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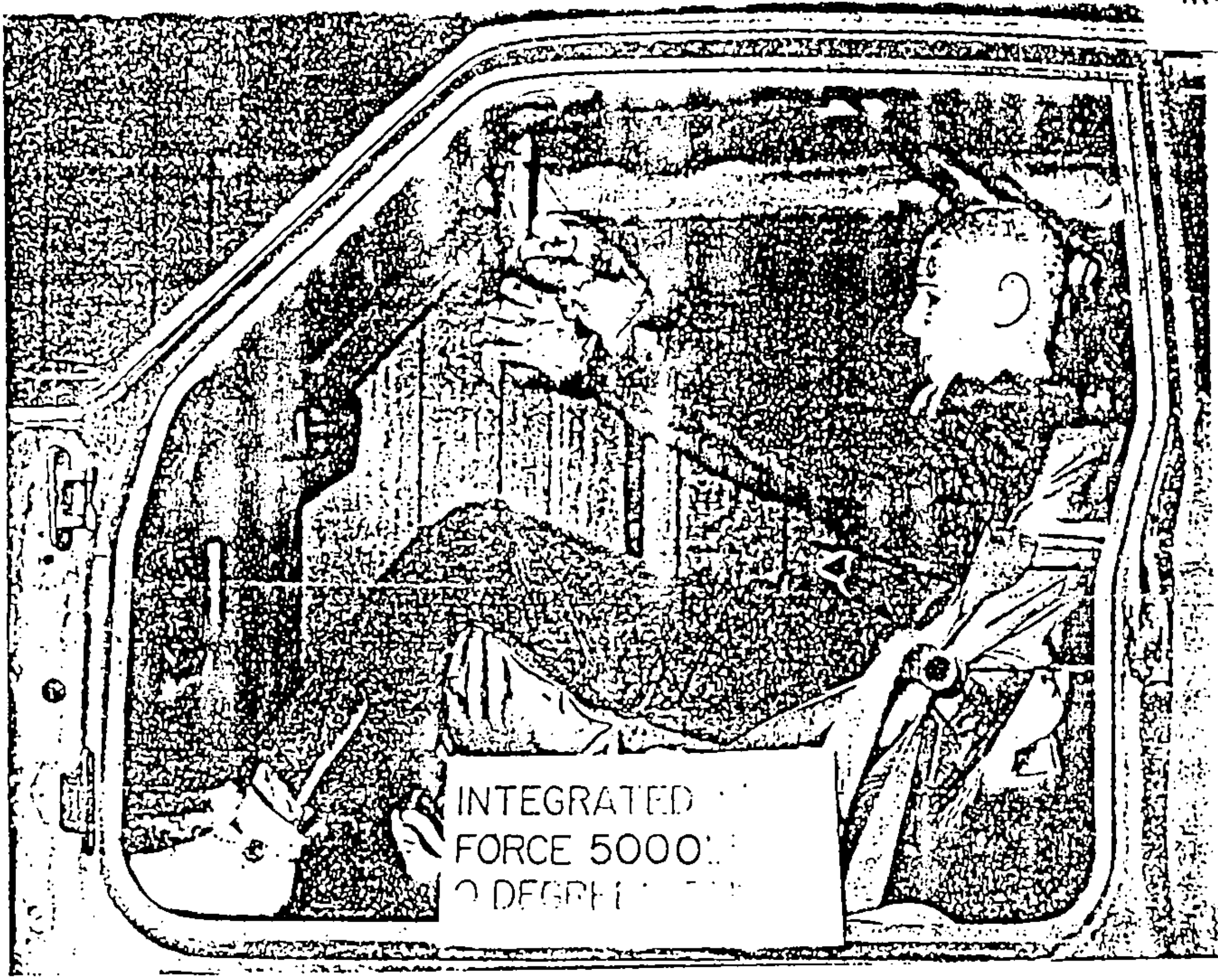

DESIGNING SAFER SEATS

Today's automotive seating package must offer not only comfort and convenience, but also a measure of collision protection for its occupants. Research activity indicates that much-improved safety is within reach of current seating designs.

Earliest automobile seats owed more to buckboard standards than to opulent carriage design. What padding they had seemed to be included for esthetic reasons—not comfort—and springing was primitive. By 1900, deeply contoured seats began to appear. Their chief contribution to safety lay in lessening the chances of passengers falling off as the car body pitched and rolled. As the primitive automobile evolved into a practical means of transportation, its passenger comforts improved somewhat. "Human factors engineering," however, was a term which existed only dimly in the future.

Ford's Model T appears to have been one of the first with forward-folding backrests in its seat design. Provision for fore/aft adjustment seems to have appeared only in the late 1920's. Improvements in seat design continued; indeed,

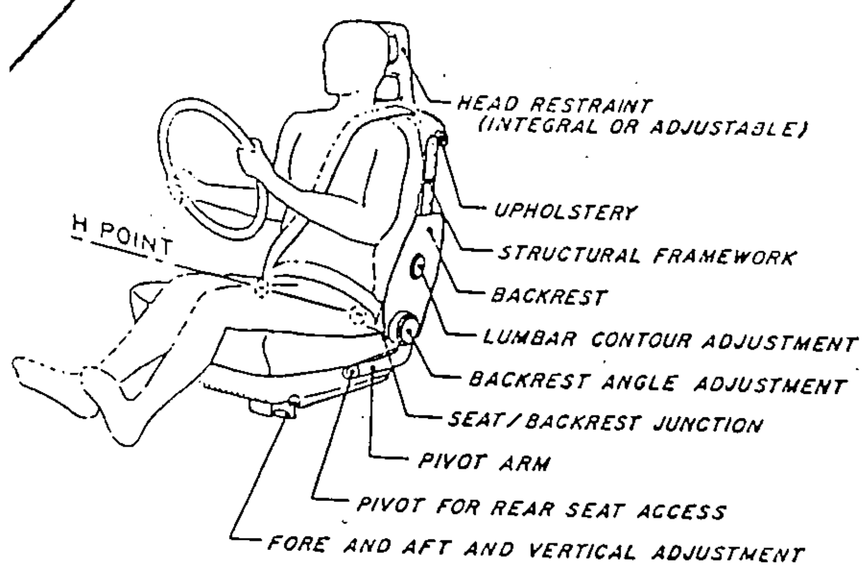

Fig. 1—Components of a modern bucket seat. Note H-point, about which backrest bending moment is computed.

y the mid-1930's, the essential ɜsign of seats, tracks, and runners osely resembled that of the mid-160's. Additional hardware, in-uding power seats (first intro-ıced on the 1952 Packard), may ıve been the only refinements ıring this period.

Modern seating configurations flect their intended use and loca-ın. Solid-back bench seats for door sedans, split-back variants 2-door use, folding backs for gon applications, and bucket its are among the seating op-ns available to today's designer. ses, vans, trucks, and motor mes all have their own special uirements. Simple longitudinal ustment has been augmented a multiplicity of mechanisms. eed, some modern seats offer ustment flexibility limited only charge in the battery.

Components

f whatever configuration, all s share certain design ele-its, including:

tructural frame members. Us-y of tubular, stamped, or d steel, these give shape to cushioning materials and smit accelerative forces.

on-structural materials. ngs, cushions, and upholstery ide load distribution and the contour necessary for comfort. These materials also serve to moderate the transmission of forces through the seat structure.

• Adjustment mechanisms. Manual or electric, these are necessary to accommodate the wide range of anthropometric variations. Minimally, longitudinal adjustment is provided. Other variations allow vertical, tilt, backrest angle, lumbar support, and head restraint adjustments. Such a fitting of seat to occupant is not only a feature of comfort; it is also important in safety considerations, both for routine operation as well as collision protection.

• Anchorages. Usually interposed between adjustment mechanism and floor pan, these components transfer forces between seat and vehicle. Under static conditions, forces of compression, tension, and shear are transmitted from the seat to the floor or side structure. In the event of collision or under handling acceleration, the resulting forces are transmitted in the opposite direction.

Design criteria

A designer must consider comfort, durability, weight, cost, and safety; probably the first and last are least amenable to quantification. Although basic components have not changed radically, the past 20 years have seen new materials and construction techniques in seat design. By and large, these have improved durability and comfort, while simultaneously controlling weight and cost. With the exception of head restraints, however, automotive seats have shown little improvement with respect to safety.

One criterion which can be cited is the measure of backrest strength. Tests conducted by Severy, Inc. indicate that 85 production seats from cars large and small, foreign and domestic, 20 years old to near new, all have backrest strength remarkably alike. And Severy researchers feel that no seat tested is fully capable of resisting occupant inertial forces for any but light impact exposures.

A fundamental parameter of safety is "restraint compliance," the change in restraint geometry induced by occupant inertial forces. A seat should be designed to transmit these forces to the vehicle, and to moderate them so that occupant displacement and acceleration avoid levels causing physiological trauma. In short—a seat should minimize injury to its occupant in the event of a collision.

Standards

Recommended practices and standards for automotive seats have arisen over the past 13 years. In 1963, two performance tests were specified in SAE Recommended Practice J 879. One test evaluated retention capability of adjusters and anchorages; the other dealt with backrest strength. The General Services Administration adopted these SAE recommendations into its federal purchasing requirements for the 1967 model year. The formation of the Federal Department of Transportation came in 1966, and the same standards were recast, with minor modification, as Federal Motor Vehicle Safety Standard (FMVSS) 207; actual adoption occurred in January, 1968.

To meet this standard, each backrest is required to sustain a rearward static moment of 3300 in.-lb per passenger. This moment is computed about the hip-pivot ("H-point" in Fig. 1) with the load applied normal to the backrest at

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Fig. 2— of uphc

its upper crossmember. FMVSS 207 also includes the requirement that forward-folding backrest locks withstand a 20 g minimum inertial load.

In 1969, FMVSS 202 promulgated headrest requirements: a head restraint must be capable of resisting a 200 lb force applied horizontally. European standards, essentially the same as FMVSS 207, were enacted by the Council of European Communities in 1974.

With this regulatory history, there is a certain irony in the fact that almost all production seats have exceeded these requirements, some by a substantial margin. For example, in its evaluation of 85 production seats, Severy found that seatback strengths varied from 4000 to 17,000 in.-lb, well over the 3300 in.-lb standard. Nevertheless, it can be restated that they feel no current seat provides adequate protection under more than moderate collision-induced forces.

Active or passive?

After almost a decade of research and development of the passive concept a growing consensus among safety researchers is appearing to redirect emphasis to active restraint systems. This has been generated by what many believe are serious shortcomings of the most common passive system, that employing air bags. Many researchers feel that air bag effectiveness is limited essentially to single-impact frontal collisions. For impacts of a secondary or nonfrontal nature, an occupant would have to depend on a lap belt used in conjunction with the air bag system. Thus, the total protection package would no longer be passive. The cost/benefit ratio of air bags has been perceived by some researchers as poor in comparison to that of a properly designed three-point active restraint. And in-service reliability of air bag systems has also been questioned.

Several consumer and industry groups have expressed the view that the active concept, using existing hardware and combined with mandatory usage statutes, would be the most effective occupant protection. Some 16 countries around the world have taken this direction; their experiences appear encouraging. This emphasis on active restraint has generated a heightened interest in seat collision performance.

Collision performance

In essence, a seat must transmit and moderate occupant inertial forces to the vehicle. In rear collisions, this is largely a function of backrest strength. The cantilever structure of a conventional seat creates something of an engineering dilemma: as its strength increases through added structure, inertial force of the structure itself can become destructive. Several researchers have suggested a form of roof anchorage to resolve this problem.

Head restraints have been found effective in reducing secondary impact injuries in rear collisions. Their effectiveness, however, is compromised by improper positioning: A 1972 study indicated that 70% of adjustable head restraints were kept in the lowermost —and least effective—position. Integral head restraints, designed with provision for rearward vision, are perceived as a solution to this

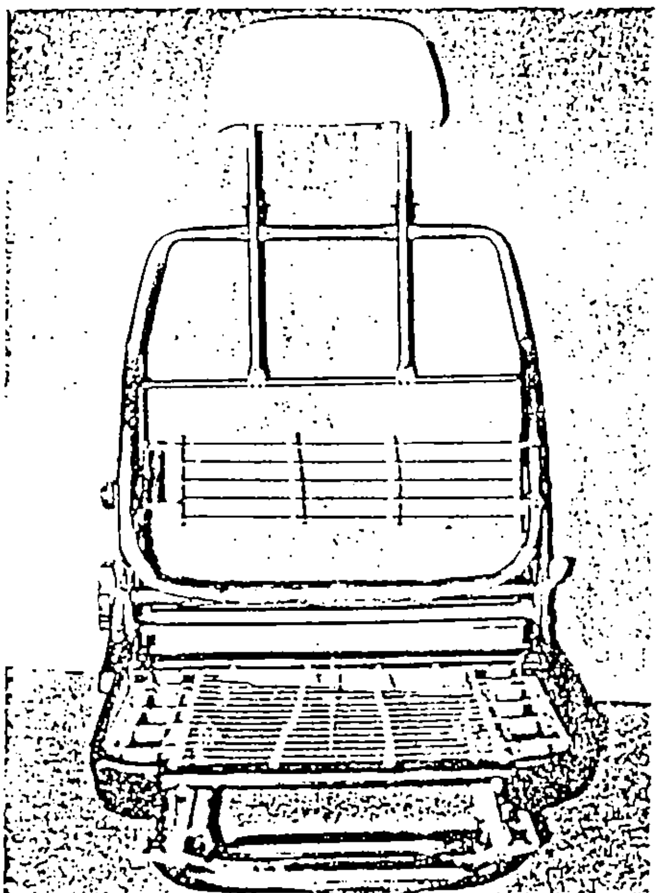

Fig. 2—Baseline design. Volvo production bucket seat, stripped of upholstery and cushions.

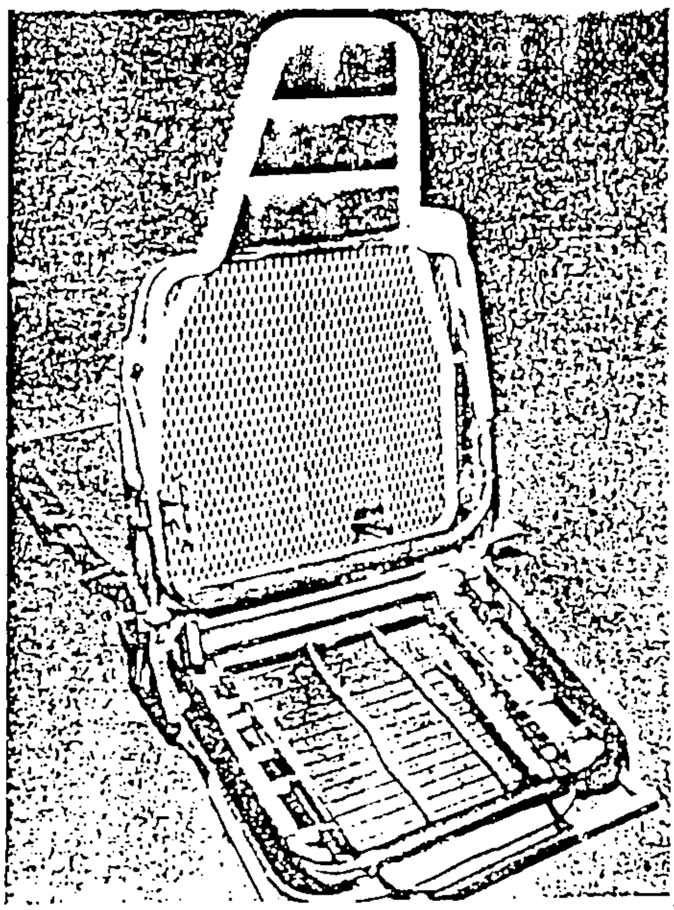

Fig. 3—Modified structure. Note roof belt and integrated restraint connector.

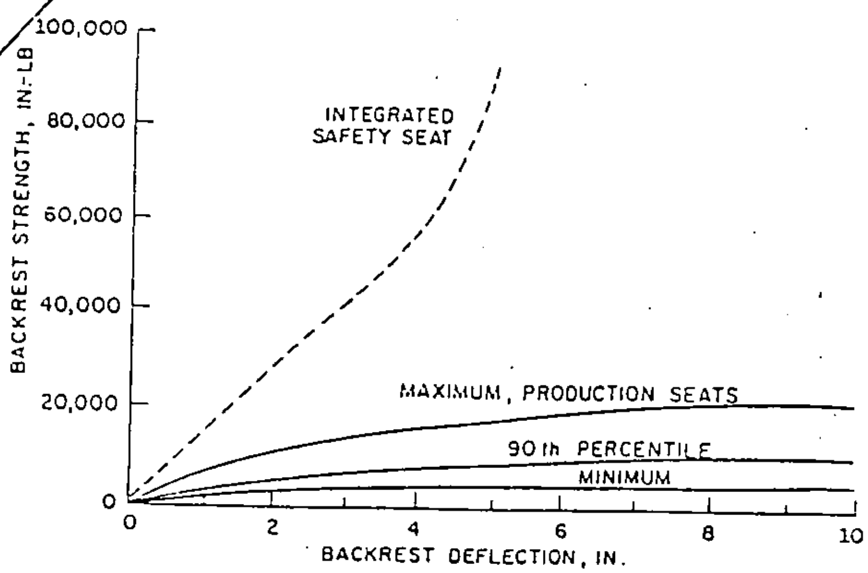

Fig. 4—Backrest deflection vs. bending moment. Static rearward force was applied about 14 in. above seat/backrest junction.

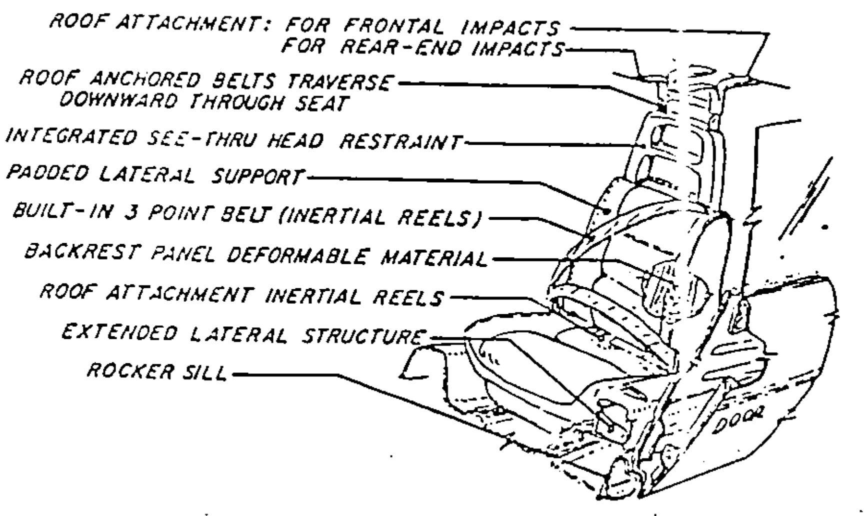

Fig. 5—Design elements of integrated safety seat.

usage problem.

Frontal protection, active or otherwise, requires moderation ("ride-down") of the occupant's inertia, and protection from secondary impacts with the vehicle interior. Belts of pre-stressed design, attached directly to the seat, have been suggested as a means of improving these capabilities.

The reclining ability of modern seats presents another design challenge. "Submarining," which shifts the belt upward across the viscera, is particularly dangerous if a backrest is in full-reclined position. Borrowing from racing car practice, researchers have incorporated an additional pair of straps attached to the seat front and fastened into a lap belt connector.

Side impacts are considered potentially the most dangerous accident mode. Crush distance is limited, and a delayed, abrupt occupant response magnifies the resulting exposure. To mitigate this, Severy has suggested a contoured seat attached through structural members to the vehicle side. This allows a more direct application of force to occur before substantial inward crush has taken place. Their velocity-time profiles of side impacts indicate that this interaction provides a more prompt but less severe occupant acceleration. This "ride-up" is similar conceptually to the ride-down capability important in frontal collision protection. Additionally, seat contours and integrated restraints can be designed to generate a pocketing effect which serves to distribute lateral forces.

Rollover injuries and fatalities occur most frequently through ejection. Evidently, proper seat belts minimize this hazard. Also, to increase survival space in rollover, it has been suggested that seat backrests can act as central pillars for the roof structure.

Integrated safety seat

Severy researchers redesigned a Volvo production bucket seat into one which they feel offers its occupant adequate protection. Their experience indicates that such safety seat design is reasonably within current state of the art.

They stripped the seat of its upholstery (Fig. 2), and modified its frame to support their special protective hardware. The modified seat structure is shown in Fig. 3; among its modifications are:

- A high-section-modulus tubular steel backrest, extending from seat attachment through head restraint, to improve strength both for rear collision and rollover space.
- Double seat tracks, for more positive anchorages and transmission of forces.
- Three-point belt inertial reels mounted to the seat frame. Severy researchers feel that fixing the belt directly to the seat optimizes the important ride-down capabilities of the entire structure.
- An energy-absorbing back panel, to moderate and to pocket occupant inertial loads during rear collisions. It also provides some kinematic control of rear seat occupants in frontal collisions.
- A pair of inertial reels for belts connecting the rear base of the seat, passed through the backrest, to roof anchorages. In modifying the basic cantilever design, these

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roof anchorages greatly reduce the bending moment at the pivot arm of the seat. The point of maximum bending moment is shifted higher in the seatback, away from the relatively fragile adjustment mechanisms. The use of inertial reels permits adjustment and folding, but provides inertial snubbing under collision forces.

The finished seat incorporates a deeply contoured geometry to distribute lateral forces. It also retains Volvo's backrest angle and lumbar support adjustments.

In laboratory testing, this modified seat showed substantial improvement over production seats. The roof anchorages, particularly, brought about a dramatic increase in backrest strength with little added weight. In Fig. 4, modified seat results are compared to data obtained in evaluating a large sample of production seat assemblies.

Implications

The researchers stress that weight savings and enhanced strength could be realized with an original design rather than a retrofit. Nevertheless, the crucial elements of design would appear to be easily incorporated into existing seating packages; these are shown in Fig. 5.

According to the researchers, there appears to be growing evidence that three-point belts, together with mandatory usage laws, represent the most effective means of occupant protection. If so, it is likely that improved seating designs will play an increasingly important role in the safety and comfort of tomorrow's motorist.

Based on SAE Paper 760810, "Automotive Seat Design And Collision Performance," by D.M. Severy, D.M. Blaisdell, and J.F. Kerkhoff, Severy, Inc. Presented at the 20th Stapp Car Crash Conference, Dearborn, Oct. 18-22.