A flat or curved, sheet-metal panel which will dent on impact should be considered where practical to install. A curved, sheet-metal panel has been used with good results on the instrument panels of some agricultural airplanes. A review of the accident records on these airplanes has shown the pilot’s head often has dented the rolled section of the instrument panel on impact sustaining only minor injuries. An even better design for protection would be a curved, thin, metal section that is padded for force distribution.

**Tolerance to Head Impacts:**

Structure within the head strike envelope should be either padded or so designed as to prevent serious head injury. Studies by A,vser and Wayne State University indicate that head impacts at more than 20 fps are not readily tolerated by humans unless the structure has been adequately covered with energy-absorbing material. However, ductile or deforming energy-absorbing structure or construction can be as effective as energy-absorbing padding provided that sharp corners and protrusions are eliminated and the structure/head contact area is large. When the design layout is free of sharp or small radiused corners, edges, and protrusions, attention can be given to design for controlling the magnitudes of the acceleration pulses to which the head may be subjected.

![Graph showing head velocity relative to seat](image)

**Figure 3-29.** Measured Head Velocities in Sled Tests With Anthropomorphic Dummies and Cadavers.

[Source: JSAAVLABS TR 70-22 (2)]

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Head acceleration is a function primarily of (a) head striking velocity, (b) head/torso mass, and (c) stopping distance. Head striking velocity is a function of (a) body geometry, (b) method of restraint (lap belt only or both lap belt and shoulder harness), and (c) seat velocity change. Figure 3-29 shows typical head velocities relative to the seat as measured on anthropomorphic dummies, cadavers, and human volunteers in dynamic seat tests using (a) lap belts only, and (b) both lap belt and shoulder harness.

Figure 3-30 shows an approximate correlation between head impact velocity, crushable material thickness (stopping distance), and average acceleration. The material thickness given in this figure is based upon an assumed rectangular acceleration-time pulse and is, therefore, the minimum material thickness suitable under ideal conditions.

![Graph showing crushable material thickness as a function of velocity change and acceleration level.]

**Figure 3-30. Crushable Material Thickness as a Function of Velocity Change and Acceleration Level.**

[Source: USAAVLABS TR 65-44 (6)]

Figure 3-31 shows an acceleration-time plot of the average acceleration versus the total period of the impulse required to approach unconsciousness limits. This plot was reported by Dr. Gurdjian and others of Wayne State University after extensive experiments with cadavers and live animals in their work on skull fracture and concussion.
Figure 3-31. Head Tolerance to Impact as a Function of Pulse Duration as Published by Wayne State University.

[Source: USAAVLABS TR 70-22 (2)]

Design accelerations which exceed the approximate unconsciousness tolerance level should be avoided if possible so that occupants will be more likely able to escape any post-crash fire hazard or to treat any serious lacerations. A designer may, by using the approximations and ranges of values for head velocities and impact tolerances of Figures 3-29 and 3-31, determine from Figure 3-30 approximate thickness of energy absorbing materials adequate for head protection. Lesser thicknesses would be adequate if installed on energy-absorbing structure.

Torso Impacts:

Figures 3-24 and 3-25 show the approximate flailing area for an occupant restrained only by a lap belt. It is apparent that control wheels, control columns, pedestals and instrument panels are primary impact hazards to an unrestrained torso. Since the upper torso, particularly the head, is a most vulnerable part of the body, it is necessary that maximum protection be provided within its strike envelope. Head impacts against local structure are a primary cause of serious injury. Protection of the head in the form of protective helmets and/or upper torso restraint and energy-absorbing structure in the occupant's immediate environment is considered essential. Under certain conditions, even the forces incurred in minor crash impacts can cause serious or fatal injuries.
Figure 3-32 shows a 95th percentile male's forward flailing area superimposed on a scale drawing conglomerate of a number of late model light airplanes.

Figure 3-32 also shows how a front seat occupant, restrained only by a seat belt, can contact an airplane's interior structure. It suggests a graphical method with which a designer may determine, for any restraint system, the approximate directions and magnitudes of impact forces with the impact hazards of a particular airplane configuration.

Figure 3-32.

[Source: CARI Report 62-13 (7)]
Protective Padding. Protective padding reduces impact accelerations by absorbing a portion of the impact force, and it reduces high load concentrations by distributing the force over a large area. Figure 3-30 approximates a guide for selecting energy-absorbing padding material and thickness. By the effective combination of padding with, where possible, yielding structure, the designer hopefully can design the airplane interior to prevent head impact accelerations from exceeding the tolerances of Figure 3-31. Report AM66-40 "Evaluation of Various Padding Materials for Crash Protection" by J. J. Swearingen gives the results of limited impact testing of various padding materials and thicknesses. The report concludes that padding alone, even up to 6 inches thick, may be borderline for protection against fatal head injuries at impact velocities of 30 feet per second and that underlying structure should be designed to deform and dissipate the energy of head impact.

Energy-absorbing materials with stress-strain curves which fall between the limits shown in Figure 3-36 will offer reasonable potential for survival of head impacts at velocities up to 20 feet per second on a flat surface with a padding thickness of between 1.5 and 2.0 inches. Head acceleration should not exceed 100G. Materials, properties, and thickness should be capable of reducing the relative head velocity from 20 to 0 feet per second while absorbing the head kinetic energy of from 60 to 90 foot-pounds. Selection of padding materials should consider the materials' performance over the airplane's anticipated operating temperature range.