Automobile-Crash Injuries

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The study was aimed at the control and reduction of personal injury to the occupant and toward reduction of physical damage to the vehicle. Conducted in three phases, the research covered:

1. Experimental investigation of the kinematics of human occupants of an automobile during crash decelerations. By use of high-speed photographic techniques it was found that the general motion characteristics of occupants of the vehicle, under imposed crash conditions, were of a predictable nature, as were the zones of physical contact.

2. Investigation of methods of reducing property damage cost in automobile accidents. In this phase of the project, impact tests and fabrication and repair studies completed on automobile body components, disclosed that the greatest promise for reduced property damage costs lay in the use of more impact resistant fabrication materials.

3. Investigation of methods of achieving protection for the passenger. Accessory equipment and replacement parts on existing vehicles were developed for safer "packaging" of the occupant, including seat belts, padding materials and steering wheel protectors.

●THE engineering research program in Automobile Crash Safety performed at the Cornell Aeronautical Laboratory, which I am privileged to explain on behalf of the sponsor Liberty Mutual Insurance Company, is a relatively small gain in a vast area of undeveloped preventive research: This research which employs the engineering laboratory, when combined with full scale research from the highway, will be another step toward establishing, eventually, a more-balanced and less-harmful man-machine relationship. The tremendous progress made in the industrial plant to safeguard the workman from machine hazards and thereby increase his productive capacity can be duplicated on the highway. Certainly, the already-staggering and ever-increasing list of traffic casualties compels more concentrated research and development in the field of human-automotive engineering.

As insurance people, we are aware of our lack of qualification to criticize automobile design and engineering, nor is it our desire to do so. We are concerned primarily with the elimination of unsafe acts or conditions which may result in damage, injury, or interruption, due to human limitations. We are convinced that the modern automobile represents a social hazard insofar as man, through mental and physical limitations is unable to cope with the potential energy of the vehicle he operates and insofar as the automobile body, because of material and fabrication weaknesses, is easily damaged upon impact, with little protection provided the occupants.

Late in 1951, representatives of Liberty Mutual Insurance Company conferred with principals at the Cornell Aeronautical Laboratory on possible areas of research in automotive safety. This request was motivated as a result of a previous investigation of property damage claims, the steadily rising cost of automobile repair work, and the serious nature of injuries sustained by occupants involved in collision accidents.

PHYSICAL DAMAGE CASE STUDY

One analysis of physical damage by F. J. Crandell, Liberty Mutual Insurance Company, covered 1,002 claim cases totalling nearly $200,000 and included accidents which occurred both in the central business district and on circumferential arteries of metropolitan Boston. The analysis was divided according to end collisions, side swipes, 90-degree collisions and fixed object collisions, with each general subject further divided into damage to front end, rear end, left front, right front, left rear, right rear, left side and right side. A summary of findings follows:

The amount of money paid out for end collisions is equal to the amount paid out for side swipes. Each type costing about $73,000; 50% of the expense of side swipes resulted from damages to the front of the car, and about 70% of the expense of end collisions is attributed also to the front end.

A total of the repair cost for side-swipes and end collisions (Front Portion) is 399 cases totalling $87,883.10.

In side swipes about 20% of the repair cost is used for the rear portion of the vehicle, while in end collisions about 30% of the cost is due to the rear end.

A total of the repair cost for side swipes and end collisions (Rear Portion) is 286 cases totalling $38,678.97.

In side swipes the sides of the autos require about 30% of the repair costs, each side's repair expenses being about the same.

In 90° collisions, the left and right sides require approximately the same amount of money for repairs.

A total of the repair cost for side swipes and 90° collisions (side portions) is 301 cases totalling $63,663.38.

Of all the repair expenses paid (968 cases, $190,225.45) the end collisions make up 40% of the expenses and cases; the side swipes make up 40% of the expenses and cases; and the 90° collisions make up 20% of the expenses and cases. (Out of the 1,002 cases investigated, only 34 were collisions with fixed objects necessitating a sum of $5,971 for repairs to the automobiles.)

In examining both front and rear of the auto, damage to the front portion costs about 60% more to repair than the rear portion.

The sides of the vehicle cost about 60% more to repair than the rear portion.

In comparing the front and sides, there are about 131 more accidents occurring to the front of the vehicle which give a difference of $48,612.82 in claims paid.

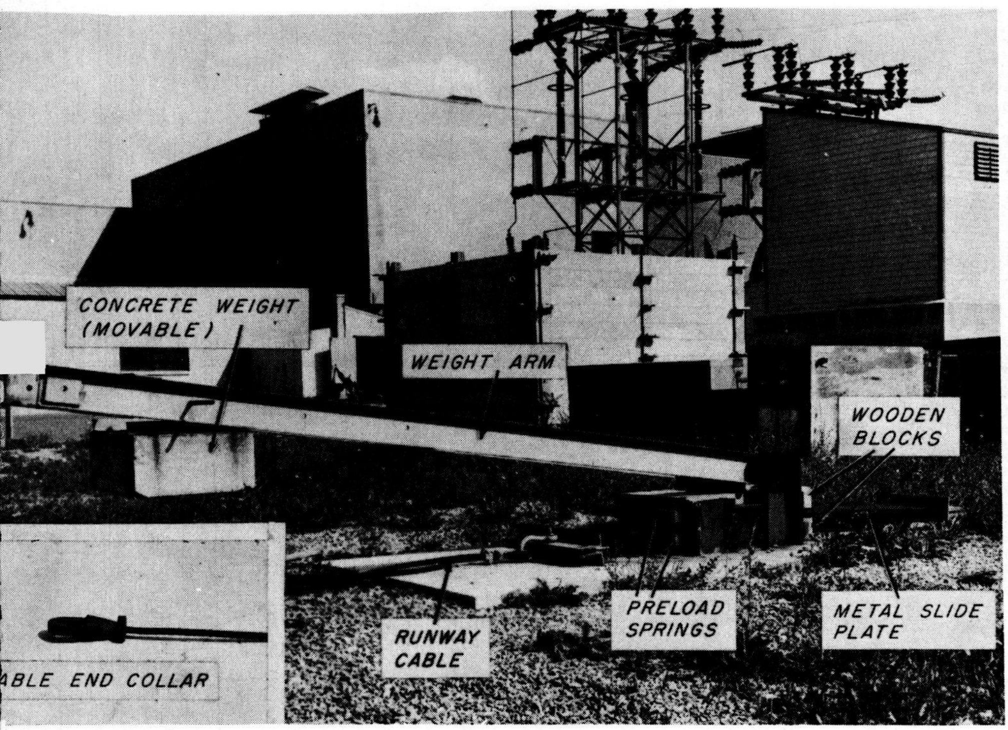


Figure 1. Friction snubbing device for simulating an automobile crash.

TABLE 1

TOTAL COST FOR PARTS AND LABOR, 1940 AND 1951
(Sample Items)
Report of Joint Staff - Automobile Manufacturers and Insurance Industries - Detroit - 1953

Item	1940	1951	Increase
Hood Top Panel (l. or r., painted)	$ 8.10	34.40	325%
Radiator Grille Assembly (comp. with upper molding)	10.70	43.00	302%
Bumper Face Bar (1940, single bar; 1951, 3 sections)	4.05	16.44	306%
Rear Fender (r. painted; 1940, individual part; 1951, replacement sec.)	9.80	35.85	265%
Average	8.16	32.42	300%

With the greatest number of cases and the greatest loss arising from damage to the front of the car, followed closely by side damage loss, it is interesting to note comparative costs on repair parts and labor for 1940 and 1951 (see Table 1). During the calendar year of 1951, the Liberty Mutual Insurance Company, representing only one of many casualty companies, paid out over $12 million on property damage settlements. This figure is only approximately one half the total cost of settling personal injury claims in the same period. These expenditures indicate the need for definite research with methods of controlling and reducing human injury and property damage resulting from automobile accidents.

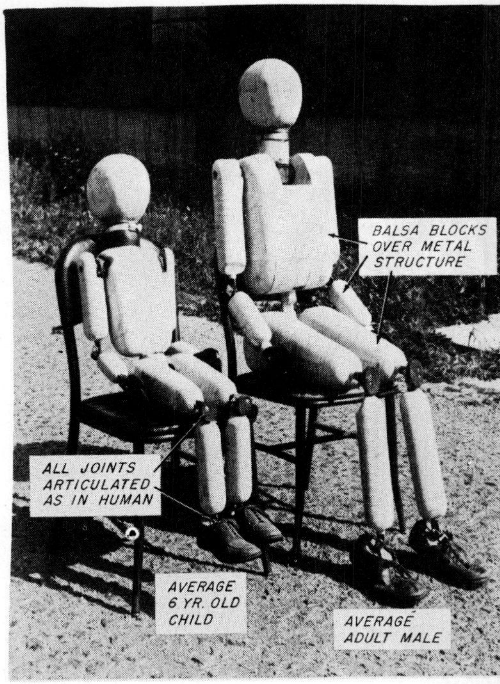


Figure 2. C.A.L. crash dummies (dynamically similar to human counterparts).

CORNELL RESEARCH PROGRAM

Due to the complexity of the overall problem of automotive safety and the wide range of variables involved, it was decided that the problem would be approached from two directions only: First and most fundamental, the time and motion characteristics imposed on the human occupant of a vehicle subjected to crash-level decelerations; and secondly,

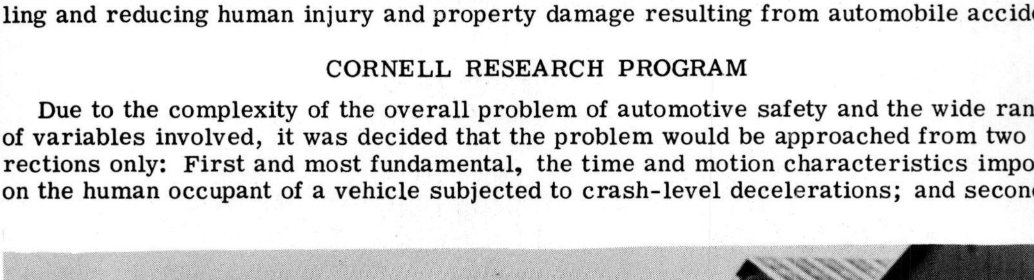


Figure 3. Crash snubbing test vehicle.

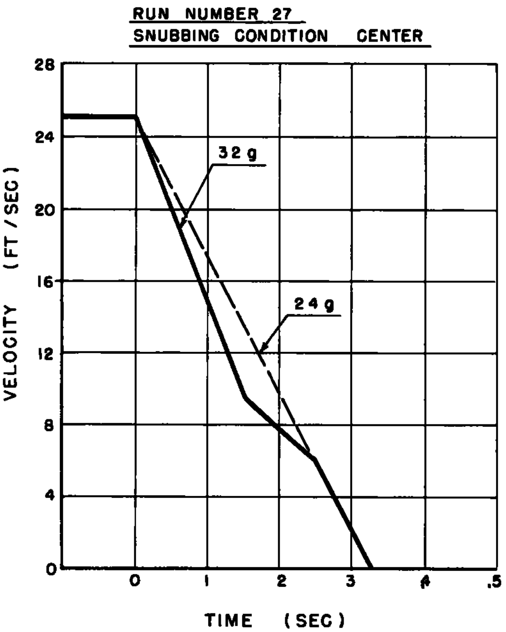


Figure 4. Automobile crash snubbing tests kinematics of the automobile.

the investigation and development of materials and equipment to improve the crash resistance of the vehicle and provide optimum protection for the occupant.

All available data on property damage and crash injuries previously collected under Hugh DeHaven, of the Cornell Medical College, were incorporated in the research, as were available data on crash-resistant materials.

The Automobile Crash Safety Research was conducted in three phases between October 1952 and October 1953, as summarized below:

Phase I. This initial and most-comprehensive phase of the research consisted of the experimental investigation of the kinematics of the human body in relation to the interior arrangement of an automobile during crash decelerations (this phase is illustrated by a 12 minute 16-mm. sound-color film).

The test equipment consisted of (1) a standard two-door passenger car, Figure 3, with auxiliary parts added, including directional steering control, ignition mod-

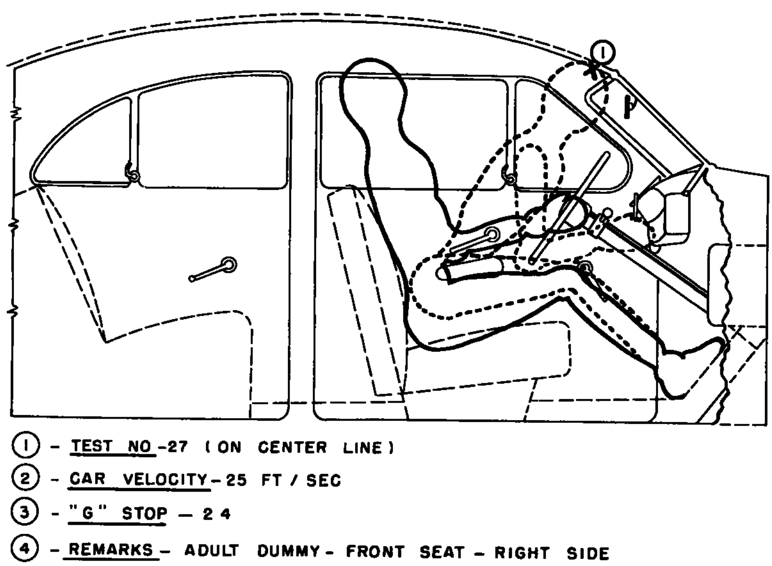


Figure 5. Kinematics and hit locations for dummies.

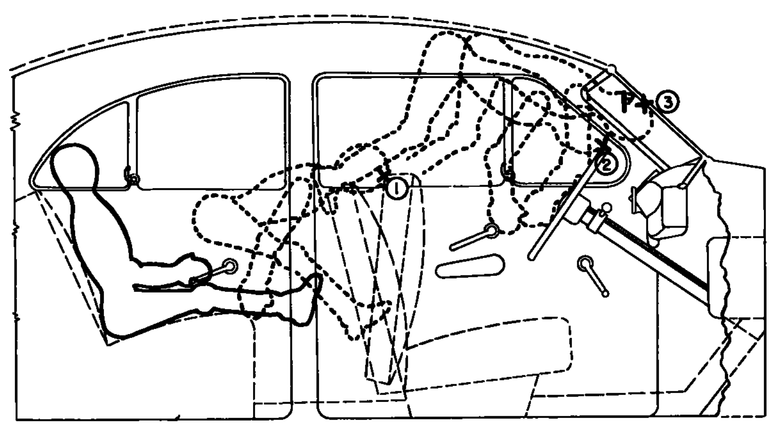
ifier, a wire screen reference grid, external throttle, and reinforcement of the front end of the car frame; (2) a crash-snubber device, Figure 1, designed to create sufficient frictional resistance to simulate crash deceleration. The snubbing force is transmitted through a 200-foot steel cable, with the kinetic energy absorbed by two large hardwood blocks at the pivot point; and (3) two dummies made of tubular steel skeleton and balsa wood, Figure 2. One dummy, 40 lb. in weight, is proportioned to represent an average adult of 153.4 lb., 5 feet 9 inches in height. The smaller dummy, weighing 22½ lbs., approximates a 6-year-old child of 45 lb.

A typical test run, No. 27, is described as follows:

Dummy position; - Adult in right front seat; 6 year old in left rear seat.
Car onset velocity; - 25 ft./sec. (17 mph)
Snubbing configuration; - Center
Average deceleration; - 2.4g
Reference figures; - 12 through 15
The kinematics of the automobile are presented (Figure 4). The diagrammatic time history of the action of the dummies relative to the car is presented (Figures 5, 6, 7).

It will be noted that the adult dummy pivoted about the hip joints to an angle which resulted in a normal blow of the head to the headliner region adjacent to the top windshield molding. This resulted in a rebound back into the seat rather than a subsequent glancing blow to windshield as previously described. The small dummy progressed forward relative to the car until his head contacted the top of the front seat back in a glancing blow. This initial contact caused a tendency to sommersault the dummy into an attitude such that his second hit was to the upper steering wheel rim. A terminal hit consisted of striking the back of the head to the windshield.

Other runs were conducted with controlled stopping distances from 1.5 to 3 feet from an onset velocity of 10 to 20 mph. and simulated both center and off-center collisions. By use of high-speed photographic techniques, it was found that the general motion characteristics of occupants of the vehicle were of a predictable nature. The paths of occupant motion and the zones of physical contact were relatively the same for imposed crash conditions of both head-on and left and right front angular collisions.



(1) - TEST NO - 27 (ON CENTER LINE)

(2) - CAR VELOCITY - 25 FT/SEC

(3) - "G" GROUP - 2 4

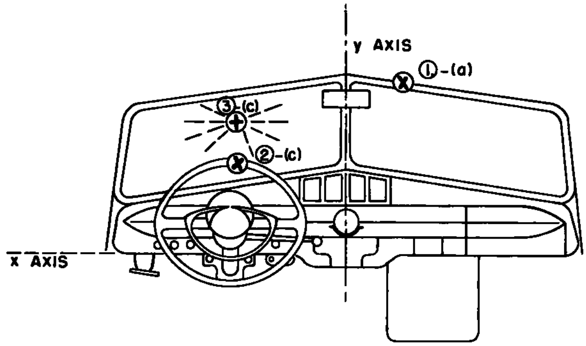
(4) - REMARKS - 6 YEAR OLD CHILD - REAR SEAT - LEFT SIDE

Figure 6. Kinematics and hit locations for dummies.

The specific initial motion characteristics of an occupant of the front seat of a vehicle during crash decelerations can be predicted to a close degree of accuracy, provided the vehicle motions are known. This is not true of the occupant of the rear seat, since the path of travel is longer and the action violent and subject to variation, depending upon whether or not contact is made with the back of the front seat in forward motion.

The hit area for front end collisions was determined by the head travel, and may be defined by a vertical arc sector extending 30 deg. down from eye-level and 45 deg. up from this same horizontal; laterally, 30 deg. right and 30 deg. left from a vertical reference plane through the body. The driver invariably received a potentially injurious blow to the torso against the steering wheel. If the magnitude of deceleration is above 2 g's, the driver, if not impaled on the steering wheel post, receives a sharp head blow against the upper windshield or windshield molding.

Experimentation with restraining belts during some test runs indicated, that when



(1) – TEST NO – 27 (ON CENTER LINE)

(2) – CAR VELOCITY – 25 FT / SEC

(3) – "G" STOP – 2 4

(4) – REMARKS – 6 YEAR OLD DUMMY – LEFT REAR – (HIT FRONT SEAT BACK, STEERING WHEEL RIM AND WINDSHIELD)

ADULT DUMMY – RIGHT FRONT – HIT SUN VISOR WITH HEAD

Figure 7. Hit locations of dummies.

properly installed, they are extremely effective in achieving the type of body control which would greatly reduce the possibility of serious injury in an automobile accident.

Phase II. In this phase of the project an investigation was conducted of methods to reduce property damage cost in automobile accidents. The problem of redesign of automotive parts or substitution of more shock resistant materials had to be approached with full appreciation of material and fabrication costs, styling and vehicle performance.

The investigation of the problem was based on the premise that, to be acceptable to either the public or automobile manufacturers, any resulting development should not materially alter the current style trends in automotive design.

Known physical properties of substitute materials were studied and compared to establish static strength and stiffness characteristics of the material selected. These were followed by experimental tests to correlate the shock and impact resistance of the material with the static strength characteristics previously established. In addition, preliminary investigations were conducted on attachment design, repair techniques and adaptability to an automotive type finish.

A thermoplastic sheet material produced by the United States Rubber Company was found to have the desired characteristics. Based on an analytical comparison of the static strength of this material and steel when used for automobile body components, the thermoplastic part would have an impact resistance approximately eighteen times greater than an equivalent steel part and be 25% lighter in weight. Drop tests, (using an 8 lb. steel ball) to establish the impact resistance under dynamic conditions, disclosed an improvement factor of approximately 14. A drop height of approximately 41 ft. resulted in damage to a 3/16 inch thermoplastic panel, comparable in nature and degree of permanent deflection, to a 3 ft. drop on an .040 inch thick steel panel.

The material can be formed to typical automotive body contours by hot draw molding methods believed to be adaptable to high production rates with relatively low cost tooling. It can also be worked with ordinary tools and machinery. Attachment or bonding between two pieces of thermoplastic or to other materials can be affected by use of conventional screws, bolts, rivets or by proper cements. Damage to the material can be repaired by methods which compare favorably in complexity and cost to the equivalent repair

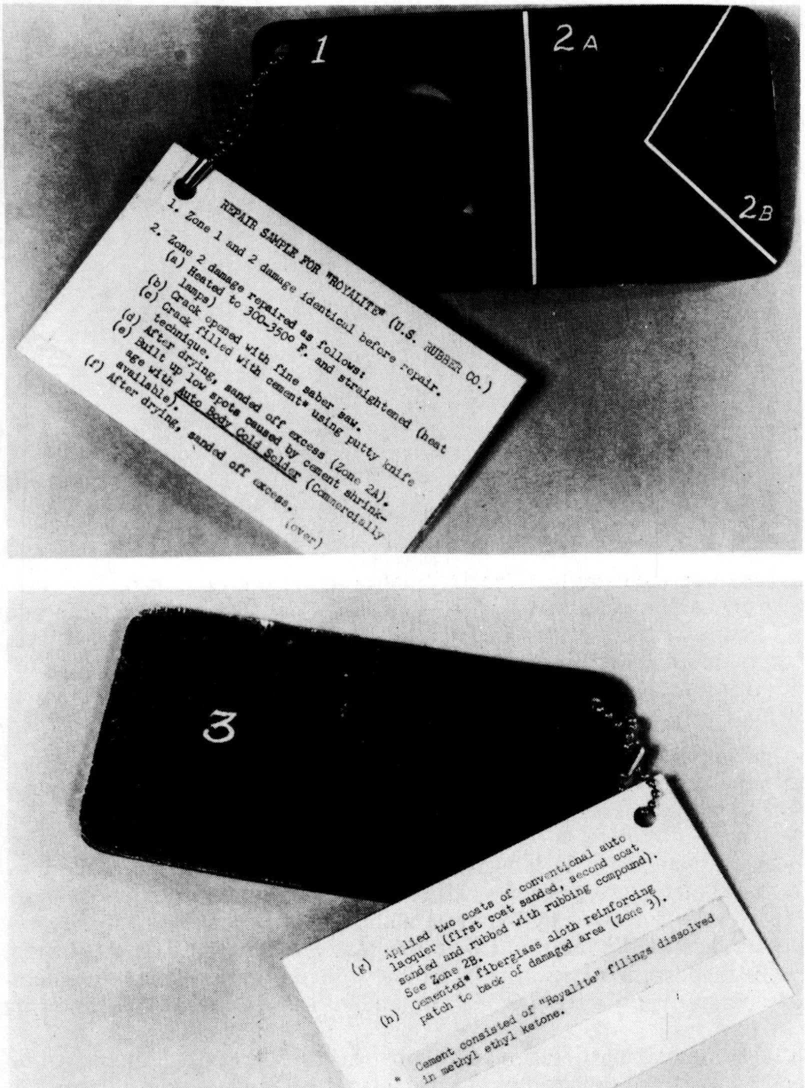


Figure 8. "Royalite" repair sample - demonstration unit.

of a steel component. Localized heating and "ironing" will restore a dented piece to the original contour (Figure 8). Cracks and tears can be repaired by filling with an appropriate cement.

The experimental impact testing disclosed one serious problem; at reduced temperatures (below $0^{o}F$), the thermoplastic sheet material tested became brittle and lost its impact tolerance. Verbal assurance by the manufacturer that this characteristic can be improved was received. However, this problem will need to be pursued further before unqualified recommendations can be made.

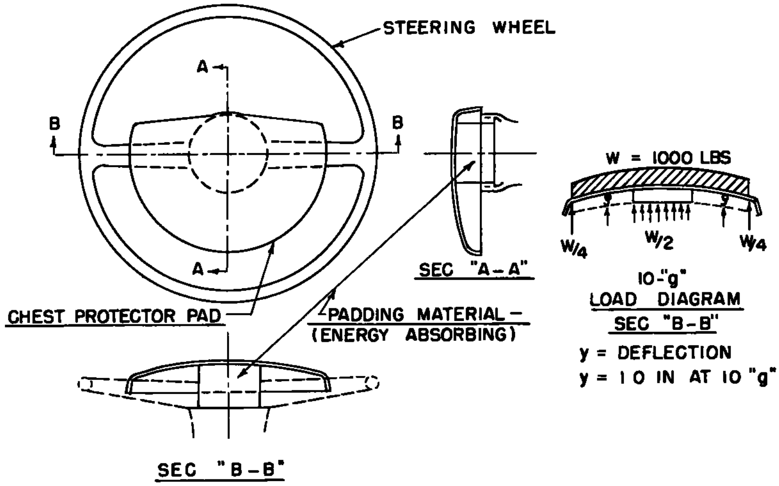


Figure 9. Chest protector pad general assembly and load diagram.

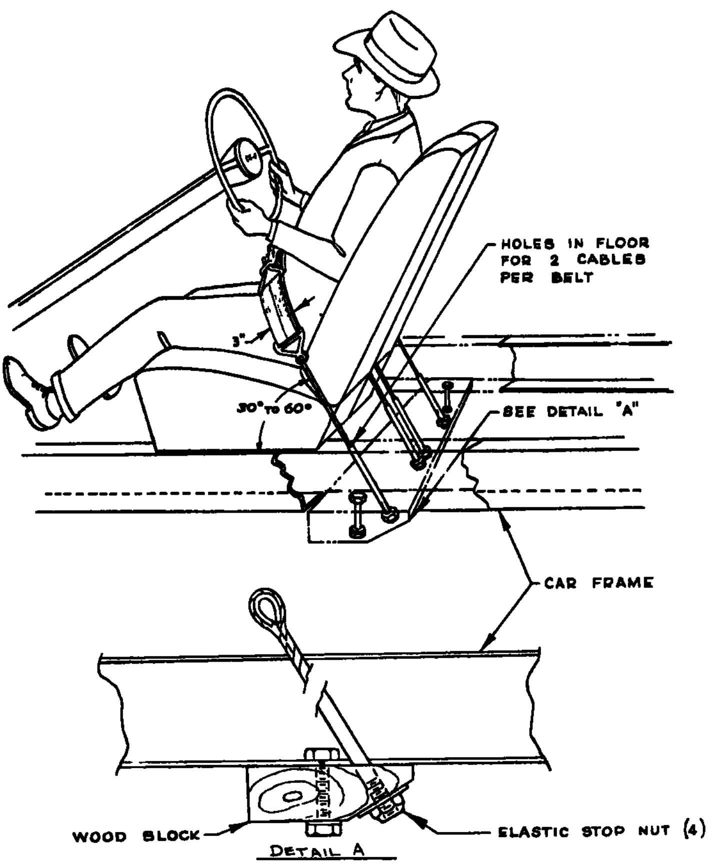


Figure 10. Suggested automobile seat belt installation.

Phase III. Phase III of the project was related to the protection or "safe packaging" of the occupant of a vehicle with emphasis placed on the development of items which could be readily installed as accessory equipment or replacement parts on existing vehicles. The primary efforts were directed toward the development of a "Chest Protection Pad," to be mounted on the steering wheel for protection of the driver against the known high injury potential of the steering wheel column. This device, designed to distribute an impact force over a wide area of the body and to absorb the energy of a body blow, was demonstrated to achieve a reduction of injury potential by a factor of approximately 4. The "Chest Protector Pad" consisted of a contoured sheet plastic shell to be attached to the steering wheel spokes with an energy absorbing padding material inserted between the column end and the shell (Figure 9).

Although no direct research efforts were expended, two additional facets of body protection are reviewed and are summarized below.

Seat belt design and installation design criteria are presented along with suggested design details for installation. The most pertinent point to consider is that the belt components, assembly installation fittings and anchorage should withstand a minimum static tensile load of 1500 lb., (Figure 10). The belt width should not be less than 2 inches and the angle of load application should be between 30 and 60 degrees to the horizontal.

Based on the results of earlier studies, an ideal padding material can be defined as one which is energy absorbing rather than energy storing but will have complete but slow recovery. It should have as low a spring rate as possible, consistant with the maximum thickness that can be utilized and the maximum impact energy anticipated (bottoming of the material under load cannot be tolerated).

CONCLUSION

We believe the monies, time, and effort expended in this particular research program have been completely justified from the standpoint of tangible experimentation with applicable results. Already, the research into motion characteristics of occupants, described above, has been incorporated as part of a larger research study sponsored by an automotive manufacturer to determine the hazards of front interior components of one of their vehicles.

Unquestionably, there still remains considerable research and development required in the field of automobile crash injury and human survival. To accomplish this search for means of eliminating the top rank hazard to human life, more funds must be earmarked for preventive research devoted to crash injury.

To make the results of such research effective in reducing fatalities and injuries resulting from car crashes, it will be necessary to create a demand from the buying public for such protection in their vehicles. This program of education, based on scientific proof, requires a campaign of practical demonstration of designed safety features which can be incorporated in their automobiles. It requires the same self-preservation motivation and professional showmanship which have shocked the public into understanding and combatting the evils of polio, cancer and tuberculosis.

Finally, the automotive industry, faced with the growing public demand for proven crash safety installations, can be expected to provide the designs needed.

In view of the necessary brevity of this presentation, I invite those of you who may be interested in specific details of this research, to write to Liberty Mutual Insurance Company, Loss Prevention Department, 175 Berkeley Street, Boston 17, Massachusetts. You will, upon request, be provided a copy of Report No. YB-846-D-1 as prepared by A. C. Smith of the Cornell Aeronautical Laboratory.