or IV exits, 20 inches (508 mm) minimum clearance, measured above the arm rests, shall be maintained between adjacent seat rows. This measurement may be made with the seat backs returned to their upright position, using no more than original seat back breakover forces, typically 25-35 pounds (111-155 N). At other seat rows, the most forward surface of the seat back shall not deform to a distance greater than one half the original distance to the forwardmost hard structure on the seat (see Figure 2 of this appendix).

b. Downward Direction. There is no limitation on downward permanent deformation, provided it can be demonstrated that the feet or legs of occupants will not be entrapped by the deformation.

c. Seat Rotation. The seat bottom rotational permanent deformation shall not result in an angle that exceeds 20 degrees pitch down or 35 degrees pitch up from the horizontal plane. This rotational deformation shall be measured between the fore and aft extremities of the seat pan at the centerline of each seat bottom (Figure 3 of this appendix). Rotation of the seat pan shall not cause entrapment of the occupant.

d. Sideward Direction.

(1) The deformed seat should not encroach more than 1.5 inches (38 mm) into the required longitudinal aisle space at heights up to 25 inches (635 mm)above the floor. The determination of which parts of the seat are at what heights is determined prior to testing.

(2) The deformed seat should not encroach more than 2.0 inches (50 mm)into the longitudinal aisle space at heights 25 inches (635 mm) or more above the floor.

e. Additional Considerations. In addition, none of the above deformations shall permit the seat to:

(1) Affect the operation of any emergency exit or encroach into an emergency exit opening for a distance from the exit not less than the width of the narrowest passenger seat installed in the airplane.

(2) Encroach into any required passageway.

(3) Encroach more than 1.5 inches (38 mm) into any cross-aisle or flight attendant assist space.

f. Deployable Items. Certain items on the seat, such as food trays, legrests, arm caps over in-arm tray tables, etc., are used by passengers in flight and are required to be stowed for taxi, takeoff and landing. Deployment of such items should be treated as "permanent deformation" if the item deploys into an area that must be used by multiple passengers (in addition to the occupant of the seat) for egress. Such deployments can be considered acceptable, even if they exceed the dimensions specified above, if they are readily pushed out of the way by normal passenger movement, and remain in a position that does not affect egress. [1]

3. Stowable Seats. Stowable seats, that may impede egress,must stow post-test and remain stowed to the extent necessary in order to satisfy the above criteria.

a. Seats that are Stowed Manually. A post-test stowage force no greater than 10 pounds (45 N) above the original stowage force may be used to stow the seat.

b. Seats that Stow Automatically. For a seat that may interfere with the opening of any exit, it must automatically retract to a position where it will not interfere with the exit. For determining encroachment into passageways, cross-aisles, andassist

[1] The underlined and bracketed section is my proposal. I think the wording "agreed" at the meeting is too loose. JG

spaces, a post-test stowage force no greater than 10 pounds (45 N), applied at a single point, may be used to assist automatic retraction.

Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

April 18, 2000

Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Attention: Mr. Thomas McSweeny, Associate Administrator for Regulation and Certification

Subject: ARAC Recommendations

Reference: ARAC Tasking, Federal Register, November 19, 1999

Dear Tom,

The Transport Airplane and Engine Issues Group is pleased to submit the following "Fast Track" reports as recommendations to the FAA in accordance with the reference tasking. These reports have been prepared by the ~~Seat~~ Test Harmonization Working Group.

Task

1 • FAR 25.562 - 16G Seat Method of Compliance – ANM - 93-732-A

• FAR 25.785(c) - Seat Belts for Inflight Use Only

2 • FAR 25.785(e) + (b) - Occupant Protection – ANM - 98-439-A

Please note that the Fast Track report for FAR 25.562 – 16G Seat Method of Compliance, has comments from the Association of Flight Attendants (AFA) attached. These comments were provided to the Working Group after the report had been accepted and unanimously agreed to by the Working Group membership. As such, the AFA comments have not been reviewed and discussed by the Working Group. At the request of AFA, TAEIG agreed to attach the comments to the report submittal and the Seat Test Working Group has agreed to review the comments when the package is returned to the Working Group for final review at Phase 4 of the Fast Track process.

Sincerely yours,

Craig R. Bolt

Craig R. Bolt
Assistant Chair, TAEIG

Attachments

Copy: Kris Carpenter, FAA-NWR
*Nick Calderone, Boeing
*Effie Upshaw, FAA Washington, DC

*letter only

crb02_040400

Recommendation

1 - What is underlying safety issue to be addressed by the FAR/JAR?

The intent of FAR/JAR 25.562 is to provide an appropriate level of safety for passengers occupying aircraft seats. The differences in FAA and JAA means of compliance to Section 25.562 led to the need for harmonizing activity.

2 - What are the current FAR and JAR standards relative to this subject?

Current FAR text: **Sec. 25.562 Emergency landing dynamic conditions.**

(a) The seat and restraint system in the airplane must be designed as prescribed in this section to protect each occupant during an emergency landing condition when—
   (1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and
   (2) The occupant is exposed to loads resulting from the conditions prescribed in this section.

(b) Each seat type design approved for crew or passenger occupancy during takeoff and landing must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 170-pound anthropomorphic test dummy, as defined by 49 CFR Part 572, Subpart B, or its equivalent, sitting in the normal upright position.
   (1) A change in downward vertical velocity (Dv) of not less than 35 feet per second, with the airplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0.08 seconds after impact and must reach a minimum of 14g.
   (2) A change in forward longitudinal velocity (Dv) of not less than 44 feet per second, with the airplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0.09 seconds after impact and must reach a minimum of 16g. Where floor rails or floor fittings are used to attach the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e., out of Parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with paragraph (b) of this section:
   (1) Where upper torso straps are used for crewmembers, tension loads in individual straps must not exceed 1,750 pounds. If dual straps are used for restraining the upper torso, the total strap tension loads must not exceed 2,000 pounds.
   (2) The maximum compressive load measured between the pelvis and the lumbar column of the anthropomorphic dummy must not exceed 1,500 pounds.
   (3) The upper torso restraint straps (where installed) must remain on the occupant's shoulder during the impact.
   (4) The lap safety belt must remain on the occupant's pelvis during the impact.
   (5) Each occupant must be protected from serious head injury under the conditions prescribed in paragraph (b) of this section. Where head contact with seats or other structure can occur, protection must be provided so that the head impact does not exceed a Head Injury Criterion (HIC) of 1,000 units.
   The level of HIC is defined by the equation:

$$HIC = \left[(t_2 - t_1) \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a(t)\, dt \right]^{2.5} \right]_{max}$$

Where:

t1 is the initial integration time.
t2 is the final integration time, and
a(t) is the total acceleration vs. time curve for the head strike, and where (t) is in seconds, and (a) is in units of gravity (g).

(6) Where leg injuries may result from contact with seats or other structure, protection must be provided to prevent axially compressive loads exceeding 2,250 pounds in each femur.
(7) The seat must remain attached at all points of attachment, although the structure may have yielded.
(8) Seats must not yield under the tests specified in paragraphs (b)(1) and (b)(2) of this section to the extent they would impede rapid evacuation of the airplane occupants.

[Amdt. 25-64, 53 FR 17646, May 17, 1988]

Current JAR text: **JAR 25.562 Emergency landing dynamic conditions**
Date: May 27, 1994

(a) The seat and restraint system in the aeroplane must be designed as prescribed in this paragraph to protect each occupant during an emergency landing condition when—
   (1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and
   (2) The occupant is exposed to loads resulting from the conditions prescribed in this paragraph.

(b) Each seat type design approved for passenger occupancy must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 170 pound (77.11kg) anthropomorphic, test dummy sitting in the normal upright position:
   (1) A change in downward vertical velocity, (v) of not less than 35 feet per second (10.67 m/s), with the aeroplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0.08 seconds after impact and must reach a minimum of 14g.
   (2) A change in forward longitudinal velocity (v) of not less than 44 feet per second (13.41 m/s), with the aeroplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0.09 seconds after impact and must reach a minimum of 16 g. Where floor rails or floor fittings are fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e. out of parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with sub paragraph (b) of this paragraph:
   (1) Where upper torso straps are used tension loads in individual straps must not exceed 1750 pounds (793.78 kg). If dual straps are used for restraining the upper torso, the total strap tension loads must not exceed 2000 pounds (907.18 kg).
   (2) The maximum compressive load measured between the pelvis and the lumbar column of the anthropomorphic dummy must not exceed 1500 pounds (680.38 kg).
   (3) The upper torso restraint straps (where installed) must remain on the occupant's shoulder during the impact.
   (4) The lap safety belt must remain on the occupant's pelvis during the impact.
   Each occupant must be protected from serious head injury under the conditions prescribed in sub-paragraph (b) of this paragraph. Where head contact with seats or other structure can occur, protection must be provided so that the head impact does not exceed a Head Injury Criterion (HIC) of 1000 units. The level of HIC is defined by the equation –

$$HIC = \left[(t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(t)\,dt\right]^{2.5}\right]_{max}$$

Where—

t(1) is the initial integration time.

t(2) is the final integration time, and

a(t) is the total acceleration vs. time curve for the head strike, and where (t) is in seconds, and (a) is in units of gravity (g).

(6) Where leg injuries may result from contact with seats or other structure, protection must be provided to prevent axially compressive loads exceeding 2250 pounds (1020.58 kg) in each femur.

(7) The seat must remain attached at all points of attachment, although the structure may have yield.

(8) Seats must not yield under the tests specified in sub-paragraphs (b)(1) and (b)(2) of this paragraph to the extent they would impede rapid evacuation of the aeroplane occupants.

2a – If no FAR or JAR standard exists, what means have been used to ensure this safety issue is addressed?

FAR/JAR exist along with regulatory guidance material.

3 - What are the differences in the FAA and JAA standards or policy and what do these differences result in?:

The only difference between the FAR and JAR regulations is that the FAR is applicable to passenger and crew seats whereas the JAR is written against passenger seats only. This was not an issue for our group because we were tasked to work passenger seats and these are the seats for which there have been differing means of compliance to the regulations.

4 - What, if any, are the differences in the current means of compliance?

The FAA has accepted a "Revised Means of Compliance (RMOC)" which bases the test article selection process on a representative seat. The JAA method of compliance required a critical case selection for the test article.

5 – What is the proposed action?

Develop harmonized means of compliance based on a "family design" concept. This results in a simplified selection of a critical case seat(s) for certification. The process also allows for similarity comparisons to previously tested seats.

For each proposed change from the existing standard, answer the following questions:

6 - What should the harmonized standard be?

See attached concept paper for Task 1.

7 - How does this proposed standard address the underlying safety issue (identified under #1)?

Use of the principles in the concept paper result in an equivalent level of safety that is mutually acceptable by the FAA and JAA.

8 - Relative to the current FAR, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

The concept paper maintains the current level of safety. The regulation remains the same. The means of showing compliance has been standardized and clarified for all industry participants.

9 - Relative to current industry practice, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

The concept paper maintains the current level of safety. The means of showing compliance has been standardized and clarified for all industry participants.

10 What other options have been considered and why were they not selected?:

Two alternative methods of demonstrating compliance were considered as follows:

a) *The Revised Means of Compliance (RMOC) Because this method of compliance relied upon a "representative" seat to test instead of a "critical case" seat the team felt that this approach was not consistent with the "intent" of the rule. Some key concepts, such as the Family of Seats, had significant value and were incorporated into the concept paper.*

b) *Traditional Critical Case Analysis - This approach, while still acceptable, as a method of compliance, was not bounded in a practical way. This led to much iteration of analysis and an inconsistent expectation in the amount of detailed analysis required for a certification program. The concept paper focuses the seat assessment on the primary load path that is consistent with the Tradition Critical Case Analysis, but outlines a clearer expectation on the type and detail of analysis required.*

11 Who would be affected by the proposed change?

The seat suppliers, airframe manufacturers, regulatory authorities and airlines would have the choice of using the new ARAC concept paper approach or using the Tradition Critical Case Method.

12 - To ensure harmonization, what current advisory material (e.g., ACJ, AMJ, AC, policy letters) needs to be included in the rule text or preamble?

AC 25.562-1a

FAA Letters issued by the Transport Standards Staff

- *FAA Memorandum dated April 30, 1993, subject: "Yaw angle for the Down Test in Dynamic Seat Test, Section 25.562".*
- *FAA Memorandum dated May 11, 1994, subject: "Seat Strength Policy for Section 25.562".*
- *FAA Memorandum dated March 13, 1995, subject: "Additional Guidance Concerning Dynamic Testing of Transport Airplane Seats".*
- *FAA Memorandum dated January 18, 1996, subject: "Pass/Fail Criteria for Section 25.562, Dynamic Testing of Seats".*
- *FAA Memorandum dated February 16, 1996, subject: "Simplified Procedure for Addressing the Head Injury Criteria of Section 25.562". Reference: Policy Letter TAD 96 002.*
- *FAA Letter dated May 8, 1996, subject: "Public Meeting Response". Reference: 96-114-3.*

- *FAA Memorandum dated November 17, 1988, subject: "Seat Tracks Approved for use in Dynamic Tests under 25.562"*
- *FAA Memorandum dated October 20, 1997, subject: "Guidance for Demonstrating Compliance with Seat Dynamic Testing for Certain Derivative Airplanes". Reference: 97-112-38*
- *FAA Memorandum dated November 19, 1997, subject: "Guidance for Demonstrating Compliance with Seat Dynamic Testing Deceleration Pulse Shapes". Reference: 97-112-43*

Although not required, it would helpful to the industry to update TSO C127 to allow use of the ARAC concept paper as a method of test article selection.

13 Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The content of ARAC-SHWG Task 1 Concept Paper should be adopted as FAA guidance material.

14 - How does the proposed standard compare to the current ICAO standard?

Unknown at this time

15 - Does the proposed standard affect other HWG's?

No

16 What is the cost impact of complying with the proposed standard?

There is no anticipated increase in the cost of compliance using this new method. Preliminary data suggests that the industry may experience a cost reduction, but this has not been substantiated at this time.

17. - If advisory or interpretive material is to be submitted, document the advisory or interpretive guidelines. If disagreement exists, document the disagreement.

All data for this task is contained in the attached concept paper.

18. Does the HWG wish to answer any supplementary questions specific to this project?

No supplementary questions have been identified at this time.

19. Does the HWG want to review the draft NPRM at "Phase 4" prior to publication in the Federal Register?

Yes. The ARAC-SHWG wishes to review the draft guidance material before it is adopted by the regulatory agencies.

20. - In light of the information provided in this report, does the HWG consider that the "Fast Track" process is appropriate for this rulemaking project, or is the project too complex or controversial for the Fast Track Process? Explain.

The Fast Track process is appropriate for this task.

SEAT HARMONIZATION WORKING

Concept Paper Vote

NAME	AFFILIATION	Task 1	Task 2	Task 3
Jurgen Feldhaus	Daimler Chrysler Aerospace Airbus	Accept 2/3/00	Accept 2/3/00	Accept 2/3/00
Ronda Ruderman	Association of Flight Attendants	Accept 2/7/00	Accept 2/7/00	Accept 2/7/00
Vahe Bilezikjian	B/E Aerospace	Accept 2/2/00	Accept 2/2/00	Accept 2/2/00
Francis S. Heming, Jr (Frank)	B.F. Goodrich Aerospace - AMI Seating	Accept 2/2/00	Accept 2/2/00	Accept 2/2/00
Uwe Johannsen	Daimler Chrysler Aerospace Airbus	Accept 2/2/00	Accept 2/2/00	Accept 2/2/00
Jean-Paul Deneuville	JAA	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Jeff Gardlin	FAA	Accept 2/15/00*	Accept 2/4/00	Accept 2/4/00
Harald Merensky	Lufthansa	Accept 1/31/00	Accept 1/31/00	Accept 1/31/00
Thomas Amthor	Recaro Aircraft Seating	Accept 2/2/00	Accept 2/2/00	Accept 2/2/00
Nigel Smith	Rumbold	Accept 2/3/00	Accept 2/3/00	Accept 2/3/00
Nathan Wilson	Sicma Aero Seat	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Martine SAINTE-MARIE	Sogerma	Accept 2/3/00	Accept 2/3/00	Accept 2/3/00
Jeanne Elliott	Teamsters Airline Division	Accept 2/7/00	Accept 2/7/00	Accept 2/7/00
J. Hugh O'Conner	Transport Canada	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Tony Hobson	UK CAA	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Daniel Freeman	Boeing	Accept 1/26/00	Accept 1/26/00	Accept 1/26/00
Nick Calderone	Boeing	Accept 2/1/00	Accept 2/1/00	Accept 2/1/00
Steven J.Hooper	J. B. Dwerlikotte Assoc., Inc	Accept 2/8/00	Accept 2/8/00	Accept 2/8/00
Stephen Soltis	FAA (through Gardlin)	Accept 2/15/00*	Accept 1/19/00	Accept 1/19/00
Clive Bradbury	British Airways	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Laurent Pinsard	JAA-DGAC	Accept 1/31/00	Accept 1/19/00	Accept 1/19/00
Stefania Randisi	Registro Aeronautico Italiono (RAI-ENAC)	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00
Gregory R. Thiele	Weber Aircraft Inc.	Accept 2/1/00	Accept 2/1/00	Accept 2/1/00
Antonio Fiordelli	Avio Interiors	Accept 2/4/00	Accept 2/4/00	Accept 2/4/00

* Accepted if the mandatory comments that were provided were incorporated into the concept paper.

1.0 Introduction

This concept paper has been developed to simplify and standardize the passenger seat test article selection process and pass/fail criteria for FAR/JAR 25.562. It presents a decision process to standardize the selection of seats based on simplified, critical case analysis. This concept paper is a further development of the concepts outlined in AC 25.562-1A, Section 6b "Selection of Test Articles".

Examples provided in this concept paper are intended to illustrate and clarify the technical principles. They are not intended to provide firm boundaries for interpreting the material.

The selection method outlined below employs a Family of Seats defined in Section 3.0. In order for individual seat part numbers to be covered by the baseline testing defined in Section 4.0, seat components are to be consistent in their design philosophy with allowable variations driven by:

- Geometric constraints within the seat structure (for example, attachment hardware may vary between the lateral beams and the seat legs due to differences in seat track buttock lines)
- Airplane interface (for example, seat back widths may vary depending on aisle width requirements)
- Other similar requirement.

However, these differences in the seats must be justified based on procedures outlined in Section 3.0. The family of seats must be established in order to use the test article selection process described in this document. The decision process outlined below defines the tests uecessary to substantiate a family of seats. Additional tests or analysis may be required to justify seat components within the family, if new and unique features are part of the seat design or to expand the seat family.

The family of seats is a philosophy in design. A group of seats can be designed using the same design concept, or as separate entities (non-family members). If the components in the seat design are carefully considered in advance, the base line testing described in this document may substantiate the majority or all of the seat part numbers for compliance to FAR/JAR 25.562. Additional tests beyond the baseline may be required to substantiate variations in seat design that are beyond the basic family principals.

Structural criticality (as required per FAR/JAR 25.307(a)) and seat family definition are two closely related, but separate topics. The objective of the requirement is to test the critical structural configuration, i.e. the seat with the critically stressed components in the primary load path. Basic seat designs that share equivalent components in the primary load path, hence the seat family concept can facilitate assessments of structural criticality. The test program defined for a family of seats may need to be expanded if there are subsequent model additions to the family, which cannot be substantiated using previous test data or appropriate engineering analysis. The need for additional tests does not change the family concept, and does not invalidate the family definition.

The seat family is defined based on design characteristics. Structural criticality assessments determine, in part, the scope of the test program within a family, not between families. The respective discussions of seat family definition and structural criticality determination are intended to be complimentary. Determinations of structural criticality assume that the family of seats has been established, and that variations within the family will be substantiated either by tests or analysis. The decision whether to conduct tests or perform analysis is made based on the guidelines given, with the underlying assumption that such choices are made within a well defined family. Therefore, a comparison between families to establish that one design is more structurally critical than another are beyond the scope of this paper, and are not recommended.

It is not possible to capture all possible design details or component configurations on a document such as this. The intent of this concept paper is to provide an understanding of the design and certification philosophy that has been harmonized for section FAR/JAR 25.562. Engineering judgement and interpretation applied to the design are acceptable as long as the principals of this document are the basis of that judgement.

Philosophically, the primary structural load path and other components that influence occupant injury criteria (e.g., HIC, shoulder restraint retention, etc.) are evaluated to generate the baseline certification tests. As much as practical, the other pass/fail criteria (e.g., lap belt retention, lumbar, egress, etc.) are assessed on tests that are conducted to show seat structural compliance. Additional structural tests should not be generated to evaluate parts of the seat that are not in the primary load path or influence occupant injury criteria. (For example, a test would not be conducted to evaluate the most critical load on a baggage bar if that is different than the most critical test for the seat structure.). The requirements of FAR/JAR 25.562 are satisfied by the substantiation of the structure through the baseline tests and the additional family tests outlined by this paper.

The following decision process should be applied in order to fully utilize the test article selection process outlined below:

<u>Step 0</u> Fully understand the family concept as it applies to the design philosophy.

<u>Step 1</u> Complete the seat structure design: understand, the geometric differences in seat components within the family. Define the primary structure for the family validation (which components are considered the legs, lateral beams, etc.).

<u>Step 2</u> Determine test seats based on the selection of test articles outlined in Section 4.0 below. These are considered the baseline tests.

<u>Step 3</u> Validate the test article selection by analyzing the primary load path as outlined in Section 4.0. Add additional tests if necessary to substantiate variations to seat components. Seat component variations should be addressed in one of three ways:

1) Establish equivalence for dynamic test purposes and no test will be required.
2) Establish criticality to determine if an added test(s) would be required.
3) Allow for bracketing the variation by test A new family should not automatically be the consequence of a requirement to evaluation the variation in a component.

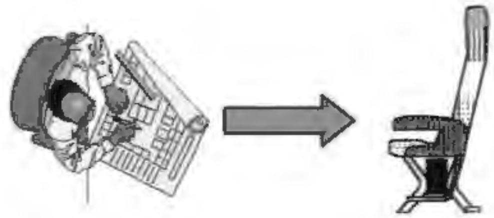
Iterate steps 1 3 as necessary.

<u>Step 4</u> Perform testing.

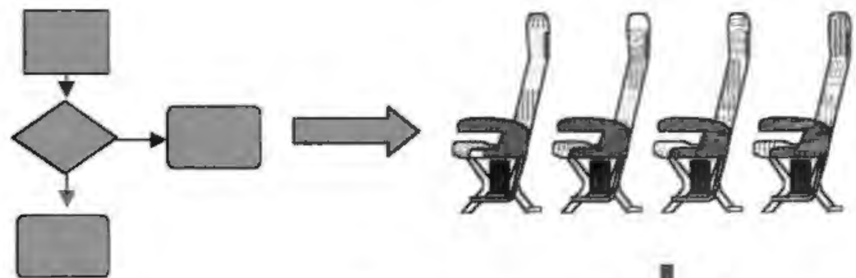
<u>Step 5</u> For changes/modifications resulting from test failures, validate the test article selection by analyzing the primary load path as outlined in Section 3.0. Some previous testing (baseline and /or additional) may have to be re-run or additional tests may have to be added.

<u>Step 6</u> Document the test results.

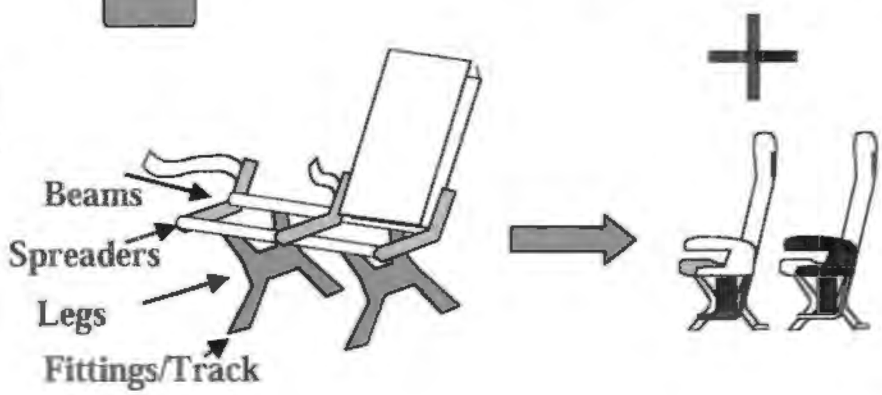
Step 1 - Complete Design



Step 2 - Determine baseline testing for seat famiy



Step 3 - Validate Family Concept - add additional tests if necessary



2.0 Definitions

These definitions are consistent within the context of this paper. It should be noted that these definitions should be checked for consistency with other guidance material.

A Family of Seats - a group of seat assemblies regardless of the number of seat places, built from equivalent components in the primary load path.

Rational Analysis - An analysis based on good engineering principles, judgement, and/or accepted methodology. This can include, but is not limited to, static/dynamic load comparison, static strength analysis, comparative static/dynamic strength analysis, engineering judgement linear static and non-linear finite analysis, and inspection.

Equivalent -Demonstrated to be comparable via analysis/testing for all aspects of intended function, performance, and related criteria.

Energy Absorbing Device - Load rate or peak load sensitive mechanism.

Primary Load Path - The components within the seat that carry the load from the point of load application to the structure that reacts the load from the seat system or sub-system.
Structural - from seat belt to fittings attaching seat system to airplane structure.
Lumbar - from bottom cushion to fittings attaching seat system to airplane structure.
HIC - from point of ATD head contact to seat back attachments.
Head Path - same as structural.

Similar Design Philosophy - A design which uses the same:

- Method of Construction (e.g., machined part vs. built up part),
- Detail part materials (alloys, heat treat, etc.)
- Manufacturing processes (machined, cast, etc.),
- Geometry, including section properties, except for minor differences resulting from space limitations within the seat or aircraft interface,
- Attachment method except for minor differences resulting from space limitations within the seat
- Load path

Typically, minor differences to geometry and attachment method must be shown to be equivalent to or less critical than the "baseline design" with regard to strength, stiffness, and seat permanent deformation.

Energy Absorber Rating - The amount of load required before the energy absorbing device initiates. The "highest rated" energy absorbing device would be the device that requires the highest load to initiate.

Beams - Lateral Beams - Cross Tubes - The lateral structural members that carry load across the seat frame from spreaders to seat legs.

Energy Absorber "Bottom-Out" The energy absorber "bottoms out" when it reaches its maximum stroke and no longer provides an energy absorption function.

Occupant Position This is assessed using the Seat Reference Point (SRP) as defined in AS8049 Revision A. Variations in SRP dimensions are in the component X, Y and Z directions The resultant change is not considered.

Instability Failure - An instantaneous loss of the load carrying capability of a structural member (e.g., the collapse of a column).

3.0 Family of Seats

A family of seats is a group of seat assemblies regardless of the number of seat places, built from equivalent components in the primary load path. Aft and side facing seats by definition are a separate seat family from forward facing seats.

The primary load path for structural tests typically includes seat components such as seat legs; lateral beams (cross tubes), spreaders, cushion supports and cushions, seatbelts and their attachments, attachments between structural members, seat track fittings and energy absorbers (Note: energy absorbers are normally integrated into the other seat components). The strength and deformation responses of these members are evaluated during structural tests.

The typical primary load path for lumbar load tests include bottom cushions, bottom cushion supports, and lateral beams (cross tubes). Also part of this load path are seat legs, spreaders, attachments between structural members, seat track fittings, and energy absorbers.

The typical primary load path for row-to-row HIC tests include components in the seat assemblies such as components installed on the seat back (e.g., food tray tables, video monitors, telephones, etc.), recline mechanism, breakover devices, seat back energy absorbers, seat back attachment hardware, and in some cases, arm rests.

The typical primary load path for head/knee path tests is the same as those for the structural tests.

In addition, some components (i.e., bottom cushions, bottom cushion support, armrests, and seat backs) affect the positioning of the occupant in the seat place that can influence ATD dynamic response and occupant injury criteria.

The discussion below describes common primary load-path components typically found in passenger seats. The components in the primary load path for each specific seat part number must be analyzed to ensure they fall within the family concept. Substantiation of variations to these components is also discussed below. These variations should be examined both between seat assemblies or within a single seat assembly.

While the discussion below addresses the evaluation of seat components as individual members, the dynamic performance of the entire seat assembly with all variations/modifications incorporated must also be evaluated against the tested seat assemblies. For example: a seat with variations from the tested seat in legs, beams *and* spreaders, might also require test, even though the change in any one element might not require test.

Seat Family Definition

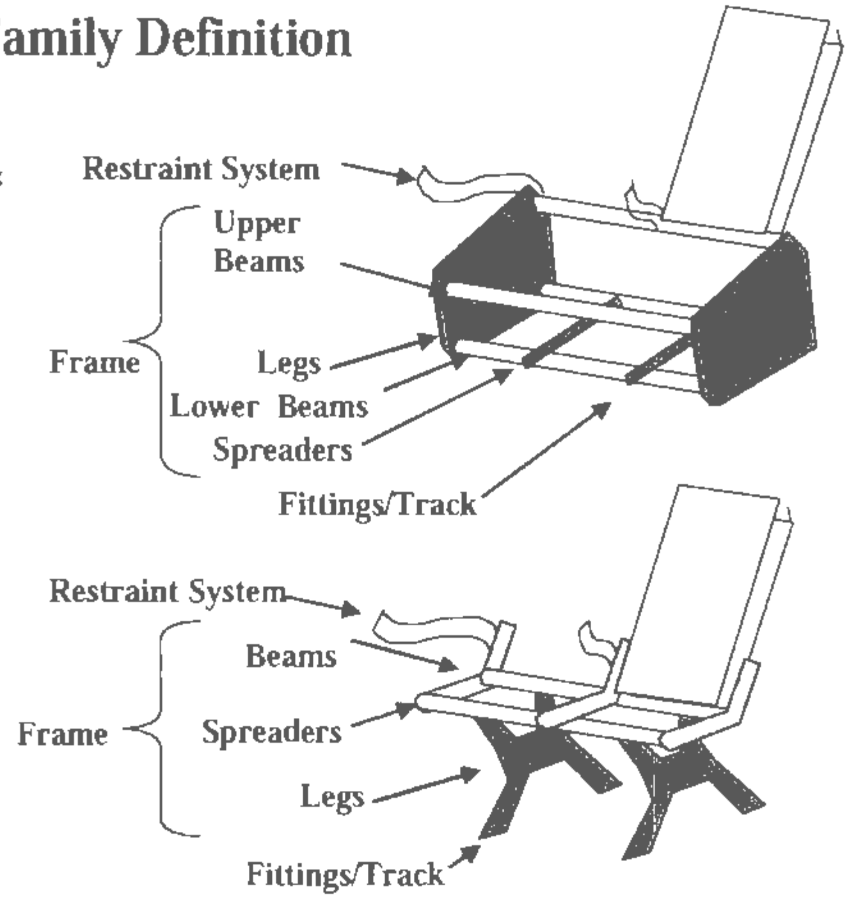
Primary Load Path Elements
Special tests should not be run addressing elements not on the primary load path. Aft facing seats by definition are a separate seat family from forward facing seats

Other Primary Load Path Elements
(not pictured)

Seat Back
(row to row HIC)
(Primary load path for aft facing seats)

Attach Fittings
(e.g. between spreaders and beams)

Bottom Cushion Seat Pan



Each section below will be structured as follows:

- Description of the family concept/principles governing that component
- Discussion and guidelines for variations within the family, which are acceptable using rational analyses without test. This is generally for changes that do not make that feature more critical than the tested feature.
- Discussion and guidelines for variations in a seat family which will require test.

The usage of the term "variations" denotes variations and changes/modifications made post test, post certification, or resulting from failures.

3.1 Seat Legs

a) *Family of Seat Principles* - Seat legs are typically the vertical structural members of the seat that provide the load path from the upper seat structure (e.g. upper beams, pan, etc.) to the lower seat structure (lower beams, track fittings, etc.). Energy absorbers may be incorporated into the seat leg design (see section 9). To be eligible to belong in a particular seat family seat legs must have the same design philosophy, section properties, and energy absorber (if used).

Note: Seat track fittings that interface with aircraft structure are covered below.

b) *Variations and Post Certification Changes Acceptable by Analysis* Variations to the seat leg geometry are acceptable without additional test(s) provided it can be shown by rational analysis that the strength, stiffness, and seat permanent deformation are equivalent to or less critical than the tested seat(s). For example, an increase in distance between the front and rear fitting would be acceptable provided it could be shown by rational analysis that (see appendix A):

- The floor fitting loads are equivalent to or less critical than the seat leg of the tested seat (e.g., linear interface loads analysis), and
- The strength of the portion of the leg that varies to accommodate the increase in distance is equivalent to or less critical than the seat leg of the tested seat
- The stiffness of the leg is similar to the critical leg in the longitudinal and vertical load conditions.

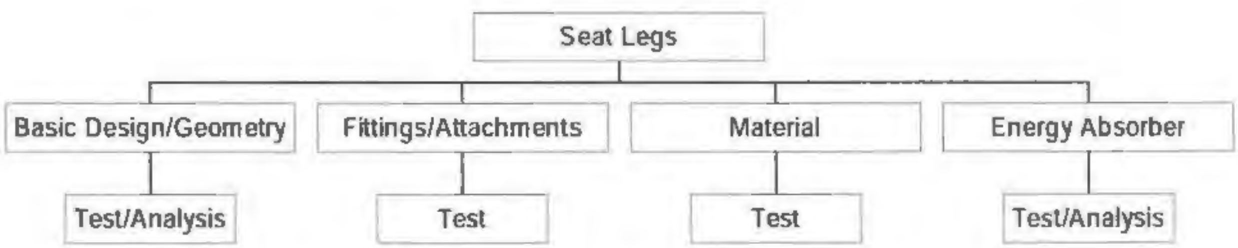
Holes or other minor variations to the seat leg that are not located in a highly stressed area are acceptable. For example, holes drilled in the leg web to attach under-seat electronics boxes are acceptable provided the hole is not in a highly stressed area of the leg.

c) *Variations and Post Certification Changes Requiring Additional Tests* - Additional tests would be selected based on the role that the variation plays in the seat performance. For example, a material change to a portion of the seat leg may require an additional 16g forward structural test, but not require additional HIC or lumbar tests.

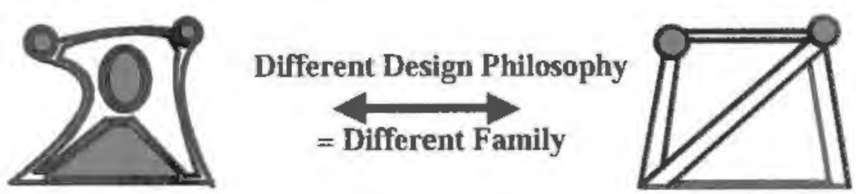
An additional test(s) must be performed for:

- Any seat with a seat leg geometry that is determined to be more critical with regard to strength, stiffness, or seat permanent deformation than the critical leg of a similar tested seat(s).
- Any seat with a seat leg energy absorber which has a variation in the load path, or which has a variation that affects the load rating or stroke/deformation of the energy absorber, from the seat(s) included in the baseline testing.

Static or dynamic component tests may be acceptable to substantiate variations to seat legs. Component test methods should be coordinated with the appropriate regulatory agency in advance of the certification program.



Note: Basic design/geometry includes small, local changes to the legs.
Fittings include attachments to cross-beams, fittings and spreaders.
Component tests may be appropriate instead of a full scale test.



3.2 Lateral Beams (Cross tubes)

a) *Family of Seat Principles* - Lateral beams (cross tubes) are typically the structural members that provide the load path from the fore-aft linkages (e.g., spreaders) and bottom cushion support to the vertical structure (e.g., legs). Lateral beams, at similar locations within the seat assemblies, must have the same design philosophy.

Two types of stiffeners are considered here. The first is a local doubler added to reinforce areas with high stress concentrations. A local doubler is defined as one whose length is of the same order of magnitude as the maximum cross-sectional dimension of the beam, e.g. one whose length is less than three times the maximum cross-sectional dimension of the beam. The second is a longer stiffener (e.g., nested tubes) used to increase beam stiffness and strength over a substantial part of the beam length. Lateral beams with long stiffeners should be treated as a different family, requiring a new, different test program since the dominant cross-section for the beam is different than other beams in the seat family.

Lateral beams can include local inserts within the family (e.g., doublers) which typically provide *local* strengthening of the beam. Inserts, at similar locations within the seat assemblies, must have the same material, manufacturing process and must have similar attachment methods. An insert configuration used in the primary load path (e.g., at the leg or spreader attachments) at all similar primary load path locations within the seat for all seats does not need additional substantiation beyond the baseline testing. For example, an insert included at any rear beam leg attachment should be included at all rear beam leg attachments for all seats in the family. Variations in geometry (length and thickness) are discussed below.

Nested tubes within a seat family must have the same material, manufacturing process and must have similar attachment methods. Variations in length are discussed below.

b) *Variations and Post Certification Changes Acceptable by Analysis* - The following variations in local inserts are acceptable without additional test(s) provided it can be shown by rational analysis that the strength, stiffness, and seat permanent deformation are equivalent to or less critical than the tested seat(s) (see appendix A).

- Insert thickness
- Insert length
- Insert location
- The elimination of a local insert in some locations of the seat assembly may be acceptable by rational analysis if the analysis *clearly* demonstrates the adequacy of the attachment without the insert.

Variations in the lateral beam length to accommodate differences in seat width are acceptable without additional test/analysis provided the seat is included in the interface load analysis used in the test article selection process in Section 4.0 of this concept paper.

Variations in nested tubes length and location are acceptable without additional test(s) provided it can be shown by rational analysis that the strength, stiffness, and seat permanent deformation are equivalent to or less critical than the tested seat(s).

c) *Variations and Post Certification Changes Requiring Additional Tests* - The structural performance of any seat with a lateral beam or nested tube possessing a variation in material, geometry (except for length), or manufacturing process from the seat(s) evaluated by test.

An additional test(s) must be performed for any seat that:

- Does not have lateral beam doublers, if used, at all similar primary load path locations within the seat,
- Has lateral beam doublersthat has a variation in material, geometry (except for length or thickness), or manufacturing process from the tested seat(s).
- Has lateral beam doublersor nested tubes which has a variation in length that is determined to be more critical with regard to strength, stiffness, or seat permanent deformation than the tested seat(s).
- Has lateral beam doublersor nested tubes that has a variation in attachment method that is determined to be more critical with regard to strength than the tested seat(s).

3.3 Seat Spreaders

a) *Family of Seat Principles* - A Seat spreader is typically a fore-aft linkage between the lateral beams. Seat spreaders often provide the structural load path for other features of the seat (e.g., seat belt attachment, seat back attachment). Spreaders, at similar locations within the seat assemblies, should have the same design.

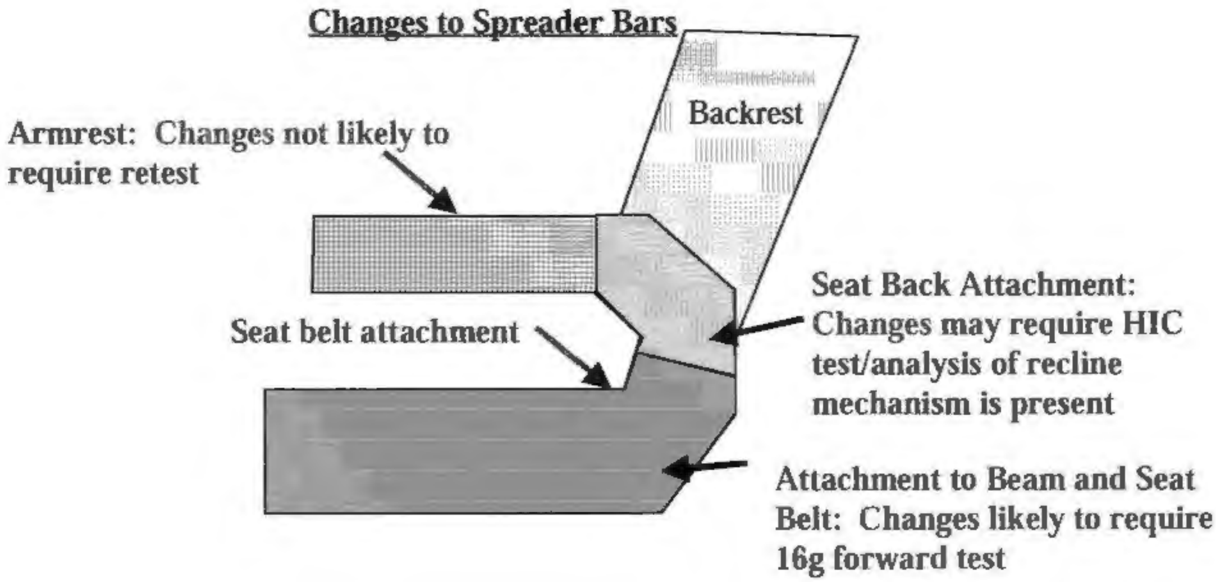
b) *Variations and Post Certification Changes Acceptable by Analysis* Variations to parts of the spreader that are not in the primary load path (for example, between the seat belt/seat back attachments and the top of the armrest) are acceptable without additional test/analysis. For example, the area of the spreader that extends beyond the seat belt or seat back attachment that incorporates an armrest attachment. The armrest attachment may vary, provided:

- The variation does not extend into the seat back/seat belt load path,
- The variation does not affect any potential ATD head contact area from an occupant in the seat behind,
- It can be shown by rational analysis that the retention of the armrest is not significantly affected.

Variations to parts of the spreader that are in the primary load path (between the seat back attachments and the lateral beams/legs) are acceptable provided it can be shown by rational analysis that the strength (compression/bending) is equivalent to or less critical than the tested seat(s).

c) *Variations and Post Certification Changes Requiring Additional Tests* An additional 16g longitudinal structural test must be added to the baseline testing for any seat with variations to parts of the spreader that are in the primary load path (between the seat belt attachments and lateral beams/legs).

An additional row to-row HIC test may be required, if variations to the spreader in any seat are within the ATD head contact area from an occupant in the seat behind or change the seat back performance with regard to HIC.



3.4 Bottom Cushion Support

a) *Family of Seat Principles* - The bottom cushion support (e.g., seat pan or diaphragm) is the structure immediately below the bottom cushion supporting the occupant weight. The primary considerations for this component regarding variations/changes are the affect on structural performance, lumbar load performance in a 14g vertical test, and the positioning of the occupant in the seat place. The bottom cushion supports at all seat place locations must have the same materials, manufacturing processes, construction method, and they must be similar in geometry and method of attachment, with the exception of section (b) below.

b) *Variations and Post Certification Changes Acceptable by Analysis* - Variations to the seat bottom cushion support geometry and method of attachment are acceptable without additional test(s), provided it can be shown by rational analysis, based on test data, that:
- The variations have no significant influence in increasing lumbar compression load (including deflection such that contact occurs with any item beneath),
- The strength is equivalent to or less critical than the tested seat.

The following variations are acceptable without additional tests:
- Variations in the bottom cushion support geometry to accommodate small difference in the seat place width (3 inches or less) provided other aspects of the geometry and the method of attachment do not vary.
- Variations in the bottom cushion support geometry having an influence on SRP location provided the SRP does not vary by more than 0.5 inch in any direction (fore, inboard, outboard, or up) from the SRP of the tested seat. In general, if all other features of a seat remain constant, head excursion with respect to the seat is shorter when the SRP moves aft. Similarly, structural loads due to overturning moments decrease as SRP is lowered. These general trends can be examined to eliminate duplication of some tests.

c) *Variations and Post Certification Changes Requiring Additional Tests* - Test(s) are required for any seat with a variation in seat bottom cushion support material or construction method from the tested seat(s).

Test(s) are required for any seat with a variation in seat bottom cushion support that has significant influence on lumbar load (including deflection such that contact occurs with any item beneath) or that is determined to be critical with regard to strength than the tested seat(s).

If a variation in the seat bottom cushion support varies the SRP more than 0.5 inches in any direction from the tested seat, the following tests/analysis must be performed:
- A 14g lumbar load test
- 16g longitudinal structural test if the SRP moves upward.
- 16g longitudinal head path analysis (if one is included in the baseline testing). This analysis would graphically modify the head path collected in previous test(s) to account for the change in SRP.
- A row-to-row HIC test should be performed if the SRP moves up or forward more than 0.5 inches. If the SRP moves down or aft, graphical analysis of the data collected in previous testing should be used to determine if the head might strike a different object.

Note: The new SRP location is directly related to any modification to the structural geometry in the seat bottom cushion support. Therefore, no SRP measurements are required in determining the "new" SRP.

3.5 Bottom Cushion

a) *Family of Seat Principles* - The bottom cushion is the component that the occupant sits directly upon. The primary considerations for this component regarding variations/changes are the affect upon lumbar load and the positioning of the occupant in the seat place. Occupant position is assessed using the Seat Reference Point (SRP) as defined in AS8049 Revision A or later. Variations in SRP dimensions discussed in this document are in the component X, Y, and Z directions (the XYZ resultant change is not considered). The bottom cushion assembly (i.e. foam sandwich) must have the same material (including density, material and manufacturing process, etc.), must be either molded or fabricated within a family, and must be similar in contour and thickness.

b) *Variations and Post Certification Changes Acceptable by Analysis* - Contour variations are acceptable without additional 16g & 14g structural tests provided the SRP does not vary by more than 0.75 inch in any direction (fore, aft, inboard, outboard, up or down) from the SRP of the tested seat. This 0.75 inches variation recognizes the inherent 0.25 inches tolerance in the SRP measurement in addition to an allowable design change of 0.5 inches. Experience has shown that geometry variations in an area three inches forward, two inches rearward and two inches sideward of each buttock reference point have the most influence on SRP.

Variations in seat cover fabric are acceptable without additional analysis. This is provided the variations do not significantly affect the SRP location.

c) *Variations and Post Certification Changes Requiring Additional Tests* - An additional test(s) must be performed for:
- Variation in bottom cushion material (excluding fabric and common fire-blocking material) would require a 14g vertical lumbar load test and 16g longitudinal head path test, if one were included in the baseline testing.
- Variation in cushion contour that moves the SRP location more than 0.75 inches up would require a 16g longitudinal structural test.
- Variation in cushion contour that moves the SRP location more than 0.75 inches in any direction would require a 16g longitudinal head path test, if one is included in the baseline testing.
- Any variation in the cushion contour in an area three inches forward, two inches rearward and two inches sideward of the buttock reference point of the previously tested cushion would require a 14g vertical lumbar load test.

3.6 Seatbelts and Anchors

a) *Family of Seat Principles* - The seat belts (occupant restraints) provide the load path from the occupant to the seat structure. The seat belt typically consists of a latching mechanism, a belt anchor (which connects the belt to the seat) and webbing (which links the latch mechanism with the belt anchors). The latching mechanism must have the same materials, manufacturing processes, construction method, means of webbing retention, and must be similar in geometry. The belt anchors must have the same materials, manufacturing processes, construction method, and must be similar in geometry. The webbing must have the same material, manufacturing process, construction method, and geometry. The stitching used to attach restraint system hardware to the webbing must be identical to the tested seat(s).

The goal is to have standards for seat belts that are sufficient to reduce or eliminate full scale testing when they are substituted on a seat family. To date, there are not sufficient standards to accomplish this. At this time, one or more full scale dynamic tests would be required to substantiate a seat belt replacement.

The quality and workmanship of the restraint system shall be consistent with TSO/JTSO C22 or TSO/JTSO C114 or equivalent.

The seat belt anchor provides the load path between the belt anchor (part of the belt assembly) and the seat structure (e.g. spreader). Seat belt anchor, at similar locations within the seat assemblies, must utilize the same materials, manufacturing processes, exhibit similar geometry and employ similar methods of attachment.

b) *Variations and Post Certification Changes Acceptable by Analysis* - Variations to the seat belt anchor or latching mechanism, are acceptable without additional test(s) provided it can be shown by rational analysis that:

- The variation does not affect the means of webbing retention, and
- The strength and stiffness are equivalent to, or less critical than the tested seat.

Variations to webbing color, latching mechanism, belt anchor finish, part labeling, connector/buckle "handedness", latch handle disengagement angle, and adjustable-side webbing length are acceptable without additional analysis.

Variations of the fixed length of the restraint system is acceptable as follows:

- The adjuster mechanism moves closer to the centerline of a 50% ATD from the previously tested position (Unless the original position of the adjuster was at the extreme side of the occupant (i.e., at the anchorage point)).
- The adjuster mechanism moves to within ±1.5 inches of the centerline of a 50% ATD (reference FAA letter 96-114 3).

c) *Variations and Post Certification Changes Requiring Additional Tests* - An additional test(s) must conducted for any of the following variations if it is determined to be more critical with regard to the component's performance in the dynamic test compared to the tested seat:
   - Changes in anchor geometry and method of attachment would require substantiation by test. Some changes to the seat belt anchor may be acceptable without test (e.g., changing a bolt to one with higher strength).
   - Latching mechanism material
   - Manufacturing process
   - Construction method
   - Stitch Pattern

   An additional test(s) must be performed for any seat with a seat belt anchor which has a variation in material, manufacturing process, construction method from the tested seat(s)unless substantiated by analysis (above).

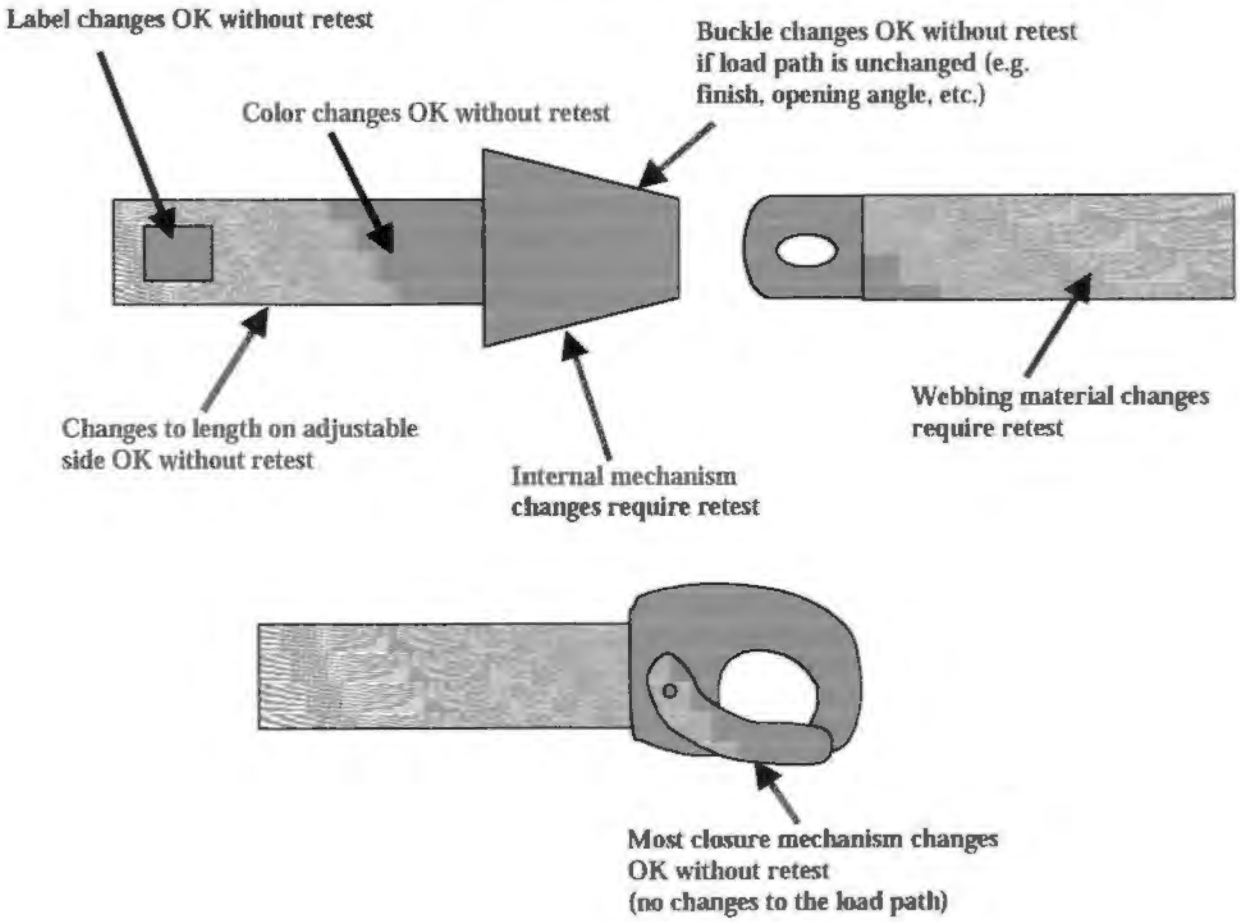
   Variations in the webbing or means of webbing retention in the latching mechanism must be addressed by parametric studies during 16g longitudinal tests (structural, HIC, head path).

   Once a belt system is qualified for a specific seat family it can replace other qualified belt systems on that same seat family. To qualify a new belt on an existing family, one 16g structural test seat with highest loaded leg (pitch and roll) must be performed. This structural substantiation is sufficient to allow use of the new belt on the seat family. The ATD head path must be compared for the seat with the new belt system and with the old belt system. This may be done on either the structural test noted above, or an additional 16g forward head path test depending on what data is available for comparison with the old belt system.
   - If the head excursion along the entire path for the new belt system is equal to or less than the old belt system, no additional substantiation is required.
   - If the head excursion along the entire path for the new belt system is greater than the old belt system, the installation limitations may need to be modified to account for this difference.

   If multiple belts are a part of an existing seat family, and a seat component is changed in the family that will require additional testing, it is not necessary to retest with every seat/belt combination. Floor reaction loads for the 16g structural tests for each belt may be used in selecting a single belt for use on testing future changes to the seat family. This would cover all belts previously qualified using the same webbing material (e.g. nylon or polyester webbing). The belt used for this follow-on testing would be the one associated with the highest floor reactions.

Note: If the test using the new seat component generates significantly higher floor reaction loads (load increases on the order of 10% or more) compared to the test without the new seat component, the belts that were not tested must be addressed to ensure they have sufficient strength. A plan outlining additional test and/or analysis of the non-tested belts must be reviewed with the appropriate regulatory agency.

Seat Belts



3.7 Attachments between structural members

a) *Family of Seat Principles* Fittings and fasteners provide the primary load path between structural components. These include, but are not limited to, the connection method of the spreader-to-beam attachment, beam to-leg attachment, and leg-to-track fitting attachment. In general, these attachments should reflect similar design philosophy at similar locations within the seat assemblies (e.g. the attachment method between the lateral beams and the seat legs should be consistent between seat assemblies).

b) *Variations and Post Certification Changes Acceptable by Analysis* Variations to the attachments between structural members due to space/geometry limitations are acceptable without additional test(s) provided
- The attachment has the same design philosophy, and
- It can be shown by rational analysis that the strength and stiffness are equivalent to or less critical than the tested seat.

c) *Variations and Post Certification Changes Requiring Additional Tests* An additional test(s) must conducted for any seat with an attachment that reflects a different design philosophy (e.g., a beam-to-leg attachment with a spreader clamp design vs. a saddle design) from the seat included in the baseline testing.

An additional test(s) must be conducted for any seat with an attachment which reflects the same design philosophy but is determined to be structurally more critical than the attachment between structural members of a similar seat included in the baseline testing.

A single 16g longitudinal or 14g vertical test is sufficient to substantiate the attachment between structural members, with a different design philosophy or variations within the same design philosophy, provided it can be determined which test condition is critical for that attachment.

3.8 Seat track fittings

a) *Family of Seat Principles* - Seat track fittings are critical components in the primary load path.

The seat track fitting provides the load path between the seat primary structure (e.g., leg or beam) and the aircraft structure (e.g., seat track). Seat track fittings must have the same load path and similar design philosophy.

b) *Variations and Post Certification Changes Acceptable by Analysis*

Variations to the seat track fitting locking mechanism engagement/adjustment device (screw, bolt, etc.) are acceptable without additional analysis provided it is not part of the load path, or does not change the load path (for example, by altering stud engagement).

Variations in seat track fitting finish are acceptable without additional analysis provided the method of finish application does not affect the strength of the part.

c) *Variations and Post Certification Changes Requiring Additional Tests* - Variations in seat track fitting geometry or method of attachment must be substantiated by test(s).

An additional test(s) must be performed for any seat with a seat track fitting which has a variation in load path, material, manufacturing process, construction method from the tested seat(s).

3.9 Energy Absorbers in Seat Leg Structures

a) *Families of Seat Principles* - Energy absorbers (EA devices) are typically incorporated in the seat leg structure to control occupant and/or structural loads. Within a family, energy absorbers must share a consistent design. While the incorporation of energy absorbing features is encouraged, the criticality assessment is not as straightforward as for other parts of the primary load path.

If all seat leg/EA combinations are identical, the normal seat dynamic test program that tests the structurally critical seat will also substantiate all the seat leg/EA combinations in this case. No additional tests are required.

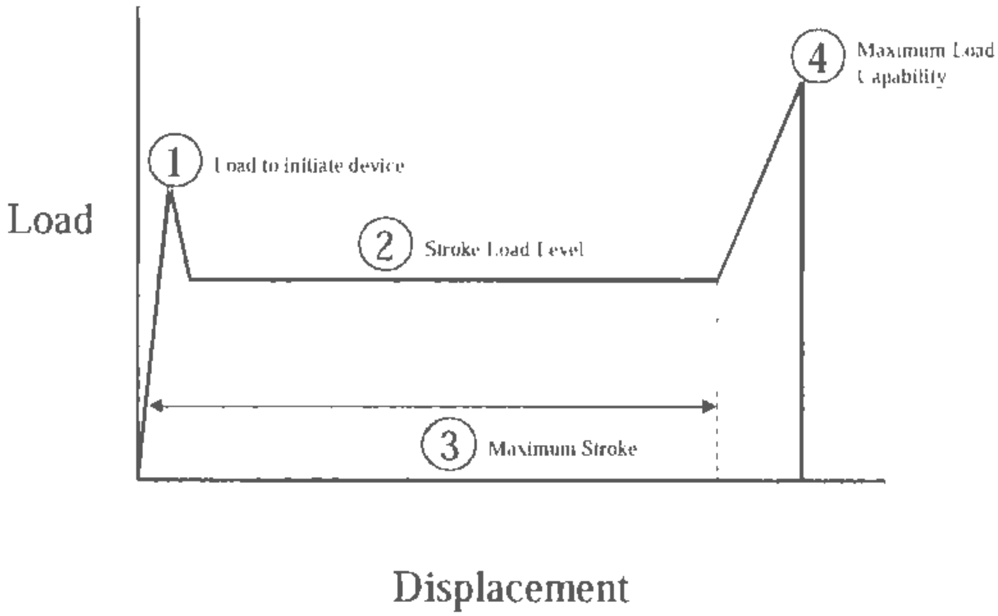
b) *Variations and Post Certification Changes Acceptable by Analysis* - When the seat leg structures are identical at all locations, but different rated EA's are at some seat leg locations (the EA's use the same design philosophy, and the EA's end attachments are identical), the leg structure must be substantiated for the highest load and the stroke of each EA device must be substantiated as follows:

Substantiation of the Leg Structure and Attachment - The normal seat dynamic test program that considers the structurally critical seat will also substantiate all the seat leg/EA combinations if none of the EA's stroke or if only the highest rated EA strokes. Either of these test results will ensure that the highest seat/floor interface loads were developed.

Substantiation of the EA Stroke - In general, a lower rated EA device should not "bottom out" unless the highest rated EA also "bottoms-out". In any event, additional tests may be required to test the lower rated EA device(s) in order to establish the highest seat/floor interface load for that device, should any EA other than the highest rated EA "bottom-out" during the test.

In all cases, additional tests must be performed, critically testing the lower rated EA devices, or the supplier must work with the appropriate regulatory agency to develop a validated predictive model for the EA devices in order to provide an adequate rational analysis in order to avoid additional tests.

The following steps outline the considerations to be used in performing a predictive rational analysis used to substantiate seat legs with different rated EA devices. This analysis should be successfully completed prior to conducting dynamic tests in order to demonstrate that there is adequate testing of the energy absorbing system and the affected seat structure:



- The fundamental performance should be characterized in terms of the maximum load capability, the load to initiate the EA device, the stroking load level, and the amount of stroke/deformation available. These parameters all need to be determined.
- Using the static interface loads and knowledge of the EA characteristics the expected performance of each EA (i.e., stroking load level and stroke length) should be predicted;
- Correlate the analytical predictions and the results of the dynamic test to ensure that during the dynamic test all EA's have performed as designed.
- Demonstrate that none of the seat/EA combinations would bottom out under their maximum load case.

EA variations that do not affect the fundamental performance, or make the stroke/deformation of the EA more critical, may be allowed without retest.

c) *Variations and Post Certification Changes Requiring Retest* - If a seat assembly has different leg structure and different rated EA's at some locations, each seat leg/EA combination must be demonstrated by tests to produce that the maximum seat/floor interface load for each individual seat leg/EA combination. This is necessary to ensure that the maximum seat leg/EA load is developed for each combination and that adequate stroke is available at each individual EA.

3.10 Seat Backs

a) *Family of Seat Principles* - The seat back supports the occupant's torso in the seated position. It is the component of the seat that is typically forward of an occupant in a row-to-row HIC situation (forward facing seats), and is the component of the seat which provides the load path to the lower seat structure in aft facing installations. The permanent deformation of seat backs can be a significant consideration for the occupant egress of the airplane. The primary consideration for this component regarding variations/changes are the affects on seat back position/angle and occupant positioning (which may affect HIC or lumbar load), the affect on structural performance and seat back permanent deformation.

The components installed on the seat back (e.g., food tray tables, video monitors, telephones, etc.), must be represented when evaluating variations/changes, as well as the recline mechanism, breakover devices, seat back energy absorbers, and seat back attachment hardware.

The seat back structural components and attachment hardware must have the same materials, manufacturing processes, construction method and they must be similar in geometry.

The seat back energy absorbers must be the same for all seat backs for all seats that are subject to the HIC criteria.

The seat back breakover must be the same for all seat backs for all seats that are subject to the HIC criteria.

When a load is applied to the seat back in the upright position, the load path within recline mechanism(s) from the seat back to the seat structure must be the same for all seat backs that are subject to the HIC criteria.

The seat back breakover must be the same for all seat backs for all seats.

Seat backs should be interchangeable between most families if the seat back accessories, back structure and method of attachment perform the same.

Once substantiated for HIC, seat backs can be arranged independently in the aircraft (subject to pitch limitations of the target seats). For example, once the business class seats pass the HIC testing, they can be installed in the aircraft with an economy class seat behind without further substantiation. Exceptions include it being paired with a seat with very unusual performance (e.g. very large deformation, substantial energy absorption, etc.)

b) *Variations and Post Certification Changes Acceptable by Analysis* Variations to components installed on the seat back are acceptable without additional test(s) provided the test article selection process in Section 4.0 (considering the component variance) shows the seat(s) selected for the row-to row HIC tests are the seat(s) that was tested.

Variations to the attachment method of components installed on the seat back are acceptable without additional test(s) provided:

- For retention, it can be shown by rational analysis that the strength is equivalent to or less critical than the tested seat(s), and
- This does not replace the test in Section 4.0 for row-to-row HIC

Variatioos to the seat back, excluding potential head contact areas, which do not significantly affect the mass/weight, center of gravity or load path stiffness of the seat back (e.g., cushion trim, dress cover, etc.) are acceptable without additional analysis.

Variations of the seat back structure width up to two inches are allowed without additional test as long as these variations in seat width do not introduce new structure in the target head strike area. Variations greater than 2 inches may require additional test(s) for HIC and B/C deformation.

Variations in the seat back upright position of ±3° are acceptable without additional analysis provided it can be shown that the variation has no influence on occupant egress from the airplane when evaluated using the seat permanent deformation data from the baseline tests (reference AC 25.562-1A). For example, applying the seat permanent deformations from the baseline tests to the "new" seat back upright position still meets the guidance for occupant egress, including 'B' vs. 'C', given in AC 25.562 1A. Additional variations in the upright position are acceptable with analysis that the variations doe not influence HIC or egress for the person in the seat, or the person behind the seat.

Variations to backrest cushion hardness and contour are acceptable provided the SRP does not vary by more than 0.75 inch from the SRP of the tested seat.

Variations to any part of the recline mechanism which does not provide a load path from the seat back to the seat structure are acceptable without additional analysis.

c) *Variations and Post Certification Changes Requiring Retest* - Variations in the seat back structure materials, manufacturing processes, or construction method from the tested seat(s) may require retest.

A HIC test(s) must be performed for any seat with a seat back (subject to the HIC criteria) which has a variation in an installed component that the test article selection process in Section 4.0, when considering the component variance, shows must be tested in addition to the tested seat(s).

A test(s) must be performed for following seats if they are required to meet the HIC criteria:

- Any seat with a seat back that has a variation in the attachment method of an installed component that has been determined to be more critical than the tested seat(s).
- Variations in the seat back attachment method, which the test article selection process in Section 4.0 shows must be tested in addition to previously tested seat(s).
- Variation in the seat back energy absorber from the tested seat(s).
- Variation in the seat back breakover from the tested seat.
- Variation to any part of the recline mechanism which provides a load path from the seat back to the seat structure from the tested seat. If a part of the recline mechanism is not considered critical in the HIC load path, variations which do not lower the strength of the load path are acceptable without test. For example, the recline mechanism can be replaced with a "solid rod" because other components in the HIC load path absorb the energy of a seat back head strike.
- Variation in backrest cushion hardness or contour that varies the SRP location more than 0.75 inch in any direction from the seat back to the seat structure from the tested seat.
- Variation in the seat back upright position of greater than ±3° from the seat back to the seat structure from the tested seat, unless an acceptable analysis is provided per section (b) above.

3.11 Seat Weight

a) *Family of Seat Principles* - The seat weight has a significant influence on the seat performance during the structural tests. Small weight variations are acceptable, but large increases must be substantiated by test. These variations are accounted for in the critical test case evaluation by interface load comparison, and mass retention evaluation. Proper planning of test article definition and testing can make accommodation of future seat weight growth. This can be accomplished by adding ballast to the test article.

b) *Variations and Post Certification Changes Acceptable by Analysis* - An increase in the seat weight of a seat that was included in the baseline testing is acceptable without additional test/analysis provided the increase is not greater than 3% of the total unoccupied tested seat system weight. It is understood that 3% is the current focus of the SAE seat committee for weight increases without test. If the SAE committee selects an alternate criterion, this would be adopted as an acceptable standard.

An increase in the weight of a seat that was not included in the baseline testing (i.e., a seat that was not tested per the test article selection process) is acceptable provided:

- The test article selection process in Section 4.0, using a seat interface load analysis with the increased seat weight, shows the seat(s) selected for the structural tests to still be the tested seats.
- If the weight increase to any seat is due to adding a specific item to a specific location on the seat:
  - Retention of the added item must be addressed from the component to the primary structure of the seat:
  - For items where the strength of the attachment method is the only issue, a static analysis/test may be sufficient.
  - For items that are likely to affect the dynamic response of the seat, dynamic testing must have substantiated local retention of a similar item of representative weight and attachment.
  - Depending on the location of the added component, testing of the component in question for retention may be conducted on a partial or unoccupied seat. These types of tests should be coordinated in advance with the appropriate regulatory agency.
- Testing must have substantiated HIC if ATD head contact with the added item is possible.
- Testing must have substantiated lumbar load if ATD contact with the added item is possible.

c) *Variations and Post Certification Changes Requiring Additional Tests* An additional test(s) must be added to the baseline testing for any seat that was included in the baseline testing with a weight increase greater than 3% of the unoccupied tested system seat weight.

An additional test(s) must be performed for any seat that was not included in the baseline testing with a weight increase if the test article selection process in Section 4.0, using a seat interface load analysis with the increased seat weight, determines that this seat should be selected for testing.

An additional test(s) must be performed for any seat with a weight increase due to adding a specific item to a specific location which was not substantiated in the baseline testing for retention of the item, HIC, or lumbar load (as appropriate).

A dynamic test of the seat with no occupants or a static test using an appropriate load factor may be acceptable to substantiate retention of an item of mass on the seat.

3.12 Armrests

a) *Families of Seat Principles* - Armrests are the seat structures that retain the occupant's sides. They are not required features on a seat and many passenger places can have armrests on one or both sides of the passenger stowed (folded up). They may influence the lumbar criteria in the 14g down test if the ATD's arms rest on them. The primary considerations for this component regarding variations/changes are the affect on retention of the component, HIC (head contact on aft part of armrest from occupant seated behind), occupant egress of the airplane (seat permanent deformations), and positioning of the occupant in the seat place.

b) *Variations and Post Certification Changes Acceptable by Analysis* - Variations to armrests are allowed provided:

- It can be shown by rational analysis that the variations have no influence on the ATD dynamic response.
- It can be shown by rational analysis that the variations have no influence on occupant egress from the airplane when evaluated using the seat permanent deformation data from the baseline tests (reference AC 25.562 1A).
- The test article selection process in Section 4.0, considering the seat with the armrest geometry variance, show the seat(s) selected for the row to row HIC tests have been tested
- Variations to the armrest attachment can be shown by rational analysis that the strength is equivalent to or less critical than the tested seat(s).

c) *Variations and Post Certification Changes Requiring Additional Tests* - Variations to armrests that are in a potential occupant head strike location should be substantiated by test/analysis.

An additional test(s) must be added for any seat that has an armrest which has a variation in attachment method that is determined to be more critical with regard to strength than the seat(s) included in the baseline testing.

An additional test(s) may be required if changes to the armrests influence the ATD response to lumbar loads. For example, if the seat geometry forces the ATD's arms over the armrests during a test, and a post-test modification to the armrest would significantly change the ATD response, an additional test may be required.

An additional row-to row HIC test may be required to be added, if geometry or material variations to the armrest in any seat are within the ATD head contact area from an occupant in the seat behind.

4.0 Test Article Selection for Baseline Tests

Test article selection from the family of seats is dependent on the installation and, in particular, the seat track. Installation on a different seat track will require re-substantiation and, in most cases, additional tests.

4.1 Structural Tests (reference section 25.562 (c)(7) and (c)(8))

Substantiation of the 16g longitudinal load condition for each family of seats:

1) Determine the 9g forward static interface loads (or any other standard load) for all seats. It is generally accepted that the interface loads calculated at 0° are sufficient to determine the most critical seat. Special seat design features *may* require interface load calculations that would take into account the aircraft tapered sections. All occupancy variations and combinations shall be considered for each seat (from unoccupied to fully occupied). The critical test case may be determined by analysis (FEM or static interface loads) and also by using test data.

2) Group the seats into two groups. Seats with two legs and seats with more than two legs.

3) For each group of seats (see attached decision chart to clarify the items below):

   a) Compare the aft fitting resultant loads of the seats within each group and identify the seat with the highest load. This seat will be tested.

   b) Subgroup the seats by lateral leg spacing.

   Note: For groups with more than two legs, define a subgroup of seats based on the minimum lateral leg spacing.

   c) Identify the subgroup with the minimum (narrowest) lateral leg spacing and identify the seat with the highest seat leg aft fitting resultant load within that subgroup.

   d) If the aft fitting resultant load of the seat identified in step 3c (narrowest leg spacing) is greater than 80% of the highest load found on the seat selected for test in step 3a then the seat identified in step 3c will also be tested. (See paragraph 6.b of AC25.562-1A and chart below).

   e) Conduct a 16g longitudinal dynamic test of each seat selected in steps 3a and 3d from each group. If the seats selected in steps 3a and 3d do not result in testing the seat with the most critical beam load, that seat should be tested as well.

f) The occupancy that produced the highest calculated seat leg resultant tension reaction in the aft fitting shall be used for the test, unless the load of the fully occupied seat is within 10% of the highest seat leg load. Due to the statically indeterminate nature of seat structure, there are assumptions used to calculate interface loads, which will result in some uncertainty. Data indicate that calculated reactions within 10% of one another are effectively equivalent. In such cases, a fully occupied seat will impart an overall greater load than a partially occupied seat. Therefore, if the fully occupied seat leg load is within 10% of the highest loaded seat leg, test the seat fully occupied.

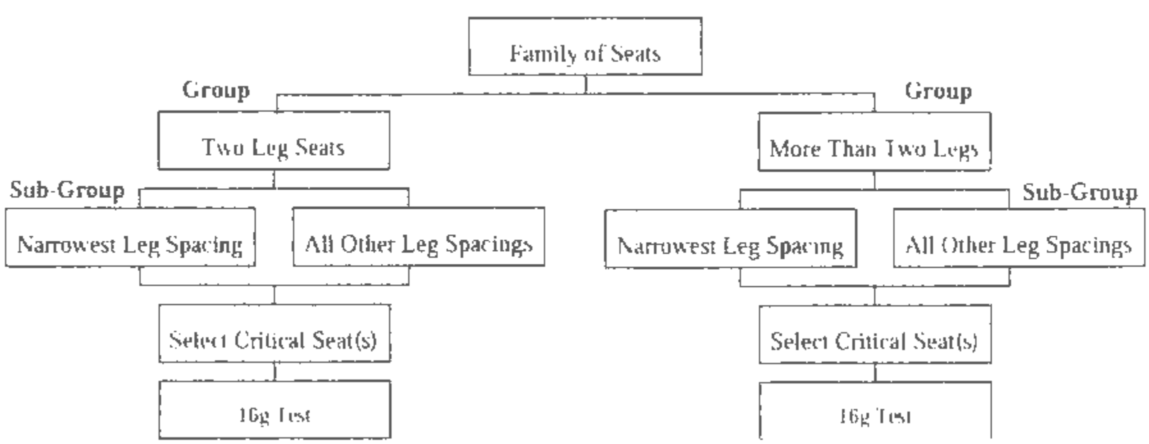
g) Select yaw, pitch, and roll for test setup per guidance given in AC 25.562-1A.

Note: If any seat in the family is intended to be installed on canted seat tracks, the yaw angle for the test shall be 10° plus or minus the aircraft installation cant angle (if it is more critical) depending on which yaw angle maximizes the calculated reaction (a test yaw angle other than the minimum required may be used to accommodate the test fixture adjustment capability).

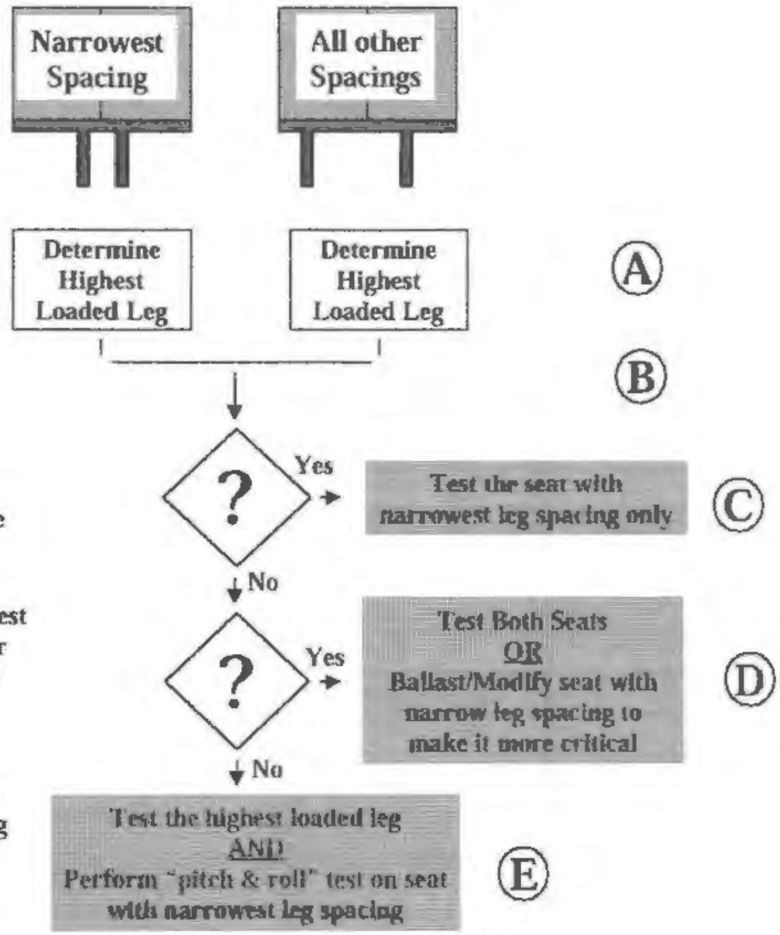
h) Baggage, life vests, and literature pocket contents shall be installed at each seat place, regardless of seat occupancy. A floor for the ATD's feet is optional for the 16g forward structural test. The floor may remain flat, or follow the warpage of the seat tracks. (Reference AC 25.562-1A paragraph 11.f)

i) Retention of a specific item of mass, including emergency equipment, need only be demonstrated once during the 16g longitudinal load condition and the item of mass may be restrained for all other 16g longitudinal tests. (Reference AC 25.562-1A, paragraph 6.a).

16g Test



Structural Test Article Decision Tree



1) Determine9g Interface Loads

2) Compare the highest loaded legs

Question: Is seat with narrowest leg spacing the one with the highest interface loads in this group?

Question: Does the seat with the narrowest leg spacing have an interface load greater than 80% of the highest interface load in this group?

Final Choice: The highest interface load on the seat with the narrowest leg spacing is less than 80% of the highest interface load in this group.

(A) 9g static interface loads are the generally accepted indicator of seat structure criticality. Based on this analysis, the highest loaded leg will indicate the most critical configuration to test. (note: other features may drive criticality (e.g beam bending, etc.) in addition to the interface loads analysis). Using 9g static interface loads, identify the highest loaded leg for the seats with the narrowest leg spacing sub-group and the highest loaded leg for the seat from the wider spaced-leg sub-group(s).

(B) Compare the interface loads of the highest loaded seat leg from the sub-groups(s). It is generally accepted that the seat with the narrowest leg spacing will exhibit the highest pre-loads during "pitch & roll"

(C) By testing the seat with the narrowest leg spacing, the test covers the highest loaded leg and the highest pre-load from "pitch & roll".

(D) If the static interface loads for the seat with narrowest leg spacing is within 20% of the seat with the wide leg spacing, it cannot be easily determined which is the more critical to test. The pre-load from "pitch & roll" contributes more to the criticality of the seat with narrow leg spacing. Since the most critical seat cannot be easily determined, either test both seats, or modify/ballast the narrow seat so that it has the more critical interface loads and the highest pre-load from "pitch & roll". Test only the narrow seat. (Note: modification of the seat should be limited to relocating seat legs along a beam to create a more critical overhang. Modifications should not change seat hardware).

The 20% margin guideline was established from industry test data and represents a conservative estimate of leg pre-load forces over a large change in seat leg pitch. This number may be established uniquely for each seat family. Ideally, this value would be established based on pre-load test data compared to the peak resultant load from a 16g longitudinal test. A new ratio would be established for a seat model from test data as follows:

$$\text{Ratio} = \frac{\text{Pre-load test data (resultant load)}}{\text{Peak resultant load from 16g longitudinal test}}$$

(E) If the highest static interface load on the seat with the narrowest leg spacing is less than 80% of the highest loaded seat in this group, it can be assumed that the narrow seat with the higher pre- load will not be more critical. Only the seat with the highest leg load need be dynamically tested. A check must still be made on the narrowest leg spacing seat to ensure the structure has enough flexibility to accommodate floor warpage. This seat should be placed on a static test fixture and the floor warpage applied. No dynamic test of this configuration is required. This is a test of the primary structure. No ATD's or other additions to test article/set-up are required.

For each family of seats, to substantiate the 14g down load condition:

1) Compare the aft fitting resultant loads of all seats in the family, regardless of the number of legs on the seat, and identify the seat with the highest load. This will usually be the same seat that was selected for the critical forward structural test. This one seat will be tested.

2) Conduct a 14g vertical dynamic test of the seat selected in step 1.

   a) Full occupancy shall be used for this test. (Note: This is to ensure the maximum compressive load is put on the structure).

   b) Life vests and literature pocket contents shall be installed at each seat place, regardless of seat occupancy. Ballast may be used for non-critical parts of the seat (e.g., under seat In-Flight Entertainment (IFE) boxes, etc.). However, if this test is also used to acquire lumbar loads, the criticality of parts should be assessed with that in mind. See discussion in section 4.3 regarding compliance with FAR/JAR 25.562(c)(2).

Note: Weights representing under-seat baggage are not required for the 14g vertical test. The ATD's identified in the FAR/JAR 25.562(c)(2) part of this test selection process shall be instrumented to collect lumbar loads.

   c) Retention of a specific item of mass, including emergency equipment, need only be demonstrated once during the 14g vertical load condition and the item of mass may be restrained for all other 14g vertical tests.

Note: Refer to AC 25.562-1A to address special design features (e.g. unique energy absorption features).

A representative floor shall be included in the test set up for the ATD(s) feet.

4.2 Deformation for Egress

The seat permanent deformations (reference AC 25.562 1A Appendix 2) shall be measured in all tests in order to show compliance to 25.562(c)(7). In addition, seat back permanent deformations shall be measured in a test where the ATD head contacts the seat back (e.g., a row to row HIC test). These permanent deformations shall be used to show compliance to 25.562(c)(8). (Note: Deformations that are an artifact of test set-up orientatinn need nnt be considered.) Some of the seat permanent deformations will be evaluated for acceptability as part of the dynamic test results (seat pan rotatinn. 'B' vs. 'C'). Some of the seat permanent deformations will be used by the seat installer to evaluate the seat installation and aircraft interior configuration (seat forward, aft, side deformations, seat back forward and aft deformations, and deployment of deployable items). The seat installer shall use the seat permanent deformations to show an acceptahle installation with regard to occupant egress of the airplane.

4.3 Occupant Injury Criteria (reference FAR/JAR 25.562 (c)(1-6))

FAR/JAR 25.562 (c) (1) - Upper Torso Restraint Tension Loads

The upper torso restraint tension loads shall be collected during a structural test where the seat is yawed in the direction that produces the highest tension load in the restraint system. Typically this is the yaw direction which puts the upper torso restraint over the shoulder of the ATD which is moved further forward as a result of the yaw.

If the 16g longitudinal test that demonstrates compliance to FAR/JAR 25.562(c)(7) is yawed in the appropriate direction, the restraint tension load data may be collected during this test and an additional test is not required.

If the 16g longitudinal test that demonstrates compliance to FAR/JAR 25.562(c)(7) is not yawed in the appropriate direction, an additional test must be added to the baseline testing. The test article for the additional test would be the same seat selected for the 16g longitudinal test that demonstrates compliance to FAR/JAR 25.562(c)(7). It would be yawed in the direction that creates the highest tension load in the restraint system, with the pitch and roll selected per the guidance in AC 25.562-1A.

FAR/JAR 25.562 (c) (2) Lumbar Loads

1) The ATD lumbar loads shall be collected during the 14g vertical test that demonstrates compliance to FAR/JAR 25.562(c)(7). An additional test for collecting lumbar loads is not required in the baseline testing (except as noted below).

   a) ATD's instrumented to measure lumbar loads shall be placed in seat places which represent the stiffest load path from the center of the occupant place to the structure and the least-stiff load path from the occupant place to the structure. This requirement will typically result in two instrumented ATD's, but will not exceed three instrumented ATD locations in a single test.

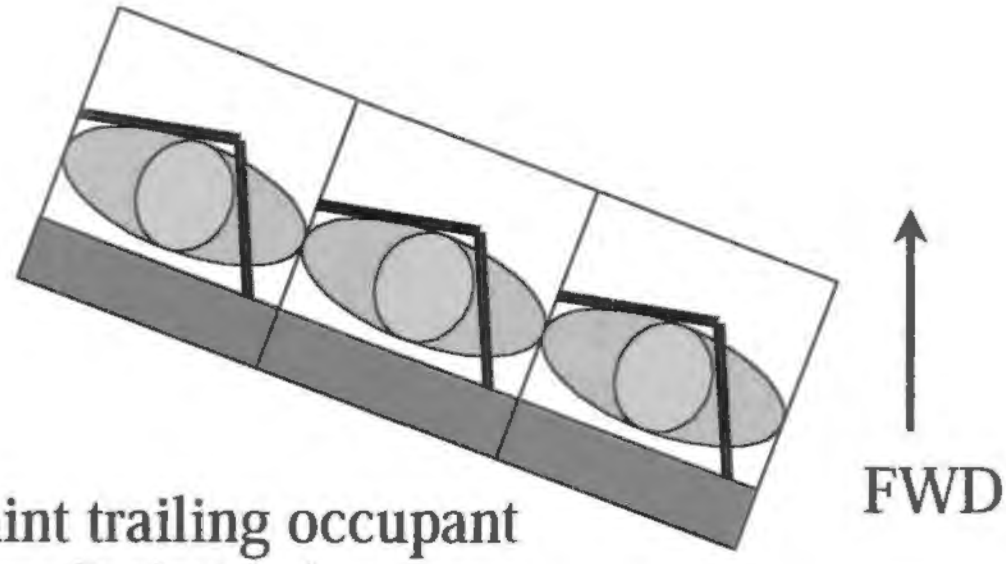
Note: Refer to AC 25.562 1A to address special design features (e.g. unique energy absorption features) which may function differently, depending on seat occupancy.

If there is an item (e.g. IFE) or structure located at a specific seat place (typically beneath the seat pan) which may influence lumbar loads due to seat deflection and/or ATD contact, then lumbar loads must be addressed and substantiated for this location in addition to the locations identified above (either data showing no contact or an additional test(s) added to the baseline testing).

FAR/JAR 25.562 (c) (3) Upper Torso Restraint Remains on Shoulder

For seats with a single upper torso restraint (e.g. a 3 point restraint), a test which demonstrates that the upper torso restraint strap remains on the ATD's shoulder during impact with the seat yawed in the most critical direction must be conducted. Typically, this is the yaw direction that puts the upper torso restraint over the shoulder of the ATD that is moved aft as a result of the yaw.

If the 16g longitudinal test which demonstrates compliance to FAR/JAR 25.562(c)(7) is yawed in the appropriate direction so that the restraint is over the trailing shoulder, the restraint retention may be demonstrated during this test and it is not required to add a test to the baseline testing.



Restraint trailing occupant
(Overhead view)

If the 16g longitudinal test that demonstrates compliance to FAR/JAR 25.562(c)(7) is not yawed in the appropriate direction, an additional test must be performed. The test article for the additional test would be the same seat selected for the 16g longitudinal test. This demonstrates compliance to FAR/JAR 25.562(c)(7), yawed in the direction most critical for the restraint strap to remain on the ATD's shoulder, and with the pitch and roll selected per the guidance in AC 25.562-1A.

For seats with a dual upper torso restraint, the 16g longitudinal test which demonstrates compliance to FAR/JAR 25.562(c)(7) is acceptable for demonstrating the upper torso restraint straps remains on the ATD's shoulder during impact and it is not required to add a test to the baseline testing.

High-speed test film/video of the test will be used to demonstrate that the upper torso restraint strap remains on the ATD shoulder during the impact.

<u>FAR/JAR 25.562(c)(4) - Lap Belt Remains on Pelvis</u>

The baseline and additional tests will demonstrate the pelvic restraint remains on the ATD pelvis during the deceleration pulse. It is not required to add any tests to the baseline testing.

High speed test film/video of all tests (baseline and additional) will be used to demonstrate that the pelvic restraint remains on the ATD pelvis during deceleration pulse. No additional tests are necessary to show compliance with this paragraph. Current guidance outlines camera placement and quantity if the lap belt angle is greater than 55° or less than 45°.

FAR/JAR 25.562 (c) (5) - HIC

1) Seat to Seat HIC

In an effort to reduce the regulatory burden and simplify/clarify the procedure for demonstrating compliance, the following procedure has been developed. This procedure should allow demonstration of compliance for HIC with two tests in the majority of cases. The procedure takes into account seat pitch, the relative position of the seat and the row behind it as well as range of occupant sizes. The intent of this procedure is to provide default conditions that can be used in lieu of conducting several tests, or performing lengthy analytical studies, and is adequate to demonstrate compliance.

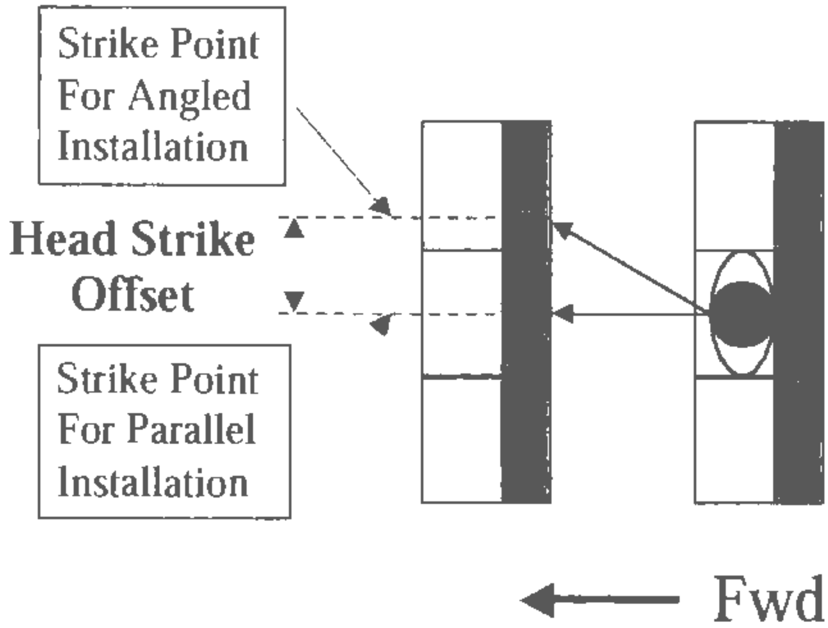
For each family of seats:

a) Identify the intended seat installation configurations from a seat-to seat HIC perspective. This may include, but is not limited to:
   i) Seats on canted seat tracks, such that the seats are parallel, but are at an angle with respect to the airplane longitudinal axis.
   ii) Seats on staggered seat tracks such that the seat places, row-to-row, are staggered.
   iii) Non parallel seat rows.
   iv) Staggered seating due to a change in the number of seat places.
   v) Different width seats which result in the seat places, row to-row, to be slightly staggered.

b) Identify the range of intended seat-to seat pitch.

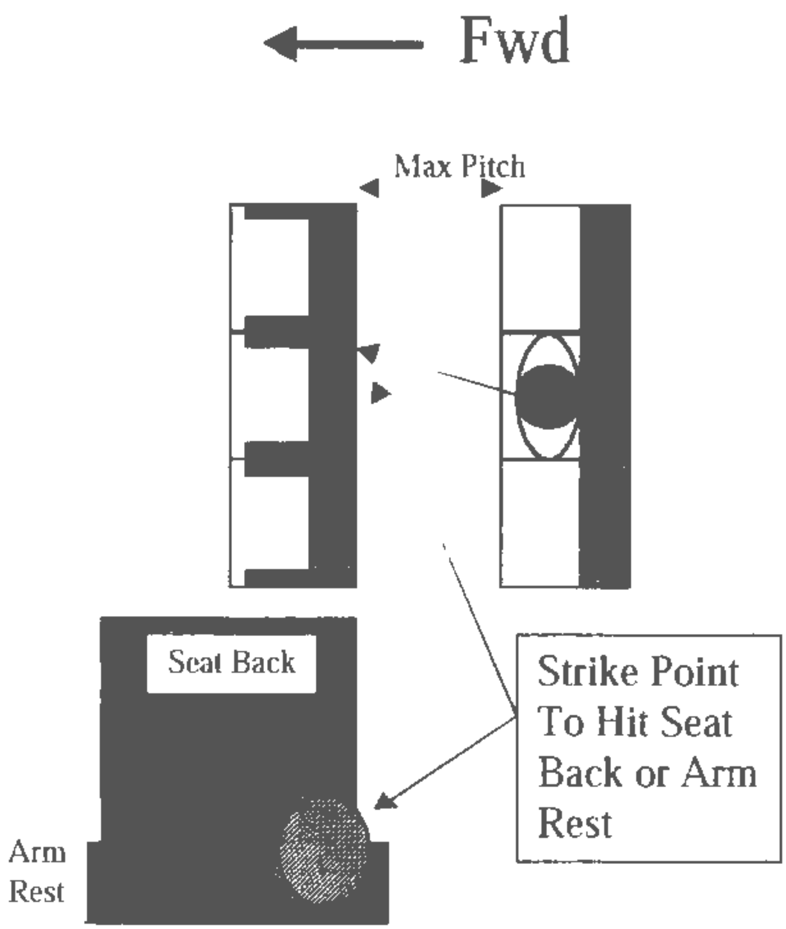
Note: For non-parallel seat installations (i.e., at the seat track break between the airplane constant and tapered sections) the SRP to SRP distance at the center of the seat place will be used as the seat pitch to determine minimum and maximum pitch when utilizing this test article selection procedure. All seat places (inboard to outboard) in the seat must be considered when determining the minimum and maximum seat pitch. Additional, unique seat pitches may be considered by choice.

c) For seats installed at an angle with respect to the airplane longitudinal axis (parallel rows or non-parallel rows), e.g., the rows in the tapered section of the aircraft:



i) Determine the head strike location of the 50% male ATD for the seats in the yawed installation configuration (inertia load direction parallel to the airplane longitudinal axis) using the path of the top of the ATD head.
ii) Determine the head strike location of the 50% male ATD for the same seats in a 0° yaw; parallel row installation configuration at the same seat to-seat pitch as the yawed installation configuration.
iii) Calculate the "head strike offset - the distance between the two contact points determined in steps 1(c)(i) and 1(c)(ii), measured on a plane perpendicular to the airplane longitudinal axis.
iv) If the cumulative offset between the staggered seats plus offset due to the installation angle head is 6.0 inches or less, the additional seat angle may be neglected for the row-to-row HIC tests.
v) If the cumulative offset between the staggered seats plus offset due to the installation angle is greater than 6.0 inches, the additional seat angle must be included in the step 1(d)(i) evaluation and included in the test set up, as necessary.

d) For two of the same part number seats in the family, installed parallel to each other:



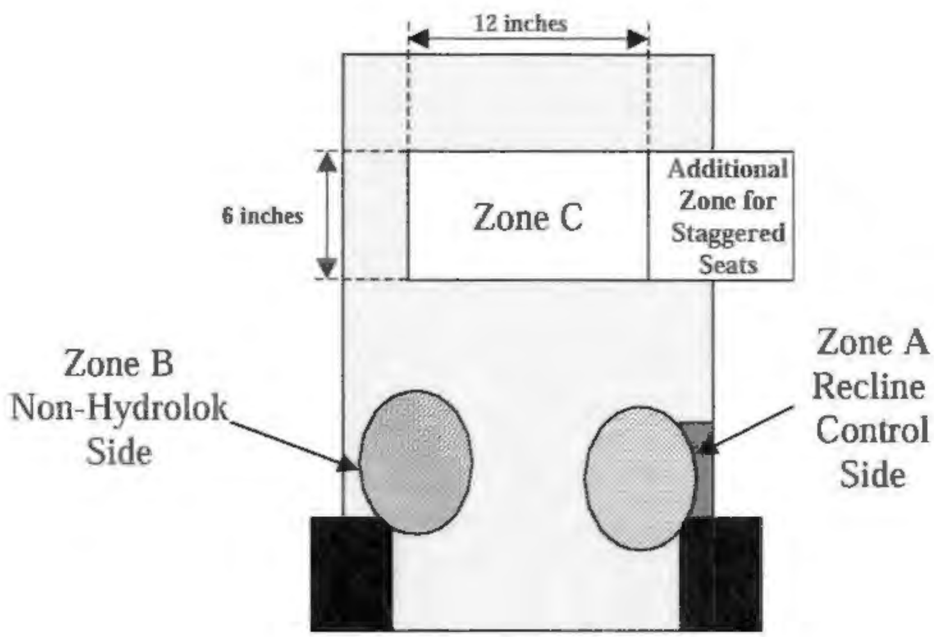
i) Determine the maximum seat pitch (within the range identified in step 1(b)) and the yaw angle (within the ±10° envelope plus additional seat installation angle per step 1(c)(v), if required) at which the 50% male ATD head impacts the lower portion of the seat back structure and/or the armrest structure. In most cases, the additional aircraft installation angle is not additive to both the plus and minus yaw angle (e.g. the analysis for an aircraft installation angle may be +10° and -14°).

Note: Impact is defmed as a solid strike by the ATD head and not a glancing blow.

ii) A test which is set up (seat pitch and yaw angle per step 1(d)(i)) with the yaw direction such that the ATD head strikes the side of the seat back with the seat recline mechanism shall be conducted (Zone A test).
iii) A test which is set up (seat pitch and yaw angle per step 1(d)(i)) with the yaw direction such that the ATD head strikes the side of the seat back without the seat recline mechanism shall be conducted (Zone B test).

Note: It is common for the recline mechanism to be positioned on the left side of some seat backs and the right side of other seat backs of the same assembly. Therefore, the seat-to-seat HIC test for Zone A and Zone B can usually be accomplished in one two row test using two instrumented ATD's with the yaw direction set to effect a head strike in Zone A by one ATD and Zone B by the other ATD. Alternatively, it may be possible to relocate one recline mechanism for test purposes. If this method is chosen, care should be taken to not alter the basic design. The intent of this procedure is to create a mirror image of the actual part, to simplify testing.

e) For same seats used in step 1(d), installed parallel to each other:



i) Determine the point of initial head contact by the 50% male ATD at the minimum pitch identified in step 1(b) and at 0° yaw angle.
ii) Evaluate the area defined by a 6 inch high by 12 inch wide rectangle centered on the initial head contact point for structures that differ significantly from the initial contact point (i.e., telephone handsets, video screens, and oxygen mask container units).
iii) Determine which structure in the 6 inch by 12 inch rectangle is the most rigid in the direction perpendicular to the aft seat back structure.
iv) A test which is set up which produces ATD head contact with the structure identified in step 1(e)(iii) shall be conducted (Zone C test).

Note: Typically, the Zone C test will be conducted at the minimum seat pitch and 0° yaw. However, when the area of concern (as identified in step 1(e)(iii)) is not at the center of the 6 inch by 12 inch rectangle, the relative position of the seats in the two row set up must be adjusted to produce the ATD head contact desired. Lateral offset or vertical adjustment of the seats' relative position will ensure that a comparable head impact velocity as that measured from the normal position Zone C test is achieved, although other methods that achieve the same objective are acceptable.

f) For seats which have staggered seat places, row-to-row:

Note: Staggered seating can result from a change in the number of seat places, different width seat assemblies, or installation on staggered seat tracks to accommodate the airplane taper section.

i) If the row-to-row seat place is staggered, and the cumulative offset between the staggered seats plus offset due to the installation angle is 6.0 inches or less, the lateral offset between the seat places may be neglected and the row to row HIC tests identified above may be conducted without including the lateral offset.
ii) If the row to row seat place is staggered more than 6.0 inches, the actual staggered installation configuration must be considered. This may broaden the Zone C evaluation window and include more objects to consider for head strike. If a test representative of the actual staggered installation configuration is determined to be required (either in addition to, or in lieu of, one of the baseline tests identified above), the test set-up (yaw direction and angle, and seat pitch) shall be that which is determined to be critical for HIC.

Note: A staggered seat installation may prove to be the critical HIC evaluation for the airplane installation, if contact with armrests or other hard structure occurs. Such an installation may require additional testing beyond the Zone A and B evaluations in step 1(d).

g) For row-to-row HIC tests:
   i) Since this test is not considered the critical case used to demonstrate compliance to structural criteria, non production seat tracks may be used, for example, steel track, or seat track from a different aircraft type may be used on this test.
   ii) Any seat or seat place that allows the ATD to strike the intended target area is acceptable.
   iii) It is acceptable to conduct the test with no ATD's in the forward seat row. The components attached to the seat back and the structure of the seat back which influence HIC must all be representative of the production seat for all seat backs or armrests which will be contacted by the ATD during the HIC test. This includes the mass/weight of the seat back, breakover mechanism, the structure of the armrest and contact area of the armrest. Other components or parts of the seat may be non-representative or deleted from the test article.
   iv) Weights representing under-seat baggage are not required for either seat row. All components that are part of the seat should be represented, at least, by ballast.
   v) Life vests and weights representing literature pocket contents are not required for the forward seat row.
   vi) A representative floor shall be included in the test set up for the ATD(s) feet.

h) For each row-to-row HIC test, a post test evaluation of the high speed film/video and evaluation of the seat back (e.g., chalk mark) must show that the intended ATD head strike was achieved with regard to location and head impact (solid head strike and not a glancing blow). If the intended ATD head strike was not achieved, an adjustment to the test set up and a retest may be required.

2) Collection of ATD Head Path Data to demonstrate no head contact with aircraft interior features (usually front row seats).

Note: It is acceptable to collect ATD head path data in the 16g longitudinal structural test.

Note: This procedure only selects a test article for the collection of head path data. Additional analysis will be required to assess the specific interior configuration (e.g. translating the yawed head path into aircraft coordinates, evaluating the airplane interior for potential head strikes using the head path data collected.).

For each family of seats:

a) Conduct a 16g longitudinal dynamic test of the seat selected in 16g longitudinal structural test identified in section 4.1 above. If more than one 16g longitudinal structural test is identified in section 4.1, select the seat with the greatest overhang to collect head path. It is acceptable to use the opposite-hand part for this seat.

h) The occupancy used in the 16g longitudinal structural test shall be used for this test.

c) The test will be conducted with no yaw, no pitch, and no roll. Representative seat track is not required for this test, since structural attachment substantiation is not under consideration (e.g. steel tracks may be used on this test).

d) The head path data of the ATD expected to move the furthest forward due to structural deformation (usually in the most overhung seat place) should be collected. The most overhung seat place is the outer (left or right) seat place with the greatest distance from the centerline of the seat leg to the outer edge of the seat.

Note: It is acceptable to conduct additional head path tests of this type on other seats to collect head path data for specific seat places.

It is also acceptable to install a bulkhead, or rigid vertical wall, at the minimum design set back from the bulkhead into the test set-up for the purpose of showing no ATD head contact during the test. It is not required for the bulkhead used in the test set-up or material to be representative of the production aircraft interior component. This is because the test is conducted to establish if head contact occurs for a specific setback distance, and the location of head contact by a 50% ATD in those cases where it does. It is the responsibility of the seat installer to utilize this data to demonstrate an acceptable installation.

e) Baggage, life vests, and literature pocket contents shall be installed at eacb seat place, regardless of seat occupancy. Items of mass on the seat (e.g. under-seat IFE boxes) may be replaced by ballast.

f) Retention of items of mass need not be demonstrated in this test and items of mass may be restrained for the test.

g) A representative floor shall be included in the test set up for the ATD(s) feet.

3) Large Clearance Installations

   a) Installations behind another seat or interior component where the distance between the seat SRP and the aft-most point on the seat or interior component is greater than 50 inches do not require dynamic test data to substantiate the HIC criteria. This is based on substantial industry data that demonstrates a seat passing structural criteria will not have a head path that extends beyond 50 inches from SRP. Current guidance for head/floor strikes and occupant/occupant strikes is contained in the current HIC Lite guidance and is considered acceptable.

   Note: Front row HIC compliance is outside the scope of the current task, but should be included in the comprehensive guidance that will be issued for 25.562 compliance.

<u>FAR/JAR 25.562 (c) (6) - Femur Loads</u>

1) Row to Row Femur Data Collection

   a) The ATD in the Zone C minimum seat pitch, 0° yaw of the row to row HIC test selected shall be instrumented for the collection of femur loads. Each leg shall be instrumented. Alternatively, previous test data from a similar seat may be used to show compliance with the femur load requirement.

2) Collection of ATD Knee Path Data for Use in Femur Load Compliance (Front Row)

Note: It is acceptable to collect ATD knee path data in the 16g longitudinal structural test. Additional analysis will be required to assess the specific interior configuration (e.g. translating the yawed knee path into aircraft coordinates, evaluating the airplane interior for potential knee strikes using the knee path data collected).

   a) The knee path data of the ATD in the must overhung seat place may be collected during the test that collected head path used to show compliance for 25.562 (c) (5). The most overhung seat place is the outer (left or right) seat place with the greatest distance from the centerline of the seat leg to the outer edge of the seat. An additional test to only collect the knee path data is not required provided it is collected during the same test that collects the head path.

   Note: It is acceptable to conduct additional knee path tests of this type on other seats to collect head and knee path data for specific seat places.

b) The knee path data collected via the high speed film/video will be used show no knee contact with any aircraft interior components in the production installation. If this analysis of the seat installation/interior configuration shows that the knee will strike an aircraft interior component, additional testing which collects the femur load will be required.

3) Large Clearance Installations

Installations behind another seat or interior component where the distance between the seat SRP and the aft most point on the seat or interior component is greater than 40 inches do not require dynamic test data regarding femur loads.

5.0 Structural Pass/Fail Criteria

The primary load path should remain intact. Yielding for energy absorption is acceptable, and generally desirable. In this sense, yielding is a controlled, predictable deformation, where load carrying capability is maintained. Instability failures in primary load carrying members are not yielding and are not acceptable unless a secondary, predictable stable state is reached.

Some damage to the primary load path is expected and acceptable, however. Damage should be evaluated considering the role of the load carrying element in its critically loaded condition. Damage that might be unacceptable in a rear leg (tension) fitting might be acceptable in a forward leg (compression) fitting, depending on the consequence of the failure mode. Deformation to the extent that rapid egress is not compromised is encouraged. Minor cracking of primary structural elements and separations of some fasteners (a minority of fasteners in a row, for example), or minor delamination can be accepted if the remainder of the structural requirements have been satisfied. That is, the primary load path is intact, the seat remains attached at all points of attachment, and the occupant restraint system remains attached at all points of attachment. Hazardous projections or sharp edges shall not be created and egress shall not be compromised as discussed in current guidance.

For the restraint system, scuffing and fraying or breakage of some fibers is expected and should be acceptable. Tearing or cutting is indicative of a problem and is not a predictable mode of failure. Tears or cuts to the restraint system are not acceptable.

5.1 Test Failures vs. Retest

A variety of different failures can result in an unsuccessful test. Failures can range from structural separation of the seat from the tracks to deployment of items that constitute an impediment to egress. All such failures should be addressed and corrective action taken. However, the necessity to repeat tests following corrective action should be subject to the same sort of decision process that is used to determine which tests are conducted initially.

Failures in any part of the primary load path, including the seat attachment to the track or restraint system attachment to the seat will almost exclusively require retest. Failures in (secondary) internal structure may be able to be addressed analytically. For example, failures in members for which analytical substantiation is acceptable when making the test article selection (using the procedures outlined elsewhere in this concept paper), may not require retest. However, each case should be assessed individually, and a determination made that the failure point would not simply be transferred to another part of the load path. Generally speaking, members for which the failure mode is not catastrophic (e.g., compressive failures in a forward leg, as opposed to a tension failure in an aft leg for a 16g forward test), are less likely to warrant retest. The extent to which a secondary load path(s) can carry the load is a factor in determining the pass/fail of a structural test.

Special attention to the seat structure prior to the removal of floor warpage is advised. Structural failure can occur as a consequence of removal of floor warpage. If it can be determined that the damage or seat deformation occurred solely as a result of, or was caused solely by, removing the floor warpage, it shall not be considered a failure.

The evaluation of the seat attachment should be made before the seat tracks are straightened (unwarped). The process of straightening the seat tracks may result in a seat attachment becoming detached. This is not a failure of the test. The assessment for seat attachment should be made after the restraining force on the pitch and roll fixture has been released. It is not necessary to return the floor to a flat condition to evaluate the seat attachment. Once the evaluation for seat attachment has been completed, the floor may be returned to a flat state in order to take deformation measurements (if applicable).

Cuts or tears in a restraint system may not require a retest if it can be demonstrated that the corrective action will be effective, and if all other pass/fail criteria were met on the test in question.

Failures of attachments of items on the seat may be addressed analytically, provided that the corrective action does not impact the primary load path of the seat/occupant system or occupant injury criteria. However, the seat must be shown to be able to carry its full weight, including any attached items. Similarly, items that deploy should not require retests, if the corrective action does not affect the dynamic behavior of the seat or occupant.

In the case of a test that exceeds the minimum test conditions where the test results in a failure, an assessment of the test conditions and the failure mode must be made and a reason for retest without change must be presented to allow a retest without modification.

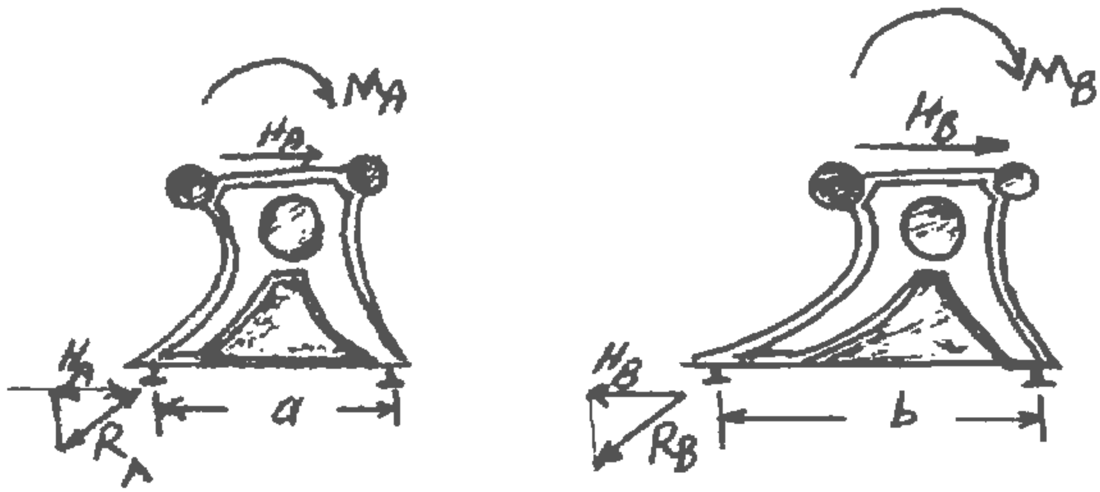
Appendix A - Sample Analysis

Example:

An example and a thought process of analytically justifying the suitability of a variant of a seat component for inclusion in a family of seats without a full scale test will be presented. The demonstration of the process will relate to a seat with a variation in the seat leg consisting of increasing the fore aft distance between the front and rear attachment of the leg to the aircraft floor.

Problem Statement:

1. Assume that a family of seats utilizing a leg (Leg A) with a certain leg pitch has been defined and certified.
2. The critical seat based on maximum reaction load has been established using the calculated interface loads derived in an acceptable manner. This seat, where leg A is the critical seat of the family based on reaction loads, has been tested.
3. A new configuration presents itself wherein all primary structural components except the leg, Leg B, of the seat belong in the family established by test. Leg B which has not been tested possesses sufficient commonality with Leg A, based on the criteria and methodology presented in Section 3.0 that an analytical evaluation is justifiable using the methodology below:
4. A schematic representation of Legs A and B are shown below. Shear load H and moment M schematically represent applied loads to the legs. For clarity only the resultant reaction at the rear attachment to the aircraft track is shown, represented by R whose horizontal component reacts load H :



a ≤ b

LEG A
Longitudinal Loading

LEG B
Longitudinal Loading

Solution Part I, Longitudinal performance:

1. $R_A > R_B$ has been determined from an interface loads analysis for the forward longitudinal loading condition (otherwise a test would be required). The values for applied loads H, M or equivalent load input information would be based on the interface loads analyses that yield R_A and R_B.

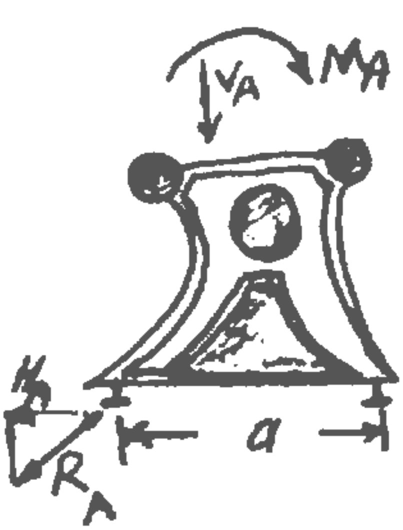
2. Perform a stress analysis of Leg A to determine internal stresses/strains under loads H_A and M_A. Similarly, perform a stress analysis of Leg B to determine internal stresses/strains under loads H_B and M_B.

3. Verify, or adjust the design of Leg B as required, so that no stress/strain in Leg B is greater than in Leg A location for location within the seat leg. Attachment hardware should be included in this verification.

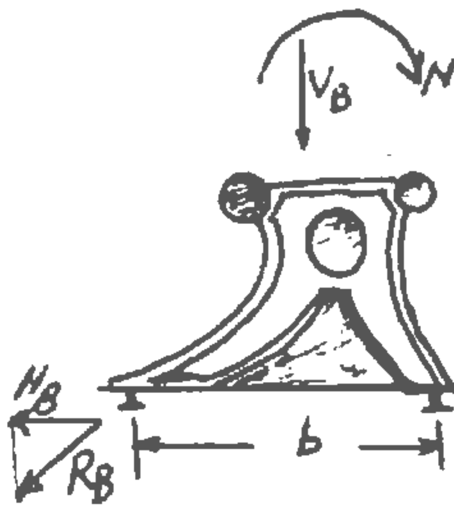
   If hand calculations are used, this requirement can involve substantial effort to demonstrate that the critical stress/strain location(s) are known and that as a result of the design change the stress/strain distribution of the new design has not changed. A global evaluation method (e.g. finite element) will determine the total stress state of the part overcoming that difficulty.

4. Calculate the forward deflection of the structure at the waterline at which H_A and H_B are applied. The deflections d_A and d_B are calculated for Leg A under H_A and M_A loading and for Leg B under H_B and M_B loading respectively. Calculate the longitudinal stiffness K_A of Leg A, and K_B, the longitudinal stiffness of Leg B wherein $K_A = H_A/d_A$ and $K_B = H_B/d_B$. Verify, or adjust the design of Leg B as required, that $K_B \leq K_A$.

Solution Part II, Vertical performance:



LEG A
Vertical Loading



LEG B
Vertical Loading

1. Perform an interface load analysis of the two seats in question to establish R_A and R_B under a vertical load condition.

2. If not obvious by comparison or from the results of solution Part I step 2: perform a stress analysis of Leg A to determine internal stresses/strains under V_A and M_A. Similarly, perform a stress analysis of Leg B to determine internal stresses/strains under V_B and M_B loading. V_A and M_A are the input loads resulting from the interface loads analysis of the seat with leg A. V_B and M_B are the input loads resulting from the interface loads analysis of the seat with Leg B.

3. Verify, or adjust, the design of Leg B as required, so that no stress/strain in Leg B is greater than in Leg A location for location within the seat leg. Attachment hardware should be included in this verification.

   If hand calculations are used, this requirement can involve substantial effort to demonstrate that the critical stress/strain location(s) are known and that as a result of the design change the stress/strain distribution of the new design has not changed. A global evaluation method (e.g. finite element) will determine the total stress state of the part overcoming that difficulty.

4. Calculate vertical deflection d_A for Leg A and vertical deflection d_B for Leg B at a fore-aft station aligned with the CG of the occupant used in the interface load analysis for vertical loading. The deflections d_A and d_B are calculated for Leg A under V_A and M_A loading and for Leg B under VB and M_B loading respectively. Calculate K_A, the vertical stiffness of Leg A, and K_B, the vertical stiffness of Leg B wherein $K_A = V_A/d_A$ and $K_B = V_B/d_B$. Verify, or adjust the design of Leg B as required, that $K_B \leq K_A$.

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: DYNAMIC EVALUATION OF SEAT RESTRAINT SYSTEMS & OCCUPANT PROTECTION ON TRANSPORT AIRPLANES

Date: 01/19/96
Initiated by: ANM-110

AC No: 25.562-1A
Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance regarding acceptable, but not the only, means of compliance with Part 25 of the Federal Aviation Regulations (FAR) applicable to dynamic testing of seats intended for use in transport category airplanes. The AC provides background and discussion of the reasoning behind the test procedures. It also describes the test facilities and equipment necessary to conduct the tests. Terms used in this AC, such as "shall" and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described herein is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the pertinent FAR. This advisory circular does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

2. CANCELLATION. Advisory Circular 25.562-1, dated 3/6/90, is cancelled.

3. RELATED REGULATIONS. Sections 25.562, 25.785, 25.787, and 25.789 of Part 25 of the Federal Aviation Regulations.

4. DISCUSSION.

a. Intent of Tests. The intent of the tests is to evaluate airplane seats, restraints, and related interior systems in order to demonstrate the structural strength and the ability of those systems to protect an occupant from injuries in a crash environment. For example, occupant injury potential, which is influenced by head strike envelopes and seat pitch, should be assessed. This assessment will be essentially qualitative.

b. Standardized Test Procedures--Reason and Practicalities. The tests described are standardized procedures that are generally to be regarded as the minimum necessary to demonstrate compliance. Such standardized procedures ensure that, to the maximum extent possible, consistent results are achieved between different test facilities. These facilities may be of varying types, as described in paragraph 7. They will often not be under the direct control of the designer or manufacturer of the article under test, and they may be primarily dedicated to testing not related to the aerospace industry. For this reason many of the procedures and evaluations described are already accepted as standards by government and commercial test facilities and have been modified only as necessary for the specific testing of civil airplane systems.

c. Standardized Test Procedures--Relationship to Design Standards. As stated above, the tests are, of necessity, standardized. The most obvious examples are the one size and weight representation of the occupant and the two discrete directions specified for the test impact. This philosophy is no different than that applied to static testing but, in the dynamic case, results in a much more complex consideration of the design factors involved in ensuring that the testing performed is adequate to demonstrate compliance with the applicable regulations.

(1) Occupant size. The dynamic tests are performed with an anthropomorphic test device (ATD) approximately representing the 50th percentile male occupant. Although the basic structural capability of the seat/restraint system is not directly demonstrated for other size occupants, aspects such as energy absorbing systems, restraint system loads and anchorage locations, and seat adjustments are typical design factors which are directly influenced by occupant size.

(2) Test Conditions. Only the two minimum impact tests are described in the dynamic test procedures discussed in this AC. These procedures therefore address the tests required to demonstrate compliance for one seat and restraint system installation. A typical use of a seat model on a particular aircraft will involve variations of seat design and installation. Additional tests may be necessary to demonstrate compliance for these variations if analysis is not adequate. An example is the lateral component of the test where it is necessary to consider the effect of loads from either side.

(3) Floor Deformation. The test procedure requires that for structural evaluation the floor should be deformed. The seat and restraint system should also perform properly if the floor remains undeformed.

(4) Head Impact. Occupant head impact with the interior of the airplane, should it occur, is evaluated by using a Head Injury Criterion (HIC) that can be measured directly in the tests described in this AC, or in alternative tests of the interior. The HIC is measured on the most critical surface within the ±10 degrees yaw envelope (measurement of the HIC does not supersede the requirements of § 25.785). The HIC does not consider injuries that can occur at low impact velocities from contact with surfaces having small contact areas or sharp edges, especially if those surfaces are relatively rigid.

(5) Femur Injury. Extensive seat testing has shown that the femur loading criterion is not exceeded. For this reason, the femur loads need not be recorded in the individual test if compliance can be shown by rational comparative analysis using data from previous tests.

NOTE: There may be several other aspects of the standardized test procedure that need to be considered when determining the test program required to demonstrate compliance or interpret the test results. The extent of the test program will depend on the most critical case determination and its applicability to other configurations. Further information on this aspect of testing is provided in paragraph 5b.

5. TEST CONDITIONS.

a. General. A minimum of two dynamic tests are required to assess the performance of an airplane seat, restraints, and related interior system. The seat, the restraint, and the nearby interior are all considered to act together as a system to provide protection to the occupant during a crash. For side-facing seats, there may be additional criteria necessary to determine that these seats provide the same level of safety as is intended by the regulation. (See paragraph 10d for additional considerations regarding side-facing seats.)

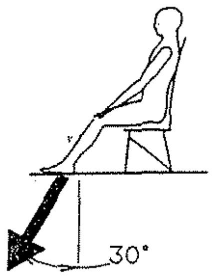
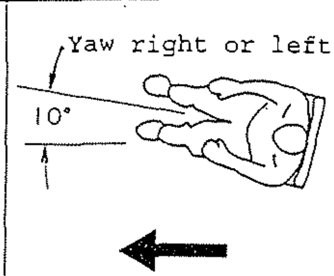
(1) Test 1 (Figure 1), as a single row seat test, determines the performance of the system in a test condition where the predominant impact force component is along the spinal column of the occupant, in combination with a forward impact force component. This test evaluates the structural adequacy of the seat, critical pelvic/lumbar column forces, and permanent deformation of the structure under downward and forward combined impact loading, and may yield data on ATD head displacement, velocity, and acceleration time histories.

(2) Test 2 (Figure 1), as a single row seat test, determines the performance of a system in a test condition where the predominant impact force component is along the longitudinal axis of the airplane and is combined with a lateral impact force component. This test evaluates the structural adequacy of the seat, permanent deformation of the structure, and the pelvic restraint and upper torso restraint (if applicable) behavior and loads, and may yield data on ATD head displacement, velocity, and acceleration time histories, and the seat leg loads imposed on the seat tracks or attachment fittings.

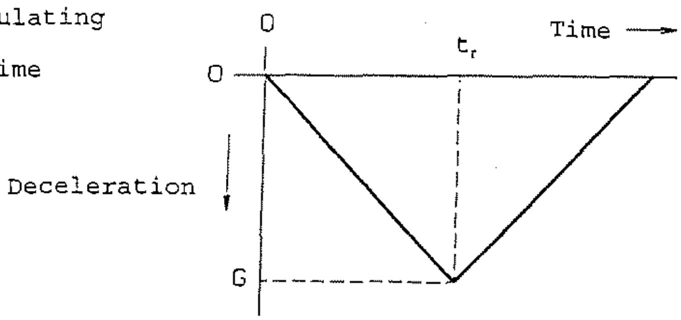
This test requires simulating airplane floor deformation by deforming the test fixture, as respectively prescribed in Figures 1 and 2 for single occupant and multiple occupant seats, prior to applying the dynamic impact conditions. The purpose of providing floor deformation for the test is to demonstrate that the seat/restraint system will remain attached to the airframe and perform properly, even though the airplane and/or seat are deformed by the forces associated with a crash.

(3) For seats placed in repetitive rows, an additional test condition, using two seats in tandem placed at representative fore and aft distance between the seats (seat pitch), similar to Test 2 with or without the floor deformation directly evaluates head and femur injury criteria (the floor deformation is required if the test also demonstrates structural performance). These injury criteria are dependent on seat pitch, seat occupancy, and the effect of hard structures within the path of head excursions in the ±10 degrees yaw attitude range of the Test 2 conditions. The test procedure using the appropriate data obtained from Test 2, as described in paragraph 13d, may be an alternative to multiple row testing.

NOTE: It may be possible to evaluate the HIC using alternative tests. Specific methodologies will require acceptance for certification.

Illustration shows a forward-facing seat Inertial load shown by arrow	TEST 1	TEST 2
		
Min V_i m/s (ft/s)	10.67 (35)	13.41 (44)
Max t_r, s	0.08	0.09
Min G.	14	16
Deform floor:		
Degrees roll	0	10
Degrees pitch	0	10

Test Pulse Simulating Aircraft Floor Deceleration-Time History:



t_r = Rise time
V_i = Impact velocity

Figure 1. Type A Seat/Restraint System Dynamic Tests

b. Consideration of test criteria. The tests should be planned to achieve "most critical" conditions for the criteria that make up each test.

(1) For multiple place seats, a rational structural analysis shall be used to determine the number and seat location for the ATDs and the direction for seat yaw in Test 2 to provide the most critical seat structural test. This will usually result in unequally loaded seat legs. The floor deformation procedure shall be selected to increase the load on the highest loaded seat leg and to load the floor track or fitting in the most severe manner; however, a special procedure has been provided, as discussed in paragraph 10c(2), to account for seats that have more than two pairs of legs.

(2) If multiple-row testing is used to gather data to assess head and femur injury protection in passenger seats, the seat pitch shall be selected so that the head would be most likely to contact hard structure in the forward seat row. The effect of the 10 degree yaw in Test 2, the seat back breakover, and front seat occupancy shall be considered. Results from previous tests or rational analysis may be used to estimate the head strike path of similar seats in similar installations. The front row may be unoccupied.

(3) If non-symmetrical upper torso restraints (such as single diagonal shoulder belts) are used in a system, they shall be installed on the test fixture in a position representative of that in the airplane and which would most likely allow the ATD to move out of the restraint. For example, in a forward-facing crew seat equipped with a single diagonal shoulder belt, the seat should be yawed in Test 2 in a direction such that the belt passes over the trailing shoulder.

(4) If a seat has vertical or horizontal adjustments, it shall be tested in the position that produces the most critical loads on the seat structure (typically the highest vertical position). Positions prohibited for takeoff and landing need not be considered. Seat adjustments that do not have a significant effect on structural loading (e.g., thigh support angle, lumbar support, armrest and headrest positions) shall be tested in the design positions for the 50th-percentile male occupant, unless special requirements dictate the positions allowed for takeoff and landing. In addition, height adjustment should be relative to the interior envelope as it relates to the upper contour (ceiling) of the airplane whenever a specific seat design is approved in a particular airplane. Therefore, the seat needs only to be raised to the point where the head of the 50th percentile ATD contacts the upper portion of the airplane interior. Height adjustment to a level above the normal 50th percentile male location is intended to validate the strength of the seat and is not related to testing for a range of occupant sizes.

6. TEST ARTICLES.

a. General. In all cases, the test article must be representative of the final production article in all structural elements, and shall include the seat cushions, restraints, and armrests. It must also include a functioning position adjustment mechanism and correctly adjusted breakover (if present). Food trays or any other service or accouterment that are part of the seat design must be representative of the final production item if they influence seat stiffness or head impact.

Otherwise they and any other items of mass that are carried on or positioned by the seat structure e.g., weights simulating luggage carried by luggage restraint bars [90 N (20 lb) per passenger place], fire extinguishers, survival equipment, emergency equipment etc. need only be representative masses. If these items of mass are placed in a position that could limit the function of an energy-absorbing feature in the test article, they should be of representative shape and stiffness, as well as weight. In addition, items of mass of any significance could become both an evacuation hazard, as well as dangerous projectiles. Nonetheless, detachment of certain items, such as an in-arm ashtray or decorative trim, can be considered inconsequential and should not be grounds for re-test (the means of restraint should be improved, however). In any case, the separation of an item of mass should not leave any sharp or injurious edges. Function of equipment or systems after the test is not required. Once an item of mass has been demonstrated to be retained in its critical loading case, subsequent tests may be conducted with the item secured for test purposes. This AC does not establish operational requirements for equipment attached to the seat system.

b. Selection of test articles. Many designs comprise a family of seats that have the same basic structural design but differ in detail. For example, a basic seat frame configuration can allow for several different seat leg locations to permit installation in different airplanes. If these differences are of a nature that their effect can be determined by rational analysis, then the analysis can determine the most critical configuration. As a minimum, the most highly stressed configuration shall be selected for the dynamic tests so that the other configurations could be accepted by comparison with that configuration. For Test 2, there are two factors that need to be considered in selecting the critical structural test configurations. First, the seat to airplane interface loads (undeformed seat) can be determined by rational analysis for all seat design and load configurations. The rational analysis can be based on static or dynamic seat/occupant analytical methods. That rational analysis can form the basis for selecting the most highly stressed critical configuration based on load. Additionally, the effects of seat deformation should also be considered. As noted, a family of seats typically includes seat models with varied seat leg locations. The effects of floor deformation are more critical for narrow spaced seat legs. Thus, a test or rational analysis of the seat model with the minimum seat leg spacing needs to be conducted to evaluate the most highly stressed critical configuration based on deformation.

The following additional items shall be considered in choosing test articles and the manner of loading:

(1) If a multiple-place seat incorporates energy-absorbing or load-limiting features that are necessary to meet the test criteria or other requirements, a partially occupied seat may adversely affect the performance of that seat. In such a case it shall be shown, by rational analysis or additional testing, that the seat will continue to perform as intended, even with fewer occupants.

(2) If different configurations of the same basic design incorporate load-carrying members, especially joints or fasteners, that differ in detail design, the performance of each detail design should be demonstrated in a dynamic test. Experience has shown that small details in the design often cause problems in meeting the test performance criteria.

(3) Additional dynamic impact testing may be required for a seat with features that could affect its performance, even though the test may not be the most critical case based on structural performance. For example, if in one of the design configurations the restraint system attachment points are located so that the pelvic restraint is more likely to slip above the ATD's pelvis during the impact, that configuration should also be dynamically tested, even though the structural loading might be less than the critical configuration in a family of seats.

(4) Typical dress cover materials, including synthetic and natural fabrics, and leather, can be used on a seat without testing more than one material, or substituted on an already certificated seat. Evaluation of such materials has shown the effect on test results is small, particularly considering other factors such as occupant clothing. It is possible that some unusual seat surfaces such as hard plastics, which exhibit very low friction coefficients, may require some additional substantiation.

7. TEST FACILITIES.

a. General. There are a number of test facilities that can be used to accomplish dynamic testing. These can be grouped into categories based on the method used to generate the impact pulse (i.e., accelerators, decelerators, or impact with rebound), and whether the facility is a horizontal (sled) design or a vertical (droptower) arrangement. Each of the designs has characteristics that have advantages or disadvantages with regard to the dynamic tests discussed in this AC. One concern is the rapid sequence of acceleration and deceleration that must take place in the tests. In an airplane crash, the acceleration phase is always gradual, and usually well separated in time from the deceleration (crash) phase. In a test, the deceleration always closely follows the acceleration. When assessing the utility of a facility for the specific test procedures outlined in the recommendations, it is necessary to understand the possible consequences of this rapid sequence of acceleration and deceleration.

b. Deceleration sled facilities. In an airplane crash, the impact takes place as a deceleration, so loads are applied more naturally in test facilities that create the test impact pulse as a deceleration. Since it is simpler to design test facilities to extract energy in a controlled manner than to impart energy in a controlled manner, several different deceleration sled facilities can be found. The deceleration sled facility at the Federal Aviation Administration's Civil Aeromedical Institute (CAMI) was used in developing the test procedures discussed in this AC. The acceleration phase of the test, where sufficient velocity for the test impact pulse is acquired, can distort the test results if the acceleration is so high that the test articles or ATDs are moved from their intended pre-test position. This inability to control the initial conditions of the test would directly affect the test results. This can be avoided by using a lower acceleration for a relatively long duration and by providing a coast phase (in which the acceleration or deceleration is almost zero) prior to the impact. This allows any dynamic oscillation in the test articles or the ATD, which might be caused by the acceleration, to decay. To guard against errors in data caused by pre-impact accelerations, data from the electronic test measurements (accelerations, loads) should be reviewed for the time period just before the test impact pulse to make sure all measurements are at the baseline (zero) level. Photometric film taken of the test should also be reviewed to make certain that the ATDs used in the test and the test articles were all in their proper position prior to the test impact pulse.

The horizontal test facility readily accommodates forward-facing seats in both tests discussed in this AC, but problems can exist in positioning the test ATDs in Test 1 if the seat is a rearward-facing or side- facing seat. In these cases, the ATDs tend to fall out of the seat due to the force of gravity and must be restrained in place using break-away tape, cords, or strings. Since each installation will present its own problems, there is no simple, generally applicable, guidance which can be given for doing this. Attention should be given to positioning the ATD against the seat back, and to proper positioning of the ATD's arms and legs. It will probably be necessary to build special supports for the break-away restraint so that they will not interfere with the function of the seat and restraint system during the test. Film taken of the test should be reviewed to make sure that the break-away restraint did break (or become slack) in a manner that did not influence the motion of the ATD or the test articles during the test.

c. Acceleration sled facilities. Acceleration sled facilities, usually based on the HYdraulically controlled Gas Energized (HYGE) accelerator device, provide the impact test pulse as a controlled acceleration at the beginning of the test. The test item and the ATDs are installed facing in the opposite direction from the velocity vector, (opposite from the direction used on a deceleration facility) to account for the change in direction of the impact. There should be no problem with the ATD or the test items being out of position due to pre-impact sled acceleration, since there is no sled movement prior to the impact test pulse. After the impact test pulse, when the sled is moving at the maximum test velocity, it must be safely brought to a stop. Most of the facilities of this design have limited track length available for deceleration, so that the deceleration levels can be relatively high and deceleration may begin immediately after the impact test pulse. Since the dynamic response of the system follows (in time) the impact test pulse, any sled deceleration that takes place during that response will affect the response and change the test results. The magnitude of change depends on the system being tested, so that no general "correction factor" can be specified. The affect can be minimized if the sled is allowed to coast, without significant deceleration, until the response is complete. If the seat or restraint system experiences a structural failure during the test pulse, the post-impact deceleration can increase the damage and perhaps result in failures of unrelated components. This will complicate the determination of the initial failure mode, and make product improvement more difficult. One other consideration is that the photometric film coverage of the response to impact test pulse must be accomplished when the sled is moving at near maximum velocity. On-board cameras or a series of track-side cameras are usually used to provide film coverage of the test. Since on-board cameras frequently use a wide angle lens placed close to the test items, it is necessary to account for the effects of distortion and parallax when analyzing the film. The acceleration sled facility faces the same problems in accommodating rearward facing or side-facing seats in Test 1 as the deceleration sled facility, and the corrective action is the same for both facilities.

d. Impact-with-rebound sled facilities. One other type of horizontal test facility used is the "impact-with-rebound" sled facility. On this facility, the impact takes place as the moving sled contacts a braking system, which stores the energy of the impact, and then returns the stored energy back to the sled, causing it to rebound in the opposite direction. This facility has the advantage over acceleration or deceleration facilities in that only one half of the required velocity for the impact would need to be generated by the facility (assuming 100 percent efficiency). Thus, the track length can be shortened and the method of generating velocity is simplified. The disadvantages of this facility combine the problems mentioned above for both acceleration facilities and deceleration facilities. Since one of the reasons for this type of facility is to allow short track length to be used, it may be difficult to obtain sufficiently low acceleration just before or after the impact pulse to resolve data error problems caused by significant pre-impact and post-impact accelerations.

e. Drop towers. Vertical test facilities can include both drop towers (decelerators) and vertical accelerators. Vertical accelerators that can produce the long duration/displacement impact pulse depicted in Figure 1 have not been generally available. However, drop towers are one of the easiest facilities to build and operate, and are frequently used. In these facilities, the pull of earth's gravity is used to accelerate the sled to impact velocity so that the need for a complex mechanical accelerating system is eliminated. Unfortunately, these facilities are difficult to use for conducting Test 2, particularly for typical forward-facing seats. In preparing for this test, the seat must be installed at an angle such that the ATD tends to fall from the seat due to gravity. The restraint system being tested cannot hold the ATD against the seat unless tightened excessively, and will not usually locate the head, arms, or legs in their proper position relative to the seat. Design and fabrication of an auxiliary "break-away" ATD positioning restraint system just for this test is a complex task. The auxiliary restraint must not only position the ATD against the seat (including maintaining proper seat cushion deflection) during the pre-release condition of 1g, it must also maintain the ATD in that proper position during the free fall to impact velocity when the system is exposed to 0g, and then it must release the ATD in a manner that does not interfere with the ATD response to impact. The usual sequence of 1g/0g impact, without the possibility of a useful "coast" phase, as done in horizontal facilities, causes shifts in initial conditions for the test impact pulse which can affect the response to the impact. The significance of this will depend on the dynamic characteristics of the system being tested, and these are seldom known with sufficient accuracy to enable the response to be corrected. In addition, the earth's gravity will oppose the final rebound of the ATDs into the seat back, so that an adequate test of seat back strength and support for the ATD cannot be obtained. The problems in Test 1, or with rear-facing seats in Test 2, are not as difficult because the seat will support the ATD occupant prior to the free fall. However, the 0g condition that exists prior to impact will allow the ATD to "float" in the seat restraint system, perhaps changing position and certainly changing the initial impact conditions. Again, use of an auxiliary break-away restraint system to correct these problems is difficult.

8. ANTHROPOMORPHIC TEST DEVICES.

a. General. The tests discussed in this AC were developed using modified forms of the ATDs specified by the United States Code of Federal Regulations, Title 49, Part 572 Anthropomorphic Test Dummies, Subpart B - 50th Percentile Male. These "Part 572B" ATDs have been shown to be reliable test devices that are capable of providing reproducible results in repeated testing. However, since ATD development is a continuing process, provision was made for using "equivalent" ATDs. ATD types should not be mixed when completing the tests discussed in this AC.

b. Modification to measure pelvic/lumbar load.

(1) To measure the axial compressive load between the pelvis and lumbar column due to vertical impact as well as downward loads caused by upper torso restraints, a load (force) transducer shall be inserted into the ATD pelvis just below the lumbar column. There is now a load cell available for this purpose that does not require major alteration to the ATD. The procedure in general is similar to that described in Figure 2. The modification shown in Figure 2 is retained in this revision of the AC to aid facilities that may already incorporate this procedure, which is still acceptable. Future revisions of this AC will not contain this modification procedure, as it is no longer the standard. The illustration shows a commercially available femur load cell, with end plates removed, that has been adapted to measure the compression load between the pelvis and the lumbar column of the ATD.

(2) A femur load cell was selected because of its availability in most test facilities and its ability to measure the compression forces without errors due to sensitivity to shear forces and bending or twisting moments which are also generated during the test. To maintain the correct seated height of the ATD the load cell must be fixed in a rigid cup which is inserted into a hole bored in the top surface of the ATD pelvis. The interior diameter of the cup provides clearance around the outside diameter of the load cell, so that the loads are transmitted only through the ends of the cell. If necessary, ballast shall be added to the pelvis to maintain the weight of the original (unmodified) assembly.

(3) Alternative approaches to measuring the axial force transmitted to the lumbar spinal column by the pelvis are acceptable if the method:

(i) Accurately measures the axial force but is insensitive to moments and forces other than that being measured;

(ii) Maintains the intended alignment of the spinal column and the pelvis, the correct seated height, and the correct weight distribution of the ATD; and

(iii) Does not alter the other performance characteristics of the ATD.

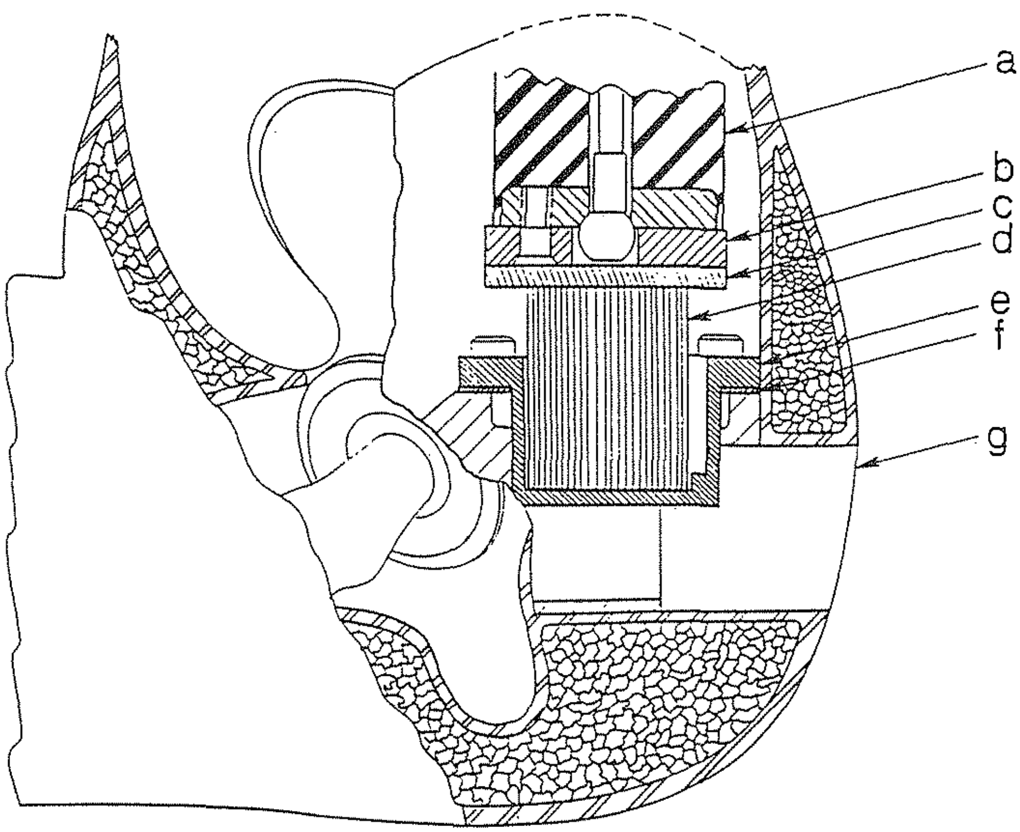


Figure 2. Installation of Pelvic--Lumbar Spine Load Cell in Part 572B ATD.

This illustration shows an acceptable adaptation of a femur load cell (d) at the base of the ATD lumbar spine (a). The load cell is in line with the centerline of the lumbar spine, and set below the top surface of the pelvis casting to maintain the seated height of the ATD. A rigid adapter cup (e) is fabricated to hold the load cell and a hole is bored in the ATD pelvis to accept the cup. Clearance must be provided between the walls of the adapter cup and the load cell for the wires leading from the cell. The bottom of the load cell is bolted to the adapter cup. Adapter plates having similar hold patterns in their periphery are fabricated for the lower surface of the lumbar spine (b) and the upper surface of the load cell (c). These plates are fastened to the lumbar spine and load cell with screws through holes matching threaded holes in those components, and are then joined together by bolts through the peripheral holes. The flange on the adapter cup has a bolt hole pattern that matches that on the pelvis. The cup is fastened to the pelvis using screws to the threaded holes in the pelvis. Spacers (f) may be placed under the flange of the cup to obtain the specified ATD seating height. Additional weight should be placed in the cavity below the adapter cup to compensate for any weight lost because of this modification. The instrument cavity plug (g) is cut to provide clearance for the adapter cup and added weight.

c. Other ATD Modifications.

(1) To prevent failure of the clavicle used in Part 572 Subpart B ATDs due to flailing, a clavicle of the same shape but of higher strength material can be substituted.

(2) Submarining indicators, such as electronic transducers, may be added on the ATD pelvis. These are located on the anterior surface of the ilium of the ATD pelvis without altering its contour, and indicate the position of the pelvic restraint as it applies loads to the pelvis. These indicators can provide a direct record that the pelvic restraint remains on the pelvis during the test, and eliminate the need for careful review of high-speed camera images to make that determination.

d. Equivalent ATDs. The continuing development of ATDs for dynamic testing of seating restraint/crash-injury-protection systems is guided by goals of improved biofidelity (human-like response to the impact environment) and reproducibility of test results. For the purposes of the tests discussed in this AC, these improved ATDs can be considered the equivalent of the Part 572B ATD if:

(1) They are fabricated in accordance with design and production specifications established and published by a regulatory agency that is responsible for crash injury protection systems;

(2) They are capable of providing data for the measurements discussed in this AC or of being readily altered to provide the data;

(3) They have been evaluated by comparison with the Part 572B ATD and are shown to generate similar response to the impact environment discussed in this AC; and

(4) Any deviations from the Part 572B ATD configuration or performance are representative of the occupant of a civil airplane in the impact environment discussed in this AC.

9. INSTRUMENTATION.

a. General.

(1) Electronic and photographic instrumentation systems shall be used to record data for qualification of seats. Electronic instrumentation shall measure the test environment, and measure and record data required for comparison of performance to pass/fail criteria.

(2) Photographic instrumentation shall be used to document the overall results of tests, confirming that the pelvic restraint remains on the ATD's pelvis, and that the upper torso restraint straps remain on the ATD's shoulder during impact, and documenting that the seat does not deform as a result of the test in a manner that would impede rapid evacuation of the airplane by the occupants and that the seat remains attached at all points of attachment. For passenger seats with lap belt angles of btween 45 and 55 degrees, submarining is typically not a problem.

For this reason, a second camera (e.g., an overhead camera) for evaluation of submarining is not necessary.

b. Electronic Instrumentation. Electronic instrumentation should be accomplished in accordance with the Society of Automotive Engineers Recommended Practice SAE J211, "Instrumentation for Impact Tests." In this practice, a data channel is considered to include all of the instrumentation components from the transducer through the final data measurement, including connecting cables and any analytical procedures that could alter the magnitude or frequency content of the data. Each dynamic data channel is assigned a nominal channel class that is equivalent to the high frequency limit for that channel, based on a constant output/input ratio versus frequency response plot which begins at 0.1 Hz (+1/2 to -1/2 dB) and extends to the high frequency limit (+1/2 to -1 dB). Frequency response characteristics beyond this high frequency limit are also specified. When digitizing data, the sample rate should be at least five times the -3 dB cutoff frequency of the presample analog filters. Since most facilities set all presample analog filters for Channel Class 1000, and since the -3 dB cutoff frequency for channel class 1000 is 1650 Hz, the minimum digital sampling rate would be about 8000 samples per second. For the dynamic tests discussed in this AC, the dynamic data channels shall comply with the following channel class characteristics:

(1) Sled or drop tower vehicle acceleration should be measured in accordance with the requirements of Channel Class 60, unless the acceleration is also integrated to obtain velocity or displacement, in which case it shall be measured in accordance with Channel Class 180 requirements.

(2) Belt-restraint system and seat attachment reaction loads (when measured) shall be measured in accordance with the requirements of Channel Class 60. Loads in restraint systems that attach directly to the test fixture can be measured by three-axis load cells fixed to the test fixture at the appropriate location. These commercially available load cells measure the forces in three orthogonal directions simultaneously, so that the direction as well as the magnitude of the force can be determined. If desired, similar load cells can be used to measure forces at other boundaries between the test fixture and the test item, such as the forces transmitted by the legs of the seat into the floor track. It is possible to use independent, single axis load cells arranged to provide similar data, but care should be taken to use load cells that can withstand significant cross axis loading or bending without causing errors in the test data.

(3) ATD head accelerations used for calculating the Head Injury Criterion (HIC) should be measured in accordance with the requirements of Channel Class 1000.

(4) ATD femur forces should be measured in accordance with Channel Class 600.

(5) ATD pelvic/lumbar column force shall be measured in accordance with the requirements of Channel Class 600.

(6) The full-scale calibration range for each channel shall provide sufficient dynamic range for the data being measured.

(7) Digital conversion of analog data shall provide sample resolution of not less than 1 percent of full-scale input.

c. Photographic Instrumentation. Photographic instrumentation shall be used for documenting the response of the ATDs and the test items to the dynamic test environment. Both high-speed and still image systems should be used.

(1) High speed cameras that provide data used to calculate displacement or velocity shall operate at a nominal speed of 500 frames per second. Photo instrumentation methods shall not be used for measurement of acceleration. The locations of the cameras and of targets or targeted measuring points within the field of view shall be measured and documented. Targets shall be at least 1/100 of the field width covered by the camera and shall be of contrasting colors or shall contrast with their background. The center of the target shall be easily discernible. Rectilinearity of the image shall be documented. If the image is not rectilinear, appropriate correction factors shall be used in the data analysis process. Photographic instrumentation should be in accordance with SAE J211, part 2.

(2) A description of photographic calibration boards or scales within the camera field of view, the camera lens focal length, and the make and model of each camera and lens shall be documented for each test. Appropriate digital or serial timing shall be provided on the image media. A description of the timing signal, the offset of timing signal to the image, and the means of correlating the time of the image with the time of electronic data shall be provided. A rigorous, verified analytical procedure shall be used for data analysis.

(3) Cameras operating at a nominal rate of 200 frames per second or greater may be used to document the response of ATDs and test items if measurements are not required. For example, actions such as movement of the pelvic restraint system webbing off of the ATD's pelvis can be observed by documentation cameras placed to obtain a "best view" of the anticipated event. These cameras shall be provided with appropriate timing and a means of correlating the image with the time of electronic data.

(4) Still image cameras shall be used to document the pre-test installation and the post-test response of the ATDs and the test items. At least four pictures shall be obtained from different positions around the test items in pre-test and post-test conditions. Where an upper torso restraint system is installed, post-test pictures shall be obtained before moving the ATD. For additional post-test pictures, the ATD's upper torso may be rotated to its approximate upright seated position so that the condition of the restraint systems may be better documented, but no other change to the post-test response of the test item or the ATD shall be made. The pictures shall document whether the seat remained attached at all points of attachment to the test fixture.

(5) Still pictures may also be used to document post-test yielding of the seat for the purpose of showing that it would not impede the rapid evacuation of the aircraft

occupants. The ATD should be removed from the seat in preparation for still pictures used for that purpose. Targets or an appropriate target grid should be included in such pictures, and the views should be selected so that potential interference with the evacuation process can be determined. For tests where the ATD's head impacts a fixture or another seat back, pictures shall be taken to document the head contact areas.

10. TEST FIXTURES.

a. General. A test fixture is required to position the test article on the sled or drop carriage of the test facility and takes the place of the airplane's floor structure. It does not need to simulate the airplane floor flexibility. It holds the attachment fittings or floor tracks for the seat and provides the floor deformation if needed for the test; it provides anchorage points if necessary for the restraint system; it provides a floor or footrest for the ATD; and it positions instrument panels, bulkheads, or a second row of seats, if required.

b. Floor Deformation.

(1) Purpose of floor deformation. The purpose of providing floor deformation for the longitudinal tests is to demonstrate that the seat system will remain attached and perform properly, even though the seat or airframe may be deformed by the forces associated with the crash. Floor deformation is not required for demonstrating compliance with injury criteria.

(2) Floor Deformation Fixture. For the typical seat with four seat legs mounted in the aircraft on two parallel tracks, the floor deformation test fixture shall consist of two parallel beams: a pitch beam that pivots about a lateral (y) axis and a roll beam that pivots about a longitudinal (x) axis (see Figure 3 for a schematic representation). The beams can be made of any rigid structural form: box, I-beam, channel, or other appropriate cross section. The pitch beam shall be capable of rotating in the x-z plane up to ±10 degrees relative to the longitudinal (x) axis. The roll beam should be capable of ±10 degrees roll about the centerline of floor tracks or fittings. A means shall be provided to fasten the beams in the deformed positions.

The beams should have provision for installing floor track or other attachment fittings on their upper surface in a manner that does not alter the above-floor strength of the track or fitting. The track or other attachment fittings must be representative in above-floor configuration and strength to that which would be used in the airplane. Structural elements below the surface of the floor that are not considered part of the floor track or seat attach fitting need not be included in the installation. Appropriate safety precautions should be taken while imposing floor deformations.

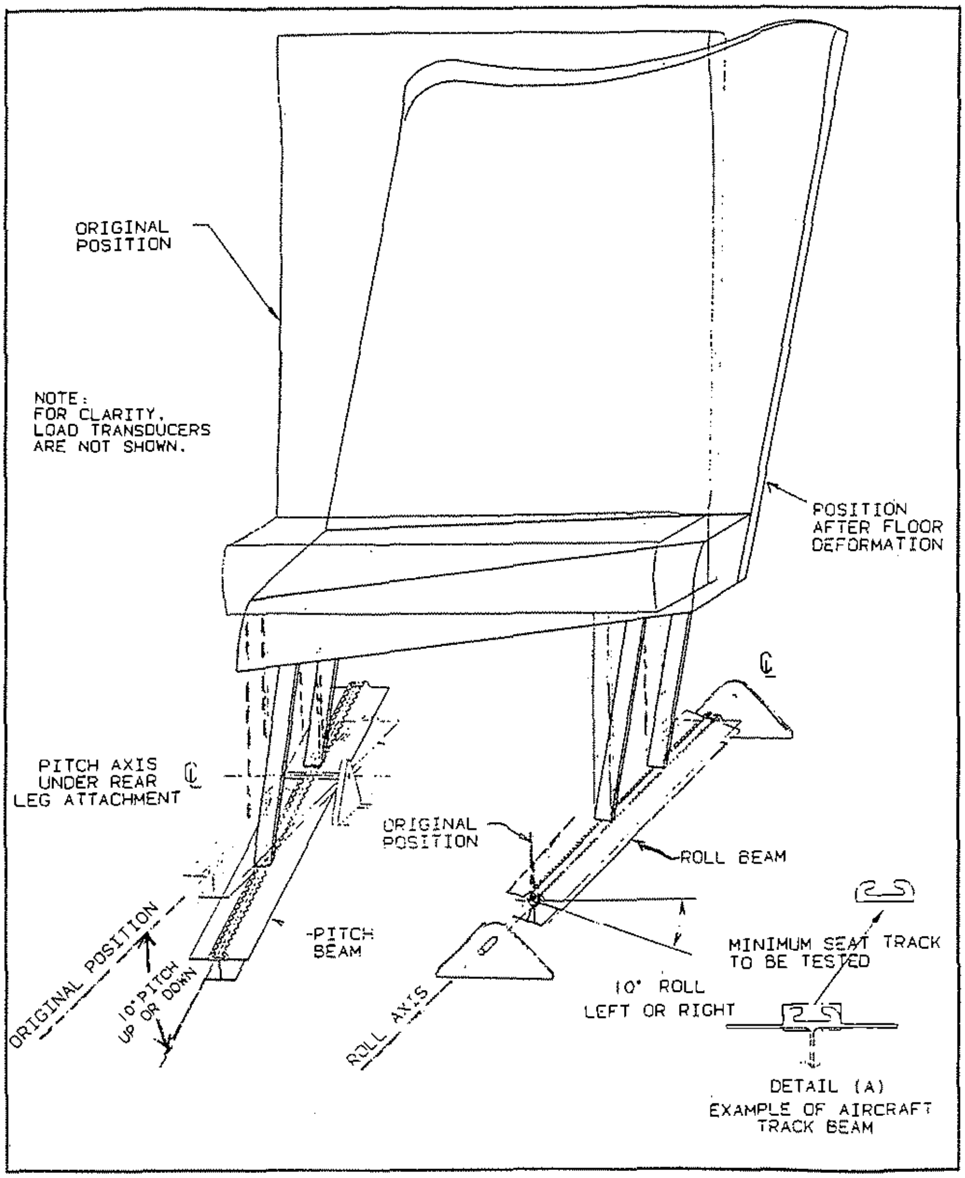


Figure 3.
Schematic Floor Deformation Fixture; Seat Legs Attached at Floor Level

(3) Airplane Floor Track or Attachment Fitting Simulation. An example of the minimum required representation of a floor track is shown in Detail A of Figure 3 for one type of seat track. The track, or other attachment fittings, must be representative of those used in the airplane. Alternatively, three components of reaction forces and three components of reaction moments may be measured during dynamic tests. These six components may be applied simultaneously, by a separate static or dynamic test, to a track or attachment fitting used on an airplane, or to a more critical track or attachment fitting than that used on an airplane, to demonstrate that the loads measured in the dynamic impact test will not fail the track or attachment fitting used on an airplane.

(4) Load Transducer Installation (Optional). The pitch and roll beams should have provisions for installing individual load transducers at each seat leg attachment point capable of measuring three reaction forces and, if necessary, three reaction moments (see paragraph 10b(3)). The load transducers should have provisions to install floor track or other attachment fittings on their upper surface in a manner that does not alter the above-floor strength of the track or fitting.

c. Other Mounting Configuration Constraints. The preceding discussion describes the fixture and floor deformation procedure that would be used for a typical seat that uses four seat legs and four attachments to the aircraft floor. These test procedures are not intended to be restricted only to those seat configurations, but shall be adapted to seats having other designs. Special test fixtures may be necessary for those different configurations. The following methods, while not covering all possible seat designs, shall be followed for the more common alternatives:

(1) Airplane seats with three legs may have one central leg at the front or back of the seat, and one leg on each side of the seat. The central leg shall be held in its undeformed position as deformation is applied to the side legs.

(2) Seats that have more than two pairs of legs should be tested with the floor warpage condition that results in the most critically stressed condition. This typically involves warping adjacent pairs of legs. Seats that employ several pairs of legs, ganged together by common cross tubes, can be distorted so that one pair (the critical pair) of legs is rolled, while the remaining legs on one side of the critical leg are pitched in unison. The legs that are pitched should be selected to increase the load on the critical leg, and stress the floor or track fitting in the most severe manner (see Figures 4 and 5).

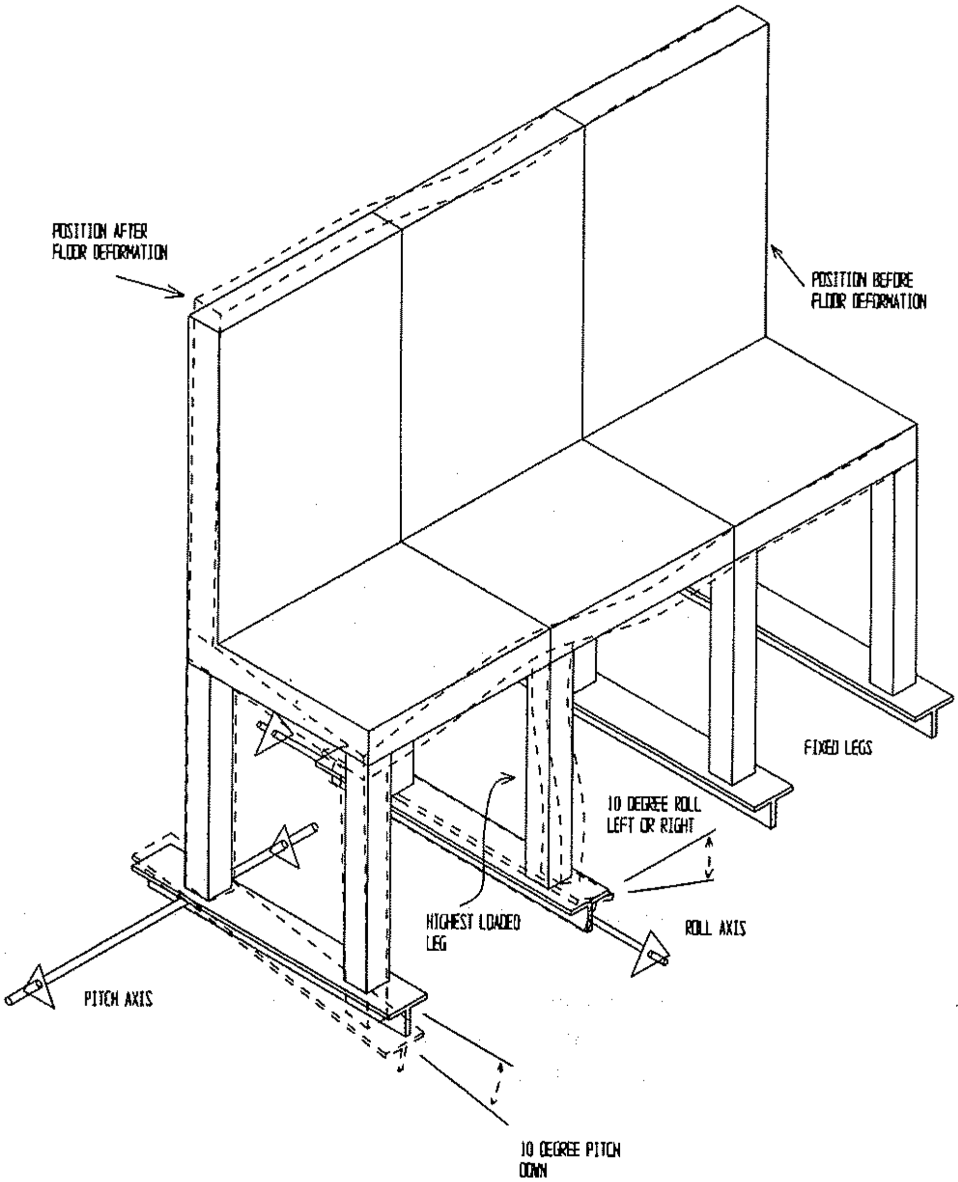


Figure 4. Floor Warpage Multiple Leg Seat

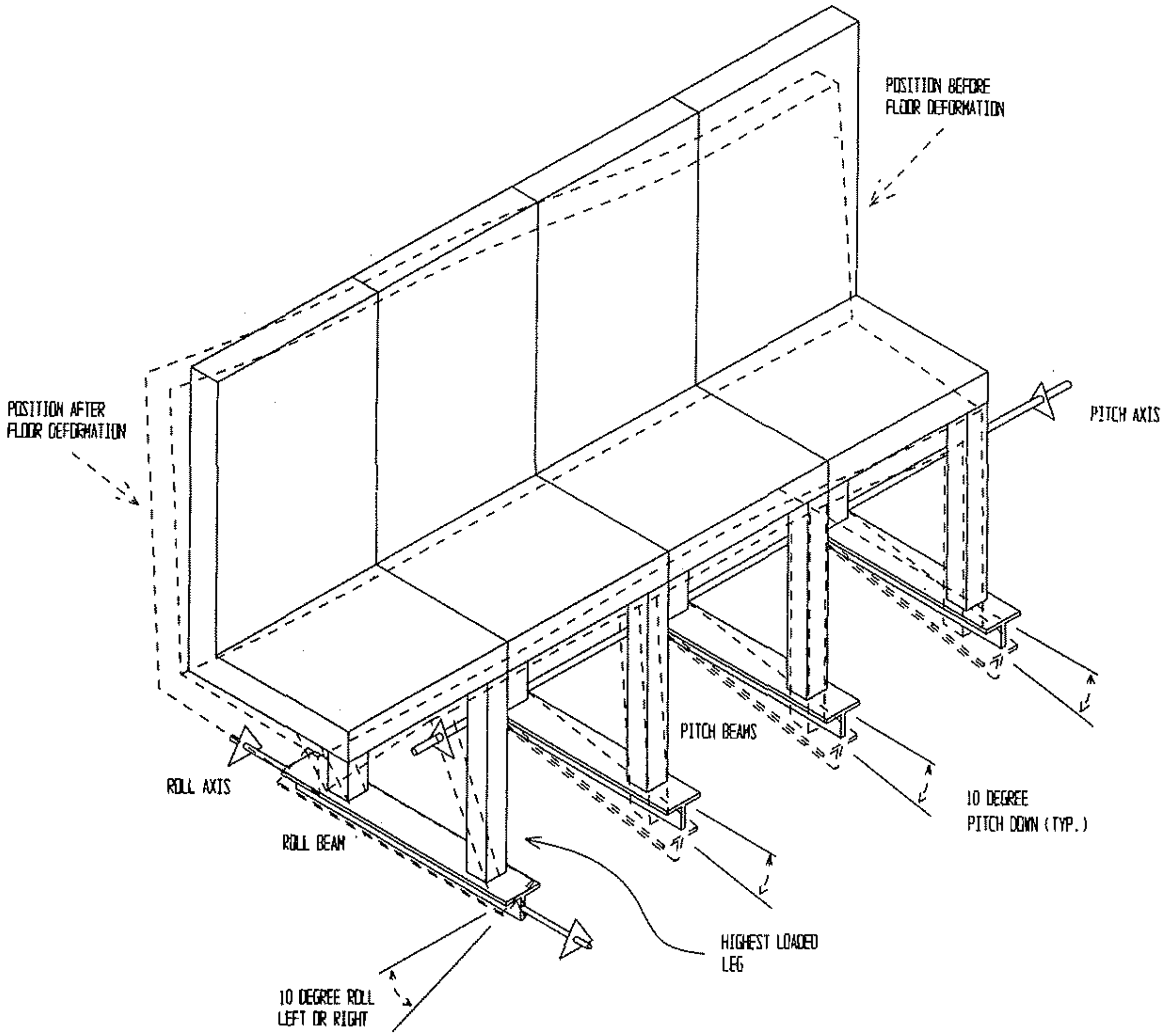


Figure 5. Floor Warpage Multiple Leg Seat

(3) Seats that are wall-mounted must be evaluated individually. There are several types of mounting schemes, some of which are discussed below. As noted in the preamble to Amendment 25-64, the dynamic impact pulses defined in § 25.562 are considered compatible with existing airframe structure. The definition of the test fixture required for floor-mounted seats takes this into account, so that extensive floor structure is not necessary for test; that is, only the seat track above the floor is used. The important consideration is the retention of the seat under dynamic conditions, and the test setup should account for this in wall-mounted seats as well. The following guidance has been established with this objective in mind.

(i) Seats that are mounted to primary airplane structure, such as a pressure bulkhead, need only be tested with the attachment fitting mounted to rigid structure, in a manner equivalent to the production installation.

(ii) Seats mounted to a structure, such as a structural bulkhead, galley or lavatory, where no integral structural members are used for attachment, should be tested with the seat attached to segments of the mounting surface. These segments are typically eight inch by eight inch sections of the panel. These sections can, in turn, be mounted to a rigid structure.

(iii) Seats that are mounted to single panel furnishings, such as class dividers or windscreens, where the panel essentially fulfills the role of the legs, should be treated the same as floor mounted seats. For the purpose of conducting tests, the entire assembly, including the panel and its attachments, should be included in the test setup. In this case, floor warpage should be applied to track-mounted furnishings.

(4) Seats that are attached to both the floor and a bulkhead should be tested on a fixture that positions the bulkhead surface in a plane through the axis of rotation of the pitch beam. The bulkhead surface should be located perpendicular to the plane of the floor (the airplane floor surface, if one were present) in the undeformed condition, or in a manner appropriate to the intended installation. Either a rigid bulkhead simulation or an actual bulkhead panel can be used. If a test fixture with a rigid bulkhead simulation is used, the seat restraint system shall attach to fittings installed in a test panel equivalent to those used in the actual installation. The seat should be attached to the bulkhead and the floor in a manner representative of the airplane installation, and the floor shall then be deformed as described in paragraph 10b.

(5) Seats that are mounted between sidewalls or to the sidewall and floor of an aircraft shall be tested in a manner that simulates airplane fuselage cross-section deformation during a crash. Brackets shall be provided to attach the seat to the test fixture at the same level above the fixture floor representing the installation above the airplane floor where the inboard tracks or attachment is located. The roll axis should be approximately at the center of the outboard track.

A sidewall bracket shall be located on the roll beam. Then, as the beams are rotated to produce the most critical loading condition (sidewall rotates outward), the combined angular and transitional deformation will simulate the deformation that could take place in a crash (see Figure 6 for a schematic representation). The seat positioning pins or locks shall be fastened in the same manner as would be used in the airplane, including the adjustment of anti-rattle mechanisms, if provided.

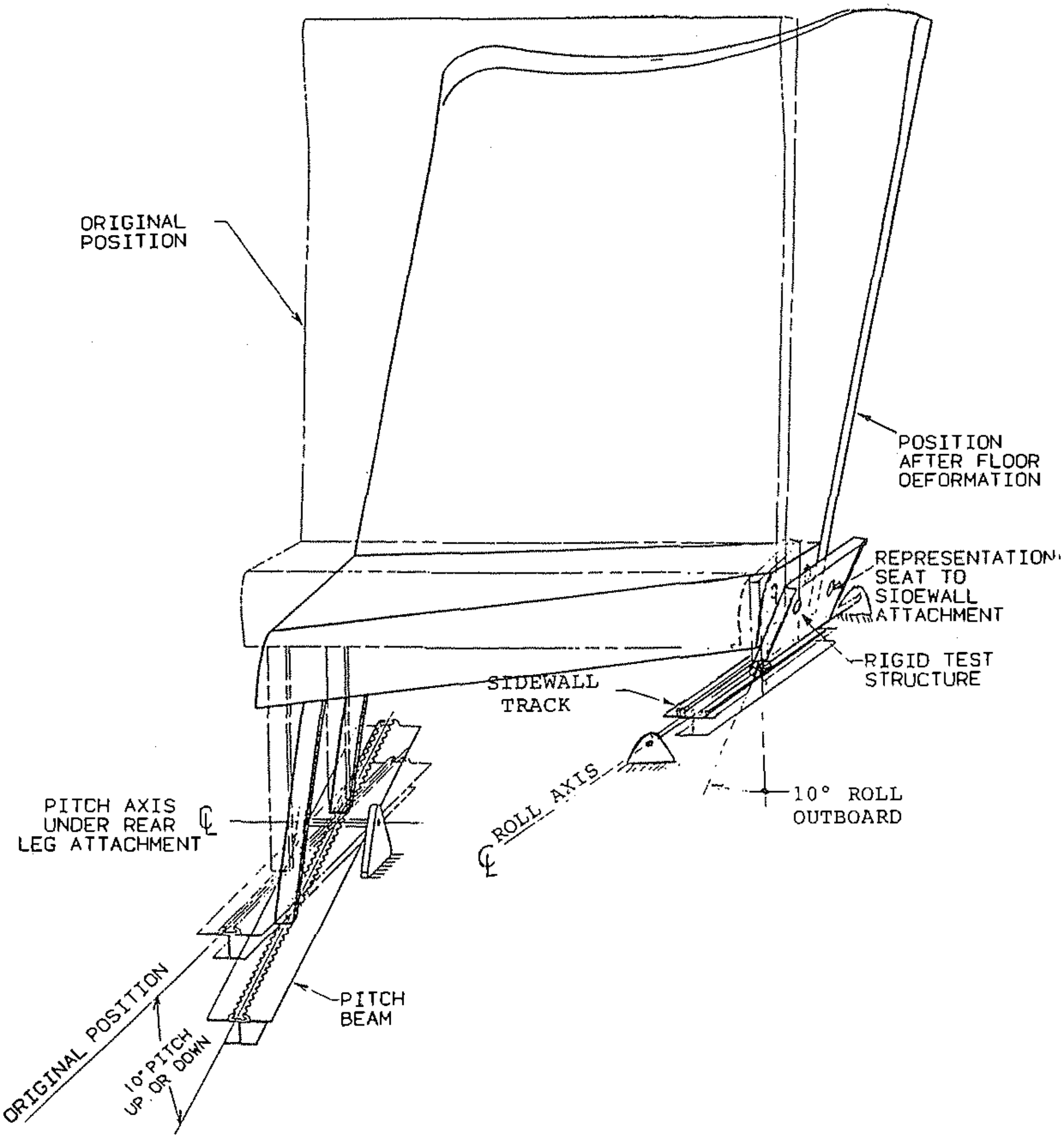


Figure 6. Schematic Test Fixture; Sidewall Mounted Seat

(6) Seats that are cantilevered from one sidewall without connection to other structure are not subject to floor deformation. A determination shall be made whether sidewall deformations could be expected that could generate a condition critical for seat performance in a crash. If sidewall deformation is likely, the entire sidewall attachment plane, or the attachment points, shall be deformed in a manner to represent the sidewall deformation. Either a rigid sidewall simulation or an actual sidewall panel may be used. If a test fixture with a rigid sidewall simulation is used, the seat/restraint system shall be attached to fittings installed in a test panel equivalent to those used in the actual installation.

(7) Seats that are mounted on a plinth. Where the plinth is used to mount a single seat, and the plinth is attached to the floor, the plinth should be considered as part of the seat assembly as an adaptor and should be deformed as described in paragraph 10b. Any items of mass attached to the plinth need to be represented and included in the dynamic testing.

(8) Seats that are mounted on a pallet (e.g., multiple seat rows). The pallet is considered part of the floor structure of the airplane. The seats should be attached to the pallet in a manner representative of the airplane installation. The seat legs should be deformed as described in paragraph 10b. Any items of mass attached to the pallet and not part of the seat structure do not need to be included in the dynamic testing.

d. Side-Facing Seats.

(1) General. All seats occupiable for takeoff and landing are subject to the specified dynamic test conditions, including side-facing seats, both single occupancy and multiple place (e.g. divans). Compliance with the structural requirements should be demonstrated for side-facing seats using the same conditions for the test and pass/fail criteria as for fore- and aft-facing seats. The seat should be loaded in the most critical case structurally. Means of restraining the ATDs may need to be adapted to ensure adequate retention during the test. The application of floor distortion will need to be assessed on an individual basis, depending on the design of the fixation of the seat. The injury criteria of § 25.562 are not adequate to demonstrate equivalent safety of side-facing seats when compared to fore- and aft-facing seats. To demonstrate equivalent safety fully in the absence of such specified criteria, the applicant must use other injury criteria which may be derived from the automotive industry, which uses side impact ATDs.

(2) Assessment Criteria. Research into side-facing seats is ongoing; therefore, in the absence of specific compliance guidance, the FAA is prepared to assess side-facing seats on the following basis:

(i) The seat must demonstrate compliance with the structural requirement.

(ii) If an acceptable side impact ATD has not been used with assessment of the corresponding injury criteria, it must be shown that the occupants are restrained in such a manner that prevents substantial energy absorption by body to body contact (on a multiple occupancy seat), and which, using the best available engineering judgment, minimizes injury to the occupant(s).

(iii) As research proceeds, the FAA will work toward establishing a more definitive policy with respect to the acceptance of side-facing seats.

e. Multiple Row Test Fixtures. In tests of passenger seats that are normally installed in repetitive rows in the airplane, head and knee impact conditions are best evaluated through tests that use at least two rows of seats. These conditions are usually critical only in Test 2. This test allows direct measurements of the head and femur injury data (see Figure 1).

(1) The fixture shall be capable of setting the airplane longitudinal axis at a yaw angle of -10 to +10 degrees. The fixture should also allow adjustment of the seat pitch and installation angle with respect to the airplane center line.

(2) To allow direct measurement of head acceleration for the head injury assessment of a seat installation where the head of the occupant is within striking distance of structure, a representative impact surface may be attached to the test fixture in front of the seat at the orientation and distance from the seat representing the airplane installation.

f. Other Fixture Applications. Test fixtures should provide a flat footrest for ATDs used in tests of passenger seats and crewmember seats that are not provided with special footrests or foot-operated airplane controls. The surface of the footrest shall be covered with carpet (or other appropriate material) and be at a position representative of the floor in the airplane installation. Test fixtures used for evaluating crew seats that are normally associated with special footrests or foot-operated controls shall simulate those components. (Note: A footrest is optional for test 2 structural tests--see paragraph 11f). Test fixtures may also be required to provide guides or anchors for restraint systems or for holding instrument panels or bulkheads, if necessary, for the planned tests. If these provisions are required, the installation shall represent the configuration of the airplane installation and be of adequate structural strength.

11. Test Preparation.

a. Preparation for the tests will involve positioning and securing the ATD, the ATD restraint system, the seat, and the instrumentation. This will be done for the specific critical condition being tested. Preparations that pertain to the normal operation of the test facility, such as safety provisions and the actual procedures for accomplishment of the tests, are specific to the test facility and will not be addressed in this AC.

b. Use of anthropomorphic dummies. Anthropomorphic dummies used in the tests discussed in this AC should be maintained to perform in accordance with the requirements described in their specification. Periodic teardown and inspection of the ATD should be accomplished to identify and correct any worn or damaged components, and appropriate ATD calibration tests (as described in their specification) should be accomplished if major components are replaced. For the tests discussed in this AC, the following procedures have been found to be adequate:

(1) Since extremes of temperature and humidity can affect ATD performance, the ATDs should be maintained at a temperature range between 66 to 78 degrees F (19 to 26 degrees C) and at a relative humidity from 10 to 70 percent for a minimum of 4 hours prior to the test.

(2) Each ATD should be clothed in form-fitting cotton stretch garments with short sleeves, mid-calf length pants, and shoes (size 11E) weighing about 2.5 pounds. The color of the clothing should be in contrast to the color of the restraint system.

(3) For tests where the ATD's head is expected to impact a fixture or another seat back, the head and face of the ATD may be treated with a suitable material to mark head contact areas. The material used must not reduce the resulting HIC values.

(4) The friction in limb joints should be set so that they barely restrain the weight of the limb when extended horizontally.

(5) The ATD should be placed in the center of the seat, in as nearly a symmetrical position as possible. The ATD should be placed in the seat in a uniform manner so as to obtain reproducible test results.

(6) The ATD's back should be against the seat back without clearance. This condition can be achieved if the ATD's legs are lifted as it is lowered into the seat. Then, the ATD is pushed back into the seat back as it is lowered the last few inches into the seat pan. Once all lifting devices have been removed from the ATD, the ATD should be "rocked" slightly to settle it in the seat.

(7) The ATD's knees should be separated about four inches.

(8) The ATD's hands should be placed on the top of it's upper legs, just behind the knees. If tests on crew seats are conducted in a mockup that has airplane controls, the ATD's hands should be lightly tied to the controls.

(9) The feet should be in the appropriate position for the type of seat tested (flat on the floor for a passenger seat, on control pedals or on a 45 degree footrest for flightcrew systems). The feet should be placed so that the centerlines of the lower legs are approximately parallel, unless the need for placing the feet on airplane controls dictates otherwise.

c. Seat adjustment. To the extent that they influence the injury criteria, all seat adjustments and controls should be in the design position intended for the 50th percentile male occupant. If seat restraint systems are being tested that are to be used in applications where special requirements dictate their position for landing or takeoff, those positions should be used in the tests.

d. Installation of instrumentation. Professional practice should be followed when installing instrumentation. Care should be taken when installing the transducers to prevent deformation of the transducer body that could cause errors in data. Lead-wires should be routed to avoid entanglement with the ATD or test article, and sufficient slack should be provided to allow motion of the ATD or test article without breaking the lead-wires or disconnecting the transducer. Calibration procedures should consider the effect of long transducer lead-wires. Head accelerometers and femur load cells should be installed in the ATD in accordance with the ATD specification and the instructions of the transducer manufacturer. The load cell between the pelvis and the lumbar column should be installed in accordance with the approach shown in Figure 2 of this AC, or in a manner that will provide equivalent data (see paragraph 8b).

(1) If an upper torso restraint is used, the tension load should be measured in a segment of webbing between the ATD's shoulders and the first contact of the webbing with hard structure (the anchor point or a webbing guide). Restraint webbing should not be cut to insert a load cell in series with the webbing, since that will change the characteristics of the restraint system. Load cells that can be placed over the webbing without cutting are commercially available. They should be placed on free webbing to minimize contact with hard structure, seat upholstery, or the ATD during the test. They should not be used on double-reeved webbing, multiple-layered webbing, locally stitched webbing, or folded webbing, unless it can be demonstrated that these conditions do not cause errors in the data. These load cells should be calibrated using a length of webbing of the type used in the restraint system. If the placement of the load cell on the webbing causes the restraint system to sag, the weight of the load cell can be supported by light string or tape that will break away during the test.

(2) Since load cells are sensitive to the inertial forces of their own internal mass and to the mass of fixtures located between them and the test article, as well as to forces applied by the test article, it may be necessary to compensate the test data for that inaccuracy if the error is significant. Data for such compensation will usually be obtained from an additional dynamic test that replicates the load cell installation, but does not include the test item.

e. Restraint system adjustment. The restraint system adjustment should be made as follows: The restraint system shall not be tightened beyond the level that could reasonably be expected in use, and the emergency locking device (inertia reel) shall not be locked prior to the impact. Automatic locking retractors shall be allowed to perform the webbing retraction and automatic locking function without assistance. Care shall be taken that emergency locking retractors that are sensitive to acceleration do not lock prior to the impact test because of preimpact acceleration applied by the test facility. If comfort zone retractors are used, they shall be adjusted in accordance with instructions given to the user of the restraint system.

(1) If manual adjustment of the restraint system is required, slack shall be removed, and the restraint system should be snug about the ATD. For test 2, this can normally be determined when two fingers will fit snugly between the belt and the pelvis of the ATD. The restraint system shall be checked and adjusted just prior to the floor deformation phase of the test.

(2) If the system is tested in other than a "horizontal floor" position, the restraint should be properly adjusted with the seat in the "horizontal floor" position and the webbing transducers installed (if required). After sufficient time has elapsed to allow the cushion to reach an equilibrium position, the webbing should be marked to indicate the correct adjustment point. The seat and ATD should then be installed on the fixture in the appropriate dynamic test orientation and the restraint system again adjusted to that same point.

(3) An alternate method to impose a 1-g preload is to measure the position of the ATD hip joints relative to the floor as shown in Figure 7 below. The ATD is then depressed into the cushion to reproduce this relative position after the ATD and seat have been installed on the fixture, as shown in Figure 8. The lap belt may be tightened to maintain this position. This load may make it impossible to insert two fingers between the lap belt and the pelvis of the ATD, but it should not produce a cushion displacement in excess of that measured by placing the ATD on the seat in a 1-g orientation.

f. A floor is not required for Test 2, but if a floor is installed, it should not influence the behavior of the seat, or unduly restrict the movement of the ATD's feet. This is a concern especially when floor distortion is applied. For consistency, a floor should be used for tests used to gather head path data.

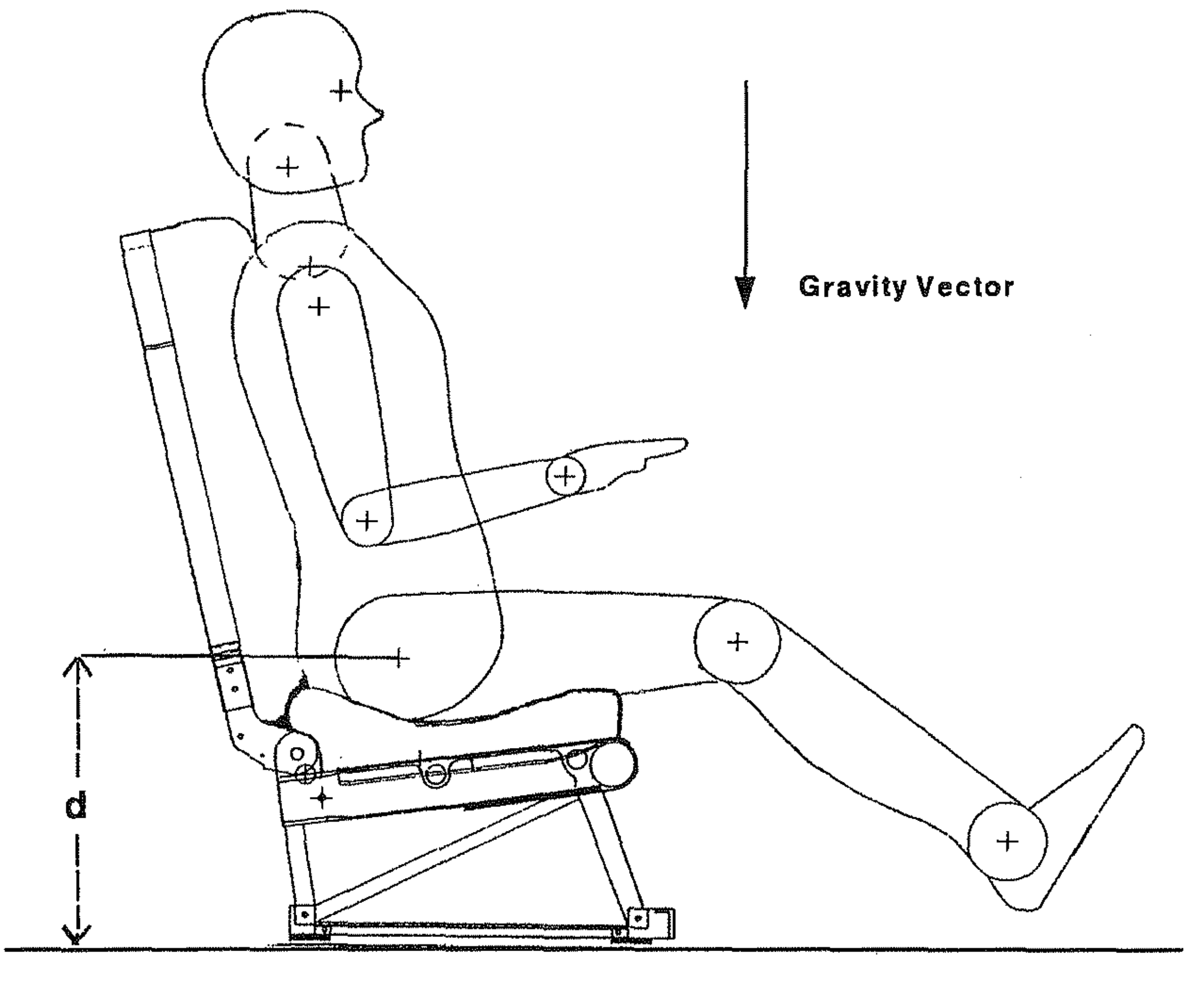


Figure 7. Measurement of 1g Preload

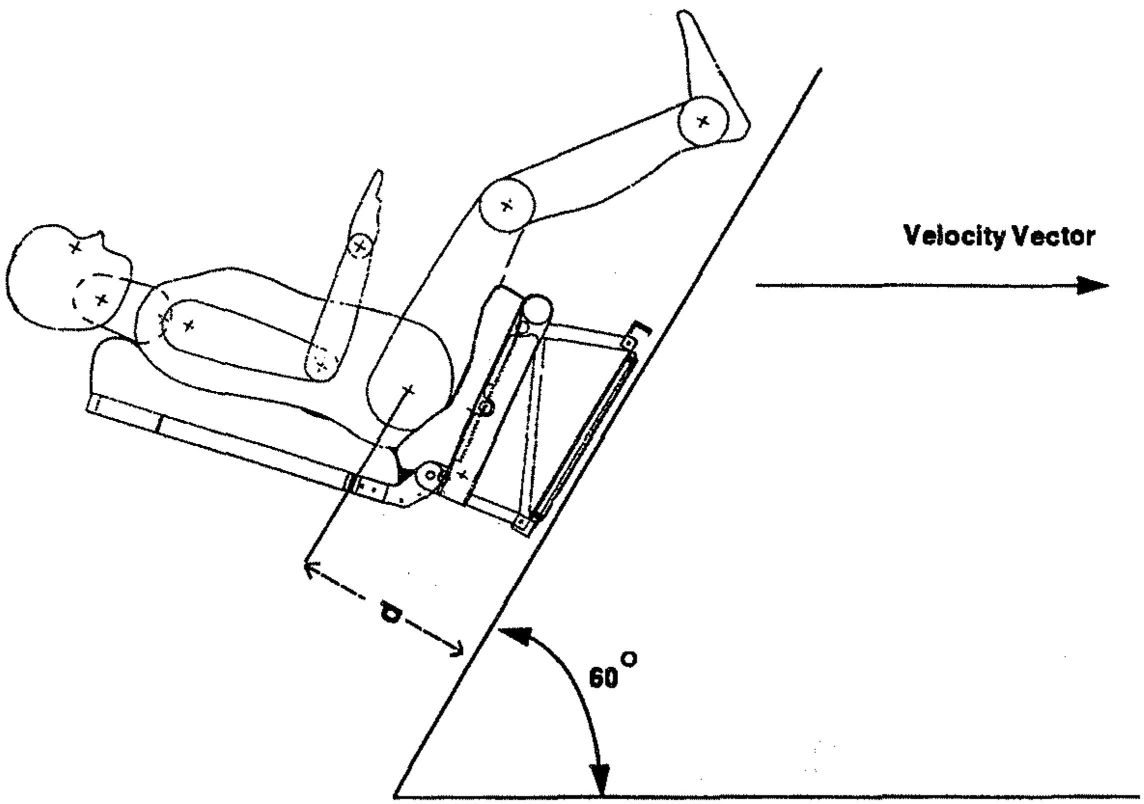


Figure 8. Test Orientation, 1g Position

12. DATA REQUIREMENTS. The data should include charts, listings, and/or tabulated results, and copies of any photo instrumentation used to support the results. The following should be recorded:

a. Impact pulse shape

b. Head Injury Criterion (HIC) results for all ATD's exposed to head impact with interior components of the airplane or head strike paths and velocities if head impact is likely but could not be evaluated by these tests

c. Total velocity change

d. Upper torso restraint system load, if applicable

e. Compressive load between the pelvis and the lumbar column

f. Retention of upper torso restraint straps, if applicable

g. Retention of pelvic restraint

h. Femur loads, if applicable

i. Seat attachment (including structural damage)

j. Seat deformation

k. Seat attachment reaction time histories

l. Retention of items of mass

m. Post test retrieval of life vest

n. Evaluation of seat egress

13. DATA ANALYSIS.

a. General. All data obtained in the dynamic tests should be reviewed for errors. Baseline drift, ringing, and other common electronic instrumentation problems should be detected and corrected before the tests. Loss of data during the test is readily observed in a plot of the data versus time and is typically indicated by sharp discontinuities in the data, often exceeding the amplitude limits of the data collection system. If these occur early in the test in essential data channels, the data should be rejected and the test repeated. If they occur late in the test after the maximum data in each channel has been recorded, the validity of the data should be carefully evaluated, and the maximum values of the data may still be acceptable for the tests described in this AC. The HIC does not represent simply a maximum data value, but an integration of data over a varying time base. The head acceleration measurements used for that computation are not acceptable if errors or loss of data are apparent in the data at any time, from the beginning of the test until the ATD and all test articles are at rest after the test.

b. Impact pulse shape. Data for evaluating the impact pulse shape is obtained from an accelerometer that measures the acceleration in the direction parallel to the inertial response shown in Figure 1 of this AC. The impact pulses intended for the tests discussed in this AC have an isosceles triangle shape. These ideal pulses are considered minimum test conditions. Since the actual acquired test pulses will differ from the ideal, it is necessary to evaluate the acquired test pulses to insure the minimum requirements are satisfied. The five properties of the ideal pulse that must be satisfied by the acquired test pulse are as follows (see Figure 1):

Pulse shape:	isosceles triangle
G_{req}:	peak deceleration required by test condition
T_{req}:	rise time required by test condition
V:	total velocity change required by test condition
V_{tr}:	velocity change required during T_{req} ($V_{tr} = V/2$)

A graphical technique can be used to evaluate pulse shapes that are not precise isosceles triangles. Appendix 1 of this AC presents the graphical method of evaluating the acquired pulse (the recorded test sled acceleration versus time). For the acquired pulse to be acceptable, the following five criteria must be met:

(1) The magnitude of the peak value for the acquired pulse, G_{pk}, must be greater than or equal to G_{req}.

(2) The actual rise time, $Tr = T_2 - T_1$, must be less than or equal to T_{req}.

(3) The result of integrating the acquired pulse during the interval from $t = T_1$ to $t = T_3$ must be equal to or greater than V_{tr}, one-half of the required velocity change for the specified test. If the magnitude of the acquired pulse is greater than the ideal pulse during the entire interval from T_1 to T_3, this requirement is automatically met.

(4) The result of integrating the acquired pulse during the interval from $t = T_1$ to $t = T_1 + 2.3\ (T_{req})$ must equal or exceed the required test velocity change, V, of the test condition. If the acquired pulse returns to zero g's at $t = T_4 < (T_1 + 2.3\ (T_{req}))$, the end of the interval of integration is reduced to $t = T_4$.

(5) If the magnitude of the acquired pulse is greater than the ideal pulse during the entire interval of $t = T_1$ to T_2, and the parameters of paragraphs (1) through (4) above are satisfied, then the acquired pulse is acceptable.

(6) If the magnitude of the acquired pulse is not greater than the ideal pulse during the entire interval $t = T_1$ to T_2, the difference between acquired pulse and the ideal must be no greater than 2.0 g's at those times when the acquired pulse is less than the ideal. The

parameters of paragraphs (1), (2), and (3) above must also be satisfied for the acquired pulse to be acceptable.

c. Total Velocity Change. Impact velocity can be obtained by measurement of a time interval and a corresponding sled displacement that occurs just before or after (if appropriate) the test impact, and then dividing the displacement by the time interval. When making such a computation, the possible errors of the time and displacement measurements shall be used to calculate a possible velocity measurement error, and the test impact velocity should exceed the velocity shown in Figure 1 by at least the velocity measurement error. If the sled is not changing velocity during the immediate preimpact or postimpact interval, the impact velocity is the total velocity change. If the sled is changing velocity during the immediate pre-impact or post-impact interval, or if the facility produces significant rebound of the sled, the total velocity change can be determined by integrating the plot of sled acceleration versus time, as described in Appendix 1. If this method is used, the sled acceleration shall be measured in accordance with Channel Class 180 requirements.

d. Head Injury Criterion (HIC).

(1) Data for determining the Head Injury Criterion (HIC) need to be collected during the tests discussed in this AC only if the ATD's head is exposed to an impact on airplane interior features (not including the floor or the ATD's own leg) during the test. The HIC is calculated according to the following equation:

$$HIC = \left[(t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(t)\,dt\right]^{2.5}\right]_{max}$$

Where: t_1 and t_2 are any two points in time (in seconds) during the head impact, and a(t) is the resultant head acceleration (expressed in g's) during the head impact.

(2) The HIC is a method for defining an acceptable degree of occupant head injury. The HIC should not exceed 1000, for head impact against interior surfaces in a crash.

(3) The HIC is invariably calculated by computer based data analysis systems, and the discussion that follows outlines the basic method for computation . The HIC is based on data obtained from three mutually perpendicular accelerometers installed in the head of the ATD in accordance with the ATD specification. Data from these accelerometers are obtained using a data system conforming to Channel Class 1000, as described in SAE Recommended Practice J211. Only the data taken during head impact with the airplane interior need be considered; this is usually indicated in the data by a rapid change in the magnitude of the acceleration. Film of the test may show head impact that can be correlated with the acceleration data by using the time base common to both electronic and photographic instrumentation. Simple contact switches that do not significantly alter the surface profile could also be used to define the initial contact time.

(4) The magnitude of the resultant acceleration vector obtained from the three accelerometers is represented as a function of time. Then, beginning at the time of initial head contact (t_1), the average value of the resultant acceleration is found for each increasing increment of time (t_2-t_1), by integrating the curve between t_1 and t_2 and then dividing the integral value by the time (t_2-t_1). This calculation should use all data points provided by the minimum 8000 samples per second digital sampling rate for the integration. However, the maximizing time intervals need be no more precise than 0.001 seconds. The average values are then raised to the 2.5 power and multiplied by the corresponding increment of time (t_2-t_1).

(5) This procedure is then repeated, increasing t_1 by 0.001 seconds for each repetition. The maximum value of the set of computations obtained from this procedure is the HIC. The procedure may be simplified by noting that the maximum value will only occur in intervals where the resultant magnitude of acceleration at t_1 is equal to the resultant magnitude of acceleration at t_2, and when the average resultant acceleration in that interval is equal to 5/3 times the acceleration at t_1 or t_2. The HIC is usually reported as the maximum value, and the time interval during which the maximum value occurs is also given.

(6) In many cases, a full system sled test to evaluate specific occupant injury conditions may not be needed to evaluate a redesign of the seat system that affects only HIC. In such cases, the photometric head path data can be gathered and used to ensure no contact will occur, or to define the head angle and velocity at impact. These data can used in a component test of severity comparable to the whole system sled test. Other factors, such as the inertial response of the impact target, must be accounted for in the component test condition so that the impact condition is representative. Component testing methods must be demonstrably comparable to whole system sled tests as a HIC measure, and the specific methodology used will require approval by the FAA.

Additionally, a seat may be designed for use in multiple locations where head contact against a range on unknown bulkhead targets is anticipated (e.g., front row seats). For these seats, HIC may be measured using a representative impact target mounted in front of the seat at the installation setback, or range of setbacks. This target will represent typical fixtures such as galleys, partitions, lavatories, and closets, and its stiffness wil be representative for those monuments. If contact occurs, the HIC must be $\leq$ 1000.

e Upper torso restraint system load. The maximum load in the upper torso restraint system webbing can be obtained directly from a plot or listing of webbing load transducer output. If a three-axis load transducer, fixed to the test fixture, is used to obtain these data, the data from each axis shall be combined to provide the resultant vector magnitude. If necessary, corrections shall be made for the internal mass of the transducer and the fixture weight it supports. This correction will usually be necessary only when the inertial mass or fixture weight is high, or when the correction becomes critical to demonstrate that the measurements fall below the specified limits.

f. Compressive load between the pelvis and lumbar column. The maximum compressive load between the pelvis and the lumbar column of the ATD can be obtained directly from a plot or listing of the output of the load transducer at that location. Since most load cells will indicate tension as well as compression, care should be taken that the polarity of the data has been correctly identified.

g. Retention of upper torso restraint straps. Retention of the upper torso restraint straps on the ATD's shoulders can be verified by observation of photometric or documentary camera coverage. The straps must remain on the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. The straps must not bear on the neck or side of the head and must not slip to the upper rounded portion of the upper arm during that time period.

h. Retention of pelvic restraint. Retention of the pelvic restraint on the ATD's pelvis can be verified by observation of photometric or documentary camera coverage. The pelvic restraint shall remain on the ATD's pelvis, bearing on or below each prominence representing the anterior superior iliac spine, until the ATD rebounds after the test impact and the pelvic restraint becomes slack. Provided that the pelvic restraint remains on the ATD's pelvis, traping of the belt between the leg and the pelvis is acceptable.

Movement of the pelvic restraint above the prominence is usually indicated by an abrupt displacement of the belt onto the ATD's soft abdominal insert which can be seen by careful observation of photo data from a camera located to provide a close view of the belt as it passes over the ATD's pelvis. This movement of the belt is sometimes indicated in measurements of pelvic restraint load (if such measurement are made) by a transient decrease or plateau in the belt force, as the belt slips over the prominence, followed by a gradual increase in belt force as the abdominal insert is loaded by the belt.

i. Femur load. Data for measuring femur loads can be collected in the tests discussed in this AC if the ATD's legs contact seats or other structure. Data need not be recorded in each individual test, if rational comparitive analysis is available for showing compliance.

14. PASS/FAIL CRITERIA. The dynamic impact tests shall demonstrate that:

a. Since the test methods described in this AC are ultimate load condtions, damage to the seat and restraint is expected. The regulation specifically accounts for yielding as an acceptable form of permanent damage. In addition, the following should be considered:

(1) The seat system remains attached to the test fixture at all points of attachment, the occupant restraint system remains attached at all points of attachment and the primary load path remains intact. For the purpose of showing compliance with the structural requirements of § 25.562, acceptable damage to the load-carrying structural elements include: bending deformation, tension deformation, compression crippling, and shear buckling. Cracking of structural elements and the shearing or separation of rivets and minor delamination of composite panels is allowed provided a continuous load path remains between the occupant and the seat attachments.

(2) Damage to seat belts, such as scuffing, fraying and breakage of fibers is considered acceptable. The seat belt should not be cut, or torn by features of the seat or the belt adjuster mechanism. Cuts or tears should be investigated as to their cause, and appropriate corrective action taken, although a retest may not be necessary.

b. If the ATD's head is exposed to impact with interior features during the test, a HIC of 1,000 is not exceeded.

c. Where upper torso restraint straps are used, tension loads in individual straps do not exceed 1,750 lbs.(7.78 kN). If dual straps are used for restraining the upper torso, the total strap tension load does not exceed 2,000 lbs.(8.90 kN).

d. The maximum compressive load measured between the pelvis and the lumbar column of the ATD does not exceed 1,500 lbs. (6.67 kN).

e. The upper torso restraint straps (where installed) remain on the ATD's shoulder during impact.

f. The pelvic restraint remains on the ATD's pelvis during impact.

g. Where leg contact with seats or other structure occurs, the axial compressive load in each femur does not exceed 2,250 lbs. (10.0 kN).

h. The seat permanent deformations are within the quantitative limits of Appendix 2 of this AC and will not significantly impede an occupant from releasing his restraints, standing, and exiting the seat. In no case should deformation of the seat cause entrapment of the occupant, whether or not the defined limits referenced in Appendix 2 are exceeded.

NOTE: It is assumed that the maximum seat deformation will result from the structural evaluation (i.e., single row Type 2 test). Once this is accomplished, it would not, therefore, be considered necessary to repeat deformation measurements after the injury criteria (multiple row) tests, unless the structural and injury criteria tests were combined into one test.

i. All deployable items must remain stowed, unless it can be shown that they do not impede egress or cause serious injury (see Appendix 2).

15. TEST DOCUMENTATION.

a. General. The tests should be documented in reports that describe the procedures, limitations, results, and deviations to the tests discussed in this AC. In addition to the specific data requirements specified in paragraph 12 of this AC, the documentation should include the following:

(1) Facility data.

(i) The name and address of the test facility performing the tests.

(ii) The name and telephone number of the individual at the test facility responsible for conducting the tests.

(iii) A brief description and/or photograph of each test fixture.

(iv) The date of the last instrumentation system calibration and the name and telephone number of the person responsible for instrumentation system calibration.

(v) A statement confirming that the data collection was done in accordance with the recommendations in this AC, or a detailed description of the actual calibration procedure used and technical analysis showing equivalence to the recommendations of this AC.

(vi) The manufacturer, governing specification, serial number, and test weight of the ATDs used in the tests, and a description of any modifications or repairs performed on the ATDs that could cause them to deviate from the specification.

(vii) A description of the photographic-instrumentation system used in the tests.

(2) Seat restraint system data.

(i) The manufacturer's name and identifying model numbers of the seat restraint system used in the tests, with a brief description of the system, including identification and a functional description of all major components and photographs or drawings, as applicable. Qualifying approvals, such as Technical Standard Order (TSO) authorizations, should be included.

(ii) For systems that are not symmetrical, an analysis supporting the selection of most critical conditions used in the tests.

b. Test Description. The description of the test should be documented in sufficient detail so that the tests could be reproduced simply by following the guidance given in the report. The procedures outlined in this AC can be referenced in the report, but should be supplemented by such details as are necessary to describe the unique conditions of the tests. For example:

(1) Pertinent dimensions and other details of the installation that are not included in the drawings of the test items should be provided. This can include footrests, restraint system webbing guides and restraint anchorages, "interior surface" simulations, bulkhead or sidewall attachments for seats or restraints, etc.

(2) The floor deformation procedure, guided by goals of most critical loading for the test articles, should be documented.

(3) The placement and characteristics of electronic and photographic instrumentation chosen for the test, beyond that information provided by the facility, should be documented. This can include special targets, grids, or marking used for interpretation of photo documentation, transducers, restraint system loads, floor reaction forces, or other measurements beyond those discussed in this AC.

(4) Any unusual or unique activity or event pertinent to conducting the test should be documented. This could include use of special "break away" restraints or support for the ATDs, test items or transducers, operational conditions or activities such as delayed or aborted test procedures, and failures of test fixtures, instrumentation system components, or ATDs.

(5) Any energy-absorbing features that are intended as part of the design, and the expected structural behavior that will result should be documented.

16. COMPUTER MODELS. Several computer models have been developed to represent the seat restraint/occupant system in a crash. Some of these models include representation of the vehicle interior as well. These models can vary in complexity from simple spring-mass dynamic models to exceedingly complex models, which can be of help in designing an entire work station. Validation of these models also varies, from no validation at all to complex validation efforts based on controlled testing and field experience. The use of these models during the design phase of seat restraint/interior systems for civil airplanes is encouraged. They can be of great assistance in predicting "most critical" conditions, in understanding the performance of systems when used by various sized occupants, in estimating head strike paths and velocities, and for many other uses of interest to the designer. The Federal Aviation Administration will continue to assess the performance of dynamic computer models, and will issue appropriate advisory material should any of these techniques be found to be useful alternatives to the tests discussed in this AC.

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APPENDIX 1

PROCEDURE FOR EVALUATING PULSE SHAPES

1. This graphical procedure may be used to evaluate the impact pulse shape acquired from a test. While this procedure is based on graphical concepts, an accurate evaluation of the pulse parameters should be obtained using the digitized data and computer algorithms that provide the analysis illustrated in the following steps:

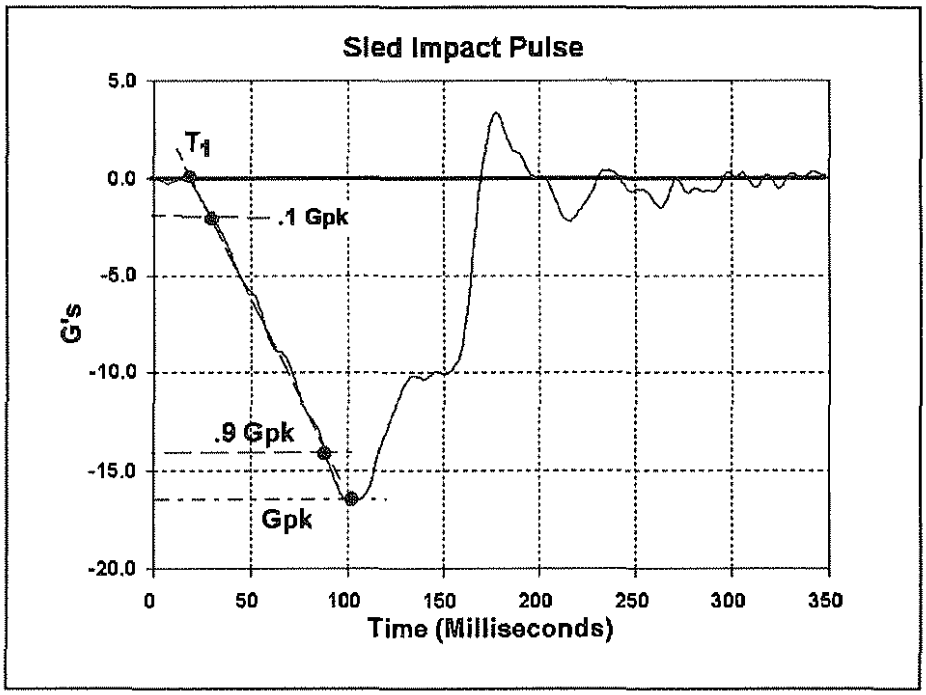


Figure 1

2. On the plot of the acquire pulse, identify the peak deceleration point, Gpk, and points on the onset of the pulse equal to 0.1 Gpk and 0.9 Gpk. Construct an onset line through the points 0.1 Gpk and 0.9 Gpk. Extend the constructed onset line to the base line of the data plot, G=0. Identify the intersection of the constructed onset line and baseline as the start of the acquired pulse, T1. For the acquired pulse to be acceptable, the magnitude of Gpk must equal or exceed the minimum required pulse, Greq for the specified test condition.

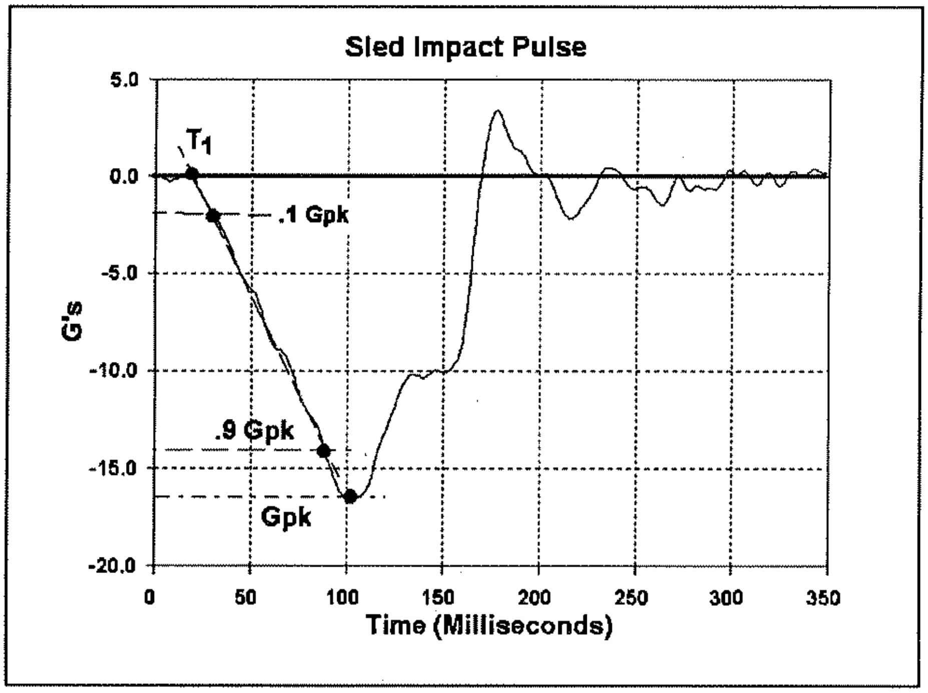


Figure 2

3. Using T_1 as the start time, construct the ideal pulse required for the test condition. Draw a vertical line and a horizontal line through the peak of the ideal pulse, Greq. The vertical line through Greq will intersect the time axis at the maximum allowed rise time, T_3. Draw another vertical line at the first intersection of the horizontal line through Greq and the acquired pulse after T_1. This vertical line will intersect the time axis at T_2. The actual rise time, $Tr = T_2 - T_1$, must be less than or equal to Treq for the acquired pulse to be acceptable.

4. Compute the velocity change, Vra, of the acquired pulse during the interval T_1 to T_3. Note that T_3 will usually occur after the peak, Gpk, of the acquired pulse. For the acquired pulse to be acceptable, Vra must be at least one-half the total velocity V, required for the specified test condition.

5. If the total velocity change for the test is calculated from the acquired pulse, use the interval starting at T_1 and ending:

a. At the point T4, where the acquired pulse first intersects the baseline, G = 0, after the time of Gpk, or

b. At the time equal to: $T_1+2.3xTreq$, whichever occurs first.

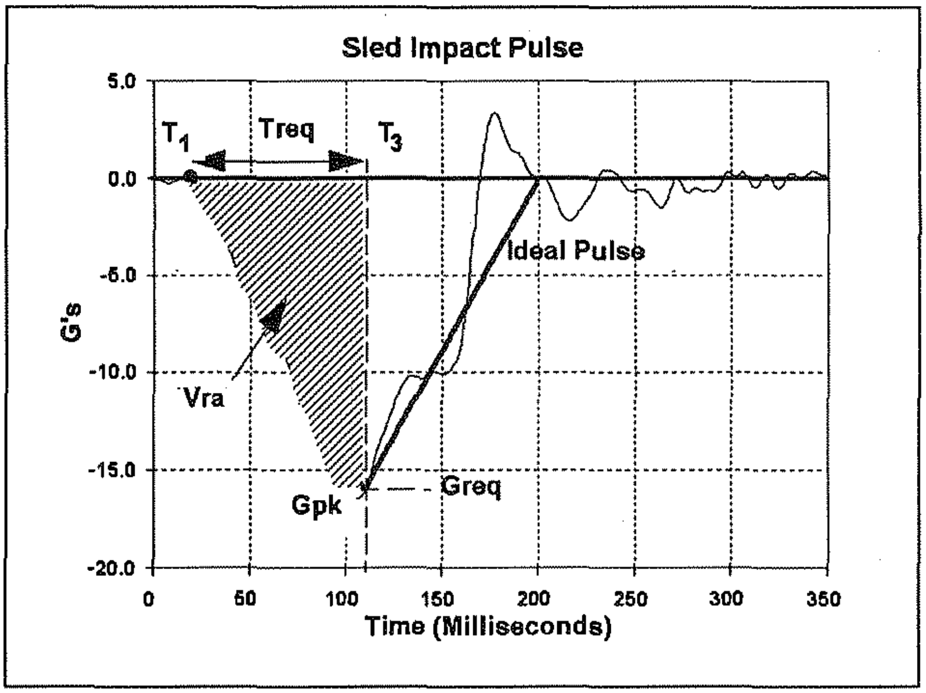


Figure 3

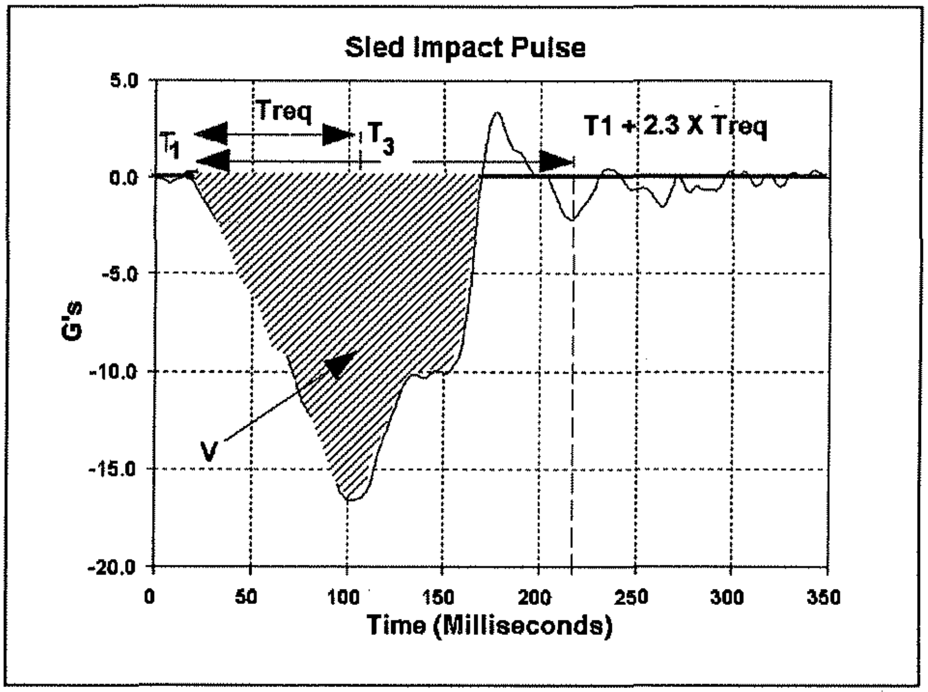

Sled Impact Pulse
Treq
T1
T3
T1 + 2.3 X Treq
V
G's
5.0
0.0
-5.0
-10.0
-15.0
-20.0
0
50
100
150
200
250
300
350
Time (Milliseconds)

Figure 4

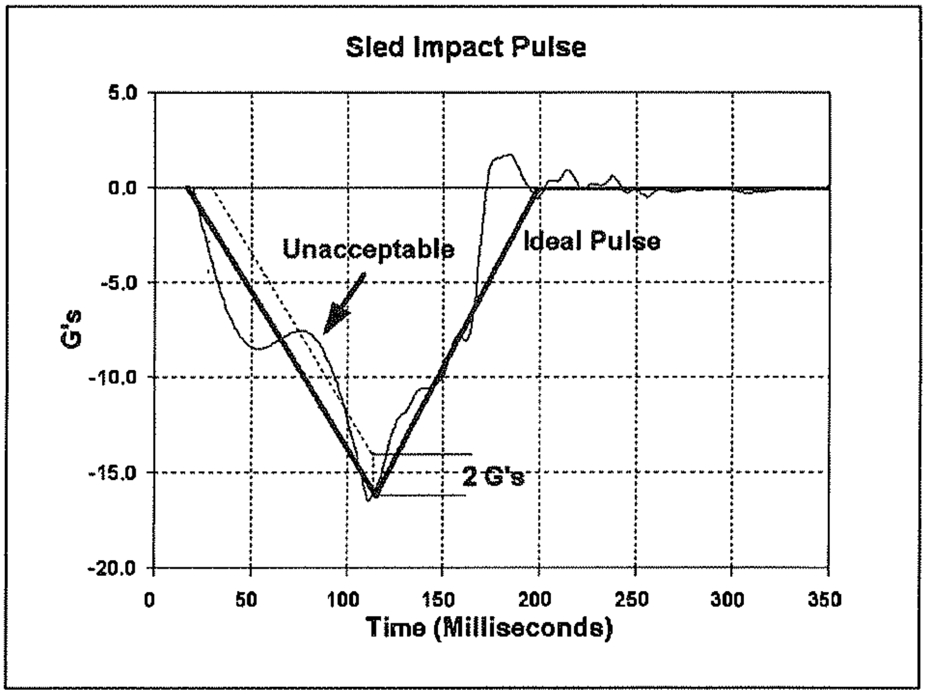


Figure 5

6. Construct a line parallel to the ideal pulse and offset by 2 G's in magnitude less than the ideal during the time interval between T1 and T2. If the magnitude of the acquired pulse is 2 G's less than the ideal at any point during the interval between T1 and T2, the pulse is not acceptable. Figure 2 is an example of an acceptable pulse shape. The acquired pulse shown in Figure 5 is unacceptable.

APPENDIX 2

SEAT DEFORMATION

1. General. Seats that are evaluated in accordance with the tests discussed in this AC may deform either due to the action of discrete energy absorber systems included in the design or due to residual plastic deformation of their structural components. If this deformation is excessive, it could impede the airplane emergency evacuation process. Each seat design may differ in this regard and should be evaluated according to its unique deformation characteristics. If floor deformations are applicable, consistency in pre and post-test measurements shall be maintained. If the pretest measurements are made before floor deformations are applied, the post-test measurements shall be made after floor deformations have been removed. Conversely, if the pretest measurements are made after floor deformations are applied, the post-test measurements shall be made before removal of floor deformations.

2. Fixed Seats. The following post-test deformations and limitations regarding emergency exit egress may be used for showing compliance with §§ 25.561(d) and 25.562(c)(8). Dimensions specified for undeformed seat rows assume the maximum permanent deformation discussed below, and are given to enable evaluation of an installation without having to make reference to test reports. In those cases where the actual permanent deformations are less than maximum, the specified dimensions for undeformed seat rows could be correspondingly decreased.

a. Forward or Rearward Directions. Seats that exhibit forward or rearward deformations should not exceed a maximum of 3.0 inches (75 mm). In this case, the clearance between undeformed seat rows, measured as shown in Figure 1, Dimension A, of this appendix, should be 9.0 inches (228 mm) or, alternatively, 6.0 inches (150 mm), plus the actual fore/aft deformation. Seat rows that lead to Type III exits are subject to the specific access requirements for those exits. This will result in greater spacing at those seat rows in the undeformed case. For seats with deformations that exceed 3.0 inches, the undeformed clearances should be increased accordingly. In addition, at seat rows leading to Type III or IV exits, 20 inches (508 mm) minimum clearance, measured above the arm rests, shall be maintained between adjacent seat rows. This measurement may be made with the seat backs returned to their upright position, using no more than original seat back breakover forces, typically 25-35 pounds (111-155 N). At other seat rows, the most forward surface of the seat back shall not deform to a distance greater than one half the original distance to the forwardmost hard structure on the seat (see Figure 2 of this appendix).

b. Downward Direction. There is no limitation on downward permanent deformation, provided it can be demonstrated that the feet or legs of occupants will not be entrapped by the deformation.

c. Seat Rotation. The seat bottom rotational permanent deformation shall not result in an angle that exceeds 20 degrees pitch down or 35 degrees pitch up from the horizontal plane. This rotational deformation shall be measured between the fore and aft extremities of the seat pan at the centerline of each seat bottom (Figure 3 of this appendix). Rotation of the seat pan shall not cause entrapment of the occupant.

d. Sideward Direction.

(1) The deformed seat should not encroach more than 1.5 inches (38 mm) into the required longitudinal aisle space at heights up to 25 inches (635 mm)above the floor. The determination of which parts of the seat are at what heights is determined prior to testing.

(2) The deformed seat should not encroach more than 2.0 inches (50 mm)into the longitudinal aisle space at heights 25 inches (635 mm) or more above the floor.

e. Additional Considerations. In addition, none of the above deformations shall permit the seat to:

(1) Affect the operation of any emergency exit or encroach into an emergency exit opening for a distance from the exit not less than the width of the narrowest passenger seat installed in the airplane.

(2) Encroach into any required passageway.

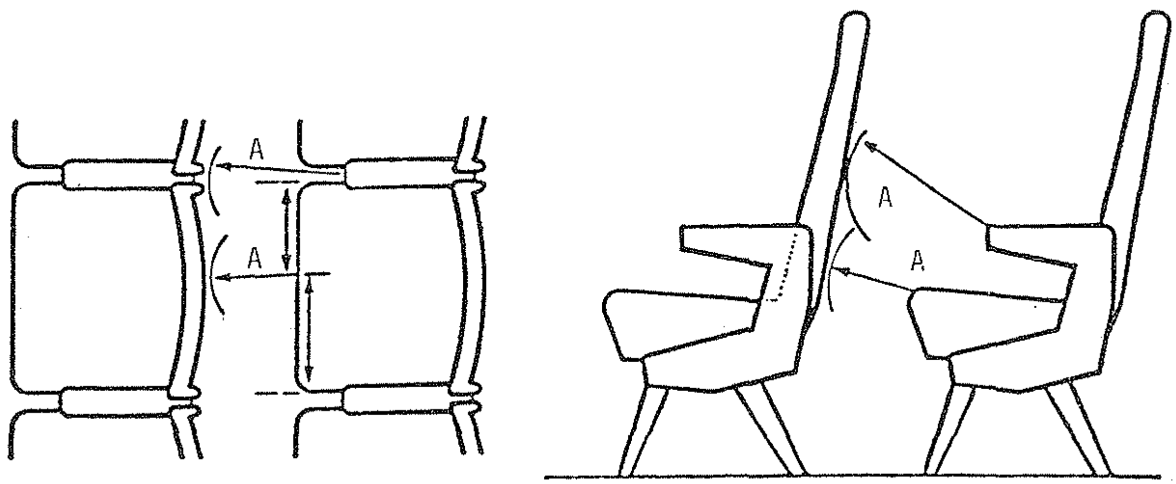
(3) Encroach more than 1.5 inches (38 mm) into any cross-aisle or flight attendant assist space.

f. Deployable Items. Certain items on the seat, such as food trays, legrests, arm caps over in-arm tray tables, etc., are used by passengers in flight and are required to be stowed for taxi, takeoff and landing. Deployment of such items should be treated as "permanent deformation" if the item deploys into an area that must be used by multiple passengers (in addition to the occupant of the seat) for egress. Such deployments can be considered acceptable, even if they exceed the dimensions specified above, if they are readily pushed out of the way by normal passenger movement, and remain in a position that does not affect egress.

3. Stowable Seats. Stowable seats, that may impede egress,must stow post-test and remain stowed to the extent necessary in order to satisfy the above criteria.

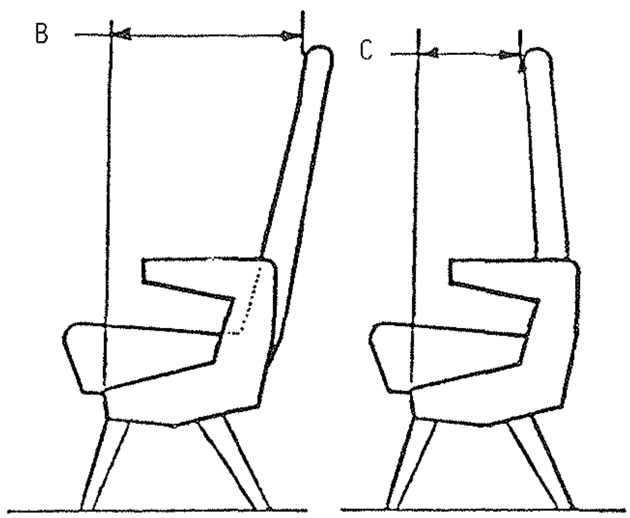
a. Seats that are Stowed Manually. A post-test stowage force no greater than 10 pounds (45 N) above the original stowage force may be used to stow the seat.

b. Seats that Stow Automatically. For a seat that may interfere with the opening of any exit, it must automatically retract to a position where it will not interfere with the exit. For determining encroachment into passageways, cross-aisles, andassist spaces, a post-test stowage force no greater than 10 pounds (45 N), applied at a single point, may be used to assist automatic retraction.



(Measurement to be taken over full width of seat bottom cushion)

Figure 1



Pre-test Condition Post-Test Condition
Dimension "C" must be at least 50 percent of Dimension "B"

Figure 2

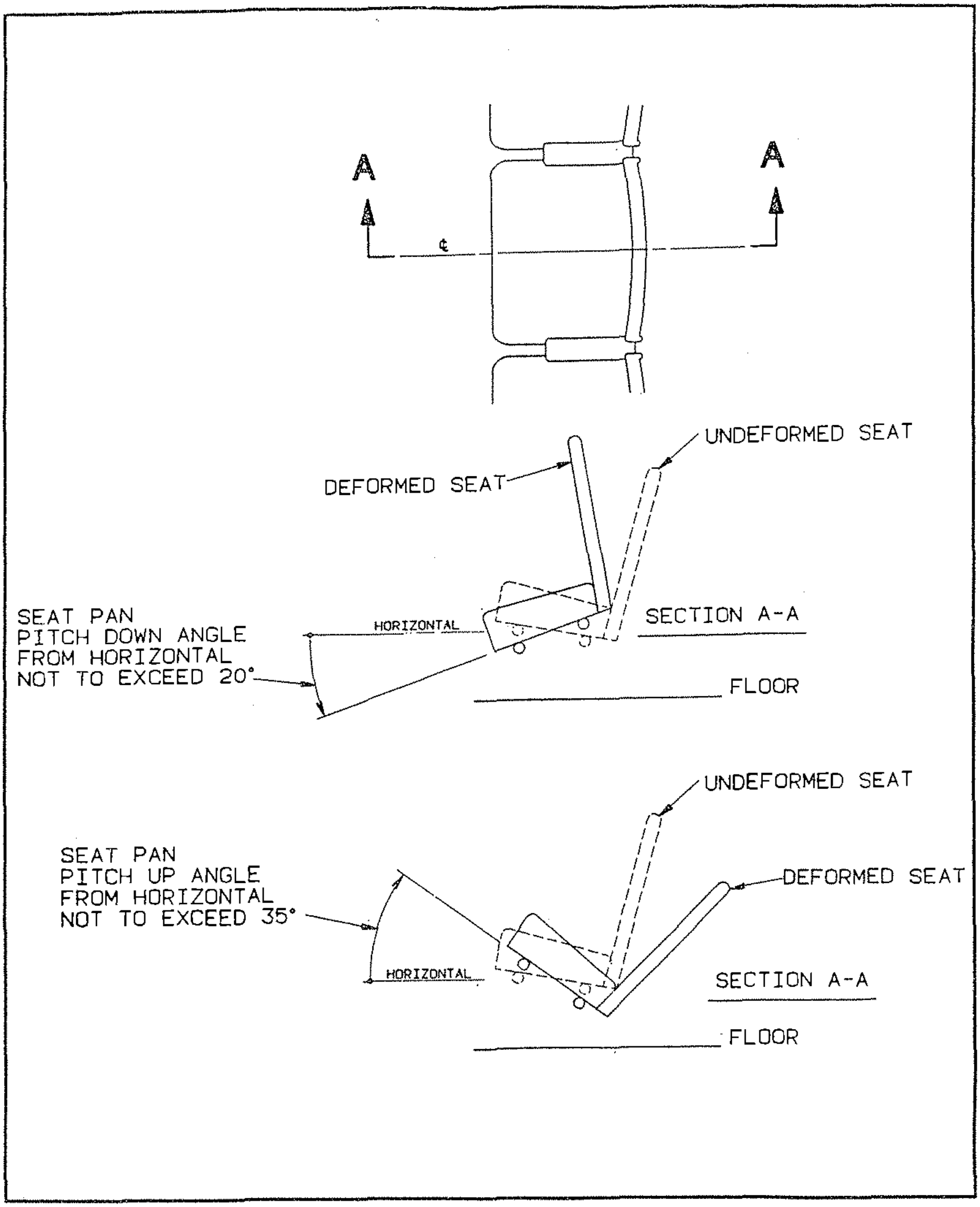


Figure 3. Maximum Post-test Seat Pan Rotation