U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: DYNAMIC TESTING OF PART 23 AIRPLANE SEAT/RESTRAINT SYSTEMS AND OCCUPANT PROTECTION

Date: 6/22/89
Initiated by: ACE-100

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Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance regarding acceptable, but not the only, means of compliance with Part 23 of the Federal Aviation Regulations (FAR) applicable to dynamic testing of airplane seats. This material is neither mandatory nor regulatory in nature.

2. RELATED REGULATIONS. Sections 23.562, 23.785, 23.787.

3. RELATED READING MATERIAL.

a. Code of Federal Regulations (CFR), 49 CFR 572, Chapter 5, Subpart B - Anthropomorphic Test Dummies (ATD).

b. Aircraft Crash Survival Design Guide, (Volumes I-V), Simula, Inc., USARTL-TR-79-22(A-E), Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, 23604, 1980.

c. Coltman, Joseph W., Design and Test Criteria for Increased Energy-Absorbing Seat Effectiveness, FAA-AM-83-3, Federal Aviation Administration, March 1983.

d. Injury Criteria for Human Exposure to Impact, Advisory Circular 21-22, Federal Aviation Administration, June 20, 1985.

e. "Motor Vehicle Instrument Panel Laboratory Impact Test Procedure - Head Area - SAE J921b," SAE Recommended Practice, 1979 SAE Handbook, Vol. 2, pp. 34.133-34.134, Society of Automotive Engineers, Inc., 1979.

f. "Instrumentation for Impact Tests - SAE J211b," SAE Recommended Practice, 1979 SAE Handbook, Volume 2, pp. 34.117-34.118, Society of Automotive Engineers, Inc., 1979.

4. BACKGROUND.

a. Dynamic Test Methods. This AC focuses on the use of dynamic test methods for evaluating the performance of airplane seats, restraint systems, and related interior systems for demonstrating structural strength and the ability of those systems to protect an occupant from serious injuries sustained in a crash environment. These methods differ from static test

methods, which are limited to demonstrating only the structural strength of the seat or restraint system. This AC describes the dynamic test procedures and provides some insight into the logic behind these procedures. It also defines the test facility and equipment characteristics necessary for conducting these tests.

b. Standardized Test Methods. Dynamic tests are often accomplished at facilities other than those of the designer or fabricator of the test article. To obtain consistent test results, it is necessary to specify the critical test procedures in detail, and then carefully follow these procedures when conducting the tests. This AC defines certain critical procedures for accomplishing the tests of the restraint systems and assessing the data obtained from the tests. Many of these procedures 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. Relation of Dynamic Tests to Design Standards. This AC describes test procedures which provide a means of showing compliance with the FAR and are useful in assessing the performance of an airplane seat, restraint system, and interior system. It is impractical to conduct sufficient tests for assessing the performance of the system throughout its entire range of desirable performance. The seat, restraint, and related interior system should be designed for the range of occupants and environments for which it is expected to perform, not just for the dynamic test conditions described in this AC.

5. DEFINITIONS.

a. Dynamics Terms.

(1) Dynamic Overshoot. The amplification of loads or accelerations transmitted to occupants or structure during impact. This amplification is the result of the dynamic response of the system. When dealing with impact injury prevention, the occupant should be considered an element of the system.

(2) Rebound. Rapid return toward the original position upon release, or rapid reduction of the deforming load, usually associated with elastic deformation.

(3) Dynamic Response. The motion or other output of a device or system resulting from a time varying excitation produced under specified conditions.

b. Seat Design Terms.

(1) Energy-Absorber (Load Limiter). A device or structure used to limit the transmitted load to a preselected level. These devices, also referred to as energy absorbers or energy attenuators, control load levels by applying a resistive force over a deformation distance without significant elastic rebound.

(2) Bottoming. The exhaustion of available stroking distance or deformation accompanied by an increase in force, e.g., when a seat stroking in the vertical direction uses all the available stroking distance or deformation and impacts the floor, or when a soft seat cushion compresses against a hard support structure.

(3) Seating/Restraint System. A system that includes the seat, the cushions, the safety belt, the shoulder harness (upper torso restraint), and the attachment devices.

c. Occupant-related Terms.

(1) Human Body Coordinate System. To help define vectors of displacement, velocity, acceleration, or force relative to the occupant, the coordinate system shown in figure 1 is often used. Although this coordinate system is not universally accepted, it is used in much of the literature discussing human tolerance.

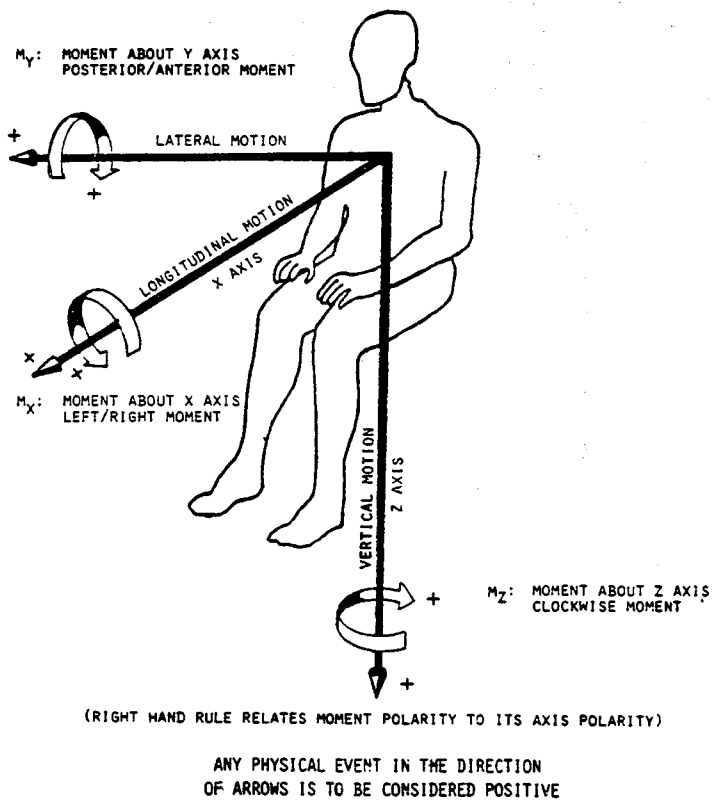


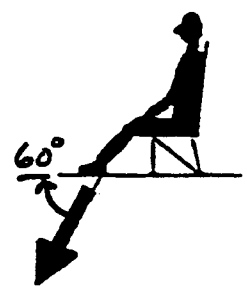
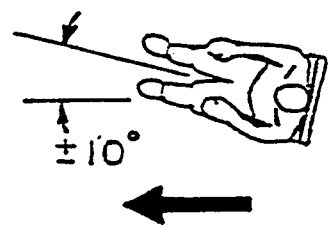
Figure 1 - TYPICAL HUMAN BODY COORDINATE SYSTEM

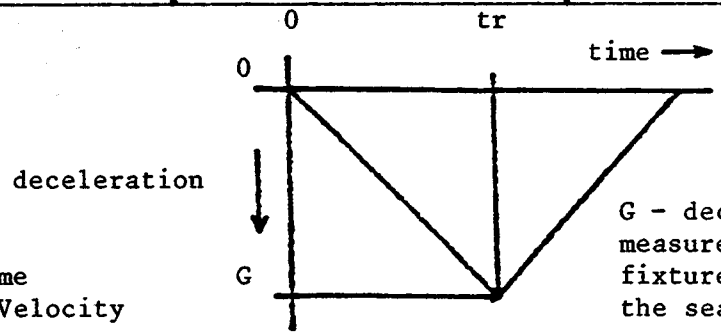
(2) Submarining. Rotation of the pelvis under and about the safety belt, often accompanied by safety belt slippage up and over the iliac crests. This may result in undesirable occupant forward motion relative to the seat and in internal or spinal column injuries.

6. DYNAMIC TEST METHODS AND FACILITIES.

a. General. A minimum of two dynamic tests are required to assess the performance of an airplane seat, restraint system, and related interior system. The seat, the restraint, and the nearby interior should all function together as a system to provide protection to the occupant during a crash. One of the tests (Test 1) determines the protection provided when the crash environment is such that a predominant impact load component is directed along the spinal column of

the occupant, in combination with a forward component. Protection against spinal injury is important under these conditions, and it may be necessary to provide energy absorbing (load limiting) capability in the seat to be able to satisfy the human injury criteria specified in § 23.562(c)(7). The other test (Test 2) evaluates the protection provided in crashes where the predominant impact is in the longitudinal direction, in combination with a lateral component. Evaluation of head injury protection is important in this test if the head is allowed to strike some interior portion of the airplane, or a seat and restraint seat forward of the occupant. This test is also a significant test of the structural strength of the system. Both tests provide the opportunity for assessing submarining (where the seat belt slips above the pelvis) and roll out of the torso restraint system (of particular concern with some single diagonal torso restraint belts). Since external crash forces frequently cause structural deformations, simulated floor or sidewall deformation is used to show that the seat can accommodate the relative deformation between the seat and the floor and still function without imposing excessive loads on the seat, the floor attachment fittings or floor tracks. The specific test conditions are shown in figure 2.

Illustration shows a forward facing seat. Dummy inertial load shown by arrow:	Test 1 (§ 23.562(b)(1))		Test 2 (§ 23.562(b)(2))	
				
	Crew	Passenger	Crew	Passenger
Min. Vi, fps	31	31	42	42
Max. tr, sec.	0.05	0.06	0.05	0.06
Min. G	19	15	26	21
Deform floor:				
degrees roll	none	none	10	10
degrees pitch	required	required	10	10



tr = rise time
Vi = Impact Velocity

G - deceleration measured on test fixture or sled near the seat position.

Figure 2 - SEAT/RESTRAINT SYSTEM DYNAMIC TESTS
NORMAL, UTILITY, OR ACROBATIC CATEGORY AIRPLANES

b. Test Facilities. There are a number of test facilities which can be used to accomplish dynamic testing. These can be grouped into categories based on the method they use 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 which have advantages or disadvantages with regard to the dynamic tests discussed in this AC. One concern is the rapid sequence of acceleration and deceleration which may 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.

(1) Deceleration Sled Facilities. In an airplane crash, the impact takes place as a deceleration, so loads are applied more naturally in test facilities which create the test impact pulse as a deceleration. Since it is simpler to design test facilities to extract energy rather 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 procedure discussed in this AC. The facility performed satisfactorily in those tests. 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 anthropomorphic test dummies 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 test dummy, 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 anthropomorphic test dummies used in the test and the test articles are 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 dummies in Test 1 if the seat is a rearward facing or side facing seat. In these cases, the test dummies tend to fall out of the seat due to the force of gravity and can be restrained in place using break-away tape, cords, or strings. Since each installation may present its own problems, there is no simple, generally applicable, guidance which can be given for doing this. However, the sled facility should conduct some preliminary impact tests to ensure that the conditions shown in figure 2 can be met and the results included in the test reports described in paragraph 8. Attention should be given to positioning the test dummy against the seat back and to proper positioning of the test dummy's arms and legs. It may be necessary to build special supports for the break-away restraint so that they do 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 test dummy or the test articles.

(2) 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 test dummies are installed facing in the opposite direction from the velocity vector, opposite from the direction used on a deceleration facility, to compensate for the change in direction of the impact. There should be no problem with the test dummies or the test items being out of position, 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 should 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 maximum response of the system usually follows (in time) the impact test pulse, any sled deceleration which takes place during that response may 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 effect 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 may 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 should 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 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.

(3) 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 accelerator facilities and decelerator 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.

(4) Drop Towers. Vertical test facilities can include both drop towers (decelerators) and vertical accelerators. Vertical accelerators which can produce the long duration/displacement impact pulse discussed in this AC 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 should be installed at an angle such that the anthropomorphic test dummies tend to fall from the seat due to gravity. The restraint system being tested cannot hold the test dummy against the seat unless tightened excessively and does not usually locate the head, arms, or legs in their proper position relative to the seat. Design and fabrication of an auxiliary "break-away" dummy positioning restraint system just for this test is a complex task. The auxiliary restraint should not only position the test dummy against the seat (including maintaining proper seat cushion deflection) during the pre-release condition of one g, it should also maintain the test dummy in that proper position during the free fall to impact velocity when the system is exposed to zero g, and then it should release the test dummy in a manner which does not interfere with the test dummy's response to impact. The usual sequence of one g/ zero g/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 depends 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, earth's gravity opposes the final rebound of the test dummies into the seat back, so that an adequate test of seat back strength and support for the dummy cannot be obtained. The problems in Test 1, or with rear facing seats in Test 2, are not as difficult because the seat supports the dummy occupant prior to the free fall. However, the zero g condition which exists prior to impact allows the test dummy 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.

c. Test Fixtures. 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 holds the attachment fittings or floor tracks for the seat, providing the floor and sidewall deformation needed for the test; it provides anchorage points, if necessary, for the restraint system; it provides a floor or footrest for the test dummy; and it positions instrument panels, bulkheads, or a second row of seats, if required, for successful testing and otherwise simulates the airplane for the test. The test fixture is usually fabricated of heavy structural steel and need not simulate lightweight airplane design or construction. The details of the fixture depend upon the requirements of the test articles, but some capability for providing floor and sidewall deformation is needed.

(1) Purpose of Floor Deformation. The purpose of providing floor deformation for the tests is to demonstrate that the seat/restraint system remains attached to the airframe and performs properly even though the airplane and seat are severely deformed by the forces associated with the crash. Typical design deficiencies addressed by this test condition include, but are not limited to, the following:

(i) Concentrated loads may be imposed on floor tracks by seat attachment fittings which fit tightly or are clamped to the track and which do not have some form of lateral "roll" relief incorporated in their design. These fittings can concentrate the forces on one lip of the floor track and break the track or the fitting.

(ii) Similarly, loads can be concentrated on one edge of a floor track or fitting having an "I" or "bulb head" cross section and prematurely break the flange or the fitting.

(iii) Detents or pins which lock the seat to the floor track can become disengaged or the mechanism which is used to disengage the detents or pins can be actuated and release the seat as the seat deforms.

(iv) Seat assemblies which provide an energy absorbing system between a seat "bucket" and a seat frame may not perform properly for a pre-loaded seat frame attached to the floor or sidewall. Deformation of the seat frame may cause the energy absorbers to receive unanticipated loads or cause excessive friction in the guides between the seat bucket and seat frame to lock the energy absorber in place.

(v) Restraint system anchorages attached to the airframe may experience excessive displacement relative to the seat if the seat deforms during the test, and such displacement may inhibit proper performance of the seat/restraint system.

(2) Method of Floor Deformation. For the typical seat with four seat legs mounted in the airplane on two parallel tracks, the floor deformation test fixture may consist of two parallel beams, a "pitch beam" which pivots about a lateral (y) axis, and a "roll beam" which pivots about a longitudinal (x) axis. The beams can be made of any fairly rigid structural form, box, I-beam, channel, or other appropriate cross section. The pitch beam should be capable of rotating in the x-z plane up to + or - 10 degrees relative to the longitudinal (x) axis. The roll beam should be capable of + or - 10 degrees roll about its own axis. A means should 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 which does not alter the above-floor strength of the track or fitting. The track or other attachment fittings should 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 which are not part of the floor track or fitting need not be included in the installation. The seat should then be installed on the parallel beams so that the seat rear leg attachment point is near the pitch beam axis of rotation and the seat positioning pins or locks fastened in the same manner as would be used in the airplane, including the adjustment of "anti-rattle" mechanisms, if provided. The remainder of the test preparations would then be completed (dummy installation and positioning, instrumentation installation, adjustment and calibration, camera checks, etc.). The "floor deformation" would be induced as the final action before the test is accomplished. The roll beam would be rotated 10 degrees and locked in place, and then the pitch beam would be rotated 10 degrees up and locked in place. It is also acceptable to rotate one track up 5 degrees and one track down for a total of 10 degrees of pitch deformation. The direction of rotation would be selected to produce the most

severe structural loading condition on the seat and floor track or fitting. If the seat is fairly flexible, it may be possible to rotate the beams by manual effort, perhaps using removable pry bars to gain mechanical advantage. However, rotation of the beams used for testing a stiff seat frame is likely to require greater effort than can be accomplished manually, and the use of removable hydraulic jacks or other devices may be necessary. If this condition is expected, provision should be made for appropriate loading points when designing the fixture. This condition is most likely to be encountered when rotating the pitch beam. Appropriate safety provisions should be made to avoid injury to operating personnel during the deformation process. If a facility anticipates testing a wide range of seat configurations, careful design of the test fixture so that it can be adjusted to fit the range of seat leg spacing enables one fixture assembly to be used for many tests.

(3) Alternative Configurations . The preceding discussion is for a floor-track system and describes the fixture and floor deformation procedure which would be used for a typical seat utilizing four seat legs and four attachments to the airplane floor. These test procedures are not intended to be restricted only to those seat configurations, but should 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, provide guidance for the more common alternatives:

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

(ii) Seats which mount solely to a bulkhead need not be subject to the floor or sidewall deformation shown in figure 2 prior to the test. The test fixture may provide either a rigid bulkhead, or hold an actual bulkhead panel. If a rigid bulkhead installation is used, the test fixture should transfer loads to the seat/restraint system through components equivalent to the attachment fitting and surrounding bulkhead panel which exist in the actual installation.

(iii) Seats which are attached to both the floor and a bulkhead would be tested on a fixture which 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 conditions, or in a manner which duplicates or represents the intended installation. Either a rigid bulkhead simulation or an actual bulkhead panel may be used. If a rigid bulkhead simulation is used, the test fixture should transfer loads to the seat/restraint system through components equivalent to the attachment fitting which would exist in the actual installation. The seats would be attached to the bulkhead and the floor in a manner representative of the airplane installation, and the floor would then be deformed as described in paragraph 4c(2).

(iv) Seats which are mounted between sidewalls or to the sidewall and floor of an airplane should be tested in a manner which simulates airplane fuselage cross-section deformation (e.g. from circular to flattened circular or ellipsoidal shape) during a crash. The test set-up including the brackets should

simulate the seat attachment at the same level above the fixture "floor" that would represent the installation above the airplane floor. A sidewall bracket should be located on the roll beam. Then, as the beams are rotated to produce the most conservative loading condition (sidewall rotates outward by 10 degrees), the combined angular and translational deformation simulates the deformation which may take place in a crash. The floor attachments should be pitched 10 degreees with respect to the undeformed floor position.

(v) Seats which are cantilevered from one sidewall without connection to other structure would not be subject to floor warpage or the standard floor deformation prescribed in § 23.562(b)(3). If sidewall deformation is likely, consideration should be given to moving the entire sidewall attachment plane, or the attachment points, in a manner to represent the sidewall deformation if this would generate a condition critical for seat attachment or seat/restraint system performance. Either a rigid sidewall simulation or an actual sidewall panel may be used. If a rigid sidewall simulation is used, the test fixture should transfer loads to the seat/restraint system through components equivalent to the attachment fitting and surrounding sidewall which would exist in the actual installation.

(vi) Multiple occupant seat assemblies may have more than two pairs of legs in some installations. These assemblies are usually of fairly constant cross section, so that adequate deformation can be generated if only the outer leg assemblies are subject to floor deformation. The inner leg pairs would be maintained in their normal, undeformed position for the dynamic tests.

(4) Other Fixture Applications. Test fixtures should provide a flat footrest for dummies used in tests of passenger seats and seats for crew members who are not provided with special footrests or foot operated airplane controls. The surface of the footrest should be covered with carpet (or other appropriate material) and be at a position representative of the undeformed floor in the airplane installation. Test fixtures used for evaluating crew seats which are normally associated with special footrests or foot operated controls should simulate the position of those components. 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 should represent the configuration of the airplane installation and be of adequate structural strength.

d. Instrumentation. Electronic and photographic instrumentation systems are used for the tests discussed in this AC. Electronic instrumentation is used to measure accelerations and forces required for verifying the test environment and for measuring most of the pass/fail criteria. Photographic instrumentation is used for documenting the overall results of the tests, confirming that the lap safety belt remained on the test dummy's pelvis and that the upper torso restraint straps remained on the test dummy's shoulder, and documenting that the seats did not deform as a result of the test in a manner which would impede rapid evacuation of the airplane by the occupants.

(1) Electronic Instrumentation. Electronic instrumentation should be accomplished in accordance with the Society of Automotive Engineers Recommended Practice SAE J211, Instrumentation for Impact Tests. Equivalent instrumentation is

also acceptable. In this SAE J211 practice, the data channel includes all of the instrumentation components from the transducer through the final data measurement, including connecting cables and any analytical procedures which alter the magnitude of frequency content of the data. Each dynamic data channel is assigned a nominal channel "class" which is equivalent to the high frequency limit for that channel, based on a constant output/input ratio vs. 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 pre-sample analog filters. Since most facilities set all pre-sample 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 should comply with the following channel class characteristics:

(i) 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 should be measured in accordance with Channel Class 180 requirements.

(ii) Belt restraint system loads should be measured in accordance with the requirements of Channel Class 60.

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

(iv) Anthropomorphic test dummy pelvic/lumbar spinal column force should be measured in accordance with the requirements of Channel Class 60.

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

(vi) Digital conversion of analog data should provide sample resolution of not less than one percent of full-scale input.

(2) Photographic Instrumentation. Photographic instrumentation should be used to document the response of the anthropomorphic test dummies and the test specimens subjected to the dynamic test environment. Both high speed motion picture and still systems should be used.

(i) High speed motion picture cameras which provide data used to calculate displacement or velocity should operate at a nominal speed of 1000 pictures per second. Photoinstrumentation methods should not be used for measurement of acceleration. The locations of the cameras and of targets or targeted measuring points within the field of view should be measured and documented. Targets should be at least 1/100 of the field width covered by the camera and should be of contrasting colors or should contrast with their background. The center of the target should be easily discernible.

Rectilinearity of the image should be documented. If the image is not rectilinear, appropriate correction factors should be used in the data analysis process. 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 should be documented for each test. Appropriate digital or serial timing should 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 should be provided. A rigorous, verified analytical procedure should be used for data analysis.

(ii) Cameras operating at a nominal rate of 200 pictures per second or greater can be used to document the response of anthropomorphic test dummies and test items if measurements are not required. For example, actions such as movement of the pelvic restraint system webbing (lap safety belt) off of the test dummy's pelvis or movement of upper torso restraint webbing off of the test dummy's shoulder can be observed by documentation cameras placed to obtain a "best view" of the anticipated event. These cameras should be provided with appropriate timing and a means of correlating the image with the time of electronic data.

(iii) Still image cameras can be used to document the pre-test installation and the post-test response of the anthropomorphic test dummies and the test items. At least four pictures should be obtained from different positions around the test items in pre-test and post-test conditions. For the post-test pictures, the upper torso of the test dummies may be rotated to their approximate upright seated position so that the condition of the restraint system may be better documented, but no other change to the post-test response of the test item or dummies should be made. The pictures should document that the seat remained attached at all points of attachment to the test fixture. Still pictures can also be used to document post-test yielding of the seat for the purpose of showing that it would allow the rapid evacuation of the airplane occupants. The test dummy occupants 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.

e. Anthropomorphic Test Dummies. The tests discussed in this AC were developed using the anthropomorphic test dummies specified by the United States Code of Federal Regulations, Title 49, Part 572 Anthropomorphic Test Dummies, Subpart B - 50th Percentile Male, and modified to allow the measurement of lumbar loads. These "Part 572B" dummies have been shown to be reliable test devices which are capable of providing reproducible results in repeated testing. However, since anthropomorphic test dummy development is a continuing process, provisions was made for using "equivalent" test dummies. Dummy types should not be mixed when completing the tests discussed in this AC.

(1) Modification for Measuring Pelvis/Lumbar Column Load. Most readily available anthropomorphic test dummies have been developed for use in automobile testing. As a result, considerable effort has been spent in perfecting their response and ability to evaluate injury protection in forward, rearward, and sideward impacts. These characteristics are also important in testing systems for use in civil airplanes, but criteria should be added to account for injuries caused by impacts which have a component in the vertical direction or by upper torso

restraint loading which produce a downward force component on the shoulders. For this purpose, a load (force) transducer is inserted into the test dummy's pelvis just below the lumbar column. This modification is shown in figure 3. The illustration shows a commercially available femur load cell, with end plates removed, which has been adapted to measure the compression load between the pelvis and the lumbar spine column of the test dummy. In order to maintain the correct seated height of the test dummy, the load cell is fixed in a rigid cup inserted into a hole bored in the top surface of the test dummy's pelvis, the top flange of which is bolted to the pelvis. If necessary, ballast should be added to the pelvis to maintain the specified weight of the assembly. 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 test dummy; and

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

(2) Other Anthropomorphic Test Dummy Modifications. Flailing of the anthropomorphic test dummy arms often causes the "clavicle" used in the Part 572B dummy to break. To reduce the frequency of this failure, the clavicle may be replaced by a component having the same shape but made of higher strength material. This may increase the dummy's weight slightly, but is acceptable for the tests discussed in this AC. Another useful modification is the use of "submarining indicators" on the dummy's pelvis. These electronic transducers are located on the anterior surface of the ilium of the dummy's pelvis without altering its contour and indicate the position of the lap safety belt as it applies loads to the pelvis. Thus, they can provide a direct record that the lap safety belt remains on the pelvis during the test, and eliminate the need for careful review of high-speed camera images to make that determination.

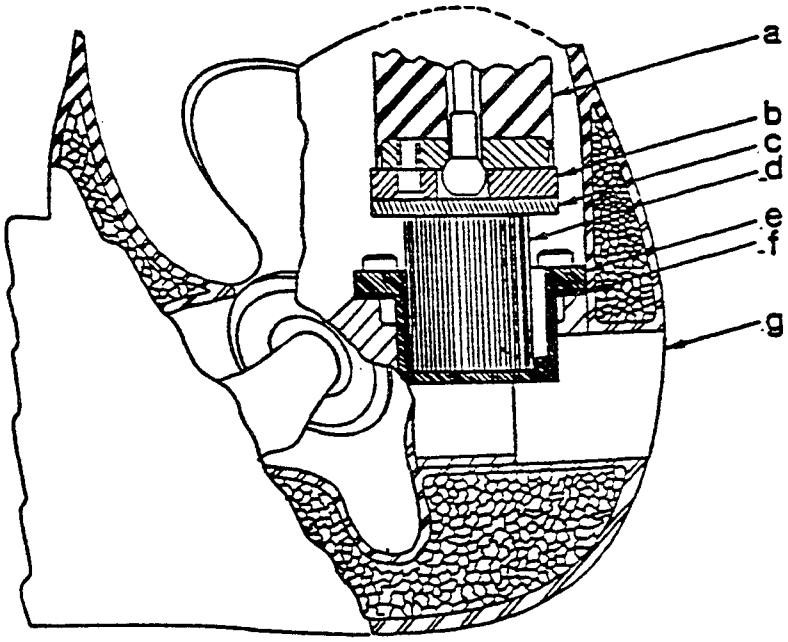
(3) Equivalent Anthropomorphic Test Dummies. The continuing development of anthropomorphic test dummies for dynamic testing of seating restraint/crash-injury-protection systems is guided by goals of improved biofidelity (human-like response to the impact environment) and reproducibility of test results. For the purpose of the tests discussed in this AC, these improved test dummies may be used as an equivalent to the Part 572B anthropomorphic test dummy if --

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

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

(iii) They have been evaluated by comparison with the Part 572B dummy; and

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



This illustration shows an acceptable installation of a femur load cell (d) at the base of the test dummy's 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 test dummy. A rigid adapted cup (e) is fabricated to hold the load cell and a hole is bored in the test dummy's pelvis to accept the cup. Clearance should be provided between the walls of the adapter cup and the load cell and for the wires leading from the cell. The bottom of the load cell is bolted to the adapted 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 which 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 dummy 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.

Figure 3 - INSTALLATION OF PELVIC-LUMBAR SPINE LOAD CELL IN PART 572B ANTHROPOMORPHIC TEST DUMMY

(4) Temperature and Humidity. Since extremes of temperature and humidity can change the performance of anthropomorphic test dummies, the tests discussed in this AC should be conducted at a temperature from 66 degrees F to 78 degrees F, and at a relative humidity from 10 percent to 70 percent. The test dummies should have been maintained under these conditions for at least four hours prior to the test.

f. Test Proposal. A test proposal should be prepared for the tests and include a selection of the test articles to be used in the tests, determination of the conservative conditions for the tests, and installation of the test articles, instrumentation and anthropomorphic test dummies on the test fixture. Additional items are also discussed in paragraph 8. Preparations which pertain to the normal operation of the test facility, such as safety provisions and the actual procedure for accomplishment of the tests, are particular to the test facility and are not discussed in this AC.

(1) Selection of Test Articles. Many seat designs compose a "family" of seats which 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 such a nature that their effect can be determined by rational analysis, then the analysis should determine the most highly stressed ("worst case") configuration. The most highly stressed configuration would normally be selected for the dynamic tests so that the other configurations may be accepted by comparison with that configuration. The HIC depend on secondary dummy impact and are more dependent on seat pitch than on seat structural stress for a given "family" of seats, so that the selection of the most highly stressed seat structure, the seat location with respect to the structure interior items, and the most critical seat pitch permits these factors to be evaluated in one test under conditions of Test 2. Critical pelvis/lumbar spinal column forces are usually found under the conditions of Test 1. Certain precautions should be used when employing this approach. For example:

(i) If different configurations of the same basic design incorporated load carrying elements, especially joints or fasteners, which differed in detail design, the performance of each detail design should be demonstrated by a dynamic test or rational analysis considering the dynamic characteristics of the design. Experience has shown that small differences in details of the design often cause problems in meeting the test performance criteria.

(ii) The most critical condition should be evaluated in the dynamic test whether it is the structural strength, retention of the occupant, or the occupant injury criteria. The test item should be representative of the final production item in all structural elements and should include seat cushions, armrests and armcaps, functioning position adjustment mechanism and correctly adjusted breakover (if present), food trays or any other service or accouterment required by the seat manufacturer or customer, and any other items of mass which are carried or positioned by the seat structure such as weights simulating

underseat luggage, fire extinguishers, survival equipment, etc. If these items of mass are placed in a position which limits the function of an energy absorbing design concept in the test item, they should be of representative shape and stiffness as well as weight. Alternatively, the seat should contain adequate design features to preclude underseat baggage from restricting the seat displacement during energy absorption. Except for seats with 2 inches or less of stroking, inherent design features should be sufficient to preclude underseat baggage or any items of mass placed under the seat from intruding into that limited stroking envelope.

(2) Occupant Seat Assemblies. The tests should be planned to achieve conservative conditions that demonstrate compliance with the criteria for each test as shown in figure 2.

(i) For multiple occupant seat assemblies, a rational structural analyis should be used to determine the number and seat location for the dummies, and the direction for seat yaw in Test 2 to provide the most critical seat structural stress. This may result in unequally loaded seat legs. The seat deformation procedure should be selected to increase the load on the highest loaded seat leg and to stress the floor track or fitting in the most severe manner.

(ii) If a seat has sitting height adjustment, it should be tested in a position which may be used by a 50th percentile male occupant in the airplane installation and in association with paragraph 6f(3)(v) below.

(iii) In some cases, it may not be possible to directly obtain or measure data for head impact during the basic test of the seat and restraint system. The design of the surrounding interior may not be known to the designer of the seat and restraint system, or the system may be used in several applications with different interior configurations. In such cases, it may be necessary to document the head strike path and the velocity along the path. This requires careful placement of photoinstrumentation cameras and location of targets on the test dummy representing the test dummy's head center of mass so that the necessary data can be obtained. These data can be used by the interior designer to demonstrate that head impact with the interior does not take place, or that any unavoidable head impacts occur within the limits of the HIC. If unavoidable head impact with the interior occurs, the interior should be subject to an impact test to ensure that the measured head impact data does not exceed the HIC specified in §23.562(c)(5)(i). This can be done by guiding the center of a rigid 6.5 inch diameter spherical head form weighing 15 pounds along the head strike path so that it contacts the interior at the velocity indicated by the measurements made in the seat/restraint system dynamic test. Accelerometers located at the center of the head form would provide the data necessary for the HIC computation. If the interior component that is impacted by the test dummy has significant inertial response to the impact environment, such as breakover seatbacks or instrument panels designed to move forward in a crash because of their own inertia, it may be necessary to evaluate those systems in a dynamic test program which includes the full dummy occupant/seat/restraint system. A suggested head impact test procedure is discussed in the Society of Automotive Engineers Recommended Practice SAE J921b, Motor Vehicle Instrument Panel Laboratory Impact Test Procedure - Head Area.

(3) Use of Anthropomorphic Test Dummies. Anthropomorphic test 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 test dummy should be accomplished to identify and correct any worn or damaged components, and appropriate dummy calibration tests (as described in the specification) should be accomplished if major components are replaced. Each test dummy should be clothed in form-fitting cotton stretch garments with short sleeves and mid-calf length pants and with shoes (size 11E) weighing about 2.5 pounds. The head and face of the test dummy can be dusted with chalk dust if it is desired to mark head contact areas on seats or other structure. The friction in limb joints should be set so that they barely restrain the weight of the limb when extended horizontally. The anthropomorphic test dummy should be placed in the seat in a uniform manner so as to obtain reproducible test results. The test dummy should be placed in a seat in accordance with the manufacturer's instructions. Where these instructions are not provided, the following guidance should be used:

(i) The test dummy should be placed in the center of the seat, in as nearly a symmetrical position as possible.

(ii) The test dummy's back should be against the seat back without clearance. This condition can be achieved if the test dummy's legs are lifted as it is lowered into the seat. Then, the test dummy 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 test dummy, the dummy should be "rocked" slightly to settle it in the seat.

(iii) The test dummy's knees should be separated about four inches.

(iv) The test dummy's hands should be placed on the top of its upper legs, just behind the knees. If tests on crew seats are conducted in a mockup which has airplane controls, the test dummy's hands should be lightly tied to the controls. If only the seat/restraint system is tested, the test dummy's hands should be tied together with a slack cord which provides about 24 inches of separation before the cord becomes tight. This prevents excessive arm flail during the test dummy's rebound phase.

(v) All seat adjustments and cockpit controls should be in the design position intended for the 50th percentile male occupant. In addition, the various seat orientation or positions for takeoff and landing should be tested. Any limitation information should be included in the seat installation instructions to preclude uses that have not been substantiated. For example, if the seat is only tested for aft-facing installations, the installation data should provide this limitation.

(vi) 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.

(4) 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 from causing errors in data. Lead-wires should be routed to avoid entanglement with the test dummy or test item, and sufficient slack should be provided to allow motion of the test dummy or test item without breaking the lead wires or disconnecting the transducer. Calibration procedures should consider the effect of long transducer lead-wires. Head accelerometers should be installed in the test dummy in accordance with the dummy specification and the instructions of the transducer manufacturer. The load cell between the pelvis and the lumbar spinal column should be installed in accordance with the approach shown in figure 3 of this AC, or in a manner which would provide equivalent data.

(i) If an upper torso restraint is used, the tension load should be measured in a segment of webbing between the test dummy's shoulders and the first contact of the webbing with hard structure (the anchorage point or a webbing guide). Restraint webbing should not be cut to insert a load cell in series with the webbing, since that would change the characteristics of the restraint system. Load cells are commercially available which can be placed over the webbing without cutting. They should be placed on free webbing and should not contact hard structure, seat upholstery, or the dummy 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 which breaks away during the test.

(ii) Loads in restraint systems which 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 which can withstand significant cross axis loading or bending without causing errors in the test data, or to use careful (often complex) installations which protect the load cells from cross axis loading or bending. 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 is usually obtained from an additional dynamic test that replicates the load cell installation but does not include the test item.

(5) Restraint System Adjustment. The restraint system should not be tighter than is reasonably expected in normal use and any emergency locking devices (inertia reel) if installed, should not be locked prior to the test. Inertia reels may not be used for some seats. Automatic locking retractors should be allowed to perform the webbing retraction and automatic locking function without assistance.

Care should be taken that emergency locking retractors which are sensitive to acceleration do not lock prior to the impact test because of pre-impact acceleration applied by the test facility which is not present in an airplane crash. If "comfort zone" retractors are used, they should be adjusted in accordance with instructions given to the user of the system. If manual adjustment of the restraint system is required, it should be sufficient to remove slack in the webbing; but it should not be adjusted so that it is unduly tight. Since the force required to adjust the length of the webbing can be as high as 11 pounds, a preload of 12-15 pounds is commonly recommended. This load is too small to be accurately measured by transducers selected to measure the high loads encountered in the impact test, so it should be measured manually as the restraint is being adjusted. Special gauges are commercially available to assist in this measurement. The preload should be checked and adjusted, if necessary, just prior to the floor deformation phase of the test.

7. 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 vs. 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; but the maximum values of the data may still be acceptable. The HIC does not represent simply a maximum data value but represents an integration of data over a varying time base not to exceed 50 microseconds elapse time. The head acceleration measurements used for that computation should not be accepted if errors or loss of data are apparent in the data from any time from the beginning of the test until test completion.

b. Impact Pulse Shape. Data for evaluating the impact pulse shape are obtained from an accelerometer which measures the accelerations on the test fixture or sled at the seat location or equivalent location in the direction parallel to the line of inertial response shown in figure 2 of this AC. The impact pulses intended for the tests discussed in this AC have a symmetrical (isosceles) triangular shape. A graphic technique may be used to evaluate test impact pulse shapes which are not precise isosceles triangles. The graphic technique, which is also similarly described in the Simula, Inc., Aircraft Crash Survival Design Guide, Volume 1, uses the following steps as shown in figure 4:

(1) Locate the calibration baseline (zero g level).

(2) Determine the peak deceleration (G_p) magnitude.

(3) Draw a reference line parallel to the calibration baseline at a magnitude equal to 10 percent of the peak deceleration (G_p). The intersection of this line with the deceleration-time trace defines point 1.

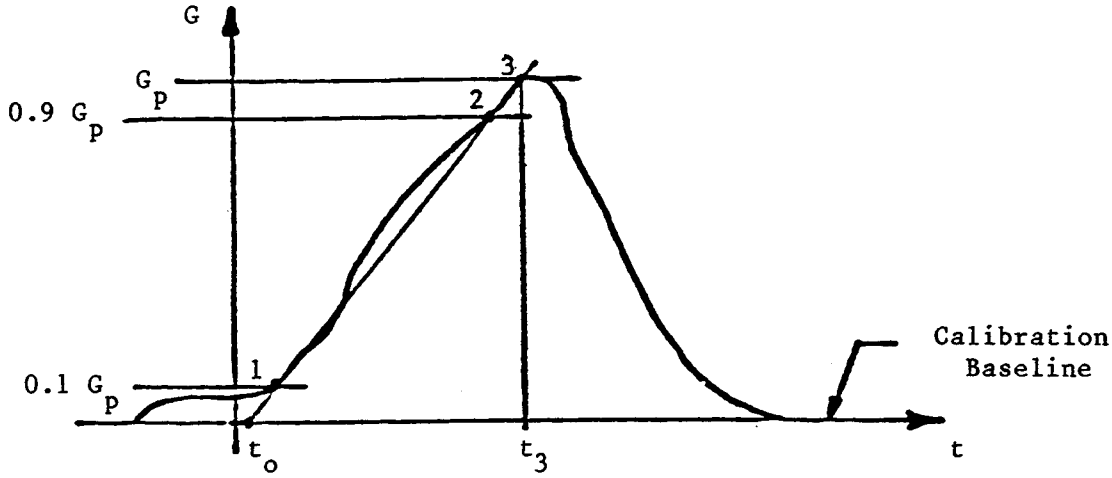


Figure 4 - PULSE SHAPE ESTIMATION

(4) Draw a second reference line parallel to the calibration baseline at a magnitude equal to 90 percent of the peak deceleration (G_p). The intersection of this line with the deceleration-time trace defines point 2.

(5) Draw a line passing through points 1 and 2.

(6) Draw a line parallel to the calibration baseline, through the point of peak deceleration (G_p). The intersection of this line with the line through points 1 and 2 defines point 3. Point 3 is used to establish the time to peak deceleration (t_3).

(7) The intersection of the line through points 1 and 3 with the calibration baseline is defined as time t_o. The requirements for the time increment (t_3-t_o) and the acceptable levels of peak deceleration (G_p) for each test are defined in paragraph 23.562(b).

(i) For each test, the area under the test data plot curve within the rise time to peak G, G_p, of the test impact pulse should represent at least one half of the impact velocity given in figure 2.

(8) The peak compressive lumbar load and upper torso harness load measured on the anthropomorphic test dummy and the peak loads measured on the upper torso restraint during the dynamic tests may be reduced by the factor (G_r/G_p) provided:

(i) G_r is the minimum peak deceleration of the sled required in either § 23.562(b)(1) or (2) as appropriate;

(ii) G_p is the measured peak test deceleration of the sled and should be at least equal to or greater than G_r.

(iii) (t_3-t_o) is less than or equal to the maximum rise time allowed by § 23.562(b)(1) or (2) as appropriate;

(iv) The test velocity is equal to or greater than that specified in § 23.562(b)(1) or (2) as appropriate; and

(v) The tests are conservative.

c. Head Injury Criterion (HIC). Data for determining the HIC need to be collected during the tests discussed in this AC only if the test dummy's head is exposed to secondary impact during the test. The HIC is calculated according to the following equation:

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

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

Most facilities can make this computation if requested. This HIC is a method for defining an acceptable limit, i.e., the maximum value of the HIC should not exceed 1000 with a time base not to exceed 50 microseconds, for head impact against broad interior surfaces in a crash. It does not consider injuries which can occur from contact with surfaces having small contact areas or sharp edges, especially if those surfaces are relatively rigid. These injuries can occur at low impact velocities, and are often described as "cosmetic" injuries; however, they can involve irreversible nerve damage and permanent disfigurement. While there is no generally accepted test procedure which can provide quantitative assessment of these injuries, a judgmental evaluation of soft tissue injuries can be made by assessing tears or cuts in a synthetic skin placed over the test dummy's head or a head form during the test. Synthetic skins are discussed in the Society of Automotive Engineers Information Report SAE J202, Synthetic Skins for Automotive Testing, 1979 SAE Handbook, Volume 2, pages 34.108-34.109. The HIC is calculated by computer based data analysis systems. The discussion which follows outlines the basic method for computing the HIC, but manual attempts to use this method with real data are likely to be tedious. The HIC is based on data obtained from three mutually perpendicular acccelerometers installed in the head of the anthropomorphic test dummy in accordance with the dummy specification. Data from these accelerometers are obtained using a data system conforming to Channel Class 1000 as described in Society of Automotive Engineers Recommended Practice SAE J211. For the tests discussed in this AC, only the data taken during a secondary head impact with the airplane interior should be used to calculate a HIC value. Head impact is often indicated in the data by a rapid change in the magnitude of the acceleration. Alternately, film of the test may show head impact which can be correlated with the acceleration data by using the time base common

to both electronic and photographic instrumentation, or simply contact switches on the impacted surface can be used to define the initial contact time. The magnitude of the resultant vector acceleration obtained from the three accelerometers is plotted against 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). This procedure is then repeated, increasing t_1 by 0.001 seconds for each repetition. The maximum value of the set of computations which is obtained from this procedure is the HIC. The procedure may be simplified by noting that the maximum value only occurs 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.

d. Impact Velocity. Impact velocity can be obtained by measurement of a time interval and a corresponding sled displacement which occurs just before the test impact and then dividing the distance by the time interval. When making such a computation, the possible errors of the time and displacement measurements should be used to calculate a possible velocity measurement error, and the test impact velocity should exceed the velocity shown in figure 2 by at least the velocity measurement error. If the sled is changing acceleration during the immediate pre-impact interval, or if the facility produces significant rebound of the sled, the effective impact velocity can be determined by integrating the plot of sled acceleration vs. time. If this method is used, the sled acceleration should be measured in accordance with Channel Class 100 requirements.

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 should be combined to provide the resultant vector magnitude. If necessary, corrections should be made for the internal mass of the transducer and the fixture weight it supports. This correction is usually 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 z axis compressive load between the pelvis and the lumbar column of the anthropomorphic test dummy can be obtained directly from a plot or listing of the output of the load transducer at that location. Since most load cells indicate tension as well as compression, care should be taken that the polarity of the data has been correctly identified.

g. Position of Upper Torso Restraint Straps. Position of the upper torso restraint webbing straps on the anthropomorphic test dummy's shoulders can be verified by observation of photometric or documentary camera coverage. The webbing should remain on the sloping portion of the test dummy's shoulder until the test dummy rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. The webbing straps should not bear on the neck or side of the head and should not slip to the upper rounded portion of the upper arm during that time period.

h. Position of Lap Safety Belt. Position of the lap safety belt on the occupant's pelvis can be verified by observation of photometric or documentary camera coverage. The lap safety belt should remain on the anthropomorphic test dummy's pelvis, bearing on or below each prominence representing the anterior superior iliac spines, until the test dummy rebounds after the test impact and the lap safety belt becomes slack. If the lap safety belt does not become slack throughout the test, the belt should maintain the proper position throughout the test. Movement of the lap safety belt above the prominence is usually indicated by an abrupt displacement of the belt into the test dummy'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 test dummy's pelvis. This movement of the belt is sometimes indicated in measurements of lap safety belt load (if such measurements 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. Retention of the lap safety belt can also be verified by "submarining indicators" located on the test dummy's pelvis without changing its essential geometry. They indicate the position of the lap safety belt by producing an electrical signal when they are under load from the belt.

i. Seat Attachment. Documentation that the seat and restraint system has remained attached at all points of attachment should be provided by still photographs which show the intact system components in the load path between the attachment points and the occupant.

j. Seat Deformation. Airplane occupant seats which are evaluated in the tests discussed in this AC can 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. The intent of this paragraph is to obtain information for the evaluation of a seat or seats in the airplane and to ensure the emergency egress standard is maintained with deformed seats as the result of the dynamic tests. If this deformation is excessive, it may impede the airplane emergency evacuation process. Each seat design may differ in this regard and should be evaluated according to its unique deformation characteristics. These deformations from the tests should be recorded and included in the test report.

8. TEST REPORT AND DOCUMENTATION.

a. General. A test plan or proposal, as part of the test report, should be prepared to specify the seat/restraint system specimen, test facility information, test descriptions, and analytical methods to be used. The tests discussed in this AC should be documented in a test report which describes the test procedures and results. In addition to the specific contents described in paragraphs 8b and 8c, the test report 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 of this AC, or a detailed description of the actual calibration procedure used and technical analysis showing equivalence to the recommendations of this AC (reference paragraph 6d(1)).

(vi) Manufacturer, governing specification, serial number, and test weight of anthropomorphic test dummies used in the tests, and a description of any modifications or repairs performed on the test dummies which may cause them to deviate from the specification.

(vii) A description of the photographic-instrumentation system used in the tests (reference paragraph 6d(2)).

(2) Seat/Restraint System Data.

(i) 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.

(ii) For systems which are not symmetrical, an analysis supporting the selection of conservative test conditions used in the tests. The test proposal submitted for approval is the proper means to document and verify the conservative test conditions. In addition, the test results refer to the test proposal if separate from the results report.

b. Test Description. The description of the test and how the tests should be conducted should be documented in sufficient detail in the test proposal or report so that the tests can be reproduced simply by following the guidance given in the test proposal or report. The procedures outlined in this AC can be referenced in the test plan or 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 which are not included in the drawings of the test items should be provided. This can include footrests, restraint system webbing guidance and restraint anchorages, "interior surface" simulations, bulkhead or sidewall attachments for seats or restraints, etc. Also, examples of the items that will be simulated or duplicated in the test should be included in the test report.

(2) Conservative loading and the required deformations for the test articles, should be documented and included in the test report.

(3) 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 metric interpretation of photodocumentation, and transducers and data channel characteristics for lap belt 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 may include use of special "break away" restraints or support for the test dummies, test items or transducers, operational conditions or activities such as delayed or aborted test procedures, and failures of test fixtures, instrumentation system components or anthropomorphic test dummies.

c. Test Report. The documentation should include the test proposal and procedures, all test results, analyses, and conclusions. The data should include charts, listings, and/or tabulated results, and copies of any photoinstrumentation used to support the results. In addition, as a minimum, the following should be included in the test result section of the test report.

(1) Impact pulse shape (reference paragraph 7b).

(2) The HIC results for all tests where the test dummies are exposed to secondary head impact with interior components (reference paragraph 7c) or head strike path and velocity data where secondary head impact is likely but is not evaluated by the tests (reference paragraph 7c).

(3) Impact velocity (reference paragraphs 7b(7)(i) and 7d).

(4) Upper torso restraint system load, if applicable (reference paragraph 7e).

(5) Compressive load between the pelvis and the lumbar column (reference paragraph 7f).

(6) Retention of upper torso restraint straps, if applicable (reference paragraph 7g).

(7) Retention of lap safety belt (reference paragraph 7h).

(8) Seat attachment (reference paragraph 7i).

(9) Seat deformation (reference paragraph 7j).

9. COMPUTER MODELS. Several computer-based analytical models have been developed to represent the seat/restraint/occupant system in a crash. Some of these models include a seat-occupant model for Part 23 airplanes and also a representation of the vehicle interior or the complete airplane 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 the seat/restraint/interior system. 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 the seat/restraint/interior systems for civil airplanes is encouraged. They can be of great assistance in predicting conservative test 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. However, at the present time, none of these computer models have been validated to be sufficient alternatives to the dynamic tests discussed in this AC. The Federal Aviation Administration continues to assess the performance of dynamic computer-based models, and may issue appropriate advisory material should any of these computer model/techniques be found to be an acceptable alternative to the tests discussed in this AC.

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