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REVIEW OF LITERATURE AND REGULATION RELATING TO THORACIC IMPACT TOLERANCE AND INJURY CRITERIA

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16. Abstract

The technical and scientific literature dealing with thoracic injury, to or within the rib cage, from blunt loading is reviewed. The history of the development of associated Federal Motor Vehicle Safety Standards is reviewed from the aspect of its relationship to the history of development of the research information. Field case data from car-to-car and car-to-tree/pole crashes has been examined and summarized.

This study suggests that the laboratory research has not adequately covered the principal variables found to exist in actual injury cases. Specifically, more research attention should be given to the shape of the impactor, to the loading location and direction, and to injuries in the contusion and/or laceration family. Correspondingly, the accident investigation process needs to be more sensitive to occupant/vehicle-interior interaction variables so that laboratory research can be properly guided.

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1.0 Introduction

The thorax, which houses vital body organs, is the site of more severe and fatal injuries (AIS 3-6) among automobile accident victims than any other body region (Ricci, 1980[1]).* Protection of this region is an important concern of automotive safety design engineers and the government agency who sets Federal Motor Vehicles Safety Standards (FMVSS). Just as in the development of knowledge about head/brain injury (see Hess, Weber, and Melvin, 1980[2]), regulators and engineers have been unable to rely on field accident data to study injury mechanisms. Instead they have used the more scientific data coming from laboratory impact experiments with animals, cadavers, and human volunteers to determine an acceptable level of protection and to measure whether or not a system achieves this level.

This study reviews the laboratory research on chest impact tolerance, as reported in the literature, and traces the development of occupant protection regulation by the National Highway Traffic Safety Administration (NHTSA) in relation to this research. Attention is focused on recent developments in biomechanical knowledge about the thorax, and suggestions for further research are made.

The main body of the report contains the review of significant literature and regulation relating to chest injury and impact tolerance and includes a list of the primary references. Appended to the report are excerpts from the Federal Register referred to in the review and an extensive bibliography. An additional appendix presents chest injury accident data from NHTSA's National Crash Severity Study (NCSS).

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*Superscript numbers refer to citations listed in section 8.0: References. Citations may also be identified by author(s) and date in Appendix B: Bibliography.

2.0 Early Research on Thoracic Tolerance and Injury Mechanisms: 1946-1966

Much of the research during this period, in which basic engineering data were sought with regard to thoracic impact tolerance and blunt injury mechanisms, is summarized in the state-of-the-art paper by Mertz and Kroell (1970)[3]. Only selected work reviewed there that relates to FMVSS development, as well as some whole-body acceleration research, will therefore be mentioned here.

Bierman, Wilder, and Hellems (1946)[4] reported on tests in which young male volunteers received chest impacts through a restraining harness attached to a dropped-weight device. With a standard lap/double-shoulder harness configuration (76 sq. in.), load "tolerance," defined as producing a painful reaction and various minor injuries, was found to be about 2000 lb. These tests led to the development of a vest-type restraining harness that distributed loads over a larger area (156 sq. in.) and absorbed some of the energy through controlled stretching. With this harness, peak loads in the range of 1800 to 3000 lb., the peaks being reached at 50 to 70 ms, were sustained without injury. The experiments also confirmed that rate of onset affected load tolerance, with peaks reached within less than 30 ms being "very uncomfortable."

Whole-body rocket-sled data provided by Stapp (1951)[5] and summarized by Eiband (1959)[6] indicated that harnessed thorax accelerations up to 40 g were tolerable as long as the duration of acceleration at this level did not exceed 0.1 second. The maximum voluntary tolerance observed was 45 g for 44 ms, with a pressure under the restraining harness calculated to be 36.5 psi. Rate of onset was again found to affect tolerance to maximum accelerations, with peaks of 30 g reached at 1000 g/s becoming debilitating.

A chest load limit of 2500 lb., which is in the range found tolerable by Bierman et al. above, was incorporated into Federal Standard no. 515/4 on energy absorbing steering systems that was issued by the General Services Administration (GSA) on June 30, 1965 [1]*, and revised as 515/4a on July 15, 1966 [2]. The test procedure involved a 15 mph impact with a 75- to 80-lb. torso-shaped body block (later to appear in an SAE standard) with a chest-area spring rate of 600 to 800 lb./in. An additional requirement was that the steering control system could not displace rearward more than 5 inches during a 30-mph (in the revised version) barrier test. Automobile safety engineers proceeded to design energy absorbing steering wheels and columns that would meet these standards.

In a brief paper describing the forthcoming SAE recommended test procedure for steering wheel systems (SAE J944, 1965[7]), Fredericks (1965)[8] noted that "the complex problems associated with tolerance of the thoracic region of the body and internal organs have not yet been delineated sufficiently to permit definition of meaningful performance requirements for chest impacts." He also observed that other parts of the body, including the abdomen, face, and neck, can also strike the steering assembly during a crash, depending on vehicle, driver, restraint, and accident variables, and that tolerance levels for these regions also need to be established.

At the Ninth Stapp Conference, static and dynamic thoracic stiffness measurements were reported by Patrick, Kroell, and Mertz

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*Bracketed numbers refer to excerpts in Appendix A of this report.

(1965)[9] for several embalmed cadaver subjects. Static loading in the anterior-posterior direction by a 4-inch-wide bar yielded force-deflection values from 185 to 400 lb./in. Chest impacts at 16.5 mph against a 6-inch-diameter padded target, however, resulted in approximately constant spring rates of 1000 lb./in. for loads up to 900 lb. for two different subjects. Rib fractures apparently occurred at this point and stiffness dropped markedly, but it then increased again to about 500 lb./in. as the internal organs began to be compressed. Peak forces of 1400 and 1600 lb. were reached in these tests, and chest deflection was about 1.5 and 2.5 in., respectively. Deflection was measured by way of film analysis of a rod inserted through the thorax and protruding from the back of the test subject. The authors pointed out the fundamental difference between the stiffness characteristics of the thorax under gradual vs. sudden loading conditions. The stiffer response in the latter case was explained as being due to the inertial force gradients developed in the thoracic cavity during impact and the viscous behavior of the thoracic viscera.

The behavior of the internal organs during blunt impact to the chest without rib fracture and the mechanism of resulting injuries to the arterial system were studied by Roberts, Moffat, and Berkas (1965)[10]. Anesthetized dogs were struck at midsternum by a 3-inch-diameter impactor. The authors found that tears in the aorta and great vessels were in the transverse rather than the longitudinal direction and therefore postulated that these tears were caused by the displacement of the heart into the left side of the chest, rather than by pressure surges within the vascular system during impact. This reasoning was probably invalid, however, because later work (e.g., Yamada, 1970[11]) has shown that arterial tissue is significantly stronger in the hoop-stress direction of the vessel than along its length and is thus more likely to experience transverse tears when stressed.

In 1966, the energy absorbing (EA) steering column, as described by Skeels (1966)[12], became standard equipment on most 1967 model-year domestic automobiles. A spectacular, very severe frontal collision was also reported, which was the first-known case of an EA column in a real accident. The lap-belted driver received no chest injuries whatever, the column having crushed 5 3/8 inches.

3.0 Standards Development: 1966-1972

3.1 FMVSS 203 and 204

In December 1966, NHTSA proposed its own regulations to supersede 515/4a. FMVSS 203, "Impact Protection for the Driver from the Steering Control System" [3], proposed to limit the force on the body block chest to 1800 lb., to limit the contact area pressure to 50 psi, and to require that the peak load would not be reached before 10 ms. A separate proposal, FMVSS 204, "Steering Control Rearward Displacement" [4], placed a 3 inch limit on this displacement.

Vehicle manufacturers argued that a need for a lower load limit, tested at 15 mph, did not appear to be based on laboratory test data, and that systems providing such lower loadings might in fact provide insufficient protection in real crashes at higher speeds. EA columns then in production had been designed to the earlier GSA specifications and were found to be working well in the field. The more stringent allowance for rearward displacement was objected to for similar reasons. The realism of the body block's chest stiffness was also called into question, as it would affect test results for both peak load and contact area pressure. Cadaver chests had indeed been found to be softer than the body block by Patrick et al. (1965)[9], both in static tests and in dynamic tests at high impact loads. A precise method for measuring contact area also needed to be specified.

Engineers involved with designing and testing EA steering systems had determined that other factors than those addressed in FMVSS 203 were important for adequate occupant protection. These design features affected the chest/shoulder load distribution and included the area of the steering wheel hub, the strength of the spokes, and the angle between the hub and the spokes, or the actual dish-shape of the system.

The rules [5,6] were finalized in February 1967. The maximum chest load was returned to 2500 lb., the allowable dynamic rearward displacement was again 5 in., and the pressure and rate-of-onset requirements were dropped. No changes were made, however, to the specifications of the body block. Later in the year, a general proposal [7] was issued stating that contact-area pressure and rate-of-onset limits were still being considered. An additional proposal [8] mentioned the possibility of requirements limiting occupant compartment intrusion from exterior impact to the front, side, rear, or roof of a vehicle.

Further chest impacts with a cadaver were reported by Patrick, Mertz, and Kroell (1967)[13]. Tests were run at increasing velocities for the same specimen and were aimed at determining rib fracture threshold. Findings were consistent with the earlier experiments, in that rib fracture apparently occurred at about 900 pounds of load during a 16.8 mph impact, and deflection was measured at 1.7 inches for a peak load of 1340 pounds. Impactor geometry problems precluded measurement of initial chest stiffness, but deflection of 1 inch occurred at about 1000 pounds load.

Design evaluation of the General Motors EA steering assembly was guided by Patrick's data and was reported by Gadd and Patrick (1968)[14]. Two embalmed, lap-belted cadavers were used in sled tests at 24.4 mph, and one subject was used in a second test at 29.4 mph. As the cadavers rotated around the lap belts into contact with the EA systems, the columns crushed from 4 to 5 3/4 inches, and the force developed on the upper body ranged from 1630 to 1810 pounds. No skeletal damage resulted from the lower speed tests, but rib fractures did occur after the higher velocity test on the repeated subject. In the case of this second cadaver, instrumentation allowed the separation of load measurements between the wheel rim and hub. Although total load was 1810 pounds in the non-injurious test, only 740 pounds were from the hub, well below the rib fracture threshold determined by Patrick et al. above for impact conditions similar to a hub alone. The wheel rim thus distributed the remainder of the load to the shoulders, abdomen, and head, but also without apparent injury. The authors concluded that the "wrap-around" effect observed in these tests significantly reduced chest loads, but that these reductions would not occur using the stiff body block of SAE J944.

The state of understanding of cardiovascular injury mechanisms during thoracic impact was summarized in the introduction to a medical-engineering study of 67 accident cases in which such injury might be expected. Lasky, Siegel, and Nahum (1968)[15] identified three possible occurrences: (1) shearing of vessels at their attachments to the heart, (2) direct compression causing bruising and other damage, particularly when heart displacement is restricted, and (3) development of fluid pressure waves within this closed system. The authors promoted the latter concept by introducing the idea of a "third collision" between the internal organs and the thoracic skeletal structure, during which "the sudden deceleration of the blood can produce a water hammer effect," or a large increase in pressure. Results of the study confirmed the value of EA steering assemblies and brought the problem of side impact injuries to light:

> The mechanisms of cardiovascular injury in side impact collisions appear to be caused both by direct impact with the side door and arm rest...They represent an increasing problem and will require rather specific design solutions that at least reduce interior penetration.

3.2 Side Impact and FMVSS 208

In December 1968, a proposal [9] on side intrusion protection was issued. Rather than providing specified limits, the proposal was in the form of a Consumer Information Regulation (CIR) that would provide an "intrusion protection value" for each car based on the work required to crush a door with a 12-inch-diameter cylinder to within 12 inches of the nearest occupant's centerline and scaled to the weight of the vehicle. Recognizing that occupants do not stay in place during impacts, the protection concept was modified in January 1970 [10] to test for the average force required to crush a door 12 inches. The resulting value was thus to be a measure of side door strength. This informational proposal, however, was never enacted.

Instead, a regulation [12] was proposed in April 1970 that would require minimum resistance of side doors to crush. NHTSA cited the following reasons for the proposal:

> Recent studies demonstrate that in side impacts the percentage of dangerous and fatal injuries increases sharply as the maximum depth of penetration increases, and that in fatal side collisions, most occupants die from side structures collapsing inward on them, rather than from their striking the door.

Tests resulting in three crush depths, 6, 12, and 18 inches, were proposed with minimum forces of, respectively, 2500 lb., 3750 lb., and twice the vehicle's weight to effect this crush. The intermediate test also included a vehicle-weight adjustment factor. In the final FMVSS 214 rule [16] issued in October, however, the force for the "initial" crush resistance test was lowered to 2250 lb. for the benefit of small cars, the weight factor was removed and the force reduced to 3500 lb. for the "intermediate" test, and a ceiling of 7000 lb. was placed on the "peak" crush test for the benefit of larger cars.

A proposal [13] issued in May 1970 was the first to incorporate automatic (passive) crash protection into FMVSS 208. The restraint systems were to be tested against "basic injury criteria with reference to an anthropomorphic dummy, expressed in terms of maximum forces and pressures on critical parts of the body." The tests were to use the dummy described in SAE J963 (1968)[16] and consisted of a frontal fixed-barrier crash at 30 mph the first year as well as lateral and rollover tests the following year. The proposal specified that "the resultant chest acceleration shall not exceed 40 g." Unlike the criteria for head protection, acceleration was not allowed to exceed this limit even for a few milliseconds. In addition, the force developed on the chest was limited to 1200 lb. and the pressure to 50 psi.

Arguments from the automobile industry and justifications from NHTSA have been summarized in a report by the U.S. National Transportation Safety Board (1979)[17]. In a moment of candor at a public meeting on the proposal, an NHTSA spokesman stated that its problem was "to establish levels of tolerance based on the best data which was available. In some cases, the data was not available." An industry spokesman certainly agreed when he commented that "apart from the requirements of S.4.4.2 [head acceleration criteria], we know of no published data which could have been used as a basis for the injury criteria levels given in this section." Indeed, the use of resultant acceleration at a single location as a measure of potential injury is more appropriate to a somewhat rigid body, such as the head, than it is to a very flexible structure like the thorax. Although the chest dynamic spring rate specified for the SAE J963 dummy was 800 to 1000 lb./in., a range similar to initial chest stiffness found experimentally in cadavers, the relationship between the test criteria and real injury was questionable.

In the laboratory, research continued with the goal of establishing reliable thorax dynamic response and injury tolerance data. Nahum, Gadd, et al. (1970)[18] conducted tests of both embalmed and unembalmed cadavers and compared the results to those of Patrick et al. (1965)[9] and (1967)[13]. Subjects were struck at known velocities by a 6-inch-diameter, 42.5-pound, rigid surface impactor. This test method effected impact conditions similar to those of the earlier tests. Load-deflection curves and rib fracture data, both from X-ray diagnosis and dissection, indicated that the fracture threshold occurred at about 2 inches deflection, a value consistent with Patrick's findings, but that thoraxes were less stiff and damage occurred at lower loads than in the earlier studies. The unembalmed specimens in the current study sustained larger deflections and more fractures at lower force levels than did the embalmed cadavers in any of the studies. Rib fractures occurred in five of six unembalmed subjects under maximum loads ranging from 350 to 680 lb. The authors postulated that the differences in gross chest stiffness might be related to differences in embalming procedures, as well as the lack thereof, but they cautioned that an unembalmed, aged cadaver subject might not in fact be a good representation of the living vehicle occupant population. The authors also suggested that thoracic injury criteria should be based on actual internal injury to the lungs, liver, aorta, etc., rather than on rib fracture only.

A revised FMVSS 208 proposal [14] was issued in September 1970 that allowed a cumulative period of 2 ms during which chest acceleration could exceed 40 g. In addition, the requirements for force and pressure limits were dropped. NHTSA stated that "Most commenters felt that the force and pressure measurements specified were beyond the state of the art," and that criteria based on acceleration alone was determined to be adequate. In the same Federal Register issue, however, NHTSA proposed [15] to lower the allowable loads on the body block chest in FMVSS 203 back to 1800 lb., while raising the test velocity to 20 mph. As justification, the agency stated that "The increasing amount of knowledge about thoracic injury threshold levels suggests that the allowable forces should be reduced." In addition, a minimum contact area of 40 square inches would be required, the steering wheel hub would have to be padded, and the rim flexible enough to allow body block contact across its full diameter. These changes were never put into effect, however, and no new revisions of the FMVSS 203 requirements have been proposed.

In November 1970, the first automatic restraint rule [17] was issued, with the chest acceleration at 40 g, except for 2 ms, as proposed. The force and pressure criteria were dropped because they "were primarily related to belt-type systems, and it has been found that no accurate means of determining these values presently exists." At the same time, a limit on the lateral component of chest acceleration of 20 g, except for a cumulative period of 2 ms, was proposed [18], along with lateral and rollover tests. NHTSA claimed that "biomechanical studies" were showing tolerance to lateral acceleration for both head and chest to be much less than frontal tolerance. A review of the literature on animal and human lateral impact tests, reported later by McElhaney, Stalnaker, et al. (1971)[19], supported this contention.

3.3 Injury Indexes and Changing Criteria

The Severity Index (SI), as described in SAE J885a (1966)[20], had become generally accepted as a fruitful step in the direction of calculating head injury potential, but there were no corresponding index and threshold values for the chest. At the Fourteenth Stapp Conference, Brinn and Staffeld (1970)[53] proposed a damage index, based on the relative displacement of body organs and structures, that could replace the SI for head acceleration tolerance and could also be used to predict thoracic injury from whole-body acceleration and blunt impact. This Effective Displacement Index (EDI) used a simple spring-mass model for the body part of interest to determine displacement as a result of input pulses of various shapes and durations. For whole-body rocket-sled data (Stapp, 1951[5]), the authors calculated not only the EDI but also the SI, noting that the latter had been employed for chest impacts by "some safety testers." The tolerable 45-g run referred to previously resulted in an SI of 972, a value very close to the head injury threshold of 1000. No SI's were calculated, however, for blunt chest impact experiments. For assessment of the latter type of injury, that found most commonly in the automotive environment, the authors recommended obtaining the EDI from a direct measurement of sternal deflection. In their closure, however, they commented that the crushing injuries now seen might change to the inertial-type injuries of the rocket-sled tests if broad, soft surfaces, such as air bags, proved practical in the future.

In February 1971, NHTSA announced [19] its intention to relax the chest injury criteria by raising the maximum resultant chest acceleration to 60 g, except for a cumulative period of 3 ms, in tests of automatic restraint systems. No separate lateral limit was mentioned. The rule [20] was issued in March with the 60-g/3-ms requirement, to be measured at the center of gravity of the upper thorax, along with the following comments:

> Several petitions stated that the chest injury criteria were set at too low a level. In some respects, a higher "g-level" on the chest actually increases the protective capabilities of the system, if properly designed, since it more effectively utilizes the available space in which the occupant can "ride down" the crash impact--an especially important factor in higher speed crashes.

In the same ruling, the SI was adopted as the criterion for head protection, but it was rejected for the chest because "The severity index is based on biomechanical data derived from head injury studies and does not adapt itself readily to chest-injury usage."

Ever since the SAE J963 dummy had been established as the test device, there had been objections on the grounds that it was inadequately specified and did not therefore yield repeatable test results. In addition, it was not designed to provide human-like biomechanical response. Once the rule was issued, with the justification that the dummy was "the best available," criticism mounted, and the issue became the basis of a suit to block the entire automatic restraint ruling.

In October 1971, a further proposal [22] was made that would require manual belt systems, which were to have been temporarily allowed and had hitherto been exempt from the test procedures, to meet the same injury criteria as the automatic systems and also include an ignition interlock. These requirements were adopted in February 1972 [23] to become effective August 1973.

At the Fifteenth Stapp Conference, Mertz and Gadd (1971)[21] provided some interesting support for the 60-g limit on chest acceleration. An instrumented stunt man jumped from 57 feet to land on his back on a thick foam mattress and registered a resultant acceleration at midsternum of 49.2 g without discomfort. After additionally reviewing human tolerance literature, the authors concluded that there was no evidence that "even a 60 g chest acceleration level would not be tolerable with an adequate restraint system" for pulse durations less than 100 ms. They recognized, however, that frontal chest impacts were characterized by compression, and that "internal organ tolerance to trauma produced by chest compression should be specified in terms of a thoracic compression limit and not an acceleration limit."

NHTSA responded in July 1972 [24] to petitions that the injury criteria requirements were not appropriate for belt systems. "To ease the [chest] requirement somewhat without permitting excessive long duration accelerations," NHTSA ruled that SI<1000 would now become the chest injury criterion for seat belt systems manufactured before August 1975. Other restraint systems continued to be required to meet the the 60-g/3-ms criterion, and it was expected that belt systems would also eventually be able to meet the same criterion. In response to comments that the SI was not intended for chest application, NHTSA stated in October that "it provides a reasonable interim measure of the effectiveness of the belt system" [25]. Two days later, a proposal [26] was issued to extend SI<1000 as the chest injury criterion for all types of restraints manufactured before August 1975, because the former criterion "causes occasional failures of restraint systems whose overall protective capabilities are judged to be good." The agency went on to say "the index operates as a check on the high amplitude, long duration spikes that present the greatest hazard to vehicle occupants." The rule [27] incorporating the above was issued in November 1972.

4.0 Dummy Development and Evaluation: 1972-1978

During this period, experimental work was largely directed toward establishing data upon which an anthropomorphic test device (ATD) with a reasonable degree of biofidelity could be constructed. Many imagined that such a test device could become the primary human surrogate for automobile crash testing.

4.1 Impact Response Corridors

Impact tests of ten cadaver chests, using a 22-pound, 6-inch-diameter impactor at 13 mph, were performed by Stalnaker, McElhaney, et al. (1972)[22], and force-deflection curves were reported and compared to results of previous experimenters. The most consistent finding was the relationship between rib fracture and rib cage deflection, no fractures being associated with deflections up to 2.1 inches in this study. Static compression tests using both human volunteers and cadavers confirmed that chest stiffness varied upward relative to the following conditions: (1) unembalmed cadaver, (2) embalmed cadaver, (3) relaxed volunteer, and (4) tense volunteer. The middle two, however, overlapped to a large extent.

Using dynamic load-deflection data published previously by Nahum et al. (1970)[18] and Kroell, Schneider, and Nahum (1971)[23], Lobdell, Kroell, et al. (1972)[24] developed recommended chest response corridors for these two velocity/impactor-mass conditions as performance guidelines for the design of dummy chest structures. Basically, for a 16-mph impact with a 51-pound mass, forces up to 1200 pounds and deflections up to 3 inches were considered acceptable. Five dummy designs currently in use were then tested under the same conditions. None, including the General Motors Hybrid I, responded within the corridors. In general, the deflections were reasonable up to 1 inch (the spring rate in SAE J963 was measured in the .75- to 1.0-inch range), but the forces required to continue deflection were much too great. None of the dummies tested achieved compressions beyond 2 inches. If used to test a restraint system, these dummies would yield excessive chest loads and accelerations. Finally, a mathematical model of a thorax and impactor was developed that was based on a 3-mass, 4 degree-of-freedom mechanical analog. The model simulations were found to correlate well with actual cadaver impact tests, including that of Stalnaker et al. (1972)[22]. The authors suggested this model could be used as a tool for improving dummy thorax design.

4.2 Part 572 and Other ATD's

As a result of the court decision of December 5, 1972, invalidating the FMVSS 208 test procedures because the test dummy was not adequately specified, NHTSA proposed [28] to adopt the GM Hybrid II as the test device for automatic restraint systems. This commercially available dummy had adequate documentation and was known to be highly repeatable. The chest structure was quite similar to the Hybrid I, however, and its impact response did not therefore fall within the corridors recommended above, but neither did the chest stiffness specified in the proposed regulation. The test procedure called for a 51.5-pound, 6-inch-diameter impactor to strike the dummy chest at 14 fps (9.5 mph) and 22 fps (15 mph). The forces were not to exceed 1400 and 2100 lb., respectively, and the deflections were not to be greater than 1.0 and 1.6 inches. These values described the performance of the Hybrid II, but did not particularly relate to the human. Nevertheless, a new Part 572 was added to Title 49 of the Code of Federal Regulations in August 1973 [31] that established this "Part 572 dummy" as NHTSA's test device.

In the meantime, another court decision related to test dummy inadequacies resulted in the issuance of a regulation [30] in June 1973 that eliminated all dynamic tests for manual belt systems as long as they were allowed. Automatic belt systems would still have to meet certain injury criteria under dynamic test conditions.

Later that year at the Seventeenth Stapp Conference, another test device, "Repeatable Pete," was introduced by McElhaney, Mate, and Roberts (1973)[25]. The general design goals for this dummy were repeatability, reproducibility, biofidelity, and durability. The chest was designed and constructed to match the dynamic response of unembalmed cadavers as determined by Stalnaker et al. (1972)[22] in 13-mph impact tests. Similar tests of the dummy's chest showed that its load-deflection curve fell within that cadaver test-band. The development of this dummy thorax was therefore a closed-loop process, in which the same laboratory made mechanical measurements, designed a physical model, and evaluated this model using the same equipment, instrumentation, and procedures. The result was a repeatable test device that also had good biomechanical response.

At the Third International Conference on Occupant Protection in 1974, Neathery, Mertz, et al. (1974)[26] presented their evaluation of this dummy. Although they found that it was superior in many respects to the GM Hybrid II, particularly with regard to thorax biofidelity, they did not think the complete dummy system was sufficiently developed to be used for restraint system qualification testing.

Tennant, Jensen, and Potter (1974)[27] then reported on another dummy, the GM-ATD 502, which was developed under contract to NHTSA. General goals were similar to those of the HSRI program, but thorax impact response was to be within the load-deflection corridors recommended by Lobdell et al. (1972)[24]. This latter objective was not met, and the authors recommended that this dummy also not be used to determine the protective capabilities of restraint systems because of its insufficient biofidelity. The authors pointed out the problems of developing a dummy component based on the best available biomechanical data, but then having to test it as part of a complete dummy system.

> It means that the performance of structures such as the neck, lumbar, and arms are also a part of the results of this test. Therefore, the rib-cage performance indicated by this test changes if any of the other components perform differently, and the development of the rib-cage depends on these other

components being in the final design testing stage and being repeatable.

4.3 Deflection Criteria: Further Cadaver Impact Data and Analysis

Tolerance to lateral impact was the subject of a paper by Stalnaker, Roberts, and McElhaney (1973)[28] also presented at the Seventeenth Stapp Conference. The 22-pound, 6-inch-diameter impactor, used in the frontal experiments, was again used here, but both a flat surface and one simulating an armrest were employed. The impact device could be preset to stop within a range of 1.8 to 3.8 inches and could maintain a constant velocity up to 3 inches of penetration. Impacts were made to both human cadavers and live infrahuman primates. Data from the latter tests were scaled relative to chest depths and breadths (called an aspect ratio) to estimate human side impact tolerance. Results of both series led to a deflection criterion for predicting chest injury. The authors suggested that a lateral deflection of 2.65 in., achieved during a 21.6-mph, 25-ms impact, would result in a 900-lb. load and a serious, but reversible injury, or level 3 on the Abbreviated Injury Scale (AIS).[3] (The deflection value was later corrected by Melvin, Mohan, and Stalnaker (1975)[29] to 3.72 in. for an AIS-3 injury, while 2.65 in. was estimated to be a non-fracture deflection level for the average male.)

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[3] This 6-point injury scale is briefly: 0 none, 1 minor, 2 moderate, 3 serious, 4 severe, 5 critical, 6 unsurvivable. At this time, rib fractures were coded as AIS-2 or 3. In 1980, the scheme was revised, and rib fractures alone are currently considered AIS-1 or 2. Further internal injury results in a higher AIS. For details see both Abbreviated Injury Scale, 1976 Revision and 1980 Revision; Morton Grove, Ill., American Association for Automotive Medicine.

Commenting on the various parameters that might be used to evaluate chest injury, the authors eliminated acceleration as being "very awkward because of the different accelerations encountered throughout the chest during impact," and force as being "cumbersome because of its dependence upon the weight of the upper torso." They concluded that, "Since most chest injuries were found to be related to the deflections of the rib cage, chest displacement was chosen for this study as the indicator for thoracic injury." The findings of this and the previous frontal-impact study (Stalnaker et al., 1972[22]) were later conveniently summarized and integrated by Stalnaker and Mohan (1974)[30], but this paper should be used in conjunction with the corrected figures found in Melvin et al. (1975)[29]. Basically, however, the conclusion was that, for either frontal or lateral impact, a chest deflection in the range of 30% to 35% of the corresponding chest dimension would result in an AIS-3 level injury, while a deflection of up to 20% to 23% would probably not result in any fracture.

Kroell, Schneider, and Nahum (1974)[31] reported data from 23 additional cadaver tests at the Eighteenth Stapp Conference. These data were integrated with previous results (Nahum et al., 1970[18] and Kroell et al., 1971[23]) and full documentation of test procedures and results were provided. After impact, the cadavers in this series were subjected to complete thoracic and abdominal necropsy, and AIS values were assigned. Correlation coefficients were then calculated for AIS vs. both peak load and chest deflection, the latter being expressed as a percentage of chest depth. Correlation with force was poor (r = .524), but deflection again proved to be a reasonable predictor of injury (r = .772), with AIS-3 injuries being associated with chest deflections in the range of 28% to 33%, although the regression line indicated 34% deflection for AIS-3 when all injury levels were analyzed. The authors suggested that further parameters, such as cadaver age and size, would contribute to an even better correlation. Although further analysis was indicated, this work was significant in that enough data of a similar type existed to allow such models of injury potential to be developed.

Neathery (1974)[32] was motivated to perform such a multivariate analysis of the available chest impact data, because these data applied to subjects of widely varying physical characteristics but were being used to predict the response of a 50th percentile male. The author therefore wished to find an appropriate means of scaling these data to determine thoracic response corridors for a range of dummy sizes. Using dimensional analysis methods, six dimensionless terms were devised based on cadaver characteristics (mass, height, chest depth, age), test conditions (impactor mass, impact velocity, gravity), and test results (peak plateau force, maximum impactor penetration).

Neathery's intent was to use data from both the Kroell group and the Stalnaker group, but detailed analysis indicated that impact responses in the two series were not similarly related to the variables chosen. Male and female data also were not apparently comparable. Regression equations to predict various impact response values were therefore developed only for the ten male cadavers from Kroell's early series. These cadaver equations were then manipulated to produce dummy response prediction equations (the age factor being dropped), and scaling rules were developed for determining biomechanically acceptable force-deflection corridors for 5th, 50th, and 95th percentile dummies tested according to Part 572 [29]. These dummy equations and associated corridors were then revised in an appendix to take Kroell's later data, just discussed, into account.

The realism of the test procedures and compliance criteria of FMVSS 208 were again called into question at the Nineteenth Stapp Conference. Although the resultant acceleration was supposedly measured at the center of gravity of the upper thorax, the accelerometer was in fact mounted on a rigid spine box, and thus it was thought to reflect spinal acceleration. Nahum, Schneider, and Kroell (1975)[33] compared sternal and spinal accelerations and resulting SI's for 18 of the unembalmed cadaver experiments reported previously (Kroell et al., 1974[31]). The authors concluded that SI<1000 is meaningless for either measurement location, the sternal SI's sometimes exceeding 20,000 and the spinal SI's usually being under 50. Although the spinal SI did correlate well with AIS (r = .720), normalized chest deflection was still recommended as the best predictor of injury for blunt impacts. The authors also attempted to calculate chest deflections by taking the difference between the second integrals of the sternal and spinal accelerations. These values were consistently high, however, and the technique was determined to be unreliable unless more precise acceleration measurements could be made.

Neathery, Kroell, and Mertz (1975)[34] carried forward the previous dimensional analysis work to develop equations predicting AIS for cadavers, using data from both the Kroell and Stalnaker series, and then to establish recommended chest deflection limits for dummy test criteria. Dummy "age" was set at 45, and the corresponding penetration-to-depth ratio (or percent deflection) associated with AIS-3 injuries was determined to be .3868. Allowable penetration for a 50th percentile male dummy was thus 3.48 inches based on a chest depth of 9.0 inches. The allowable percent deflection recommended here is greater than those suggested by Melvin et al. (1975)[29] and Kroell et al. (1974)[31], because the latter did not adjust for age.

Neathery et al. went on to specify appropriate biomechanical response corridors for the three dummy sizes in terms of sternal deflection, which is approximately 0.5 inch less than maximum chest penetration. In the process of arriving at these recommendations, the authors first demonstrated, with cadaver blunt-impact data, that the force produced by the impactor on the cadaver sternum was not predictive of the injury sustained, while at the same time body-block chest load was being used in FMVSS 203 to certify EA steering systems. They also cited the work of Nahum et al. (1975)[33] on the apparent lack of validity of the spinal acceleration and SI injury criteria of FMVSS 208, and they pointed out that biomechanical response corridors have been defined in terms of load-deflection and not acceleration. The authors therefore came to the conclusion that, only if a dummy has proper biofidelity and if a chest deflection criterion is used, can that dummy predict injury under conditions of blunt frontal impact to the chest. Further, if current practices are invalid for predicting blunt injury, such as from a steering system, they must also be questioned for other occupant protection environments.

As a final word on deflection, Viano (1978)[35] cautioned against emphasizing thoracic skeletal damage to the exclusion of organ and vascular injury, which is in fact more serious. After reviewing the Kroell series of cadaver data, he concluded that deflection and injury potential have a linear relationship only to a point, and that beyond that point the rib cage collapses and the likelihood of "life-threatening" injury increases dramatically. He suggested that this stability limit for frontal chest loading was a penetration-to-depth ratio of about .32, which is consistent with previous estimates. The important point to note, however, is the critical need to stay below this level of compression lest serious injury result.

4.4 Load Criteria: Integration of Laboratory and Field Accident Data

During the period under discussion, a number of programs combining accident investigation and laboratory simulation were undertaken. Gloyns and Mackay (1974)[36] reported that not all steering systems complying with FMVSS 203 actually provided protection for their drivers from serious chest and abdominal injury. Further, the authors observed that the damage sustained by certain systems under standard test conditions did not resemble that seen in the field. They found that a criterion of peak load alone could not distinguish between protective and non-protective designs, but that differences could be shown if effective loaded area was also taken into account.

Patrick, Bohlin, and Andersson (1974)[37] analyzed the injury experience of 169 Volvo occupants restrained by three-point belts and compared this to results of 72 sled simulations using instrumented pre-Part 572 dummies in a standard Volvo interior environment. Belt loads and accelerations were measured during the tests, and SI values were calculated with the goal of determining reasonable injury threshold parameters. Among the actual accident victims, chest injuries were the most prevalent. The authors calculated that there was a 50% chance that these occupants would receive at least an AIS-3 injury at a barrier equivalent velocity (BEV) of 45 mph, which, for a dummy in the Volvo system, would result in a peak chest acceleration of 85 g, an SI of 560, and a load at the upper end of the shoulder belt of 1930 lb. The authors suggested therefore that the 60-g limit (even with the 3 ms exclusion) was too restrictive, and that the SI<1000 criterion left too much leeway. The SI was also found not to be a suitable predictor of rib fracture, these fractures occurring when the SI's were estimated to range from essentially zero to 710. Belt load at the upper end of the shoulder harness was found to be "the most sensitive parameter to thoracic injury" because of its direct association with forces on the chest. Even so, rib fractures occurred in crashes ranging from 10 to 53 mph, which, when simulated, resulted in belt loads on the dummies ranging from 800 to 2310 lb. Even at the higher velocities, fewer than 40% of the occupants did indeed sustain fractures. The injury tolerance variability shown by these data emphasizes the difficulties inherent in trying to establish meaningful injury threshold parameters.

Three papers comparing experimental injuries to cadavers with injuries observed in actual crashes were presented at the Nineteenth Stapp Conference: Cromack and Ziperman (1975)[38], Patrick and Levine (1975)[39], and Tarriere, Fayon, et al. (1975)[40]. All three investigations dealt with cadavers and occupants restrained by three-point lap/shoulder belts, and all found that the cadavers received more severe chest injuries in similar crash environments than did their living counterparts, although the nature of the injuries was the same.

Patrick and Levine, in their study, measured upper torso belt loads on the nine cadavers tested. (The horizontal load component was also calculated, these being generally 10% to 15% lower than the measured load at typical shoulder belt angles, but only the latter loads will be cited to facilitate comparison with other studies.) For tests ranging from 20 to 40 mph BEV, loads resulting in rib fracture ranged from 1020 to 1930 lb., while the range for non-fracture was 560 to 1560 lb. Although the two 20-mph runs did not result in rib fracture, three of the four 40-mph runs did produce fractures. In contrast, rib fracture did occur among the Volvo occupants at speeds under 20 mph, but a lower percentage of living occupants received fractures at the higher speeds than did the cadavers. The authors also pointed out that the average number of ribs fractured per subject was much higher for the cadavers (5.6) than for the Volvo occupants (0.9) at BEV's of 30 mph or more. Although age can be a factor, it was probably not significant here, the cadavers in this series ranging in age at death from 32 to 61 years. Despite the range of tolerance displayed in these as in other tests, the authors suggested that the threshold for cadaver rib fracture corresponded to a horizontal upper shoulder belt force of about 1000 lb.

Fayon, Tarriere, et al. (1975)[41] also found that when adjusted for subject weight, the load on the thorax correlated fairly well (r = .71) with the number of rib fractures in 31 dynamic tests using three-point belted cadavers. The authors also showed that the relationship between deflection and injury is dependent on the rate of loading and on the nature of the load application (i.e., belt or disk impactor). The correlation between chest acceleration and injury was found to be poor.

In the meantime, FMVSS 208 still used acceleration as the basis for the chest injury criterion for all automatic restraint systems, SI<1000 also still being allowed as the "interim" criterion. Manufacturers requested that the SI be made permanent because it emphasized the importance of impact duration relative to injury tolerance and also, no doubt, because it was clearly a very generous criterion. NHTSA responded in July 1976 [34] and, for administrative reasons, did propose to extend the SI into August 1977, which, by default, would reinstate the "reasonable" 60-g/3-ms criterion after that time for both frontal and lateral impact tests. The agency claimed that, "Two years of frontal and oblique crash testing involving 20 vehicles and 56 dummies supports this conclusion, in that no dummy recorded chest accelerations greater than 60 g for more than 3 milliseconds." In the same notice, NHTSA suggested that the lateral and rollover test requirements might be dropped if manual lap belts were supplied along with otherwise automatic systems. In August 1976, the extension to August 1977 was formally made [35], but other issues were left unresolved.

At the 6th Experimental Safety Vehicles Conference, Eppinger (1976)[42] reported his analysis of 108 experimental impact tests with cadavers, restrained by three-point belt systems, that had been conducted in recent years. He found that the number of ribs fractured was a statistically significant function of cadaver weight, age at death, and maximum upper torso belt force. Using dimensional analysis to scale the weight factor and statistical analysis to account for age, a relationship between thoracic fractures and shoulder belt load was developed. This relationship was applied to the driver/passenger population for a 30-mph frontal barrier impact to derive an optimum load limit, given certain belt slack, that would minimize rib fracture. The optimum level for 2 inches of slack was 1300 lb., and for 3 inches of slack the level rose to 1500 lb. Eppinger also suggested that further analysis was needed to address the problem of life-threatening internal organ injuries.

In December 1976, a notice [36] was issued asking for comments as to how belt restraint systems could be improved. While indicating that injury criteria might be reinstated for manual belt systems, NHTSA suggested that an upper torso belt load limit might also be added.

Foret-Bruno, Hartemann, et al. (1978)[43] were able to relate vehicle occupant injuries to shoulder belt loads, in frontal crashes involving Peugeot and Renault vehicles, because of an energy absorbing belt system in which several ribbons of fabric tear successively as the force increases. No rib fractures were received by occupants less than 30 years old under loads up to about 1630 lb. After age 50, however, fractures began to occur at about 950 lb. Comparing these results to Eppinger's predictions of rib fractures in cadavers of the same ages, the authors found that cadavers could be expected to sustain from 3 to 5 more rib fractures than did the living occupant.

5.0 Global Approaches to Thoracic Injury: 1976-1980

Investigations into thoracic injury tolerance and its measurable indicators had, until this time, concentrated on localized impacts to human surrogates instrumented with one or perhaps two sensing devices. A new approach, described by Robbins, Melvin, and Stalnaker (1976)[44], used ten accelerometers located on the sternum, spine, and ribs at prescribed points around the thorax. This array of sensors allowed the measurement of the kinematic response of this flexible, ellipsoidal body, subject to blunt impact in various test modes and including different impact directions. From these acceleration measurements, the magnitude and velocity of deformations could be inferred. These data describing global thoracic motion would then be correlated with observed injuries. The system was designed to be usable both with cadavers and with dummies.

The first series of experiments, reported by Robbins et al., were frontal impacts using 13 cadaver and 20 baboon subjects restrained by three-point belts, EA steering assemblies and/or airbags. AIS was used as the indicator of injury level, rather than number of fractures, because the former addressed the full range of thoracic injuries. Various combinations of anthropometric and accelerometer measurements were used to try to develop linear regression models that would predict injury levels. With the limited number of subjects and the many possible parameters, the modeling effort was not as successful as had been hoped. The baboon series, however, in which the subjects were more similar to each other, yielded better predictions than the cadaver series, the former having an average error of less than 0.13 AIS.

Side impact experiments that followed the frontal impact series were reported by Melvin, Robbins, and Stalnaker (1976)[45] at the 6th Experimental Safety Vehicles Conference. These tests compared the kinematic response of cadavers to that of the Part 572 dummy and the British Transport and Road Research Laboratory (TRRL) side impact dummy. (The TRRL dummy had no arms; design details can be found in Harris, 1976.[46]) The same ten-accelerometer system was used on the thoraxes of the seven cadavers, but the two dummies were instrumented according to Part 572 requirements. The subjects were seated sideways on the sled next to either a rigid wall structure or a padded, contoured surface representing a vehicle side interior. At impact, the subjects slid into these structures. The differences in whole-body kinematics were marked and were due primarily to the very compliant shoulder structures of the cadavers compared to the fairly rigid dummy structures. The visually obvious consequence of this difference was the response of the head/neck system. The side of the cadaver heads impacted the wall with considerable force, while the dummy heads rotated laterally and barely touched the wall, if at all. Further implications were apparent, however, for determining thoracic injury potential, if indeed existing dummies did not deform as humans do. It was clear that these dummies were totally inappropriate for side impact testing. It should also be noted that, in the 20-mph lateral impact using the padded structure, the Part 572 dummy recorded a left-right acceleration of 102 g, while the cadaver recorded 19 g.

In February 1977, NHTSA issued a rule [37] that relaxed certain requirements for dummy thorax calibration. In the preamble to the rule, NHTSA claimed not to agree with criticism from vehicle manufacturers that "the dummy construction is unsuited to measurements of laterally-imposed force, thereby rendering the dummy unobjective in the lateral impact environment." The agency added, however, that NHTSA's current proposal to drop lateral and rollover tests if lap belts were used gave the manufacturers a way out.

The rule [39] allowing the lap belt in lieu of these dynamic tests was issued in July 1977, making the whole question of dummy lateral response characteristics "largely academic," according to NHTSA. The agency also addressed the industry's request that "the severity index be continued as the chest injury criterion until a basis for using chest deflection is developed in place of chest acceleration." It was further suggested that "a shift from the temporary severity index measure to the

60-g/3-ms measurement would be wasteful," because there was "no strong indication" that one was more meaningful than the other. NHTSA responded that the SI was only an indirect limit on acceleration and therefore allowed higher loads than did a direct limit on acceleration. The latter was considered to be a better injury predictor under specific test conditions. The 60-g/3-ms criterion was thus retained. In the following year, the criterion was also incorporated into a proposed revision of FMVSS 213 on child restraint systems [40], despite a lack of biomechanical test data to indicate its validity for children, and became part of the rule [42] in December 1979.

The Robbins series of frontal and side impact experiments with cadavers was increased to 51, the additional tests being primarily controlled frontal and lateral tests with a 51.5-lb. flat-faced impactor. For these tests, two additional accelerometers were added to the spinal locations. With these data, a new approach to injury-predictive modeling, using a non-linear Adaptive Learning Network (ALN) program, was tried and reported by Eppinger, Augustyn, and Robbins (1978).[47] With the goal of eventually being able to duplicate as much of the kinematic response of cadavers as possible in a dummy structure, models were exercised with increasingly fewer parameters to reach an optimum set that might be mechanically feasible while still adequately predicting injury. Both AIS and number of ribs fractured were used as injury measures.

The parameters chosen for analysis included measured accelerations, first and second integrals of these, and differences between accelerations at two points. Data from both frontal and lateral impacts were included, as well as cross-products of values for each to create "oblique" parameters. Age and sex were also used. The maximum number of parameters was 13, and, with the full set, high predictive capabilities were achieved for both AIS and rib fractures. However, the AIS model using only seven parameters was nearly as good ($R^2 = 91.1$), and, for rib fractures, nine parameters were adequate ($R^2 = 94.6$). It is interesting that age did not prove to be a significant variable, perhaps because the "structural response" parameters actually reflected the effects of age on injury potential.

This modeling approach selected key parameters that could theoretically be used as a basis for designing and constructing a "universal" dummy with valid responses when impacted from any direction. A word of caution is in order, however, regarding the use of multiple acceleration measurements, their integrals, differences, and cross-products, to arrive at a known value (AIS). While it may be possible to achieve a reasonable end result, the relationships among parameters that the model must use to achieve these results may not themselves be reasonable. Further analysis may be needed to validate this approach.

At the 7th Experimental Safety Vehicles Conference, Robbins, Lehman, and Augustyn (1979)[48] presented their analysis of only the lateral cadaver tests, both sled and flat impactor. To differentiate among the many subjects with identical AIS ratings, a modified AIS that introduced a rib fracture bias was proposed but not used in the final analysis. Some adjustments on data processing procedures were made, so that the first and second integrals of acceleration (similar to, but not exactly velocity and deformation, because the vector direction was not precisely known) could be more accurately calculated. Using regression techniques, injury prediction models were developed using various acceleration-based parameters. The first integral of the left upper rib acceleration (impact forces were on the left side) proved to have the highest correlation with injury ($R^2 = 0.778$). Other significant parameters came from measurements on the right upper rib, the spine (laterally oriented accelerometers), and the lower sternum (accelerometer oriented perpendicular to impact). The authors concluded that, if the instrumentation system used in the cadaver tests were integrated into a dummy design, and if the dummy could exhibit the same responses as the cadavers at these accelerometer locations, it was reasonable to assume that this dummy could be used as a valid test device to predict injury.

ATD's based on this global approach and also on the load-deflection approaches, discussed in previous sections, have been developed and are currently being evaluated. These are the GM Hybrid III, based on the Lobdell corridors and described in Foster, Kortge, and Wolanin (1977)[49]; the Association Peugeot-Renault (APR) dummy, based on load-deflection data of the Tarriere series and described in Stalnaker, Tarriere, et al. (1979)[50]; and the HSRI Side Impact Dummy (SID), based on the acceleration data of the Robbins series and described in Melvin, Robbins, and Benson (1979).[51] The Hybrid III is limited to frontal impact biofidelity, and the latter two were designed only for side impact testing. The omnidirectional ATD has yet to be attempted.

6.0 Review of Clinical Literature Dealing with Thoracic Injury

To provide some background on and insight into the mechanisms of actual thoracic injuries, clinical literature was selected and reviewed. Both keyword searches of the computerized records of the National Library of Medicine's National Interactive Retrieval System and traditional methods of library search were used. Approximately 200 articles were located and visually scanned for pertinence to this study. Of these, approximately forty were selected for further study. Intense review reduced this set to the sixteen articles identified in the following bibliographic table (Table 1). These articles do not properly belong to the scientific/technical biomechanics literature dealing with thoracic injury and are not therefore integrated into Appendix B of this report.

TABLE 1

Clinical Literature Bibliographic Table

1. Blair, E., Topuzlu, C., and Davis, J. 1971. Delayed or missed diagnosis in blunt chest trauma. The Journal of Trauma, 11:129-145.

2. Liedtke, A. and DeMuth, W. 1973. Nonpenetrating cardiac injuries: A collective review. American Heart Journal, 86:687-696.

3. Pellegrini, R., Layton, T., DiMarco, R., Grant, K., and Marrangoni, A. 1980. Multiple cardiac lesions from blunt trauma. The Journal of Trauma, 20:169-173.

4. Paton, B., Elliott, D., Taubman, J., and Owens, J. 1971. Acute treatment of traumatic aortic rupture. The Journal of Trauma, 11:1-14.

5. O'Sullivan, M., Spagna, P., Bellinger, S., and Doohen, D. 1972. Rupture of the right atrium due to blunt trauma. The Journal of Trauma, 12:208-214.

6. Conn, J., Hardy, J., Chavez, C., and Fain, W. 1971. Challenging arterial injuries. The Journal of Trauma, 11:167-177.

7. Olson, R. and Johnson, J. 1971. Diagnosis and management of intra-thoracic tracheal rupture. The Journal of Trauma, 11:789-792.

8. Bricker, D. and Hallman, G. 1970. Complete transection of the thoracic Aorta: Management of a case associated with massive total body injury. The Journal of Trauma, 10:420-426.

9. Noon, G., Boulafendis, D., and Beall, A. 1971. Rupture of the heart secondary to blunt trauma. *The Journal of Trauma*, 11:122-128.

10. Relihan, M. and Litwin, M. 1973. Morbidity and mortality associated with flail chest injury: A review of 85 cases. *The Journal of Trauma*, 13:663-671.

11. Naccarelli, G., Haisty, W., and Kahl, F. 1980. Left ventricular to right atrial defect and tricuspid insufficiency secondary to nonpenetrating cardiac trauma. *The Journal of Trauma*, 20:887-891.

12. Shackford, S., Virgilio, R., Smith, D., Rice, C., and Weinstein, M. 1978. The significance of chest wall injury in the diagnosis of traumatic aneurysms of the thoracic aorta. *The Journal of Trauma*, 18:493-496.

13. Irving, M. and Irving, P. 1967. Associated injuries in head injured patients. *The Journal of Trauma*, 7:500-511.

14. Sutorius, D., Schreiber, J., and Helmsworth, J. 1973. Traumatic disruption of the thoracic aorta. *The Journal of Trauma*, 13:583-590.

15. Laasonen, E., Penttila, A., and Sumuvuori, H. 1980. Acute lethal trauma of the trunk: Clinical, radiologic, and pathologic findings. *The Journal of Trauma*, 20:657-662.

16. Weisz, G., Schramek, A., and Barzilai, A. 1974. Injury to the driver. *The Journal of Trauma*, 14:212-215.

It may be useful to highlight the differences in approach between biomechanical and clinical literature in dealing with injury. The technical biomechanics literature has dealt with kinematic and kinetic responses of the thorax under impulsive, blunt loadings. Structural failure featured "fractured" ribs and "contused" or "lacerated" organs or vessels. The injury statistics from field cases are also described with similar combinations of terms from a few categories. Table 2 lists the categories and terms used. The clinical literature, on the other hand, is far more specific about injury type and location and does not lend itself to generalizations. Further, the authors of the clinical literature reviewed are not concerned about creating a statistical basis for analysis of injury types or degrees, but rather are primarily concerned with matters of diagnosis and treatment in order to reduce mortality and morbidity among those who reach medical treatment facilities. In addition, injuries generated in an automotive environment are often combined with non-automotive injury cases. Finally, this literature treats the development of secondary ailments triggered by the original trauma, an aspect of injury development that is largely absent from the biomechanics literature.

TABLE 2

Case Injury Descriptive Terms

Injury Level	Body Element	Injury Type	Direction	Body Region
None	Skeletal	Laceration	Right	Head
Minor	Vertebrae	Contusion	Left	Face
Moderate	Joints	Abrasion	Bilateral	Neck
Severe	Digestive	Fracture	Central	Shoulder
Serious	Liver	Pain	Front	Upper Extrem.
Critical	Nervous System	Concussion	Back	Upper Arm
Maximum	Brain	Hemorrhage	Upper	Elbow
Unknown	Spinal Cord	Avulsion	Lower	Forearm
	Eyes/Ears	Rupture	Whole	Wrist/Hand
	Arteries	Sprain	Unknown	Chest
	Heart	Dislocation		Abdomen
	Spleen	Crushing		Back
	Urogenital	Amputation		Pelvic/Hip
	Kidneys	Burn		Lower Extrem.
	Respiratory	Asphyxia		Knee
	Pulmonary	Unknown		Lower Leg
	Muscles			Ankle/Foot
	Integumentary			Whole
	Unknown			Unknown

6.1 General Description of the Thorax Elements of Interest

The thorax or chest, as referred to here, consists of the rib cage and the organs surrounded by it, but not the overlying tissue.

Rib Cage. The cage structure consists of the twelve thoracic vertebrae, the sternum, and the twelve rib-pairs. The upper seven pairs articulate with the sternum directly through cartilaginous extensions of the ribs. The next two pairs articulate indirectly, and the lower three pairs are not connected to the sternum at all. The rib cage partially covers some of the upper abdominal organs. The diaphragm, a dome-shaped, thin muscle, is the lower thoracic boundary separating the thoracic and abdominal contents. Portions or all of the ribs from the seventh pair to the twelfth are thus well below the diaphragm and enclose, to a variable degree, the liver, stomach, spleen, pancreas, and kidneys.

Lungs. The lungs are covered by a membrane (the visceral pleura) that quite closely fits the lungs' contours. Another membrane (the parietal pleura) lines the inner surface of the chest wall, covers the diaphragm, and encloses the structures in the middle of the thorax. These two sacs, left and right, are separate from each other. Each sac has potential space between the visceral and the parietal pleura that is known as the pleural cavity. Air or blood may fill this potential space when thoracic injury occurs.

Mediastinum and Heart. The space between the right and left pleural sacs is known as the mediastinum. The mediastinum can be crudely pictured on a plane x-ray plate. Fluid filling this space leads to an observed "widening of the mediastinum," as seen on the plate, and serves as a primary diagnostic signal of possible distress of the heart or the great vessels. The bodies of the thoracic vertebrae extend into the mediastinum to approximately one-third of the thorax depth at the level of the heart and the great vessels. (These vessels are the pulmonary arteries (left and right), the pulmonary veins (left and right), the aorta, and the vena cava (superior and inferior). The inferior vena cava receives blood from the lower parts of the body and the superior from the head, neck, and upper extremities.)

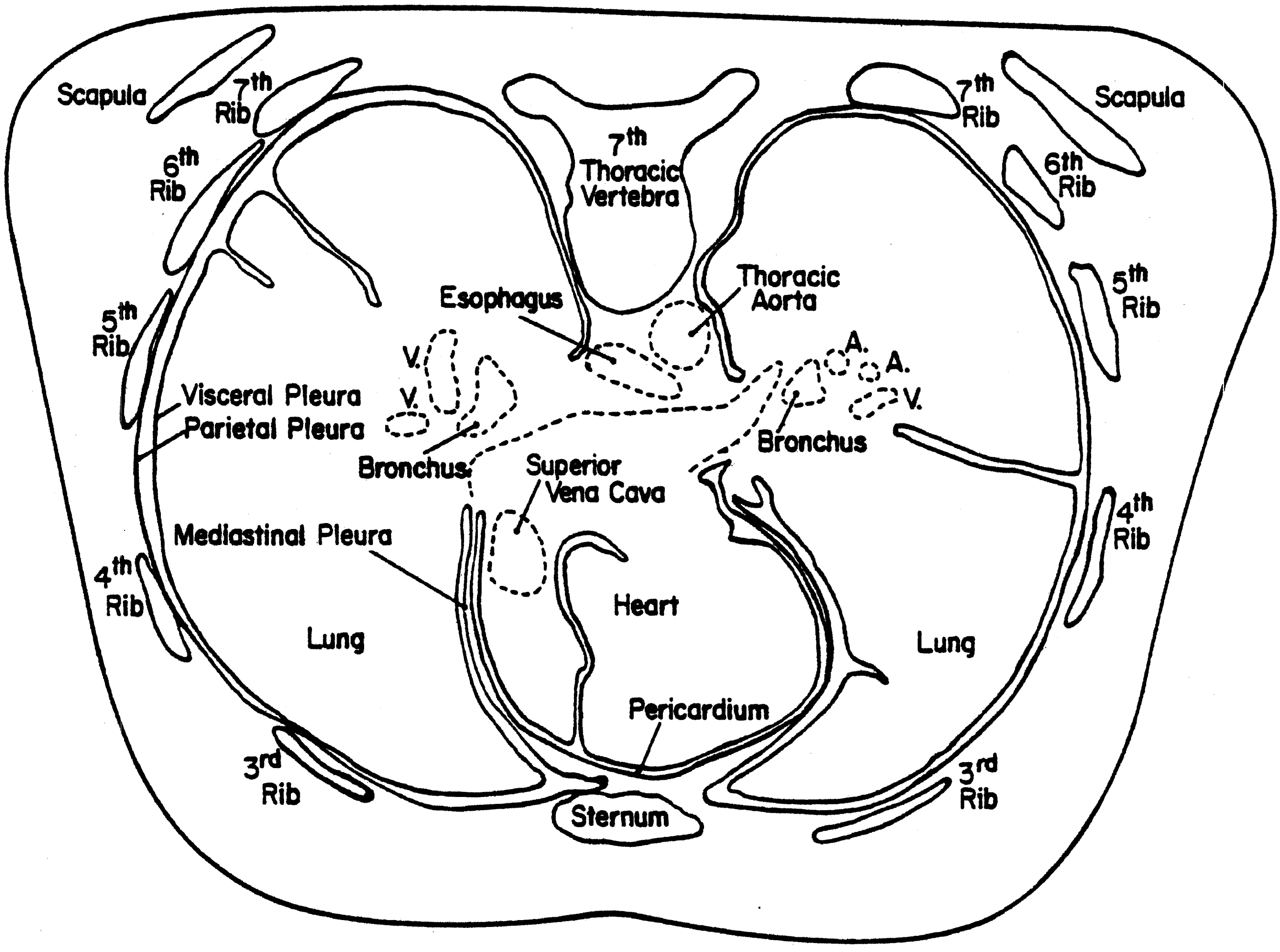
The heart is generally divided into four parts, the left and right atrium and ventricle parts. The heart is encased in a two-layered sac (the pericardium). The inner membrane covers the outside of the heart and lines the inside of the fibrous outer sac. In general, the two layers of the sac are completely separate and form therefore a potential pericardial space. This sac also extends along the first inch of the great vessels. Fluid build-up in the pericardial sac will put pressure on the heart, constricting it and reducing cardiac output. This condition is referred to as a pericardial tamponade.

A partial tracing of a plate illustrating the relative position of the above structures and organs at about the mid-height of the thorax is found as Figure 1.

6.2 Injury Descriptions

Generally, we shall divide our discussion of thoracic injury among injury of the ribs, injury of the lungs, and injury of the heart. Rib fracture by itself was not included in the clinical literature reviewed, so this injury will not be discussed except to the extent that rib fracture can be used as a diagnostic indicator.

Flail Chest. The flail chest is a condition of instability or flapping of the chest wall. This results in chest motion opposite to



Adapted from: A.C. Eycleshymer and D.M. Schoemaker. 1911.
<u>A Cross-Section Anatomy</u>. New York: Appleton.

FIGURE 1. Cross-Section at Mid-Height of Thoracic Cage

that occurring during normal breathing. The literature indicates that it is common for the flail chest either not to have developed by the time of first diagnosis in an emergency room, or to be missed in the emergency room diagnosis. Neither the existence of head injury or unconscious state nor the number of ribs fractured seems to differentiate between early and late flailing development. Although flail chest is directly related to trauma-induced instability of the thoracic cage, a change in pulmonary compliance due to airway injury, an accumulation of secretions, or artery-to-vein shunting due to lung contusions may develop in a few hours after the trauma and lead to increased effort in breathing. Oxygen levels in the arterial blood may fall below required levels, carbon dioxide tensions may rise with cardiac arrest, or radical pH changes of body fluid may result. Tracheal injury or rupture may also be a contributing factor leading to the flail chest.

The flail chest is not directly an injury in its own right and thus cannot be related to a specific class of blow other than blunt trauma to the front or side of the rib cage. As a matter of interest, immediate treatment requires placing a breathing tube into the airway and providing mechanical respiratory assistance. It is also generally advantageous for the surgeon to later cut an opening into the trachea to facilitate breathing. However important these treatments may be, the development of bacterial infection of the bronchial tubes, the trachae, or the lungs follows in the majority of cases. Furthermore, mechanically assisted ventilation causes pulmonary blood volume and left atrial pressure to decrease. In turn, there is a reflex of the vagus nerve that results in an increased release of an antidiuretic hormone, causing water retention and leading to pulmonary edema.

Lung Contusion. It appears that lung bruising (contusion) occurs in over half of the cases having flail chests. Lung contusion commonly occurs in cases with no rib fracture and is also commonly associated with abdominal injury. Clinical evidence of lung contusion appears to be masked by the presence of rib fractures, air or blood in the pulmonary pleural cavity, collapse of a lung, or inflammation of the lungs due to sucking in of fluids. Lung contusion can be inferred in the second or third day after injury by blood gas studies. Comparison of the time history of the oxygen partial pressures between the air in the lung and the arterial blood provides a basis for the diagnosis of a contusion. In the absence of a contusion, the oxygen partial-pressure difference will fall by the end of twenty-four hours, and in the presence of contusion it will rise to a large difference at about forty-eight hours after trauma.

Lung contusion may double the probability of the development of pneumonia, which is said to be the most serious problem and most common cause of death in cases involving severe thoracic trauma, given survival beyond one to two days. The development of pneumonia prolongs the use of respirators and calls for increased oxygen levels (100% for prolonged periods). Oxygen toxicity added to pneumonia and contusion is considered uniformly fatal in its consequences. Further, the contused lung is more susceptible to simple "blowout." Lung contusion is also likely to lead to local areas being left airless with a resulting artery-to-vein shunting occurring and local pneumonitis. The shunting apparently leads to increased strain on the heart and an ultimate decrease in arterial oxygen.

Hemothorax or Pneumothorax. The pleural cavity represents "potential" space. When blood or air enters this space, the situation is described as hemothorax or pneumothorax. The combined hemopneumothorax case also exists. Treatment is by entubing the area and often physically cutting into the cavity to remove clotted blood. In either the hemo- or pneumothorax case, it is important to prevent compression or collapse of the lung by draining the cavity. Neither is properly an "injury," although each is reported on both accident and medical reports. Original pneumothorax would most likely result from a fractured rib cutting through the pulmonary pleura. Late-developing pneumothorax seems to be the result of a "blowout" of the lung at a contused location when on mechanical respiratory assistance. Hemothorax could result from several different blood vessel injury locations. It need not be accompanied by rib fracture, but usually occurs when vessels tear at the same time that adjacent ribs are fractured.

Heart and Great Vessels. Contusion of the muscle wall of the heart frequently occurs in the same cases in which severe contusion of the lung(s) is found. Diagnosis at the time of admission is seldom made. Since oxygen shortage in the arterial blood would result from the lung injury and contribute to the ECG pattern characteristic of reduced blood supply to the heart muscle, the heart contusion would not be distinguishable. Contusion of the heart is generally discovered at the time of autopsy. It is not considered a primary cause of death in the short run but does seem to add to the overall set of problems of a lung-injured case, sometimes in the form of oxygen shortage in the brain and cardiac arrest. Treatment for and the general course of heart muscle contusion are similar to those associated with myocardial infarction, except that coronary vasodilators and anticoagulants are of little benefit.

Among heart injuries, rupture of the muscle wall is the lesion quite frequently found at autopsy following fatalities from nonpenetrating chest trauma. Rupture of the right ventricle is most common, followed by the left ventricle, the right atrium, and the left atrium. Survival is seldom over thirty minutes, and successful surgical treatment is rare. Survival long enough to reach a medical facility corresponds to the pericardial tamponade situations. Interventricular wall (septum) perforation is a less acute form of rupture. Congestive heart failure in the first two weeks is common if this rupture is not diagnosed and surgically repaired. Animal studies have suggested that this perforation is more likely when the blow is delivered late in the dilation of the ventricles or early in the contraction period.

Late true aneurysm, i.e., the thinning or stretching of the heart's muscle wall, or late pseudoaneurysm, i.e., the dilation of an artery at a nearby site, are further complications of heart trauma. Morbidity and mortality are high in these instances.

Heart valve rupture, particularly the left side aortic valve in people with pre-existing disease conditions, is not rare in blunt chest and abdominal trauma. Rapid progression of congestive heart failure in one or two years is the expected outcome of untreated cases.

Pericardial disruption, the rending of the double layered sac containing the heart and the beginning of the great vessels, is found in a significant portion of those cases examined at autopsy following blunt chest trauma. The tears are typically transverse and extend across the upper base of the heart near the reflection of the visceral (inner) and parietal (outer) pericardium. Naturally, such a tear in the presence of heart muscle injury and bleeding can produce fatal, gross loss of blood from the heart. Smaller tears may allow a sufficient tamponade to occur to control bleeding adequately and long enough to allow treatment. In the absence of pericardial rending of any great extent, the pericardium "potential" space may be filled with blood creating a cardiac tamponade with serious results. Surgical puncture of the pericardium and removal of this blood is required but is a dangerous procedure. An inflammatory reaction in the pericardium following blunt trauma is ordinarily well resolved.

Aneurysms of the aorta are not uncommon among people suffering blunt thoracic trauma sufficient to cause bony injury and a widened mediastinum. Aortography is required to confirm the aneurysm. Aortic aneurysms appear to be associated most frequently with upper sternal and/or upper rib fractures. To physically visualize the aorta, consider this image. From the left ventricle, a single great vessel (the ascending aorta) rises upward. This vessel arches above the heart and then turns down, rearward, and to the left, becoming the thoracic aorta (the descending aorta). From the top of the arch of the aorta, the brachiocephalic trunk artery, the left common carotid artery, and the left subclavian artery arise. The brachiocephalic trunk branches in a few centimeters into the right common carotid and right subclavian arteries. The coronary arteries originate at the base of the ascending aorta.

Ruptures of the aorta appear to occur in several regions. Because clinical literature is being reviewed, one must suspect that there is case selection being performed according to the author's specialty or interest, and one should not therefore accept sweeping statements that indicate preferred locations for rupture. However, it appears that the site of the rupture is ordinarily just distal (most outboard) to the left subclavian artery. It is estimated that only ten to twenty percent of thoracic aortic rupture cases live long enough for operative care to be achieved, and that even these cases often show few signs of external injury.

6.3 Observations Regarding the Clinical Literature on Thoracic Injury

The clinical literature on thoracic injury is very instructive. As far as a biomechanics-oriented reader is concerned, this literature does provide the basis for a mechanistic description of thoracic structure and an appreciation for its failures under blunt loading. This literature does not, however, directly establish any well-founded hypotheses regarding injury mechanisms or tolerances such as could be related to location, distribution, direction, or time history of external loading. It does serve to establish a background against which the biomechanics researcher might create hypotheses. It seems clear that greater levels of communication between field accident reporting and medical analysis of cases could establish the basis for laboratory practice devoted to generating a better connection between loading and injury.

One must suspect that the health of local tissue prior to injury, as well as the traumatized person's overall health and reserve capacities, have a significant effect on susceptibility to injury. Furthermore, missed diagnoses of significant injuries, inadequate treatment capabilities, delayed outcomes of injury, and the general absence of autopsy of trauma fatalities seem to preclude descriptive statistics on detailed thoracic injury.

7.0 Field Case Data

Driver thoracic injuries in frontal crashes commonly involve contact between the thorax and the steering wheel. The development of distributed force on the thorax is reasonably assured in this situation. The driver's upper torso must receive an integrated, effective force-time input equivalent to the upper torso's momentum in order for the torso to come to rest. This impulse would be the net effect of the forces, consisting of the separate forces delivered through the connections of the neck, arms, and lower torso with the upper torso plus the force delivered by the hub-rim and spokes of the steering wheel. The loading distribution and time history of the thorax/steering-wheel interaction is of interest in considering specific injuries of the thorax.

The technical literature dealing with experimental frontal impacts to the human thorax has generally been restricted to situations in which the impulse has been delivered by a six-inch diameter impactor in the body's plane of symmetry and "normal to" the sternum, with the body in a seated position. There is a variety of evidence to indicate that a horizontal, center-plane impact by a six-inch diameter striker only poorly models the situations in which real crashes produce thoracic injury from steering-wheel-delivered impulses. This last comment is not a criticism of the research reported in the literature since, surely, standardized laboratory procedures are required in order to allow correlation of research done at different times and places. The comment is designed to suggest that a greater variety of test conditions will be required if the various injury mechanisms associated with impulsive steering wheel loading of the thorax are to be understood.

Figures 2 and 3 are derived from data generated by the MVMA 2-D computer simulation of an occupant interacting with a vehicle interior during a frontal crash. The simulation used average values for all parameters of the vehicle and occupant and was run three times with only one parameter changed between runs. This parameter was the height of the steering wheel hub. The three values used were an average height and that height increased and decreased by 7 cm. The most significant observation is that altering this parameter did not have a gross effect on thoracic spinal deceleration (Figure 2) but did have a significant effect upon the level of force delivered to the thorax (Figure 3). The explanation for these two aspects of the data lies in the detail of the data tables.

Raising or lowering the steering assembly relative to the occupant results in some of the load normally delivered directly to the thorax being taken by the head or abdomen. This force is still, however, delivered indirectly to the thorax by way of the neck or mid-torso. Thus, even though the direct force input to the thorax from the steering assembly is higher for the mid-mount height than for the high or low mounts, the deceleration of the thoracic spine for all three heights remains about the same. Thus one finds support in this data for an argument that, all other parameters being the same, the thoracic injury outcome of similar real-world crashes should depend upon the height of

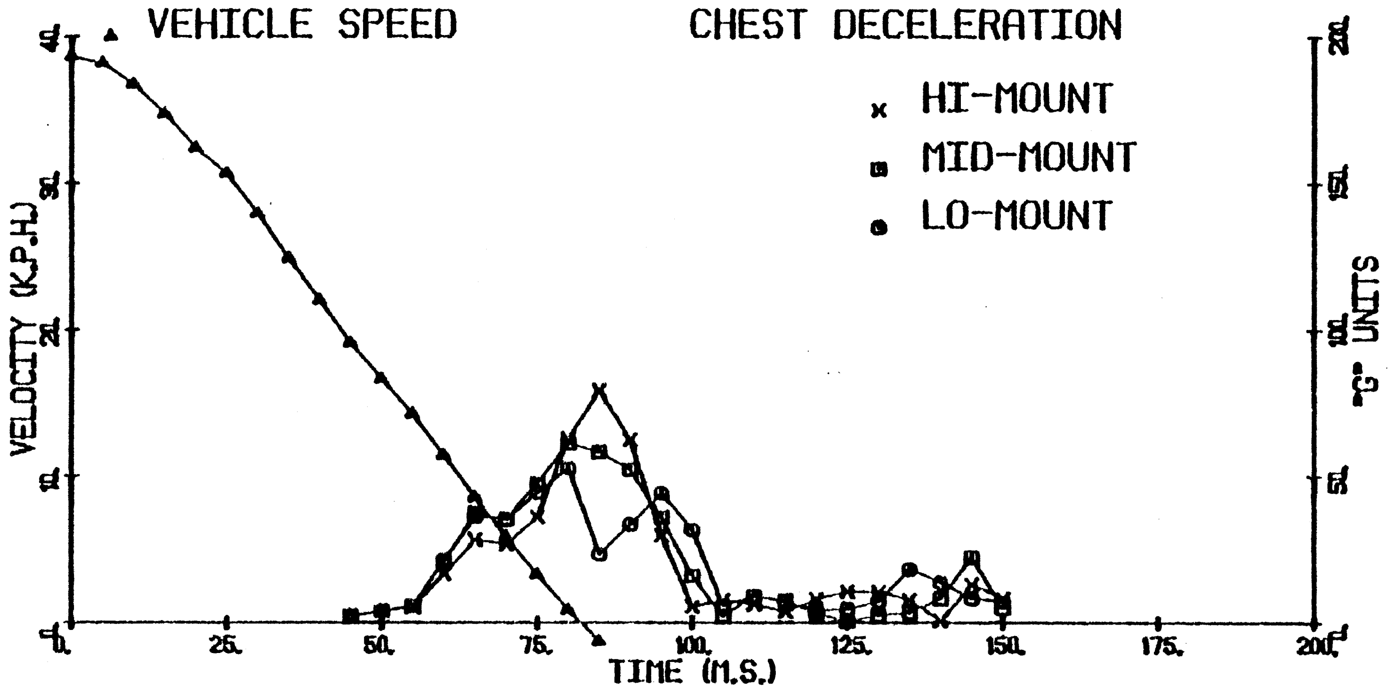


FIGURE 2. Deceleration of the Thoracic Spine as a Function of Steering Wheel Height

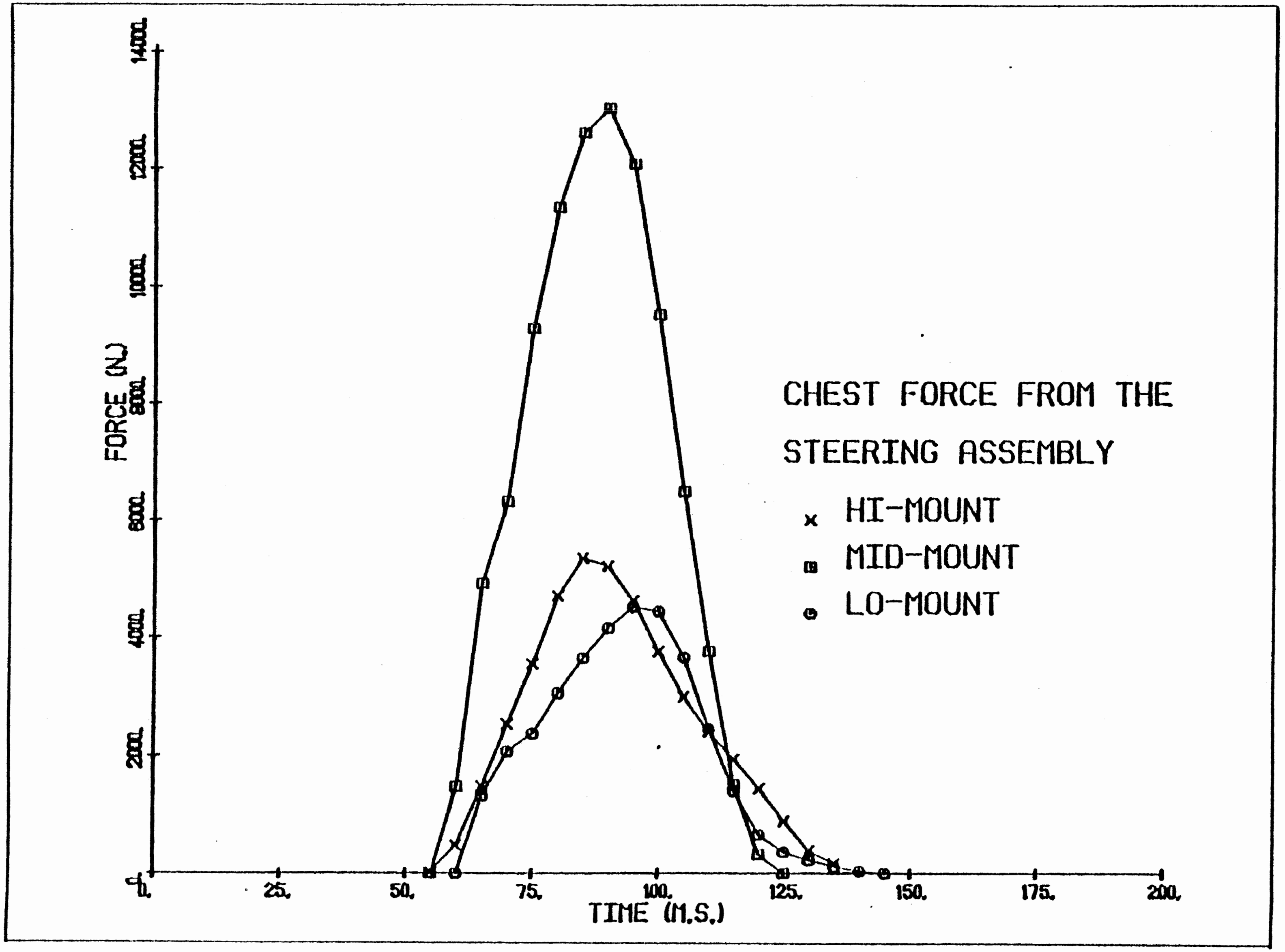


FIGURE 3. Force on Thorax as a Function of Steering Wheel Height

the driver's thorax relative to the steering wheel at the moment of interaction in a crash. This relative height can of course be affected by the driver's sitting posture and thus may be difficult to ascertain.

In addition to thorax/steering-wheel relative height, there are several other factors that seem important. We have inferred that the vertical component of the impulsive force on the thorax may be significant and thus a factor to be considered in accident investigation. NHTSA has had a relatively large number of barrier crashes of automobiles performed in connection with enforcement of FMVSS 204, "Steering Control Rearward Displacement." Data have been extracted from Kahane (1980)[52] relative to the vertical movement of the hub of the steering assembly during a barrier crash. Figure 4 (a through p) shows these data for sixteen domestic 1975-76 vehicles plotted as functions of time. These figures should be viewed with the understanding that the time interval from 75 to 100 ms is the interval during which the driver's thorax would be loaded longitudinally by the column. Upward or downward movement of the steering hub during a time interval involving strong longitudinal thoracic loading should be presumed to deliver an associated upward or downward shear type of thoracic loading. Several vehicles from this collection appear to be candidates for such shear-type loading. The vertical line on each of these plots indicates the approximate time at which the hub reversed its fore and aft motion relative to the undisturbed occupant compartment.

To study thorax/steering-wheel interaction in actual crashes, two data files were accessed: the National Crash Severity Study (NCSS) and the Huelke/Sherman team cases from the University of Michigan Vehicle Occupant Report (UMIVOR). These files were searched for cases in which

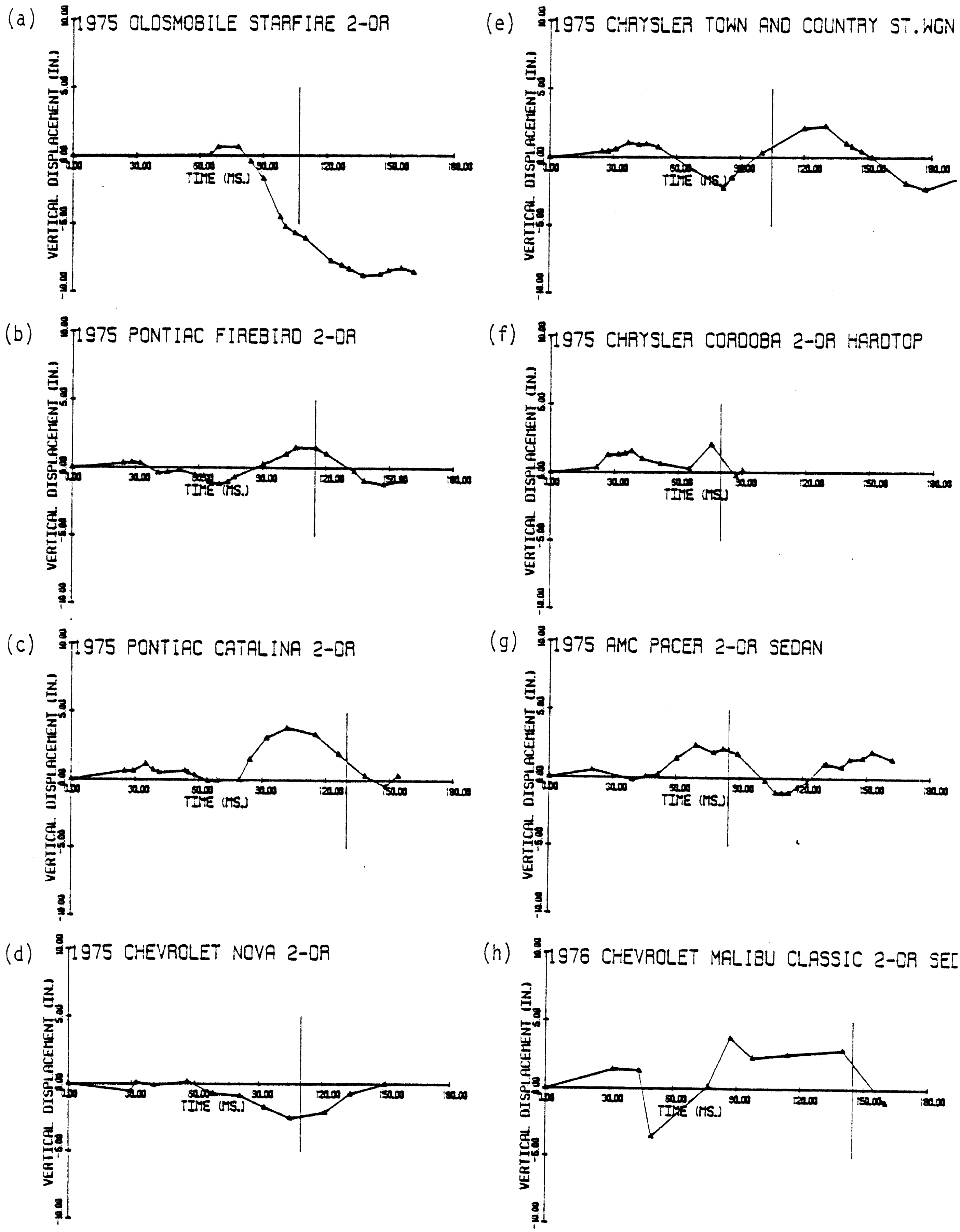


FIGURE 4. Vertical Displacement of Steering Wheel hubs as Functions of Time

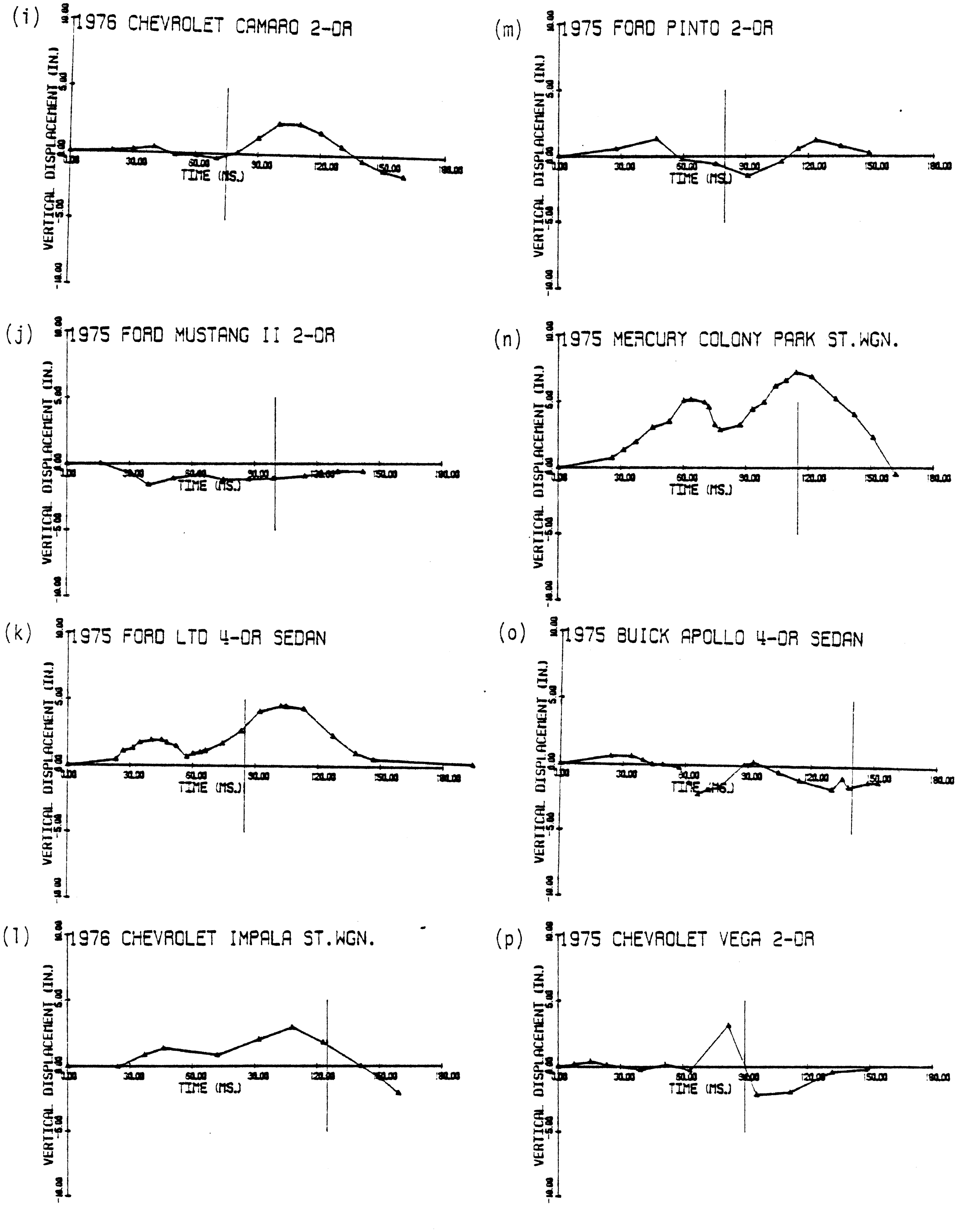


FIGURE 4--Continued

(1) the injured occupant was the driver; (2) the crash was frontal and, for car-to-car crashes, a barrier equivalent velocity could be estimated; (3) the injury was to the thorax; (4) the contact related to the injury was the steering wheel; and (5) photographs of the steering wheel had been included. The UMIVOR file contains two variables that appeared to be related to the thorax/steering-wheel interaction. These variables describe spoke damage and rim damage, each with a 0-3 damage scale defined by the words "none," "deformed slightly," "severely bent," and "broken." A review of NCSS case photographs of steering wheels by a trained investigator from the UMIVOR team provided values for these two variables for each NCSS case. These two variables were summed creating a total steering wheel disruption (TSWD) parameter. The sums were then used as symbols on plots showing thorax AIS versus barrier equivalent velocity (BEV). Figures 5 and 6 display the results for 41 NCSS cases and 32 UMIVOR cases respectively. Each figure displays the expected relationship of thoracic injury to BEV, i.e., that an increase in BEV is predictive, although poorly, of an increase in thorax AIS values. Note that TSWD values of 0 or 1 are associated with BEV's of less than 17 mph.

The NCSS data in Figure 5 contain 5 of 41 cases with a thorax AIS of 1, while the UMIVOR data in Figure 6 contain 23 of 32 with a thorax AIS of 1. If AIS 1-2 is used for comparison, the corresponding numbers are 14 of 41 for NCSS and 26 of 32 for UMIVOR. Thus the NCSS data set has 27 of 41, or 66 percent, of its cases at the thorax AIS of 3 or more, while the UMIVOR data set has 6 of 32, or 19 percent, of its cases in that severity range. In the NCSS cases, 7 of 41 are at BEV of less than 17 mph, while in the UMIVOR cases, 15 of 32 cases are at BEV of

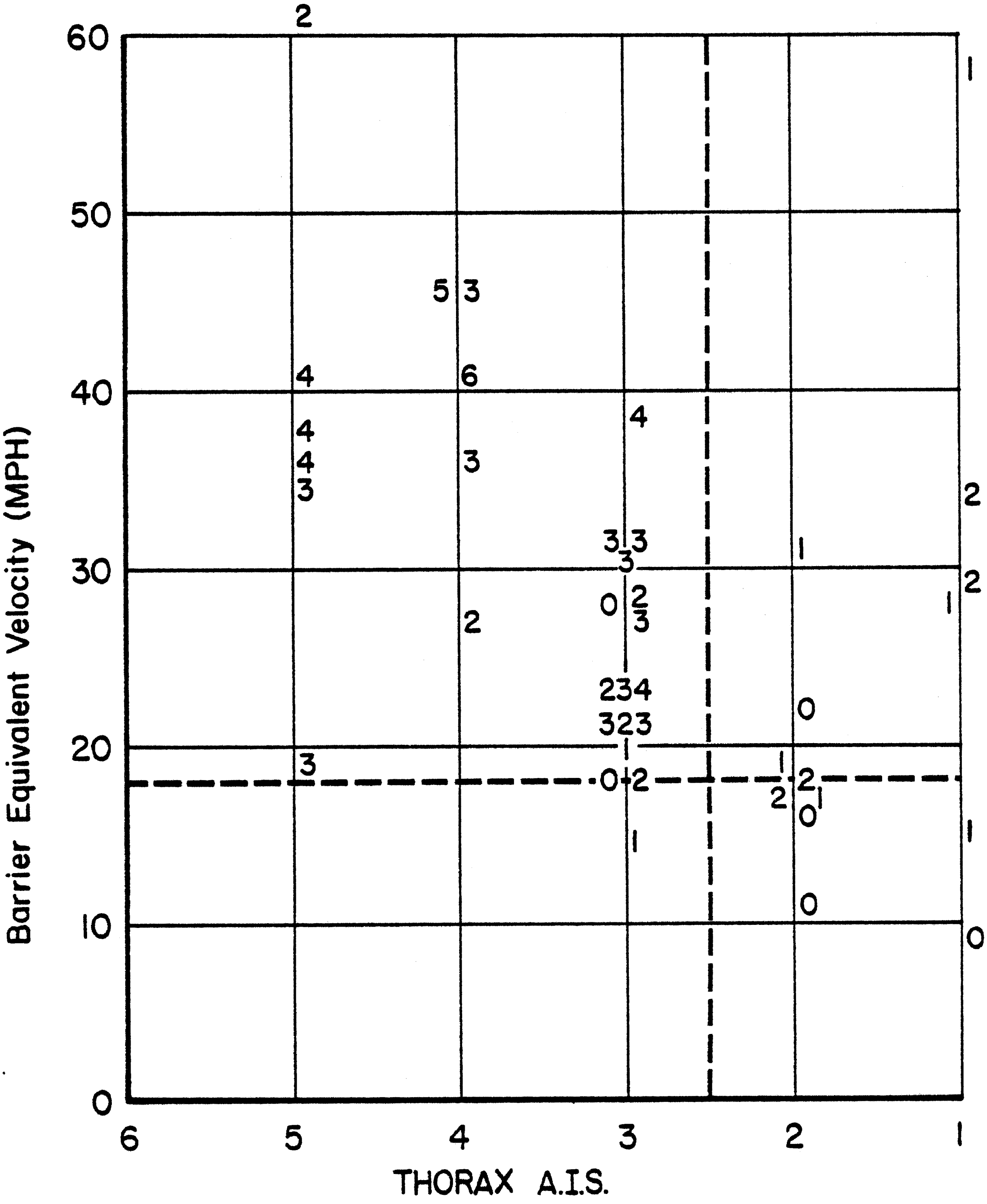

THORAX A.I.S. vs. B.E.V. (NCSS CASES)
PARAMETER is Total Steering Wheel Disruption

FIGURE 5

THORAX A.I.S. vs. B.E.V. (UMIVOR CASES)
PARAMETER is Total Steering Wheel Disruption

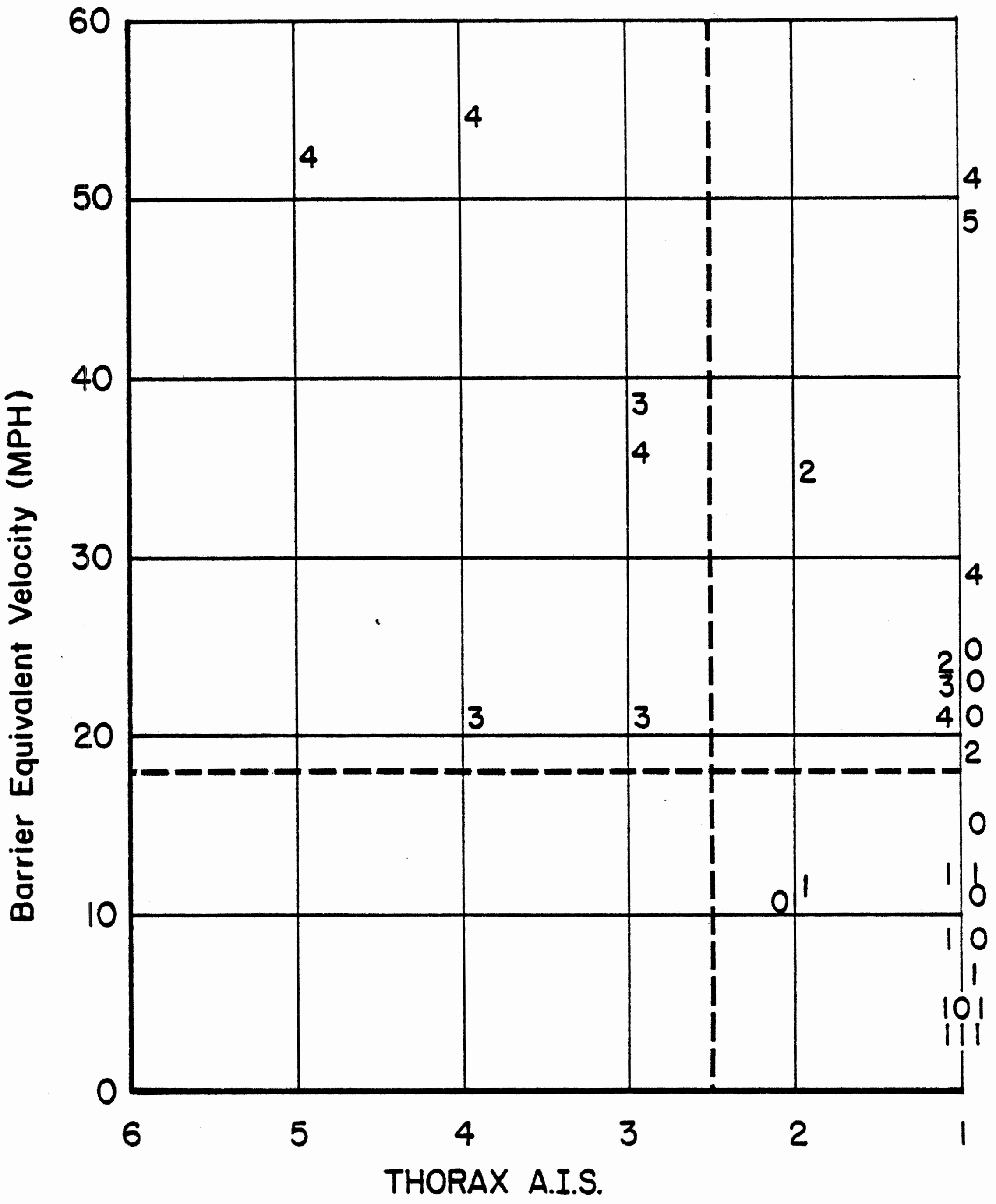


FIGURE 6

less than 17 mph. The UMIVOR cases are, on average, far less severe than the NCSS cases. With regard to the NCSS data, higher AIS values, higher BEV values, and higher TSWD codes do go together. This is not direct evidence that the nature of the steering wheel disruption is responsible for the nature or degree of injury. The higher injury levels tend to be lacerative in nature, however, and higher TSWD values do indicate that stronger gradients of thoracic deformation might have occurred. Thus a hypothesis of a relationship is not without a basis of support.

Table 3 contains an index of NCSS cases examined in detail along with a summary of injury-related data. All cases are of the driver/car-to-car/front-crush type. Figures 7, 8, and 9 present correlations of the thorax AIS values for these cases with computed DOT CRASH2 velocity changes, barrier equivalent velocity changes, and peak deceleration based upon CRASH2-developed forces respectively. The correlation coefficients are between 0.4 and 0.5. Table 4 contains a summary of the regression relationship between the DOT CRASH2 velocity change and thorax AIS for drivers and right-front-seat occupants in a variety of crash formats. Case indexes and correlation sketches for each occupant/crash type, other than the one discussed above, can be found in Appendix C as Tables 5 through 11 and Figures 10 through 30 respectively.

The index of the UMIVOR cases examined is also found in Appendix C as Table 12. Figures 31 through 62 contain computer-created case-report sketches of these UMIVOR cases. The index of the NCSS cases examined is found, repeated, as Table 13. Figures 63 through 131 contain a different type of computer-generated case-report sketch. These sketches are included to provide readers who do not have a readily available

TABLE 3

DRIVER CHEST INJURY CAR TO CAR CRASH, FRONT CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
66119	170109028	2 AIS	FRACTURE	UNKNOWN	13 G	17 MPH	23 MPH
		2 AIS	FRACTURE	UNKNOWN			
87109	170112035	1 AIS	PAIN	UNKNOWN	13 G	14 MPH	18 MPH
11308	170402003	2 AIS	FRACTURE	UNKNOWN	7 G	11 MPH	11 MPH
11302	170505013	1 AIS	ABRASION	UNKNOWN	14 G	28 MPH	15 MPH
87109	170809029	1 AIS	CONTUSION	STEERING ASSEMBL	5 G	9 MPH	11 MPH
11101	170930042	2 AIS	FRACTURE	STEERING ASSEMBL	9 G	17 MPH	13 MPH
11506	180304007	1 AIS	CONTUSION	STEERING ASSEMBL	13 G	15 MPH	13 MPH
12202	370529059	2 AIS	CONTUSION	UNKNOWN	10 G	22 MPH	17 MPH
11401	370828036	1 AIS	ABRASION	STEERING ASSEMBL	27 G	34 MPH	25 MPH
12118	370924023	1 AIS	CONTUSION	STEERING ASSEMBL	44 G	40 MPH	51 MPH
12102	380304029	2 AIS	FRACTURE	STEERING ASSEMBL	14 G	49 MPH	0 MPH
11318	470611032	1 AIS	CONTUSION	UNKNOWN	25 G	29 MPH	21 MPH
11203	471012030	2 AIS	FRACTURE	STEERING ASSEMBL	10 G	19 MPH	17 MPH
11302	570501001	2 AIS	FRACTURE	UNKNOWN	21 G	31 MPH	29 MPH
66109	670512035	2 AIS	FRACTURE	UNKNOWN	32 G	64 MPH	9 MPH
11402	671010031	2 AIS	CONTUSION	STEERING ASSEMBL	27 G	47 MPH	25 MPH
11518	671021094	1 AIS	PAIN	STEERING ASSEMBL	19 G	24 MPH	39 MPH
11105	671118097	1 AIS	PAIN	STEERING ASSEMBL	11 G	28 MPH	17 MPH
11308	170525052	3 AIS	FRACTURE	UNKNOWN	11 G	20 MPH	15 MPH
12104	170618030	3 AIS	FRACTURE	UNKNOWN	48 G	50 MPH	25 MPH
12102	170715035	3 AIS	FRACTURE	UNKNOWN	10 G	20 MPH	14 MPH
13407	170805004	3 AIS	FRACTURE	STEERING ASSEMBL	17 G	27 MPH	20 MPH
12202	170924050	3 AIS	FRACTURE	STEERING ASSEMBL	15 G	22 MPH	23 MPH
12102	180305036	3 AIS	FRACTURE	STEERING ASSEMBL	17 G	35 MPH	24 MPH
		3 AIS	CONTUSION	STEERING ASSEMBL			
66109	180317048	3 AIS	FRACTURE	STEERING ASSEMBL	24 G	26 MPH	28 MPH
12105	180322060	3 AIS	OTHER	STEERING ASSEMBL	23 G	47 MPH	42 MPH
12101	271020034	3 AIS	FRACTURE	STEERING ASSEMBL	15 G	32 MPH	0 MPH
12102	370510018	3 AIS	FRACTURE	UNKNOWN	14 G	31 MPH	0 MPH
14118	370628031	3 AIS	CONTUSION	UNKNOWN	22 G	21 MPH	32 MPH
13202	370917060	3 AIS	FRACTURE	STEERING ASSEMBL	20 G	36 MPH	33 MPH
85109	371111003	3 AIS	FRACTURE	STEERING ASSEMBL	19 G	18 MPH	29 MPH
11102	371231017	3 AIS	FRACTURE	STEERING ASSEMBL	8 G	23 MPH	12 MPH
11308	470210012	3 AIS	FRACTURE	STEERING ASSEMBL	5 G	6 MPH	9 MPH
		1 AIS	CONTUSION	STEERING ASSEMBL			
13402	471029034	3 AIS	FRACTURE	STEERING ASSEMBL	9 G	18 MPH	0 MPH
13402	471125061	3 AIS	FRACTURE	STEERING ASSEMBL	8 G	18 MPH	25 MPH
66109	480105026	2 AIS	FRACTURE	STEERING ASSEMBL	13 G	16 MPH	0 MPH
12206	571231075	3 AIS	FRACTURE	STEERING ASSEMBL	14 G	24 MPH	11 MPH
11103	670217097	3 AIS	FRACTURE	SIDE INTERIOR	6 G	30 MPH	0 MPH
66109	670223090	3 AIS	FRACTURE	SIDE INTERIOR	25 G	47 MPH	0 MPH
12201	670606020	3 AIS	FRACTURE	UNKNOWN	10 G	17 MPH	10 MPH
12201	671016105	3 AIS	OTHER	STEERING ASSEMBL	33 G	41 MPH	39 MPH
11408	671203006	2 AIS	FRACTURE	STEERING ASSEMBL	22 G	44 MPH	0 MPH
11105	680204016	3 AIS	FRACTURE	STEERING ASSEMBL	13 G	27 MPH	13 MPH
12101	680205020	1 AIS	PAIN	STEERING ASSEMBL	25 G	58 MPH	0 MPH

TABLE 3 (Continued)

11302	680223065		3 AIS	FRACTURE	STEERING ASSEMBL	10 G	22 MPH	18 MPH
			2 AIS	FRACTURE	STEERING ASSEMBL			
62209	770927035		3 AIS	FRACTURE	STEERING ASSEMBL	34 G	42 MPH	54 MPH
11301	370811020		4 AIS	OTHER	UNKNOWN	22 G	35 MPH	34 MPH
			3 AIS	FRACTURE	UNKNOWN			
11101	370821009		3 AIS	FRACTURE	STEERING ASSEMBL	22 G	32 MPH	43 MPH
11302	570313033	(FATAL)	4 AIS	FRACTURE	UNKNOWN	24 G	36 MPH	47 MPH
			4 AIS	OTHER	UNKNOWN			
13201	570614020		3 AIS	CONTUSION	UNKNOWN	2 G	5 MPH	0 MPH
12102	670105017		3 AIS	FRACTURE	STEERING ASSEMBL	11 G	25 MPH	26 MPH
			3 AIS	HEMORRHAGE	STEERING ASSEMBL			
86109	780108008		3 AIS	CONTUSION	STEERING ASSEMBL	27 G	30 MPH	25 MPH
			3 AIS	CONTUSION	STEERING ASSEMBL			
11318	170215016	(FATAL)	5 AIS	LACERATION	STEERING ASSEMBL	14 G	18 MPH	33 MPH
14108	170608007		5 AIS	LACERATION	UNKNOWN	38 G	40 MPH	42 MPH
			5 AIS	LACERATION	UNKNOWN			
11108	170704001		5 AIS	LACERATION	UNKNOWN	32 G	28 MPH	56 MPH
			5 AIS	LACERATION	UNKNOWN			
76119	171203010		2 AIS	FRACTURE	STEERING ASSEMBL	19 G	18 MPH	19 MPH
12118	171223045	(FATAL)	5 AIS	LACERATION	STEERING ASSEMBL	28 G	44 MPH	36 MPH
13201	180322060		5 AIS	LACERATION	STEERING ASSEMBL	42 G	64 MPH	55 MPH
			5 AIS	LACERATION	STEERING ASSEMBL			
12118	270206022		4 AIS	FRACTURE	STEERING ASSEMBL	44 G	40 MPH	42 MPH
			3 AIS	CONTUSION	STEERING ASSEMBL			
12106	470219040	(FATAL)	4 AIS	FRACTURE	UNKNOWN	39 G	49 MPH	44 MPH
11318	470918025		4 AIS	FRACTURE	STEERING ASSEMBL	70 G	68 MPH	71 MPH
12106	570501001	(FATAL)	5 AIS	LACERATION	UNKNOWN	42 G	36 MPH	39 MPH
			3 AIS	FRACTURE	UNKNOWN			
			2 AIS	FRACTURE	UNKNOWN			
65108	570821054	(FATAL)	5 AIS	LACERATION	STEERING ASSEMBL	34 G	33 MPH	33 MPH
			3 AIS	FRACTURE	STEERING ASSEMBL			
			3 AIS	CONTUSION	STEERING ASSEMBL			
66109	670131102		5 AIS	LACERATION	UNKNOWN	21 G	30 MPH	49 MPH
12118	170521029		5 AIS	LACERATION	UNKNOWN	18 G	44 MPH	49 MPH
11401	170608007	(FATAL)	3 AIS	CONTUSION	UNKNOWN	19 G	26 MPH	31 MPH
12108	180108002	(FATAL)	5 AIS	LACERATION	STEERING ASSEMBL	34 G	50 MPH	44 MPH
66109	371013031		6 AIS	CRUSHING	UNKNOWN	46 G	59 MPH	7 MPH
66109	670109033		6 AIS	CRUSHING	UNKNOWN	71 G	86 MPH	0 MPH

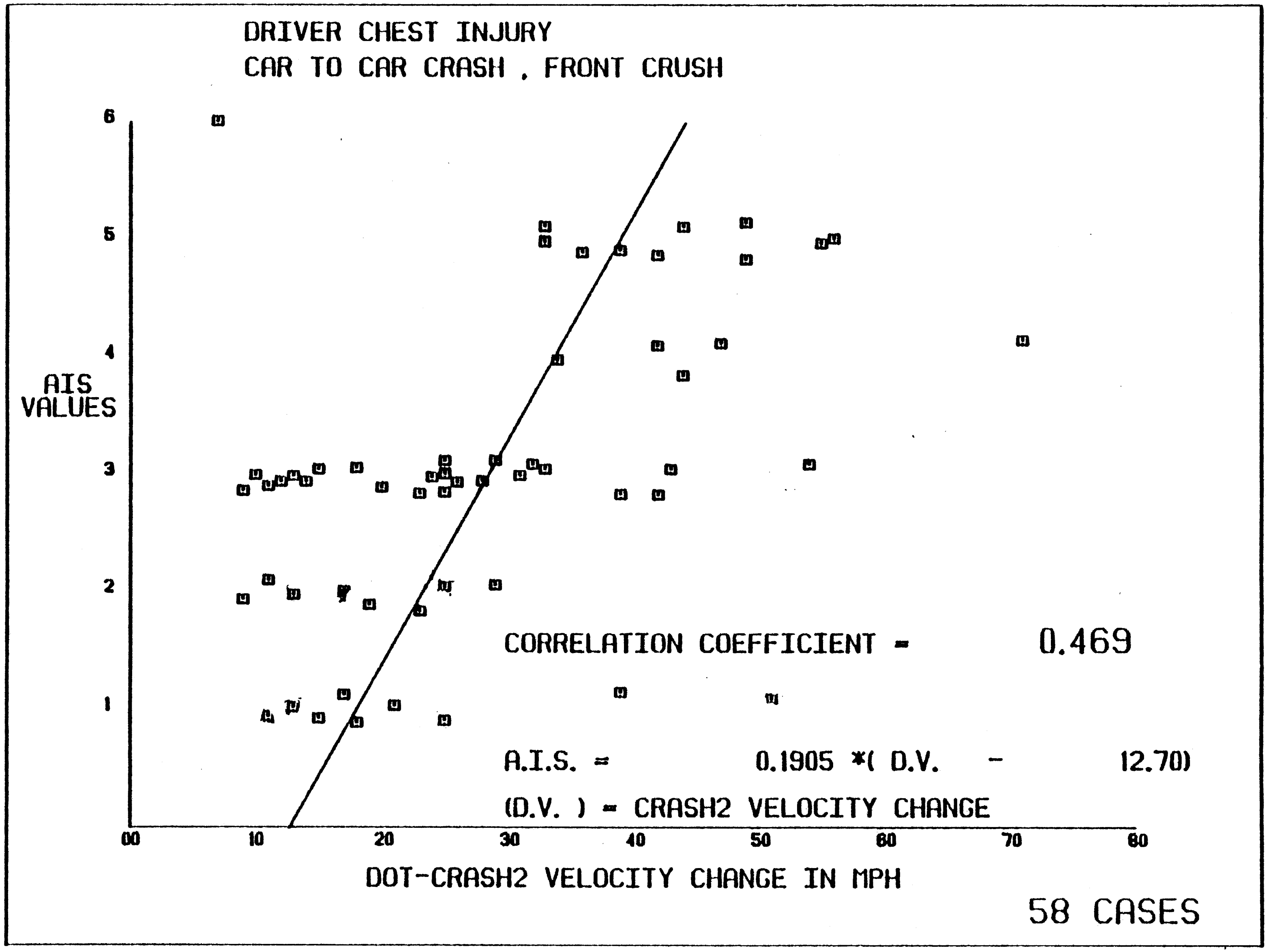

DRIVER CHEST INJURY
CAR TO CAR CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
CORRELATION COEFFICIENT = 0.469
A.I.S. = 0.1905 *(D.V. - 12.70)
(D.V.) = CRASH2 VELOCITY CHANGE
DOT-CRASH2 VELOCITY CHANGE IN MPH
58 CASES

FIGURE 7

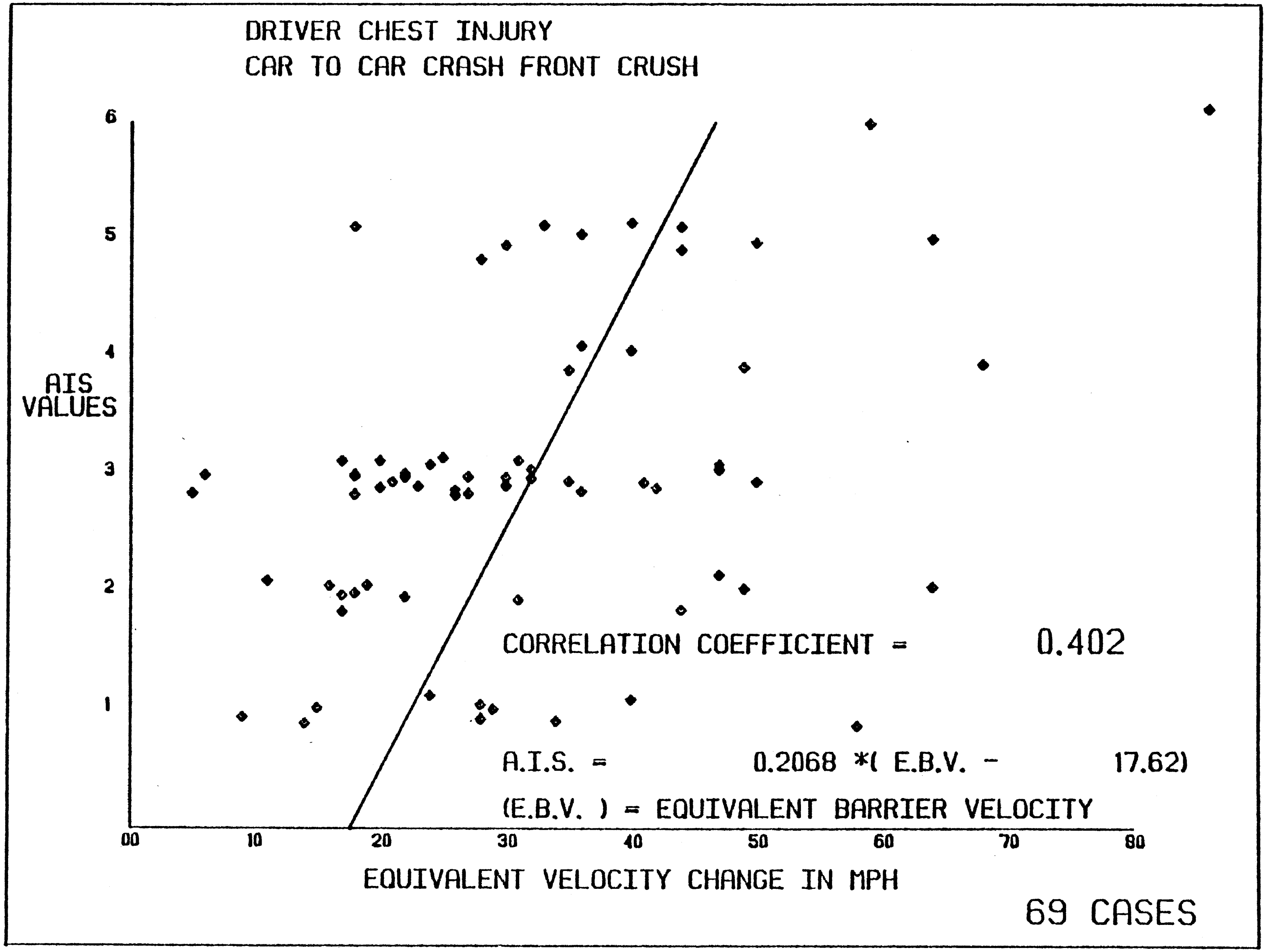

DRIVER CHEST INJURY
CAR TO CAR CRASH FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.402
A.I.S. = 0.2068 *(E.B.V. - 17.62)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
69 CASES

FIGURE 8

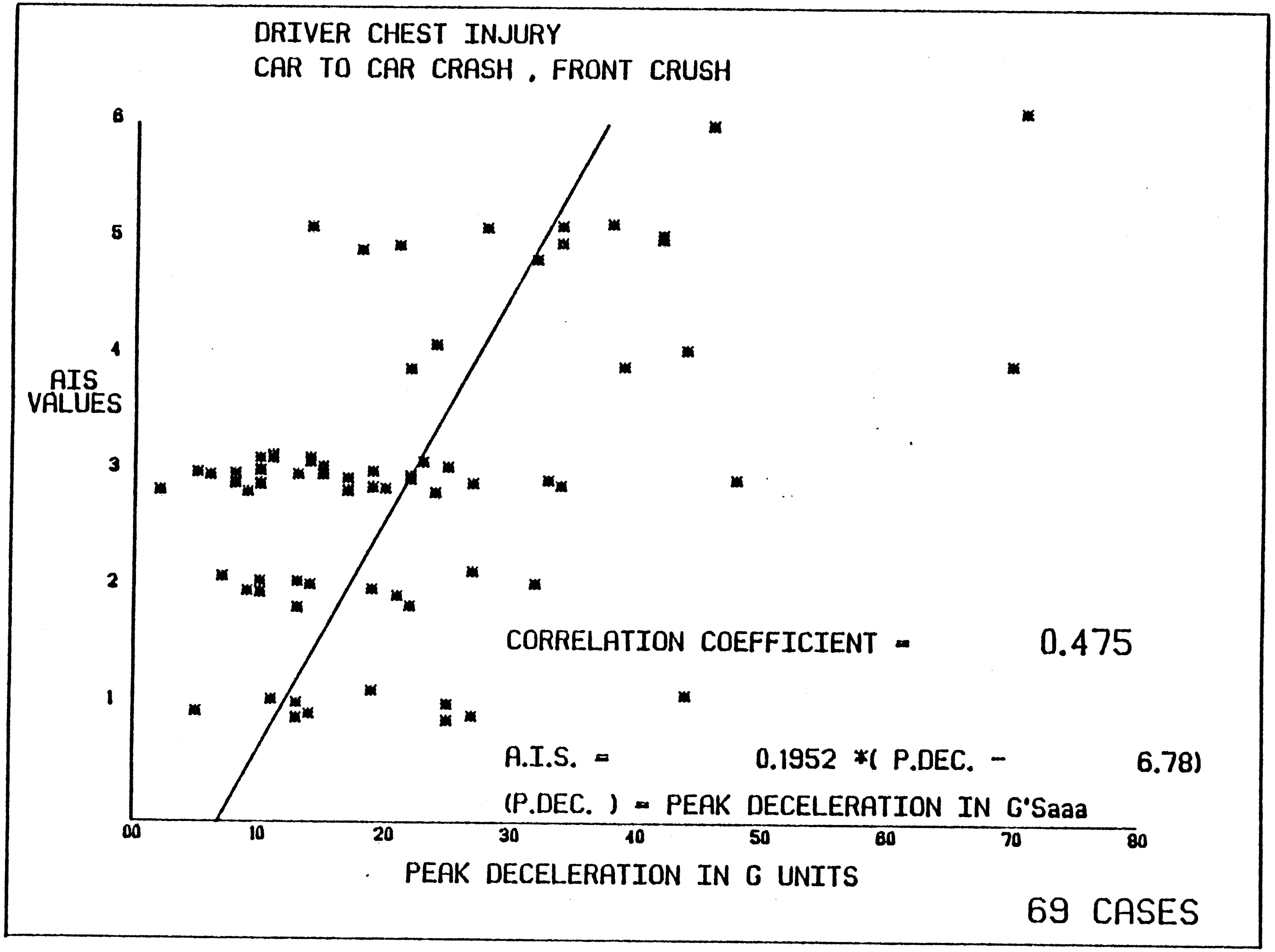

DRIVER CHEST INJURY
CAR TO CAR CRASH , FRONT CRUSH
AIS VALUES
1
2
3
4
5
6
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
CORRELATION COEFFICIENT = 0.475
A.I.S. = 0.1952 *(P.DEC. - 6.78)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
69 CASES

FIGURE 9

TABLE 4

CHEST INJURY PREDICTION FROM DELTA-V

(NCSS CASES)

Front Occupant	AIS Prediction Equation	N	Correlation Coeff.
Driver			
Car to car, front crush	AIS = 0.1905 (Delta V - 12.70)	58	R = 0.469
Car to car, left crush	AIS = 1.7084 (Delta V - 13.60)	31	R = 0.109
Car to pole, front crush	AIS = 1.8996 (Delta V - 21.42)	26	R = 0.075
Car to pole, left crush	AIS = 0.4795 (Delta V - 13.89)	4	R = 0.370
Right Passenger			
Car to car, front crush	AIS = 1.0826 (Delta V - 23.36)	24	R = 0.087
Car to car, Right crush	AIS = 0.1333 (Delta V + 1.25)	8	R = 0.664
Car to pole, front crush	AIS = 0.0935 (Delta V + 9.10)	8	R = 0.671
Car to pole, right crush	AIS = 0.2169 (Delta V - 2.43)	18	R = 0.635

means of using the original data files with a fuller understanding of the field cases.

8.0 Conclusions and Recommendations

Selected sets of scientific and clinical literature, regulatory background, and case studies dealing with automobile occupants' thoracic injuries during automobile crashes have been reviewed. The bulk of the reported research on the engineering characteristics of the human thorax under blunt, impulsive loading is concentrated on the force-time, force-deflection, and deflection-time histories of the thorax, with the loading being delivered by cylindrical strikers in the central plane and normal to the sternum. Significant biodynamic testing has been done under side impulsive loading with multiple accelerometer locations on the bony thoracic cage. Predictions of injury, on the AIS scale, have been made based upon relative sternum-spinal deflections or sternal loading, as well as upon rib fracture in central plane human cadaver studies. Also, predictions of injury, in the case of lateral loading, have been developed based upon combinations of signals, and the time integrals of signals, from the thoracic bony cage instrumentation. Most commonly, in the case of human cadavers, rib fracture has played a prominent part in injury predictions, i.e., in predicting the injury a living human would receive under similar loading.

The research literature relating to automotive crash blunt thoracic loading does not deal to any the great extent with injury to the lungs, great vessels of the thorax, or the heart. Research relative to the mechanisms of the development of contusions, aneurysms, or tearing of the lungs, great vessels, or heart is generally absent in the literature. Research dealing with the influence of the geometry of impactors and/or with variations in the relative height, centerline offset, or angle of the delivered impulse is particularly absent.

Field studies of crashes have produced only a small fraction of cases that can be even roughly modeled to predict the linear or angular time history of the crashing vehicle. These field studies have almost uniformly ignored the probable positioning of the occupant's thorax relative to vehicle landmarks, such as the steering wheel hub or the upper instrument panel's surface in frontal crash cases. The result of these two circumstances is the almost total inability to infer the general nature of the impulsive loading on an occupant's thorax. This general inability is compounded by the known or predictable sensitivity of injury to local force or local deformation patterns.

Two broad recommendations follow from this study. First, detailed laboratory human cadaver impact studies should be carried out under protocols that allow insight into the contusions and lacerations of the lungs, the great vessels of the thorax, and the heart, under conditions in which both the impactor shape and impact location and angle are varied. Associated live surrogate testing would be required to allow study of the living system's reaction to contusions and lacerations. Second, intensive efforts to devise means of accurately reconstructing the pre-crash relative position of the occupant's thorax as well as the occupant-vehicle kinematics and kinetics should be undertaken. Motion of the vehicle elements contacted by the thorax during a crash should be given particular attention.

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APPENDIX A

Appendix A: Federal Register Excerpts

[1] Fed. Std. No. 515/4, June 30, 1965.
Impact Absorbing Steering Wheel and
Column Displacement for Automotive Vehicles.

. . .

S3.1 The steering wheel assembly shall be so constructed that when it is impacted at a relative velocity of 22 feet per second with a torso shaped body block as shown in figure 1, weighing 75-80 pounds, and having a spring rate load of 600-800 pounds, the force developed during collapse of the wheel shall not exceed 2,500 pounds. The spring rate is determined by loading the chest of the torso shaped body block with a 4-inch wide flat contact surface so that it is 90 degrees to the longitudinal axis of the body block, parallel to the backing plate and within 15 to 20 inches from the top of the head form. The load is measured when the flat contact surface has moved down 1/2 inch, and the spring rate is determined by doubling this load figure.

. . .

S3.3 The steering column shall be so designed that when the front structure of the automotive vehicle collapses during the SAE J850 barrier collision test at 20 miles per hour, the upper end of the steering column shall not be displaced rearward, relative to an undisturbed point to the rear of the steering wheel position, more than 5 inches.

[2] Fed. Std. No. 515/4a, July 15, 1966.
Energy Absorbing Steering Control
System for Automotive Vehicles.

. . .

S3.3 The steering control system shall be designed so that when it is impacted at a relative velocity of 22 feet per second with a torso shaped body block as shown in figure 1, weighing 75-80 pounds, and having a spring rate load of 600-800 pounds per inch, it will absorb the energy of the body block. The force developed during collapse of the system shall not exceed 2,500 pounds. Load the chest of the torso shaped body block with a 4-inch wide flat contact surface so that it is 90 degrees to the longitudinal axis of the body block, parallel to the backing plate and within 15 to 20 inches from the top of the head form. Measure the load when the flat contact surface has compressed the body block material 1/2 inch. The spring rate is double this load figure.

...

S3.5 The steering control system shall be so designed that when the front structure of the automotive vehicle collapses during the SAE Recommended Practice J850, Barrier Collision Tests, or equivalent, at 30 miles per hour, the upper end of the steering control system shall not be displaced rearward, relative to an undisturbed point to the rear of the steering wheel position, more than 5 inches.

[3] 31 FR 15219, December 3, 1966.
FMVSS 203, proposal; Docket 3, Notice 1.
Impact Protection for the Driver from the Steering Control System

. . .

S4.1 When the steering control system is impacted by a body block in accordance with Society of Automotive Engineers Recommended Practice J944, "Steering Wheel Assembly Laboratory Test Procedure," February 1966, or an approved equivalent, at a relative velocity of 15 miles per hour--

(a) The force developed on the chest of the body block shall not exceed 1,800 pounds;

(b) The pressure in the area of contact shall not exceed 50 p.s.i.; and,

(c) Peakload shall not be reached within 10 milliseconds after impact.

[4] 31 FR 15219, December 3, 1966.
FMVSS 204, proposal; Docket 3, Notice 1.
Steering Control Rearward Displacement

. . .

S4.1 The upper end of the steering column and shaft shall not be displaced horizontally rearward parallel to the longitudinal axis of the vehicle relative to an undisturbed point on the vehicle more than 3 inches, determined by dynamic measurement, in a barrier collision test at 30 miles per hour conducted in accordance with Society of Automotive Engineers Recommended Practice J850, "Barrier Collision Tests," February 1963.

[5] 32 FR 2414, February 3, 1967.
FMVSS 203, rule; Docket 3.
Impact Protection for the Driver from the Steering Control System

S.1 Purpose and scope. This standard specifies requirements for steering control systems that will minimize chest, neck, and facial injuries to the driver as a result of impact.

. . .

S4.1 When the steering control system is impacted by a body block in accordance with Society of Automotive Engineers Recommended Practice J944, "Steering Wheel Assembly Laboratory Test Procedure," December 1965, or an approved equivalent, at a relative velocity of 15 miles per hour, the impact force developed on the chest of the body block transmitted to the steering control system shall not exceed 2,500 pounds.

[6] 32 FR 2414, February 3, 1967.
FMVSS 204, rule; Docket 3.
Steering Control Rearward Displacement

. . .

S4.1 The upper end of the steering column and shaft shall not be displaced horizontally rearward parallel to the longitudinal axis of the vehicle relative to an undisturbed point on the vehicle more than 5 inches, determined by dynamic measurement, in a barrier collision test at 30 miles per hour minimum conducted in accordance with Society of Automotive Engineers Recommended Practice J850, "Barrier Collision Tests," February 1963.

[7] 32 FR 14280, October 14, 1967.
FMVSS 203, proposal; Docket 2-3.
Impact Protection for the Driver from the Steering Control System

Standard No. 203, issued January 31, 1967 (32 F.R. 2411), specified requirements for steering control systems that will minimize chest, neck, and facial injuries to the driver as a result of impact.

The Administrator is considering extending these requirements to include a maximum pressure in the area of contact with the chest and rate of onset of force after impact.

[8] 32 FR 14281, October 14, 1967.
FMVSS 214, 216, proposal; Docket 2-6.
Intrusion

The Administrator is considering the issuance of a Federal Motor Vehicle Safety Standard specifying requirements to limit the amount of intrusion or penetration on exterior impact, including front, side, rear, and roof, of vehicle and other structures into passenger compartments of passenger cars, multipurpose passenger vehicles, trucks, and buses.

[9] 33 FR 18386, December 11, 1968.
CIR 103, proposal; Docket 28-3, Notice 2.
Side Intrusion Protection for Occupants
of Passenger Compartments

(a) Purpose and scope. The purpose of this section is to provide information on the degree of side intrusion protection afforded occupants during side impact.

. . .

(2) Prepare a loading device consisting of a rigid steel cylinder or semi-cylinder 12 inches in diameter, 24 inches in length, with corner radii of not more than 0.50 inches.

. . .

(4) Using the loading device, apply a load to the outer panel of each side door in a horizontal direction towards the center of the car and at 90 degrees to a vertical plane passing through the car's longitudinal center line. Apply the load at a rate of not more than 10 inches per second until the door's inner panel contacts a vertical plane parallel to, and 12 inches outboard of, a longitudinal vertical plane through the center of the designated seating position closest to the door being tested.

. . .

(6) Obtain the side intrusion protection value as follows:

(i) From the results obtained in subparagraph (5) of this paragraph, plot a curve of load versus displacement.

(ii) Obtain the integral of the applied load with respect to the displacement between the displacement limits as specified in subparagraph (5) of this paragraph. (This may be done by measuring the area under the curve.) This figure, expressed in inch-pounds, represents the work required to deform the door.

(iii) Divide the results obtained in accordance with subdivision (ii) of this subparagraph by the vehicle test weight in pounds.

. . .

The quotient, rounded to the nearest tenth, is the side intrusion protection value for the door.

[10] 35 FR 813, January 21, 1970.
CIR 103, proposal; Docket 20-3, Notice 3.
Side Door Strength

. . .

The first proposal called for a measurement of the work required to deform the door inward to the point where the inner panel is 12 inches outboard of the center of the occupant's designated seating position. The test was intended to produce a direct measure of intrusion protection, based in part on the assumption that the intrusion protection offered by the vehicle was proportional to the distance of the driver's or outboard passenger's seating position from the door. It has been determined that this assumption may be questionable, in that the driver or outboard passenger tends to be thrown against the door when another vehicle collides with the side adjacent to him. Therefore, further study is needed in order to arrive at an appropriate method of deriving and presenting meaningful intrusion protection data. The strength of the door has been found to be a significant safety factor, however, without reference to the seating positions. In the present proposal, therefore, the quantity measured is the average force required to crush the door a standard distance of 12 inches, with an adjustment for the weight of the vehicle. The name of the section has accordingly been changed to Side Door Strength.

. . .

(4) Using the loading device, apply a load to the outer panel of the door in an inboard direction normal to a vertical plane along the vehicle's longitudinal centerline. Apply the load such that the loading device travel rate does not exceed one-half inch per second, and continue application until the loading device travels 12 inches (the "crush distance").

. . .

(6) Determine the equivalent crush resistance as follows:

(i) From the results obtained in subparagraph (5) of this paragraph, plot a curve of load versus displacement and obtain the integral of the applied load with respect to the crush distance. This quantity, expressed in inch-pounds and divided by the crush distance, represents the average resistance force in pounds required to deflect the door.

(ii) Determine the equivalent crush resistance of the door by the following equation:

Equivalent crush resistance=
Average resistance force+1/4 (3000-W)

Where W is the curb weight of the vehicle in pounds plus 200.

[11] 35 FR 5120, March 26, 1970.
FMVSS 213, rule.
Child Seating Systems

. . .

Because it is not fully developed, the body of a young child cannot safely tolerate the concentrated loads that an adult's body can. Therefore, it is not medically sound to restrain a child so that restraint loads are concentrated solely on his pelvis or his thorax. The widest possible distribution of those loads is desirable. As one respondent pointed out, the available information does not disclose in what proportion the loads should be distributed. Nevertheless, the Director has decided to retain the requirement that child seating systems must distribute restraint forces on both the pelvis and thorax of their occupants. In the circumstances, a requirement for distribution of restraint forces, even if the extent of distribution is unspecified, seems preferable to no requirement at all.

[12] 35 FR 6512, April 23, 1970.
FMVSS 214, proposal; Docket 2-6, Notice 2.
Side Door Strength

. . .

This notice proposes a new motor vehicle safety standard, which would set a minimum strength requirement for side doors of passenger cars, on the basis of a test substantially the same as that specified for the consumer information requirement.

Recent studies demonstrate that in side impacts the percentage of dangerous and fatal injuries increases sharply as the maximum depth of penetration increases, and that in fatal side collisions, most occupants die from side structures collapsing inward on them, rather than from their striking the door. To protect occupants from such hazards, a strong door structure is required, in conjunction with an effective restraint system and energy-absorbing material on the vehicle's surfaces.

In order to establish a minimum level of protection, a static test is proposed that would set up three requirements that side doors must meet. The initial resistance, defined as the average force required to crush the door 6 inches inward, is set at a minimum of 2,500 pounds. The equivalent crush resistance, the average force required to crush the door 12 inches corrected by a factor involving the vehicle's weight, is set at a minimum of 3,750 pounds. This is the quantity measured in the consumer information proposal on Side Door Strength. Finally, the peak resistance, the greatest resisting force measured over 18 inches of crush, is set at a minimum of twice the vehicle's weight.

[13] 35 FR 7187, May 7, 1970.
FMVSS 208, proposal; Docket 69-7, Notice 4.
Occupant Crash Protection

. . .

The purpose of this notice is to propose a motor safety standard for Occupant Crash protection, which would specify performance requirements for protection of vehicle occupants in crashes both by systems that do and those that do not require voluntary action. The proposed standard would replace the existing Standard No. 208, Seat Belt Installations.

. . .

The proposed standard establishes basic injury criteria with reference to an anthropometric dummy, expressed in terms of maximum forces and pressures on critical parts of the body. It would require passenger cars manufactured on or after January 1, 1972, to meet these criteria with dummies placed at each designated seating position, in a frontal fixed barrier crash at 30 miles per hour. Since it appears that some manufacturers will be unable to meet these requirements by that date with systems that are purely passive, because of inadequate supplies of such systems, passenger cars manufactured during calendar year 1972 would be permitted to meet the criteria with advanced systems, such as vehicle-sensitive 3-point belts, that do require action by the occupants. On or after January 1, 1973, passenger cars would be required to meet the frontal crash test, and in addition a lateral impact test and a rollover test, by means requiring no action by vehicle occupants.

. . .

The anthropometric dummy is an important part of the test requirements of the proposed standard. The specifications of SAE Recommended practice J963, "Anthropometric Test Device for Dynamic Test," are employed for the purposes of this proposal. It is recognized that these specifications, evidently the most complete set available at this time, may not provide totally reproducible results in testing vehicle performance. Further work on this subject is in progress, and comments are specifically requested on any changes that should be made.

. . .

S4. Occupant protection requirements.

S4.1 Frontal barrier crash. When the vehicle impacts a fixed collision barrier perpendicularly or at any angle up to 30 degrees from the perpendicular in either direction, while moving longitudinally forward at any speed up to 30 miles per hour, it shall meet the injury criteria of S4.4, under the conditions of S6.

S4.2 Lateral barrier crash. When the vehicle impacts a fixed collision barrier perpendicularly, while moving laterally at 15 miles per hour, it shall meet the injury criteria of S4.4, under the conditions of S6 except that all adjustable vehicle windows are fully open.

S4.3 Rollover. When the vehicle is subjected to 2 complete rollovers on level ground from a forward speed between 30 and 60 miles per hour, under the conditions of S6 except that all adjustable vehicle windows are fully open, no anthropometric test device shall be ejected from the passenger compartment.

. . .

S4.4.3 The resultant chest acceleration shall not exceed 40g.

. . .

S4.4.6 The force on the chest shall not exceed 1,200 pounds, and the pressure on the chest shall not exceed 50 pounds per square inch.

[14] 35 FR 14911, September 25, 1970.
FMVSS 208, Docket 69-7, Notice 6.
Occupant Crash Protection

The purpose of this notice is to propose requirements for occupant crash protection for vehicles manufactured on or after January 1, 1972. A previous notice published on May 7, 1970 (35 F. R. 7187) proposed requirements for both "passive" crash protection and for interim "active" systems, and a public meeting was held on June 24 and 25, 1970, to discuss the contents of that proposed standard. On the basis of comments and information received since the earlier notice, this notice proposes modified requirements for the interim systems effective January 1, 1972.

. . .

Under this proposed standard, manufacturers of passenger cars would be given three options under which they could provide occupant crash protection in vehicles manufactured on or after January 1, 1972.

The first option would be a passive protection system that requires no action by vehicle occupants. A variety of systems may be used to meet this requirement, among which are passive cushioning of the vehicle interior, self-fastening belt systems, crash deployed nets, "blankets," and air bags.

The second option would require a Type 1 lap belt in all positions, and would either (1) be tested by a 30-m.p.h. barrier crash with anthropometric dummies restrained by lap belts in the front outboard seating positions, with the same injury criteria as the passive system; or (2) conform to the updated requirements proposed in the notices of proposed amendment to Motor Vehicle Safety Standards No. 201 and 203 (35 F.R. 14936, 35 F.R. 14940).

The third option would be an improved combination of lap-and-shoulder belt system in the front outboard seating positions, with lap belts in other positions. The front outboard systems would be tested by a 30-m.p.h. crash in which belt systems, used with test dummies, would be required to remain intact.

. . .

Several comments were received concerning the injury criteria specified for passive systems. Most commentors felt that the force and pressure measurements specified were beyond the state of the art. It has been determined that an adequate measurement of injury can be made in terms of head acceleration, chest acceleration, and the force transmitted through each femur, and values for each of these injury criteria are specified in this notice.

. . .

S3.1 First option--passive protection system. When the vehicle perpendicularly impacts a fixed collision barrier, while moving longitudinally forward at any speed up to 30 m.p.h., it shall meet the injury criteria of S5, under the test conditions of S4 using unrestrained anthropomorphic test devices, by means that require no action by vehicle occupants.

S3.2 Second option--combination system. The vehicie shall--

. . .

(d) Meet either--

(1) The injury criteria of S5, under the test conditions of S4 with anthropomorphic test devices at each front outboard position restrained only by Type 1 seat belt assemblies, when the vehicle perpendicularly impacts a fixed collision barrier while moving longitudinally forward at any speed up to 30 m.p.h.; or

(2) The requirements proposed, as an amendment to Standard No. 201 (35 F.R. 14936) for the windshield header, the A-pillar, and Zones 1, 2, 3, and 4; and the requirements proposed, as an amendment to Standard No. 203 (35 F.R. 14940) for the steering control assembly.

S3.3 <u>Third option--belt system</u>. The vehicle shall--

(a) Except in convertibles and open-body type vehicles, have a Type 2 seat belt assembly, with either an integral or detachable upper torso portion, at each front outboard seating position, that conforms to Standard No. 209 and S3.4 and S3.5 of this standard;

(b) Have a seat belt warning system at each front outboard seating position that conforms to S3.6;

(c) Have either a Type 1 or a Type 2 seat belt assembly that conforms to S3.4 and S3.5 at all designated seating positions, and other than those specified in S3.3 (a); and

(d) When the vehicle perpendicularly impacts a fixed collision barrier, while moving longitudinally forward at any speed up to 30 m.p.h., under the test conditions of S4 with anthropomorphic test devices at each front outboard position restrained by Type 2 seat belt assemblies, experience no complete separation of any element of a seat belt assembly.

. . .

[15] 35 FR 14940, September 25, 1970.
FMVSS 203, proposal; Docket 2-3, Notice 2.
Impact Protection for Driver from Steering Control System

. . .

The purpose of this notice is to propose several amendments to strengthen the standard.

The total stress placed on the driver's body in an impact with the steering assembly is the sum of several factors: the total force imposed, the surface area over which the force is distributed, and the contour of the impacted steering assembly surface. The lower the force, the larger the surface, and the smoother the contours, the greater the protection afforded the driver. This notice proposes to deal with each of these factors.

The existing Standard No. 203 specifies a maximum allowable force of 2,500 pounds on a body block impacted at 15 miles per hour. The increasing amount of knowledge about thoracic injury threshold levels suggests that the allowable forces should be reduced. Accordingly it is proposed to reduce maximum permissible force on the body block to 1,800 pounds at an impact velocity of 20 m.p.h.

There is presently no minimum requirement for the effective surface area of a steering assembly. It is proposed to require the area of the steering assembly in contact with the body block on impact to be at least 40 square inches. Given the present technological difficulties of pressure measurement during impacts, this appears to be the most feasible method of insuring survivable pressure levels on the driver's body. To complement the surface area requirement, the notice also proposes to require padding over the steering wheel hub.

The dynamic contours of the steering assembly are specified in three ways. During impact, the body block may contact no rigid surface edge with a radius of less than one-fourth on an inch. The assembly may not fracture or fall apart in such a way as to produce an edge or point capable of causing injury. Finally, the steering wheel rim must pivot or flex to allow the body block to contact the wheel across its full diameter well before the maximum allowable load is attained. Each of these requirements is intended to reduce the possibility of chest injuries attributable to fractured or protruding components.

. . .

S4. Requirements. When a vehicle is tested in accordance with S5, its steering control system shall meet the following requirements with the steering wheel at any position of rotation.

S4.1 When a steering control system is impacted at 20 m.p.h. in accordance with S5.1--

(a) The resultant force imposed on the body block shall not exceed 1,800 pounds;

(b) The body block shall not contact any rigid material edge having a radius of less than one-fourth of an inch; and

(c) The rim, spokes, hub, and hub pad of the steering wheel shall not disengage from the steering column or from each other and shall be free of sharp points or edges that could contribute to occupant injury.

S4.2 A steering control system in which the angle of the steering column segment nearest the driver is not more than 45 degrees from the horizontal shall meet the following requirements in addition to those of S4.1:

(a) The wheel hub shall be covered with a pad having a thickness at all points of at least 1 inch, consisting of force distributing material that, when tested in accordance with S5.2, compresses by an amount within the acceptable range shown in Figure 1 and recovers at a rate of not more than 4.4 feet per second.

(b) When impacted in accordance with S5.1 at 20 m.p.h. the area of contact of the steering wheel rim and hub pad with the body block shall be not less than 40 square inches.

(c) When impacted in accordance with S5.1 at 20 m.p.h. the area of contact of the steering wheel rim with the body block as the resultant force on the body block reaches 1,200 pounds shall include the uppermost and lowermost points of the rim face.

[16] 35 FR 16801, October 30, 1970.
FMVSS 214, rule; Docket 2-6, Notice 3.
Side Door Strength

. . .

The proposal required a door to provide an average crush resistance of 2,500 pounds during the first 6 inches of crush. One comment stated that equivalent protection can be provided by structures further to the interior of the door and that the proper measure of protection is the force needed to deflect the inner door panel rather than that needed to deflect the other panel. Although inboard mounted structures may be effective in preventing intrusion if the door has a large cross section, with a correspondingly large distance between the protective structure and the inner panel, the standard as issued reflects the determination that doors afford the greatest protection if the crush resisting elements are as close to the outer panel as possible. It follows from this determination that the surface whose crush is to be measured must be the outer panel rather than the inner one. The value specified for the initial crush resistance has, however, been reduced from 2,500 pounds to 2,250 pounds, a value that has been determined to be more appropriate, particularly for lighter vehicles.

. . .

The comments revealed a considerable difference of opinion concerning the value and validity of the concept of "equivalent crush resistance." The equivalent crush resistance was to be derived by adding 1/4 (3000-W) to the average force required to crush the door 12 inches. It had been thought that the resulting bias against heavier vehicles was necessary in that their greater mass would cause them to move sideways less in a collision than light vehicles, with more of the impacting force being absorbed by the door. Recent studies, however, show that occupants of heavier vehicles involved in side collisions generally suffer a lower proportion of serious injuries and fatalities than persons in lighter vehicles. In light of these studies and other information, the standard retains the basic crush resistance requirement, but deletes the weight correction factor. Since it is no longer appropriate to use the term "equivalent crush resistance," in its place the standard employs the phrase "intermediate crush resistance." The slightly lower figure of 3,500 pounds has been substituted for the 3,750 pound force proposed in the notice. The effect of the change is to increase slightly the crush resistance required for vehicles having curb weight less than 1,800 pounds, and to decrease it slightly for vehicles weighing more than 1,800 pounds.

Similar reasoning lies behind a change in the requirement for peak crush resistance. The available information does not support a peak crush requirement that increases indefinitely with increasing vehicle curb weight. The standard therefore sets a ceiling of 7,000 pounds to the requirement that the door have a peak crush resistance of twice the vehicle's curb weight. In effect, the requirement is unchanged from the proposal for vehicles weighing less than 3,500 pounds and is diminished for vehicles exceeding that weight.

. . .

S1. Purpose and scope. This standard specifies strength requirements for side doors of a motor vehicle to minimize the safety hazard caused by intrusion into the passenger compartment in a side impact accident.

S2. Application. This standard applies to passenger cars.

S3. Requirements. Each vehicle shall be able to meet the following requirements when any of its side doors that can be used for occupant egress are tested according to S4.

S3.1 Initial crush resistance. The initial crush resistance shall be not less than 2,250 pounds.

S3.2 Intermediate crush resistance. The intermediate crush resistance shall not be less than 3,500 pounds.

S3.3 Peak crush resistance. The peak crush resistance shall be not less than two times the curb weight of the vehicle or 7,000 pounds, whichever is less.

. . .

(f) Determine the initial crush resistance, intermediate crush resistance, and peak crush resistance as follows:

(1) From the results recorded in subparagraph (e) of this paragraph, plot a curve of load versus displacement and obtain the integral of the applied load with respect to the crush distances specified in subdivisions (2) and (3) of this paragraph. These quantities, expressed in inch-pounds and divided by the specified crush distances, represent the average forces in pounds required to deflect the door those distances.

(2) The initial crush resistance is the average force required to deform the door over the initial 6 inches of crush.

(3) The intermediate crush resistance is the average force required to deform the door over the initial 12 inches of crush.

(4) The peak crush resistance is the largest force recorded over the entire 18-inch crush distance.

[17] 35 FR 16927, November 3, 1970.
FMVSS 208, rule; Docket 69-7, Notice 7.
Occupant Crash Protection

The purpose of this amendment to Standard 208 is to specify occupant crash protection requirements for passenger cars, multipurpose passenger vehicles, trucks, and buses, manufactured on or after July 1, 1973, with additional requirements coming into effect for certain of those vehicles manufactured on or after July 1, 1974.

. . .

That notice also proposes a minimum vehicle speed of 15 miles per hour for deployment of crash-deployed systems.

The notice of proposed rulemaking published on September 25, 1970 (35 F.R. 14941), proposed injury criteria that are modified from the May 7 notice. These criteria would limit head accelerations to 67g except for cumulative periods of 3 milliseconds with a maximum of 90g, limit chest accelerations to 40g except for cumulative periods of 2 milliseconds, and limit the axial force through each upper leg to 1,400 pounds. Comments to the May 7 and the September 25 notices varied widely in their recommendations. Some advocated the use of severity indices, while others disrupted the methods or the quantitative levels of the indices. The levels proposed in the September 25 notice are adopted in this standard, with the head acceleration changed from 67g to 70g, as the best available criteria for the quantities measured. Consideration will be given to adoption of a severity index or other criteria as further research results become known. Research results and comments related to the problem indicate, however, that human tolerances for lateral accelerations on the head and chest are significantly lower than for forward ones, and the separate notice issued today (35 F.R. 16937) proposes additional injury criteria with respect to the lateral component of head and chest accelerations.

Several of the injury criteria proposed in the May 7 notice have been omitted from the standard. The forces and pressures on the chest, abdominal, and pelvic regions were primarily related to the performance of belt-type systems, and it has been found that no accurate means of determining these values presently exists. They are not considered as critical as the acceleration values that are specified in the standard, and, as recommended by many of the comments, they have been omitted.

. . .

The fact that some injury criteria, such as force and pressure, cannot be accurately measured by anthropomorphic test devices suggests that alternate steps must be taken to insure that these criteria are kept to tolerable levels.

On consideration of all available data, it has been determined that dummies conforming to the SAE specifications are the most complete and satisfactory ones presently available. More complete specifications have been added for the configuration of the pelvis, the positioning of the dummies in the vehicle, and the instrumentation techniques. The positioning of instrumentation within the dummies is specified to insure more consistent and repeatable results. A requirement that acceleration data be filtered to exclude frequencies higher than 250 cycles per second has been added, in response to several comments, to eliminate sharp spikes due to electronic noise and dummy resonance that are not considered significant with respect to injury.

The position of adjustable seats has been set midway between the forwardmost and rearmost positions, to provide a more realistic test than the proposed one with the seat fully forward. For the same reason, and to assess more accurately the vehicle's protection performance, it is specified that the doors shall be unlocked for all tests, and adjustable steering controls shall be placed in the center of the driving adjustment range; these aspects were not covered in the proposal.

. . .

S5.3 The resultant acceleration at the center of gravity of the upper thorax shall not exceed 40g for a cumulative duration of more than 2 milliseconds. [Criteria for the lateral component of upper thorax acceleration are proposed in a separate notice published today (35 F.R. 16937).]

[18] 35 FR 16937, November 3, 1970.
FMVSS 208, proposal; Docket 69-7, Notice 8.
Occupant Crash Protection

The purpose of this notice is to propose amendments to the revised Motor Vehicle Safety Standard No. 208, Occupant Crash Protection, issued today (35 F.R. 16926), that would add additional injury criteria for lateral acceleration of the head and chest, specify test conditions for the lateral moving barrier crash test and the rollover test, omit the exception of openbody type vehicles from the rollover requirement that was proposed in the notice of May 7, 1970 (35 F.R. 7187), and establish a minimum vehicle speed for actuation of crash-deployed protection systems.

The standard as issued provides . . . that the resultant chest accelerations shall be not more than 40g, except for a cumulative duration of 2 milliseconds.

Biomechanical studies indicate that the lateral acceleration tolerance of the head and chest are significantly less than the frontal acceleration tolerance. It is accordingly proposed that in addition to the criteria described above for the resultant accelerations, a requirement be added . . . limiting the lateral component of chest accelerations to 20g, except for a cumulative period of 2 milliseconds.

. . .

A moving barrier test is proposed in place of the fixed barrier collision. The moving barrier speed is set at 20 m.p.h., a speed calculated to approximate the impact of a 15-mile-per-hour fixed barrier impact, or a 30-mile-per-hour car-to-car collision.

. . .

This notice proposes a procedure for rollover testing whereby the vehicle is launched transversely with a specified deceleration pulse from a raised carriage-type platform onto a concrete surface.

. . .

To avoid variable results from collisions between dummies, the standard provides that dummies are to be positioned only in the outboard positions on the side of the impact, for the lateral impact test, and only in the outboard positions on the lower side of the vehicles as mounted on the test platform, for the rollover test.

. . .

A final proposed amendment concerns the minimum vehicle speed for deployment of crash-deployed systems. Comments on the May 7 notice and other information indicate that fixed energy-absorption materials are capable of meeting the occupant protection requirements at low speeds. It is therefore proposed to raise the minimum deployment speed for crash-deployed systems to 15 miles per hour. It is proposed to retain the requirement that the minimum deployment speed be applicable at any angle of impact, since presently available sensors can provide the necessary directional-velocity discrimination, and it is important that crash-deployed systems do not deploy except in crash situations for which they are designed.

[19] 36 FR 2815, February 10, 1971.
FMVSS 208, notice.
Occupant Crash Protection, Notice of 1972 Requirements

This notice is issued as advance public information, for the purpose of informing motor vehicle manufacturers of the main highlights of the Occupant Crash Protection standard (No. 208) that will apply to passenger cars beginning January 1, 1972, to enable them to initiate preparation for production with minimum loss of the remaining leadtime. The features of the standard set forth herein represent final decisions with respect to the standard, which is presently being prepared for issuance in the near future.

Passenger cars, at each designated seating position, must meet at least one of three sets of requirements, or options, as follows:

First Option--Complete Passive Protection System

1. The vehicle shall provide passive protection in frontal fixed barrier crash tests up to 30 m.p.h., and up to 30 degrees to either side of the perpendicular, and in lateral and rollover crash tests. Seat belts are not required, and except for the completely passive type belt system, may not be used for testing.

2. The test dummy is as described in SAE J963, with instrumentation as described in SAE J211.

3. The injury criteria are (a) a maximum head severity index of 1,000, calculated according to SAE J885a, (b) a maximum chest acceleration of 60g, except for periods with cumulative duration of not more than 3 milliseconds, and (c) a maximum upper leg force of 1,400 pounds.

Second Option--Lap Belt Protection System with Belt Warning

. . .

4. For front outboard seats, the vehicles shall meet a perpendicular 30 m.p.h. fixed barrier crash test with instrumented test dummies and injury criteria as described in the first option, but with the dummies lap-belted. No shoulder belt is required, and even if furnished is not used for testing under this option.

. . .

Third Option--Lap and Shoulder Belt Protection System with Belt Warning

1. The vehicle shall provide a lap and shoulder belt assembly for the front outboard seats, and lap belts at the other seating positions.

2. A belt warning system as described above is required for the lap-belt portions of the front outboard seating positions. Requirements for lap-belt retractors, method of release, and for ranges of adjustment are the same as in the second option.

3. The lap and shoulder belts in the front outboard positions are tested with dummies in a perpendicular 30-m.p.h. fixed barrier crash, with the requirement that there be no structural failures of the restraint system.

[20] 36 FR 4600, March 10, 1971.
FMVSS 208, rule; Docket 69-7, Notice 9.
Occupant Crash Protection

The purpose of this amendment to Standard No. 208, 49 CFR 571.21, is to specify occupant crash protection requirements for passenger cars, multipurpose passenger vehicles, trucks, and buses manufactured on or after January 1, 1972, with additional requirements coming into effect for certain of those vehicles on August 15, 1973, August 15, 1975, and August 15, 1977. The requirements effective for the period beginning on January 1, 1972, were the subject of a notice of proposed rulemaking published September 25, 1970 (35 F.R. 14941), and appear today for the first time in the form of a rule. The requirements for subsequent periods were issued in rule form on November 3, 1970 (35 F.R. 16927), and are reissued today in amended form as the result of petitions for reconsideration.

. . .

The standard establishes quantitative criteria for occupant injury, as determined by use of anthropomorphic test devices . . . For the upper thorax, it is a deceleration of 60g except for a cumulative period of not more than 3 milliseconds.

. . .

On January 1, 1972, a passenger car will be required to provide one of three options for occupant protection: (1) Passive protection system that meets the above injury criteria in all impact modes at all seating positions; (2) lap belts at all positions, with a requirement that the front outboard positions meet the injury criteria with lap-belted dummies in a 30-m.p.h. barrier crash without belt or anchorage failure, and lap belts in other positions.

. . .

On August 15, 1973, a passenger car will be required to provide one of two options for occupant protection: (1) Passive protection that meets the injury criteria in all impact modes at all seating positions; or (2) a system that provides passive protection for the front positions in a perpendicular frontal fixed barrier crash, that includes lap belts at all seating positions such that the injury criteria are met at the front positions both with and without lap belts fastened in a perpendicular frontal fixed barrier crash, and that has a seat belt warning system at the front outboard positions.

. . .

On and after August 15, 1975, a passenger car will be required to meet the injury criteria in all impact modes at all seating positions by passive means.

. . .

The third option proposed in the September 25 notice has been adopted with some changes. It consists of an improved combination of lap and shoulder belts in the front outboard seating positions, with lap belts in other positions. The belts and anchorages at the front outboard positions must be capable of restraining a dummy in a 30-m.p.h. frontal perpendicular impact without separation of the belts or their anchorages.

. . .

The date on which a passenger car must provide passive means of meeting the injury criteria in a side impact is changed to August 15, 1975, to reflect the greater leadtime needed to develop such passive systems. To provide uniform phasing, and allow time for development of passive protection in the angular-impact and rollover modes, the effective dates for these requirements is also set at August 15, 1975. Thus, after August 15, 1975, each passenger car must meet the crash protection requirements at each seating position in all impact modes by means that require no action by vehicle occupants.

. . .

A number of petitions objected to the requirement for a minimum speed below which a crash-developed system may not deploy. Upon consideration of the petition, it has been determined that it is preferable to allow manufacturers freedom in the design of their protective systems at all speeds, and this requirement is hereby deleted from the standard.

The injury criteria specified in the November 3 amendment were the subject of numerous petitions.

. . .

The severity index is based on biomechanical data derived from head injury studies and does not adapt itself readily to chest-injury usage. Several petitions stated that the chest injury criteria were set at too low a level. In some respects, a higher "g-level" on the chest actually increases the protective capabilities of the system, if properly designed, since it more effectively utilizes the available space in which the occupant can "ride down" the crash impact--an especially important factor in higher-speed crashes. Therefore, in accordance with data currently available, a chest tolerance level of 60g, except for a cumulative period of 3 milliseconds, is hereby adopted.

. . .

The use of the anthropomorphic test device described in SAE J963 was objected to by several petitioners, on the grounds that further specifications are needed to ensure repeatability of test results. The Administration finds no sufficient reason to alter its conclusion that the SAE specification is the best available. The NHTSA is sponsoring further research and examining all available data, however, with a view to issuance of further specifications for these devices.

[21] 36 FR 19254, October 1, 1971.
FMVSS 208, rule; Docket 69-7, Notice 12.
Occupant Crash Protection

The purpose of this notice is to respond to petitions filed pursuant to Part 553.35 of Title 49, Code of Federal Regulations, requesting reconsideration of Motor Vehicle Safety Standard No. 208, Occupant Crash Protection (49 CFR 571.21), published on March 10, 1971 (36 F.R. 4600).

. . .

Several petitioners noted that the requirements for anthropomorphic test devices specified in the standard, mainly those set forth in SAE Recommended Practice J963, do not completely define all the characteristics of the dummies that may be relevant to their (and the vehicle's) performance in a crash test. The NHTSA considers the comment valid. It would actually be difficult, if not impossible, to describe the test dummy in performance terms with such specificity that every dummy that could be built to the specifications would perform identically under similar conditions. Of course, since the dummy is merely a test instrument and not an item of regulated equipment, it is not necessary to describe it in performance terms; its design could legally be "frozen" by detailed, blueprint-type drawings and complete equipment specifications. Such an action does not, however, appear to be desirable at this time. Considerable development work is in process under various auspices to refine the dynamic characteristics of anthropomorphic devices, to determine which designs are most practicable, offer the most useful results, and best simulate the critical characteristics of the human body. The NHTSA is monitoring this work (and sponsoring some of it), and intends to propose amendments of the standard in accordance with it to add more detailed performance and descriptive specifications for the test dummies, although no changes are being made in that respect by this notice.

[22] 36 FR 19266, October 1, 1971.
FMVSS 208, proposal; Docket 69-7, Notice 13.
Occupant Crash Protection in Passenger Cars

. . .

In response to requests by several manufacturers for a delay in the date by which passive protection must be provided in passenger cars, for the reasons discussed in the notice of action on the petitions, it is hereby proposed that a third option be allowed for the period from August 15, 1973, to August 15, 1975.

. . .

(7) All belts would be required to conform to Standard No. 209; the front outboard belts, whether lap belts or nondetachable lap and shoulder belt combinations, would have to meet the injury criteria of the standard when tested with dummies in a 30-m.p.h. frontal barrier crash; and the lap belts in the front center position (if any) must remain intact in the same crash test. Although a detachable shoulder belt is not prohibited at the front outboard positions, an assembly with a detachable shoulder belt would have to meet the injury criteria with the lap belt alone.

. . .

S4.1.2 Passenger cars manufactured from August 15, 1973 to August 14, 1975.

. . .

S4.1.2.3 Third option--lap and shoulder belt protection system with ignition interlock and belt warning.

. . .

(d) At each front outboard designated seating position meet the frontal crash position requirements of S5.1, in a perpendicular impact, with the test device restrained by a Type 1 seat belt assembly or a Type 2 seat belt assembly with a nondetachable upper torso portion; and

(e) When it perpendicularly impacts a fixed collision barrier, while moving longitudinally forward at any speed up to and including 30 m.p.h., under the test conditions of S8.1, with an anthropomorphic test device at any front-center seating position restrained by a Type 1 or Type 2 seat belt assembly, experience no complete separation of any load-bearing element of the seat belt assembly or anchorage.

[23] 36 FR 3911, February 24, 1972.
FMVSS 208, rule; Docket 69-7, Notice 16.
Occupant Crash Protection

The purpose of this notice is to amend Standard No. 208, Occupant Crash Protection, as proposed September 29, 1971 (36 F.R. 19266, October 1, 1971) with respect to the occupant protection options available between August 15, 1975. The amendments proposed on September 29 are adopted essentially as proposed, with minor modifications.

The notice proposed a third occupant protection option (S4.1.2.3) for passenger cars manufactured between August 15, 1973 and August 15, 1975. The salient feature of the new option was the use of seat belts equipped with an ignition system that would prevent the engine from starting if any front seat occupant did not have his belt fastened. The belts at the front outboard positions would have to meet the injury criteria of the standard in a 30-m.p.h. frontal barrier crash, and any lap belt in the center position would have to remain intact in the same crash. If shoulder belts were provided at the front positions, they would have to be nondetachable and have emergency locking retractors.

. . .

4. A new section S4.1.2.3 is added, reading as follows:

S4.1.2.3 Third option--lap and shoulder belt protection system with ignition interlock and belt warning.

. . .

(d) At each front outboard designated seating position, meet the frontal crash protection requirements of S5.1, in a perpendicular impact, with the test device restrained by a Type 1 seat belt assembly or a Type 2 seat belt assembly with a nondetachable upper torso portion; and

(e) When it perpendicularly impacts a fixed collision barrier, while moving longitudinally forward at any speed up to and including 30 m.p.h., under the test conditions of S3.1, with an anthropomorphic test device at any front center seating position restrained by a Type 1 or Type 2 seat belt assembly, experience no complete separation of any load-bearing element of the seat belt assembly or anchorage.

[24] 37 FR 13265, July 6, 1972.
FMVSS 208, rule; Docket 69-7, Notice 20.
Occupant Crash Protection

The purpose of this notice is to respond to petitions for reconsideration of the seat belt interlock requirements of Motor Vehicle Safety Standard No. 208, Occupant Crash Protection, 49 CFR 571.208, as published February 24, 1972 (37 F.R. 3911). The issues in the petitions relating to the applicability of the head injury criterion of S6.2 to seat belt systems have been answered in a notice published June 23, 1972 (37 F.R. 12393). The remaining issues are discussed herein.

. . .

The petitions directed their strongest objections to the application of the injury criteria to belt systems. Partial relief has been granted to belt systems with respect to the head injury criterion. The chest and femur criteria, to which a lesser amount of criticism has been directed, are not considered to present the same level of difficulty for belt systems of current design as the head.

However, it has been decided to make an interim adjustment of the chest injury criterion with respect to seat belts by applying to them a criterion using the severity index formerly applied to the head. The effect of this is to ease the requirement somewhat without permitting excessive long duration accelerations. A well designed belt system of the current types will be capable of meeting the revised criterion. It is expected that improvements now in prospect will allow belt systems to meet the 60g's, 3 millisecond criterion in 1975.

. . .

S6.3 The resultant acceleration at the center of gravity of the upper thorax shall not exceed 60g., except for intervals whose cumulative duration is not more than 3 milliseconds. However, in the case of a vehicle manufactured before August 15, 1975, when the dummy is restrained by seat belt system, the resultant acceleration at the center of gravity of the upper thorax shall not exceed a severity index of 1000, calculated by the method described in SAE Information Report J885a, October 1966.

[25] 37 FR 22871, October 26, 1972.
FMVSS 208, rule; Docket 69-7, Notice 23.
Occupant Crash Protection

The purpose of this notice is to reply to petitions filed pursuant to 49 CFR 553-35 requesting reconsideration of the requirements of Motor Vehicle Safety Standard No. 208 relating to seat belts in vehicles manufactured after August 15, 1973, as amended by Notices 19 and 20 of Docket 69-7 (37 F.R. 12393; 37 F.R. 13265).

1. Seat belts and the injury criteria of S6. The primary objection raised by petitioners is that Notices 19 and 20 did not altogether revoke the requirement that seat belts used to meet the 1973 interlock option must be capable of meeting the injury criteria of S6. Although review of the petitions suggests that additional modification of the head injury criterion is advisable, the NHTSA declines to grant petitioners' request for complete relief from the injury criteria.

Review of the petitions for reconsideration of Notice 16 showed that belts would have difficulty meeting the full criteria. Since leadtime was insufficient for major design changes in belts before 1973, it was found necessary either to remove the injury criteria or modify them so that the changes needed to enable belts to conform could be made in 1973.

Upon review, it was concluded that the injury criteria, even in modified form, would have the beneficial effect of regulating the overall protection characteristics of the occupant compartment and belt system. Regulation of the seat belt as a separate component, as in Standard 209, does not insure that the belt will be installed in a manner calculated to insulate the occupant from injurious contact with the interior of the vehicle. It was therefore decided to retain the injury criteria, with such modifications as seemed necessary to allow manufacturers to conform to S4.1.2.3 by August 15, 1973.

. . .

The chest injury criterion of S6.2 was modified for seat belts by Notice 20, which substituted a severity index of 1,000 for the 60g 3 millisecond criterion applied to other restraint systems. Although the use of the severity index as an indicator of chest injury has not been common practice, the agency has decided that it provides a reasonable interim measure of the effectiveness of the belt system. The severity index of 1,000 is therefore retained as the criterion for belt systems until August 15, 1975.

. . .

S6.3 The resultant acceleration at the center of gravity of the upper thorax shall not exceed 60g, except for intervals whose cumulative duration is not more than 3 milliseconds. However, in the case of a passenger car manufactured before August 15, 1975, or a truck or multipurpose passenger vehicle with a GVWR of 10,000 pounds or less manufactured before August 15, 1977, when the dummy is restrained by a seat belt system, the resultant acceleration at the center of gravity of the upper thorax shall not exceed a severity index of 1,000, calculated by the method described in SAE Information Report J885a, October 1966.

[26] 37 FR 23115, October 28, 1972.
FMVSS 208, proposal; Docket 69-7, Notice 24.
Occupant Crash Protection--Femur and Chest Injury Criteria

The purpose of this notice is to propose amendments to the injury criteria for the femur and the chest in Motor Vehicle Safety Standard No. 208, Occupant Crash Protection, 49 CFR 571.208.

The NHTSA hereby proposes that the injury criteria of Standard No. 208 be amended, by raising the maximum permissible load on the femur from 1,400 to 1,700 pounds, and by substituting a severity index of 1,000 for the present 60g, 3-millisecond limit as the chest injury criterion applicable to vehicles manufactured before August 15, 1975. The proposal is in response to a petition for rule making submitted by General Motors, but it also reflects analysis of data received by this agency since the existing injury criteria were promulgated.

. . .

Similarly, the chest injury criterion of 60g (except for a cumulative 3-millisecond interval) causes occasional compliance failures of restraint systems whose overall protective capabilities are judged to be good. It appears likely that such failures are part of a transient phase in the production of these systems. In the face of similar problems with seat belt systems, the agency previously substituted a severity index of 1,000 as the criterion applicable to belt systems in vehicles manufactured before August 15, 1975 (37 F.R. 13265, July 6, 1972). The considerations which made the severity index acceptable as an interim measure for seat belts now appear also to be applicable to other restraint systems. In particular, the index operates as a check on the high amplitude, long duration spikes that present the greatest hazard to vehicle occupants. It is therefore proposed that the severity index of 1,000 be used as the chest injury criterion for vehicles manufactured before August 15, 1975, regardless of the type of restraint system.

[27] 37 FR 24903, November 23, 1972.
FMVSS 208, rule; Docket 69-7, Notice 25.
Chest and Femur Injury Criteria

The purpose of this notice is to amend the injury criteria specified for the chest and femur under sections S6.3 and S6.4 of Motor Vehicle Safety Standard No. 208, Occupant Crash Protection, 49 CFR 571.208. The amendments adopted hereby are those proposed in a notice of proposed rule making published on October 28, 1972 (Notice 24; 37 F.R. 23116).

The injury criterion for the chest is amended with respect to all vehicles manufactured before August 15, 1975, by substituting a severity index value of 1,000 as the measure of injury potential in place of the criterion of 60g's for 3 milliseconds. The substitution had previously been made for vehicles equipped with seat belt systems manufactured before August 15, 1975. The amendment made hereby is based on a finding that the severity index is an acceptable interim measure for restraint systems other than belt systems.

. . .

S6.3 The resultant acceleration at the center of gravity of the upper thorax shall not exceed 60g's, except for intervals whose cumulative duration is not more than 3 milliseconds. However, in the case of a passenger car manufactured before August 15, 1975, or a truck or multipurpose passenger vehicle with a GVWR of 10,000 pound or less manufactured before August 15, 1977, the resultant acceleration at the center of gravity of the upper thorax shall be such that the severity index calculated by the method described in SAE Information Report J885a, October 1966, shall not exceed 1,000.

[28] 38 FR 8455, April 2, 1973.
Part 572, proposal; Docket 73-8; Notice 1.
Occupant Crash Protection--Proposed Test Dummy Specifications.

The purpose of this notice is to propose specifications for the test dummy to be used in testing vehicles for compliance with Motor Vehicle Safety Standard No. 208, Occupant Crash Protection, and to propose an amendment to Standard No. 208 incorporating the new specification.

. . .

On December 5, 1972, the U. S. Court of Appeals for the Sixth Circuit rendered a decision . . . that the test dummy specifications (primarily SAE Recommended Practice J963) were inadequate and did not meet the statutory requirement that the standard be phrased in objective terms. The Court noted three specific respects in which it considered the specifications to be inadequate: (1) The absence of an adequate flexibility criterion for the dummy's neck; (2) permissible variations in the test procedure for determining thorax dynamic spring rate; and (3) the absence of specific, objective specifications for construction of the dummy's head.

. . .

The dummy design that has been tentatively selected by the NHTSA, and is hereby proposed, is a composite design using components developed by Alderson Research Laboratories, Sierra Engineering Co., and General Motors. This dummy design has been designated by General Motors as the "GM Hybrid II Dummy," and has undergone extensive testing by GM. In the judgement of the NHTSA, on the basis of information received to date and on the basis of the agency's own test program, it represents the most satisfactory design that is currently commercially available.

. . .

The NHTSA is continuing to support advanced research and development work on devices that simulate the human body. It is widely recognized that the technology in this area is in a relatively early stage of development. In the judgement of this agency, however, the device proposed for use by this notice is fully adequate for the purpose, and it is anticipated that, as finally issued, the proposed dummy specifications will remain stable for several years.

. . .

The thorax proposed for the dummy conforms to the most recent Alderson specification, in which steel ribs are combined with a leather sternum. The damping properties of this design more nearly resemble the behavior of the human chest than did earlier designs. Its performance is evaluated in an impact test using a cylindrical impactor. The test has been found capable of detecting variances due to thorax design, and is considered to provide a good calibration check for the thorax.

The configuration of the lumbar spine and pelvis are largely derived from Alderson designs, with the addition of a lumbar spine sepment designed by General Motors to provide greater uniformity of movement of the lower back. Its performance is evaluated in a static bending test of the torso with all components in place.

. . .

To reduce variances in performance caused by differences in instrumentation location and mounting, the proposed regulation also specified the manner in which instruments are to be located and mounted.

In light of the above, it is proposed that Chapter V of Title 49, Code of Federal Regulations, be amended by adding a new Part 572, "Test Dummy Specifications" as set forth below.

It is also proposed that section S8.1.8 of Standard No. 208 be amended by substituting a reference to the Part 572 dummy for the present reference to the SAE J963 dummy. It is further proposed that the first and second restraint options available to manufacturers before passive protection becomes mandatory, suspended by the Chrysler decision, be reinstated in the standard, thereby permitting manufacturers to elect to install passive restraint systems during that period.

The NHTSA does not intend hereby to make the Part 572 dummy applicable to seat belts under the third option in 1973 (S4.1.2.3).

[29] 38 FR 9830, April 20, 1973.
FMVSS 208, proposal; Docket 69-7, Notice 26.
Occupant Crash Protection--Proposed Interlock Amendments

. . .

The initial amendment proposed by this notice is the deletion of the injury criteria as applied to belts under the interlock option in 1973. This amendment is proposed as a direct consequence of the decision of the U.S. Court of Appeals for the Sixth Circuit in Ford v. National Highway Traffic Safety Administration, No. 72-1179, decided February 2, 1973. The court in Ford ruled that its earlier opinion in Chrysler v. Volpe, Sixth Circuit, No. 71-1339 et al., decided December 5, 1973, was dispositive of the Ford petition, and therefore invalidated those portions of the seat belt interlock option that rely on the test dummy for measurement of injury criteria.

Although under the court's decisions there is no obstacle to the imposition of injury criteria within a reasonable time after the agency specifies a new test dummy, the recently proposed test dummy regulation will not result in a final specification in time for manufacturers to conduct a new series of seat belt evaluation tests before the 1974 model year. Accordingly, it is proposed that the paragraph requiring belts to meet the injury criteria (S4.1.2.3.1(d)) be deleted.

Also affected by the invalidation of the test dummy is the requirement that the center front seat belt restrain a dummy in a 30-mi/h barrier test without belt breakage (S4.1.2.3.1(e)). To reinstate this requirement for 1974 models, the agency would need to reestablish a dummy, specification in time for certification tests to be run. Present information indicates that the breakage test requirement does not contribute substantially to the performance of belt systems. It is therefore proposed that the requirement be deleted.

[30] 38 FR 16072, June 20, 1973.
FMVSS 208, rule; Docket 69-7, Notice 27.
Seat belt Interlock Requirements

. . .

As amended, therefore, S4.1.2.3.1(a) provides that at the front outboard positions a manufacturer may install either a Type 2 seat belt assembly that conforms to standard No. 209, or a type 1 seat belt assembly that meets the injury criteria of S5.1. Insofar as the injury criteria themselves are contingent upon the establishment of an adequate method of measurement through the adoption of a new test dummy, a manufacturer who intends to produce vehicles with type 1 belts at the front outboard positions will have to await the adoption of the new dummy regulation and its incorporation into the options under S4.1.2.

. . .

S4.1.2.3 Third option--lap and shoulder belt protection system with ignition interlock and belt warning--

S4.1.2.3.1 Except for convertibles and open-body vehicles, the vehicle shall--

(a) At each front outboard designated seating position have a seat belt assembly that conforms to S7.1 and S7.2 of this standard, a seat belt warning system that conforms to S7.3 and a belt interlock system that conforms to S7.4. The belt assembly shall be either a type 2 seat belt assembly with a nondetachable shoulder belt that conforms to standard No. 209 (571.209), or a type 1 seat belt assembly such that with a test device restrained by the assembly the vehicle meets the frontal crash protection requirements of S5.1 in a perpendicular impact.

(b) At any center front designated seating position, have a type 1 or type 2 seat belt assembly that conforms to standard No. 209 (571.209) and to S7.1 and S7.2 of this standard, and a seat belt warning system that conforms to S7.3; and

(c) At each other designated seating position, have a type 1 or type 2 seat belt assembly that conforms to standard No. 209 (Part 571.209) and to S7.1 and S7.2 of this standard.

[31] 38 FR 20449, August 1, 1973.
Part 572, rule; Docket 73-8, Notice 2.
Anthropomorphic Test Dummy--Occupant Crash Protection

The purposes of this notice are (1) to adopt a regulation that specifies a test dummy to measure the performance of vehicles in crashes, and (2) to incorporate the dummy into Motor Vehicle Safety Standard No. 208 (49 CFR 571.208), for the limited purpose of evaluating vehicles with passive restraint options between August 15, 1973, and August 15, 1975. The question of the restraint system requirements to be in effect after August 15, 1975, is not addressed by this notice and will be the subject of future rulemaking action.

The test dummy regulation (49 CFR Part 572) and the accompanying amendment to Standard No. 208 were proposed in a notice published April 2, 1973 (38 FR 8455). The dummy described in the regulation is to be used to evaluate vehicles manufactured under Sections S4.1.2.1 and S4.1.2.2, (the first and second options in the period from August 15, 1973, to August 15, 1975), and the section incorporating the dummy is accordingly limited to those sections. The dummy has not been specified for use with any protection systems after August 15, 1975, nor with active belt systems under the third restraint option (S4.1.2.3). The recent decision in Ford v. NHTSA, 473 F.2d 1241 (6th Cir. 1973), removed the injury criteria from such systems. To make the dummy applicable to belts under the third option, the agency would have to provide additional notice and opportunity to comment.

. . .

The immediate purpose of this rulemaking is to reconstitute those portions of the standard that will enable manufacturers to build passive restraint vehicles during the period when they are optional. The test dummy selected by the agency "GM Hybrid II", a composite developed by General Motors largely from commercially available components. GM had requested NHTSA to adopt the Hybrid II on the grounds that it had been successfully used in vehicle tests with passive restraint systems, and was as good as, or better than, any other immediately available dummy system. On consideration of all available evidence, the NHTSA concurs

. . .

The provisions of the dummy regulation have been modified somewhat from those proposed in the notice of proposed rulemaking, largely as a result of comments from GM. Minor corrections have been made in the drawings and materials specifications as a result of comments by GM and the principal dummy suppliers.

. . .

The dummy specifications, as finally adopted, reproduces the Hybrid II in each detail of its design and provides, as a calibration check, a series of performance criteria based on the observed performance of normally functioning Hybrid II components. The performance criteria are wholly derivative and are intended to filter out dummy aberrations that escape detection in the manufacturing process or that occur as a result of impact damage. The revisions in the performance criteria, as discussed hereafter, are intended to eliminate potential variances in the test procedures and to hold the performance of the Hybrid II within the narrowest possible range.

. . .

With respect to the thorax test, each of the minor procedural changes requested by GM has been adopted.

. . .

The test procedures for the spine and abdomen test are specified in much greater detail than before, on the basis of suggestions by GM and others that the former procedures left too much room for variance.

. . .

572.8 Thorax.

(c) When impacted by a test probe conforming to 572.11 (a) at 14 fps and at 22 fps in accordance with paragraph (d) of this section, the thorax shall resist with forces measured by the test probe of not more than 1400 pounds and 2100 pounds, respectively, and shall deflect by amounts not greater than 1.0 inches and 1.66 inches, respectively. The internal hysteresis in each impact shall not be less than 50 percent.

. . .

(a) The test probe used for thoracic and knee impact tests is a cylinder 6 inches in diameter that weighs 51.5 pounds including instrumentation. Its impacting end has a flat right face that is rigid and that has an edge radius of 0.5 inches.

[32] 39 FR 38380, October 31, 1974.
FMVSS 208, rule; Docket 74-39, Notice 1.
Seat Belt Interlock Option

This notice amends Standard No. 208, Occupant crash protection, 49 CFR 571.208, by eliminating the ignition interlock. Parallel changes are made to the passive seat belt assembly requirements (S7.) of the standard.

[33] 40 FR 33462, August 8, 1975.
Part 572, proposal; Docket 73-8, Notice 3.
Anthropomorphic Test Dummy.*

. . .

Several manufacturers questioned the objectivity of the dummy as a whole because Part 572 does not include a "whole systems" calibration of the assembled dummy. The NHTSA has considered the advisability of such a test and has decided against it for several reasons. Foremost is the difficulty of devising a calibration procedure which introduces no significant variability into the test. It is clear that Standard No. 208 dynamic deceleration of the dummy introduces many complex variables into the test, such as restraint design and vehicle design. In the description of sled testing of the GM50X dummy (ref. Reports: SAE #740590, DOT-HS-299-3-569), General Motors pointed out that their results demonstrate the complexity of the problem.

Another reason for not introducing a "whole systems" calibration is that the experience to date with well-controlled hard seat sled tests of the dummy show good measurement stability of the dummy as a whole system as long as the dummy meets Part 572 specifications. The most recent presentation of such information appears in an SAE paper by General Motors engineers, comparing an advanced dummy with the Part 572 dummy (Proceedings of Third International Conference on Occupant Protection, pg. 369). Table 10 of that paper shows the coefficient of variation of a Hybrid II dummy to be only 4.5 percent in a measure of Head Injury Criteria and 3.3 percent in a measure of Chest Severity Index. Variation of these criteria between dummies is 3.5 percent and 6 percent respectively. Similar conclusions were reached by J. Versace and R. J. Berton of the Ford Motor Company in SAE paper 750395, "Determination of Restraint Effectiveness", pg. 5. Based on experience of this nature, and in view of the extensive specification in Part 572, the NHTSA concludes that a "whole systems" calibration is not required to establish the dummy as an objective measuring device.

*This notice is unusual in that it refers to and comments on specific technical papers.

[34] 41 FR 29715, July 19, 1976.
FMVSS 208, proposal; Docket 74-14, Notice 5.
Occupant Crash Protection

The requirements of Standard No. 208 (49 CFR 571.208) have been implemented in three stages. The current stage for passenger cars specifies a choice of three means to provide occupant protection (S4.1.2) and is scheduled to end August 31, 1976. The Secretary of Transportation has initiated a process for the establishment of future occupant crash protection requirements (41 FR 24070, June 14, 1976), but this process will not be completed early enough to permit the specification of new requirements by August 31, 1976. For this reason, the National Highway Traffic Safety Administration proposes the extension of the existing requirements for an interim period of one year.

. . .

Two of the three available options permit a manufacturer to provide certain levels of occupant protection by means that do not require action by the vehicle occupant (commonly known as passive protection). While most vehicles are manufactured in satisfaction of the third option which does not specify passive protection (S4.1.2.3), General Motors Corporation and Volkwagenwerk AG (Volkswagen) have equipped a small number of their vehicles with passive protection.

. . .

The changes proposed herein, requirements, injury criteria, and test procedures for the passive protection options, arose in the context of a March 1974 NHTSA proposal to mandate passive restraints for all vehicles (39 FR 10271 March 19, 1974). While that proposal is superseded by the Department's more recent proposal, the agency has evaluated manufacturer comments made on the March 1974 proposal and at a subsequent public meeting on passive protection (40 FR 13330, March 26, 1975). The agency's own continuing research and development activities also have provided the basis for reproposal of some of the technical modifications first proposed in March 1974, as well as some additional new specifications. References to manufacturer comments in the following discussion, unless otherwise indicated, are to comments made on the March 1974 proposal.

In developing its optional passive belt system, Volkswagen raised the question of the feasibility of small cars meeting lateral impact requirements: A 20-mph impact by a 4,000-pound, 60-inch high flat surface. Because small cars are particularly vulnerable to side impact, it is most important to maintain practicable protection levels for them based on the weight of the average car which is likely to impact them. However, it may be difficult for small cars to meet the impact requirements using a 4,000-pound barrier in the next few years. Accordingly, a lap belt option would be provided. This conforms to the option in the Department's proposal. A similar lap belt option is proposed for the rollover requirement in conformity with the Department's proposal.

. . .

Manufacturers questioned several aspects of the frontal and lateral crash modes and their associated injury criteria. It was suggested that chest acceleration limits be based on a severity index in place of the 60g, 3-millisecond limit found in the standard, in order to emphasize the effect of time duration on injury tolerance. The current requirement does in fact consider time duration by permitting acceleration levels higher than 60g for periods less than 3 milliseconds, and this level is considered reasonable. Two years of frontal and oblique crash testing involving 20 vehicles and 56 dummies supports this conclusion, in that no dummy recorded chest accelerations greater than 60g for more than 3 milliseconds.

[35] 41 FR 36494, August 30, 1976.
FMVSS 208, Docket 74-14, Notice 6.
Occupant Crash Protection

This notice amends Standard No. 208, Occupant Crash Protection, to continue until August 31, 1977, the present three options available for occupant crash protection in passenger cars.

This extension of the present occupant crash protection options of Standard No. 208 (49 CFR 571.208) was proposed July 19, 1976 (41 FR 29715), along with several other subjects that will be the subject of a future notice. Vehicle manufacturers supported the proposal but requested that the options be extended indefinitely instead of being limited to a 1-year extension.

. . .

The Secretary of Transportation has initiated a process for the establishment of future occupant crash protection requirements under Standard No. 208 (41 FR 24070, June 14, 1976). The Secretary's proposal addresses the long term issues involved, and this 1-year extension of requirements is intended to provide the time necessary to reach that decision. Because a 1-year extension is consistent with the process that has been established and because a longer extension was not proposed for comment, the NHTSA declines to extend the existing requirements as recommended by the manufacturers.

Other matters proposed in the notice that underlies this action will be treated at a later date.

[36] 41 FR 54961, December 16, 1976.
FMVSS 208, notice; Docket 74-14, Notice 7.
Advance Notice Concerning Improvements of Seat Belt Assemblies

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Would the establishment of injury criteria and dynamic tests for seat belt assemblies installed in vehicles be an appropriate means to improve seat belt effectiveness?

. . .

The NHTSA, as it stated in April 1973 (38 FR, April 20, 1973), believes that a structural integrity requirement does not contribute substantially to the performance of belt systems, which are required by Standard No. 209 to have higher breaking strength than they would be subjected to during a 30-m.p.h. barrier impact. The agency considers that a more appropriate assessment of a belt system's protective performance capability lies in its ability to properly restrain a Part 572 test dummy in a simulated crash environment. The agency is contemplating a requirement for a dynamic test for belt systems. The test would be a frontal and frontal oblique test at 30 m.p.h. into a fixed flat barrier. A number of alternatives exist to evaluate the belt systems protective performance. First, the head and chest accelerations and femur force levels measured on the dummy could be limited to some levels, although these may not necessarily be the existing levels specified in S5 of FMVSS 208.

Another option is to limit the torso belt load applied to the test dummy. This criteria would be in addition to head, chest, and femur criteria. The data in a recent paper presented by Eppinger at the Sixth International Conference on Experimental Safety Vehicles indicates that 1,200 pounds of shoulder belt force can produce multiple rib fractures.

[37] 42 FR 7148, February 7, 1977.
Part 572, rule; Docket 73-8, Notice 4.
Dummy Calibration Test Procedures and Dummy Design Specifications

This notice amends Part 572, Anthropomorphic Test Dummy, to specify several elements of the dummy calibration test procedures and make minor changes in the dummy design specifications. Part 572 is also reorganized to provide for accommodation of dummies other than the 50th-percentile male dummy in the future.

. . .

General Motors (GM), Chrysler Corporation, Ford Motor Company, and the Motor Vehicle Manufacturers Association (MVMA) stated that the dummy construction is unsuited to measurements of laterally-imposed force, thereby rendering the dummy unobjective in the "lateral impact environment." While the agency does not agree with these objections, the modified performance levels put forward by the Department of Transportation and the agency would allow manufacturers to install lap belts if they do not wish to undertake lateral or rollover testing. Any manufacturer that is concerned with the objectivity of the dummy is such impacts would provide lap belts at the front seating positions in lieu of conducting the lateral or rollover tests.

. . .

The major suggestion by vehicle and dummy manufacturers was a slight revision of the thorax resistance and deflection values, which must not be exceeded during impact of the chest. The present values (1400 pounds and 1.0 inch at 14 fps, 2100 pounds and 1.6 inches at 22 fps) were questioned by GM, which recommends an increase in both resistance and deflection values to better reflect accurate calibration of a correctly designed dummy. Comparable increases were recommended by Humanoid and Sierra. ARL noted that the present values are extremely stringent.

The agency's experience with calibration of the thorax since issuance of the proposal confirms that a slight increase in values is appropriate, although not the amount of increase recommended by the manufacturers. The values have accordingly been modified to 1450 pounds and 1.1 inches at 14 fps, and 2250 pounds and 1.7 inches at 22 fps. The agency does not set a minimum limit on the values as recommended by General Motors because the interaction of the deflection and resistance force values make lower limits unnecessary. The changes in values should ease ARL's concern about the seating surface, although the agency's own experience does not indicate that a significant problem exists with the present specifications of the surface.

In conjunction with these changes, the agency has reduced the maximum permissible hysteresis of the chest during impact to 70 percent as recommended by GM.

[38] 42 FR 28200, June 2, 1977.
Part 572, notice; Docket 73-8, Notice 5.
Delay of Response to Petitions for Reconsideration

This notice announces a delay until approximately July 1, 1977, of the National Highway Traffic Safety Administration's (NHTSA) response to two petitions for reconsideration that have been filed concerning a recent amendment (February 7, 1977; 42 FR 7148) of the agency's test dummy specification (Part 572, Anthropomorphic Test Dummy, 49 CFR Part 572). It is the policy of the NHTSA to respond to petitions for reconsideration within 120 days of the publication of a final rule (49 CFR Part 553, Appendix), which would necessitate a response by June 7, 1977, in this instance. When a response will not be issued within 120 days, it is the agency's policy to publish in the Federal Register notice of the date by which it expected that action will be taken.

A petition filed by General Motors Corporation requested correction of lumbar load and angle requirements and also commented on "whole system" objectivity and lateral impact response of the dummy, Ford Motor Company also requested the same lumbar load corrections, questioned lateral impact response, and requested reconsideration of the requirement that the dummy be used for testing without requiring recalibration. The petitions are on file in the NHTSA public docket (Room 5108, 400 Seventh Street SW, Washington, D.C. 20590).

The Part 572 test dummy is used to simulate the occupant of a motor vehicle for purposes of evaluating certain types of crash protection systems provided in accordance with Standard No. 208, Occupant Crash Protection (49 CFR 571.208). The Department of Transportation has recently proposed three approaches to future occupant protection under Standard No. 208 (March 24, 1977; 42 FR 15935), and one of the proposed approaches entails use of the Part 572 dummy as a compliance test instrument. The objectivity of the dummy as a measurement device was the issue that the NHTSA addressed in the February 1977 amendment that gave rise to the GM and Ford petitions.

The agency assumes from the small number of petitions for reconsideration that it is aware of and has addressed all of the questions about objectivity that are known to interested persons with exception of the two subject petitions.

[39] 42 FR 34299, July 5, 1977.
FMVSS 208 and Part 572, rule; Docket 74-14, Notice 11;
Docket 73-8, Notice 7.
Occupant Crash Protection

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Notice 5 was issued July 15, 1976 (41 FR 29715; July 19, 1976) and proposed that Standard No. 208's existing specification for passenger protection in frontal, lateral and rollover modes (S4.1.2.1) be modified to specify passive protection in the frontal mode only, with an option to provide passive protection or belt protection in the lateral and rollover crash modes. Volkswagen had raised the question of the feasibility of small cars meeting the standard's lateral impact requirements: A 20-mph impact by a 4,000 pound, 60-inch high flat surface. The agency noted the particular vulnerability of small cars to side impact and the need to provide protection for them based on the weight of other vehicles on the highway, but agreed that it would be difficult to provide passive lateral protection in the near future. Design problems also underlay the proposal to provide a belt option in place of the existing passive rollover requirement.

Ford Motor Company argued that a lateral option would be inappropriate in Standard No. 208 as long as the present dummy is used for measurement of passive system performance. This question of dummy use as a measuring device is treated later in this notice. General Motors Corporation (GM) supported the option without qualification, noting that the installation of a lap belt with a passive system "would provide comparable protection to lap/shoulder belts in side and rollover impacts." Chrysler did not object to the option, but noted that the lap belt option made the title of S4.1.2.1 ("complete passive protection") misleading. Volkswagen noted that its testing of belt systems without the lap belt portion showed little loss in efficacy in rollover crashes. No other comments on this proposal were received. The existing option, S4.1.2.1 is therefore adopted as proposed so that manufacturers will be able to immediately undertake experimental work on passive restraints on an optional basis in conformity with the Secretary's decision.

. . .

While not proposed for change, vehicle manufacturers commented on a second injury criterion of the standard. A limitation of the acceleration experienced by the dummy thorax during the barrier crash to 60g except for intervals whose cumulative duration is not more than 3 milliseconds (ms). Until August 31, 1977, the agency has specified the Society of Automotive Engineers (SAE) "severity index" as a substitute for the 60g-3ms limit, because of greater familiarity of the industry with that criterion.

General Motors recommended that the severity index be continued as the chest injury criterion until a basis for using chest deflection is developed in place of chest acceleration. GM cited data which indicate that chest injury from certain types of blunt frontal impact is a statistically significant function of chest deflection in humans while not a function of impact force or spinal acceleration. GM suggested that a shift from the temporary severity index measure to the 60g-3ms measurement would be wasteful, because there is no "strong indication" that the 60g-3ms measurement is more meaningful than the severity index, and some restraint systems might have to be redesigned to comply with the new requirement.

Unlike GM, Chrysler argued against the use of acceleration criteria of either type for the chest and rather advocated that the standard be delayed until a dummy chest with better deflection characteristics is developed.

The Severity Index Criterion allows higher loadings and, therefore, increases the possibility of adverse effect on the chest. It only indirectly limits the accelerations and hence the forces which can be applied to the thorax. Acceleration in a specific impact environment is considered to be a better predictor of injury than the Severity Index.

NHTSA only allowed belt systems to meet the Severity Index Criterion of 1,000 instead of the 60g-3ms criterion out of consideration for leadtime problems, not because the Severity Index Criterion was considered superior. It is recognized that restraint systems such as lap-shoulder belts apply more concentrated forces to the thorax than air cushion restraint, and that injury can result at lower forces and acceleration levels. it is noted that the Agency is considering rulemaking to restrict forces that may be applied to the thorax by the shoulder belt of any seat belt assembly (41 FR 54961, December 16, 1976).

. . .

The test dummy also represents a balancing between realism (biofidelity) and objectivity (repeatability). One-piece cast metal dummies could be placed in the seating positions and instrumented to register crash forces. One could argue that these dummies did not act at all like a human and did not measure what would happen to a human, but a lack of repeatability could not be ascribed to them. At the other end of the spectrum, an extremely complex and realistic surrogate could be substituted for the existing Part 572 dummy, which would act realistically but differently each time, as one might expect different humans to do.

The existing Part 572 dummy represents 5 years of effort to provide a measuring instrument that is sufficiently realistic and repeatable to serve the purposes of the crash standard. Like any measuring instrument, it has to be used with care. As in the case of any complex instrumentation, particular care must be exercised in its proper use, and there is little expectation of literally identical readings.

The dummy is articulated, and built of materials that permit it to react dynamically similarly to a human. It is the dynamic reactions of the dummy that introduce the complexity that makes a check on repeatability desirable and necessary. The agency therefore devised five calibration procedures as standards for the evaluation of the important dynamic dummy response characteristics.

Since the specifications and calibration procedures were established in August 1973, a substantial amount of manufacturing and test experience has been gained in the Part 572 dummy. The quality of the dummy as manufactured by the three available domestic commercial sources has improved to the point where it is the agency's judgement that the device is a repeatable and reproducible as instrumentation of such complexity can be. As noted, GM and Ford disagree and raised three issues with regard to dummy objectivity in their petitions for reconsideration.

Lateral response characteristics. Recent sled tests of the Part 572 dummy in lateral impacts show a high level of repeatability from test to test and reproducibility from one dummy to another ("Evaluation of Part 572 Dummies in Side Impacts"--DOT-HS-020858). Further modification of the lateral and rollover passive restraint requirements into an option that can be met by installation of a lap belt makes the lateral response characteristics of the dummy largely academic. As noted in Notice 4 of Docket 73-8 (42 FR 7148; February 7, 1977) "Any manufacturer that is concerned with the objectivity of the dummy in such (lateral) impacts would provide lap belts at the front seating positions in lieu of conducting the lateral or rollover tests."

While the frontal crash test can be conducted at any angle up to 30 degrees from perpendicular to the barrier face, it is the agency's finding that the lateral forces acting on the test instrument are secondary to forces in the midsagittal plane and do not operate as a constraint on vehicle and restraint design. Compliance tests conducted by NHTSA to date in the 30-degree oblique impact condition have consistently generated similar dummy readings. In addition, they are considerably lower than in perpendicular barrier impact tests, which renders them less critical for compliance certification purposes.

[40] 43 FR 21470, May 18, 1978.
FMVSS 213, proposal; Docket 74-9, Notice 4.
Child Restraint Systems

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This notice is being issued in response to public requests. It would amend the existing child restraint standard by extending its applicability to all types of child restraints designed for use in motor vehicles. It would also upgrade existing child restraint performance requirements by improving the performance criteria and by replacing static tests with dynamic tests using anthropomorphic child dummies. The amendments are intended to reduce the number of children under 5 years of age that are killed or injured in motor vehicle accidents.

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SUMMARY OF PROPOSED AMENDMENTS

The most significant amendments proposed by this notice are set forth below:

(1) Dynamic tests would be used to evaluate the performance of the child seating system in a manner which simulated an actual vehicle crash. The simulated crash would be straight forward (0 degree frontal) at 30 m.p.h.

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(3) Injury criteria would be specified for both the head and chest of the dummy for child restraints recommended by their manufacturers for children over 20 pounds. Padding requirements would have to be met by restraints to be used by children weighing not more than 20 pounds.

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TEST DUMMIES

A six-month old dummy and a three-year old dummy have been tentatively selected for testing child restraint systems under the proposed standard. The six-month old dummy was specified in the 1974 proposal as being of "sailcloth construction filled with plastic pellets and lead shot for correct weight distribution." The dummy has since been dynamically tested, modified, and retested in infant carriers of three different manufacturers. The new dummy represents an advance in the state-of-the-art and is vastly superior to the former dummy. Very precise definitions of the new dummy are contained in a set of five blueprints and an engineering description which are available in docket 74-9 to all interested persons.

The tentatively selected three-year old dummy is the NHTSA test dummy SA103C, a slightly modified version of the Alderson Model VIP-3C dummy.

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Injury criteria (expressed in terms of limits on resultant acceleration) are proposed for both the head and chest of the thee-year-old test dummy to allow a quantitative evaluation of the dynamic performance of the child restraints to be made. This approach permits the measurement of padding effectiveness during the dynamic test, thus eliminating any need for a separate test for that purpose and the costs associated with such a test. Since the construction of the six-month-old dummy prevents installing accelerometers so that they will stay in place within the dummy during a test and give accurate measurements, the injury criteria would apply only to restraints recommended by their manufacturers for use by children weighing over 20 pounds.

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Unlike the 1974 proposal, this proposal does not contain requirements for lateral dynamic tests and for limits on lateral excursion.

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571.213

3. A new Federal Motor Vehicle Safety Standard No. 213-80, Child Restraint Systems, would be added to read as set forth below.

571.213-80 Standard No. 213-80; child restraint systems.

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S5.1.2 Injury criteria. When tested in accordance with S6.1, each child restraint system that, in accordance with S5.5.2(f), is recommended for use by children weighing more than 20 pounds, shall--

. . .

(b) Limit the resultant acceleration at the location of the accelerometer mounted in the test dummy upper thorax as specified in Part 572 to not more than 60g's, except for intervals whose cumulative duration is not more than 3 milliseconds.

[41] 44 FR 70204, December 6, 1979.
FMVSS 214, proposal; Docket 79-04, Notice 1.
Side Impact Protection

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SUMMARY: The purpose of this advance notice is to announce that the National Highway Traffic Safety Administration is considering the proposal of an amendment to Safety Standard No. 214, Side Door Strength, to upgrade motor vehicle side impact protection and to extend the applicability of the standard to light trucks, vans and multipurpose passenger vehicles. (Standard No. 214 now only applies to passenger cars.) The notice also announced that a public meeting will be held to permit all interested persons to present oral and written views concerning the proposed upgrade of the standard.

The standard currently specifies crush-resistance requirements for the side doors of passenger cars under static test conditions. The primary purpose of the contemplated upgrade is to establish performance criteria for occupant protection under dynamic crash tests. The performance criteria that would be established would require a higher level of protection for occupants involved in side impact collisions than presently exists, and under test conditions that more closely approximate real-world crashes.

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Research projects are currently underway to generate data concerning occupant compartment integrity and ways to reduce occupant injuries by changing side door structures and modifying vehicle interiors. Data from these and other studies will be used to upgrade Standard No. 214. The primary thrust of the new standard will be to develop performance requirements based on dynamic crash tests representing real-world accidents, rather than the laboratory type static crush tests of the existing rule. It is anticipated that performance would be determined by measuring the forces (accelerations) to which vehicle passengers, simulated by instrumented test dummies, are subjected when their vehicle is struck in the side by a moving barrier that represents another vehicle. The agency is involved in four major areas of activity to establish such performance requirements:

1. Development of a test procedure, including the development of a moving barrier impactor to simulate the striking vehicle.

2. Development of an instrumented test dummy and the establishment of appropriate injury criteria.

3. Development of vehicles that can be used to demonstrate improved performance in side impact crashes.

4. Analysis of existing accident data in furtherance of the other three activities.

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DEVELOPMENT OF AN ANTHROPOMORPHIC TEST DEVICE (DUMMY)

The test dummy is a key element in the development and application of a new side impact protection regulation. It is an important part of the final regulation because of the need for an objective measuring device.

The dummy selection process included a search for an existing dummy that would be appropriate for use in the upgraded side impact regulation. The investigation began with two existing dummies that have the potential for being used in side impact testing. One of these is the Part 572 anthropomorphic test device that is specified for use in existing occupant protection safety standards. This dummy has the advantage of being a proven piece of equipment with extensive documentation and testing. The second dummy is one developed at the Transport and Road Research Laboratory (TRRL) in the United Kingdom. That dummy has the advantage of having been developed specifically for use in side impact tests.

An initial study was done by the NHTSA in 1975 to evaluate the response of these dummies in lateral impacts. This was followed by a more recent program which included testing under additional side impact conditions. Based on the results of these tests, the agency decided that neither dummy was adequate in all respects and that a new or revised dummy was necessary for use in evaluating side impact protection. Therefore, the NHTSA plans to use the Part 572 as the basic dummy, making those changes that are necessary in the thorax and shoulder to adequately measure injury response in side impact collisions. In addition to the dummy which is being developed by the NHTSA, there are other dummies which have recently been developed for use in side impact work. The NHTSA will conduct a parallel evaluation and test program of these dummy designs to establish the relevancy and quality of their response for use in side impact applications.

Questions on dummy design which are as yet unanswered and for which the agency seeks specific comments include:

(1) Does the test dummy used in side impact protection testing need an arm (impact side) to be acceptable as a human surrogate? Does the presence of an arm create special problems in dummy response?

(2) Is a modified Part 572 dummy the best appropriate test device that can currently be found?

. PERFORMANCE CRITERIA AND LEVELS

The agency contemplates developing thoracic and head injury criteria and performance requirements to prevent occupant ejection from the vehicle. The primary basis for development of a criteria for limiting chest injuries in side impact accidents consists of human surrogate tests which have been run in the United States and Europe. Comparing the results of these tests with the consequences of real-world accidents has been initiated, but has not progressed to the point of providing adjusted estimates of an appropriate performance criteria. The criteria currently being considered by the agency are estimates of the threshold force level between AIS 3 and AIS 4 injuries to the chest (the AIS scale is an injury severity index). The rationale behind the choice of this level is that injuries which are judged to be AIS 4, 5, or 6 are considered to be life-threatening and have a high probability of resulting in a fatality. Under the proposed criteria, injury levels could not be greater than the forces on the test dummy's chest judged to be equivalent to AIS 3 injuries. Thus, most life-threatening chest injuries to the victims of crashes covered by this regulation would be eliminated.

Based on the work with human surrogates, there are three schools of thought concerning the proper criteria for measuring performance in side impact protection. One school concludes that chest deflection is the best measurement of injury to victims of side impacts. The most recent work in this area has been done at the Peugeot-Renault Association. The results of this work suggest that a limit of 4.5 cm on chest deflection is a proper criterion. A second school of thought concludes that the acceleration signals from spinal accelerometers provide the best source of data for predicting injury. The results of this work suggest two criteria for use in improving occupant protection in side crashes: (1) a limit of 40G (3 msec) on the peak acceleration in the lateral direction; and (2) a limit of 120,000 ft-lb/sec (160 kilowatts) on the peak rate-of-change of energy in the lateral direction. This work is summarized in a paper by Burgett and Hackney given at the 7th ESV Conference in June 1979 (Docket 79-04; General Reference). The third school of thought in this area holds that the change of velocity of the near side rib is a good measure of injury. This work has resulted in several suggested criteria which are based primarily on the lateral change of velocity of the near side rib. One criterion would limit the velocity change to 30 ft/sec. The details of this work are contained in the progress reports on NHTSA contract number DOT-HS-4-00921.

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Questions about performance criteria which are as yet unanswered and for which the agency specifically seeks comments include:

(1) Is it appropriate to base a performance criteria solely on the results of cadaver tests? Are these data sources other than those used by NHTSA which are suitable for development of performance criteria?

(2) Are there parameters other than those presented here which would be more appropriate for establishing performance requirements, e.g., chest severity index?

(3) What are the advantages and disadvantages of the various criteria that are set forth here? What methods for evaluating various criteria are available? Can the various criteria provide accurate predictions of injuries and fatalities occurring in real accidents? Are the various criteria sufficiently distinct in the compliance test environment to generate meaningful dummy response?

(4) Are the injury criteria keyed to the most appropriate AIS level (i.e., not greater than AIS 3)?

[42] 44 FR 72131, December 13, 1979.
FMVSS 213, rule; Docket 74-9, Notice 6.
Child Restraint Systems Seat Belt Assemblies and Anchorages

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SUMMARY: This rule establishes a new Standard No. 213, Child Restraint Systems, which applies to all types of child restraints used in motor vehicles. It also upgrades existing child restraint performance requirements by setting new performance criteria and by replacing the current static tests with dynamic sled tests that simulate vehicle crashes and use anthropomorphic child test dummies. The new standard would reduce the number of children under 5 years of age killed or injured in motor vehicle accidents.

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Several manufacturers (GM, Ford, Questor, and others) and JPMA objected to the proposed head and chest acceleration limits that must not be exceeded in the dynamic testing. They argued that the acceleration limits are based on biomechanical data for adults and there is no data showing their applicability to children. Because of the lack of biomechanical data on children's tolerance to impact forces, NHTSA has conducted tests of child restraints with live primates to serve as surrogates for three-year-old children. Primates are similar in certain respects to children and have been used by GM, Ford, and others as surrogates in child restraint testing to assess potential injuries to children in crashes. In simulated 30 mph crashes conducted for NHTSA, similar to the test prescribed in the proposed standard, the primates either were not injured or sustained only minor injuries. NHTSA has also conducted child restraint tests using instrumented test dummies representing three-year-old children instead of primates. In the tests, the forces measured on the test dummies, which had not been injurious to the primates, did not exceed the head and chest accelerations criteria proposed in the standard. NHTSA is thus confident that the child restraints which do not exceed these performance criteria in the prescribed tests should prevent or reduce injuries to children in crashes.

Use of instrumented test dummies should not unduly raise the price of child restraints. Since many child restraint systems are already close to compliance, the cost per restraint of any needed design and testing costs should be minimal.

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S5.1.2 Injury criteria. When tested in accordance with S6.1, each child restraint system that, in accordance with S5.5.2(f), is recommended for use by children weighing more than 20 pounds, shall--

. . .

(b) Limit the resultant acceleration at the location of the accelerometer mounted in the test dummy upper thorax as specified in Part 572 to not more than 60 g's, except for intervals whose cumulative duration is not more than 3 milliseconds.

. . .

S5.2.2 Torso impact protection. Each child restraint system other than a car bed shall comply with the applicable requirements of S5.2.2.1 and S5.2.2.2.

S5.2.2.1

(a) The system surface provided for the support of the child's back shall be flat or concave and have a continuous surface area of not less than 85 square inches.

(b) Each system surface provided for support of the side of the child's torso shall be flat or concave and have a continuous surface of not less than 24 square inches for systems recommended for children weighing 20 pounds or more, or 48 square inches for systems recommended for children weighing less than 20 pounds.

(c) Each horizontal cross section of each system surface designed to restrain forward movement of the child's torso shall be flat or concave and each vertical longitudinal cross section shall be flat or convex with a radius of curvature of the underlying structure of not less than 3 inches.

APPENDIX B

Appendix B: Bibliography

Citations are arranged in alphabetical order by author(s) and then in chronological order. The year cited is the date of publication, unless the paper was presented earlier at a conference. In the latter case, the date of presentation of the work is cited, and the date of publication of the proceedings, if different, is given at the end of the reference.

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APPENDIX C

Appendix C: NCSS and UMIVOR Thoracic Injury Accident Data

TABLE OF CONTENTS

NCSS Cases: Correlations of Thorax AIS with Crash Severity Indicators

TABLE 5

DRIVER CHEST INJURY CAR TO CAR CRASH, LEFT-SIDE CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
11401	170407021	2 AIS	FRACTURE	UNKNOWN	16 G	19 MPH	0 MPH
11509	171129058	2 AIS	FRACTURE	SIDE INTERIOR	17 G	15 MPH	0 MPH
12104	171129065	2 AIS	FRACTURE	STEERING ASSEMBL	50 G	38 MPH	0 MPH
14102	171215032	2 AIS	FRACTURE	WINDOW FRAME	9 G	16 MPH	11 MPH
66109	180303020	2 AIS	FRACTURE	STEERING ASSEMBL	16 G	17 MPH	14 MPH
11318	370821033	2 AIS	FRACTURE	UNKNOWN	10 G	12 MPH	11 MPH
11102	470916027	1 AIS	CONTUSION	EXTERIOR OBJECT	15 G	24 MPH	10 MPH
11101	471006009	1 AIS	PAIN	STEERING ASSEMBL	12 G	22 MPH	15 MPH
11103	471105053	2 AIS	FRACTURE	STEERING ASSEMBL	7 G	13 MPH	0 MPH
11307	471211010	2 AIS	FRACTURE	STEERING ASSEMBL	13 G	20 MPH	10 MPH
13201	671222106	1 AIS	PAIN	SIDE INTERIOR	22 G	25 MPH	32 MPH
11101	680209025	2 AIS	FRACTURE	STEERING ASSEMBL	12 G	22 MPH	15 MPH
87109	170116031	1 AIS	CONTUSION	UNKNOWN	11 G	11 MPH	11 MPH
11304	170125084	3 AIS	FRACTURE	UNKNOWN	11 G	19 MPH	15 MPH
13107	170218020	3 AIS	FRACTURE	SIDE ARMRESTS	25 G	25 MPH	30 MPH
		3 AIS	HEMORRHAGE	SIDE ARMRESTS			
66139	170716023	3 AIS	FRACTURE	UNKNOWN	6 G	9 MPH	10 MPH
14108	170805023	3 AIS	FRACTURE	SIDE ARMRESTS	18 G	21 MPH	0 MPH
13408	170910015	3 AIS	FRACTURE	STEERING ASSEMBL	17 G	15 MPH	0 MPH
11302	171215035	3 AIS	FRACTURE	STEERING ASSEMBL	7 G	9 MPH	21 MPH
11306	180227042	1 AIS	CONTUSION	SIDE HARDWARE	16 G	17 MPH	14 MPH
12104	180311001	2 AIS	FRACTURE	STEERING ASSEMBL	27 G	46 MPH	22 MPH
11401	180317056	3 AIS	FRACTURE	SIDE INTERIOR	16 G	19 MPH	15 MPH
11308	280320024	3 AIS	CONTUSION	SIDE INTERIOR	20 G	20 MPH	0 MPH
		3 AIS	FRACTURE	SIDE INTERIOR			
13201	370617048	3 AIS	FRACTURE	UNKNOWN	17 G	29 MPH	22 MPH
		1 AIS	ABRASION	UNKNOWN			
11401	371218037	3 AIS	FRACTURE	STEERING ASSEMBL	10 G	17 MPH	7 MPH
		1 AIS	CONTUSION	UNKNOWN			
12118	470105018	3 AIS	FRACTURE	STEERING ASSEMBL	34 G	35 MPH	0 MPH
11401	471010019	3 AIS	FRACTURE	UNKNOWN	11 G	17 MPH	0 MPH
12102	480311012	3 AIS	FRACTURE	SIDE HARDWARE	14 G	26 MPH	14 MPH
		3 AIS	OTHER	SIDE HARDWARE			
13409	570310027	1 AIS	CONTUSION	UNKNOWN	10 G	14 MPH	7 MPH
11306	570520060	3 AIS	FRACTURE	UNKNOWN	27 G	22 MPH	4 MPH
		3 AIS	OTHER	UNKNOWN			
11293	570522054	3 AIS	FRACTURE	UNKNOWN	11 G	16 MPH	0 MPH
		3 AIS	OTHER	UNKNOWN			
11306	580215046	1 AIS	PAIN	UNKNOWN	10 G	14 MPH	11 MPH
11203	580305009	3 AIS	FRACTURE	SIDE INTERIOR	10 G	21 MPH	18 MPH
11302	670517053	3 AIS	FRACTURE	UNKNOWN	12 G	17 MPH	14 MPH
11401	671103005	3 AIS	OTHER	SIDE INTERIOR	19 G	26 MPH	28 MPH
		3 AIS	FRACTURE	SIDE INTERIOR			
12102	780207009	3 AIS	FRACTURE	SIDE INTERIOR	12 G	17 MPH	14 MPH
		3 AIS	OTHER	SIDE INTERIOR			
11501	470825041	4 AIS	FRACTURE	SIDE ARMRESTS	7 G	8 MPH	11 MPH
		4 AIS	LACERATION	SIDE ARMRESTS			

TABLE 5 (Continued)

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     11302    571011040         4 AIS CONTUSION      STEERING ASSEMBL      14 G       26 MPH       11 MPH
     11501    470611032         4 AIS HEMORRHAGE     UNKNOWN               16 G       21 MPH       14 MPH
     11318    570910027         5 AIS RUPTURE        SIDE INTERIOR         73 G       59 MPH        0 MPH
     13202    470624047         6 AIS CRUSHING       UNKNOWN               12 G       22 MPH       16 MPH
     12108    673023061         6 AIS CRUSHING       SIDE INTERIOR         13 G       19 MPH        0 MPH
     12106    780212017         5 AIS LACERATION     SIDE HARDWARE         32 G       29 MPH       22 MPH
/COMPILE        TIME=90
```

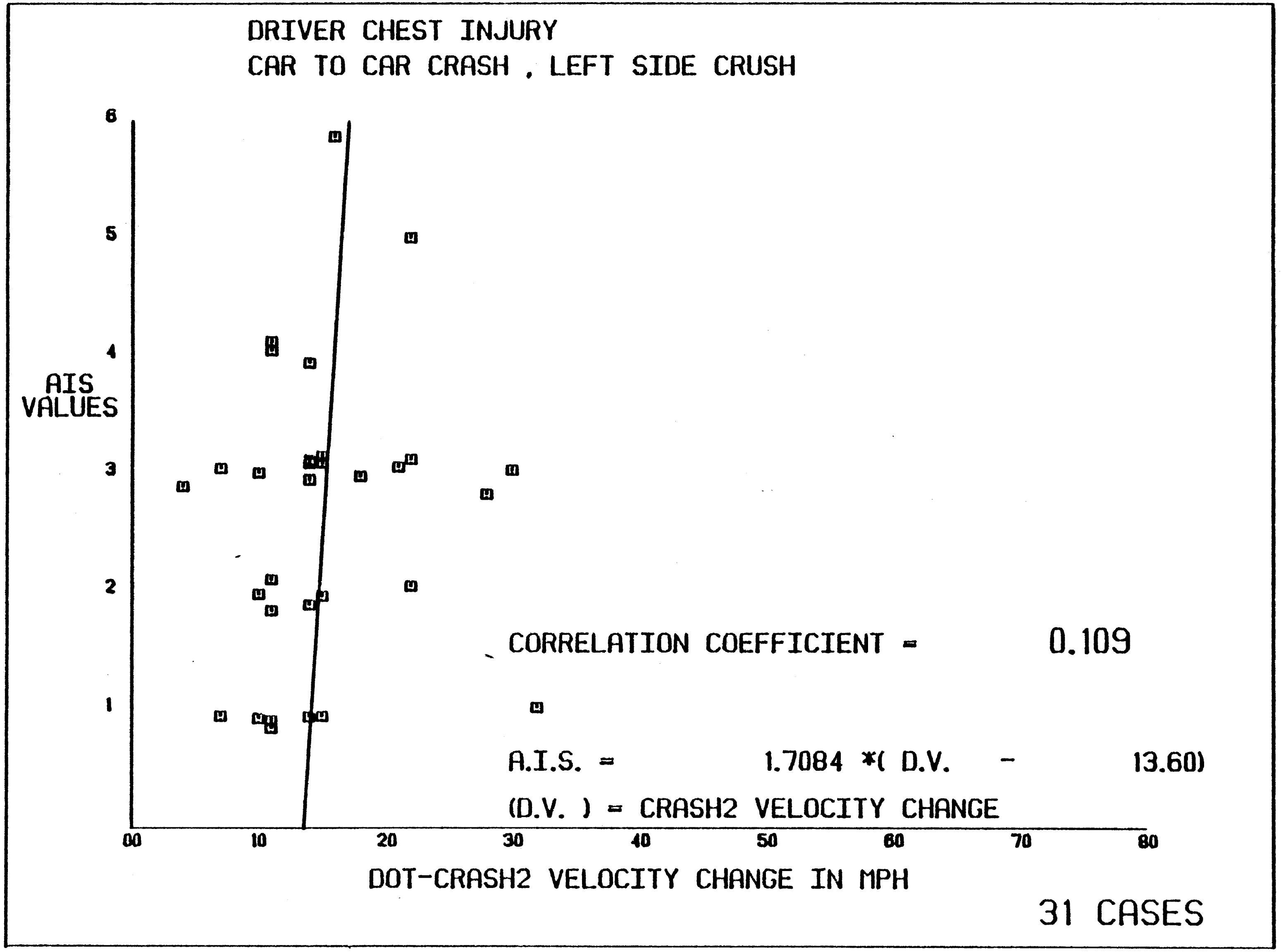

DRIVER CHEST INJURY
CAR TO CAR CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
DOT-CRASH2 VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.109
A.I.S. = 1.7084 *(D.V. - 13.60)
(D.V.) = CRASH2 VELOCITY CHANGE
31 CASES

FIGURE 10

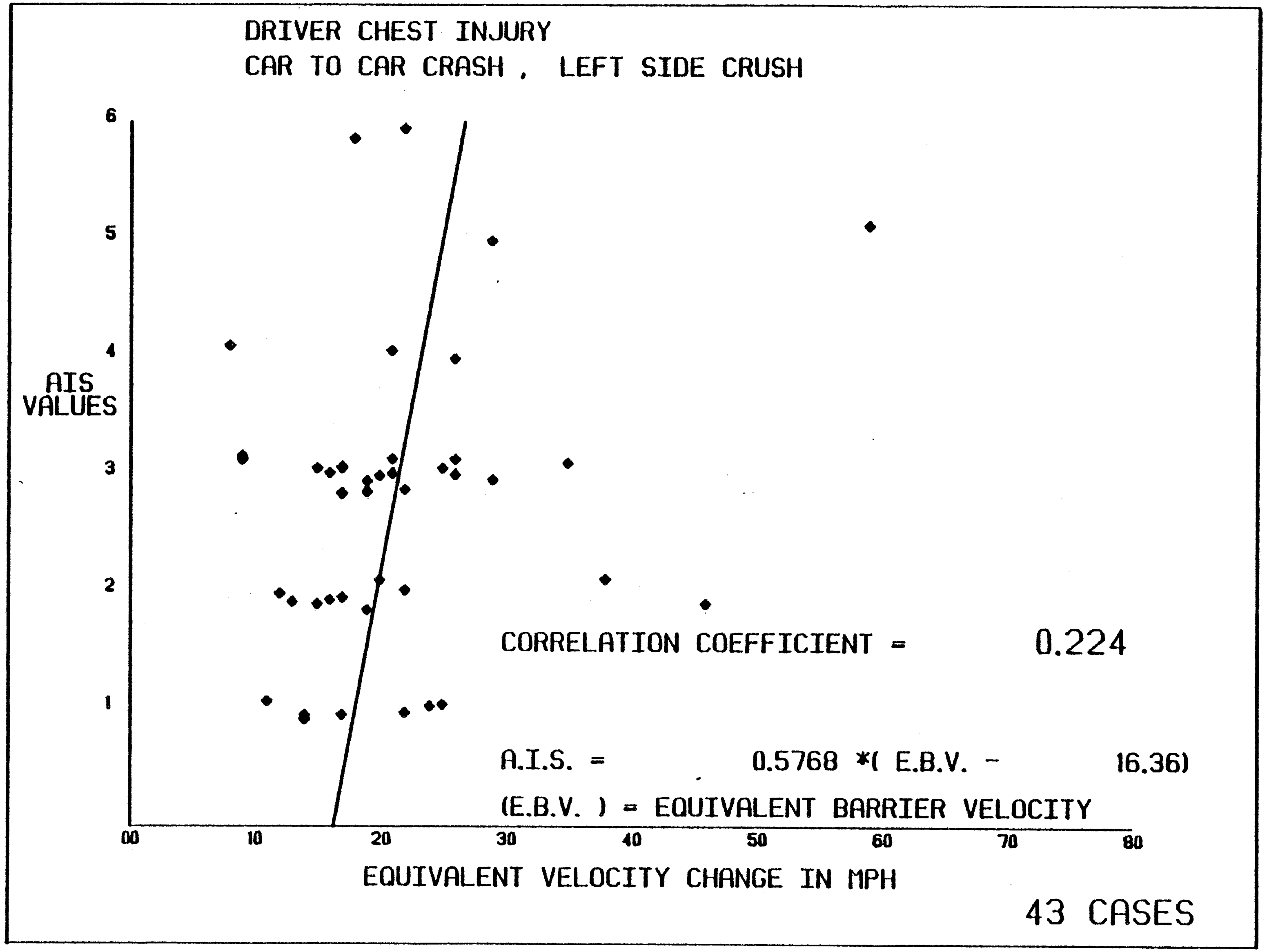

DRIVER CHEST INJURY
CAR TO CAR CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.224
A.I.S. = 0.5768 *(E.B.V. - 16.36)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
43 CASES

FIGURE 11

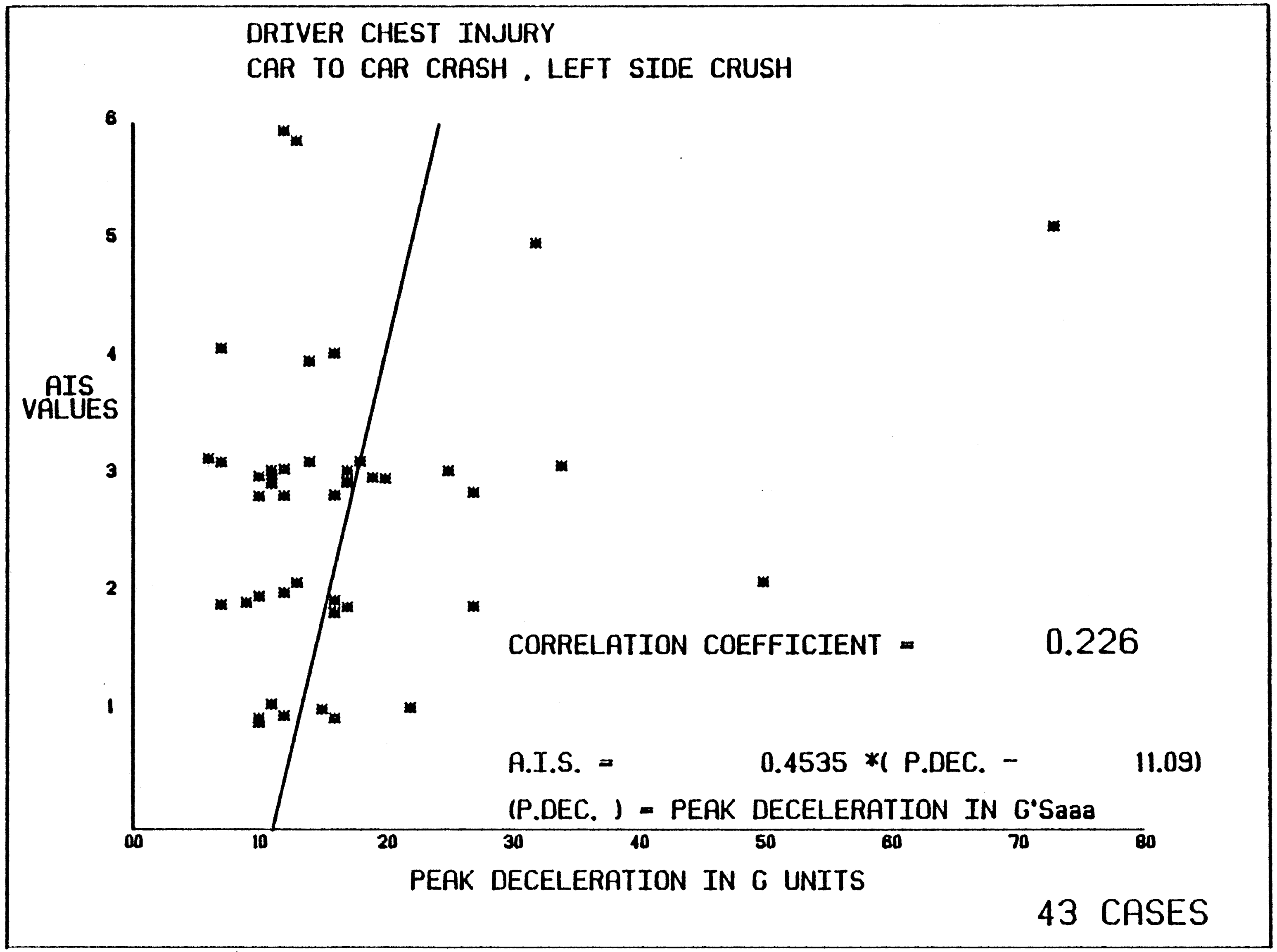

DRIVER CHEST INJURY
CAR TO CAR CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
CORRELATION COEFFICIENT = 0.226
A.I.S. = 0.4535 *(P.DEC. - 11.09)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
43 CASES

FIGURE 12

TABLE 6

DRIVER CHEST INJURY CAR TO TREE/POLE CRASH, FRONT CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
12102	300314024	1 AIS	ABRASION	STEERING ASSEMBL	10 G	29 MPH	21 MPH
11391	470417026	1 AIS	CONTUSION	UNKNOWN	6 G	10 MPH	0 MPH
11302	570226053	2 AIS	FRACTURE	STEERING ASSEMBL	13 G	20 MPH	0 MPH
11302	570810049	2 AIS	FRACTURE	STEERING ASSEMBL	1 G	9 MPH	22 MPH
		1 AIS	CONTUSION	STEERING ASSEMBL			
11401	500318041	2 AIS	FRACTURE	STEERING ASSEMBL	15 G	25 MPH	0 MPH
12207	671100019	1 AIS	ABRASION	STEERING ASSEMBL	7 G	16 MPH	16 MPH
13206	170702013	3 AIS	OTHER	UNKNOWN	9 G	20 MPH	29 MPH
11401	171109037	3 AIS	FRACTURE	STEERING ASSEMBL	6 G	16 MPH	16 MPH
86109	370309006	3 AIS	OTHER	UNK EXTER OBJECT	10 G	15 MPH	16 MPH
11401	370706058	3 AIS	FRACTURE	UNKNOWN	11 G	16 MPH	17 MPH
66109	370726071	2 AIS	FRACTURE	UNKNOWN	34 G	40 MPH	47 MPH
11402	370811021	3 AIS	CONTUSION	STEERING ASSEMBL	15 G	27 MPH	28 MPH
		3 AIS	FRACTURE	STEERING ASSEMBL			
66109	470402007	3 AIS	FRACTURE	UNKNOWN	4 G	5 MPH	7 MPH
12108	470918033	2 AIS	FRACTURE	STEERING ASSEMBL	8 G	13 MPH	15 MPH
11503	471222033	3 AIS	FRACTURE	STEERING ASSEMBL	9 G	18 MPH	20 MPH
11306	580204002	3 AIS	FRACTURE	STEERING ASSEMBL	32 G	29 MPH	0 MPH
11401	670424087	3 AIS	FRACTURE	UNKNOWN	9 G	25 MPH	14 MPH
11308	680226071	1 AIS	CONTUSION	INSTRUMENT PANEL	11 G	20 MPH	18 MPH
66109	680317054	3 AIS	FRACTURE	STEERING ASSEMBL	11 G	15 MPH	18 MPH
61209	680331090	3 AIS	CONTUSION	SIDE INTERIOR	21 G	40 MPH	37 MPH
11507	170528039	2 AIS	FRACTURE	UNKNOWN	23 G	43 MPH	37 MPH
11101	171104027	3 AIS	FRACTURE	STEERING ASSEMBL	8 G	21 MPH	27 MPH
11318	270210011	4 AIS	LACERATION	UNKNOWN	33 G	35 MPH	28 MPH
12206	470220010	3 AIS	CONTUSION	UNKNOWN	18 G	33 MPH	22 MPH
11318	670703014	4 AIS	FRACTURE	UNKNOWN	18 G	31 MPH	31 MPH
		3 AIS	CONTUSION	UNKNOWN			
13406	170410030	1 AIS	ABRASION	UNKNOWN	13 G	24 MPH	19 MPH
66109	170515020	5 AIS	RUPTURE	UNKNOWN	9 G	24 MPH	24 MPH
13401	170731063	5 AIS	LACERATION	UNKNOWN	1 G	5 MPH	29 MPH
		3 AIS	CONTUSION	UNKNOWN			
12102	170806006	5 AIS	LACERATION	STEERING ASSEMBL	15 G	40 MPH	0 MPH
		5 AIS	LACERATION	STEERING ASSEMBL			
		3 AIS	FRACTURE	STEERING ASSEMBL			
11302	680303007	5 AIS	LACERATION	STEERING ASSEMBL	8 G	21 MPH	20 MPH
11302	770903002	5 AIS	CONTUSION	STEERING ASSEMBL	6 G	13 MPH	19 MPH
		3 AIS	CONTUSION	STEERING ASSEMBL			
		3 AIS	OTHER	STEERING ASSEMBL			

```
/COMPILE      TIME=90
```

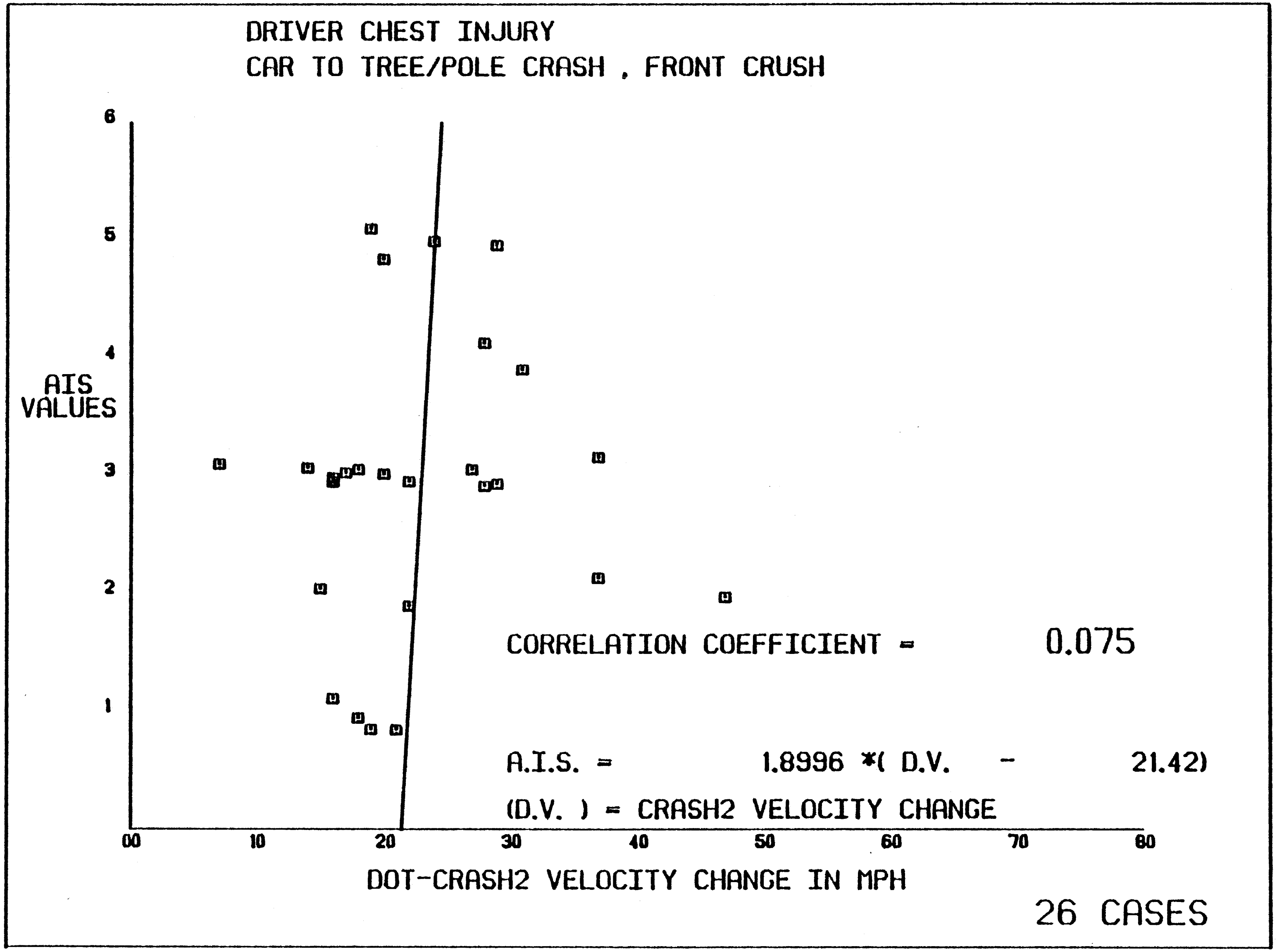

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
CORRELATION COEFFICIENT = 0.075
A.I.S. = 1.8996 *(D.V. - 21.42)
(D.V.) = CRASH2 VELOCITY CHANGE
DOT-CRASH2 VELOCITY CHANGE IN MPH
26 CASES

FIGURE 13

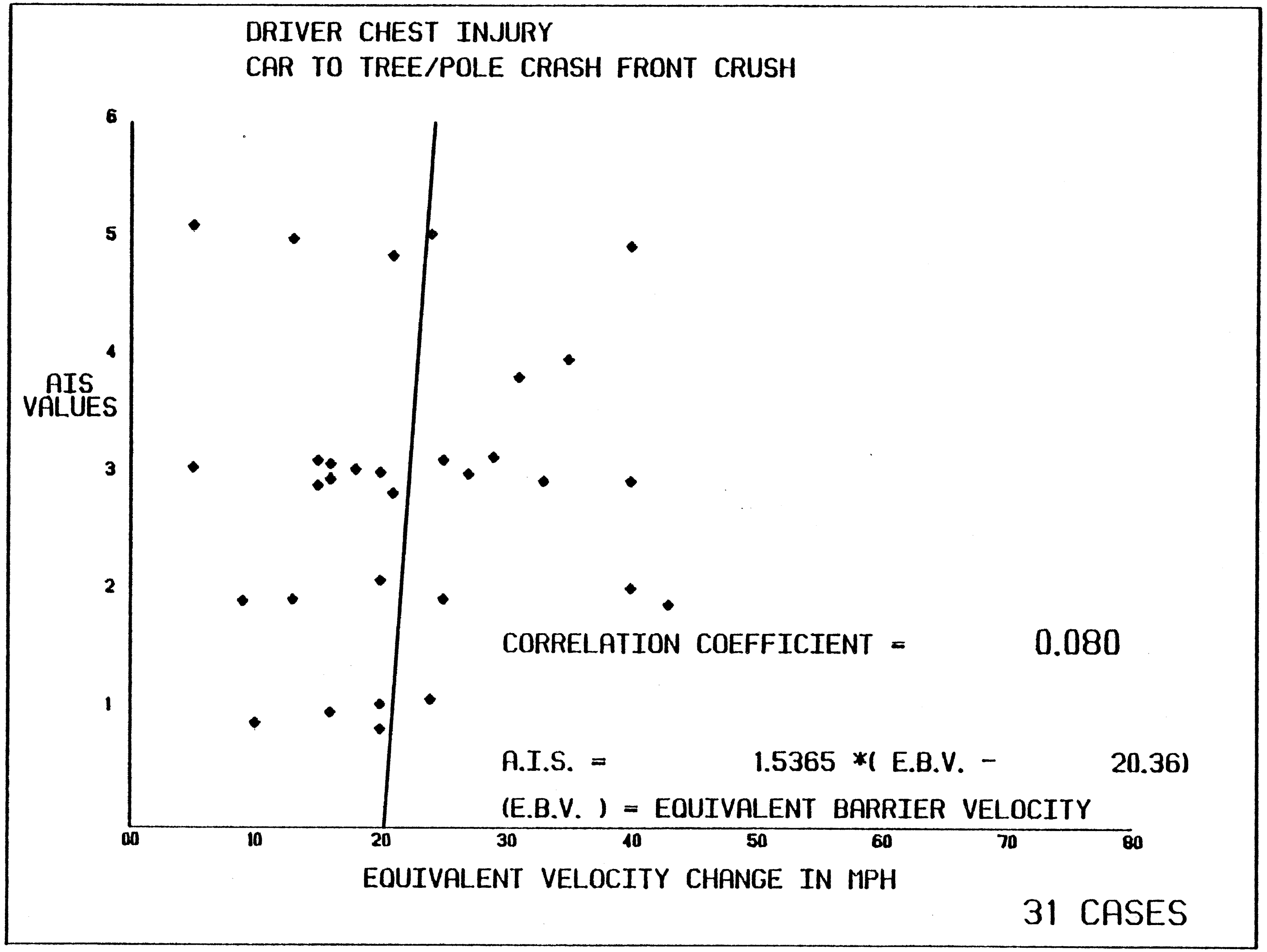

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.080
A.I.S. = 1.5365 *(E.B.V. - 20.36)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
31 CASES

FIGURE 14

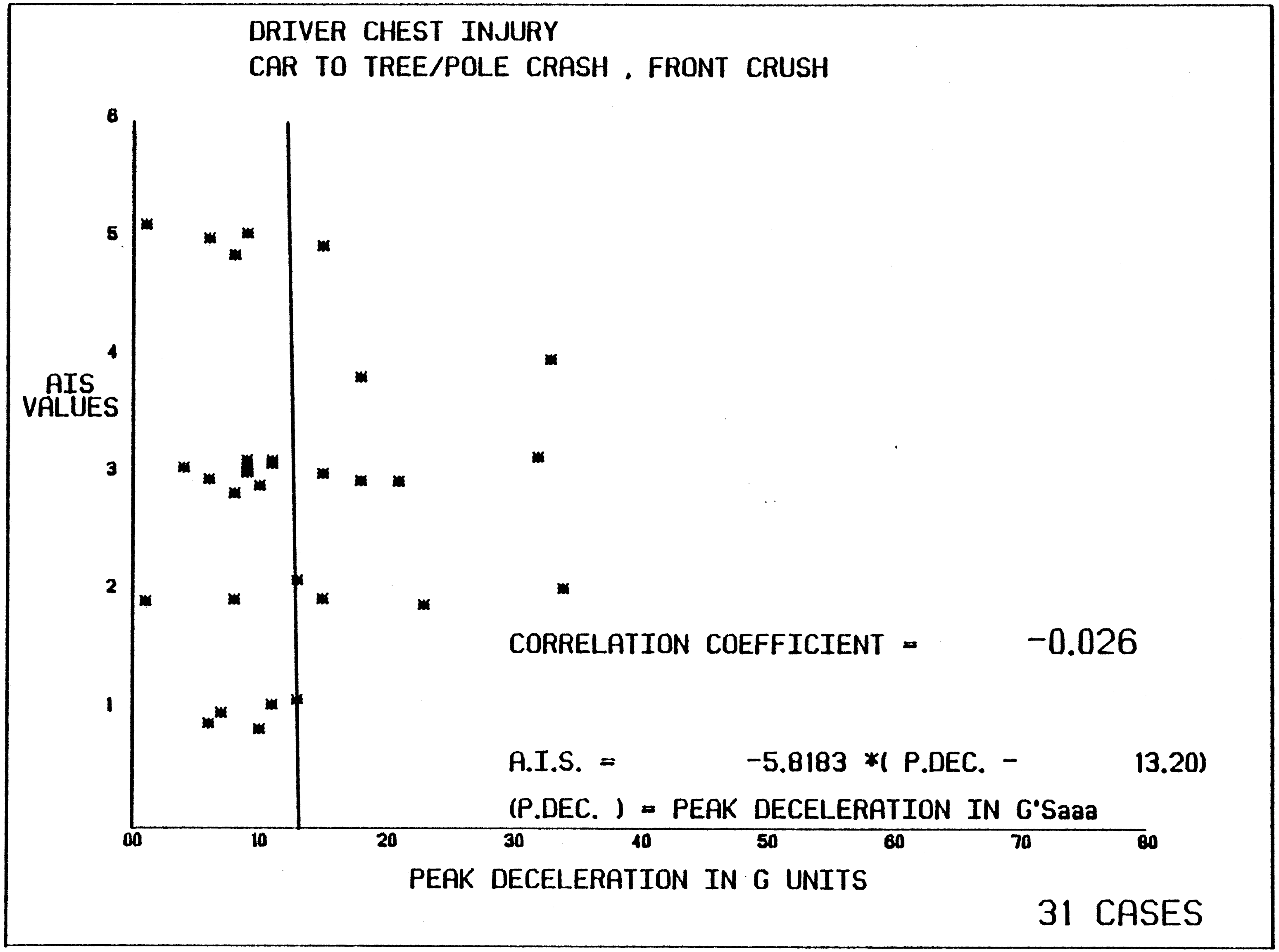

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
CORRELATION COEFFICIENT = -0.026
A.I.S. = -5.8183 *(P.DEC. - 13.20)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
PEAK DECELERATION IN G UNITS
31 CASES

FIGURE 15

TABLE 7

```
                  DRIVER CHEST INJURY                    CAR TO TREE/POLE CRASH, LEFT-SIDE CRUSH
------------------------------------------------------------------------------------------------------------------------
      VEHICLE  NCSS CASE             LEVEL   TYPE            OBJECT CONTACTED        PEAK          EQUIVALENT   DOT-CRASH2
      CODE                           INJURY  INJURY                                  DECELERATION  BARRIER      DELTA-V
                                                                                                   SPEED
------------------------------------------------------------------------------------------------------------------------
       13401   780112012             2 AIS FRACTURE          SIDE INTERIOR           12 G          15 MPH       16 MPH
       11310   670213038             3 AIS FRACTURE          UNKNOWN                 16 G          32 MPH        0 MPH
       12108   470906023             3 AIS HEMORRHAGE        SIDE INTERIOR           37 G          35 MPH        0 MPH
       11301   170313006             5 AIS LACERATION        UNKNOWN                 28 G          38 MPH       37 MPH
                                     4 AIS HEMORRHAGE        UNKNOWN
       11302   471109016             4 AIS OTHER             STEERING ASSEMBL        23 G          28 MPH       20 MPH
       12108   600129077             6 AIS CRUSHING          SIDE INTERIOR           10 G          13 MPH       18 MPH
/COMPILE         TIME=99
```

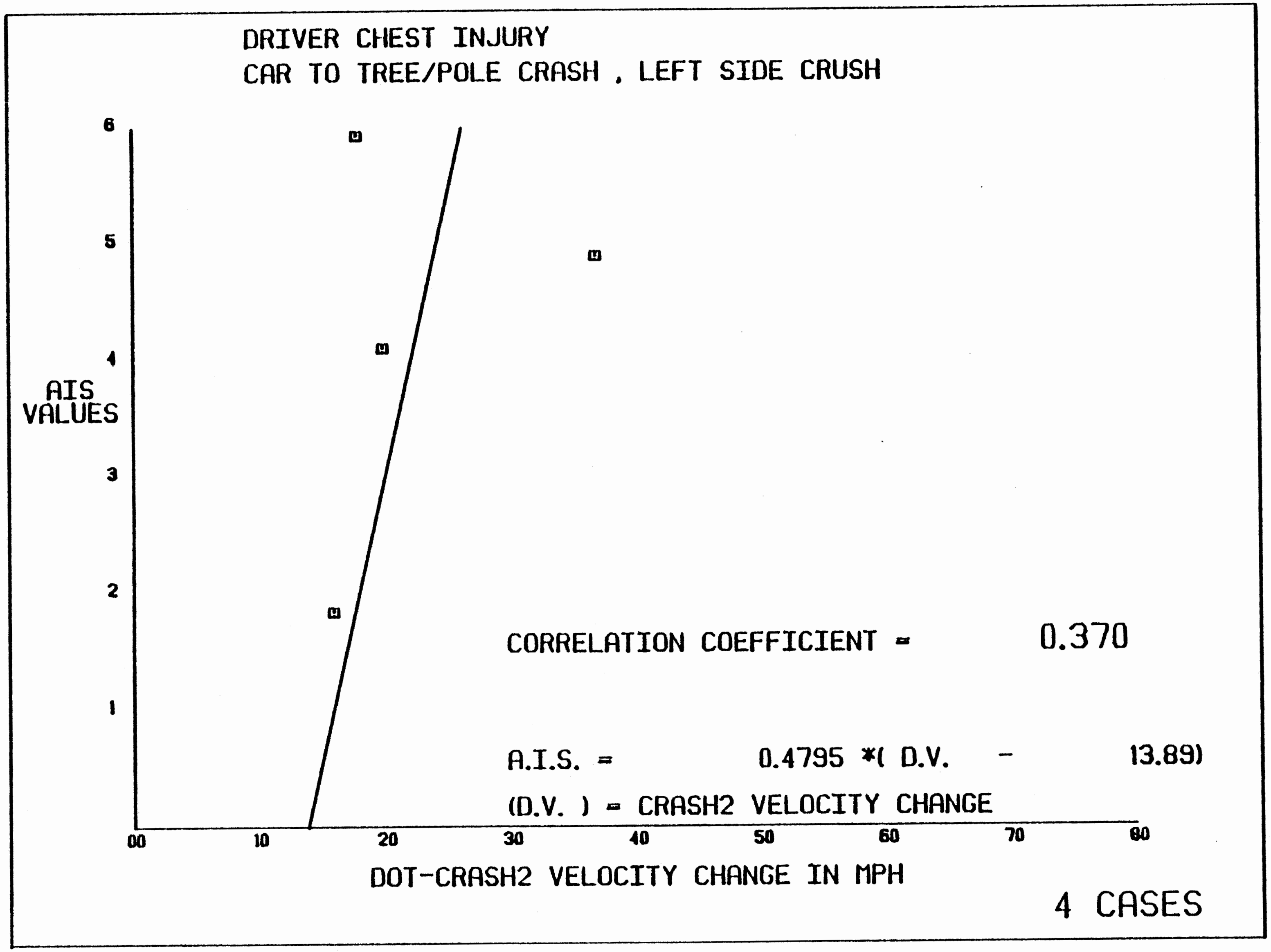

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
CORRELATION COEFFICIENT = 0.370
A.I.S. = 0.4795 *(D.V. - 13.89)
(D.V.) = CRASH2 VELOCITY CHANGE
00
10
20
30
40
50
60
70
80
DOT-CRASH2 VELOCITY CHANGE IN MPH
4 CASES

FIGURE 16

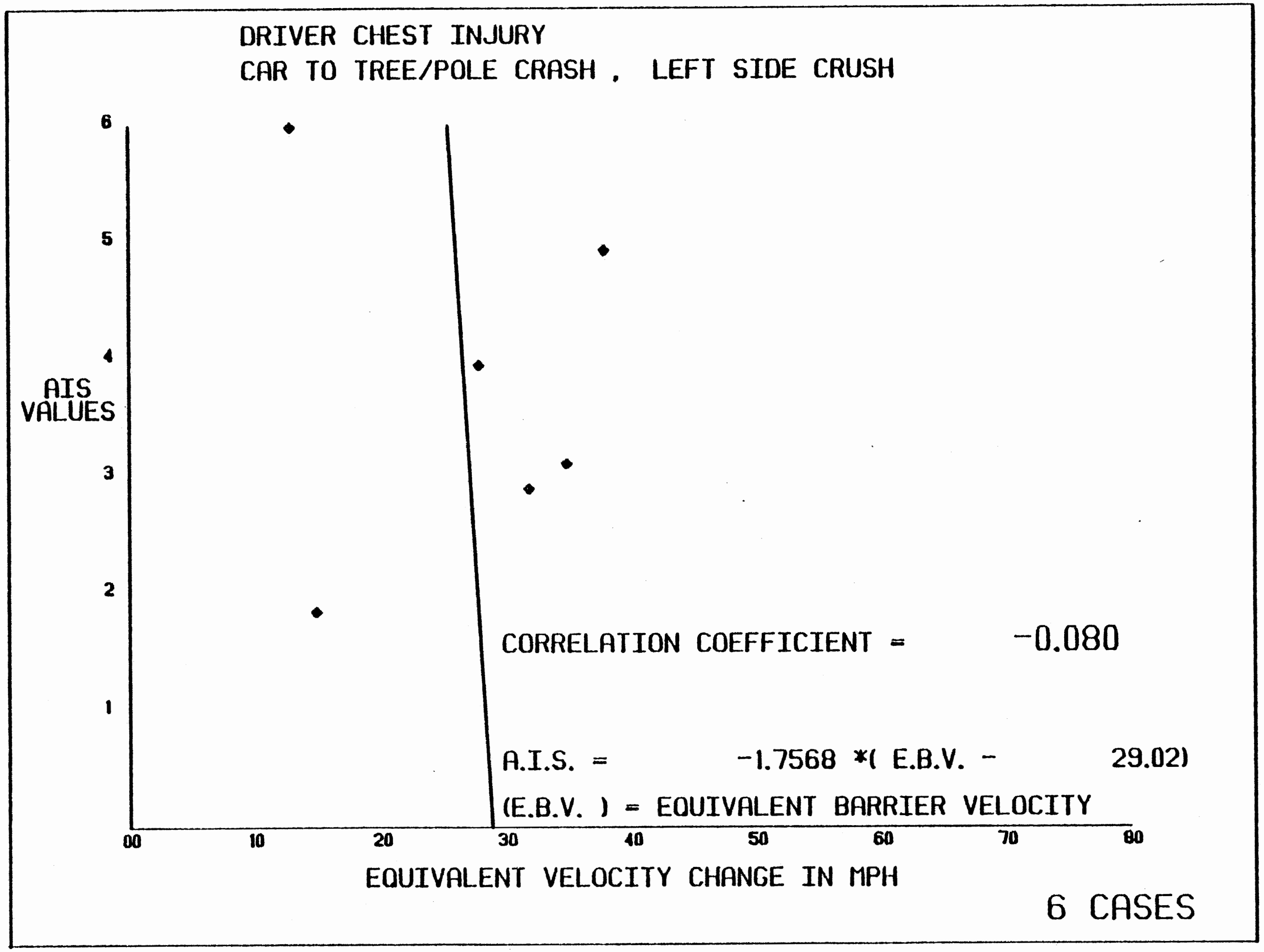

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = -0.080
A.I.S. = -1.7568 *(E.B.V. - 29.02)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
6 CASES

FIGURE 17

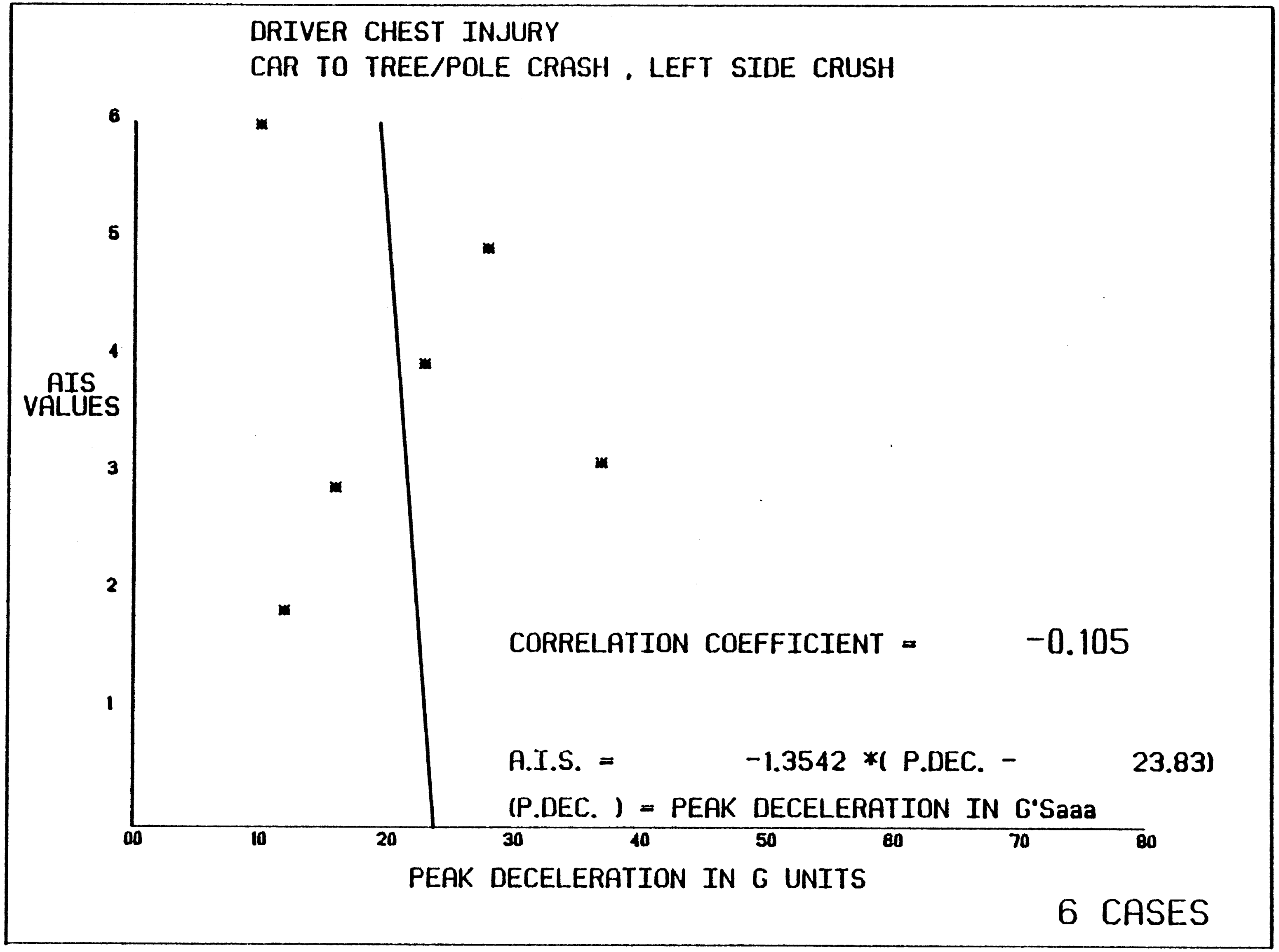

DRIVER CHEST INJURY
CAR TO TREE/POLE CRASH , LEFT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
CORRELATION COEFFICIENT = -0.105
A.I.S. = -1.3542 *(P.DEC. - 23.83)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
PEAK DECELERATION IN G UNITS
6 CASES

FIGURE 18

TABLE 8

RIGHT-FRONT PASSENGER CHEST INJURY CAR TO CAR CRASH, FRONT CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
12102	170715035	2 AIS	FRACTURE	UNKNOWN	10 G	20 MPH	14 MPH
11502	180217037	2 AIS	FRACTURE	INSTRUMENT PANEL	4 G	9 MPH	9 MPH
11308	670911031	2 AIS	FRACTURE	SIDE ARMRESTS	9 G	11 MPH	12 MPH
11408	671203006	1 AIS	CONTUSION	INSTRUMENT PANEL	22 G	44 MPH	0 MPH
06109	780109000	2 AIS	FRACTURE	UNKNOWN	27 G	30 MPH	25 MPH
11103	270322039	3 AIS	HEMORRHAGE	UNKNOWN	18 G	36 MPH	18 MPH
		3 AIS	HEMORRHAGE	UNKNOWN			
		3 AIS	FRACTURE	UNKNOWN			
61809	270522036	3 AIS	OTHER	UNKNOWN	13 G	23 MPH	22 MPH
		2 AIS	FRACTURE	UNKNOWN			
11309	271008035	3 AIS	FRACTURE	INSTRUMENT PANEL	6 G	23 MPH	13 MPH
11302	370924026	3 AIS	HEMORRHAGE	STEERING ASSEMBL	11 G	23 MPH	20 MPH
		2 AIS	FRACTURE	STEERING ASSEMBL			
11318	480216028	3 AIS	HEMORRHAGE	GLOVE COMPARTMEN	31 G	29 MPH	45 MPH
03209	570416027	1 AIS	CONTUSION	UNKNOWN	8 G	21 MPH	10 MPH
11302	570501001	3 AIS	FRACTURE	UNKNOWN	21 G	31 MPH	29 MPH
12108	570908023	3 AIS	FRACTURE	UNKNOWN	14 G	27 MPH	30 MPH
		3 AIS	CONTUSION	UNKNOWN			
		3 AIS	OTHER	UNKNOWN			
12102	571006019	3 AIS	OTHER	INSTRUMENT PANEL	8 G	15 MPH	8 MPH
		2 AIS	FRACTURE	INSTRUMENT PANEL			
13401	671002005	3 AIS	FRACTURE	GLOVE COMPARTMEN	18 G	39 MPH	29 MPH
06109	671029130	1 AIS	LACERATION	INSTRUMENT PANEL	45 G	57 MPH	45 MPH
13102	170703004	4 AIS	CONTUSION	UNKNOWN	11 G	16 MPH	17 MPH
12108	180108002	1 AIS	CONTUSION	GLOVE COMPARTMEN	34 G	50 MPH	44 MPH
66109	470606002	4 AIS	CONTUSION	UNKNOWN	13 G	31 MPH	37 MPH
		4 AIS	FRACTURE	UNKNOWN			
11101	570303002	4 AIS	FRACTURE	UNK EXTER OBJECT	6 G	15 MPH	26 MPH
		3 AIS	OTHER	UNK EXTER OBJECT			
11101	680226084	3 AIS	FRACTURE	GLOVE COMPARTMEN	21 G	37 MPH	52 MPH
11302	170704001	5 AIS	LACERATION	UNKNOWN	46 G	81 MPH	45 MPH
		5 AIS	LACERATION	UNKNOWN			
12101	271002044	3 AIS	OTHER	GLOVE COMPARTMEN	13 G	23 MPH	14 MPH
66109	371013031	6 AIS	CRUSHING	UNKNOWN	46 G	59 MPH	7 MPH
06109	480216028	6 AIS	CRUSHING	UNKNOWN	56 G	51 MPH	49 MPH

/COMPILE TIME=90

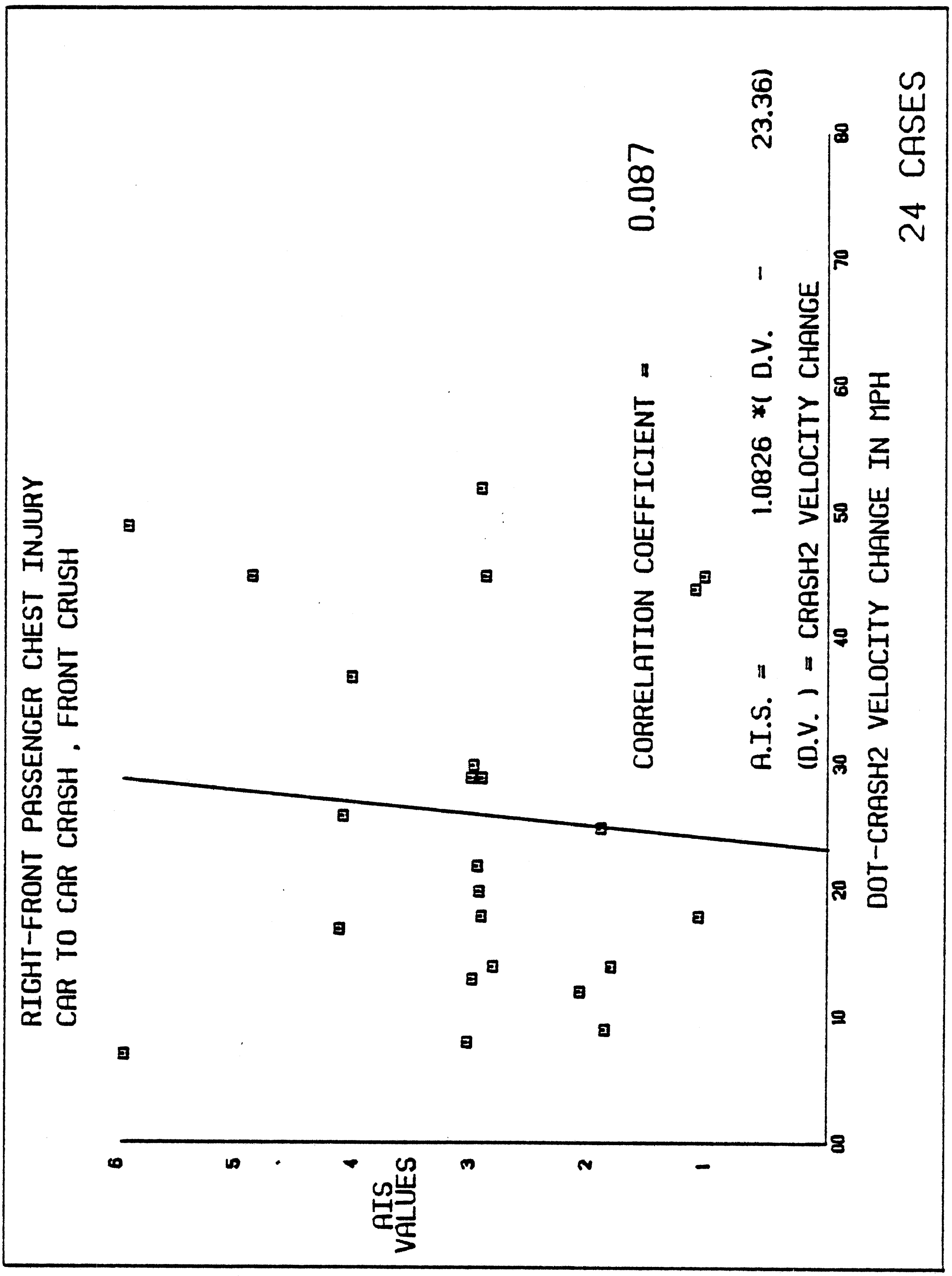

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH , FRONT CRUSH
CORRELATION COEFFICIENT = 0.087
A.I.S. = 1.0826 *(D.V. - 23.36)
(D.V.) = CRASH2 VELOCITY CHANGE
AIS VALUES
1
2
3
4
5
6
00
10
20
30
40
50
60
70
80
DOT-CRASH2 VELOCITY CHANGE IN MPH
24 CASES

FIGURE 19

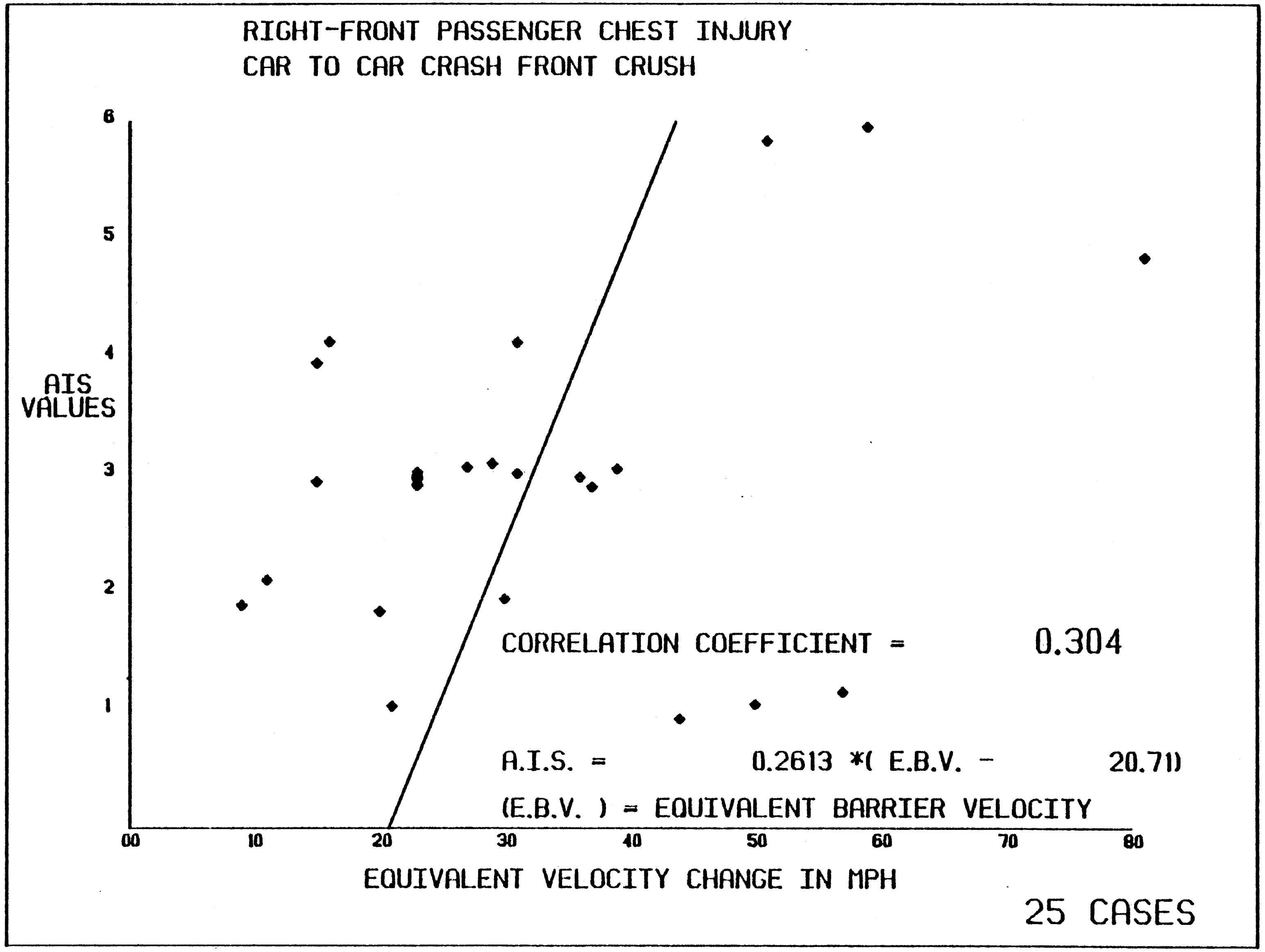

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.304
A.I.S. = 0.2613 *(E.B.V. - 20.71)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
25 CASES

FIGURE 20

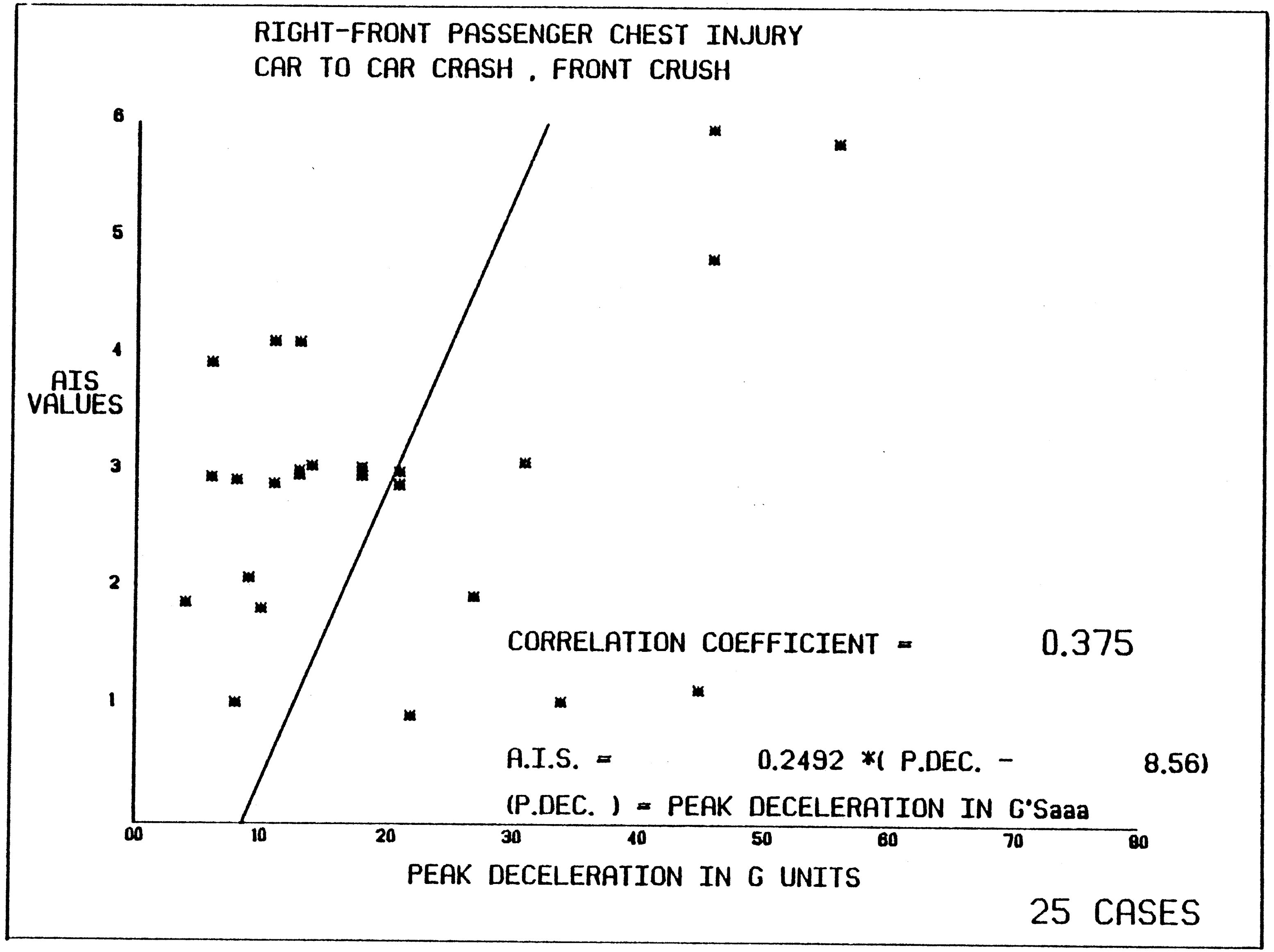

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
CORRELATION COEFFICIENT = 0.375
A.I.S. = 0.2492 *(P.DEC. - 8.56)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
25 CASES

FIGURE 21

TABLE 9

RIGHT-FRONT PASSENGER CHEST INJURY   CAR TO CAR CRASH, RIGHT-SIDE CRUSH

VEHICLE CODE	NASS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
12102	180112024	1 AIS	CONTUSION	INSTRUMENT PANEL	7 G	14 MPH	0 MPH
11103	180311040	1 AIS	CONTUSION	SIDE HARDWARE	13 G	19 MPH	15 MPH
12105	570223049	2 AIS	FRACTURE	UNKNOWN	11 G	19 MPH	17 MPH
11405	670522115	2 AIS	FRACTURE	UNKNOWN	11 G	16 MPH	12 MPH
12108	670713061	2 AIS	FRACTURE	UNKNOWN	15 G	17 MPH	13 MPH
12118	680317052	2 AIS	FRACTURE	OTHER OCCUPANTS	11 G	10 MPH	10 MPH
09109	771230028	1 AIS	PAIN	UNKNOWN	16 G	16 MPH	11 MPH
11301	170521030	3 AIS	FRACTURE	UNKNOWN	16 G	19 MPH	11 MPH
11402	170706017	3 AIS	FRACTURE	UNKNOWN	12 G	16 MPH	12 MPH
11501	171119034	3 AIS	FRACTURE	SIDE INTERIOR	15 G	25 MPH	11 MPH
		3 AIS	HEMORRHAGE	SIDE INTERIOR			
11102	171215033	3 AIS	FRACTURE	SIDE INTERIOR	14 G	26 MPH	6 MPH
11402	370126013	3 AIS	FRACTURE	SIDE INTERIOR	16 G	19 MPH	8 MPH
03209	670714062	3 AIS	FRACTURE	UNKNOWN	21 G	19 MPH	13 MPH
11101	671016117	3 AIS	OTHER	SIDE ARMRESTS	26 G	39 MPH	0 MPH
		3 AIS	CONTUSION	SIDE ARMRESTS			
11103	680204016	3 AIS	FRACTURE	SIDE ARMRESTS	11 G	13 MPH	14 MPH
11302	470210011	3 AIS	FRACTURE	OUTSIDE SURFACE	23 G	49 MPH	24 MPH
66119	571229066	4 AIS	CONTUSION	SIDE INTERIOR	19 G	25 MPH	0 MPH
		3 AIS	FRACTURE	SIDE INTERIOR			
		3 AIS	CONTUSION	SIDE INTERIOR			
12108	171111020	5 AIS	LACERATION	SIDE INTERIOR	27 G	40 MPH	31 MPH
11304	470530045	5 AIS	LACERATION	UNKNOWN	15 G	16 MPH	19 MPH
		3 AIS	FRACTURE	UNKNOWN			
13208	170305002	5 AIS	LACERATION	UNKNOWN	15 G	17 MPH	42 MPH
12102	271014007	4 AIS	LACERATION	WINDOW FRAME	16 G	19 MPH	19 MPH

/COMPILE TIME=90

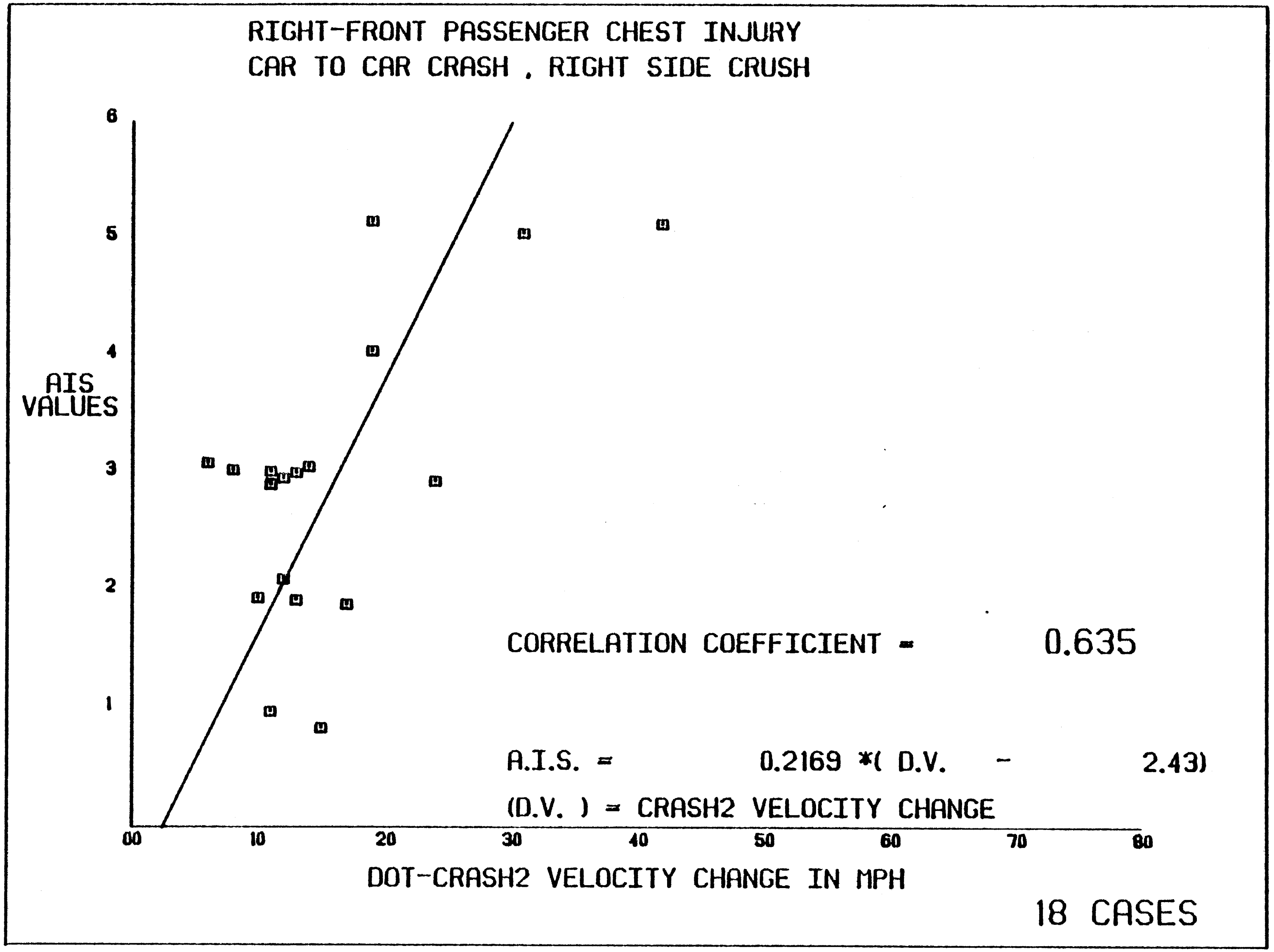

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
DOT-CRASH2 VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.635
A.I.S. = 0.2169 *(D.V. - 2.43)
(D.V.) = CRASH2 VELOCITY CHANGE
18 CASES

FIGURE 22

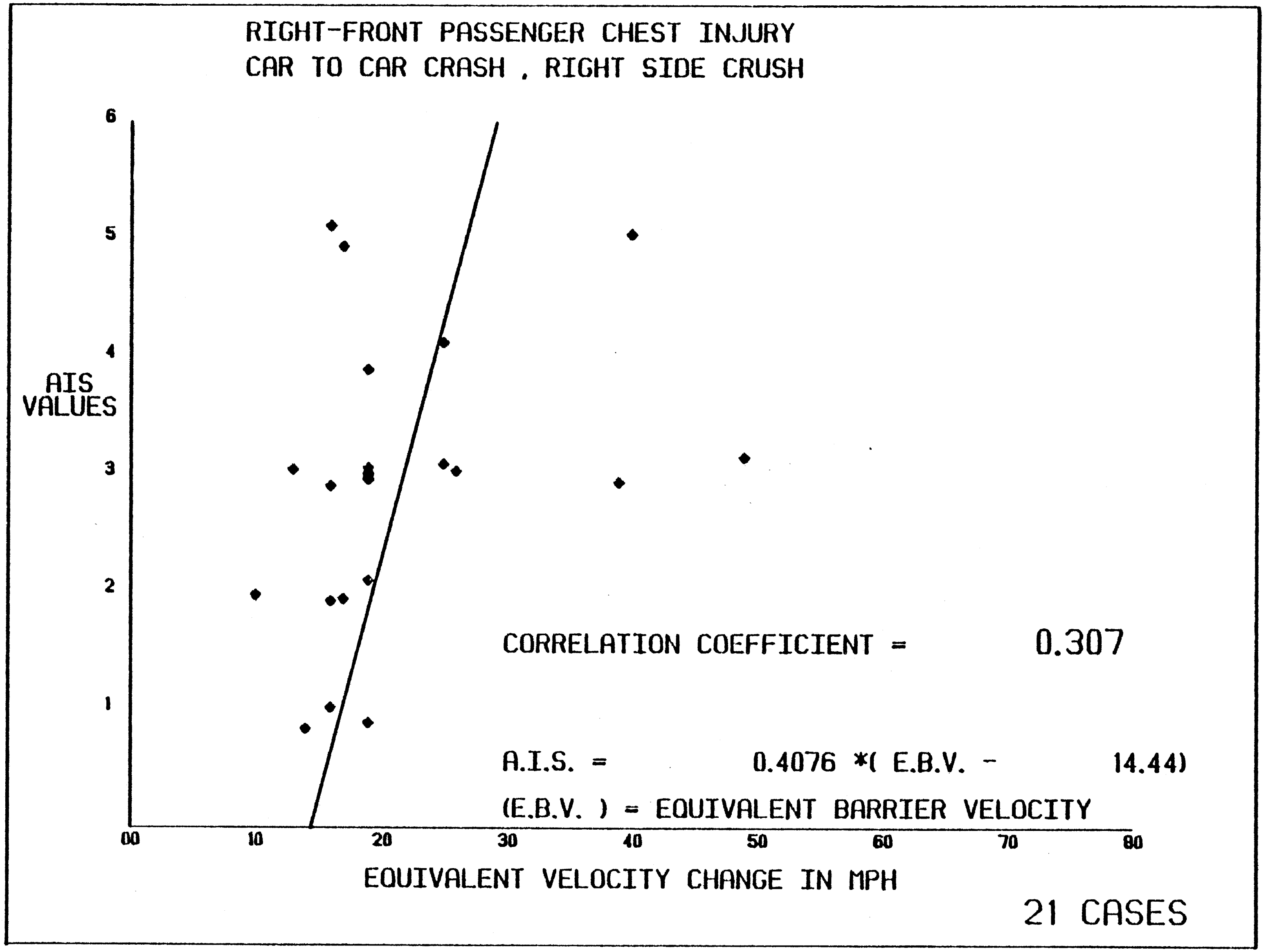

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.307
A.I.S. = 0.4076 *(E.B.V. - 14.44)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
21 CASES

FIGURE 23

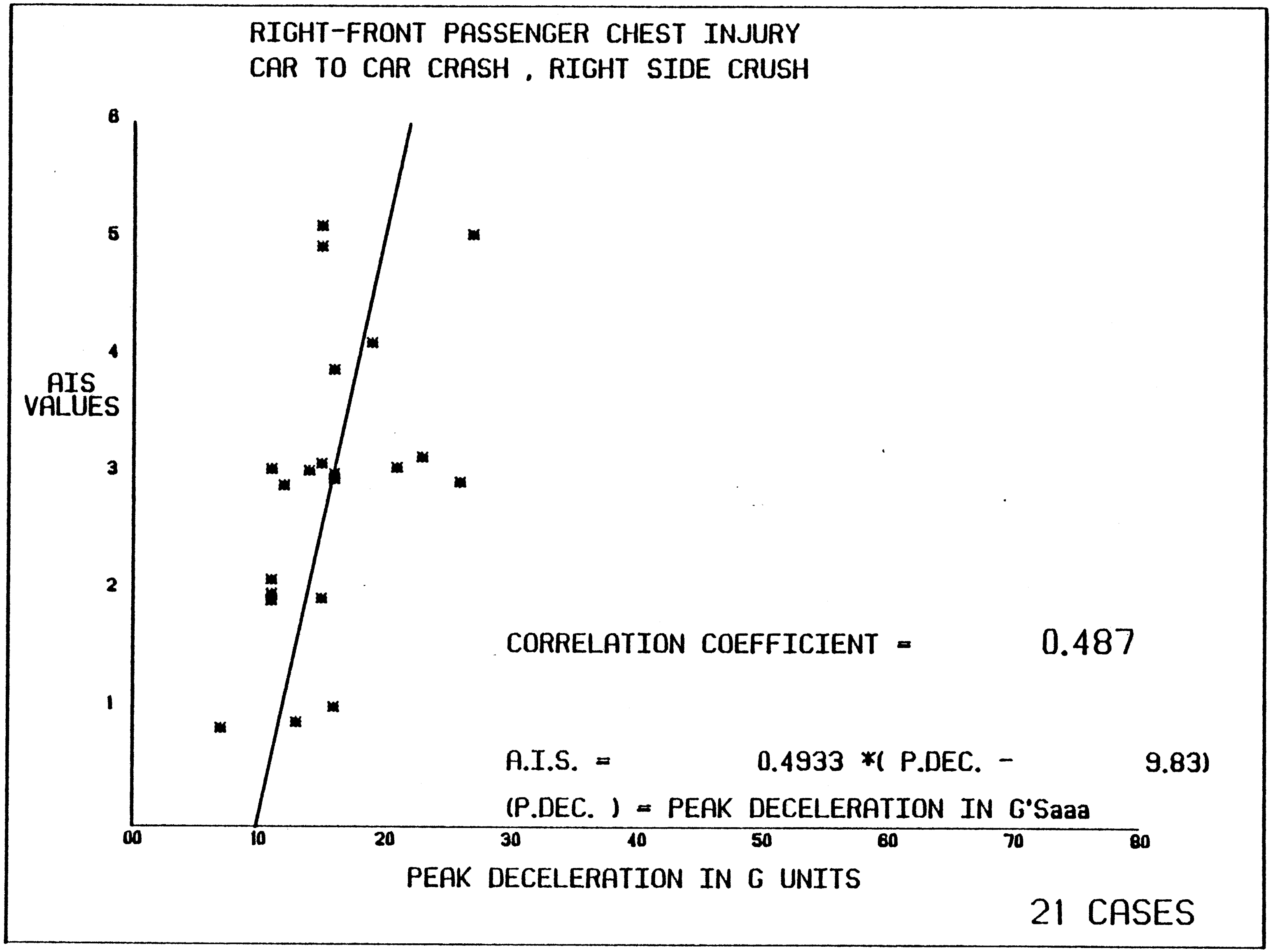

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO CAR CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
CORRELATION COEFFICIENT = 0.487
A.I.S. = 0.4933 *(P.DEC. - 9.83)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
21 CASES

FIGURE 24

TABLE 10

RIGHT-FRONT PASSENGER CHEST INJURY CAR TO TREE/POLE CRASH, FRONT CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
11307	470416030	1 AIS	CONTUSION	UNKNOWN	2 G	6 MPH	12 MPH
12102	570320058	2 AIS	CONTUSION	UNKNOWN	16 G	30 MPH	25 MPH
		2 AIS	FRACTURE	UNKNOWN			
11318	470603006	3 AIS	FRACTURE	UNKNOWN	8 G	10 MPH	12 MPH
11592	471125075	3 AIS	OTHER	HARDWARE ITEMS	9 G	18 MPH	18 MPH
12208	580301007	3 AIS	FRACTURE	GLOVE COMPARTMEN	9 G	12 MPH	18 MPH
		2 AIS	FRACTURE	GLOVE COMPARTMEN			
11401	670424087	3 AIS	FRACTURE	UNKNOWN	9 G	25 MPH	14 MPH
11302	270511026	4 AIS	FRACTURE	UNKNOWN	6 G	17 MPH	18 MPH
		4 AIS	OTHER	UNKNOWN			
11302	570205008	5 AIS	LACERATION	UNKNOWN	45 G	66 MPH	53 MPH

/COMPILE TIME=90

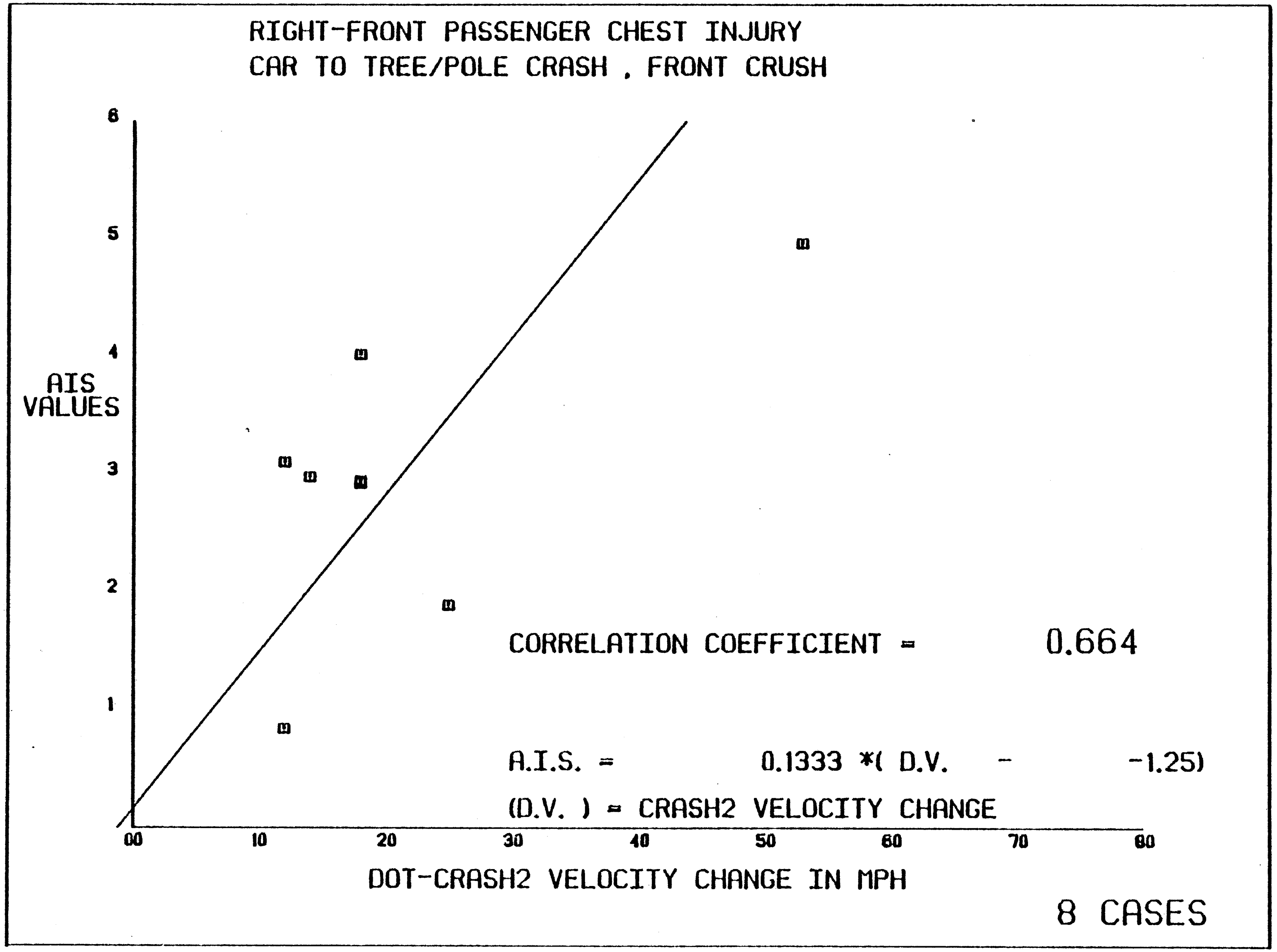

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
CORRELATION COEFFICIENT = 0.664
A.I.S. = 0.1333 *(D.V. - -1.25)
(D.V.) = CRASH2 VELOCITY CHANGE
DOT-CRASH2 VELOCITY CHANGE IN MPH
8 CASES

FIGURE 25

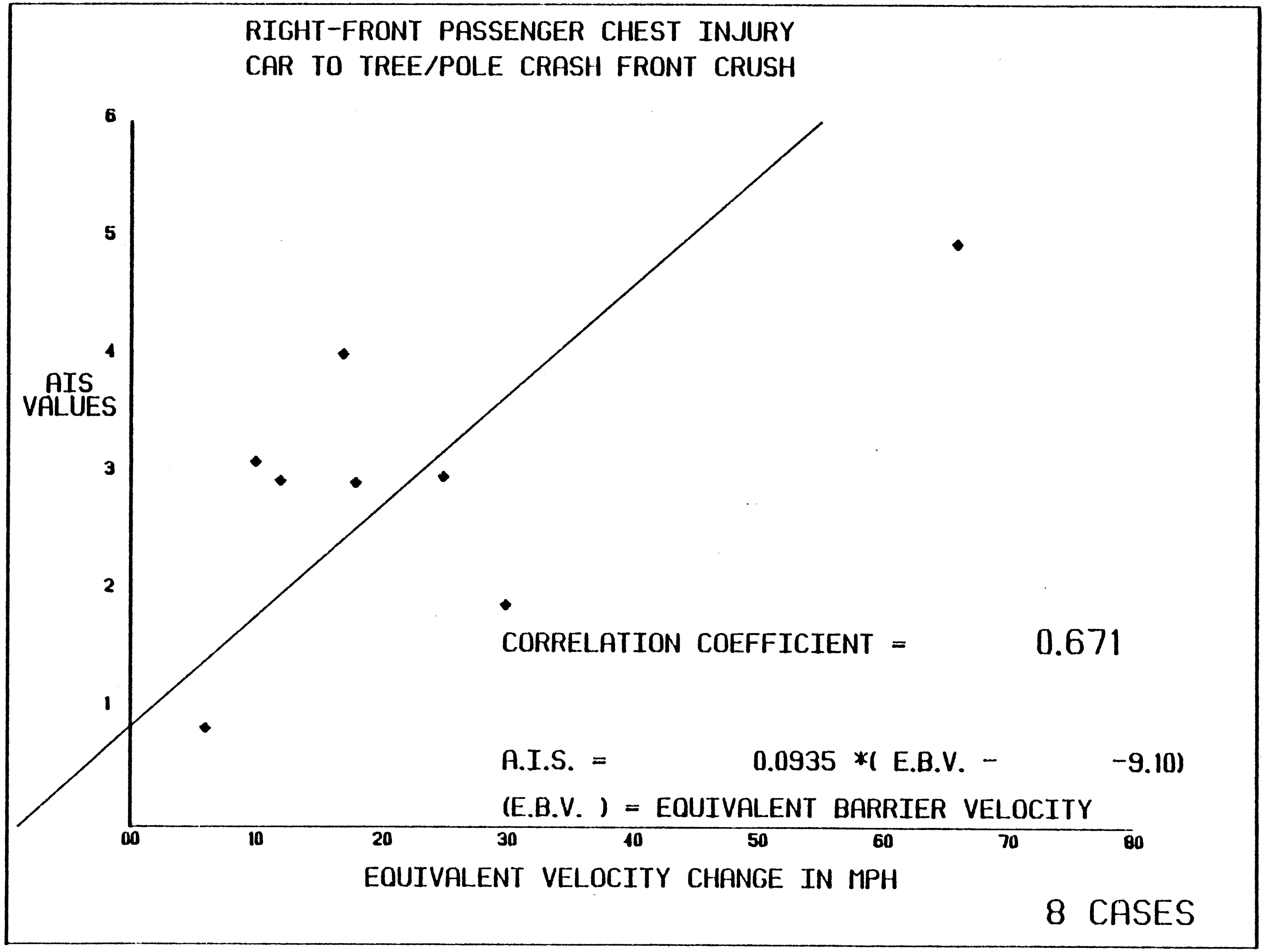

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.671
A.I.S. = 0.0935 *(E.B.V. - -9.10)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
8 CASES

FIGURE 26

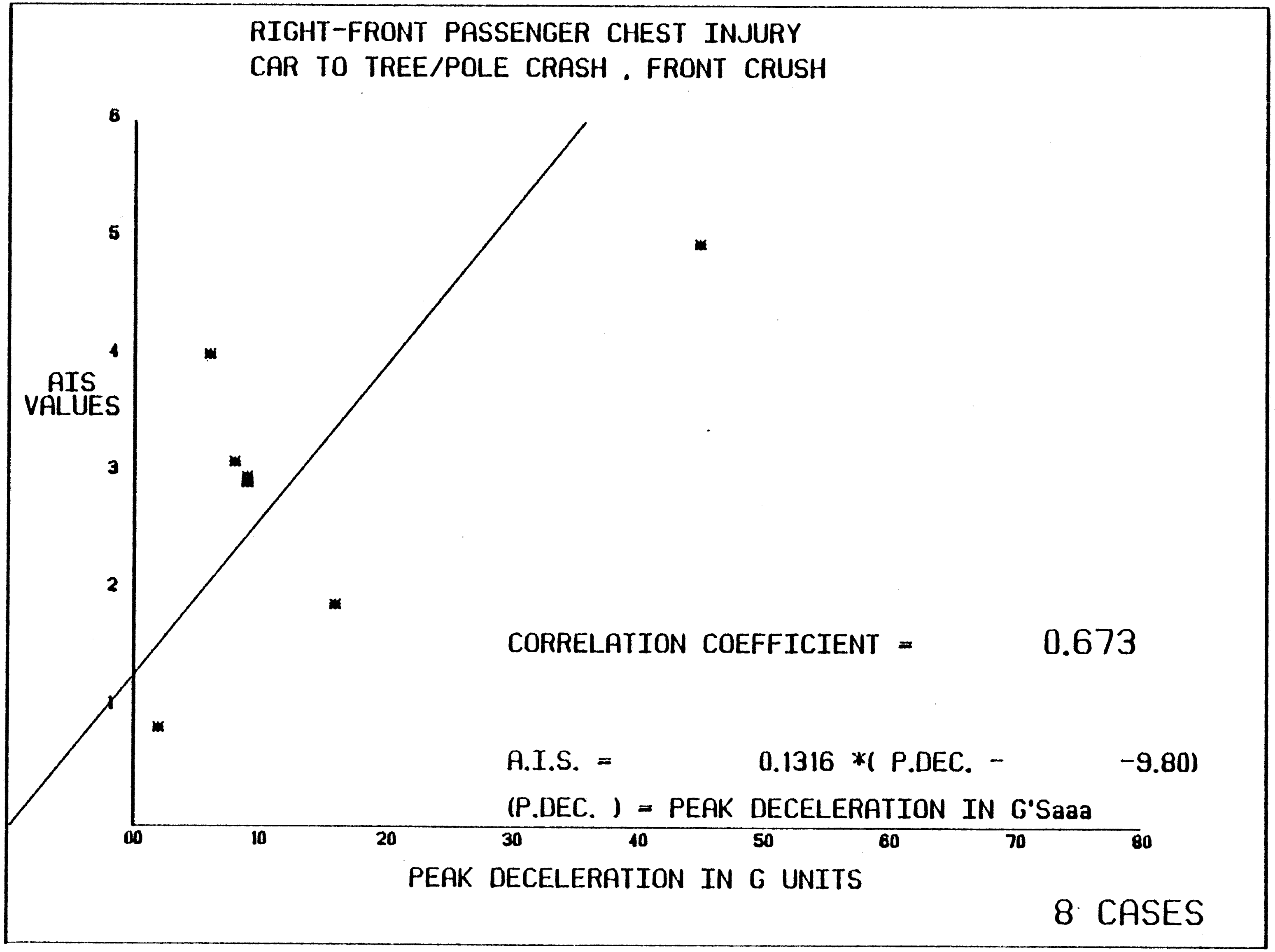

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH , FRONT CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
CORRELATION COEFFICIENT = 0.673
A.I.S. = 0.1316 *(P.DEC. - -9.80)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
8 CASES

FIGURE 27

TABLE 11

RIGHT-FRONT PASSENGER CHEST INJURY CAR TO TREE/POLE CRASH, RIGHT-SIDE CRUSH

VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
13102	570806017	3 AIS	OTHER	UNKNOWN	3 G	12 MPH	0 MPH
11501	670822056	4 AIS	OTHER	INSTRUMENT PANEL	16 G	26 MPH	27 MPH
		4 AIS	CONTUSION	INSTRUMENT PANEL			
13408	170618029	6 AIS	RUPTURE	UNKNOWN	44 G	53 MPH	61 MPH
11307	471227052	6 AIS	CRUSHING	UUUUUUUUUUUUUUUU	9 G	16 MPH	0 MPH
86119	770928038	6 AIS	LACERATION	UNKNOWN	47 G	45 MPH	38 MPH

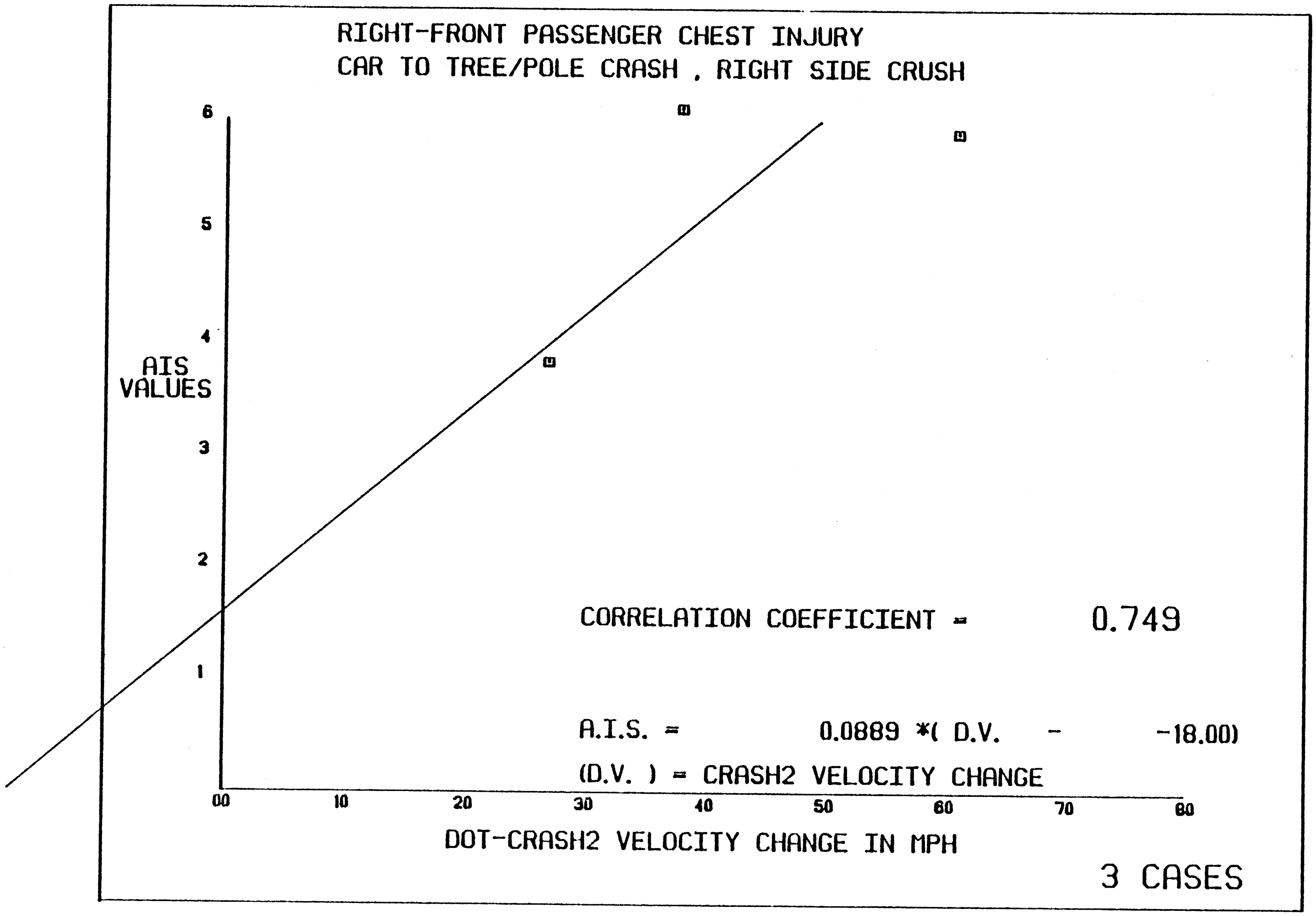

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
DOT-CRASH2 VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.749
A.I.S. = 0.0889 *(D.V. - -18.00)
(D.V.) = CRASH2 VELOCITY CHANGE
3 CASES

FIGURE 28

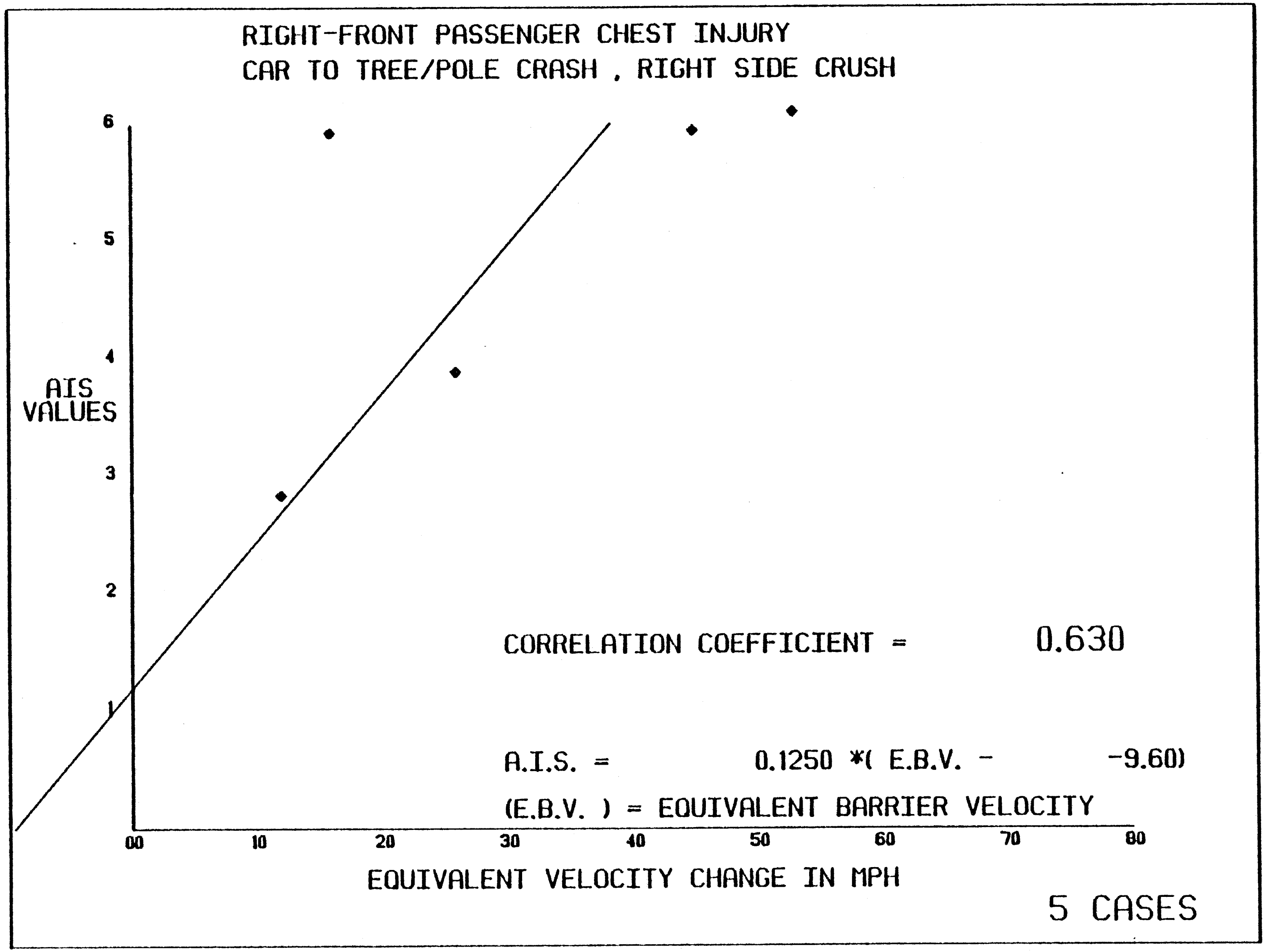

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
EQUIVALENT VELOCITY CHANGE IN MPH
CORRELATION COEFFICIENT = 0.630
A.I.S. = 0.1250 *(E.B.V. - -9.60)
(E.B.V.) = EQUIVALENT BARRIER VELOCITY
5 CASES

FIGURE 29

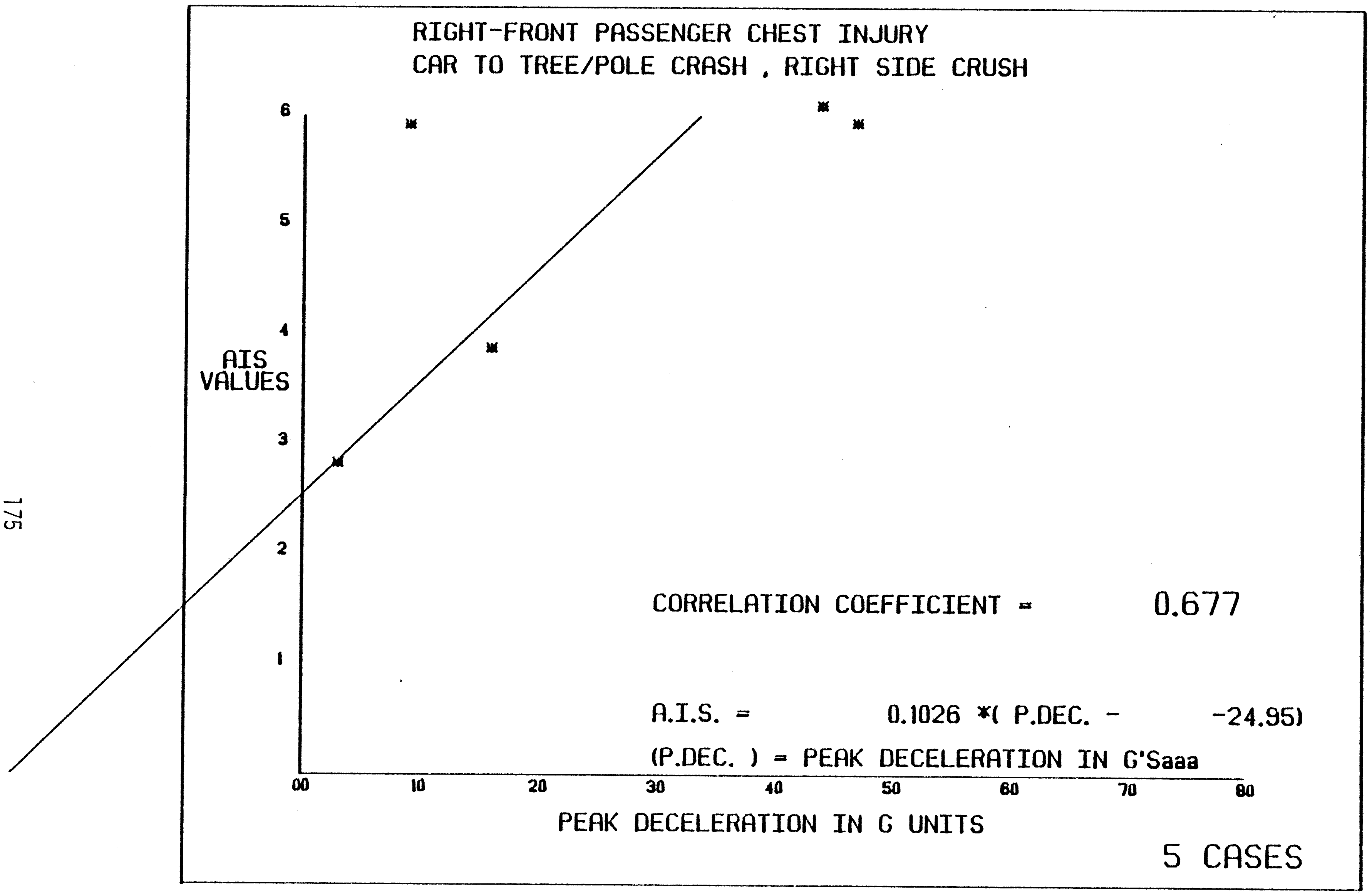

RIGHT-FRONT PASSENGER CHEST INJURY
CAR TO TREE/POLE CRASH , RIGHT SIDE CRUSH
AIS VALUES
6
5
4
3
2
1
00
10
20
30
40
50
60
70
80
PEAK DECELERATION IN G UNITS
CORRELATION COEFFICIENT = 0.677
A.I.S. = 0.1026 *(P.DEC. - -24.95)
(P.DEC.) = PEAK DECELERATION IN G'Saaa
5 CASES

FIGURE 30

TABLE 12

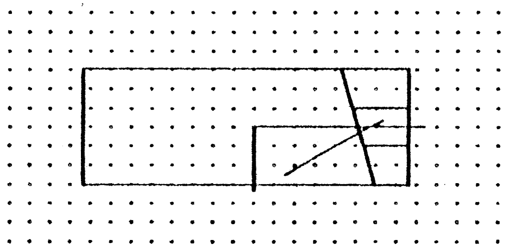
Driver Chest Injury
Object Contacted: Steering Wheel
Car-to-Car Crash, Front Crush

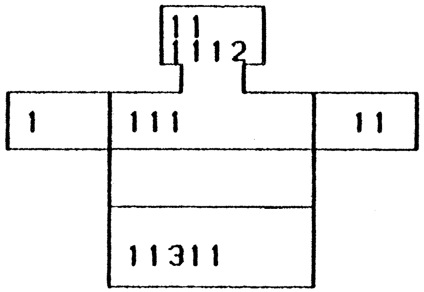
UMIVOR CASE NO.	VEHICLE CODE	AIS LEVEL	TYPE INJURY	B.E.V.	T.S.W.D.
15741	62109	1	Contusion	51.0	4
-	-	1	Pain	-	-
16081	13218	1	Contusion	11.2	0
15291	12205	1	Abrasion	48.1	5
15181	11205	1	Contusion	23.3	0
38672	12204	1	Contusion	3.6	1
38651	11506	1	Contusion	22.6	3
-	-	1	Fracture	-	-
37001	11401	1	Contusion	15.0	0
35331	13201	1	Contusion	12.1	1
34531	11507	1	Contusion	18.4	2
-	-	1	Pain	-	-
34281	11508	1	Pain	12.6	1
34001	14101	1	Contusion	24.1	0
38942	11205	1	Contusion	23.4	2
39272	11205	1	Contusion	4.2	0
39471	12107	1	Contusion	8.4	0
39561	13418	1	Contusion	3.4	1
40021	13101	1	Pain	8.7	1
40042	11308	1	Contusion	4.6	1
40061	12208	1	Contusion	3.4	1
40081	11304	1	Contusion	4.8	1
40082	11304	1	Contusion	6.4	1
15881	12106	1	Pain	20.7	0
16721	11318	1	Contusion	20.4	4
16921	11301	1	Pain	29.4	4
34732	11401	2	Fracture	11.8	1
40311	87109	2	Fracture	34.8	2
16871	11301	2	Fracture	10.4	0
-	-	1	Contusion	-	-
15701	11301	3	Fracture	35.1	4
-	-	2	Fracture	-	-
15671	11408	3	Fracture	20.6	3
-	-	1	Contusion	-	-
-	-	1	Pain	-	-
39581	13418	3	Fracture	38.4	3
-	-	3	Contusion	-	-
17061	11304	4	Contusion	20.6	3
-	-	1	Contusion	-	3
16361	12107	4	Fracture	54.9	4
-	-	3	Contusion	-	-
-	-	4	Hemorrhage	-	-
17441	11304	5	Rupture	52.5	4
-	-	1	Abrasion	-	-
-	-	1	Abrasion	-	-

```
UMIVOR NUMBER 15741        215   ON     12/17/78
1978 Hatchback                          MAKE CODE = 62109       SERIES CODE =  226
CASE   VEHICLE WEIGHT =    1775         LB.  VDI = 11FDEW4      MAX. CRUSH =   33
STRUCK VEHICLE WEIGHT =    2910         LB.  VDI = 10FZEW3      MAX. CRUSH =   28
BARRIER EQUIVALENT VELOCITY FROM VDI =    51.0  M.P.H.
L=   60.8     C1=   33.3    C2=   27.7    C3=   22.1    C4=   16.6    D=    0.0
```

```
BODY REGION               Chest          Chest       Chest
DIRECTION                 Right          Central     Right          Left
TYPE INJURY               Contusion      Pain        Abrasion       Fracture
BODY ELEMENT              Integumentary  Muscles     Integumentary  Skeletal
INJURY LEVEL              Minor          Minor       Minor          Severe
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Steering wheel
Steering wheel
Lower instrument panel
Lower instrument panel
Lower instrument panel
Mirror
Mirror
Middle instrument pane
Impact force, "whiplas
Middle instrument pane
Lower instrument panel
Lower instrument panel
Lower instrument panel
Lower instrument panel
```

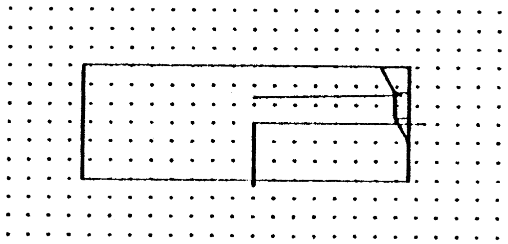
```
PEAK ACCELERATION =    66.5 G UNITS        AGE =   19
CRUSH ENERGY =      1848704.               HEIGHT =   67
MASS FACTOR =   1.333                      WEIGHT =   158
                                           SEX = MALE
```

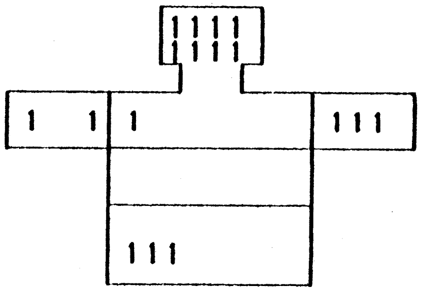
FIGURE 31

UMIVOR NUMBER 16081 2240 ON 2/18/79
1978 Hatchback MAKE CODE = 13218 SERIES CODE = 742
CASE VEHICLE WEIGHT = 2112 LB. VDI = 12FYEW2 MAX. CRUSH = 21
STRUCK VEHICLE WEIGHT = 4182 LB. VDI = 7BZEW2
BARRIER EQUIVALENT VELOCITY FROM VDI = 11.2 M.P.H.
L= 40.1 C1= 14.3 C2= 7.1 C3= 7.1 C4= 0.0 D= -10.1

BODY REGION	Chest	Face	Face	Arm (upper)
DIRECTION	Central	Superior/upper	Inferior/lower	Right
TYPE INJURY	Contusion	Contusion	Laceration	Contusion
BODY ELEMENT	Integumentary	Integumentary	Digestive	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Windshield
Steering wheel
Steering wheel
Steering wheel
Lower instrument panel
Lower instrument panel
Windshield
Upper instrument panel
Surface of side interi
Glove compartment area
Front seat-back(s)
Surface of side interi
Control knob(s) and le

PEAK ACCELERATION = 10.3 G UNITS
CRUSH ENERGY = 106377.
MASS FACTOR = 1.000

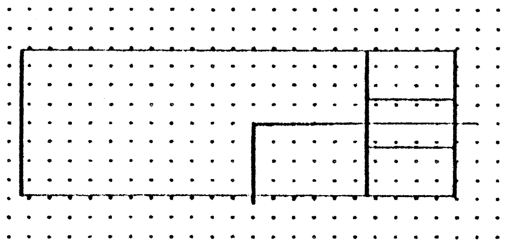
AGE = 23
HEIGHT = 68
WEIGHT = 141
SEX = FEMALE

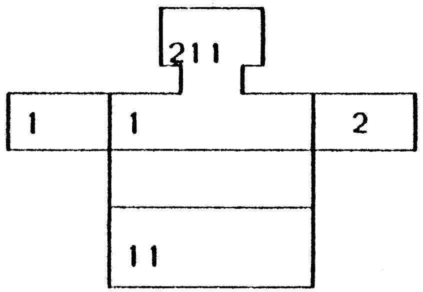
FIGURE 32

```
UMIVOR NUMBER 15291      1125   ON      8/20/78
1978 2-door hardtop (no upper B-pil     MAKE CODE = 12205       SERIES CODE = 1323
CASE    VEHICLE WEIGHT =    4758      LB.  VDI = 12FDEW4       MAX. CRUSH =   53
STRUCK VEHICLE WEIGHT =   5078       LB.  VDI = 12FYEW4       MAX. CRUSH =   54
BARRIER EQUIVALENT VELOCITY FROM VDI =   48.1  M.P.H.
L=    77.0      C1=    43.2     C2=    43.2     C3=    43.2     C4=    43.2     D=     0.0
```

```
BODY REGION                 Chest          Face          Wrist/hand     Elbow
DIRECTION                   Right          Central       Left           Bilateral
TYPE INJURY                 Abrasion       Fracture      Sprain         Abrasion
BODY ELEMENT                Integumentary  Respiratory   Joints         Integumentary
INJURY LEVEL                Minor          Moderate      Moderate       Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Steering wheel
Steering wheel
Surface of side interi
Foot controls (includi
Impact force, "whiplas
```

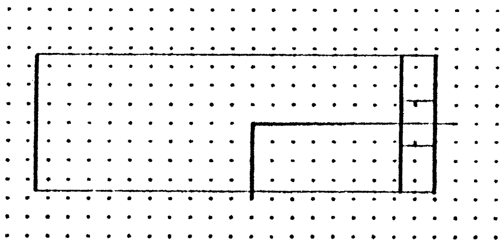
```
PEAK ACCELERATION =    38.7 G UNITS          AGE =   32
CRUSH ENERGY =      4409435.                 HEIGHT =    70
MASS FACTOR =   1.000                        WEIGHT =   205
                                             SEX = MALE
```

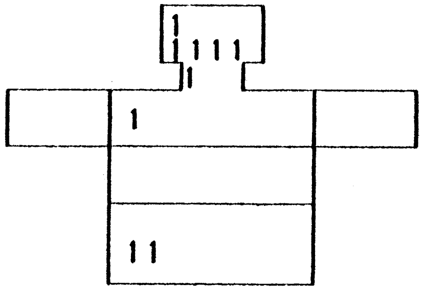
FIGURE 33

UMIVOR NUMBER 15181 1842 ON 7/16/78
1978 4-door sedan MAKE CODE = 11205 SERIES CODE = 1021
CASE VEHICLE WEIGHT = 4222 LB. VDI = 12FDEW2 MAX. CRUSH = 11
STRUCK VEHICLE WEIGHT = 3274 LB. VDI = 6BDEW2 MAX. CRUSH = 1
BARRIER EQUIVALENT VELOCITY FROM VDI = 23.3 M.P.H.
L= 72.6 C1= 16.8 C2= 16.8 C3= 16.8 C4= 16.8 D= 0.0

BODY REGION	Chest	Head/skull	Neck	Knee
DIRECTION	Central	Superior/upper	Posterior/back	Right
TYPE INJURY	Contusion	Concussion	Pain	Contusion
BODY ELEMENT	Integumentary	Brain	Muscles	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





PEAK ACCELERATION = 22.8 G UNITS
CRUSH ENERGY = 916899.
MASS FACTOR = 1.000

AGE = 68
HEIGHT = 68
WEIGHT = 180
SEX = MALE

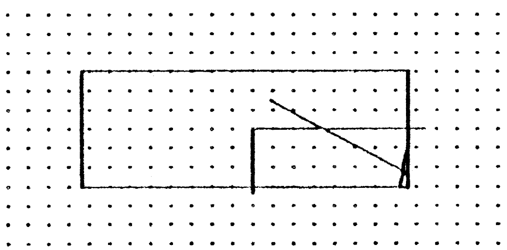
OBJECTS CONTACTED
Sunvisor, fitting(s) &
Impact force, "whiplas
Steering wheel
Lower instrument panel
Windshield
Lower instrument panel
Front seat-back(s)
Impact force, "whiplas
Add-on tape deck, radi
Heater or air conditio
Head restraint

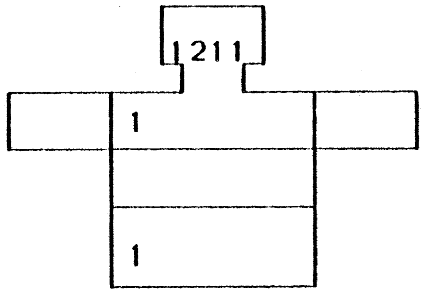
FIGURE 34

```
UMIVOR NUMBER 38672      1523   ON      10/ 6/79
1979 2-door sedan or coupe (any upp     MAKE CODE = 12204        SERIES CODE = 1711
CASE    VEHICLE WEIGHT =    2548        LB.  VDI =   1FRMW1      MAX. CRUSH =     1
STRUCK VEHICLE WEIGHT =     3214        LB.  VDI =   9LFEW1      MAX. CRUSH =     4
BARRIER EQUIVALENT VELOCITY FROM VDI =     3.6  M.P.H.
L=    20.2     C1=     0.0    C2=     2.4    C3=     2.4    C4=     4.8    D=    20.2
```

```
BODY REGION             Chest          Head/skull     Face           Knee
DIRECTION               Unknown        Right          Unknown        Right
TYPE INJURY             Contusion      Concussion     Contusion.     Contusion
BODY ELEMENT            Integumentary  Brain          Integumentary  Integumentary
INJURY LEVEL            Minor          Moderate       Minor          Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Steering wheel
Windshield
Windshield
Lower instrument panel
Surface of side interi
```

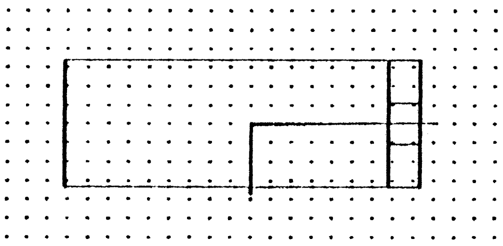
```
PEAK ACCELERATION =     2.2 G UNITS          AGE =  38
CRUSH ENERGY =       12968.                  HEIGHT =   74
MASS FACTOR =  1.333                         WEIGHT =  220
                                             SEX = MALE
```

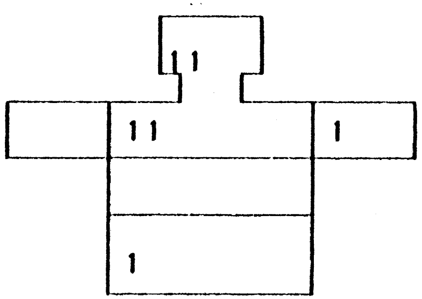
FIGURE 35

UMIVOR NUMBER 38651 2234 ON 10/ 4/79
1979 2-door sedan or coupe (any upp MAKE CODE = 11506 SERIES CODE = 333
CASE VEHICLE WEIGHT = 3349 LB. VDI = 12FDEW2 MAX. CRUSH = 17
STRUCK VEHICLE WEIGHT = 3874 LB. VDI = 11FDMW3 MAX. CRUSH = 15
BARRIER EQUIVALENT VELOCITY FROM VDI = 22.6 M.P.H.
L= 67.2 C1= 15.6 C2= 15.6 C3= 15.6 C4= 15.6 D= 0.0

BODY REGION	Chest	Chest	Face	Knee
DIRECTION	Left	Unknown	Superior/upper	Right
TYPE INJURY	Fracture	Contusion	Abrasion	Abrasion
BODY ELEMENT	Skeletal	Integumentary	Integumentary	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Windshield
Control knob(s) and le
Steering wheel
Steering wheel
Steering wheel
Air conditioning or ve

PEAK ACCELERATION = 24.2 G UNITS
CRUSH ENERGY = 686706.
MASS FACTOR = 1.000

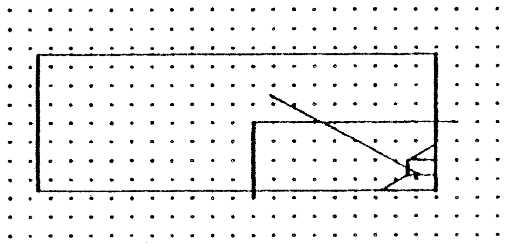
AGE = 55
HEIGHT = 70
WEIGHT = 224
SEX = MALE

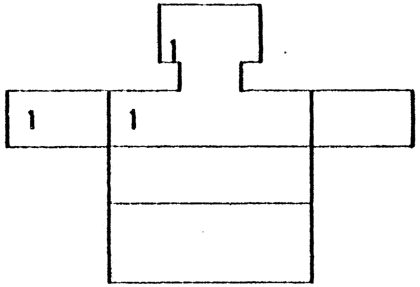
FIGURE 36

```
UMIVOR NUMBER 37001      1605   ON      4/ 3/79
1976 2-door sedan or coupe (any upp     MAKE CODE = 11401        SERIES CODE =  612
CASE    VEHICLE WEIGHT =    3854        LB.  VDI =   1FREW3      MAX. CRUSH =    14
STRUCK VEHICLE WEIGHT =    3505         LB.  VDI = 10LFEW3       MAX. CRUSH =    14
BARRIER EQUIVALENT VELOCITY FROM VDI =    15.0  M.P.H.
L=    24.2     C1=     0.0     C2=    14.0     C3=    14.0     C4=    28.1     D=    24.2
```

```
BODY REGION                  Chest          Head/skull       Shoulder
DIRECTION                    Central        Superior/upper   Bilateral
TYPE INJURY                  Contusion      Contusion        Pain
BODY ELEMENT                 Integumentary  Integumentary    Muscles
INJURY LEVEL                 Minor          Minor            Minor
```

```
GRID OF POINTS AT 10" BY 10" SPACING
```





```
OBJECTS CONTACTED
Windshield
Impact force, "whiplas
Steering wheel
```

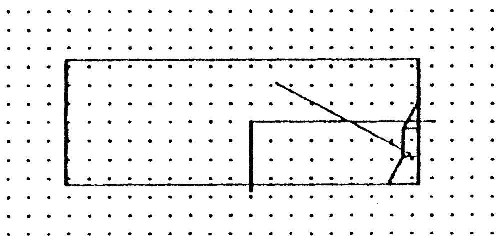
```
PEAK ACCELERATION =     8.2 G UNITS        AGE =  32
CRUSH ENERGY =       345063.               HEIGHT =   61
MASS FACTOR =   1.333                      WEIGHT =  116
                                           SEX = FEMALE
```

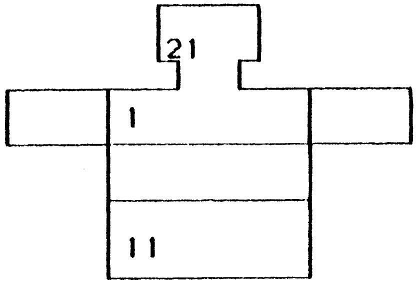
FIGURE 37

UMIVOR NUMBER 35331 1905 ON 11/27/78
1977 2-door sedan or coupe (any upp MAKE CODE = 13201 SERIES CODE = 738
CASE VEHICLE WEIGHT = 3510 LB. VDI = 1FZEW2 MAX. CRUSH = 23
STRUCK VEHICLE WEIGHT = 3340 LB. VDI = 12FDEW2 MAX. CRUSH = 5
BARRIER EQUIVALENT VELOCITY FROM VDI = 12.1 M.P.H.
L= 44.4 C1= 0.0 C2= 7.8 C3= 7.8 C4= 15.6 D= 11.2

BODY REGION	Chest	Head/skull	Knee	Leg (lower)
DIRECTION	Bilateral	Superior/upper	Bilateral	Bilateral
TYPE INJURY	Contusion	Concussion	Contusion	Pain
BODY ELEMENT	Skeletal	Brain	Integumentary	Muscles
INJURY LEVEL	Minor	Moderate	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Mirror
Steering wheel
Lower instrument panel
Lower instrument panel

PEAK ACCELERATION = 9.5 G UNITS
CRUSH ENERGY = 204280.
MASS FACTOR = 1.333

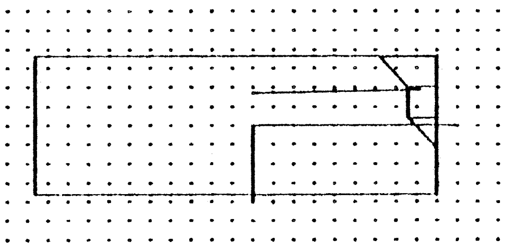
AGE = 53
HEIGHT = 66
WEIGHT = 147
SEX = FEMALE

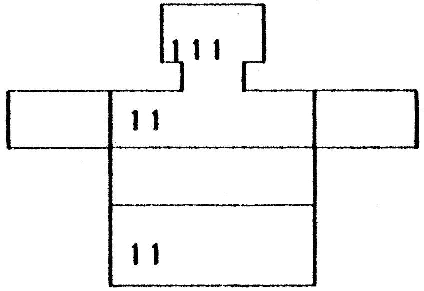
FIGURE 38

```
UMIVOR NUMBER 34531      1444   ON      9/26/78
1977 2-door sedan or coupe (any upp     MAKE CODE = 11507        SERIES CODE =  333
CASE    VEHICLE WEIGHT =    3803      LB.  VDI = 12FYEW3        MAX. CRUSH =    27
STRUCK VEHICLE WEIGHT =    3578      LB.  VDI = 11FYEW3        MAX. CRUSH =    29
BARRIER EQUIVALENT VELOCITY FROM VDI =    18.4  M.P.H.
L=   47.9     C1=   28.1     C2=    14.0     C3=    14.0     C4=     0.0     D=  -12.1
```

```
BODY REGION                  Chest          Chest          Head/skull        Face
DIRECTION                    Central        Right          Superior/upper    Inferior/lower
TYPE INJURY                  Contusion      Pain           Laceration        Laceration
BODY ELEMENT                 Integumentary  Muscles        Integumentary     Integumentary
INJURY LEVEL                 Minor          Minor          Minor             Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
Windshield
Steering wheel
Steering wheel
Lower instrument panel
Steering wheel
Steering wheel column
```

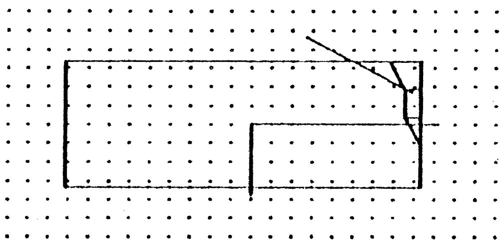
```
PEAK ACCELERATION =    14.2 G UNITS         AGE =  45
CRUSH ENERGY =      512954.                 HEIGHT =   72
MASS FACTOR =  1.000                        WEIGHT =  194
                                            SEX = MALE
```

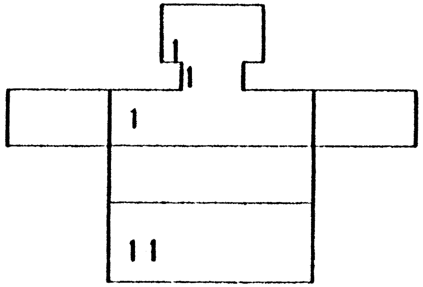
FIGURE 39

UMIVOR NUMBER 34281 1405 ON 8/17/78
1978 2-door sedan or coupe (any upp MAKE CODE = 11508 SERIES CODE = 342
CASE VEHICLE WEIGHT = 3219 LB. VDI = 1FYEW2 MAX. CRUSH = 17
STRUCK VEHICLE WEIGHT = 3704 LB. VDI = 10LYEW3 MAX. CRUSH = 13
BARRIER EQUIVALENT VELOCITY FROM VDI = 12.6 M.P.H.
L= 44.4 C1= 15.6 C2= 7.8 C3= 7.8 C4= 0.0 D= -11.2

BODY REGION	Chest	Head/skull	Neck	Knee
DIRECTION	Central	Superior/upper	Posterior/back	Bilateral
TYPE INJURY	Pain	Contusion	Pain	Contusion
BODY ELEMENT	Muscles	Integumentary	Muscles	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Mirror
Impact force, "whiplas
Steering wheel
Lower instrument panel
Windshield
Steering wheel column

PEAK ACCELERATION = 10.3 G UNITS
CRUSH ENERGY = 204280.
MASS FACTOR = 1.333

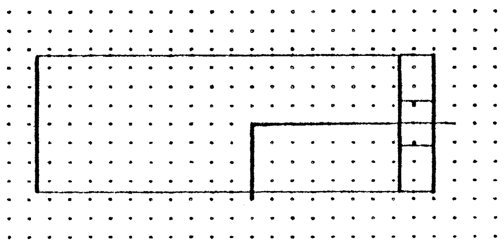
AGE = 22
HEIGHT = 64
WEIGHT = 125
SEX = FEMALE

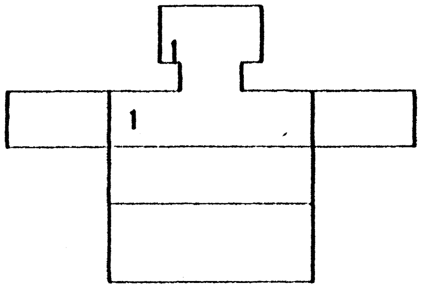
FIGURE 40

```
UMIVOR NUMBER 34001      1208   ON      7/14/78
1975 Station wagon                        MAKE CODE = 14101       SERIES CODE = 1152
CASE    VEHICLE WEIGHT =    3944      LB.  VDI = 12FDEW2       MAX. CRUSH =    12
STRUCK VEHICLE WEIGHT =    3565      LB.  VDI = 46BDEW2       MAX. CRUSH =     7
BARRIER EQUIVALENT VELOCITY FROM VDI =    24.1  M.P.H.
L=    72.6     C1=    16.8     C2=    16.8     C3=    16.8     C4=    16.8     D=     0.0
```

```
BODY REGION                 Chest          Face
DIRECTION                   Central        Superior/upper
TYPE INJURY                 Contusion      Laceration
BODY ELEMENT                Integumentary  Integumentary
INJURY LEVEL                Minor          Minor
```

GRID OF POINTS AT 10" BY 10" SPACING

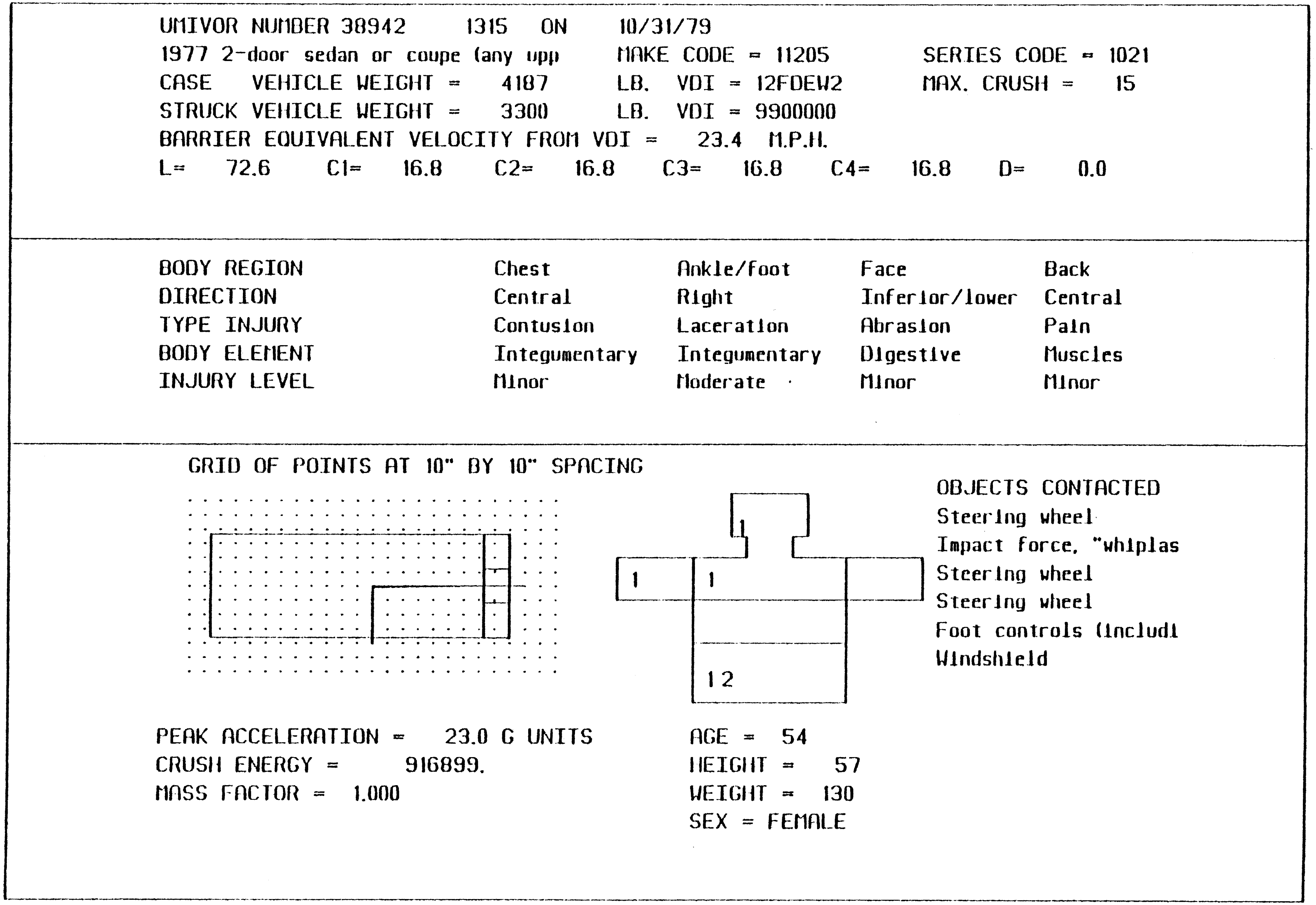




```
OBJECTS CONTACTED
Windshield
Steering wheel
```

```
PEAK ACCELERATION =    24.4 G UNITS        AGE =  27
CRUSH ENERGY =      916899.                HEIGHT =    72
MASS FACTOR =   1.000                      WEIGHT =  227
                                           SEX = MALE
```

FIGURE 41



```
UMIVOR NUMBER 38942     1315   ON     10/31/79
1977 2-door sedan or coupe (any upp     MAKE CODE = 11205        SERIES CODE = 1021
CASE    VEHICLE WEIGHT =    4187      LB.  VDI = 12FDEW2       MAX. CRUSH =    15
STRUCK VEHICLE WEIGHT =   3300      LB.  VDI = 9900000
BARRIER EQUIVALENT VELOCITY FROM VDI =   23.4  M.P.H.
L=    72.6     C1=    16.8     C2=    16.8     C3=    16.8     C4=    16.8     D=     0.0

BODY REGION            Chest          Ankle/foot     Face              Back
DIRECTION              Central        Right          Inferior/lower    Central
TYPE INJURY            Contusion      Laceration     Abrasion          Pain
BODY ELEMENT           Integumentary  Integumentary  Digestive         Muscles
INJURY LEVEL           Minor          Moderate       Minor             Minor

  GRID OF POINTS AT 10" BY 10" SPACING
                                                          OBJECTS CONTACTED
                                                          Steering wheel
                                                          Impact force, "whiplas
                                                          Steering wheel
                                                          Steering wheel
                                                          Foot controls (includi
                                                          Windshield

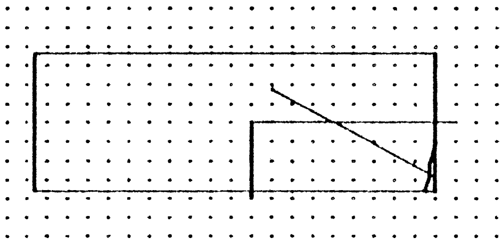
PEAK ACCELERATION =    23.0 G UNITS          AGE =   54
CRUSH ENERGY =       916899.                 HEIGHT =    57
MASS FACTOR =   1.000                        WEIGHT =   130
                                             SEX = FEMALE
```

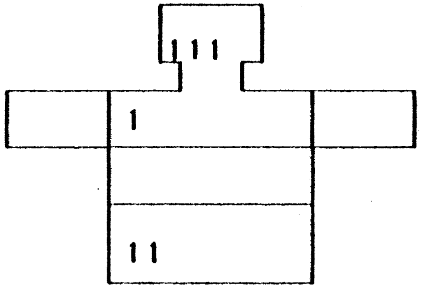
FIGURE 42

UMIVOR NUMBER 39272 2145 ON 12/14/79
1977 4-door sedan MAKE CODE = 11205 SERIES CODE = 1021
CASE VEHICLE WEIGHT = 4222 LB. VDI = 1FREE1 MAX. CRUSH = 7
STRUCK VEHICLE WEIGHT = 3894 LB. VDI = 10LFEE2 MAX. CRUSH = 11
BARRIER EQUIVALENT VELOCITY FROM VDI = 4.2 M.P.H.
L= 24.2 C1= 0.0 C2= 2.8 C3= 2.8 C4= 5.6 D= 24.2

BODY REGION	Chest	Head/skull	Face	Knee
DIRECTION	Right	Right	Bilateral	Left
TYPE INJURY	Contusion	Contusion	Contusion	Contusion
BODY ELEMENT	Integumentary	Integumentary	Eyes/ears	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Mirror
Mirror
Lower instrument panel
Steering wheel
Front seat-back(s)
Front seat-back(s)
Steering wheel column

PEAK ACCELERATION = 2.3 G UNITS
CRUSH ENERGY = 30309.
MASS FACTOR = 1.333

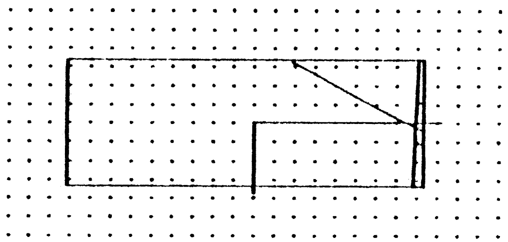
AGE = 68
HEIGHT = 66
WEIGHT = 130
SEX = FEMALE

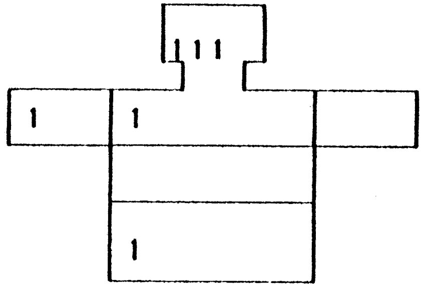
FIGURE 43

```
UMIVOR NUMBER 39471          30   ON       1/ 5/80
1980 2-door sedan or coupe (any upp      MAKE CODE = 12107         SERIES CODE =  271
CASE    VEHICLE WEIGHT =    3120       LB.   VDI =   1FDEW1        MAX. CRUSH =     7
STRUCK VEHICLE WEIGHT =    3261       LB.   VDI = 10LYEW3         MAX. CRUSH =    11
BARRIER EQUIVALENT VELOCITY FROM VDI =      8.4  M.P.H.
L=    67.2      C1=      2.6     C2=      3.5     C3=      4.3     C4=      5.2     D=      0.0
```

```
BODY REGION               Chest           Head/skull      Face            Forearm
DIRECTION                 Right           Superior/upper  Superior/upper  Right
TYPE INJURY               Contusion       Contusion       Laceration      Contusion
BODY ELEMENT              Integumentary   Integumentary   Integumentary   Integumentary
INJURY LEVEL              Minor           Minor           Minor           Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Roof or convertible to
Windshield
Steering wheel
Steering wheel
Lower instrument panel
Mirror
```

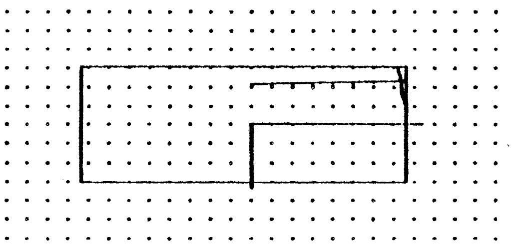
```
PEAK ACCELERATION =      9.3  G UNITS          AGE =   55
CRUSH ENERGY =        89181.                    HEIGHT =    70
MASS FACTOR =   1.333                           WEIGHT =   176
                                                SEX = MALE
```

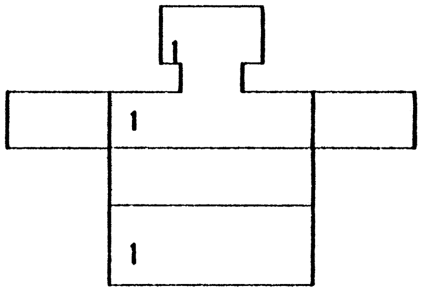
FIGURE 44

```
UMIVOR NUMBER 39561     2105   ON      1/10/80
1979 Hatchback                        MAKE CODE = 13418       SERIES CODE =  527
CASE   VEHICLE WEIGHT =   2121      LB.  VDI = 12FLEW1       MAX. CRUSH =    7
STRUCK VEHICLE WEIGHT =   3677      LB.  VDI = 9900000
BARRIER EQUIVALENT VELOCITY FROM VDI =    3.4  M.P.H.
L=   20.2     C1=    4.8    C2=     2.4    C3=     2.4    C4=     0.0    D=  -20.2
```

```
BODY REGION                 Chest          Head/skull     Knee
DIRECTION                   Bilateral      Left           Bilateral
TYPE INJURY                 Contusion      Laceration     Contusion
BODY ELEMENT                Integumentary  Integumentary  Integumentary
INJURY LEVEL                Minor          Minor          Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
Steering wheel
Steering wheel column
Lower instrument panel
```

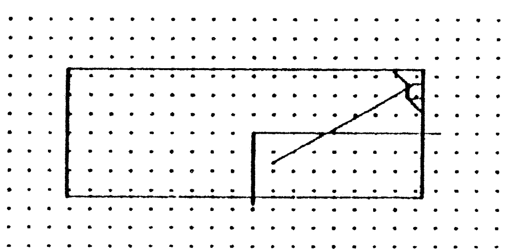
```
PEAK ACCELERATION =    2.3 G UNITS          AGE =  24
CRUSH ENERGY =       9727.                  HEIGHT =   64
MASS FACTOR =  1.000                        WEIGHT =   99
                                            SEX = FEMALE
```

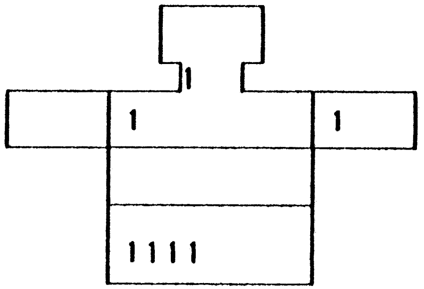
FIGURE 45

```
UMIVOR NUMBER 40021      1643  ON      2/25/80
1978 2-door sedan or coupe (any upp     MAKE CODE = 13101        SERIES CODE = 1235
CASE    VEHICLE WEIGHT =    3439      LB.  VDI = 11FLEW2         MAX. CRUSH =   16
STRUCK VEHICLE WEIGHT =    4105       LB.  VDI = 9800000
BARRIER EQUIVALENT VELOCITY FROM VDI =    8.7  M.P.H.
L=   22.4     C1=   15.6    C2=    7.8   C3=    7.8   C4=    0.0    D=  -22.4
```

```
BODY REGION            Chest       Knee                        Elbow
DIRECTION              Central     Bilateral     Left          Left
TYPE INJURY            Pain        Contusion     Contusion     Contusion
BODY ELEMENT           Muscles     Integumentary Integumentary Integumentary
INJURY LEVEL           Minor       Minor         Minor         Minor
```

```
GRID OF POINTS AT 10" BY 10" SPACING
```





```
OBJECTS CONTACTED
Steering wheel
Lower instrument panel
Steering wheel
Impact force, "whiplas
Impact force, "whiplas
Impact force, "whiplas
```

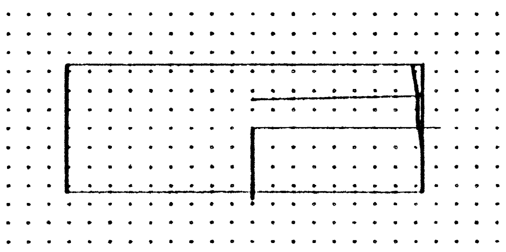
```
PEAK ACCELERATION =     4.9 G UNITS        AGE =  54
CRUSH ENERGY =       103069.               HEIGHT =   64
MASS FACTOR =   1.333                      WEIGHT =  169
                                           SEX = FEMALE
```

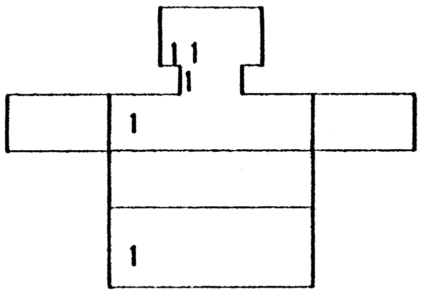
FIGURE 46

```
UMIVOR NUMBER 40042      1700   ON      2/25/80
1980 2-door sedan or coupe (any upp     MAKE CODE = 11308        SERIES CODE =  129
CASE    VEHICLE WEIGHT =    3115       LB.  VDI = 12FYEW1       MAX. CRUSH =    6
STRUCK VEHICLE WEIGHT =    4021       LB.  VDI =  1FREE1       MAX. CRUSH =    6
BARRIER EQUIVALENT VELOCITY FROM VDI =     4.6  M.P.H.
L=   44.4     C1=     5.2    C2=     2.6    C3=     2.6    C4=     0.0    D=  -11.2
```

```
BODY REGION               Chest          Head/skull       Neck            Leg (lower)
DIRECTION                 Bilateral      Superior/upper   Posterior/back  Bilateral
TYPE INJURY               Contusion      Contusion        Pain            Contusion
BODY ELEMENT              Integumentary  Integumentary    Muscles         Integumentary
INJURY LEVEL              Minor          Minor            Minor           Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
Steering wheel
Impact force, "whiplas
Lower instrument panel
```

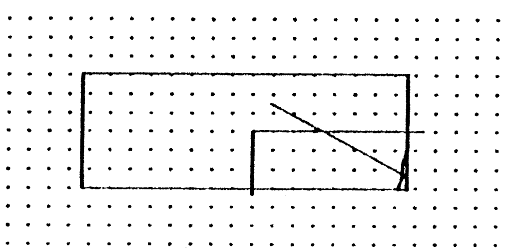
```
PEAK ACCELERATION =     4.0 G UNITS        AGE =  51
CRUSH ENERGY =       26824.                HEIGHT =   68
MASS FACTOR =   1.000                      WEIGHT =   156
                                           SEX = FEMALE
```

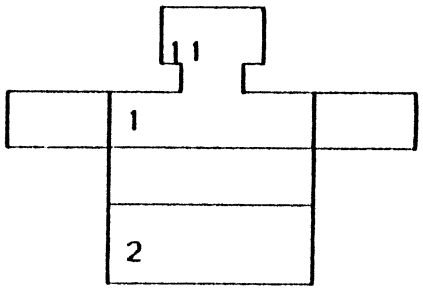
FIGURE 47

UMIVOR NUMBER 40061 1814 ON 2/25/80
1978 Station wagon MAKE CODE = 12208 SERIES CODE = 964
CASE VEHICLE WEIGHT = 2765 LB. VDI = 1FREK1 MAX. CRUSH = 7
STRUCK VEHICLE WEIGHT = 3801 LB. VDI = 10LFEE1 MAX. CRUSH = 3
BARRIER EQUIVALENT VELOCITY FROM VDI = 3.4 M.P.H.
L= 20.2 C1= 0.0 C2= 2.4 C3= 2.4 C4= 4.8 D= 20.2

BODY REGION	Chest	Pelvic/hip	Head/skull	Head/skull
DIRECTION	Unknown	Anterior/front	Right	Right
TYPE INJURY	Contusion	Fracture	Laceration	Contusion
BODY ELEMENT	Integumentary	Skeletal	Integumentary	Integumentary
INJURY LEVEL	Minor	Moderate	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Steering wheel
Other (e.g. fire)
Other (e.g. fire)
Other occupant(s)
Other occupant(s)

PEAK ACCELERATION = 2.0 G UNITS
CRUSH ENERGY = 12968.
MASS FACTOR = 1.333

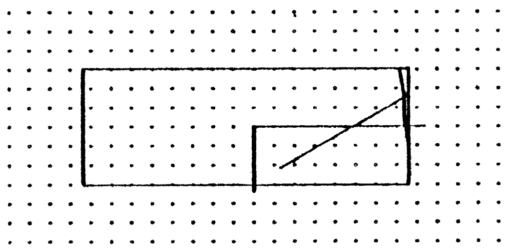
AGE = 33
HEIGHT = 59
WEIGHT = 101
SEX = FEMALE

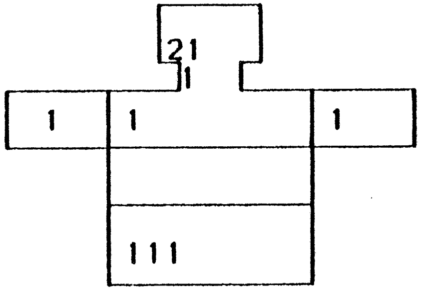
FIGURE 48

UMIVOR NUMBER 40081   1803 ON   3/ 2/80
1978 Hatchback   MAKE CODE = 11304   SERIES CODE = 152
CASE VEHICLE WEIGHT = 2738 LB. VDI = 11FYEW1   MAX. CRUSH = 10
STRUCK VEHICLE WEIGHT = 3336 LB. VDI = 12FLEN2   MAX. CRUSH = 19
BARRIER EQUIVALENT VELOCITY FROM VDI = 4.8 M.P.H.
L= 40.1 C1= 4.8 C2= 2.4 C3= 2.4 C4= 0.0 D= -10.1

BODY REGION	Chest	Head/skull	Neck	Arm (upper)
DIRECTION	Bilateral	Superior/upper	Posterior/back	Left
TYPE INJURY	Contusion	Concussion	Pain	Contusion
BODY ELEMENT	Integumentary	Brain	Muscles	Integumentary
INJURY LEVEL	Minor	Moderate	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Windshield
Steering wheel
Impact force, "whiplas
Surface of side interi
Lower instrument panel
Steering wheel
A-pillar

PEAK ACCELERATION = 4.0 G UNITS
CRUSH ENERGY = 25703.
MASS FACTOR = 1.333

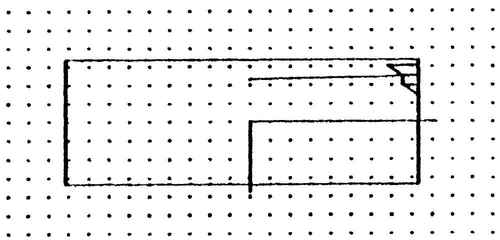
AGE = 23
HEIGHT = 66
WEIGHT = 119
SEX = MALE

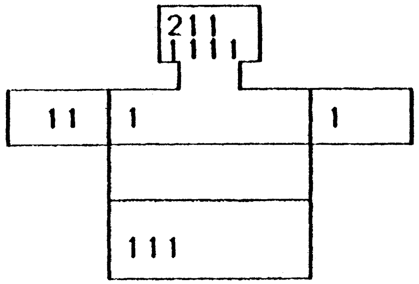
FIGURE 49

```
UMIVOR NUMBER 40082      1803   ON      3/ 2/80
1979 2-door sedan or coupe (any upp     MAKE CODE = 11306       SERIES CODE =  151
CASE    VEHICLE WEIGHT =    3336        LB.  VDI = 12FLEN2       MAX. CRUSH =    19
STRUCK VEHICLE WEIGHT =    2738         LB.  VDI = 11FYEW1       MAX. CRUSH =    10
BARRIER EQUIVALENT VELOCITY FROM VDI =      6.4  M.P.H.
L=    16.0      C1=    15.6     C2=      7.8     C3=      7.8     C4=      0.0     D=  -22.4
```

```
BODY REGION              Chest          Head/skull       Face             Face
DIRECTION                Right          Superior/upper   Superior/upper   Inferior/lower
TYPE INJURY              Contusion      Concussion       Contusion        Laceration
BODY ELEMENT             Integumentary  Brain            Integumentary    Integumentary
INJURY LEVEL             Minor          Moderate         Minor            Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
PEAK ACCELERATION =     3.1 G UNITS        AGE =  28
CRUSH ENERGY =        55273.               HEIGHT =   66
MASS FACTOR =   1.000                      WEIGHT =  141
                                           SEX = FEMALE
```

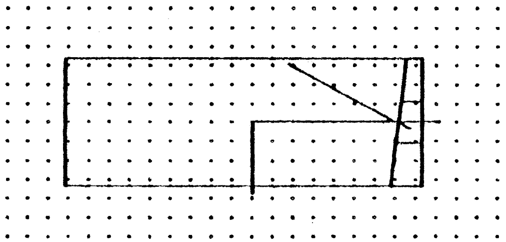
```
OBJECTS CONTACTED
Steering wheel
Steering wheel
Other (e.g. fire)
Steering wheel
Impact force, "whiplas
Lower instrument panel
Windshield
Glove compartment area
Windshield
Windshield
Steering wheel column
Mirror
Lower instrument panel
Mirror
```

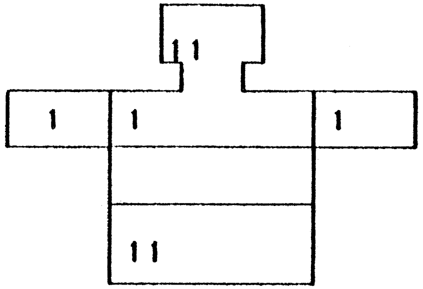
FIGURE 50

UMIVOR NUMBER 15881 1000 ON 1/15/79
1978 4-door sedan MAKE CODE = 12106 SERIES CODE = 233
CASE VEHICLE WEIGHT = 3258 LB. VDI = 1FDEW2 MAX. CRUSH = 13
STRUCK VEHICLE WEIGHT = 2681 LB. VDI = 9LZEW2 MAX. CRUSH = 7
BARRIER EQUIVALENT VELOCITY FROM VDI = 20.7 M.P.H.
L= 67.2 C1= 7.8 C2= 10.4 C3= 13.0 C4= 15.6 D= 0.0

BODY REGION	Chest	Head/skull	Forearm	Leg (lower)
DIRECTION	Whole region	Left	Left	Bilateral
TYPE INJURY	Pain	Laceration	Contusion	Contusion
BODY ELEMENT	Muscles	Integumentary	Integumentary	Integumentary
INJURY LEVEL	Minor	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Mirror
Steering wheel
Lower instrument panel
Front seat-back(s)
Head restraint
Floor

PEAK ACCELERATION = 22.1 G UNITS
CRUSH ENERGY = 558157.
MASS FACTOR = 1.333

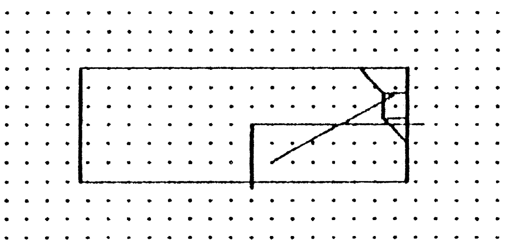
AGE = 56
HEIGHT = 66
WEIGHT = 130
SEX = FEMALE

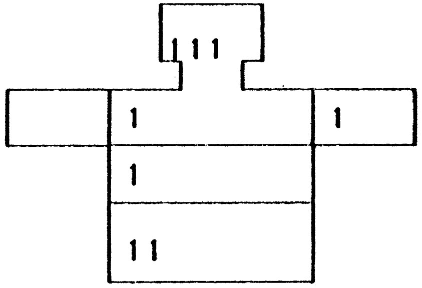
FIGURE 51

```
UMIVOR NUMBER 16721      1600   ON     10/ 5/79
1979 Hatchback                         MAKE CODE = 11318        SERIES CODE =  126
CASE    VEHICLE WEIGHT =    2110       LB.  VDI = 11FYEW3       MAX. CRUSH =    23
STRUCK VEHICLE WEIGHT =     3713       LB.  VDI = 9900000
BARRIER EQUIVALENT VELOCITY FROM VDI =    20.4  M.P.H.
L=    40.1      C1=    23.8     C2=     11.9     C3=     11.9     C4=     0.0     D=  -10.1
```

```
BODY REGION          Chest          Face             Face           Elbow
DIRECTION            Right          Superior/upper   Left           Left
TYPE INJURY          Contusion      Laceration       Laceration     Contusion
BODY ELEMENT         Integumentary  Integumentary    Integumentary  Integumentary
INJURY LEVEL         Minor          Minor            Minor          Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
A-pillar
Surface of side interi
Steering wheel
Steering wheel
Steering wheel column
Surface of side interi
Windshield
Lower instrument panel
Lower instrument panel
Window glass (side)
```

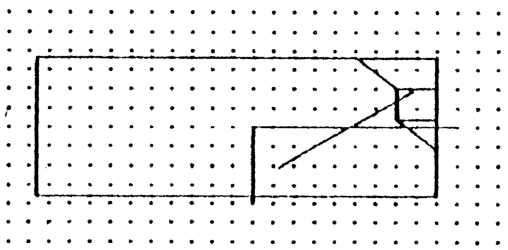
```
PEAK ACCELERATION =    18.6 G UNITS        AGE =  30
CRUSH ENERGY =      352382.                HEIGHT =   74
MASS FACTOR =   1.333                      WEIGHT =  229
                                           SEX = MALE
```

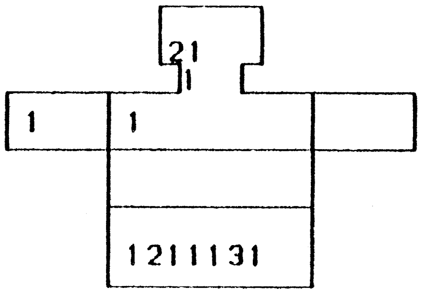
FIGURE 52

```
UMIVOR NUMBER 16921      1845   ON     11/12/79
1979 4-door sedan                      MAKE CODE = 11301       SERIES CODE =  131
CASE   VEHICLE WEIGHT =   3611        LB.  VDI = 11FYEW4      MAX. CRUSH =   53
STRUCK VEHICLE WEIGHT =   4608        LB.  VDI = 10FYEW3      MAX. CRUSH =   41
BARRIER EQUIVALENT VELOCITY FROM VDI =    29.4  M.P.H.
L=   47.9     C1=   39.3    C2=    19.6     C3=    19.6    C4=     0.0    D=  -12.1
```

```
BODY REGION              Chest         Ankle/foot     Face          Knee
DIRECTION                Central       Right          Central       Left
TYPE INJURY              Pain          Fracture       Fracture      Fracture
BODY ELEMENT             Muscles       Joints         Respiratory   Skeletal
INJURY LEVEL             Minor         Severe         Moderate      Moderate
```

```
  GRID OF POINTS AT 10" BY 10" SPACING
```





```
OBJECTS CONTACTED
Hardware item (specifi
Steering wheel
Lower instrument panel
Lower instrument panel
Lower instrument panel
Foot controls (includi
Beneath instrument pan
Beneath instrument pan
```

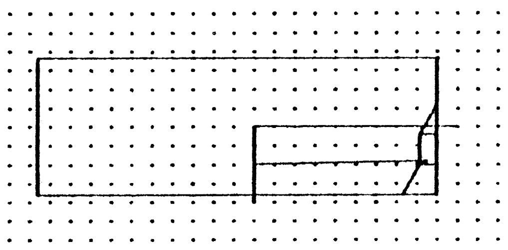
```
PEAK ACCELERATION =    23.3 G UNITS        AGE =   31
CRUSH ENERGY =     1252311.                HEIGHT =   68
MASS FACTOR =  1.333                       WEIGHT =  174
                                           SEX = MALE
```

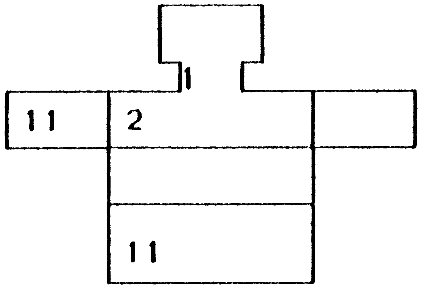
FIGURE 53

UMIVOR NUMBER 34732   1840   ON   10/22/78
1976 2-door sedan or coupe (any upp   MAKE CODE = 11401   SERIES CODE = 612
CASE VEHICLE WEIGHT = 3836 LB.   VDI = 12FZEW2   MAX. CRUSH = 31
STRUCK VEHICLE WEIGHT = 3783 LB.   VDI = 12FZEW3   MAX. CRUSH = 34
BARRIER EQUIVALENT VELOCITY FROM VDI = 11.8 M.P.H.
L= 47.9   C1= 0.0   C2= 8.4   C3= 8.4   C4= 16.8   D= 12.1

BODY REGION	Chest	Neck	Pelvic/hip	Wrist/hand
DIRECTION	Central	Left	Right	Right
TYPE INJURY	Fracture	Contusion	Contusion	Abrasion
BODY ELEMENT	Skeletal	Integumentary	Integumentary	Integumentary
INJURY LEVEL	Moderate	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Steering wheel
Restraint system webbi
Impact force, "whiplas

PEAK ACCELERATION = 9.2 G UNITS
CRUSH ENERGY = 214881.
MASS FACTOR = 1.000

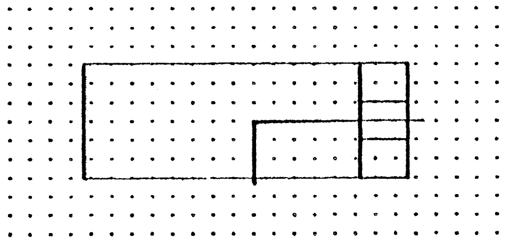
AGE = 27
HEIGHT = 68
WEIGHT = 165
SEX = MALE

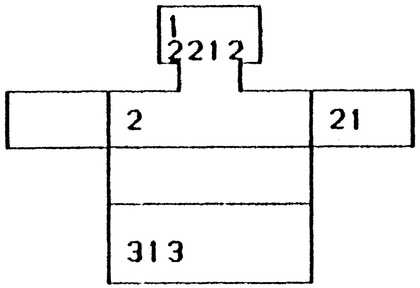
FIGURE 54

```
UMIVOR NUMBER 40311      2000   ON      3/20/80
1979 Hatchback                         MAKE CODE = 87109      SERIES CODE = 1612
CASE   VEHICLE WEIGHT =   2531     LB.  VDI = 12FDEW3     MAX. CRUSH =   24
STRUCK VEHICLE WEIGHT =   4346     LB.  VDI =  1FYEW2     MAX. CRUSH =   19
BARRIER EQUIVALENT VELOCITY FROM VDI =   34.8  M.P.H.
L=   60.8     C1=   23.8    C2=    23.8    C3=    23.8    C4=    23.8    D=     0.0
```

```
BODY REGION          Chest       Pelvic/hip     Ankle/foot     Head/skull
DIRECTION            Left        Left           Left           Left
TYPE INJURY          Fracture    Dislocation    Fracture       Concussion
BODY ELEMENT         Skeletal    Joints         Joints         Brain
INJURY LEVEL         Moderate    Severe         Severe         Moderate
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
Steering wheel
Steering wheel
Lower instrument panel
Floor
Windshield
Steering wheel column
Upper instrument panel
```

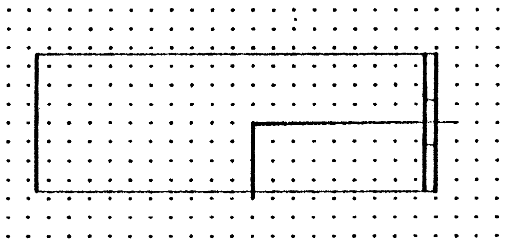
```
PEAK ACCELERATION =   38.6 G UNITS        AGE =  30
CRUSH ENERGY =     1224220.                HEIGHT =   70
MASS FACTOR =  1.000                       WEIGHT =  160
                                           SEX = MALE
```

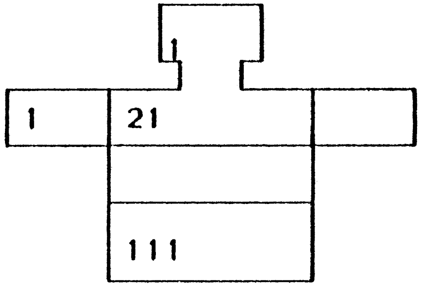
FIGURE 55

UMIVOR NUMBER 16871 1447 ON 10/31/79
1977 4-door sedan MAKE CODE = 11301 SERIES CODE = 122
CASE VEHICLE WEIGHT = 3602 LB. VDI = 12FDEW1 MAX. CRUSH = 5
STRUCK VEHICLE WEIGHT = 3682 LB. VDI = 6BDEW2 MAX. CRUSH = 14
BARRIER EQUIVALENT VELOCITY FROM VDI = 10.4 M.P.H.
L= 72.6 C1= 5.6 C2= 5.6 C3= 5.6 C4= 5.6 D= 0.0

BODY REGION	Chest	Chest	Face	Wrist/hand
DIRECTION	Central	Central	Inferior/lower	Bilateral
TYPE INJURY	Fracture	Contusion	Laceration	Laceration
BODY ELEMENT	Skeletal	Integumentary	Digestive	Integumentary
INJURY LEVEL	Moderate	Minor	Minor	Minor

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Windshield
Steering wheel
Lower instrument panel
Lower instrument panel

PEAK ACCELERATION = 11.0 G UNITS
CRUSH ENERGY = 154967.
MASS FACTOR = 1.000

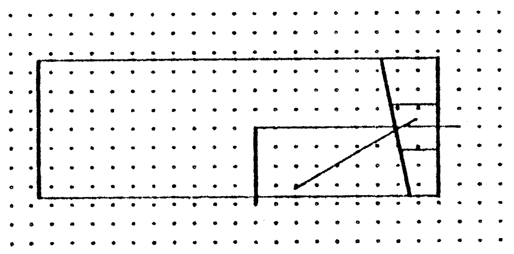
AGE = 46
HEIGHT = 72
WEIGHT = 189
SEX = MALE

FIGURE 56

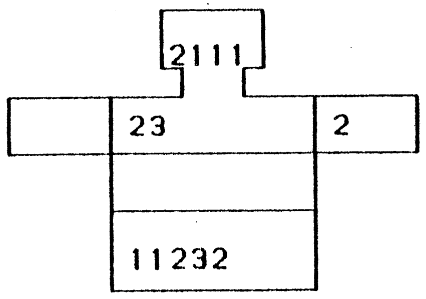
UMIVOR NUMBER 15701 855 ON 12/ 1/78
1978 4-door sedan MAKE CODE = 11301 SERIES CODE = 122
CASE VEHICLE WEIGHT = 3792 LB. VDI = 11FDEW3 MAX. CRUSH = 33
STRUCK VEHICLE WEIGHT = 3439 LB. VDI = 11FDEW4 MAX. CRUSH = 41
BARRIER EQUIVALENT VELOCITY FROM VDI = 35.1 M.P.H.
L= 72.6 C1= 28.1 C2= 23.4 C3= 18.7 C4= 14.0 D= 0.0

BODY REGION	Chest	Chest	Leg (lower)	Head/skull
DIRECTION	Left	Right	Right	Superior/upper
TYPE INJURY	Fracture	Fracture	Fracture	Concussion
BODY ELEMENT	Skeletal	Skeletal	Skeletal	Brain
INJURY LEVEL	Severe	Moderate	Severe	Moderate

GRID OF POINTS AT 10" BY 10" SPACING



PEAK ACCELERATION = 35.7 G UNITS
CRUSH ENERGY = 1875803.
MASS FACTOR = 1.333



AGE = 41
HEIGHT = 68
WEIGHT = 174
SEX = MALE

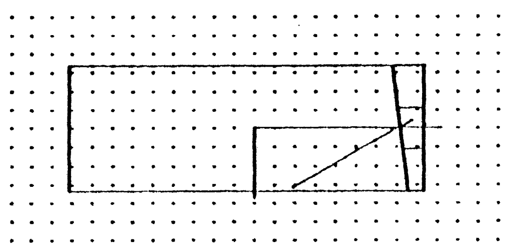
OBJECTS CONTACTED
Windshield
Sunvisor, fitting(s) &
Upper instrument panel
Other (e.g. fire)
Steering wheel
Steering wheel
Steering wheel
Control knob(s) and le
Lower instrument panel
Lower instrument panel
Lower instrument panel
Lower instrument panel
Windshield
Upper instrument panel

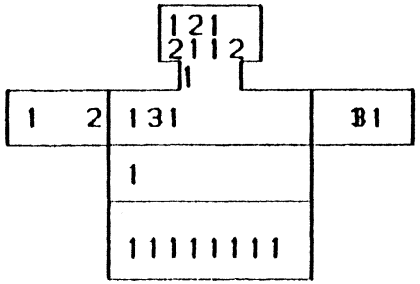
FIGURE 57

```
UMIVOR NUMBER 15671       1940   ON     11/26/78
1978 2-door sedan or coupe (any upp     MAKE CODE = 11408         SERIES CODE =  642
CASE    VEHICLE WEIGHT =    3276       LB.  VDI = 11FDEK2        MAX. CRUSH =   21
STRUCK VEHICLE WEIGHT =    3631       LB.  VDI =  4RPAK6         MAX. CRUSH =   43
BARRIER EQUIVALENT VELOCITY FROM VDI =    20.6  M.P.H.
L=   67.2     C1=    15.6     C2=    13.0    C3=    10.4     C4=     7.8    D=     0.0
```

```
BODY REGION                 Chest          Chest          Chest          Elbow
DIRECTION                   Left           Whole region   Left           Right
TYPE INJURY                 Fracture       Pain           Contusion      Dislocation
BODY ELEMENT                Skeletal       Muscles        Integumentary  Joints
INJURY LEVEL                Severe         Minor          Minor          Severe
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Steering wheel
Steering wheel
Impact force, "whiplas
Restraint system webbi
Steering wheel
Steering wheel
Surface of side interi
Lower instrument panel
Lower instrument panel
Internal flying glass
Steering wheel
Steering wheel
Glove compartment area
Instrument panel (spec
```

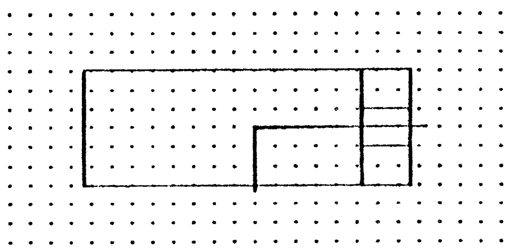
```
PEAK ACCELERATION =    22.0 G UNITS        AGE =   19
CRUSH ENERGY =       558157.               HEIGHT =    66
MASS FACTOR =   1.333                      WEIGHT =   145
                                           SEX = FEMALE
```

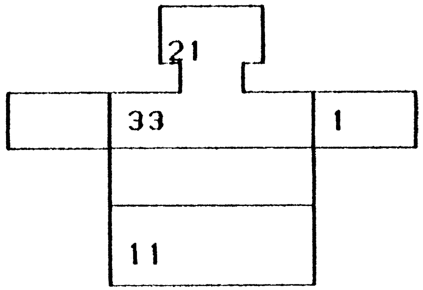
FIGURE 58

```
UMIVOR NUMBER 39581     1825   ON      1/ 9/80
1978 Hatchback                       MAKE CODE = 13418       SERIES CODE =  527
CASE    VEHICLE WEIGHT =    2077     LB.  VDI = 12FDEW3      MAX. CRUSH =    18
STRUCK VEHICLE WEIGHT =    3699      LB.  VDI = 9800000
BARRIER EQUIVALENT VELOCITY FROM VDI =    38.4  M.P.H.
L=   60.8     C1=   23.8    C2=    23.8    C3=    23.8    C4=    23.8    D=     0.0
```

```
BODY REGION            Chest        Chest              Face             Face
DIRECTION              Right        Right              Superior/upper   Inferior/lower
TYPE INJURY            Fracture     Contusion          Laceration       Contusion
BODY ELEMENT           Skeletal     Pulmonary/lungs    Integumentary    Digestive
INJURY LEVEL           Severe       Severe             Moderate         Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Steering wheel
Steering wheel
Steering wheel
Steering wheel
Control knob(s) and le
Heater or air conditio
Lower instrument panel
Lower instrument panel
```

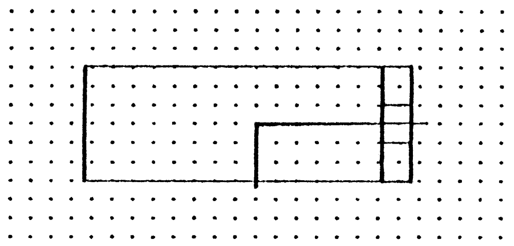
```
PEAK ACCELERATION =    47.0 G UNITS        AGE =  31
CRUSH ENERGY =     1224220.                HEIGHT =  393
MASS FACTOR =  1.000                       WEIGHT = 2202
                                           SEX = FEMALE
```

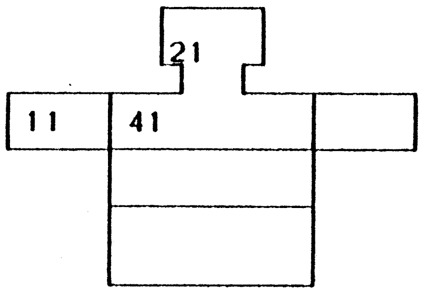
FIGURE 59

```
UMIVOR NUMBER 17061      1540   ON     12/17/79
1979 Hatchback                         MAKE CODE = 11304        SERIES CODE =  152
CASE    VEHICLE WEIGHT =    2773       LB.  VDI = 12FDEW2       MAX. CRUSH =    17
STRUCK VEHICLE WEIGHT =     2824       LB.  VDI =  9LYEW3       MAX. CRUSH =    23
BARRIER EQUIVALENT VELOCITY FROM VDI =    20.6  M.P.H.
L=    60.8      C1=    14.3     C2=    14.3     C3=    14.3     C4=    14.3     D=     0.0
```

```
BODY REGION                  Chest          Chest           Head/skull        Head/skull
DIRECTION                    Central        Bilateral       Superior/upper    Left
TYPE INJURY                  Contusion      Contusion       Concussion        Contusion
BODY ELEMENT                 Heart          Integumentary   Brain             Integumentary
INJURY LEVEL                 Serious        Minor           Moderate          Minor
```

GRID OF POINTS AT 10" BY 10" SPACING





```
OBJECTS CONTACTED
Windshield
Windshield
Impact force, "whiplas
Steering wheel
```

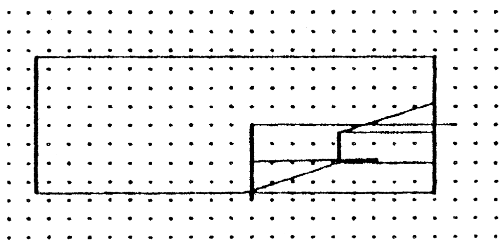
```
PEAK ACCELERATION =    21.9 G UNITS          AGE =  20
CRUSH ENERGY =       472532.                 HEIGHT =   66
MASS FACTOR =   1.000                        WEIGHT =  145
                                             SEX = FEMALE
```

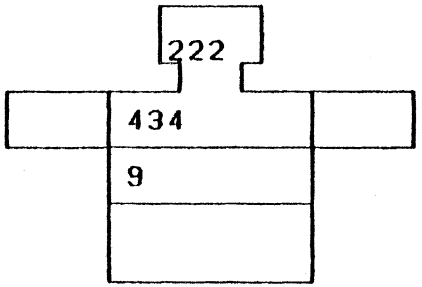
FIGURE 60

UMIVOR NUMBER 16361 1710 ON 5/ 5/79
1979 2-door sedan or coupe (any upp MAKE CODE = 12107 SERIES CODE = 271
CASE VEHICLE WEIGHT = 4021 LB. VDI = 12FZAW9 MAX. CRUSH = 141
STRUCK VEHICLE WEIGHT = 4870 LB. VDI = 9800000
BARRIER EQUIVALENT VELOCITY FROM VDI = 54.9 M.P.H.
L= 47.9 C1= 0.0 C2= 47.0 C3= 47.0 C4= 93.9 D= 12.1

BODY REGION	Chest	Chest	Chest	Abdomen
DIRECTION	Bilateral	Bilateral	Bilateral	Unknown
TYPE INJURY	Fracture	Hemorrage	Contusion	Unknown
BODY ELEMENT	Skeletal	Pulmonary/lungs	Pulmonary/lungs	Unknown
INJURY LEVEL	Serious	Serious	Severe	Unknown

GRID OF POINTS AT 10" BY 10" SPACING





OBJECTS CONTACTED
Upper instrument panel
Upper instrument panel
Upper instrument panel
Steering wheel
Steering wheel
Lower instrument panel

PEAK ACCELERATION = 40.7 G UNITS
CRUSH ENERGY = 4846342.
MASS FACTOR = 1.000

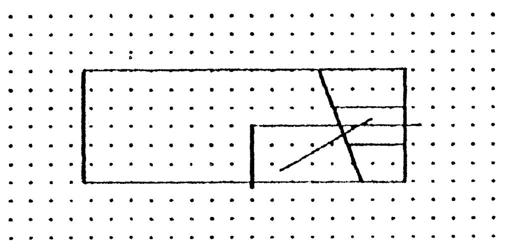
AGE = 40
HEIGHT = 70
WEIGHT = 141
SEX = MALE

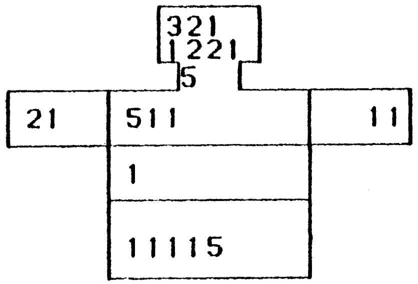
FIGURE 61

```
UMIVOR NUMBER 17441       2255  ON      3/26/80
1979 Hatchback                          MAKE CODE = 11304        SERIES CODE =  152
CASE   VEHICLE WEIGHT =    2709         LB.  VDI = 11FDEW5       MAX. CRUSH =    69
STRUCK VEHICLE WEIGHT =    3550         LB.  VDI = 11FLEK4       MAX. CRUSH =    21
BARRIER EQUIVALENT VELOCITY FROM VDI =    52.5  M.P.H.
L=   60.8     C1=    42.8    C2=    35.6    C3=    28.5    C4=    21.4    D=     0.0
```

```
BODY REGION            Chest       Chest          Chest          Neck
DIRECTION              Central     Central        Right          Posterior/back
TYPE INJURY            Rupture     Abrasion       Abrasion       Fracture
BODY ELEMENT           Heart       Integumentary  Integumentary  Vertebrae
INJURY LEVEL           Critical    Minor          Minor          Critical
```

GRID OF POINTS AT 10" BY 10" SPACING





```
PEAK ACCELERATION =    55.4 G UNITS     AGE =   22          OBJECTS CONTACTED
CRUSH ENERGY =     2989621.             HEIGHT =   61       A-pillar
MASS FACTOR =   1.333                   WEIGHT =   130      Steering wheel
                                        SEX = FEMALE        Steering wheel
                                                            Lower instrument panel
                                                            Lower instrument panel
                                                            Steering wheel
                                                            Steering wheel
                                                            Lower instrument panel
                                                            Foot controls (includi
                                                            Steering wheel
                                                            Steering wheel
                                                            Instrument panel (spec
                                                            A-pillar
                                                            Surface of side interi
```

FIGURE 62

TABLE 13

DRIVER CHEST INJURY CAR TO CAR CRASH, FRONT CRUSH

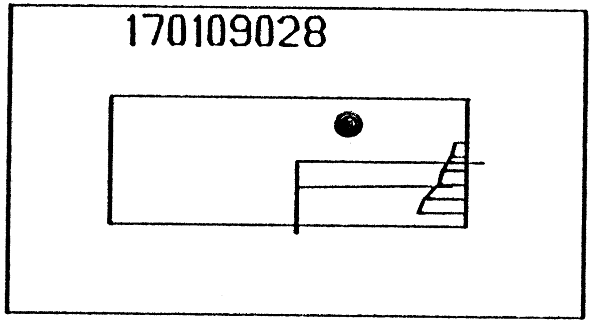
VEHICLE CODE	NCSS CASE	LEVEL INJURY	TYPE INJURY	OBJECT CONTACTED	PEAK DECELERATION	EQUIVALENT BARRIER SPEED	DOT-CRASH2 DELTA-V
66119	170109028	2 AIS	FRACTURE	UNKNOWN	13 G	17 MPH	23 MPH
		2 AIS	FRACTURE	UNKNOWN			
87109	170112035	1 AIS	PAIN	UNKNOWN	13 G	14 MPH	18 MPH
11308	170402003	2 AIS	FRACTURE	UNKNOWN	7 G	11 MPH	11 MPH
11302	170505013	1 AIS	ABRASION	UNKNOWN	14 G	28 MPH	15 MPH
87109	170809029	1 AIS	CONTUSION	STEERING ASSEMBL	5 G	9 MPH	11 MPH
11101	170930042	2 AIS	FRACTURE	STEERING ASSEMBL	9 G	17 MPH	13 MPH
11506	180304007	1 AIS	CONTUSION	STEERING ASSEMBL	13 G	15 MPH	13 MPH
12202	370529059	2 AIS	CONTUSION	UNKNOWN	10 G	22 MPH	17 MPH
11401	370828036	1 AIS	ABRASION	STEERING ASSEMBL	27 G	34 MPH	25 MPH
12118	370924023	1 AIS	CONTUSION	STEERING ASSEMBL	44 G	40 MPH	51 MPH
12102	380304029	2 AIS	FRACTURE	STEERING ASSEMBL	14 G	49 MPH	0 MPH
11318	470611032	1 AIS	CONTUSION	UNKNOWN	25 G	29 MPH	21 MPH
11203	471012030	2 AIS	FRACTURE	STEERING ASSEMBL	10 G	19 MPH	17 MPH
11302	570501001	2 AIS	FRACTURE	UNKNOWN	21 G	31 MPH	29 MPH
66109	670512035	2 AIS	FRACTURE	UNKNOWN	32 G	64 MPH	9 MPH
11402	671010031	2 AIS	CONTUSION	STEERING ASSEMBL	27 G	47 MPH	25 MPH
11518	671021094	1 AIS	PAIN	STEERING ASSEMBL	19 G	24 MPH	39 MPH
11105	671118097	1 AIS	PAIN	STEERING ASSEMBL	11 G	28 MPH	17 MPH
11308	170525052	3 AIS	FRACTURE	UNKNOWN	11 G	20 MPH	15 MPH
12104	170618030	3 AIS	FRACTURE	UNKNOWN	48 G	50 MPH	25 MPH
12102	170715035	3 AIS	FRACTURE	UNKNOWN	10 G	20 MPH	14 MPH
13407	170805004	3 AIS	FRACTURE	STEERING ASSEMBL	17 G	27 MPH	20 MPH
12202	170924050	3 AIS	FRACTURE	STEERING ASSEMBL	15 G	22 MPH	23 MPH
12102	180305036	3 AIS	FRACTURE	STEERING ASSEMBL	17 G	35 MPH	24 MPH
		3 AIS	CONTUSION	STEERING ASSEMBL			
66109	180317048	3 AIS	FRACTURE	STEERING ASSEMBL	24 G	26 MPH	28 MPH
12105	180322060	3 AIS	OTHER	STEERING ASSEMBL	23 G	47 MPH	42 MPH
12101	271020034	3 AIS	FRACTURE	STEERING ASSEMBL	15 G	32 MPH	0 MPH
12102	370510018	3 AIS	FRACTURE	UNKNOWN	14 G	31 MPH	0 MPH
14118	370628031	3 AIS	CONTUSION	UNKNOWN	22 G	21 MPH	32 MPH
13202	370917060	3 AIS	FRACTURE	STEERING ASSEMBL	20 G	36 MPH	33 MPH
85109	371111003	3 AIS	FRACTURE	STEERING ASSEMBL	19 G	18 MPH	29 MPH
11102	371231017	3 AIS	FRACTURE	STEERING ASSEMBL	8 G	23 MPH	12 MPH
11308	470210012	3 AIS	FRACTURE	STEERING ASSEMBL	5 G	6 MPH	9 MPH
		1 AIS	CONTUSION	STEERING ASSEMBL			
13402	471029034	3 AIS	FRACTURE	STEERING ASSEMBL	9 G	18 MPH	0 MPH
13402	471125061	3 AIS	FRACTURE	STEERING ASSEMBL	8 G	18 MPH	25 MPH
66109	480105026	2 AIS	FRACTURE	STEERING ASSEMBL	13 G	16 MPH	0 MPH
12206	571231075	3 AIS	FRACTURE	STEERING ASSEMBL	14 G	24 MPH	11 MPH
11103	670217097	3 AIS	FRACTURE	SIDE INTERIOR	6 G	30 MPH	0 MPH
66109	670223090	3 AIS	FRACTURE	SIDE INTERIOR	25 G	47 MPH	0 MPH
12201	670606020	3 AIS	FRACTURE	UNKNOWN	10 G	17 MPH	10 MPH
12201	671016105	3 AIS	OTHER	STEERING ASSEMBL	33 G	41 MPH	39 MPH
11408	671203006	2 AIS	FRACTURE	STEERING ASSEMBL	22 G	44 MPH	0 MPH
11105	680204016	3 AIS	FRACTURE	STEERING ASSEMBL	13 G	27 MPH	13 MPH
12101	680205020	1 AIS	PAIN	STEERING ASSEMBL	25 G	58 MPH	0 MPH

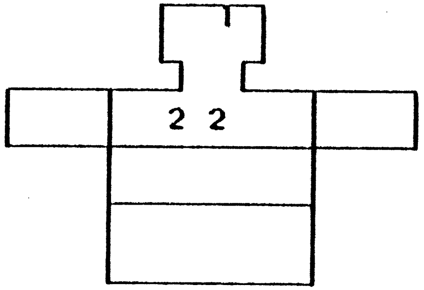
TABLE 13 (Continued)

11302	680223065	3 AIS FRACTURE	STEERING ASSEMBL	10 G	22 MPH	18 MPH
		2 AIS FRACTURE	STEERING ASSEMBL			
62209	770927035	3 AIS FRACTURE	STEERING ASSEMBL	34 G	42 MPH	54 MPH
11301	370811020	4 AIS OTHER	UNKNOWN	22 G	35 MPH	34 MPH
		3 AIS FRACTURE	UNKNOWN			
11101	370821009	3 AIS FRACTURE	STEERING ASSEMBL	22 G	32 MPH	43 MPH
11302	570313033	4 AIS FRACTURE	UNKNOWN	24 G	36 MPH	47 MPH
		4 AIS OTHER	UNKNOWN			
13201	570614020	3 AIS CONTUSION	UNKNOWN	2 G	5 MPH	0 MPH
12102	670105017	3 AIS FRACTURE	STEERING ASSEMBL	11 G	25 MPH	26 MPH
		3 AIS HEMORRHAGE	STEERING ASSEMBL			
86109	780108008	3 AIS CONTUSION	STEERING ASSEMBL	27 G	30 MPH	25 MPH
		3 AIS CONTUSION	STEERING ASSEMBL			
11318	170215016	5 AIS LACERATION	STEERING ASSEMBL	14 G	18 MPH	33 MPH
14108	170608007	5 AIS LACERATION	UNKNOWN	38 G	40 MPH	42 MPH
		5 AIS LACERATION	UNKNOWN			
11108	170704001	5 AIS LACERATION	UNKNOWN	32 G	28 MPH	56 MPH
		5 AIS LACERATION	UNKNOWN			
76119	171203010	2 AIS FRACTURE	STEERING ASSEMBL	19 G	18 MPH	19 MPH
12118	171223045	5 AIS LACERATION	STEERING ASSEMBL	28 G	44 MPH	36 MPH
13201	180322060	5 AIS LACERATION	STEERING ASSEMBL	42 G	64 MPH	55 MPH
		5 AIS LACERATION	STEERING ASSEMBL			
12118	270206022	4 AIS FRACTURE	STEERING ASSEMBL	44 G	40 MPH	42 MPH
		3 AIS CONTUSION	STEERING ASSEMBL			
12106	470219040	4 AIS FRACTURE	UNKNOWN	39 G	49 MPH	44 MPH
11318	470918025	4 AIS FRACTURE	STEERING ASSEMBL	70 G	68 MPH	71 MPH
12106	570501001	5 AIS LACERATION	UNKNOWN	42 G	36 MPH	39 MPH
		3 AIS FRACTURE	UNKNOWN			
		2 AIS FRACTURE	UNKNOWN			
65108	570821054	5 AIS LACERATION	STEERING ASSEMBL	34 G	33 MPH	33 MPH
		3 AIS FRACTURE	STEERING ASSEMBL			
		3 AIS CONTUSION	STEERING ASSEMBL			
66109	670131102	5 AIS LACERATION	UNKNOWN	21 G	30 MPH	49 MPH
12118	170521029	5 AIS LACERATION	UNKNOWN	18 G	44 MPH	49 MPH
11401	170608007	3 AIS CONTUSION	UNKNOWN	19 G	26 MPH	31 MPH
12108	180108002	5 AIS LACERATION	STEERING ASSEMBL	34 G	50 MPH	44 MPH
66109	371013031	6 AIS CRUSHING	UNKNOWN	46 G	59 MPH	7 MPH
66109	670109033	6 AIS CRUSHING	UNKNOWN	71 G	86 MPH	0 MPH

```
NCSS CASE NO. 170109028  5 PM  SUN   9  JAN  1977
     70  PASS CAR  FOREIGN SPORTS    VOLKSWAGEN       66119
3  CDC EXTENT TO    FRONT       SIDE FROM    12OCLOCK
OAIS=  2   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  1
A CHAIN CRASH        TYPE CRASH WITH INTERMEDIATE CAR
L=  37  C1=  6  C2=  8  C3= 12  C4= 14  C5= 21  C6= 24  D=  8  ICOD=       2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=  23   DELTA-V =      23
```

```
BODY REGION                 CHEST              CHEST              FACE
DIRECTION                   LEFT               CENTRAL            WHOLE REGION
TYPE INJURY                 FRACTURE           FRACTURE           LACERATION
BODY ELEMENT                SKELETAL           SKELETAL           INTEGUMENTARY
INJURY LEVEL                MODERATE AIS2      MODERATE AIS2      MINOR AIS1
OBJECT CONTACTED            UNKNOWN            UNKNOWN            UNKNOWN
```



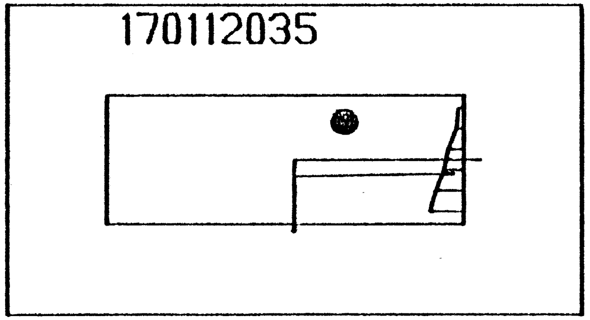


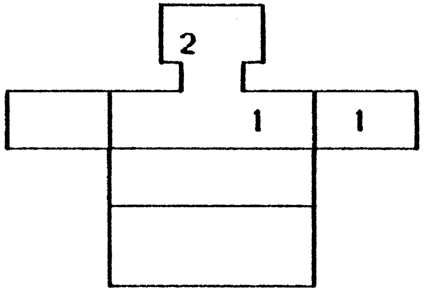
```
IXP =    4  IYP =   68  ZONE =    3
WEIGHT        =      3053.      FORCE          =     40346.
CRUSH ENERGY=     350735.      MASS FACTOR =    0.94
OCCUPANT OAIS   2        SEATING POSITION 11
AGE = 30           SEX =  1          HEIGHT=  99       WEIGHT= 999
```

FIGURE 63

```
   NCSS CASE NO. 170112035  11AM  WED  12  JAN  1977
         76  WAGON     SUB-COMP/IMPORT   TOYOTA            87109
   2  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
   OAIS=  2   RESTRAINT= NOT USED        EJECT/TRAP= NONE            WEIGHTING F=  1
   A V/V HEAD ON      TYPE CRASH WITH LUXURY CAR
   L=  54  C1=  3  C2=  4  C3=  8  C4= 10  C5= 14  C6= 17  D=  0  ICOD=      2
  LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  18   DELTA-V =     18
```

```
  BODY REGION                FACE              WRIST-HAND        CHEST
  DIRECTION                  SUPERIOR/UPPER    LEFT              CENTRAL
  TYPE INJURY                LACERATION        CONTUSION         PAIN
  BODY ELEMENT               INTEGUMENTARY     INTEGUMENTARY     MUSCLES
  INJURY LEVEL               MODERATE AIS2     MINOR AIS1        MINOR AIS1
  OBJECT CONTACTED           UNKNOWN           UNKNOWN           UNKNOWN
```



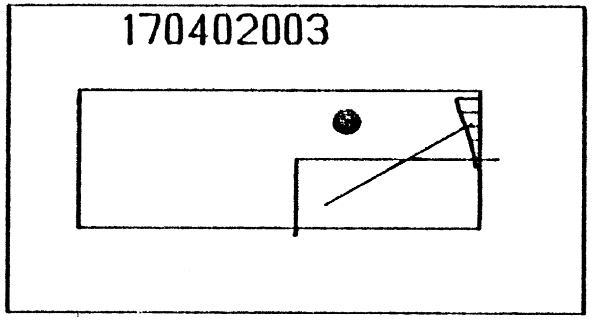


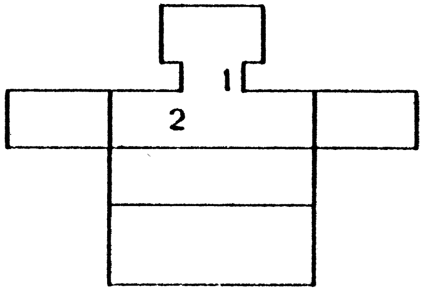
```
  IXP =   3  IYP =  60  ZONE =   2
  WEIGHT       =      3053.     FORCE        =     40452.
  CRUSH ENERGY=    249213.      MASS FACTOR =   0.97
  OCCUPANT OAIS  2       SEATING POSITION 11
  AGE = 48          SEX =  1           HEIGHT=  99       WEIGHT= 999
```

FIGURE 64

```
NCSS CASE NO. 170402003  MIDN  SAT   2  APL  1977
      72  PASS CAR  COMPACT           CHEVROLET          11308
2  CDC EXTENT TO   FRONT      SIDE FROM  11OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH INTERMEDIATE CAR
L=  36  C1= 12  C2= 10  C3=  7  C4=  5  C5=  3  C6=  2  D=-14  ICOD=     2
LATERAL DELTA-V=   6  LONGITUDINAL DELTA-V=  10   DELTA-V =     11
```

```
BODY REGION                CHEST            KNEE              NECK
DIRECTION                  LEFT             LEFT              POSTERIOR/BACK
TYPE INJURY                FRACTURE         OTHER             PAIN
BODY ELEMENT               SKELETAL         UNKNOWN           MUSCLES
INJURY LEVEL               MODERATE AIS2    INJURED/UNK SEV   MINOR AIS1
OBJECT CONTACTED           UNKNOWN          UNKNOWN           UNKNOWN
```



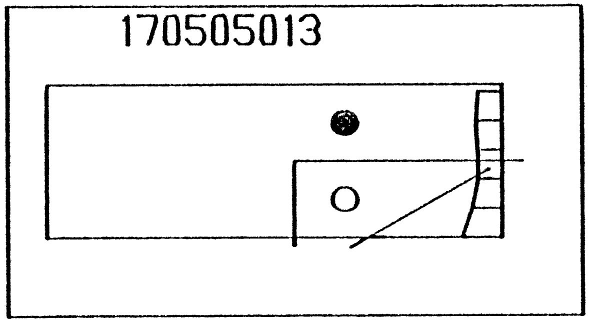


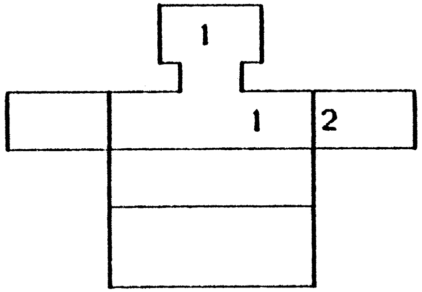
```
IXP =   2 IYP =  23  ZONE =   1
WEIGHT        =     3547.      FORCE        =    24921.
CRUSH ENERGY=    140274.      MASS FACTOR =   0.81
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 58          SEX =  2          HEIGHT=  99       WEIGHT= 999
```

FIGURE 65

```
NCSS CASE NO. 170505013  3 PM  THU   5  MAY  1977
      75  PASS CAR  FULL SIZE          CHEVROLET          11302
2  CDC EXTENT TO    FRONT       SIDE FROM   11OCLOCK
OAIS=  2   RESTRAINT= NOT USED          EJECT/TRAP= NONE               WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH FULL-SIZE CAR
L=  76  C1= 12  C2= 13  C3= 12  C4= 12  C5= 15  C6= 20  D=  2  ICOD=      2
LATERAL DELTA-V=   8  LONGITUDINAL DELTA-V=  13   DELTA-V =     15
```

```
BODY REGION                 WRIST-HAND        FACE              CHEST
DIRECTION                   LEFT              CENTRAL           LEFT
TYPE INJURY                 FRACTURE          FRACTURE          ABRASION
BODY ELEMENT                JOINTS            RESPIRATORY       INTEGUMENTARY
INJURY LEVEL                MODERATE AIS2     MINOR AIS1        MINOR AIS1
OBJECT CONTACTED            UNKNOWN           UNKNOWN           UNKNOWN
```



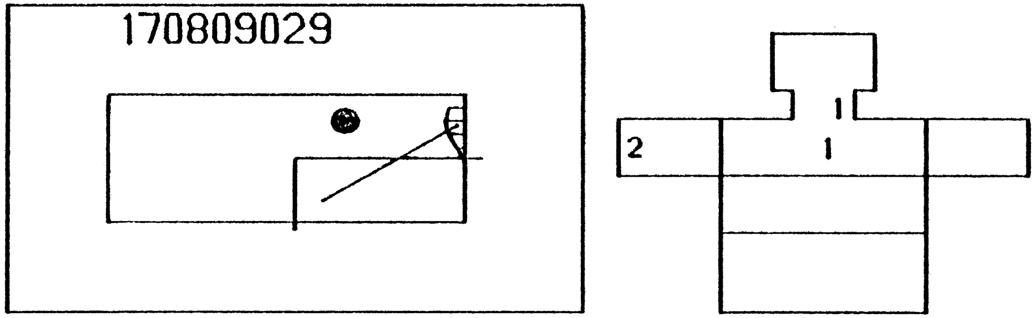


```
IXP =    3  IYP =   55  ZONE =    2
WEIGHT        =        4865.      FORCE         =      71012.
CRUSH ENERGY=     907983.       MASS FACTOR =   0.59
OCCUPANT OAIS   2        SEATING POSITION 11
AGE = 32            SEX =   4           HEIGHT=  60       WEIGHT= 160
```

FIGURE 66

```
NCSS CASE NO. 170809029  7 AM  TUE   9  AUG  1977
      73  WAGON     SUB-COMP/IMPORT   TOYOTA             87109
2  CDC EXTENT TO    FRONT       SIDE FROM   11OCLOCK
OAIS=  2   RESTRAINT= NOT USED          EJECT/TRAP= NONE            WEIGHTING F=  4
A V/V ANG FRONT    TYPE CRASH WITH INTERMEDIATE CAR
L=  21  C1=  8  C2= 10  C3=  8  C4=  4  C5=  0  C6=  0  D=-16  ICOD=      2
LATERAL DELTA-V=   6  LONGITUDINAL DELTA-V=  10   DELTA-V =     11
```

```
BODY REGION                  ARM               CHEST             NECK
DIRECTION                    RIGHT             WHOLE REGION      POSTERIOR/BACK
TYPE INJURY                  CONTUSION         CONTUSION         PAIN
BODY ELEMENT                 MUSCLES           INTEGUMENTARY     MUSCLES
INJURY LEVEL                 MODERATE AIS2     MINOR AIS1        MINOR AIS1
OBJECT CONTACTED             SIDE INTERIOR     STEERING ASSEMBL  UNKNOWN
```

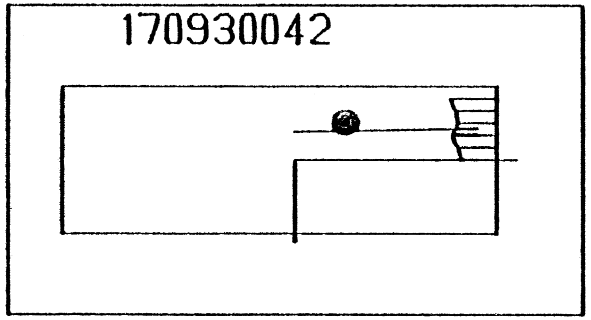


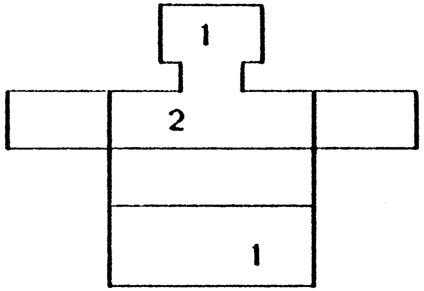
```
IXP =   2  IYP =  24  ZONE =   1
WEIGHT      =       3053.      FORCE          =      16095.
CRUSH ENERGY=     89393.      MASS FACTOR =   0.81
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 49          SEX =  1          HEIGHT=  72       WEIGHT= 185
```

FIGURE 67

```
NCSS CASE NO. 170930042  4 PM  FRI  30  SEP  1977
      77  PASS CAR  INTERMEDIATE      BUICK              11101
2  CDC EXTENT TO    FRONT       SIDE FROM   12OCLOCK
OAIS=  2   RESTRAINT= NOT USED        EJECT/TRAP= NONE              WEIGHTING F=  4
A V/V HEAD ON       TYPE CRASH WITH COMPACT CAR
L=  32  C1= 23  C2= 20  C3= 19  C4= 22  C5= 19  C6= 17  D=-16  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  13   DELTA-V =     13
```

```
BODY REGION                CHEST              FACE               KNEE
DIRECTION                  RIGHT              CENTRAL            LEFT
TYPE INJURY                FRACTURE           LACERATION         OTHER
BODY ELEMENT               SKELETAL           RESPIRATORY        INTEGUMENTARY
INJURY LEVEL               MODERATE AIS2      MINOR AIS1         MINOR AIS1
OBJECT CONTACTED           STEERING ASSEMBL   WINDSHIELD         STEERING ASSEMBL
```



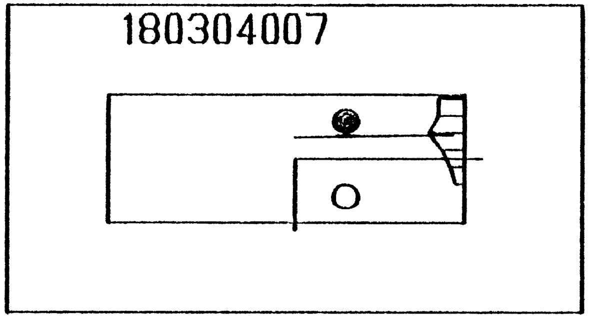


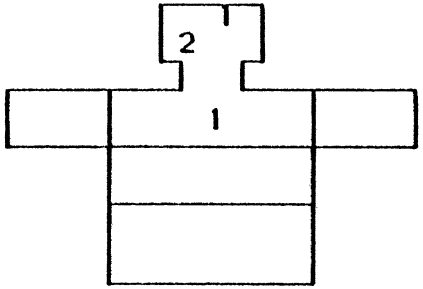
```
IXP =   4  IYP =  28  ZONE =   1
WEIGHT        =       4247.      FORCE        =     39414.
CRUSH ENERGY=     487983.      MASS FACTOR =   0.95
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 58          SEX =  1          HEIGHT=  70        WEIGHT= 160
```

FIGURE 68

NCSS CASE NO. 180304007 6 PM SAT 4 MAR 1978
72 PASS CAR SPECIALTY/PONY PONTIAC 11506
2 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 2 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH INTERMEDIATE CAR
L= 45 C1= 13 C2= 13 C3= 18 C4= 11 C5= 7 C6= 4 D= -9 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 13 DELTA-V = 13

BODY REGION	HEAD-SKULL	CHEST	FACE
DIRECTION	WHOLE REGION	LEFT	INFERIOR/LOWER
TYPE INJURY	CONCUSSION	CONTUSION	LACERATION
BODY ELEMENT	BRAIN	INTEGUMENTARY	INTEGUMENTARY
INJURY LEVEL	MODERATE AIS2	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	WINDSHIELD	STEERING ASSEMBL	WINDSHIELD



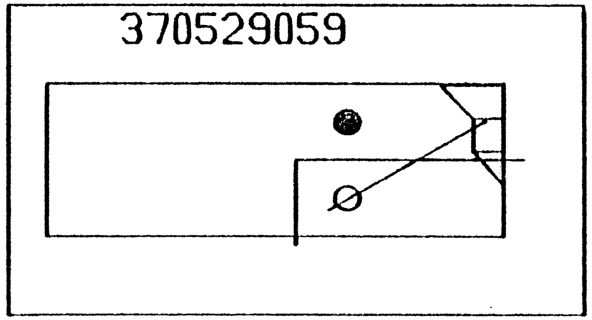


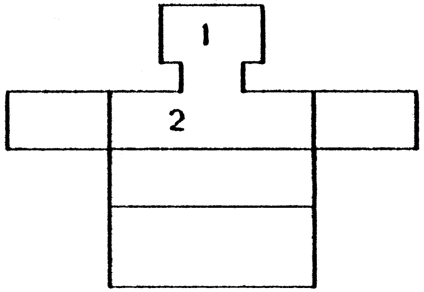
IXP = 3 IYP = 31 ZONE = 1
WEIGHT = 3053. FORCE = 41070.
CRUSH ENERGY= 288431. MASS FACTOR = 0.96
OCCUPANT OAIS 2 SEATING POSITION 11
AGE = 41 SEX = 2 HEIGHT= 62 WEIGHT= 146

FIGURE 69

```
NCSS CASE NO. 370529059  3 PM  SUN  29  MAY  1977
      73  PASS CAR  FULL SIZE          MERCURY            12202
3  CDC EXTENT TO   FRONT      SIDE FROM   11OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH FULL-SIZE CAR
L=  52  C1= 31  C2= 15  C3= 15  C4=  0  C5=  0  C6=  0  D=-13  ICOD=       1
LATERAL DELTA-V=   5  LONGITUDINAL DELTA-V=  17   DELTA-V =     17
```

```
BODY REGION                  CHEST            FACE              UNKNOWN
DIRECTION                    UNKNOWN          INFERIOR/LOWER    UNKNOWN
TYPE INJURY                  CONTUSION        LACERATION        OTHER
BODY ELEMENT                 INTEGUMENTARY    DIGESTIVE         MISSING
INJURY LEVEL                 MODERATE AIS2    MINOR AIS1        INJURED/UNK SEV
OBJECT CONTACTED             UNKNOWN          UNKNOWN           UNKNOWN
```



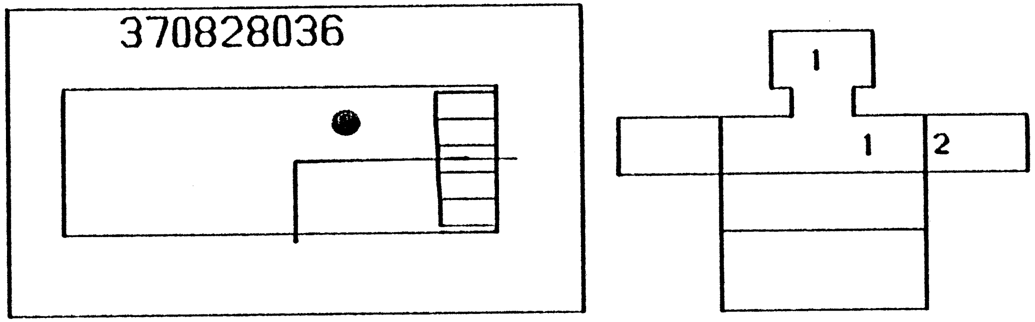


```
IXP =   4  IYP =  25  ZONE =   1
WEIGHT        =      4865.     FORCE        =     52057.
CRUSH ENERGY=     774658.     MASS FACTOR =   0.81
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 54          SEX =  1          HEIGHT=  74       WEIGHT= 230
```

FIGURE 70

```
NCSS CASE NO. 370828036  3 PM  SUN  28  AUG  1977
      71  PASS CAR  INTERMEDIATE        OLDSMOBILE         11401
3  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE            TYPE CRASH WITH INTERMEDIATE CAR
L=  70  C1= 30  C2= 30  C3= 29  C4= 29  C5= 28  C6= 28  D=  0  ICOD=       2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  25   DELTA-V =      25
```

```
BODY REGION                 WRIST-HAND          FACE                CHEST
DIRECTION                   LEFT                CENTRAL             CENTRAL
TYPE INJURY                 FRACTURE            FRACTURE            ABRASION
BODY ELEMENT                JOINTS              RESPIRATORY         INTEGUMENTARY
INJURY LEVEL                MODERATE AIS2       MINOR AIS1          MINOR AIS1
OBJECT CONTACTED            STEERING ASSEMBL    STEERING ASSEMBL    STEERING ASSEMBL
```

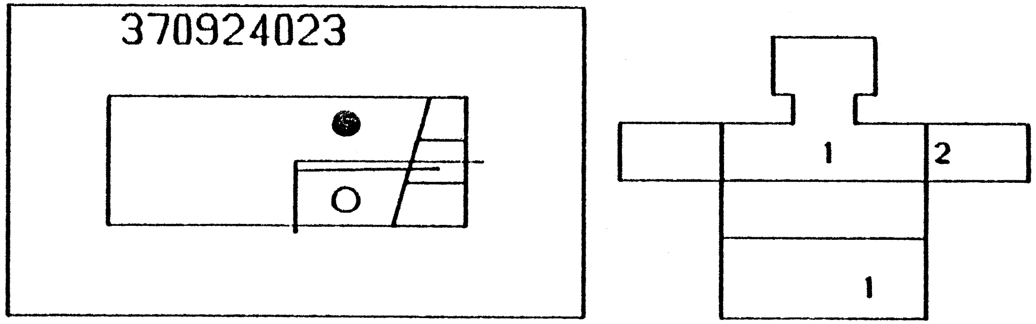


```
IXP =   6  IYP =   49  ZONE =   2
WEIGHT      =        4247.      FORCE        =     117656.
CRUSH ENERGY=    1982454.      MASS FACTOR =    1.00
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 18          SEX =  1           HEIGHT=  76       WEIGHT= 200
```

FIGURE 71

```
NCSS CASE NO. 370924023  8 AM  SAT  24  SEP  1977
      72  WAGON      SUB-COMP/USA      FORD                 12118
4  CDC EXTENT TO    FRONT       SIDE FROM   12OCLOCK
OAIS=  2   RESTRAINT= NOT USED          EJECT/TRAP= NONE             WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH LUXURY CAR
L=  67  C1= 18  C2= 24  C3= 30  C4= 36  C5=  0  C6=  0  D=  0  ICOD=      1
LATERAL DELTA-V=  13  LONGITUDINAL DELTA-V=  50   DELTA-V =     51

BODY REGION                 WRIST-HAND         CHEST              KNEE
DIRECTION                   LEFT               CENTRAL            BILATERAL
TYPE INJURY                 FRACTURE           CONTUSION          LACERATION
BODY ELEMENT                JOINTS             INTEGUMENTARY      INTEGUMENTARY
INJURY LEVEL                MODERATE AIS2      MINOR AIS1         MINOR AIS1
OBJECT CONTACTED            PARKING BRAKE.     STEERING ASSEMBL   INSTRUMENT PANEL
```

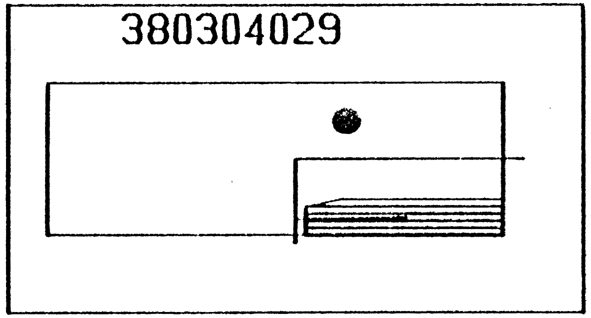


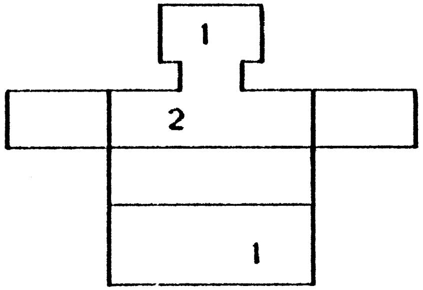
```
IXP =   8 IYP =  55  ZONE =   2
WEIGHT       =       3053.      FORCE        =    134996.
CRUSH ENERGY=    1976827.      MASS FACTOR =   0.99
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 21           SEX =  2           HEIGHT=  65       WEIGHT= 115
```

FIGURE 72

```
NCSS CASE NO. 380304029  2 AM  SAT   4  MAR  1978
      73  PASS CAR  FULL SIZE         FORD              12102
8  CDC EXTENT TO   FRONT      SIDE FROM  12OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V REAR           TYPE CRASH WITH SUB-COMPACT CAR
L=  19  C1= 80  C2= 97  C3= 97  C4= 97  C5= 97  C6= 97  D= 31  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =     0
```

```
BODY REGION               CHEST             FACE              THIGH
DIRECTION                 CENTRAL           WHOLE REGION      RIGHT
TYPE INJURY               FRACTURE          LACERATION        LACERATION
BODY ELEMENT              SKELETAL          INTEGUMENTARY     INTEGUMENTARY
INJURY LEVEL              MODERATE AIS2     MINOR AIS1        MINOR AIS1
OBJECT CONTACTED          STEERING ASSEMBL  WINDSHIELD        INSTRUMENT PANEL
```



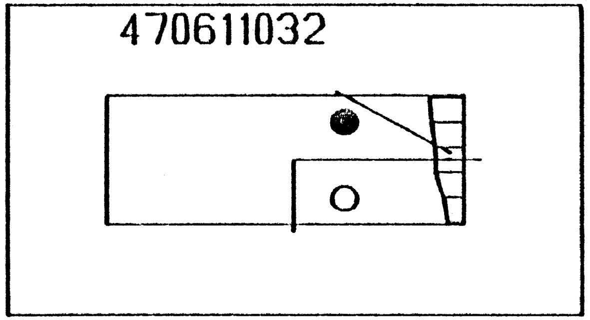


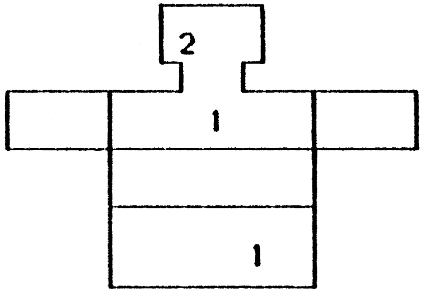
```
IXP =  21  IYP =  89  ZONE =   3
WEIGHT       =      4865.      FORCE        =      72639.
CRUSH ENERGY=   3769738.      MASS FACTOR =   0.80
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 23           SEX =  1           HEIGHT=  72       WEIGHT= 165
```

FIGURE 73

```
NCSS CASE NO. 470611032  2 PM  SAT  11  JUN  1977
      73  PASS CAR  SUB-COMP/USA      CHEVROLET         11318
2  CDC EXTENT TO   FRONT      SIDE FROM   1 OCLOCK
OAIS=  2   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH INTERMEDIATE CAR
L=  65  C1= 17  C2= 16  C3= 14  C4= 14  C5= 10  C6=  8  D=  0  ICOD=      2
LATERAL DELTA-V=  11  LONGITUDINAL DELTA-V=  18   DELTA-V =     21
```

```
BODY REGION              FACE              CHEST            BACK
DIRECTION                RIGHT             CENTRAL          INFERIOR/LOWER
TYPE INJURY              AVULSION          CONTUSION        PAIN
BODY ELEMENT             EYES,EARS         INTEGUMENTARY    MUSCLES
INJURY LEVEL             MODERATE AIS2     MINOR AIS1       MINOR AIS1
OBJECT CONTACTED         UNKNOWN           UNKNOWN          UNKNOWN
```



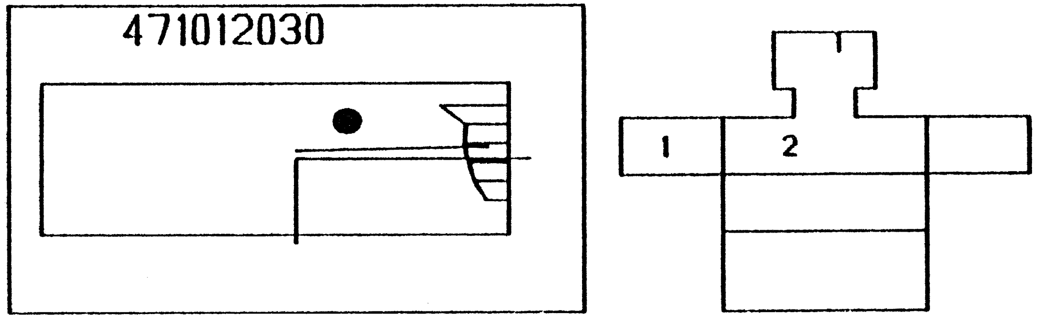


```
IXP =   3  IYP =  44  ZONE =   2
WEIGHT       =      3053.     FORCE        =     78105.
CRUSH ENERGY=    682021.      MASS FACTOR =   0.63
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 19           SEX =  2          HEIGHT=  64       WEIGHT= 120
```

FIGURE 74

NCSS CASE NO. 471012030 4 PM WED 12 OCT 1977
77 PASS CAR LUXURY/LIMOSINE CADILLAC 11203
3 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 2 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V REAR TYPE CRASH WITH INTERMEDIATE CAR
L= 50 C1= 34 C2= 21 C3= 22 C4= 20 C5= 17 C6= 11 D= -3 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 17 DELTA-V = 17

BODY REGION	CHEST	WRIST-HAND	FACE
DIRECTION	RIGHT	RIGHT	WHOLE REGION
TYPE INJURY	FRACTURE	FRACTURE	LACERATION
BODY ELEMENT	SKELETAL	JOINTS	INTEGUMENTARY
INJURY LEVEL	MODERATE AIS2	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	STEERING ASSEMBL	INSTRUMENT PANEL	WINDSHIELD

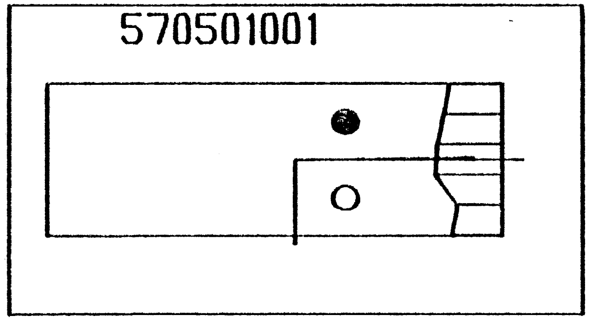


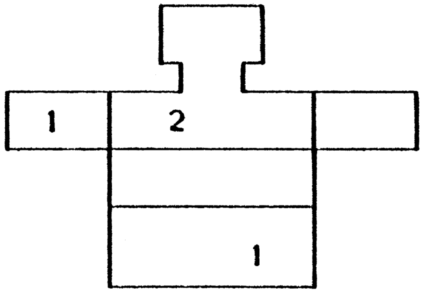
IXP = 4 IYP = 42 ZONE = 2
WEIGHT = 5309. FORCE = 53187.
CRUSH ENERGY= 788008. MASS FACTOR = 1.00
OCCUPANT OAIS 2 SEATING POSITION 11
AGE = 68 SEX = 1 HEIGHT= 73 WEIGHT= 165

FIGURE 75

NCSS CASE NO. 570501001 9 AM SUN 1 MAY 1977
71 PASS CAR FULL SIZE CHEVROLET 11302
3 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 2 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH COMPACT CAR
L= 79 C1= 26 C2= 29 C3= 32 C4= 33 C5= 22 C6= 25 D= 0 ICOD= 2
LATERAL DELTA-V= 5 LONGITUDINAL DELTA-V= 29 DELTA-V = 29

BODY REGION	CHEST	WRIST-HAND	KNEE
DIRECTION	RIGHT	RIGHT	RIGHT
TYPE INJURY	FRACTURE	DISLOCATION	CONTUSION
BODY ELEMENT	SKELETAL	JOINTS	JOINTS
INJURY LEVEL	MODERATE AIS2	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	UNKNOWN	UNKNOWN	UNKNOWN



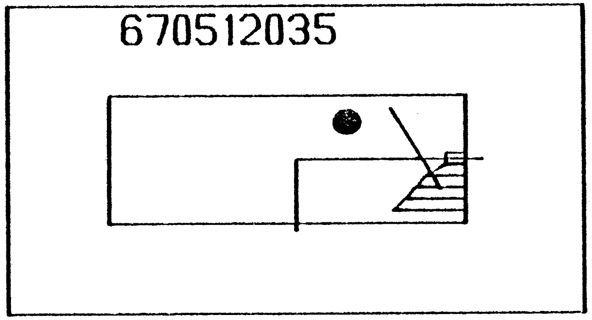


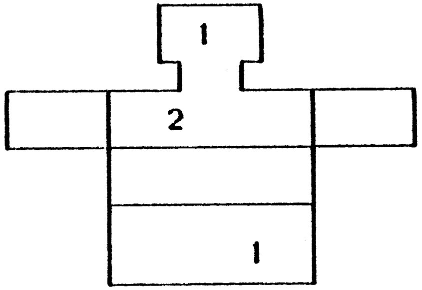
IXP = 6 IYP = 48 ZONE = 2
WEIGHT = 4865. FORCE = 106767.
CRUSH ENERGY= 1973000. MASS FACTOR = 1.00
OCCUPANT OAIS 2 SEATING POSITION 11
AGE = 70 SEX = 1 HEIGHT= 99 WEIGHT= 999

FIGURE 76

```
NCSS CASE NO. 670512035  4 PM  THU  12  MAY  1977
      73  PASS CAR  SUB-COMP/IMPORT   VOLKSWAGEN        66109
4  CDC EXTENT TO   FRONT      SIDE FROM   2 OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V SIDE           TYPE CRASH WITH COMPACT CAR
L=  30  C1= 10  C2= 10  C3= 20  C4= 25  C5= 30  C6= 36  D= 12  ICOD=      2
LATERAL DELTA-V=   5  LONGITUDINAL DELTA-V=   8   DELTA-V =      9
```

```
BODY REGION               CHEST           FACE              BACK
DIRECTION                 LEFT            SUPERIOR/UPPER    INFERIOR/LOWER
TYPE INJURY               FRACTURE        LACERATION        CONTUSION
BODY ELEMENT              SKELETAL        INTEGUMENTARY     INTEGUMENTARY
INJURY LEVEL              MODERATE AIS2   MINOR AIS1        MINOR AIS1
OBJECT CONTACTED          UNKNOWN         UNKNOWN           UNKNOWN
```



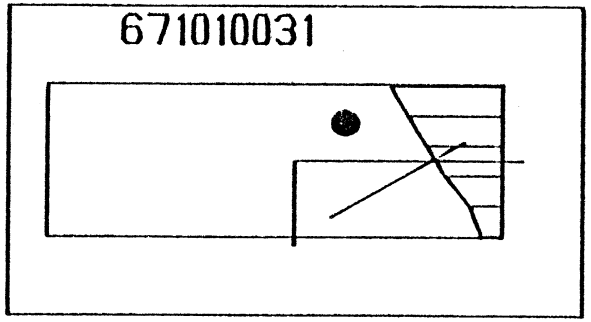


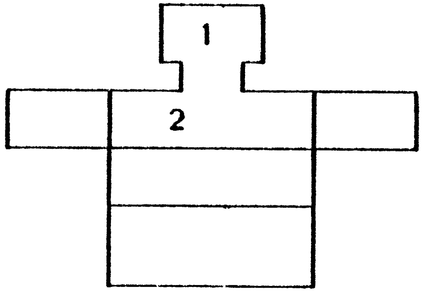
```
IXP =   7  IYP =  72  ZONE =   3
WEIGHT        =      3053.      FORCE        =     97839.
CRUSH ENERGY=    2550002.      MASS FACTOR =   0.51
OCCUPANT OAIS   2        SEATING POSITION 11
AGE = 26           SEX =  1          HEIGHT=  70       WEIGHT= 210
```

FIGURE 77

```
NCSS CASE NO. 671010031  5 PM  MON  10  OCT  1977
      75  PASS CAR  FULL SIZE        OLDSMOBILE        11402
3  CDC EXTENT TO    FRONT      SIDE FROM   11OCLOCK
OAIS=  2   RESTRAINT= NOT USED        EJECT/TRAP= NONE                 WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH COMPACT CAR
L=  78  C1= 55  C2= 46  C3= 37  C4= 28  C5= 16  C6= 10  D=  0  ICOD=      2
LATERAL DELTA-V=  13  LONGITUDINAL DELTA-V=  22   DELTA-V =     25
```

```
BODY REGION                CHEST             FACE              UNKNOWN
DIRECTION                  LEFT              SUPERIOR/UPPER    UNKNOWN
TYPE INJURY                CONTUSION         LACERATION        OTHER
BODY ELEMENT               INTEGUMENTARY     INTEGUMENTARY     MISSING
INJURY LEVEL               MODERATE AIS2     MINOR AIS1        INJURED/UNK SEV
OBJECT CONTACTED           STEERING ASSEMBL  WINDSHIELD        MISSING
```



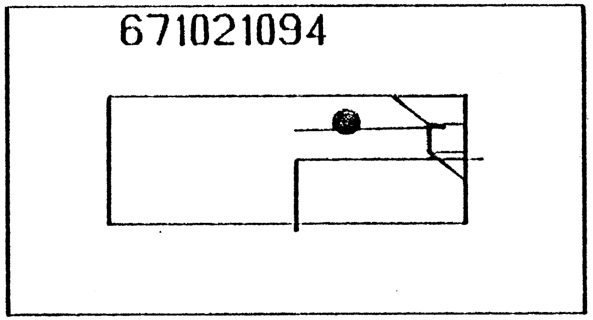


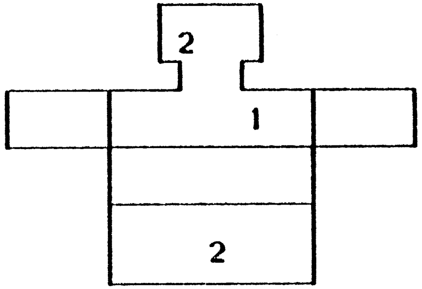
```
IXP =   8  IYP =  37  ZONE =   2
WEIGHT         =      4865.      FORCE         =    133682.
CRUSH ENERGY=   3461745.      MASS FACTOR =   0.77
OCCUPANT OAIS  2        SEATING POSITION 11
AGE = 73          SEX =  2          HEIGHT=  60        WEIGHT= 135
```

FIGURE 78

```
NCSS CASE NO. 671021094  4 PM  FRI  21  OCT  1977
      75  PASS CAR  SUB-COMP/USA      PONTIAC            11518
4  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  2   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH COMPACT CAR
L=  44  C1= 36  C2= 18  C3= 18  C4=  0  C5=  0  C6=  0  D=-11  ICOD=      1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  39   DELTA-V =     39
```

```
BODY REGION                FACE              KNEE              CHEST
DIRECTION                  SUPERIOR/UPPER    RIGHT             CENTRAL
TYPE INJURY                LACERATION        LACERATION        PAIN
BODY ELEMENT               INTEGUMENTARY     INTEGUMENTARY     MUSCLES
INJURY LEVEL               MODERATE AIS2     MODERATE AIS2     MINOR AIS1
OBJECT CONTACTED           WINDSHIELD        INSTRUMENT PANEL  STEERING ASSEMBL
```



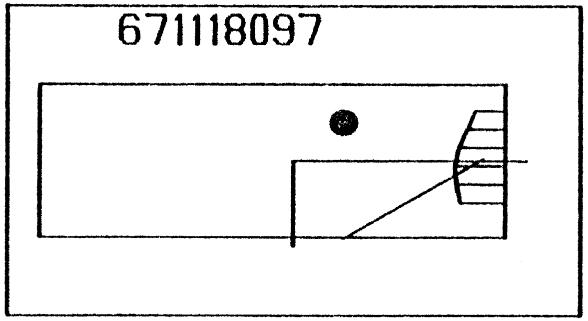


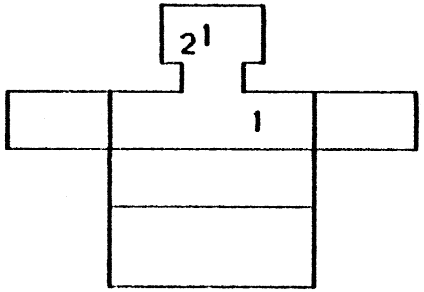
```
IXP =    6  IYP =   25  ZONE =    1
WEIGHT        =        3053.      FORCE         =     60494.
CRUSH ENERGY=     697448.     MASS FACTOR =    0.93
OCCUPANT OAIS   2        SEATING POSITION 11
AGE = 18            SEX =  1            HEIGHT=  67        WEIGHT= 160
```

FIGURE 79

NCSS CASE NO. 671118097 10PM FRI 18 NOV 1977
76 PASS CAR PERSONAL LUXURY BUICK 11105
2 CDC EXTENT TO FRONT SIDE FROM 11OCLOCK
OAIS= 2 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH COMPACT CAR
L= 48 C1= 15 C2= 19 C3= 23 C4= 25 C5= 24 C6= 22 D= -2 ICOD= 2
LATERAL DELTA-V= 9 LONGITUDINAL DELTA-V= 15 DELTA-V = 17

BODY REGION	FACE	FACE	CHEST
DIRECTION	INFERIOR/LOWER	INFERIOR/LOWER	BILATERAL
TYPE INJURY	LACERATION	LACERATION	PAIN
BODY ELEMENT	DIGESTIVE	INTEGUMENTARY	MUSCLES
INJURY LEVEL	MODERATE AIS2	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	STEERING ASSEMBL	STEERING ASSEMBL	STEERING ASSEMBL



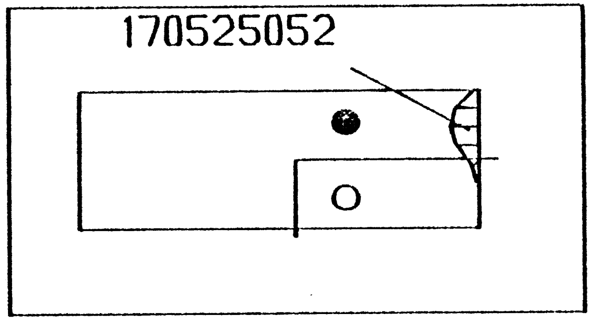


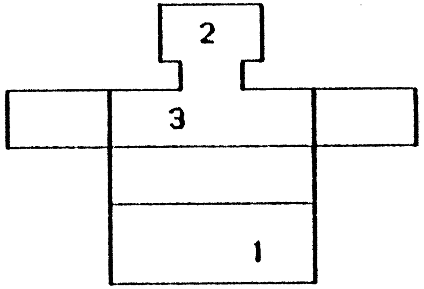
IXP = 4 IYP = 49 ZONE = 2
WEIGHT = 5309. FORCE = 61820.
CRUSH ENERGY= 1088722. MASS FACTOR = 0.65
OCCUPANT OAIS 2 SEATING POSITION 11
AGE = 28 SEX = 2 HEIGHT= 61 WEIGHT= 96

FIGURE 80

```
NCSS CASE NO. 170525052  10AM  WED  25  MAY  1977
      73  PASS CAR  COMPACT            CHEVROLET           11308
2  CDC EXTENT TO   FRONT       SIDE FROM   1 OCLOCK
OAIS=  3   RESTRAINT= LAP ONLY          EJECT/TRAP= NONE             WEIGHTING F=  4
A V/V HEAD ON       TYPE CRASH WITH FULL-SIZE CAR
L=  49  C1=  2  C2= 12  C3= 14  C4= 11  C5=  4  C6=  1  D=-12  ICOD=      2
LATERAL DELTA-V=   7  LONGITUDINAL DELTA-V=  13   DELTA-V =     15
```

```
BODY REGION                CHEST             FACE               KNEE
DIRECTION                  LEFT              INFERIOR/LOWER     BILATERAL
TYPE INJURY                FRACTURE          LACERATION         CONTUSION
BODY ELEMENT               SKELETAL          DIGESTIVE          JOINTS
INJURY LEVEL               SEVERE AIS3       MODERATE AIS2      MINOR AIS1
OBJECT CONTACTED           UNKNOWN           UNKNOWN            UNKNOWN
```



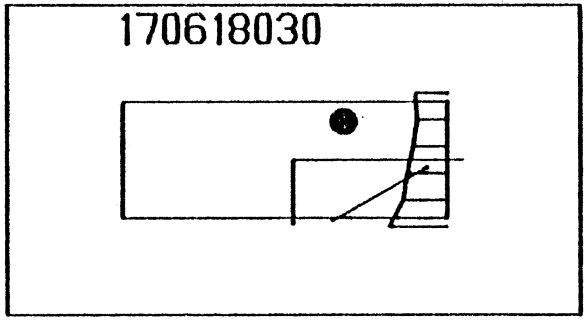


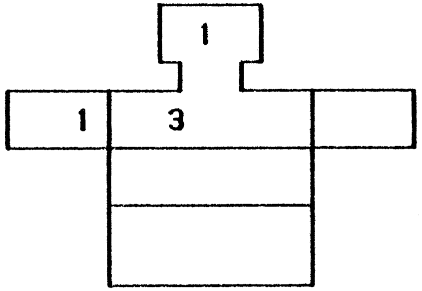
```
IXP =    2 IYP =   28  ZONE =    1
WEIGHT       =        3547.      FORCE         =     42181.
CRUSH ENERGY=     301914.       MASS FACTOR =    0.52
OCCUPANT OAIS  3         SEATING POSITION 11
AGE = 58            SEX =   2           HEIGHT=  63       WEIGHT= 162
```

FIGURE 81

NCSS CASE NO. 170618030 7 AM SAT 18 JUN 1977
76 PASS CAR MINI-SPECIALTY FORD 12104
3 CDC EXTENT TO FRONT SIDE FROM 11OCLOCK
OAIS= 3 RESTRAINT= LAP ONLY EJECT/TRAP= NONE WEIGHTING F= 4
A V/V SIDE TYPE CRASH WITH INTERMEDIATE CAR
L= 70 C1= 16 C2= 15 C3= 17 C4= 20 C5= 22 C6= 29 D= 0 ICOD= 2
LATERAL DELTA-V= 13 LONGITUDINAL DELTA-V= 22 DELTA-V = 25

BODY REGION	CHEST	FACE	FOREARM
DIRECTION	LEFT	SUPERIOR/UPPER	RIGHT
TYPE INJURY	FRACTURE	ABRASION	LACERATION
BODY ELEMENT	SKELETAL	INTEGUMENTARY	INTEGUMENTARY
INJURY LEVEL	SEVERE AIS3	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	UNKNOWN	UNKNOWN	UNKNOWN



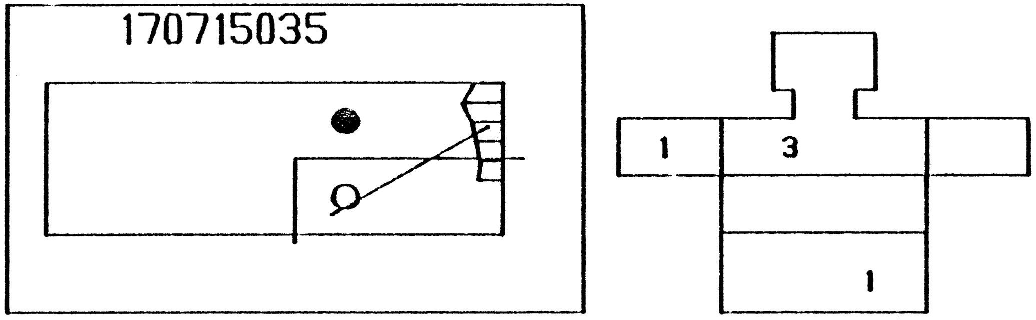


IXP = 6 IYP = 56 ZONE = 2
WEIGHT = 2203. FORCE = 106740.
CRUSH ENERGY= 1315129. MASS FACTOR = 0.59
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 51 SEX = 1 HEIGHT= 68 WEIGHT= 150

FIGURE 82

```
NCSS CASE NO. 170715035  10PM  FRI  15  JUL  1977
      75  PASS CAR  FULL SIZE          FORD                12102
 2  CDC EXTENT TO    FRONT       SIDE FROM   11OCLOCK
 OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE                WEIGHTING F=  1
 A V/V SIDE          TYPE CRASH WITH INTERMEDIATE CAR
 L=  51  C1= 14  C2= 20  C3= 15  C4= 13  C5= 11  C6= 12  D=-14  ICOD=       2
LATERAL DELTA-V=    7  LONGITUDINAL DELTA-V=  12   DELTA-V =      14
```

```
BODY REGION                CHEST             UPPER EXTREM        LOWER EXTREM
DIRECTION                  BILATERAL         BILATERAL           BILATERAL
TYPE INJURY                FRACTURE          CONTUSION           CONTUSION
BODY ELEMENT               SKELETAL          INTEGUMENTARY       INTEGUMENTARY
INJURY LEVEL               SEVERE AIS3       MINOR AIS1          MINOR AIS1
OBJECT CONTACTED           UNKNOWN           UNKNOWN             UNKNOWN
```

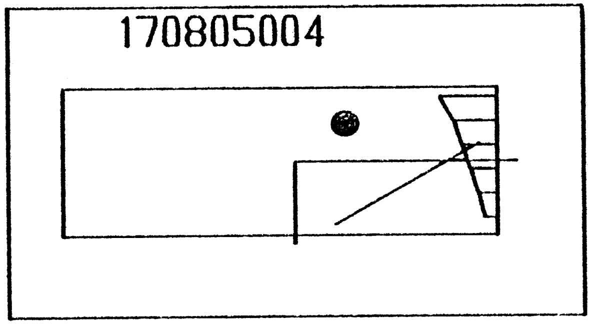


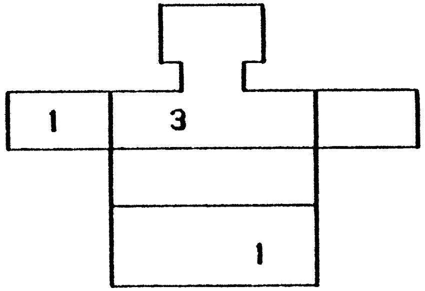
```
IXP =   3 IYP =  29  ZONE =   1
WEIGHT       =       4865.      FORCE        =     49391.
CRUSH ENERGY=    657470.      MASS FACTOR =   0.77
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 43          SEX =  2           HEIGHT=  99       WEIGHT= 999
```

FIGURE 83

```
NCSS CASE NO. 170805004  8 AM  FRI   5  AUG  1977
      76  PASS CAR  SPECIALTY/INTERM  PLYMOUTH          13407
3  CDC EXTENT TO   FRONT       SIDE FROM   110CLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE           TYPE CRASH WITH LUXURY CAR
L=  63  C1= 28  C2= 21  C3= 17  C4= 13  C5=  9  C6=  6  D= -2  ICOD=      2
LATERAL DELTA-V=  10  LONGITUDINAL DELTA-V=  17   DELTA-V =     20
```

```
BODY REGION                CHEST            FOREARM          KNEE
DIRECTION                  RIGHT            BILATERAL        LEFT
TYPE INJURY                FRACTURE         ABRASION         ABRASION
BODY ELEMENT               SKELETAL         INTEGUMENTARY    INTEGUMENTARY
INJURY LEVEL               SEVERE AIS3      MINOR AIS1       MINOR AIS1
OBJECT CONTACTED           STEERING ASSEMBL INSTRUMENT PANEL HARDWARE ITEMS
```



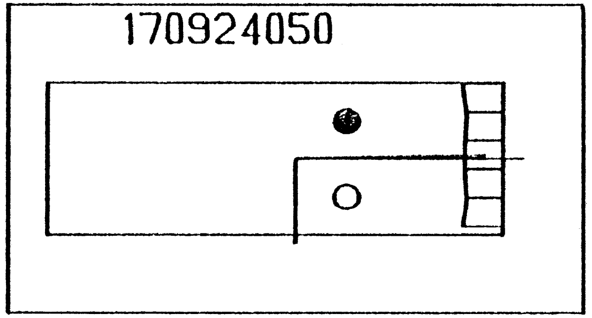


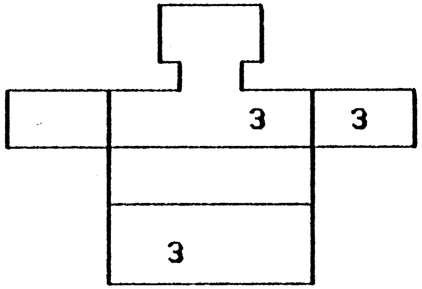
```
IXP =    4 IYP =   38  ZONE =    2
WEIGHT        =       4247.      FORCE          =      72902.
CRUSH ENERGY=     923468.      MASS FACTOR =    0.72
OCCUPANT OAIS   3        SEATING POSITION 11
AGE = 51           SEX =  1          HEIGHT=  71        WEIGHT= 240
```

FIGURE 84

```
NCSS CASE NO. 170924050  4 PM  SAT  24  SEP  1977
      77  PASS CAR  FULL SIZE          MERCURY           12202
2  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH FULL-SIZE CAR
L=  75  C1= 20  C2= 18  C3= 19  C4= 19  C5= 18  C6= 20  D= -2  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=  23   DELTA-V =     23
```

```
BODY REGION                 PELVIC-HIP        FOREARM           CHEST
DIRECTION                   LEFT              LEFT              RIGHT
TYPE INJURY                 DISLOCATION       FRACTURE          FRACTURE
BODY ELEMENT                JOINTS            SKELETAL          SKELETAL
INJURY LEVEL                SEVERE AIS3       SEVERE AIS3       SEVERE AIS3
OBJECT CONTACTED            STEERING ASSEMBL  SIDE INTERIOR     STEERING ASSEMBL
```



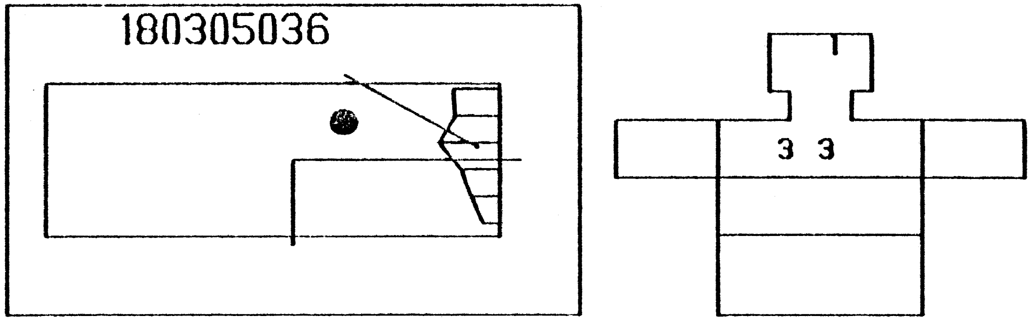


```
IXP =   4  IYP =  47  ZONE =   2
WEIGHT        =        4865.     FORCE         =     75077.
CRUSH ENERGY=   1018947.       MASS FACTOR =   1.00
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 54          SEX =  1           HEIGHT=  74       WEIGHT= 270
```

FIGURE 85

NCSS CASE NO. 180305036 MIDN SUN 5 MAR 1978
74 PASS CAR FULL SIZE FORD 12102
3 CDC EXTENT TO FRONT SIDE FROM 1 OCLOCK
OAIS= 3 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH FULL-SIZE CAR
L= 70 C1= 23 C2= 22 C3= 30 C4= 19 C5= 14 C6= 8 D= -2 ICOD= 2
LATERAL DELTA-V= 12 LONGITUDINAL DELTA-V= 21 DELTA-V = 24

BODY REGION	CHEST	CHEST	FACE
DIRECTION	LEFT	LEFT	UNKNOWN
TYPE INJURY	FRACTURE	CONTUSION	LACERATION
BODY ELEMENT	SKELETAL	PULMONARY	INTEGUMENTARY
INJURY LEVEL	SEVERE AIS3	SEVERE AIS3	MINOR AIS1
OBJECT CONTACTED	STEERING ASSEMBL	STEERING ASSEMBL	UNKNOWN

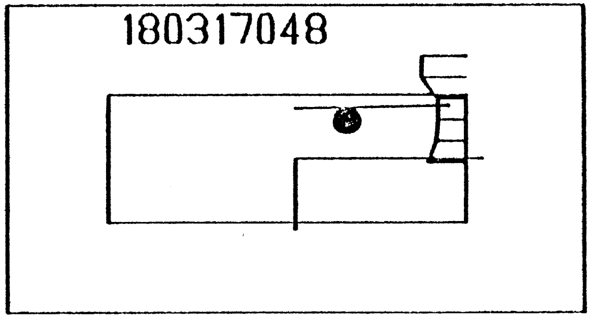


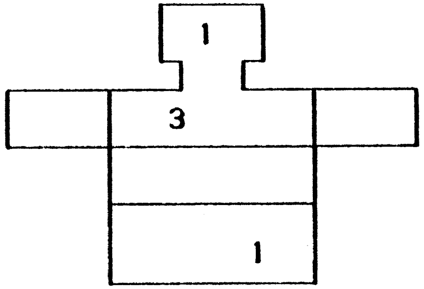
IXP = 4 IYP = 41 ZONE = 2
WEIGHT = 4865. FORCE = 84787.
CRUSH ENERGY= 1452630. MASS FACTOR = 0.61
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 65 SEX = 1 HEIGHT= 99 WEIGHT= 999

FIGURE 86

NCSS CASE NO. 180317048 9 PM FRI 17 MAR 1978
72 PASS CAR SUB-COMP/IMPORT VOLKSWAGEN 66109
2 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 3 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 4
A UNLISTED TYPE CRASH WITH FULL-SIZE CAR
L= 56 C1= 22 C2= 22 C3= 14 C4= 14 C5= 15 C6= 19 D=-26 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 28 DELTA-V = 28

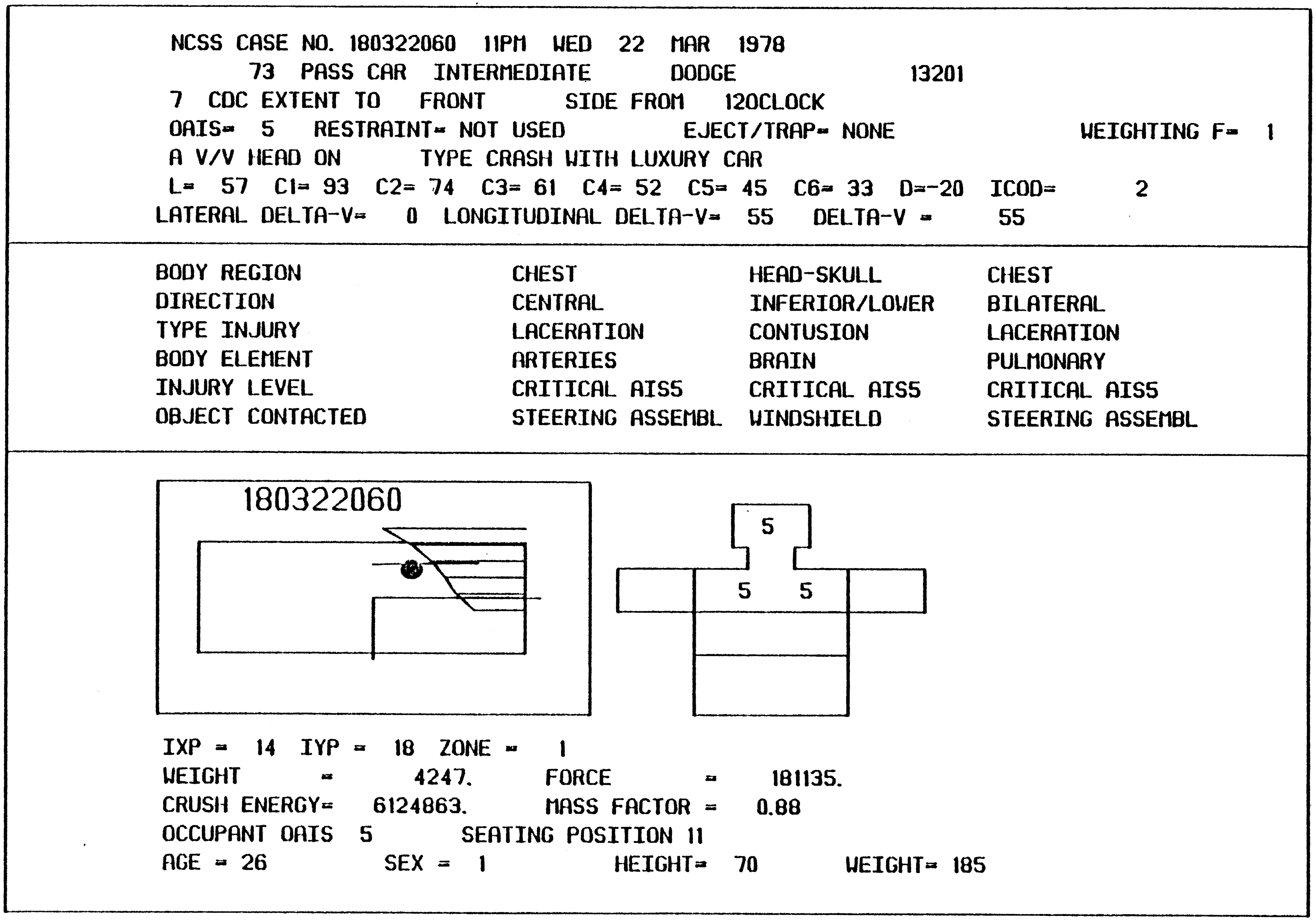
BODY REGION	CHEST	FACE	KNEE
DIRECTION	RIGHT	SUPERIOR/UPPER	BILATERAL
TYPE INJURY	FRACTURE	LACERATION	CONTUSION
BODY ELEMENT	SKELETAL	INTEGUMENTARY	JOINTS
INJURY LEVEL	SEVERE AIS3	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	STEERING ASSEMBL	WINDSHIELD	INSTRUMENT PANEL





IXP = 5 IYP = 8 ZONE = 1
WEIGHT = 3053. FORCE = 73409.
CRUSH ENERGY= 695717. MASS FACTOR = 0.81
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 63 SEX = 1 HEIGHT= 70 WEIGHT= 170

FIGURE 87



NCSS CASE NO. 180322060 11PM WED 22 MAR 1978
73 PASS CAR INTERMEDIATE DODGE 13201
7 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 5 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH LUXURY CAR
L= 57 C1= 93 C2= 74 C3= 61 C4= 52 C5= 45 C6= 33 D=-20 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 55 DELTA-V = 55

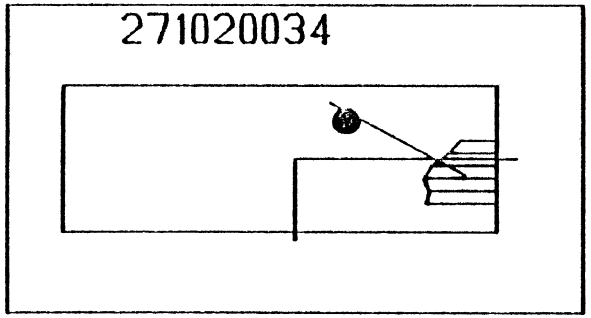
BODY REGION	CHEST	HEAD-SKULL	CHEST
DIRECTION	CENTRAL	INFERIOR/LOWER	BILATERAL
TYPE INJURY	LACERATION	CONTUSION	LACERATION
BODY ELEMENT	ARTERIES	BRAIN	PULMONARY
INJURY LEVEL	CRITICAL AIS5	CRITICAL AIS5	CRITICAL AIS5
OBJECT CONTACTED	STEERING ASSEMBL	WINDSHIELD	STEERING ASSEMBL

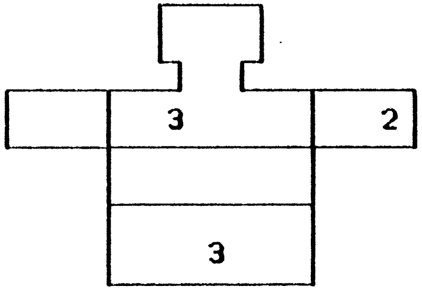
IXP = 14 IYP = 18 ZONE = 1
WEIGHT = 4247. FORCE = 181135.
CRUSH ENERGY= 6124863. MASS FACTOR = 0.88
OCCUPANT OAIS 5 SEATING POSITION 11
AGE = 26 SEX = 1 HEIGHT= 70 WEIGHT= 185

FIGURE 88

```
NCSS CASE NO. 271020034  8 AM  THU  20  OCT  1977
      71  PASS CAR  INTERMEDIATE      FORD               12101
3  CDC EXTENT TO   FRONT      SIDE FROM   1 OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH LUXURY CAR
L=  33  C1= 18  C2= 24  C3= 32  C4= 36  C5= 33  C6= 35  D=  7  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=    0   DELTA-V =      0
```

```
BODY REGION                CHEST             THIGH             ARM
DIRECTION                  RIGHT             RIGHT             LEFT
TYPE INJURY                FRACTURE          FRACTURE          FRACTURE
BODY ELEMENT               SKELETAL          SKELETAL          SKELETAL
INJURY LEVEL               SEVERE AIS3       SEVERE AIS3       MODERATE AIS2
OBJECT CONTACTED           STEERING ASSEMBL  INSTRUMENT PANEL  STEERING ASSEMBL
```



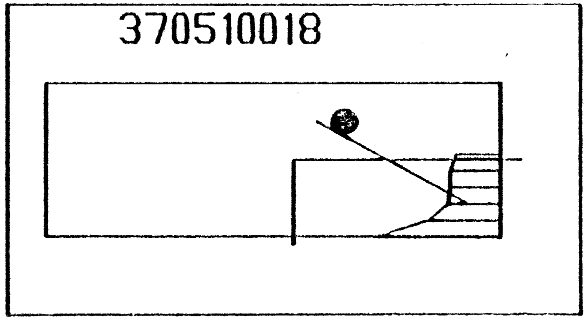


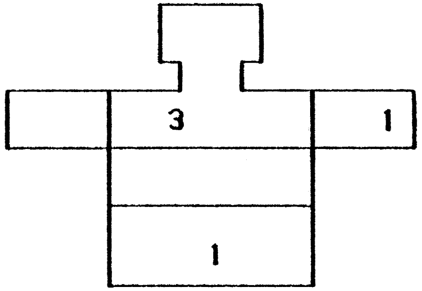
```
IXP =    7  IYP =   61  ZONE =   2
WEIGHT        =     4247.      FORCE         =     66517.
CRUSH ENERGY=    1375859.      MASS FACTOR =   0.76
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 59           SEX =  2          HEIGHT=  99       WEIGHT= 999
```

FIGURE 89

```
NCSS CASE NO. 370510018  8 AM  TUE  10  MAY  1977
      76  PASS CAR  FULL SIZE          FORD              12102
3  CDC EXTENT TO   FRONT      SIDE FROM   1 OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH INTERMEDIATE CAR
L=  43  C1= 22  C2= 25  C3= 25  C4= 26  C5= 36  C6= 62  D= 19  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0

BODY REGION                CHEST             LEG              ARM
DIRECTION                  LEFT              LEFT             LEFT
TYPE INJURY                FRACTURE          ABRASION         CONTUSION
BODY ELEMENT               SKELETAL          INTEGUMENTARY    INTEGUMENTARY
INJURY LEVEL               SEVERE AIS3       MINOR AIS1       MINOR AIS1
OBJECT CONTACTED           UNKNOWN           UNKNOWN          UNKNOWN
```



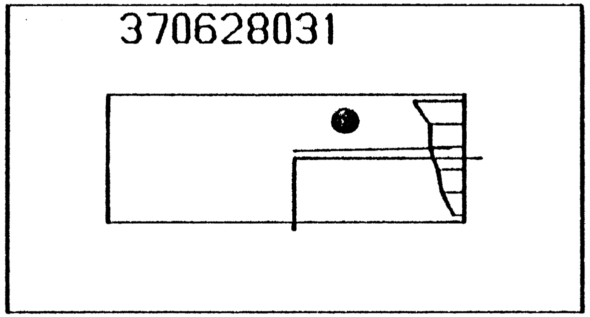


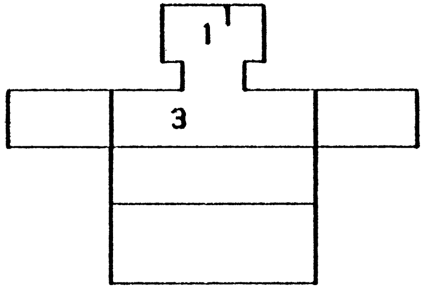
```
IXP =    7  IYP =   78  ZONE =    3
WEIGHT        =        4865.      FORCE          =      71682.
CRUSH ENERGY=    1727848.      MASS FACTOR =   0.89
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 52          SEX =  1          HEIGHT=  70       WEIGHT= 200
```

FIGURE 90

```
NCSS CASE NO. 370628031  5 PM  TUE  28  JUN  1977
      75  PASS CAR  SUB-COMP/USA      AMERICAN MOTORS   14118
3  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= TRAPPED           WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH FULL-SIZE CAR
L=  60  C1= 25  C2= 17  C3= 17  C4= 13  C5= 11  C6=  5  D=  0  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  32   DELTA-V =     32
```

```
BODY REGION                 CHEST           HEAD-SKULL        FACE
DIRECTION                   RIGHT           LEFT              SUPERIOR/UPPER
TYPE INJURY                 CONTUSION       LACERATION        ABRASION
BODY ELEMENT                PULMONARY       INTEGUMENTARY     INTEGUMENTARY
INJURY LEVEL                SEVERE AIS3     MINOR AIS1        MINOR AIS1
OBJECT CONTACTED            UNKNOWN         UNKNOWN           UNKNOWN
```



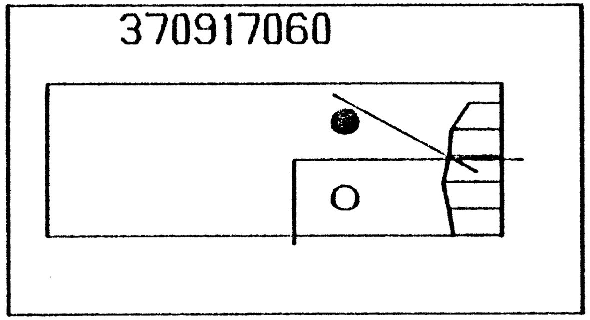


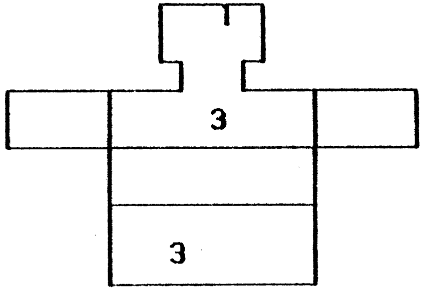
```
IXP =    4  IYP =   42  ZONE =   2
WEIGHT        =      3053.      FORCE        =      67986.
CRUSH ENERGY=    587393.     MASS FACTOR =   0.99
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 31           SEX =  1           HEIGHT=  99       WEIGHT= 999
```

FIGURE 91

NCSS CASE NO. 370917060 7 PM SAT 17 SEP 1977
70 PASS CAR FULL SIZE DODGE 13202
3 CDC EXTENT TO FRONT SIDE FROM 1 OCLOCK
OAIS= 3 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH LUXURY CAR
L= 69 C1= 16 C2= 25 C3= 26 C4= 29 C5= 26 C6= 24 D= 5 ICOD= 2
LATERAL DELTA-V= 9 LONGITUDINAL DELTA-V= 32 DELTA-V = 33

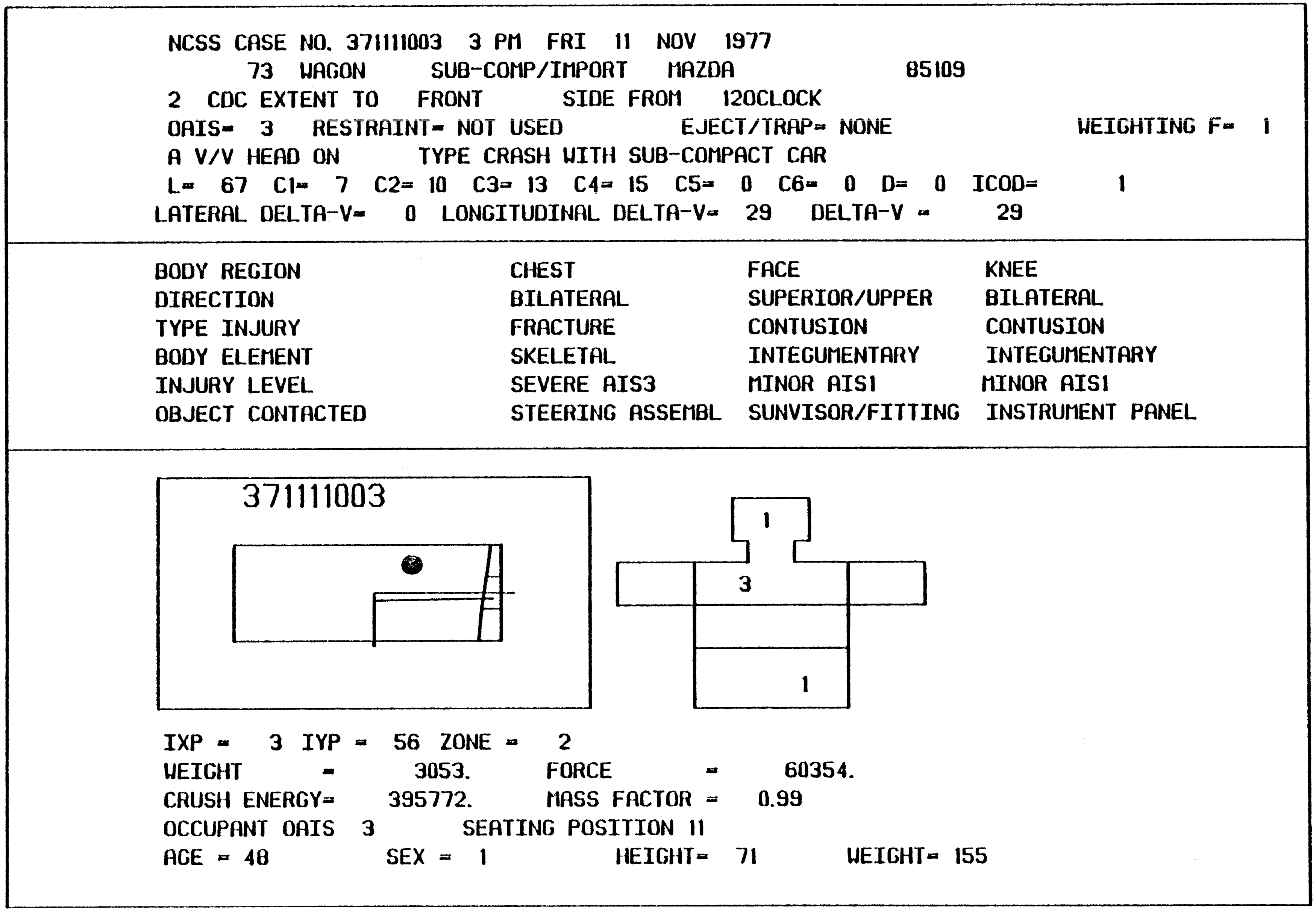
BODY REGION	LEG	CHEST	FACE
DIRECTION	RIGHT	BILATERAL	INFERIOR/LOWER
TYPE INJURY	FRACTURE	FRACTURE	LACERATION
BODY ELEMENT	SKELETAL	SKELETAL	DIGESTIVE
INJURY LEVEL	SEVERE AIS3	SEVERE AIS3	MINOR AIS1
OBJECT CONTACTED	HARDWARE ITEMS	STEERING ASSEMBL	WINDSHIELD





IXP = 5 IYP = 57 ZONE = 2
WEIGHT = 4865. FORCE = 98565.
CRUSH ENERGY= 1922423. MASS FACTOR = 0.73
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 54 SEX = 2 HEIGHT= 67 WEIGHT= 160

FIGURE 92



```
NCSS CASE NO. 371111003  3 PM  FRI  11  NOV  1977
      73  WAGON     SUB-COMP/IMPORT   MAZDA             85109
2  CDC EXTENT TO    FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED        EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH SUB-COMPACT CAR
L=  67  C1=  7  C2= 10  C3= 13  C4= 15  C5=  0  C6=  0  D=  0  ICOD=      1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  29   DELTA-V =     29
```

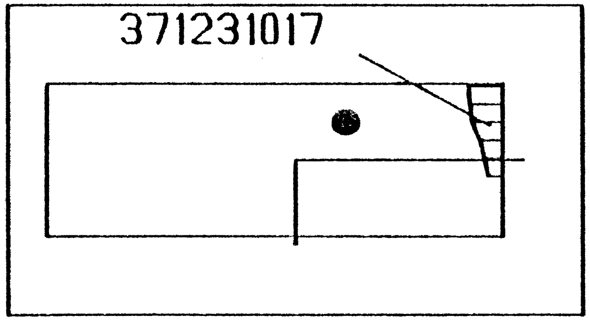
```
BODY REGION            CHEST            FACE              KNEE
DIRECTION              BILATERAL        SUPERIOR/UPPER    BILATERAL
TYPE INJURY            FRACTURE         CONTUSION         CONTUSION
BODY ELEMENT           SKELETAL         INTEGUMENTARY     INTEGUMENTARY
INJURY LEVEL           SEVERE AIS3      MINOR AIS1        MINOR AIS1
OBJECT CONTACTED       STEERING ASSEMBL SUNVISOR/FITTING  INSTRUMENT PANEL
```

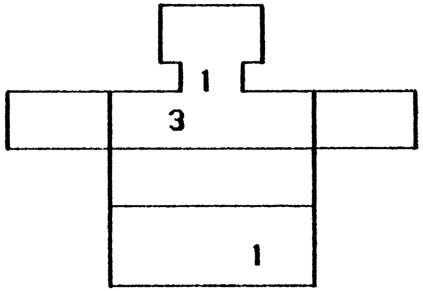
```
IXP =   3 IYP =  56  ZONE =   2
WEIGHT       =    3053.     FORCE        =    60354.
CRUSH ENERGY=    395772.    MASS FACTOR =   0.99
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 48          SEX =  1          HEIGHT=  71       WEIGHT= 155
```

FIGURE 93

```
NCSS CASE NO. 371231017  6 PM  SAT  31  DEC  1977
      73  PASS CAR  FULL SIZE          BUICK               11102
2  CDC EXTENT TO   FRONT       SIDE FROM   1 OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE                WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH INTERMEDIATE CAR
L=  47  C1= 17  C2= 16  C3= 15  C4= 11  C5=  9  C6=  7  D=-15  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  12   DELTA-V =     12
```

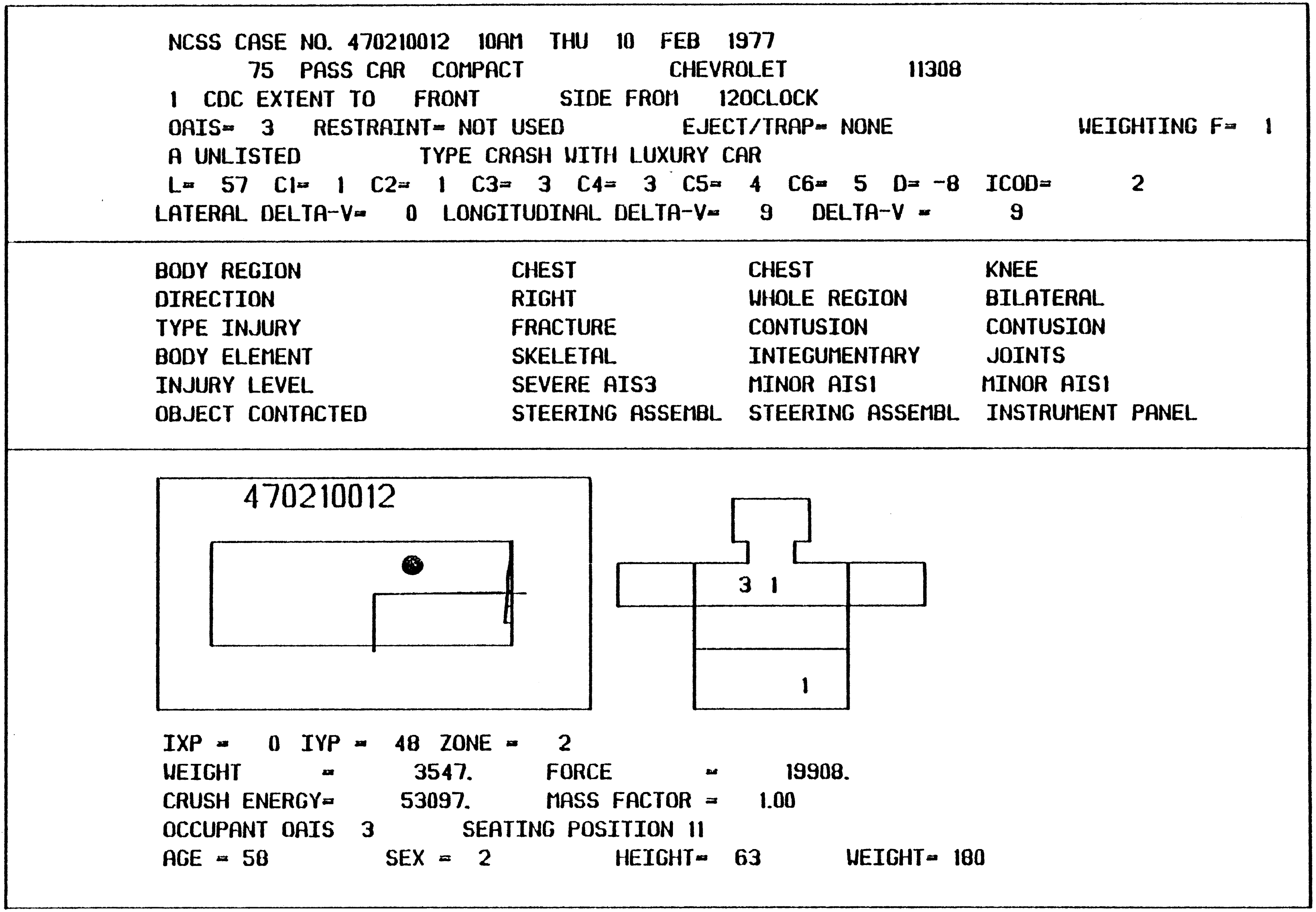
```
BODY REGION               CHEST             NECK             LEG
DIRECTION                 LEFT              LEFT             LEFT
TYPE INJURY               FRACTURE          CONTUSION        CONTUSION
BODY ELEMENT              SKELETAL          INTEGUMENTARY    INTEGUMENTARY
INJURY LEVEL              SEVERE AIS3       MINOR AIS1       MINOR AIS1
OBJECT CONTACTED          STEERING ASSEMBL  UNKNOWN          INSTRUMENT PANEL
```





```
IXP =   3 IYP =  26  ZONE =   1
WEIGHT        =       4865.      FORCE        =      41913.
CRUSH ENERGY=    519053.     MASS FACTOR =   0.50
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 41           SEX =  2           HEIGHT=  99       WEIGHT= 999
```

FIGURE 94



```
NCSS CASE NO. 470210012  10AM  THU  10  FEB  1977
      75  PASS CAR  COMPACT            CHEVROLET          11308
1  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE               WEIGHTING F=  1
A UNLISTED           TYPE CRASH WITH LUXURY CAR
L=  57  C1=  1  C2=  1  C3=  3  C4=  3  C5=  4  C6=  5  D= -8  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   9   DELTA-V =      9

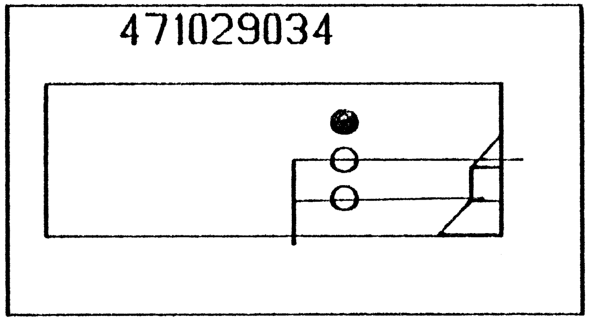
BODY REGION                 CHEST               CHEST               KNEE
DIRECTION                   RIGHT               WHOLE REGION        BILATERAL
TYPE INJURY                 FRACTURE            CONTUSION           CONTUSION
BODY ELEMENT                SKELETAL            INTEGUMENTARY       JOINTS
INJURY LEVEL                SEVERE AIS3         MINOR AIS1          MINOR AIS1
OBJECT CONTACTED            STEERING ASSEMBL    STEERING ASSEMBL    INSTRUMENT PANEL

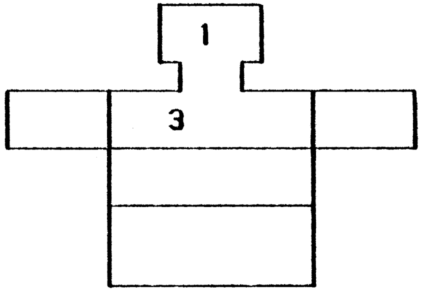
IXP =   0  IYP =  48  ZONE =   2
WEIGHT       =      3547.      FORCE        =     19908.
CRUSH ENERGY=     53097.      MASS FACTOR =    1.00
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 58          SEX =  2          HEIGHT=  63       WEIGHT= 180
```

FIGURE 95

```
NCSS CASE NO. 471029034  3 AM  SAT  29  OCT  1977
      70  PASS CAR  FULL SIZE          PLYMOUTH           13402
3  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH COMPACT CAR
L=  52  C1=  0  C2= 15  C3= 15  C4= 31  C5=  0  C6=  0  D= 13  ICOD=      1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0
```

```
BODY REGION                 CHEST              FACE               UNKNOWN
DIRECTION                   LEFT               INFERIOR/LOWER     UNKNOWN
TYPE INJURY                 FRACTURE           LACERATION         OTHER
BODY ELEMENT                SKELETAL           INTEGUMENTARY      MISSING
INJURY LEVEL                SEVERE AIS3        MINOR AIS1         INJURED/UNK SEV
OBJECT CONTACTED            STEERING ASSEMBL   STEERING ASSEMBL   MISSING
```



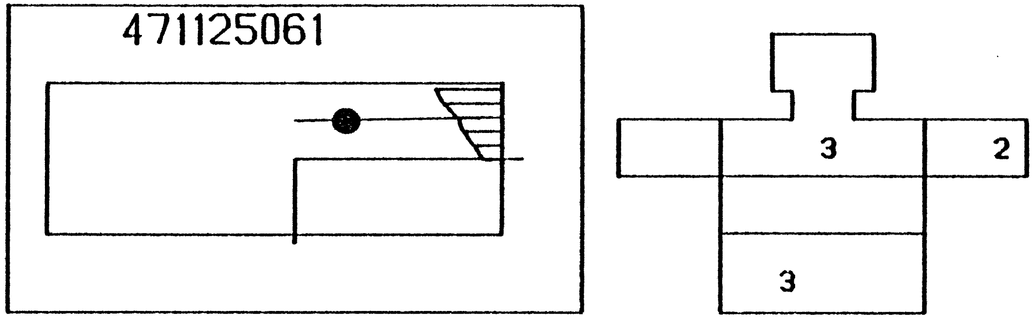


```
IXP =    4  IYP =   74  ZONE =    3
WEIGHT        =       4865.      FORCE          =      45084.
CRUSH ENERGY=     581020.      MASS FACTOR =    0.90
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 49           SEX =  1           HEIGHT=  66       WEIGHT= 145
```

FIGURE 96

```
NCSS CASE NO. 471125061  6 PM  FRI  25  NOV  1977
      71  PASS CAR  FULL SIZE         PLYMOUTH          13402
 3  CDC EXTENT TO    FRONT      SIDE FROM   12OCLOCK
 OAIS=  3   RESTRAINT= NOT USED        EJECT/TRAP= UNKNOWN          WEIGHTING F=  1
 A V/V HEAD ON      TYPE CRASH WITH INTERMEDIATE CAR
 L=  37  C1= 33  C2= 29  C3= 22  C4= 19  C5= 14  C6=  9  D=-18  ICOD=      2
LATERAL DELTA-V=   7  LONGITUDINAL DELTA-V=  25   DELTA-V =     25
```

```
BODY REGION                PELVIC-HIP        CHEST             ARM
DIRECTION                  LEFT              LEFT              LEFT
TYPE INJURY                DISLOCATION       FRACTURE          FRACTURE
BODY ELEMENT               JOINTS            SKELETAL          SKELETAL
INJURY LEVEL               SEVERE AIS3       SEVERE AIS3       MODERATE AIS2
OBJECT CONTACTED           STEERING ASSEMBL  STEERING ASSEMBL  STEERING ASSEMBL
```

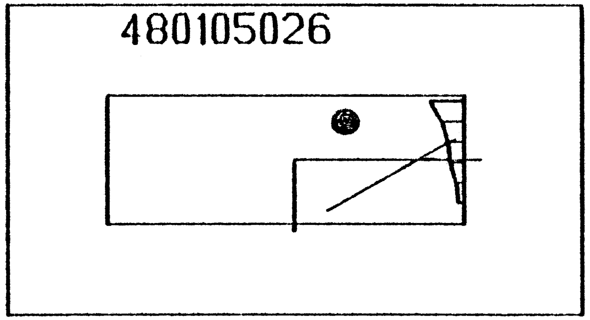


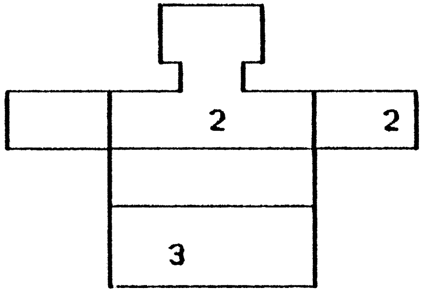
```
IXP =   5  IYP =  23  ZONE =   1
WEIGHT       =       4865.      FORCE        =     40041.
CRUSH ENERGY=    620253.      MASS FACTOR =   0.91
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 58            SEX =  2           HEIGHT=  65      WEIGHT= 135
```

FIGURE 97

NCSS CASE NO. 480105026 2 PM THU 5 JAN 1978
77 PASS CAR SUB-COMP/IMPORT VOLKSWAGEN 66109
2 CDC EXTENT TO FRONT SIDE FROM 11OCLOCK
OAIS= 3 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 4
A V/V HEAD ON TYPE CRASH WITH COMPACT CAR
L= 53 C1= 17 C2= 11 C3= 8 C4= 7 C5= 4 C6= 3 D= -4 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 0 DELTA-V = 0

BODY REGION	LEG	CHEST	ELBOW
DIRECTION	LEFT	CENTRAL	LEFT
TYPE INJURY	FRACTURE	FRACTURE	FRACTURE
BODY ELEMENT	SKELETAL	SKELETAL	JOINTS
INJURY LEVEL	SEVERE AIS3	MODERATE AIS2	MODERATE AIS2
OBJECT CONTACTED	AC/VENT DUCT	STEERING ASSEMBL	HARDWARE ITEMS



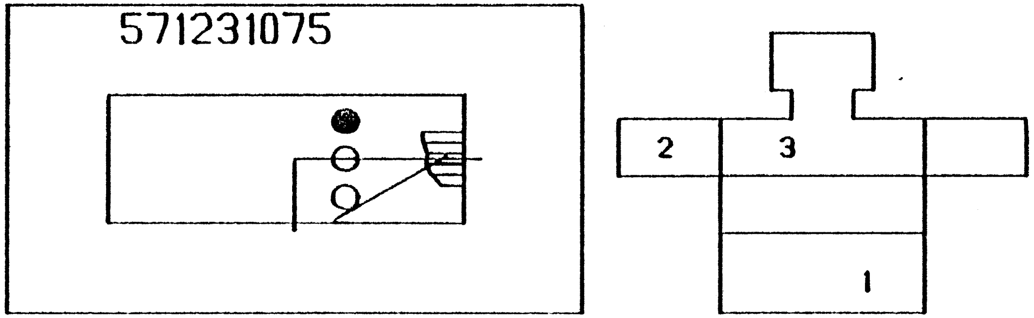


IXP = 2 IYP = 33 ZONE = 1
WEIGHT = 3053. FORCE = 40621.
CRUSH ENERGY= 253918. MASS FACTOR = 0.75
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 66 SEX = 1 HEIGHT= 67 WEIGHT= 165

FIGURE 98

```
NCSS CASE NO. 571231075  8 PM  SAT  31  DEC  1977
      76  PASS CAR  SPECIALTY/PONY    MERCURY          12206
2  CDC EXTENT TO   FRONT      SIDE FROM   11OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V SIDE         TYPE CRASH WITH INTERMEDIATE CAR
L=  28  C1= 21  C2= 20  C3= 18  C4= 19  C5= 16  C6= 11  D=  0  ICOD=      2
LATERAL DELTA-V=   6  LONGITUDINAL DELTA-V=  10   DELTA-V =     11
```

```
BODY REGION                CHEST              SHOULDER           LEG
DIRECTION                  RIGHT              RIGHT              RIGHT
TYPE INJURY                FRACTURE           FRACTURE           CONTUSION
BODY ELEMENT               SKELETAL           SKELETAL           INTEGUMENTARY
INJURY LEVEL               SEVERE AIS3        MODERATE AIS2      MINOR AIS1
OBJECT CONTACTED           STEERING ASSEMBL   STEERING ASSEMBL   INSTRUMENT PANEL
```

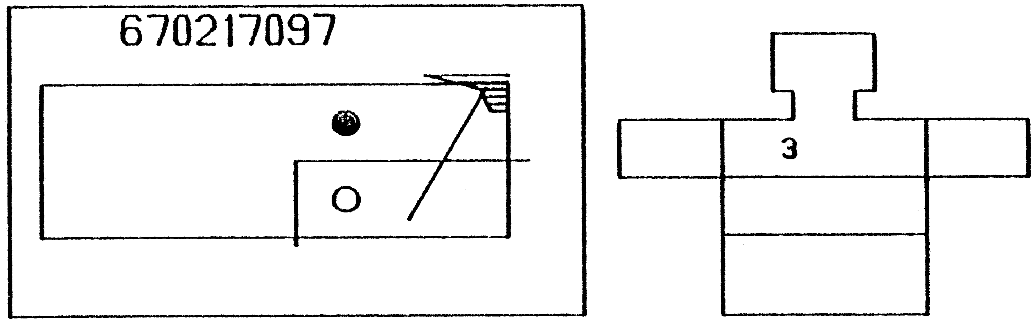


```
IXP =    5  IYP =   48  ZONE =   2
WEIGHT       =       3053.      FORCE        =     43991.
CRUSH ENERGY=    494232.      MASS FACTOR =   0.68
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 52          SEX =  1           HEIGHT=  72       WEIGHT= 175
```

FIGURE 99

```
NCSS CASE NO. 670217097  11AM  THU  17  FEB  1977
      73  PASS CAR  LUXURY/LIMOSINE   BUICK               11103
4  CDC EXTENT TO    FRONT      SIDE FROM    10OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  4
A V/V SIDE          TYPE CRASH WITH INTERMEDIATE CAR
L=  19  C1= 41  C2= 25  C3= 13  C4= 12  C5= 10  C6=  8  D=-35  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0

BODY REGION                CHEST            UNKNOWN          UNKNOWN
DIRECTION                  LEFT             UNKNOWN          UNKNOWN
TYPE INJURY                FRACTURE         OTHER            OTHER
BODY ELEMENT               SKELETAL         MISSING          MISSING
INJURY LEVEL               SEVERE AIS3      INJURED/UNK SEV  INJURED/UNK SEV
OBJECT CONTACTED           SIDE INTERIOR    MISSING          MISSING
```

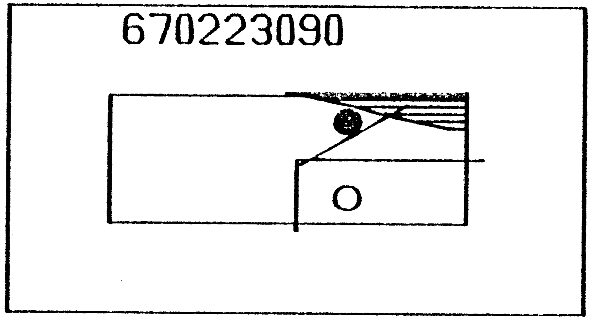


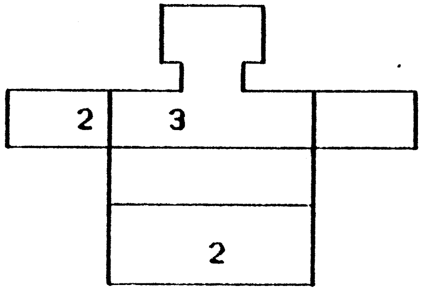
```
IXP =    4  IYP =    2  ZONE =    1
WEIGHT        =       5309.      FORCE         =     35371.
CRUSH ENERGY=    1008606.      MASS FACTOR =   0.51
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 61          SEX =   2          HEIGHT=  67       WEIGHT= 111
```

FIGURE 100

```
NCSS CASE NO. 670223090  9 AM  WED  23  FEB  1977
      72  PASS CAR  SUB-COMP/IMPORT   VOLKSWAGEN        66109
7  CDC EXTENT TO   FRONT       SIDE FROM   110CLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE             WEIGHTING F=  1
A UNKNOWN            TYPE CRASH WITH FULL-SIZE CAR
L=  19  C1= 89  C2= 71  C3= 55  C4= 42  C5= 26  C6=  9  D=-26  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0
```

```
BODY REGION               CHEST            PELVIC-HIP       SHOULDER
DIRECTION                 LEFT             UNKNOWN          UNKNOWN
TYPE INJURY               FRACTURE         FRACTURE         FRACTURE
BODY ELEMENT              SKELETAL         SKELETAL         SKELETAL
INJURY LEVEL              SEVERE AIS3      MODERATE AIS2    MODERATE AIS2
OBJECT CONTACTED          SIDE INTERIOR    SIDE INTERIOR    A-PILLAR
```



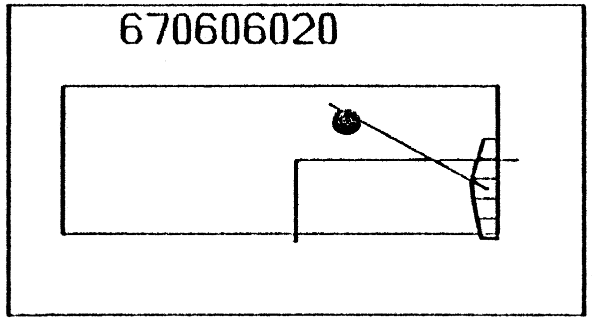


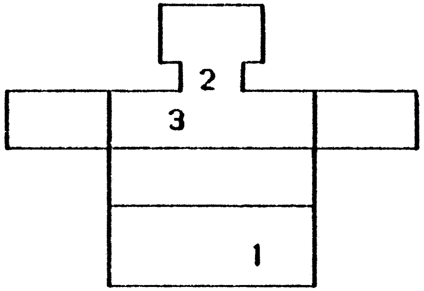
```
IXP =  16  IYP =   7  ZONE =   1
WEIGHT        =      3053.      FORCE        =    77901.
CRUSH ENERGY=   2692824.      MASS FACTOR =   1.00
OCCUPANT OAIS  3         SEATING POSITION 11
AGE = 24          SEX =  4          HEIGHT=  99        WEIGHT= 999
```

FIGURE 101

```
           NCSS CASE NO. 670606020  8 PM  MON   6  JUN  1977
                 74  PASS CAR  INTERMEDIATE      MERCURY          12201
           2  CDC EXTENT TO   FRONT      SIDE FROM   1 OCLOCK
           OAIS=  3   RESTRAINT= NOT USED        EJECT/TRAP= NONE               WEIGHTING F=  1
           A V/V HEAD ON      TYPE CRASH WITH FULL-SIZE CAR
           L=  52  C1=  7  C2= 10  C3= 13  C4= 12  C5= 10  C6=  8  D= 15  ICOD=      2
          LATERAL DELTA-V=   5  LONGITUDINAL DELTA-V=   9   DELTA-V =     10
```

```
          BODY REGION               CHEST            NECK               LEG
          DIRECTION                 LEFT             ANTERIOR/FRONT     LEFT
          TYPE INJURY               FRACTURE         OTHER              CONTUSION
          BODY ELEMENT              SKELETAL         DIGESTIVE          INTEGUMENTARY
          INJURY LEVEL              SEVERE AIS3      MODERATE AIS2      MINOR AIS1
          OBJECT CONTACTED          UNKNOWN          UNKNOWN            UNKNOWN
```



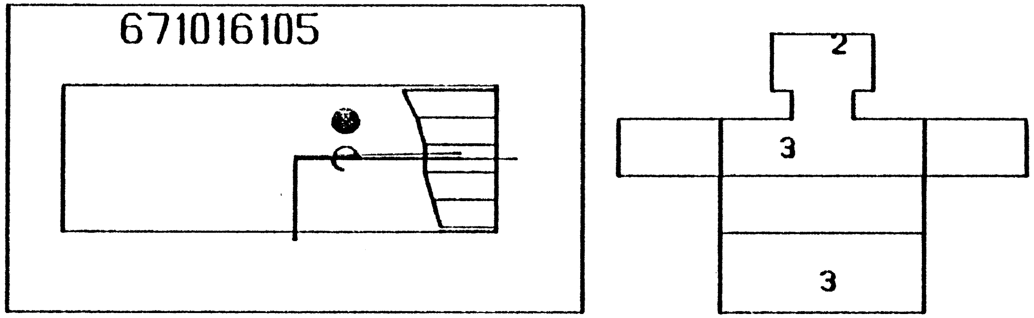


```
           IXP =   2 IYP =  69  ZONE =   3
           WEIGHT         =       4247.      FORCE          =     45492.
           CRUSH ENERGY=      403533.      MASS FACTOR =    0.77
           OCCUPANT OAIS  3        SEATING POSITION 11
           AGE = 52           SEX =  1           HEIGHT=  68       WEIGHT= 160
```

FIGURE 102

```
NCSS CASE NO. 671016105  4 AM  SUN  16  OCT  1977
      72  PASS CAR  INTERMEDIATE      MERCURY          12201
3  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED        EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V REAR          TYPE CRASH WITH FULL-SIZE CAR
L=  72  C1= 46  C2= 39  C3= 35  C4= 35  C5= 31  C6= 27  D=  0  ICOD=     2
LATERAL DELTA-V=   5  LONGITUDINAL DELTA-V=  38   DELTA-V =     39
```

```
BODY REGION                 CHEST              LEG                FACE
DIRECTION                   RIGHT              LEFT               BILATERAL
TYPE INJURY                 OTHER              FRACTURE           LACERATION
BODY ELEMENT                PULMONARY          SKELETAL           INTEGUMENTARY
INJURY LEVEL                SEVERE AIS3        SEVERE AIS3        MODERATE AIS2
OBJECT CONTACTED            STEERING ASSEMBL   INSTRUMENT PANEL   WINDSHIELD
```

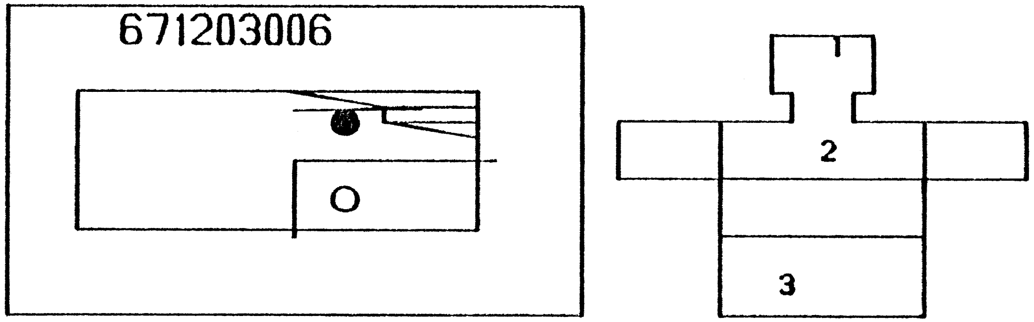


```
IXP =   8  IYP =  46  ZONE =   2
WEIGHT        =      4247.      FORCE        =    143652.
CRUSH ENERGY=   2910607.      MASS FACTOR =   1.00
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 26           SEX =  1           HEIGHT=  70       WEIGHT= 215
```

FIGURE 103

```
NCSS CASE NO. 671203006  9 AM  SAT   3  DEC  1977
      76  PASS CAR  COMPACT             OLDSMOBILE        11408
9  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= UNKNOWN          WEIGHTING F=  1
A V/V ANG FRONT    TYPE CRASH WITH INTERMEDIATE CAR
L=  24  C1= 93  C2= 46  C3= 46  C4=  0  C5=  0  C6=  0  D=-24  ICOD=      1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0
```

```
BODY REGION                   PELVIC-HIP        CHEST             FACE
DIRECTION                     ANTERIOR/FRONT    LEFT              SUPERIOR/UPPER
TYPE INJURY                   FRACTURE          FRACTURE          LACERATION
BODY ELEMENT                  SKELETAL          SKELETAL          INTEGUMENTARY
INJURY LEVEL                  SEVERE AIS3       MODERATE AIS2     MINOR AIS1
OBJECT CONTACTED              SIDE INTERIOR     STEERING ASSEMBL  WINDSHIELD
```

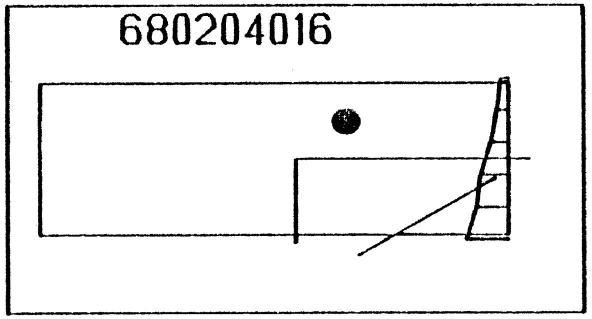


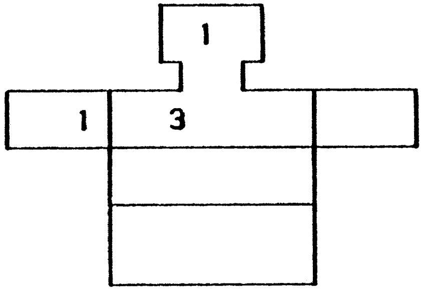
```
IXP =   14  IYP =   12  ZONE =   1
WEIGHT        =       3547.     FORCE         =     80739.
CRUSH ENERGY=   2354362.    MASS FACTOR =   0.83
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 59            SEX =  1           HEIGHT=  99      WEIGHT= 999
```

FIGURE 104

NCSS CASE NO. 680204016 9 PM SAT 4 FEB 1978
74 PASS CAR PERSONAL LUXURY BUICK 11105
2 CDC EXTENT TO FRONT SIDE FROM 11OCLOCK
OAIS= 3 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V SIDE TYPE CRASH WITH LUXURY CAR
L= 85 C1= 4 C2= 6 C3= 9 C4= 14 C5= 16 C6= 21 D= 0 ICOD= 2
LATERAL DELTA-V= 7 LONGITUDINAL DELTA-V= 12 DELTA-V = 13

BODY REGION	CHEST	FACE	WRIST-HAND
DIRECTION	LEFT	SUPERIOR/UPPER	BILATERAL
TYPE INJURY	FRACTURE	LACERATION	PAIN
BODY ELEMENT	SKELETAL	INTEGUMENTARY	MUSCLES
INJURY LEVEL	SEVERE AIS3	MINOR AIS1	MINOR AIS1
OBJECT CONTACTED	STEERING ASSEMBL	WINDSHIELD	STEERING ASSEMBL



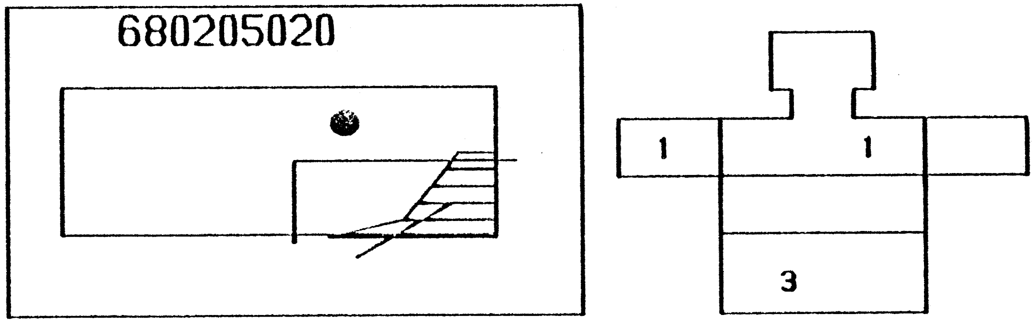


IXP = 2 IYP = 63 ZONE = 2
WEIGHT = 5309. FORCE = 71818.
CRUSH ENERGY= 874738. MASS FACTOR = 0.55
OCCUPANT OAIS 3 SEATING POSITION 11
AGE = 35 SEX = 1 HEIGHT= 70 WEIGHT= 171

FIGURE 105

```
NCSS CASE NO. 680205020  2 PM  SUN   5  FEB  1978
      72  WAGON     INTERMEDIATE      FORD                12101
4  CDC EXTENT TO   FRONT       SIDE FROM   11OCLOCK
OAIS=  3   RESTRAINT= NOT USED        EJECT/TRAP= NONE             WEIGHTING F=  1
A V/V ANG SIDE      TYPE CRASH WITH INTERMEDIATE CAR
L=  44  C1= 19  C2= 25  C3= 32  C4= 39  C5= 46  C6= 82  D= 18  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0
```

```
BODY REGION            LEG               ELBOW             CHEST
DIRECTION              RIGHT             BILATERAL         RIGHT
TYPE INJURY            FRACTURE          CONTUSION         PAIN
BODY ELEMENT           SKELETAL          INTEGUMENTARY     MUSCLES
INJURY LEVEL           SEVERE AIS3       MINOR AIS1        MINOR AIS1
OBJECT CONTACTED       INSTRUMENT PANEL  STEERING ASSEMBL  STEERING ASSEMBL
```

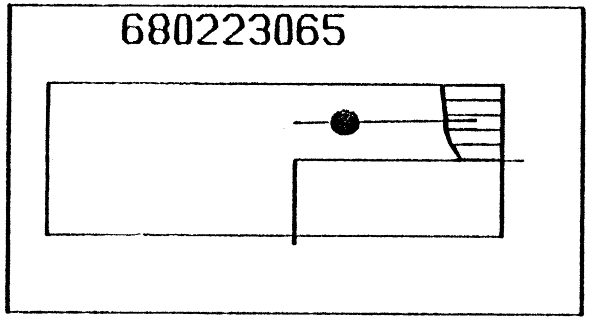


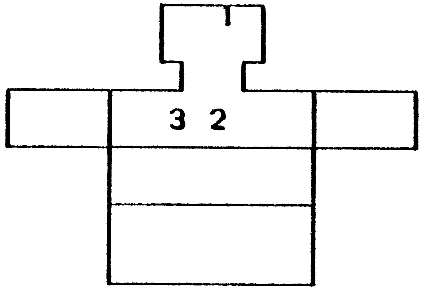
```
IXP =  10  IYP =  79  ZONE =   3
WEIGHT       =       4247.      FORCE        =   109479.
CRUSH ENERGY=   3072164.      MASS FACTOR =   0.52
OCCUPANT OAIS  3       SEATING POSITION 11
AGE = 62         SEX =  1          HEIGHT=  73       WEIGHT= 195
```

FIGURE 106

```
NCSS CASE NO. 680223065  11AM  THU  23  FEB  1978
      71  PASS CAR  FULL SIZE         CHEVROLET          11302
3  CDC EXTENT TO    FRONT       SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH LUXURY CAR
L=  39  C1= 30  C2= 29  C3= 28  C4= 28  C5= 25  C6= 20  D=-20  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=  18   DELTA-V =      18
```

```
BODY REGION                CHEST            CHEST            FACE
DIRECTION                  RIGHT            CENTRAL          SUPERIOR/UPPER
TYPE INJURY                FRACTURE         FRACTURE         LACERATION
BODY ELEMENT               SKELETAL         SKELETAL         INTEGUMENTARY
INJURY LEVEL               SEVERE AIS3      MODERATE AIS2    MINOR AIS1
OBJECT CONTACTED           STEERING ASSEMBL STEERING ASSEMBL WINDSHIELD
```



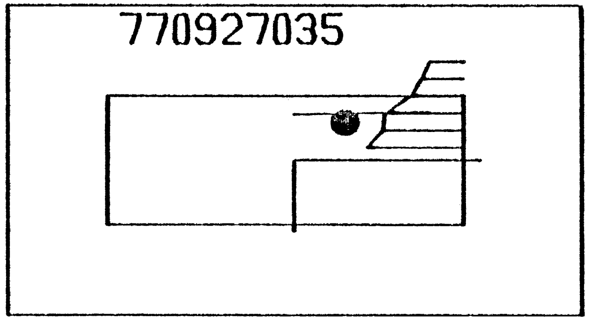


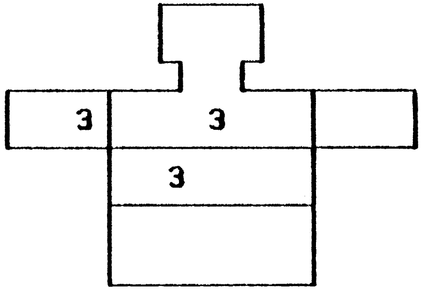
```
IXP =    6  IYP =   23  ZONE =   1
WEIGHT        =        4865.      FORCE         =     50838.
CRUSH ENERGY=      902936.      MASS FACTOR =   0.92
OCCUPANT OAIS   3         SEATING POSITION 11
AGE = 55            SEX =  2            HEIGHT=  66       WEIGHT= 140
```

FIGURE 107

```
NCSS CASE NO. 770927035  MIDN  TUE  27  SEP  1977
      71  PASS CAR  SUB-COMP/IMPORT   CAPRI/GERMAN       62209
5  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED          EJECT/TRAP= TRAPPED            WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH LUXURY CAR
L=  45   C1= 17   C2= 21   C3= 26   C4= 39   C5= 40   C6= 48   D=-29  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=  54   DELTA-V =     54
```

```
BODY REGION                 ABDOMEN             CHEST               FOREARM
DIRECTION                   INFERIOR/LOWER      RIGHT               RIGHT
TYPE INJURY                 CONTUSION           FRACTURE            FRACTURE
BODY ELEMENT                UROGENTIAL          SKELETAL            SKELETAL
INJURY LEVEL                SEVERE AIS3         SEVERE AIS3         SEVERE AIS3
OBJECT CONTACTED            STEERING ASSEMBL    STEERING ASSEMBL    A-PILLAR
```



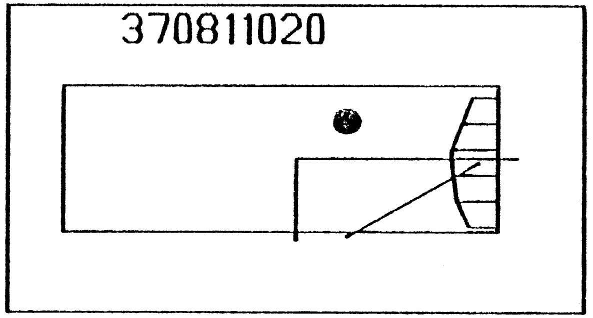


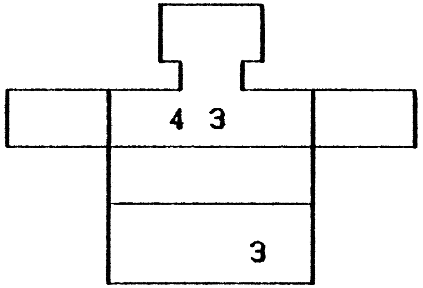
```
IXP =    9  IYP =   12  ZONE =    1
WEIGHT          =       3053.      FORCE         =     105708.
CRUSH ENERGY=    1894553.      MASS FACTOR =   0.84
OCCUPANT OAIS  3        SEATING POSITION 11
AGE = 27          SEX =  1           HEIGHT=  74       WEIGHT= 190
```

FIGURE 108

```
NCSS CASE NO. 370811020  2 PM  THU  11  AUG  1977
     71  PASS CAR  INTERMEDIATE      CHEVROLET          11301
2  CDC EXTENT TO   FRONT      SIDE FROM   11OCLOCK
OAIS=  4   RESTRAINT= NOT USED         EJECT/TRAP= TRAPPED          WEIGHTING F=  1
A V/V SIDE         TYPE CRASH WITH INTERMEDIATE CAR
L=  68  C1= 13  C2= 18  C3= 23  C4= 22  C5= 20  C6= 14  D=  2  ICOD=      2
LATERAL DELTA-V=  17  LONGITUDINAL DELTA-V=  30   DELTA-V =     34
```

```
BODY REGION             CHEST              CHEST             PELVIC-HIP
DIRECTION               BILATERAL          BILATERAL         LEFT
TYPE INJURY             OTHER              FRACTURE          FRACTURE
BODY ELEMENT            PULMONARY          SKELETAL          SKELETAL
INJURY LEVEL            SERIOUS AIS4       SEVERE AIS3       SEVERE AIS3
OBJECT CONTACTED        UNKNOWN            UNKNOWN           UNKNOWN
```



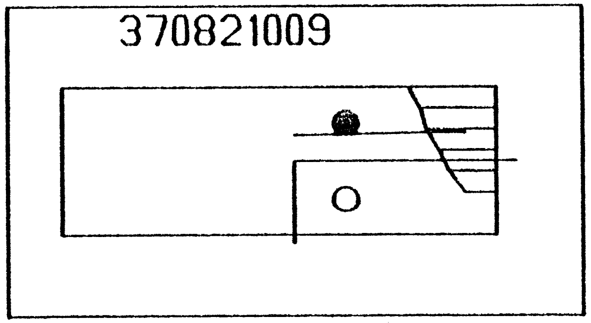


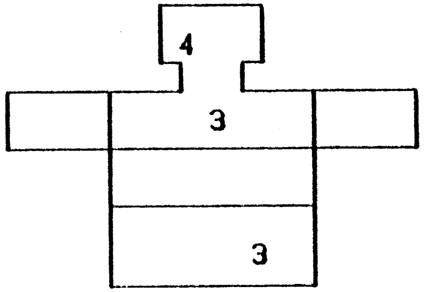
```
IXP =   4  IYP =  53  ZONE =   2
WEIGHT       =       4247.     FORCE        =     93968.
CRUSH ENERGY=    1320071.      MASS FACTOR =   0.62
OCCUPANT OAIS  4       SEATING POSITION 11
AGE = 39          SEX =  1           HEIGHT=  99       WEIGHT= 999
```

FIGURE 109

```
NCSS CASE NO. 370821009  4 PM  SUN  21  AUG  1977
      75  PASS CAR  INTERMEDIATE      BUICK              11101
3  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  4   RESTRAINT= NOT USED         EJECT/TRAP= NONE             WEIGHTING F=  1
A UNLISTED          TYPE CRASH WITH INTERMEDIATE CAR
L=  55  C1= 43  C2= 37  C3= 34  C4= 28  C5= 23  C6= 15  D=-11  ICOD=      2
LATERAL DELTA-V=  11  LONGITUDINAL DELTA-V=  41   DELTA-V =     43
```

```
BODY REGION             HEAD-SKULL       CHEST              KNEE
DIRECTION               WHOLE REGION     RIGHT              LEFT
TYPE INJURY             CONCUSSION       FRACTURE           FRACTURE
BODY ELEMENT            BRAIN            SKELETAL           JOINTS
INJURY LEVEL            SERIOUS AIS4     SEVERE AIS3        SEVERE AIS3
OBJECT CONTACTED        WINDSHIELD       STEERING ASSEMBL   INSTRUMENT PANEL
```



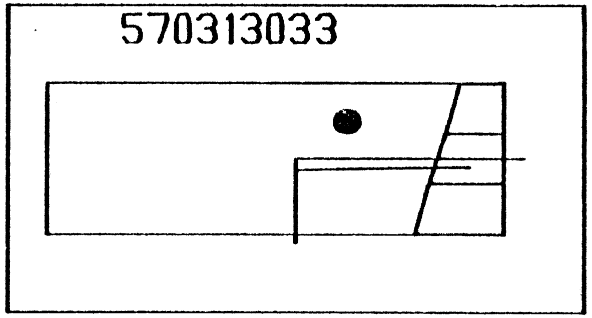


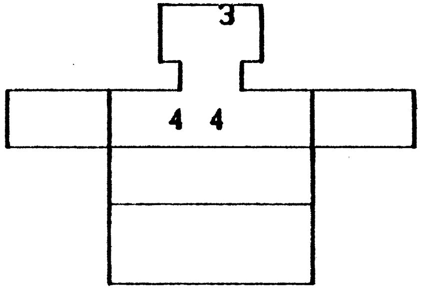
```
IXP =    7 IYP =   30  ZONE =    1
WEIGHT        =       4247.      FORCE        =     95737.
CRUSH ENERGY=    1748440.      MASS FACTOR =   0.95
OCCUPANT OAIS   4        SEATING POSITION 11
AGE = 67           SEX =  1           HEIGHT=  99       WEIGHT= 999
```

FIGURE 110

```
      NCSS CASE NO. 570313033  11PM  SUN  13  MAR  1977
            73  PASS CAR  FULL SIZE         CHEVROLET         11302
      4  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
      OAIS=  4   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
      A V/V HEAD ON      TYPE CRASH WITH FULL-SIZE CAR
      L=  79  C1= 22  C2= 29  C3= 37  C4= 44  C5=  0  C6=  0  D=  0  ICOD=      1
     LATERAL DELTA-V=   2  LONGITUDINAL DELTA-V=  47   DELTA-V =     47

     BODY REGION              CHEST            CHEST            FACE
     DIRECTION                BILATERAL        BILATERAL        SUPERIOR/UPPER
     TYPE INJURY              FRACTURE         OTHER            FRACTURE
     BODY ELEMENT             SKELETAL         PULMONARY        SKELETAL
     INJURY LEVEL             SERIOUS AIS4     SERIOUS AIS4     SEVERE AIS3
     OBJECT CONTACTED         UNKNOWN          UNKNOWN          UNKNOWN
```



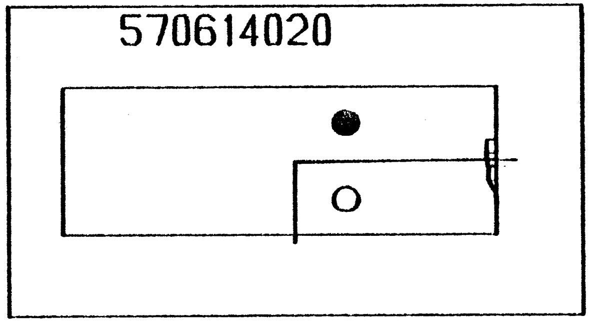


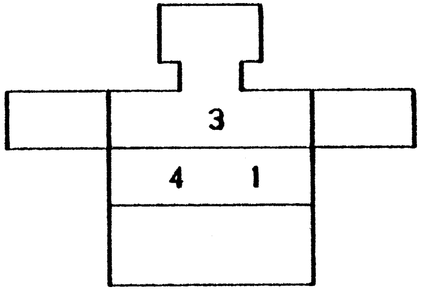
```
      IXP =   7  IYP =  55  ZONE =   2
      WEIGHT       =        4865.      FORCE         =    120465.
      CRUSH ENERGY=    2550938.      MASS FACTOR =   0.99
      OCCUPANT OAIS   4       SEATING POSITION 11
      AGE = 36          SEX =  1           HEIGHT=  72       WEIGHT= 207
```

FIGURE 111

```
NCSS CASE NO. 570614020  2 PM  TUE  14  JUN  1977
      73  PASS CAR  INTERMEDIATE     DODGE            13201
1  CDC EXTENT TO    FRONT      SIDE FROM   12OCLOCK
OAIS=  4    RESTRAINT= NOT USED          EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V SIDE           TYPE CRASH WITH COMPACT CAR
L=  21  C1=  5  C2=  5  C3=  4  C4=  4  C5=  0  C6=  0  D=  0  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =      0
```

```
BODY REGION             ABDOMEN          CHEST            ABDOMEN
DIRECTION               RIGHT            RIGHT            WHOLE REGION
TYPE INJURY             LACERATION       CONTUSION        CONTUSION
BODY ELEMENT            LIVER            PULMONARY        INTEGUMENTARY
INJURY LEVEL            SERIOUS AIS4     SEVERE AIS3      MINOR AIS1
OBJECT CONTACTED        UNKNOWN          UNKNOWN          UNKNOWN
```



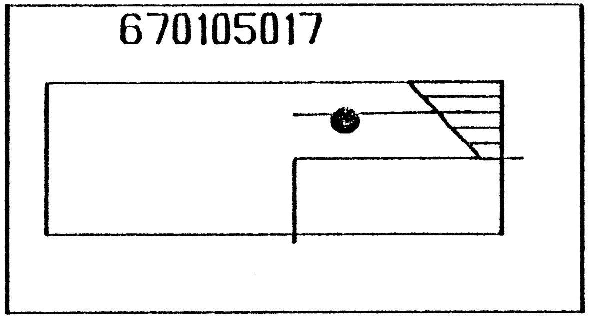


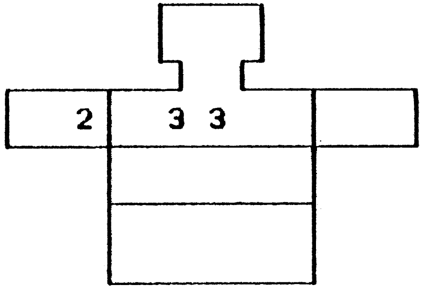
```
IXP =    1  IYP =   49  ZONE =   2
WEIGHT       =      4247.      FORCE        =      9623.
CRUSH ENERGY=      44289.      MASS FACTOR =   1.00
OCCUPANT OAIS   4        SEATING POSITION 11
AGE = 19           SEX =  4           HEIGHT=  99        WEIGHT= 999
```

FIGURE 112

```
NCSS CASE NO. 670105017  7 AM  WED   5  JAN  1977
      70  PASS CAR  FULL SIZE         FORD                12102
4  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  4   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH COMPACT CAR
L=  41  C1= 46  C2= 39  C3= 31  C4= 25  C5= 17  C6= 10  D=-20  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  26   DELTA-V =     26
```

```
BODY REGION                 CHEST              CHEST              SHOULDER
DIRECTION                   RIGHT              RIGHT              RIGHT
TYPE INJURY                 FRACTURE           HEMORRHAGE         FRACTURE
BODY ELEMENT                SKELETAL           PULMONARY          SKELETAL
INJURY LEVEL                SEVERE AIS3        SEVERE AIS3        MODERATE AIS2
OBJECT CONTACTED            STEERING ASSEMBL   STEERING ASSEMBL   STEERING ASSEMBL
```



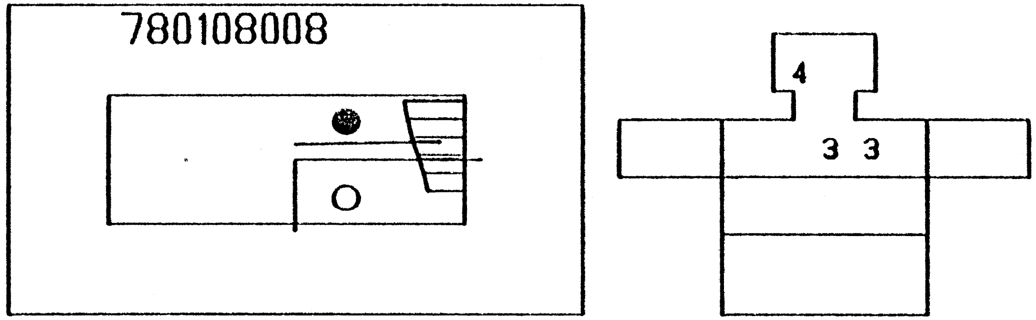


```
IXP =    7 IYP =   19  ZONE =    1
WEIGHT        =         4865.      FORCE        =      54957.
CRUSH ENERGY=    1080175.      MASS FACTOR =   0.89
OCCUPANT OAIS   4        SEATING POSITION 11
AGE = 37            SEX =   2            HEIGHT=   73       WEIGHT= 140
```

FIGURE 113

```
NCSS CASE NO. 780108008  2 PM  SUN   8  JAN  1978
      76  PASS CAR  SUB-COMP/IMPORT   DATSUN            86109
3  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  4   RESTRAINT= NOT USED          EJECT/TRAP= NONE            WEIGHTING F=  1
A V/V REAR          TYPE CRASH WITH INTERMEDIATE CAR
L=  47  C1= 30  C2= 28  C3= 26  C4= 23  C5= 20  C6= 18  D= -7  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  25   DELTA-V =     25
```

```
BODY REGION                HEAD-SKULL        CHEST             CHEST
DIRECTION                  WHOLE REGION      CENTRAL           LEFT
TYPE INJURY                CONCUSSION        CONTUSION         CONTUSION
BODY ELEMENT               BRAIN             HEART             PULMONARY
INJURY LEVEL               SERIOUS AIS4      SEVERE AIS3       SEVERE AIS3
OBJECT CONTACTED           SUNVISOR/FITTING  STEERING ASSEMBL  STEERING ASSEMBL
```

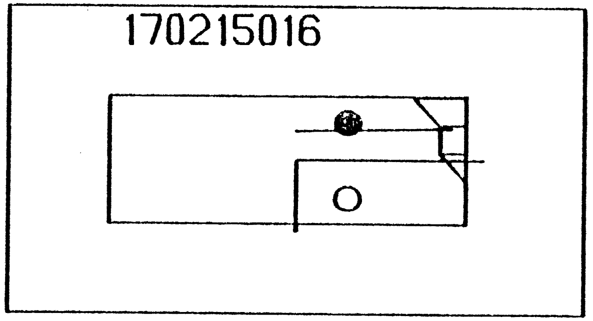


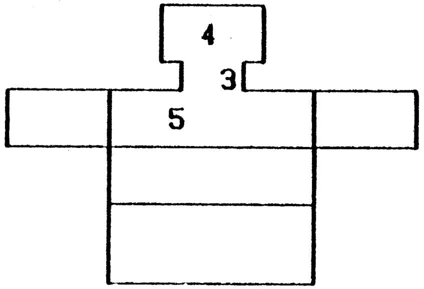
```
IXP =    7  IYP =   36  ZONE =    2
WEIGHT        =       3053.       FORCE         =     85340.
CRUSH ENERGY=    1112215.       MASS FACTOR =   0.98
OCCUPANT OAIS   4        SEATING POSITION 11
AGE  = 27           SEX =  2           HEIGHT=  63        WEIGHT= 140
```

FIGURE 114

```
NCSS CASE NO. 170215016  2 PM  TUE  15  FEB  1977
      71  PASS CAR  SUB-COMP/USA      CHEVROLET          11318
3  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH FULL-SIZE CAR
L=  44  C1= 26  C2= 13  C3= 13  C4=  0  C5=  0  C6=  0  D=-11  ICOD=      1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  33   DELTA-V =     33
```

```
BODY REGION                 CHEST             HEAD-SKULL        NECK
DIRECTION                   CENTRAL           POSTERIOR/BACK    POSTERIOR/BACK
TYPE INJURY                 LACERATION        CONTUSION         FRACTURE
BODY ELEMENT                ARTERIES          BRAIN             VERTEBRAE
INJURY LEVEL                CRITICAL AIS5     SERIOUS AIS4      SEVERE AIS3
OBJECT CONTACTED            STEERING ASSEMBL  MIRRORS           UNK EXTER OBJECT
```



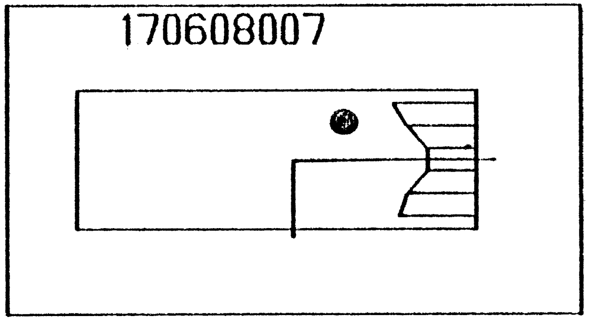


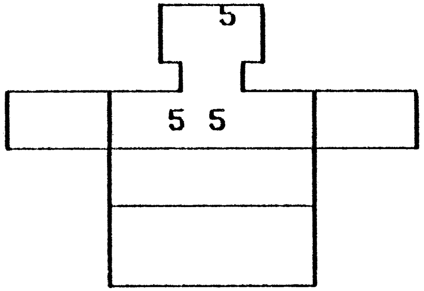
```
IXP =   4  IYP =  25  ZONE =   1
WEIGHT        =      3053.      FORCE        =     44850.
CRUSH ENERGY=    380202.      MASS FACTOR =   0.93
OCCUPANT OAIS   5        SEATING POSITION 11
AGE = 18           SEX =  2            HEIGHT=  64       WEIGHT= 115
```

FIGURE 115

```
NCSS CASE NO. 170608007  11PM  WED   8  JUN  1977
      71  WAGON      COMPACT            AMERICAN MOTORS   14108
4  CDC EXTENT TO    FRONT       SIDE FROM    12OCLOCK
OAIS=  5   RESTRAINT= NOT USED          EJECT/TRAP= UNKNOWN          WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH INTERMEDIATE CAR
L=  59  C1= 41  C2= 34  C3= 24  C4= 24  C5= 34  C6= 38  D=  0  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  42   DELTA-V =     42
```

```
BODY REGION                CHEST            CHEST             HEAD-SKULL
DIRECTION                  RIGHT            CENTRAL           POSTERIOR/BACK
TYPE INJURY                LACERATION       LACERATION        CONTUSION
BODY ELEMENT               ARTERIES         HEART             BRAIN
INJURY LEVEL               CRITICAL AIS5    CRITICAL AIS5     CRITICAL AIS5
OBJECT CONTACTED           UNKNOWN          UNKNOWN           UNKNOWN
```



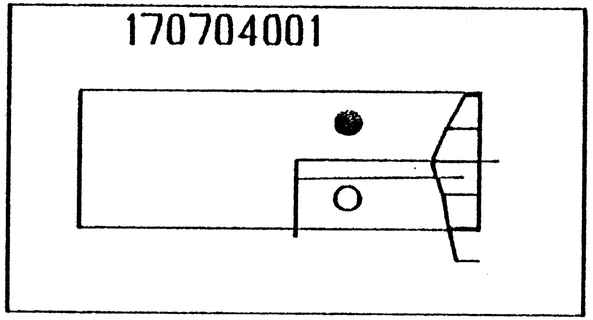


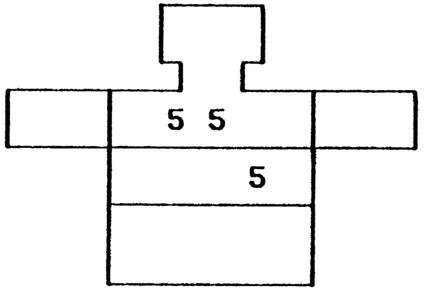
```
IXP =    8  IYP =   49  ZONE =    2
WEIGHT        =        3547.      FORCE        =    136684.
CRUSH ENERGY=    2337408.     MASS FACTOR =    1.00
OCCUPANT OAIS  5        SEATING POSITION 11
AGE = 21          SEX =   1           HEIGHT=   71       WEIGHT= 156
```

FIGURE 116

```
NCSS CASE NO. 170704001  1 AM  MON    4  JUL  1977
      75  PASS CAR  COMPACT            BUICK               11108
9  CDC EXTENT TO    FRONT      SIDE FROM   120CLOCK
OAIS=  5   RESTRAINT= NOT USED          EJECT/TRAP= NONE              WEIGHTING F=  1
A V/V HEAD ON        TYPE CRASH WITH FULL-SIZE CAR
L=  87  C1=  8  C2= 17  C3= 24  C4= 18  C5= 15  C6= 11  D=  9  ICOD=       2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  56   DELTA-V =     56
```

```
BODY REGION                 CHEST             CHEST             ABDOMEN
DIRECTION                   CENTRAL           CENTRAL           RIGHT
TYPE INJURY                 LACERATION        LACERATION        LACERATION
BODY ELEMENT                ARTERIES          HEART             LIVER
INJURY LEVEL                CRITICAL AIS5     CRITICAL AIS5     CRITICAL AIS5
OBJECT CONTACTED            UNKNOWN           UNKNOWN           UNKNOWN
```



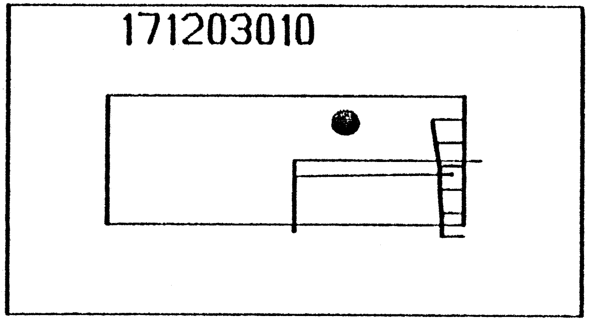


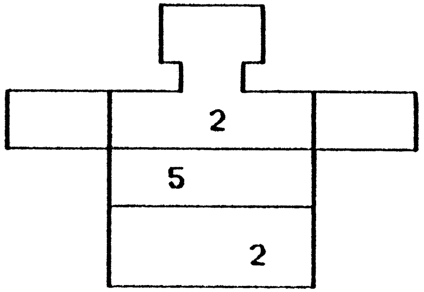
```
IXP =   4  IYP =  61  ZONE =   2
WEIGHT        =       3547.      FORCE         =    114456.
CRUSH ENERGY=    1131485.      MASS FACTOR =   0.97
OCCUPANT OAIS  5        SEATING POSITION 11
AGE = 55           SEX =  1           HEIGHT=  62       WEIGHT= 168
```

FIGURE 117

```
NCSS CASE NO. 171203010  11AM  SAT   3  DEC  1977
      76  PASS CAR  FOREIGN SPORTS    FIAT                 76119
2  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= LAP ONLY          EJECT/TRAP= NONE              WEIGHTING F=  1
A CHAIN CRASH       TYPE CRASH WITH INTERMEDIATE CAR
L=  61  C1= 16  C2= 14  C3= 12  C4= 12  C5= 11  C6= 11  D=  9  ICOD=      2
LATERAL DELTA-V=    0  LONGITUDINAL DELTA-V=  19   DELTA-V =      19
```

```
BODY REGION              ABDOMEN           CHEST              LEG
DIRECTION                INFERIOR/LOWER    RIGHT              LEFT
TYPE INJURY              LACERATION        FRACTURE           FRACTURE
BODY ELEMENT             DIGESTIVE         SKELETAL           SKELETAL
INJURY LEVEL             CRITICAL AIS5     MODERATE AIS2      MODERATE AIS2
OBJECT CONTACTED         RESTRAINT WEB     STEERING ASSEMBL   HARDWARE ITEMS
```



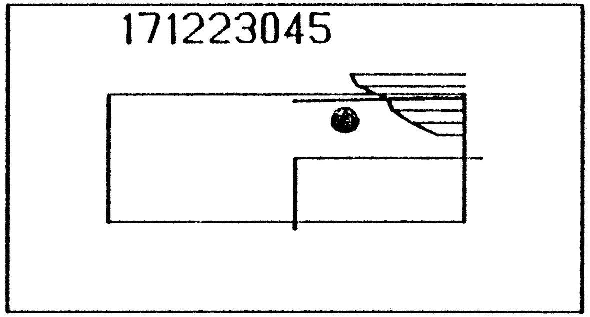


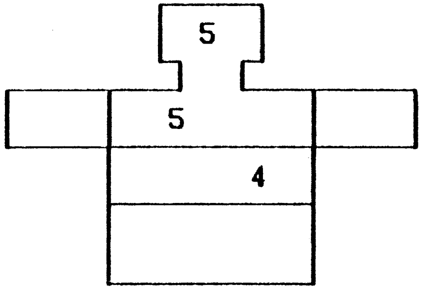
```
IXP =   3 IYP =  60  ZONE =   2
WEIGHT      =     3053.      FORCE        =     60010.
CRUSH ENERGY=    419762.     MASS FACTOR =   0.98
OCCUPANT OAIS   5       SEATING POSITION 11
AGE = 55           SEX =  1          HEIGHT=  69       WEIGHT= 155
```

FIGURE 118

```
NCSS CASE NO. 171223045  8 PM  FRI  23  DEC  1977
      71  PASS CAR  SUB-COMP/USA      FORD                 12118
6  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED         EJECT/TRAP= PART. EJECTION    WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH INTERMEDIATE CAR
L=  32  C1= 56  C2= 52  C3= 38  C4= 35  C5= 26  C6= 13  D=-28  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  36   DELTA-V =     36
```

```
BODY REGION                CHEST            HEAD-SKULL        ABDOMEN
DIRECTION                  CENTRAL          POSTERIOR/BACK    RIGHT
TYPE INJURY                LACERATION       CONTUSION         LACERATION
BODY ELEMENT               ARTERIES         BRAIN             LIVER
INJURY LEVEL               CRITICAL AIS5    CRITICAL AIS5     SERIOUS AIS4
OBJECT CONTACTED           STEERING ASSEMBL SUNVISOR/ROOF     STEERING ASSEMBL
```



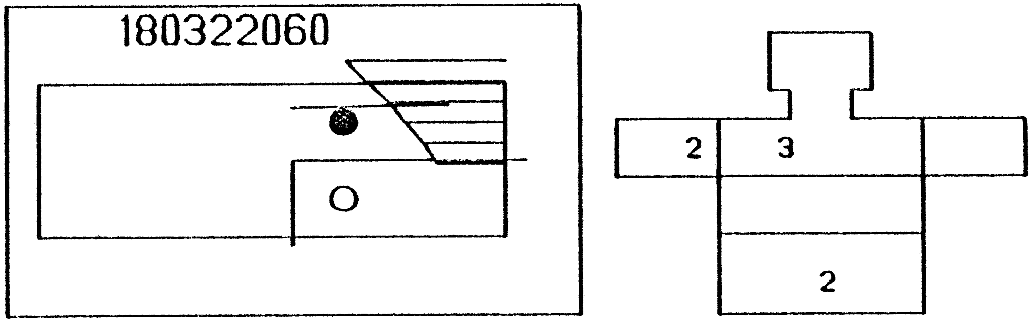


```
IXP =  11  IYP =   3  ZONE =   1
WEIGHT       =     3053.      FORCE        =     87458.
CRUSH ENERGY=   1849306.      MASS FACTOR =   0.77
OCCUPANT OAIS  5        SEATING POSITION 11
AGE = 38          SEX =  1          HEIGHT=  69       WEIGHT= 240
```

FIGURE 119

```
NCSS CASE NO. 180322060  11PM  WED  22  MAR  1978
      73  PASS CAR  PERSONAL LUXURY   FORD                12105
6  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  3   RESTRAINT= NOT USED         EJECT/TRAP= NONE             WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH INTERMEDIATE CAR
L=  54  C1= 78  C2= 68  C3= 57  C4= 49  C5= 40  C6= 33  D=-25  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  42   DELTA-V =     42
```

```
BODY REGION                 CHEST            KNEE              SHOULDER
DIRECTION                   UNKNOWN          LEFT              RIGHT
TYPE INJURY                 OTHER            FRACTURE          FRACTURE
BODY ELEMENT                PULMONARY        JOINTS            SKELETAL
INJURY LEVEL                SEVERE AIS3      MODERATE AIS2     MODERATE AIS2
OBJECT CONTACTED            STEERING ASSEMBL INSTRUMENT PANEL  STEERING ASSEMBL
```

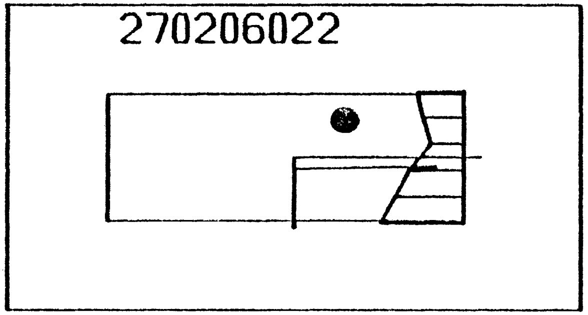


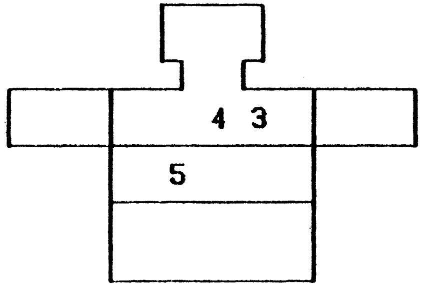
```
IXP =   12  IYP =   13  ZONE =    1
WEIGHT        =        5309.      FORCE          =    123977.
CRUSH ENERGY=    4030258.      MASS FACTOR =   0.85
OCCUPANT OAIS  3          SEATING POSITION 11
AGE = 31           SEX =  1          HEIGHT=  67       WEIGHT= 999
```

FIGURE 120

```
NCSS CASE NO. 270206022  6 AM  SUN   6  FEB  1977
      75  WAGON     SUB-COMP/USA      FORD              12118
4  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= UNKNOWN          EJECT/TRAP= NONE             WEIGHTING F=  1
A V/V SIDE          TYPE CRASH WITH LUXURY CAR
L=  70  C1= 23  C2= 20  C3= 16  C4= 27  C5= 34  C6= 41  D=  0  ICOD=      2
LATERAL DELTA-V=   7  LONGITUDINAL DELTA-V=  42   DELTA-V =     42
```

```
BODY REGION                 ABDOMEN            CHEST              CHEST
DIRECTION                   RIGHT              RIGHT              BILATERAL
TYPE INJURY                 LACERATION         FRACTURE           CONTUSION
BODY ELEMENT                LIVER              SKELETAL           PULMONARY
INJURY LEVEL                CRITICAL AIS5      SERIOUS AIS4       SEVERE AIS3
OBJECT CONTACTED            STEERING ASSEMBL   STEERING ASSEMBL   STEERING ASSEMBL
```



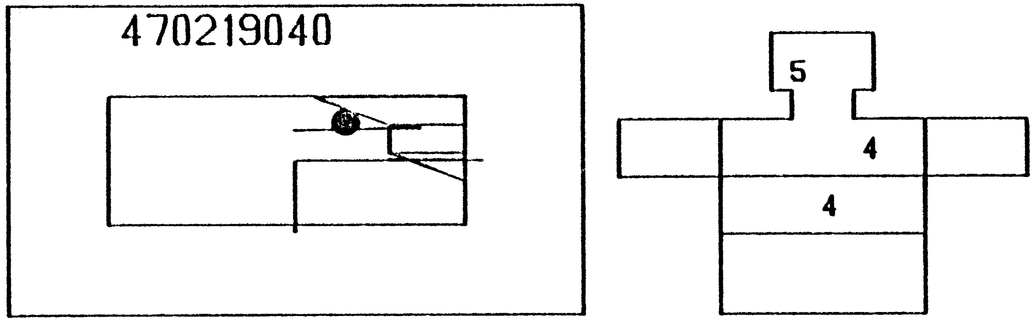


```
IXP =    7 IYP =   57  ZONE =    2
WEIGHT        =       3053.      FORCE        =     135067.
CRUSH ENERGY=    1970428.      MASS FACTOR =   0.99
OCCUPANT OAIS  5       SEATING POSITION 11
AGE = 38           SEX =  4           HEIGHT=  65       WEIGHT= 151
```

FIGURE 121

```
NCSS CASE NO. 470219040  3 AM  SAT  19  FEB  1977
      71  PASS CAR  SPECIALTY/PONY    FORD                 12106
7  CDC EXTENT TO   FRONT      SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED         EJECT/TRAP= UNKNOWN            WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH FULL-SIZE CAR
L=  44  C1= 74  C2= 37  C3= 37  C4=  0  C5=  0  C6=  0  D=-11  ICOD=       1
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  44   DELTA-V =     44
```

```
BODY REGION                HEAD-SKULL         ABDOMEN          CHEST
DIRECTION                  SUPERIOR/UPPER     RIGHT            RIGHT
TYPE INJURY                CONCUSSION         LACERATION       FRACTURE
BODY ELEMENT               BRAIN              LIVER            SKELETAL
INJURY LEVEL               CRITICAL AIS5      SERIOUS AIS4     SERIOUS AIS4
OBJECT CONTACTED           UNKNOWN            UNKNOWN          UNKNOWN
```

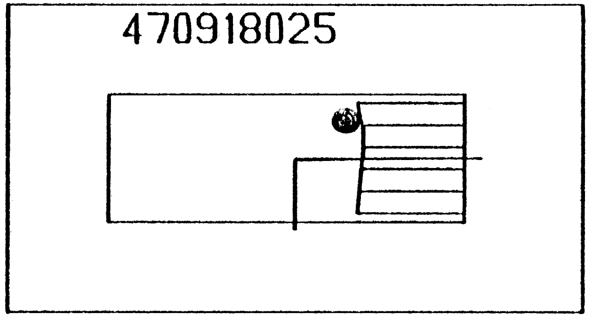


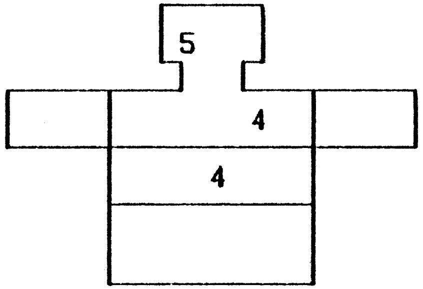
```
IXP =  12  IYP =  25  ZONE =   1
WEIGHT       =       3053.      FORCE        =   119942.
CRUSH ENERGY=   2774886.      MASS FACTOR =   0.92
OCCUPANT OAIS   5       SEATING POSITION 11
AGE = 24           SEX =  1          HEIGHT=  99       WEIGHT= 999
```

FIGURE 122

```
NCSS CASE NO. 470918025  11AM  SUN  18  SEP  1977
      77  WAGON     SUB-COMP/USA      CHEVROLET         11318
5  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED         EJECT/TRAP= TRAPPED          WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH COMPACT CAR
L=  58  C1= 53  C2= 50  C3= 50  C4= 51  C5= 52  C6= 53  D=  0  ICOD=      2
LATERAL DELTA-V=  12  LONGITUDINAL DELTA-V=  70   DELTA-V =     71
```

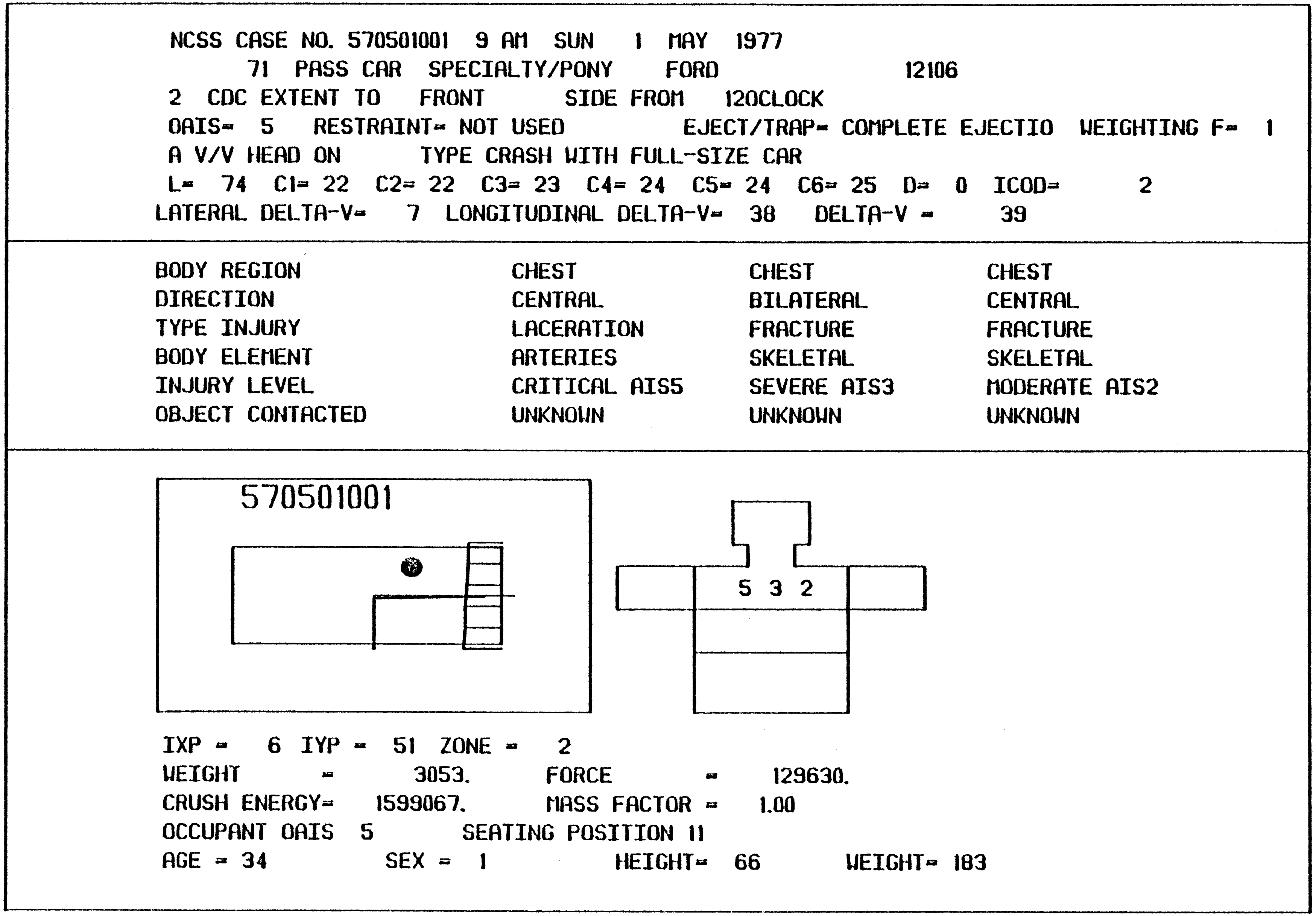
```
BODY REGION                HEAD-SKULL       ABDOMEN           CHEST
DIRECTION                  WHOLE REGION     RIGHT             RIGHT
TYPE INJURY                CONCUSSION       LACERATION        FRACTURE
BODY ELEMENT               BRAIN            LIVER             SKELETAL
INJURY LEVEL               CRITICAL AIS5    SERIOUS AIS4      SERIOUS AIS4
OBJECT CONTACTED           WINDSHIELD       STEERING ASSEMBL  STEERING ASSEMBL
```





```
IXP =  14  IYP =  50  ZONE =   2
WEIGHT        =       3053.      FORCE         =    216672.
CRUSH ENERGY=    5693341.      MASS FACTOR =   1.00
OCCUPANT OAIS  5       SEATING POSITION 11
AGE = 35          SEX =  1           HEIGHT=  99       WEIGHT= 999
```

FIGURE 123



```
NCSS CASE NO. 570501001  9 AM  SUN   1  MAY  1977
      71  PASS CAR  SPECIALTY/PONY    FORD               12106
2  CDC EXTENT TO    FRONT       SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED         EJECT/TRAP= COMPLETE EJECTIO  WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH FULL-SIZE CAR
L=  74  C1= 22  C2= 22  C3= 23  C4= 24  C5= 24  C6= 25  D=  0  ICOD=      2
LATERAL DELTA-V=   7  LONGITUDINAL DELTA-V=  38   DELTA-V =     39

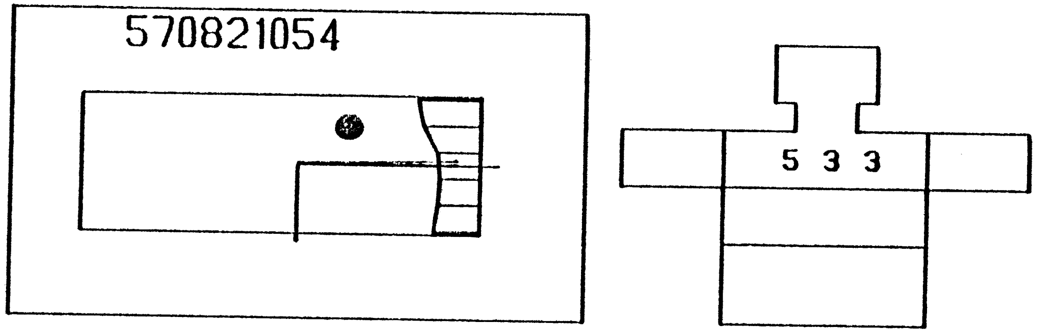
BODY REGION              CHEST            CHEST            CHEST
DIRECTION                CENTRAL          BILATERAL        CENTRAL
TYPE INJURY              LACERATION       FRACTURE         FRACTURE
BODY ELEMENT             ARTERIES         SKELETAL         SKELETAL
INJURY LEVEL             CRITICAL AIS5    SEVERE AIS3      MODERATE AIS2
OBJECT CONTACTED         UNKNOWN          UNKNOWN          UNKNOWN
```

```
IXP =   6  IYP =  51  ZONE =   2
WEIGHT       =        3053.      FORCE        =    129630.
CRUSH ENERGY=     1599067.      MASS FACTOR =   1.00
OCCUPANT OAIS  5        SEATING POSITION 11
AGE = 34           SEX =  1          HEIGHT=  66       WEIGHT= 183
```

FIGURE 124

```
NCSS CASE NO. 570821054  6 AM  SUN  21  AUG  1977
     71  PASS CAR  COMPACT            MERCEDES          65108
3  CDC EXTENT TO    FRONT     SIDE FROM   12OCLOCK
OAIS=  5   RESTRAINT= NOT USED          EJECT/TRAP= NONE                 WEIGHTING F=  1
A V/V HEAD ON      TYPE CRASH WITH LUXURY CAR
L=  69  C1= 31  C2= 28  C3= 21  C4= 20  C5= 21  C6= 23  D=  0  ICOD=      2
LATERAL DELTA-V=   6  LONGITUDINAL DELTA-V=  32   DELTA-V =     33
```

BODY REGION	CHEST	CHEST	CHEST
DIRECTION	CENTRAL	BILATERAL	BILATERAL
TYPE INJURY	LACERATION	FRACTURE	CONTUSION
BODY ELEMENT	ARTERIES	SKELETAL	PULMONARY
INJURY LEVEL	CRITICAL AIS5	SEVERE AIS3	SEVERE AIS3
OBJECT CONTACTED	STEERING ASSEMBL	STEERING ASSEMBL	STEERING ASSEMBL

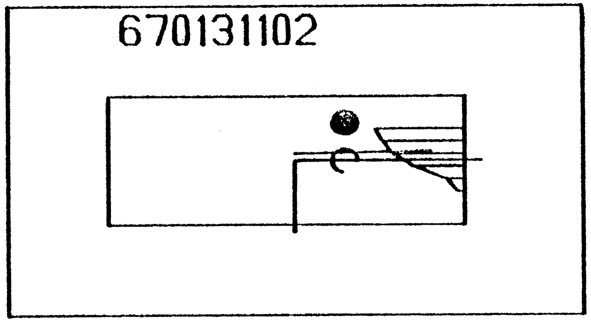


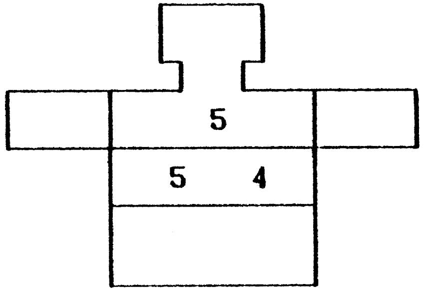
```
IXP =   6  IYP =  46  ZONE =   2
WEIGHT      =       3547.      FORCE        =   122914.
CRUSH ENERGY=   1604762.       MASS FACTOR =   1.00
OCCUPANT OAIS  5        SEATING POSITION 11
AGE = 29          SEX =  1          HEIGHT=  70       WEIGHT= 160
```

FIGURE 125

```
NCSS CASE NO. 670131102  8 PM  MON  31  JAN  1977
      74  PASS CAR  SUB-COMP/IMPORT   VOLKSWAGEN        66109
6  CDC EXTENT TO   FRONT       SIDE FROM   120CLOCK
OAIS=  5   RESTRAINT= NOT USED          EJECT/TRAP= UNKNOWN           WEIGHTING F=  1
A V/V HEAD ON       TYPE CRASH WITH FULL-SIZE CAR
L=  33  C1= 44  C2= 40  C3= 35  C4= 25  C5=  9  C6=  3  D=  0  ICOD=      2
LATERAL DELTA-V=   8  LONGITUDINAL DELTA-V=  48   DELTA-V =     49
```

BODY REGION	ABDOMEN	CHEST	ABDOMEN
DIRECTION	RIGHT	CENTRAL	LEFT
TYPE INJURY	LACERATION	LACERATION	RUPTURE
BODY ELEMENT	LIVER	ARTERIES	SPLEEN
INJURY LEVEL	CRITICAL AIS5	CRITICAL AIS5	SERIOUS AIS4
OBJECT CONTACTED	UNKNOWN	UNKNOWN	UNKNOWN



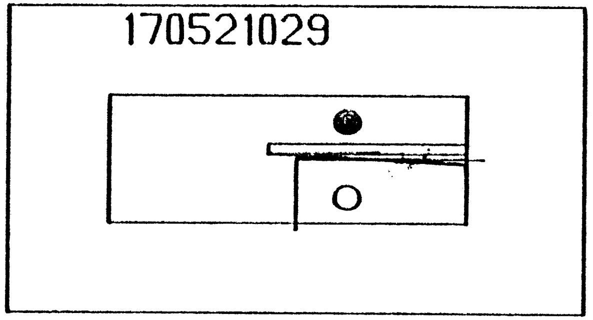


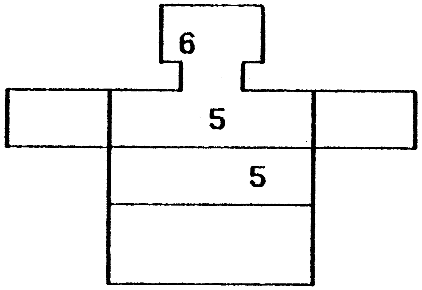
```
IXP =   9  IYP =  42  ZONE =   2
WEIGHT       =      3053.      FORCE        =      65317.
CRUSH ENERGY=   1124939.       MASS FACTOR =   1.00
OCCUPANT OAIS   5        SEATING POSITION 11
AGE = 23          SEX =  1            HEIGHT=  72       WEIGHT= 230
```

FIGURE 126

```
NCSS CASE NO. 170521029  10AM  SAT  21  MAY  1977
      76  PASS CAR  SUB-COMP/USA       FORD              12118
9  CDC EXTENT TO    FRONT      SIDE FROM   12OCLOCK
OAIS=  6   RESTRAINT= NOT USED        EJECT/TRAP= NONE            WEIGHTING F=  1
A UNLISTED           TYPE CRASH WITH FULL-SIZE CAR
L=  16  C1= 97  C2= 97  C3=  0  C4=  0  C5=  0  C6=  0  D=  0  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  49   DELTA-V =     49
```

```
BODY REGION                 HEAD-SKULL        CHEST            ABDOMEN
DIRECTION                   WHOLE REGION      CENTRAL          RIGHT
TYPE INJURY                 CRUSHING          LACERATION       LACERATION
BODY ELEMENT                ALL SYSTEMS       ARTERIES         LIVER
INJURY LEVEL                MAXIMUM-FATAL     CRITICAL AIS5    CRITICAL AIS5
OBJECT CONTACTED            UNKNOWN           UNKNOWN          UNKNOWN
```



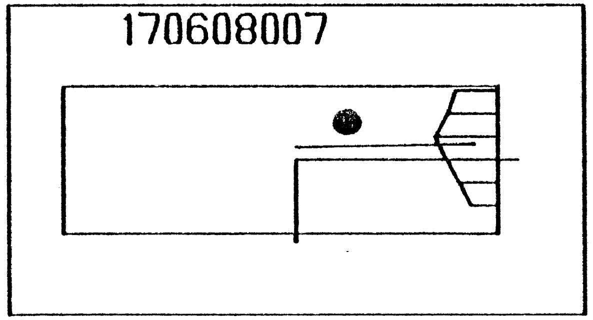


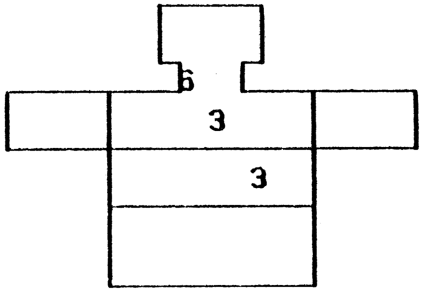
```
IXP =  24  IYP =  44  ZONE =   2
WEIGHT       =       3053.       FORCE        =     56700.
CRUSH ENERGY=   2453573.      MASS FACTOR =    1.00
OCCUPANT OAIS  6        SEATING POSITION 11
AGE = 64           SEX =  1           HEIGHT=  71        WEIGHT= 140
```

FIGURE 127

NCSS CASE NO. 170608007 11PM WED 8 JUN 1977
73 PASS CAR INTERMEDIATE OLDSMOBILE 11401
3 CDC EXTENT TO FRONT SIDE FROM 12OCLOCK
OAIS= 6 RESTRAINT= NOT USED EJECT/TRAP= NONE WEIGHTING F= 1
A V/V HEAD ON TYPE CRASH WITH COMPACT CAR
L= 60 C1= 21 C2= 25 C3= 31 C4= 25 C5= 19 C6= 13 D= -6 ICOD= 2
LATERAL DELTA-V= 0 LONGITUDINAL DELTA-V= 31 DELTA-V = 31

BODY REGION	NECK	CHEST	ABDOMEN
DIRECTION	POSTERIOR/BACK	BILATERAL	RIGHT
TYPE INJURY	FRACTURE	CONTUSION	CONTUSION
BODY ELEMENT	VERTEBRAE	PULMONARY	LIVER
INJURY LEVEL	MAXIMUM-FATAL	SEVERE AIS3	SEVERE AIS3
OBJECT CONTACTED	UNKNOWN	UNKNOWN	UNKNOWN



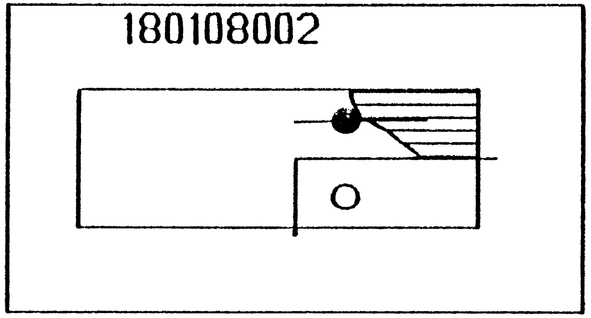


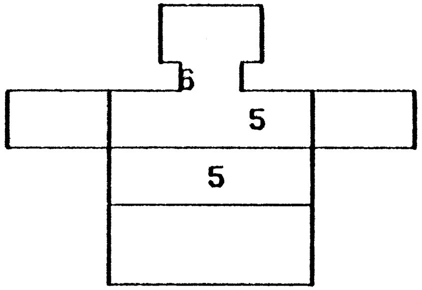
IXP = 5 IYP = 39 ZONE = 2
WEIGHT = 4247. FORCE = 84082.
CRUSH ENERGY= 1214338. MASS FACTOR = 0.99
OCCUPANT OAIS 6 SEATING POSITION 11
AGE = 21 SEX = 1 HEIGHT= 72 WEIGHT= 245

FIGURE 128

```
  NCSS CASE NO. 180108002  10PM  SUN   8  JAN  1978
        78  PASS CAR  COMPACT           FORD               12108
  6  CDC EXTENT TO   FRONT       SIDE FROM   12OCLOCK
  OAIS=  6   RESTRAINT= NOT USED         EJECT/TRAP= NONE              WEIGHTING F=  1
  A V/V HEAD ON       TYPE CRASH WITH FULL-SIZE CAR
  L=  34  C1= 63  C2= 61  C3= 57  C4= 45  C5= 37  C6= 28  D=-18  ICOD=      2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=  44   DELTA-V =     44
```

```
BODY REGION                NECK               ABDOMEN             CHEST
DIRECTION                  POSTERIOR/BACK     RIGHT               CENTRAL
TYPE INJURY                FRACTURE           LACERATION          LACERATION
BODY ELEMENT               VERTEBRAE          LIVER               ARTERIES
INJURY LEVEL               MAXIMUM-FATAL      CRITICAL AIS5       CRITICAL AIS5
OBJECT CONTACTED           HEAD REST          STEERING ASSEMBL    STEERING ASSEMBL
```



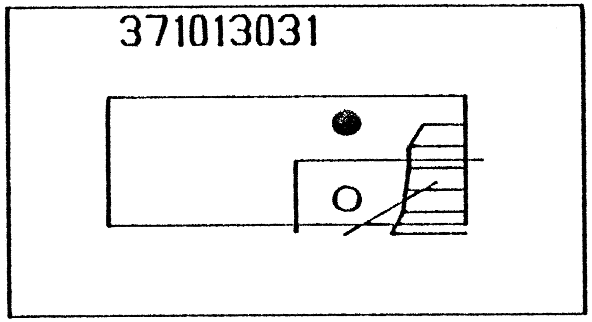


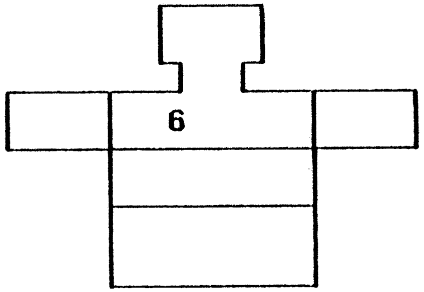
```
IXP =  13  IYP =  22  ZONE =   1
WEIGHT       =      3547.      FORCE        =    121313.
CRUSH ENERGY=    3263204.      MASS FACTOR =   0.90
OCCUPANT OAIS  6        SEATING POSITION 11
AGE = 44           SEX =  2          HEIGHT=  64       WEIGHT= 150
```

FIGURE 129

```
NCSS CASE NO. 371013031  8 PM  THU  13  OCT  1977
      71  PASS CAR  SUB-COMP/IMPORT   VOLKSWAGEN        66109
4  CDC EXTENT TO   FRONT      SIDE FROM   11OCLOCK
OAIS=  6   RESTRAINT= NOT USED        EJECT/TRAP= UNKNOWN          WEIGHTING F=  1
A UNLISTED          TYPE CRASH WITH INTERMEDIATE CAR
L=  57  C1= 21  C2= 28  C3= 28  C4= 30  C5= 31  C6= 37  D= 10  ICOD=      2
LATERAL DELTA-V=   7  LONGITUDINAL DELTA-V=   0   DELTA-V =      7
```

```
BODY REGION               CHEST            UNKNOWN           UNKNOWN
DIRECTION                 WHOLE REGION     UNKNOWN           UNKNOWN
TYPE INJURY               CRUSHING         OTHER             OTHER
BODY ELEMENT              ALL SYSTEMS      MISSING           MISSING
INJURY LEVEL              MAXIMUM-FATAL    INJURED/UNK SEV   INJURED/UNK SEV
OBJECT CONTACTED          UNKNOWN          MISSING           MISSING
```



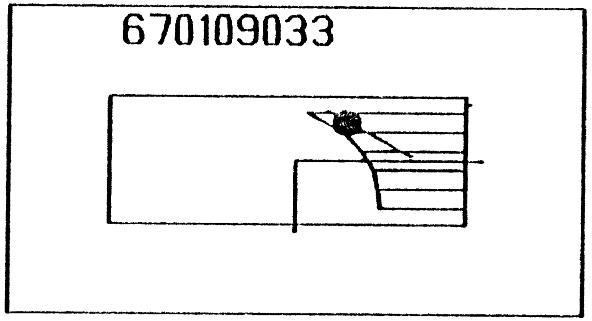


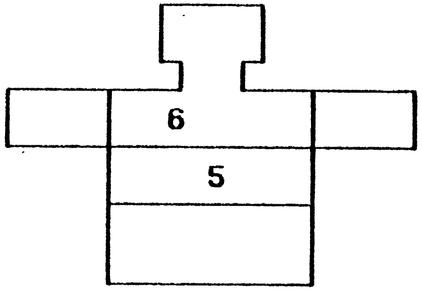
```
IXP =    8  IYP =  67  ZONE =    2
WEIGHT        =      3053.      FORCE         =    142907.
CRUSH ENERGY=    2549415.       MASS FACTOR =    0.59
OCCUPANT OAIS   6          SEATING POSITION 11
AGE = 59          SEX =  1          HEIGHT=  99       WEIGHT= 999
```

FIGURE 130

```
NCSS CASE NO. 670109033  MIDN  SUN   9  JAN  1977
      72  PASS CAR  SUB-COMP/IMPORT   VOLKSWAGEN        66109
8  CDC EXTENT TO    FRONT       SIDE FROM   1 OCLOCK
OAIS=  6   RESTRAINT= NOT USED         EJECT/TRAP= TRAPPED          WEIGHTING F=  1
A UNLISTED          TYPE CRASH WITH FULL-SIZE CAR
L=  50  C1= 78  C2= 60  C3= 51  C4= 45  C5= 43  C6= 42  D=  0  ICOD=       2
LATERAL DELTA-V=   0  LONGITUDINAL DELTA-V=   0   DELTA-V =       0
```

```
BODY REGION              CHEST            ABDOMEN          UNKNOWN
DIRECTION                WHOLE REGION     RIGHT            UNKNOWN
TYPE INJURY              CRUSHING         LACERATION       OTHER
BODY ELEMENT             ALL SYSTEMS      LIVER            MISSING
INJURY LEVEL             MAXIMUM-FATAL    CRITICAL AIS5    INJURED/UNK SEV
OBJECT CONTACTED         UNKNOWN          UNKNOWN          UNKNOWN
```





```
IXP =  15  IYP =  46  ZONE =   2
WEIGHT      =      3053.      FORCE        =    218140.
CRUSH ENERGY=   6932804.      MASS FACTOR =   0.76
OCCUPANT OAIS   6       SEATING POSITION 11
AGE = 38          SEX =  1           HEIGHT=  68       WEIGHT= 170
```

FIGURE 131