AEROSPACE RECOMMENDED PRACTICE

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IMPACT PROTECTIVE DESIGN OF OCCUPANT ENVIRONMENT - TRANSPORT AIRCRAFT

1. PURPOSE

The purpose of this ARP is to provide design criteria, based on currently available information, for the impact safety design of cabin occupant environment.

2. INTRODUCTION

Incapacitating, serious, and fatal injuries are sometimes sustained by occupants of aircraft involved in low force, survivable accidents. These are a result of the occupants' striking or being struck by objects which, by virtue of their form, mass, and shape, impose a force of high magnitude on small areas of the body. Although the impact forces which the various parts of the human body can withstand without serious, incapacitating, or fatal injury are not precisely known, some facts are available for consideration when designing for impact protection.

(In utilizing the information set forth in this recommended practice, it should be recognized that experience and data in the field of impact bio-mechanics are limited. Injuries are the result of complex conditions. Therefore, caution should be exercised in relating various factors such as the magnitude, duration, onset rate, direction and distribution of force, as well as other environmental factors. Furthermore, individual tolerance to impact varies widely - see SAE Information Report J885a, Human Tolerance to Impact Conditions as Related to Motor Vehicle Design.)

In general, the design of restraint and structural components that may strike or be struck by the cabin occupants should be such that restraint or striking forces will be distributed over large portions of the skeletal structure and its overlying muscular tissue, so as to maintain acceleration-time-energy factors below those expressed as general parameters in Section 6. It should also be borne in mind that the expenditure of impact energy over long deceleration distances and over large surface areas is desirable (i.e., striking one's head against a small diameter, rigid steel tube is obviously more dangerous than sustaining the same type of impact against a deformable thin sheet of soft aluminum).

3. DEFINITIONS

3.1 Occupant Environment - The occupant environment is defined as the structural area and components thereof which comprise and/or are within an aircraft cabin and which the passengers and cabin personnel may be in contact with or may strike during expected or unexpected turbulent flight and other emergency conditions, such as unexpected crash landings involving accelerations of a magnitude up to and including those for which the aircraft and the interior components have been designed.

3.2 Structural Area - The structural area is the area defined by an envelope of points which enclose a three dimensional space adjacent to the occupants and which any and all parts of the occupants' bodies may reach or strike during the conditions cited in paragraph 3.1.

4. SEATS

4.1 When the seat is subjected to the maximum deceleration loads for which it is designed, it should be incapable of imposing loads on the human body exceeding the general criteria expressed in Section 6.

4.2 Design principles and materials which provide a maximum amount of energy absorption should be utilized so as to reduce the loads imposed on the occupant's body.

4.3 Where rigid structural members are required, they should be so located and shielded and/or provided with energy absorbing materials as to preclude the possibility of severe body strikes during normal or abnormal reaction of the occupant and/or of the seat structure to deceleration and/or acceleration loads.

4.4 Rigid tubular structures adjacent to the legs, arms, pelvis, spine, chest, and skull should be given special attention in relation to the provision of adequate shielding and/or use of energy absorbing material.

4.5 All directions of potential loading of the seated occupants should be given special attention. For example, in the vertical direction (downward) the pelvis may "bottom out" against the structure immediately below the seat-pan, possibly resulting in spinal injury.

4.6 In designing seat-backs of rearward facing seats, special attention should be given to providing adequate over-all support to the entire posterior of the hips, upper torso, and head; this is necessary to preclude the possibility of the torso's "extruding" itself through the seat-back structure, thereby flexing the spine and placing heavy flexion and/or extension loads on the spinal extremities (lumbar and cervical areas).

4.7 Armrests should provide adequate restraint for the sides of the buttocks during application of lateral loads, but should not impose loads against the soft tissue and internal viscera located between the rib cage and pelvis, nor against the rib cage itself. The height and rigidity of the armrests should also be related to potential load imposition on the torso and rib cage when the body is flexed sideward during lateral deceleration of the occupant and seat.

4.8 No sharp, rigid edges of small radius should be used. Components which normally or potentially may be in direct contact with the body should be designed with large radii, contain ample surface area, and be free of rigid or brittle structures.

4.9 Ash trays, lighting fixtures, switches, recline handles, vents, and other such equipment should be recessed and of smooth contour, non-shatterable, and incapable of causing serious puncture or lacerating wounds.

4.10 Detachable serving trays or shelves, when stowed in the seat and/or within striking range of the body, should be so designed as to present only large, low mass, or energy absorbing structures to the body or head. If it is necessary to use rigid, sharp attachment hardware on trays, they should be incapable of being stowed in such a manner as to present such items to the body or head.

4.11 The design of integral stowed trays (when in position for use) should preclude imposition of serious injury to the body or head during impact; this objective may be achieved through progressive failure or retraction of the tray or through the body/tray size-mass-density relationship. Failure of integral trays due to body impact should not result in the presentation of rigid, spear-like points. To preclude the tray's being brought inadvertently into a position making body strikes more likely, tray locks should resist acceleration loads imposed from any direction as well as jolts and distortion of the seat.

4.12 The heads and upper torsos of occupants of rearward facing seats should be restricted from moving up over and/or around the top of the seat-backs during decelerations imposed from any point within a 45 deg cone whose axis passes through the center of gravity of the occupants and is parallel to the longitudinal axis of the aircraft.

4.13 The materials and structures utilized for impact energy absorption should be capable of providing a uniform pattern of pressure distribution on the human body as anatomical parts contact and progressively "enter" and/or displace the energy absorbing material. Impact pressure applied to surface areas of the anatomy should not exceed a pressure equal to 20 times the body mass acting on the contact area.

4.14 Additional protection for the head, face, and chest of occupants in forward facing seats may be achieved by utilizing "break-over" seat-backs which pivot forward due to their own inertia (or by other automatic means) at the lower hinge point at longitudinal loads not in excess of 3 g. (Also see ARP 750, Passenger Seat Design).

5. CABIN

5.1 Side walls, partitions, bulkheads, and other large surface structures should have energy absorbing characteristics related to the criteria in Section 6. Any edges, corners, or other breaks in the surface continuity should be of generous radii and should be of a non-shattering material.

5.2 Accessory components, such as magazine racks, TV receivers and other entertainment devices, oxygen mask outlets, lighting fixtures, air duct orifices, and switches should be located out of striking range. Or they should be recessed, of smooth contour, non-shatterable, and incapable of causing serious puncture or lacerating wounds.

5.3 Window frames and associated components should also be designed with energy absorbing characteristics. Any edges, corners, or other breaks in the surface continuity should be of generous radii and should be made of non-shattering material.

5.4 Overhead racks and storage units should not only be designed with energy absorbing characteristics, but their method of attachment should also preclude their coming loose and falling on the occupants, acting as projectiles, or interfering with evacuation.

5.5 Assist handles and other equipment which, by their very nature, may require substantial mass and density should be recessed or otherwise located so as to minimize the possibility of body impact. In any event, all exposed surfaces and contours should be of generous dimensions and radii.

5.6 Galley and galley equipment should be designed insofar as practicable to conform to the criteria expressed in Section 6 (also see ARP 695, Galley Installations, and ARP 583B, Cabin Attendant Stations).

6. REFERENCE DATA

6.1 According to reference 7.3, all structures that can impact the frontal areas of the skull should deform to the skull curvature (shape) at impact velocities up to 40 fps; these impacts should not produce decelerations of the skull of more than 30 g as related to the conditions cited in 7.3.

6.2 The average energy necessary to produce a single linear fracture of the head has been found to be: to the front midline region, 571 in.-lb; to the back midline region, 517 in.-lb; top midline region, 710 in.-lb; in the region above the ear on either side, 615 in.-lb; but the energy necessary for fracture of the frontal midline area varied from 425 to 803 in.-lb (reference 7.4).

6.3 Four hundred inch-pounds of energy delivered for a period of approximately .01 to .05 seconds is considered to be the maximum energy which may be impacted without resulting in severe concussion or fracture (reference 7.5).

6.4 Information concerning infant or child tolerance to head impact is not yet known (reference 7.6).

6.5 A concussion may be produced by a blow delivered by a relatively flat hard object to the middle of the forehead and producing an average temporal pressure of more than 28 psi lasting 0.004 seconds or longer (reference 7.7).

6.6 In impacts resulting in head motions not restricted by head supports, bending or stretching of the neck with resulting symptoms of pain has frequently been the principle limiting feature. Any effort toward optimum restraint of the upper torso must consider simultaneous restraint of the head. Restraint of relative motion of head motion with respect to spine and shoulders is an optimum solution, but has not yet been solved (reference 7.8).

6.7 Vertical (downward) deceleration has been found tolerable for healthy young males without injury at 18.5 g (for 0.060 seconds, with maximum onset rate of 1540 g/sec) (reference 7.9), and 35 g (for 0.010 seconds at 1500 g/sec) is maximum tolerated without symptoms of cerebral concussion (reference 7.10).

6.8 Vertical (upward) deceleration has been found tolerable for healthy young males to limits of 24 g peak with 30 fps velocity change at 500 g/sec onset rate (reference 7.11). Much higher forces have been survived in free-fall impacts (reference 7.12).

6.9 Rearward deceleration (as in a rearward facing seat) in which restraint pressures are imposed uniformly over the entire posterior of the torso and head may be tolerated without injury in healthy young males up to 40 g at 2000 g/sec rate of onset to .100 seconds (references 7.13 and 7.14).

6.10 Sideward facing (lateral) impact may cause injury above 12 g at .100 seconds (onset rate of 1000 g/sec) (reference 7.15), with lap belt restraint alone for healthy young male occupants, and non-reversible injury above 34 g for .122 seconds (onset rate of 500 g/sec) (reference 7.16), with both shoulder harness and lap belt restraint.

6.11 Forward deceleration of the healthy young male restrained only by a seat belt of 2-in. width and properly positioned on the hips may be tolerated up to 33 g for 0.035-0.065 seconds (at 2300 g/sec onset rate) with minor complaints, with human tolerance limits for non-reversible injury to 50 g peaks at 500 g/sec rate of onset for 0.025 seconds duration for healthy young males with both full torso and lap belt restraint (reference 7.14).

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