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# INJURY CRITERIA MODEL FOR RESTRAINT SYSTEM EFFECTIVENESS EVALUATION

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16. Abstract

This report describes an injury criteria model, formulated in computer language and a restraint system effectiveness index for evaluating the degree to which the vehicle environment can prevent or reduce occupant injuries. The need for criteria of this type is based on the fact that, if the degree of protection offered to a vehicle occupant by a restraint system or a vehicle interior (a function of the distribution and magnitude of the forces transmitted to the occupant) could be expressed in quantitative terms, then: (1) more meaningful comparisons could be made between restraint configurations; and, (2) areas of needed biomechanical research and statistical accident investigations could be more readily identified on the basis of the sensitivity of the results when the injury or effectiveness criteria are applied. The injury criteria model consists of three parts: (1) an injury rating based on available human tolerance data including type of injury, seriousness and the magnitude of physical quantities such as force and acceleration which are related to injury production; (2) a relative motion criterion based on the extent to which adjacent body segments can move with respect to one another; and, (3) an index giving the probability of the crash event being studied. The analytical effectiveness index is hypothesized to be a function of the parameters defining a restraint environment (occupant, vehicle interior and restraints, and crash definition), the probability that an occupant will be using the vehicle location for which the restraint system is provided, and the probability that the restraint system will be in use by the occupant. The models are based on an extensive review of the literature and examples of their use given.

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# 1.0 INTRODUCTION

This report deals with the development of an injury criteria model, formulated in computer language, and a restraint system effectiveness index for evaluating the degree to which the vehicle environment can prevent serious occupant injuries. The need for criteria of this type is based on the fact that, if the degree of protection offered to a vehicle occupant by a restraint system or a vehicle interior (a function of the distribution and magnitude of the forces transmitted to the occupant) could be expressed in quantitative terms, then: (1) more meaningful comparisons could be made between various restraint configurations; and, (2) areas of needed biomechanical research and statistical accident investigations could be more readily identified on the basis of the sensitivity of the results when applying the injury or effectiveness criteria.

The injury criteria model has been programmed for use with the HSRI Two- and Three-Dimensional Mathematical Crash Victim Simulators but also can be applied to experimental data gathered from impact sled or barrier crash tests. It consists of three parts: (1) an injury rating based on available human tolerance data including type of injury, seriousness, and the magnitude of physical quantities such as force and acceleration which are related to injury production; (2) a relative motion criterion based on the extent to which adjacent body segments can move with respect to one another; and, (3) an index reflecting the probability of a single simulated crash event.

This injury criteria model is based on an extensive review of the state of the art of impact tolerance data. The literature which was studied is based on clinical studies of accident victims as well as impact sled tests on both human volunteers and animal subjects. Much of the research which has been carried out does not offer an adequate data base for an injury criteria model for several reasons - human clinical studies lack precise information describing the accident such as velocity of the impacting vehicle; human volunteer tests have necessary limitations on the level of impact; and laboratory animal tests lack techniques for scaling observed injuries to man.

In order to rate the overall protective capacity of a restraint system, an analytical effectiveness index (M) has been developed. Use of this index involves application of the injury criteria model to various occupant sizes, impact velocities, impact directions, etc. Thus, the effectiveness index (M) of a particular restraint system is based on multiple applications of the injury criteria model. Applications of this index are made to general restraint system performance evaluation, to use in connection with estimating compliance to motor vehicle safety standards, to estimation of the protective payoff offered by the introduction of safety-related motor vehicle hardware as a function of the probability of usage of such hardware, and to updating of the injury criteria model.

In addition to this introductory section, the report has five parts. The injury criteria model is presented in part 2.0 with a discussion of its basis and applications. This is followed in part 3.0 by a review of the development of the injury criteria model including the literature sources from which data were gathered. Part 4.0 provides data on the probability of occurrence of various accident situations and part 5.0 shows example applications of the injury criteria model, used in conjunction with the Two- and Three-Dimensional Mathematical Crash Victim Simulators. Part 6.0 introduces the analytical restraint system effectiveness index (M) and provides sample applications.

# 2.0 THE INJURY CRITERIA MODEL

The injury criteria model presented in this part of the report includes a severity rating for various types of injuries based on available human impact tolerance data and a probability index reflecting the likelihood of a particular type of collision situation. The basis for and use of the criteria are explained.

## 2.1 BASIS FOR THE INJURY CRITERIA MODEL

A major problem in developing improved occupant-protecting restraint systems has been the lack of a method for rating in any consistent and quantitative manner test results generated in the many experimental research studies which have been conducted in the past several years. Thousands of impact sled tests, full-scale vehicle barrier collisions, and impact studies using laboratory animals have produced body accelerations, seat belt forces, motion profiles, physiological data, etc. Much of this data is buried in lengthy reports and film libraries. It is rare when comparable data are gathered in geographically separated laboratories. Surprisingly, it is also rare when comparable data are gathered in two different research projects within the same laboratory even though the end objectives may be the same - improvement of restraint system performance.

The problem is to define a measure of performance for restraint systems which can be universally applied. The ultimate measure of performance for a restraint system is based entirely on the level of protection offered to the occupant when the system is called upon to accomplish the task for which it was designed. Thus, the performance rating model should consist of a quantitative evaluation of the injury producing potential of any collision-occupant-vehicle combination.

This observation has led to the injury criteria model. It is based entirely upon forces, accelerations, or motions experienced by the human body in a collision environment. This model, when completely refined, will be applicable to any type of crash, seat, restraint system, or vehicle. Because it is independent of these external elements and dependent only upon the human subject, it is also capable of being used in such diverse studies as pedestrian impact, aircraft impact, pilot ejection, and others.

The injuries which are considered are related to measurable physical quantities. Therefore, the model can serve as a guide to the data acquisition requirements for an experimental impact research program. It implies that those quantities such as body accelerations which are relatable to injury should receive the highest priority in preparation of a data acquisition system for any determination of restraint effectiveness. Other physical quantities relatable to the structural performance of a seat or vehicle environment should be considered separately unless they relate directly to occupant injury production.

As a supplement to the type of injury criteria model which is being proposed, the probability of occurrence for the event is considered. Among the variables which must be included are the type of accident, seating, location of the occupant, and the potential usage of restraint systems. This last variable is necessitated by the fact that usage may vary for different restraints particularly when active systems such as lap belt-shoulder harness combinations are compared with passive systems such as airbags.

Two types of information are available in the literature which describe injury causation, human tolerance, and injury severity. One of these is ordinarily based on accident investigation and provides an injury scale defining types of injuries and a numerical ranking of the severity of the injury. The other source of information is a vast body of literature describing impact tolerance gathered on human volunteers, accidental free-fall impacts, cadavers, and animal subjects. On occasion an attempt is made to relate the magnitude of a physically measurable quantity to a particular type of injury.

It is the objective of this report to combine elements of a numerical injury rating scale with human tolerance data and thus to propose an injury criteria model which can be universally applied to problems in impact protection. This is supplemented with data rating the probability that the particular impact situation being studied will occur.

## 2.2 STATEMENT OF THE INJURY CRITERIA MODEL

The three parts of the injury criteria model are shown in Tables I, II, and III. Tolerance data used in the criteria are summarized in Table I. Table II lists angular motion ranges and flexibility for the various body segments based on range of motion data gathered from humans. The three elements of event probability are listed in Table III.

The tolerance data summarized in Table I consists of nine physical quantities relating to the production of injury. A limiting magnitude and literature reference is given for each quantity. When the nature of each injury is evaluated it is clear that severity varies from minor subject discomfort to critical life-endangering. In order to rate and compare the severity of each injury, the injury scale proposed by Van Kirk[8] has been adopted. In this scale

Minor injury = 1-4/26
Moderate injury = 8-10/26
Moderately severe injury = 12-14/26
Severe injury = 16-18/26
Critical injury = 20-22/26
Fatal injury = 24-26/26

This injury scale was chosen because it has sufficient detail to allow a matching of available tolerance data with specific injuries.

TABLE I. SUMMARY OF TOLERANCE DATA USED IN INJURY CRITERIA MODEL

| Quantity | Magnitude | Reference Number | Nature of Injury or Data | Weighting Code |
|---|---|---|---|---|
| 1. severity index | 1. $\int a^{2.5}\,dt \leq 1000$* | 1. | 1. Internal head injury. Dangerous to life. | 1. 22/26 |
| 2. head pitch acceleration | 2. $<2000$ rad/sec$^2$ | 2. | 2. 50% chance of cerebral concussion. | 2. 12/26 |
| 3. head lateral g-level | 3. 46 g peak | 3. | 3. Human volunteer subject experienced headache and sore neck for 3 days. | 3. 1/26 |
| 4. chest load | 4. <1800 lb. (Steering wheel rim and hub) | 4. | 4. Rib fractures of cadaver | 4. 13/26 |
| 5. shoulder belt load | 5. <1800 lb. combined | 5. | 5. Predicted tolerance level without injury. | 5. 1/26 |
| 6. pelvic belt load | 6. <5000 lb. | 6. | 6. Maximum voluntary load. | 6. 1/26 |
| 7. knee load (each) | 7. <1500 lb. | 7. | 7. Comminuted patella fracture. | 7. 12/26 |
| 8. chest a-p g-load | 8. <45 g | 7. | 8. Volunteer data with no injury.<br>(duration = .09 sec)<br>(rise time = 500 g/sec)<br>Higher rise times or longer durations can decrease this value significantly. | 8. 4/26 |
| 9. chest s-i g-load | 9. <25 g | 7. | 9. Volunteer data. Fractured vertebrae observed at this level. | 9. 16/26 |

*NOTE: a = head anterior-posterior acceleration g-level.

TABLE II. SUMMARY OF ANGULAR MOTION LIMITS USED IN INJURY CRITERIA MODEL

Seven-Joint Model

| | Joint | Flexion | Hyperextension |
|---|---|---|---|
| 1. | hip | 120 | 0 |
| 2. | lower spine | 20 | 45 |
| 3. | upper spine | 20 | 30 |
| 4. | neck | 60 | 60 |
| 5. | shoulder | 180 | 60 |
| 6. | elbow | 135 | 0 |
| 7. | knee | 135 | 0 |

NOTE: All quantities measured from an erect standing position with arms initially at sides.

Two-Joint Model

| Joint | Motion | Direction | Stiff Torso | Flexible Torso |
|---|---|---|---|---|
| 1. neck | pitch | hyperextension | 60 | 90 |
| | pitch | flexion | 60 | 100 |
| | roll | lateral flexion | 40 | 57 |
| | yaw | rotation | 70 | 87 |
| 2. hip | pitch | hyperextension | 0 | 30 |
| | pitch | flexion | 120 | 140 |
| | roll | lateral flexion | 0 | 17 |
| | yaw | leg spread | 30 | 47 |

NOTE: All quantities measured from an erect standing position except leg spread.

## TABLE III. PROBABILITY OF OCCURRENCE OF PREDICTED INJURIES*

Event Probability = A x B x C

A = accident type probability
- front (39[illegible])
- right front oblique (15.8%)
- left front oblique (14.2%)
- right lateral (5.4%)
- left lateral ([illegible].0%)
- right rear oblique (2.4%)
- left rear oblique (2.4%)
- rear end (2.3%)

B = occupant position probability
- driver (100%)
- center front (5.9%)
- right front (29.2%)
- left rear (6.2%)
- center rear (3.7%)
- right rear (7.1%)

C = restraint use probability
- lap belt (19.7%)
- lap belt plus upper torso (4.6%
- lap belt plus airbag
- airbag (~100%)

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*Statistical data are obtained from HSRI Accident Data Banks and are based on data gathered in Washtenaw County, Michigan during the period 1968-1970.

The nine tolerance quantities which have been chosen combine available data into a criterion which is universally applicable to various types of impact situations. The list should be updated and expanded as new tolerance values become available and quantities already on the list become more clearly defined.

Most of the quantities in the list have received some acceptance by experts in the field and individually are widely used. Severity index is one of the foremost among these tolerance values although some questions have been raised concerning the data base.[7] In order to reflect the fact that the tolerance of the head to resist impact is different for various types of loadings and motions, values for rotational pitch acceleration and lateral g-level have been chosen. Both of these quantities can be regarded as preliminary. Ommaya[2] has stated that the value for head pitch acceleration should be "considered only as a usefuly hypothesis which requires further evaluation." Likewise the g-tolerance to a blow on the side of the head is approximate due to the difficulty in obtaining reliable data from accelerometer packs attached to the head of human subjects. The value for the load which can be supported by the chest was obtained from tests on human cadavers, conducted primarily to study the production of injury by the steering wheel rim and post. Because of the use of cadavers, no relationships between a force of this magnitude applied to the chest and injuries to the thoracic contents can be made. Both the pelvic and shoulder belt loads have been estimated on the basis of human volunteer data and represent non-injury levels. The knee load tolerance of 1500 lb has been estimated on the basis of cadaver specimens, and could be applied equally well in injuries of the femur and the pelvis as has been proposed by Patrick[9]. Concluding the list are g-tolerance levels for chest impact in the anterior posterior and superior inferior directions. The value for anterior-posterior deceleration was estimated on the basis of forward-facing impact sled tests; that for superior-inferior acceleration was estimated from vertical ejection seat testing using volunteer humans.

The primary application of the data given in Table I will be in cases of frontal or rearward impact. Very little data are available from human testing in side impact. In addition, little has been accomplished in determining the tolerance to impact forces of individual body organs. In order to do this it will be necessary to measure the internal pressures and motions required to displace organs such as liver, spleen, and heart to such a degree that tissue failure and thus injury will occur.

As an example of the incomplete status of the data presented in Table I, consider a blow to the head. Linear accelerations can be applied to the head in the three spatial directions. Because the linear dimensions of the brain are different in these three directions, it is likely that the brain tearing or shear patterns will be different when the impact location is varied.

It is even likely that tolerance to a vertical acceleration of the head is different in the positive and negative directions. For instance, if the head is accelerated downward, the brain is supported by the top of the calvarium, whereas in an upward acceleration, the brain mass will tend to extrude into the brain stem. Data available on fore-aft accelerations is already included in Table I; additional information is currently being gathered at The University of Michigan in order to propose a sound criterion for side impact to the head. There is initial evidence that the tolerance to a side blow is different from the tolerance to a frontal blow.

It is also necessary to consider angular accelerations of three types - pitch, roll, and yaw. The tolerance levels proposed by Ommaya[2] and others refer to a rearward pitching motion of the head called whiplash. At the present time, this tolerance level cannot be considered as finalized. Yawing motion of the head consists of turning to the right or left around a vertical axis, and rolling motion of the head consists of turning the head down towards the shoulders about a horizontal line running fore-aft through the body. Again, it is likely that tolerance values for the different types of motions will vary because of the geometric and structural properties of the head.

Not only is the specification of six different tolerance limits a problem but also the combined action of one or more of these linear and angular motions is equally troublesome. It is likely that the tolerance levels for the case where an angular and a linear acceleration are applied simultaneously will be lower than for the case where the individual loadings are applied independently. For engineering materials and structures the possible applied loadings are combined to form a mathematically formulated failure criterion. Depending on material and structural nonlinearities, the functional relation between the loads can be exceedingly complex.

One problem which has complicated determination of a head injury criteria is the lack of highly controlled experiments. The experiments have often involved combined linear and angular accelerations. The precise loading on the head is usually not known, hence the confusion over the mechanism causing concussion. These effects must be separated before a fully acceptable injury criteria will be available.

Table II and Figures 1 and 2 summarize the angular motion limits used in the injury criteria model. The model is designed particularly as a specification to be used with mathematical simulations predicting occupant motions in a crash situation but also can be used with anthropometric dummies provided the data are adjusted to reflect the flexibility of a test device. All data are derived from Recommended Practice J963 of the Society of Automotive Engineers and represent voluntary motion ranges. The fact that the numbers presented in Table II reflect voluntary motion limits and not injuries again emphasizes a lack of tolerance data.

Table II is divided into two parts, one presenting a seven-joint model of the body capable of two-dimensional motions (Figure 3) and the other a two-joint model capable of motions in three-dimensional space (Figure 4). These models have been used in the development of the Two- and Three-Dimensional Mathematical Crash Victim Simulators at the Highway Safety Research Institute[10,11]. For the seven-joint model, two-dimensional flexion and hyperextension ranges are given for the hip, lower spine, upper spine, neck, shoulder, elbow and knee. The values given for the lower spine, upper spine, and neck represent the flexibility of the lumbar, thoracic, and cervical vertebrae respectively.

For the two-joint model additional rotational motion ranges are given to allow three-dimensional movements. Specifications are given for both a stiff and a flexible torso. A stiff torso means that no motion can occur in any direction at the upper and lower spine joints, and is thus defined to be one rigid mass including the shoulders and arms. In addition there is no flexibility in the lower extremities thus eliminating the knee joint. It should be noted that the values for pitch angular motion at the neck and hip are the same as for the seven-joint, two-dimensional model. These quantities are supplemented by the three-dimensional roll and yaw motions.

The two-joint flexible torso model takes into account the fact that the spinal column is capable of substantial flexure. The flexibility which was originally associated with the two spinal joints is now lumped into the neck and hip ranges of motion. Twisting of the torso (yaw) and bending to the side (roll) are included to make the representation three-dimensional.

The final element of the injury criteria model deals with the probability of the event being studied and is summarized in Table III. The chance that a particular vehicle occupant will receive injuries in a given collision is a function of

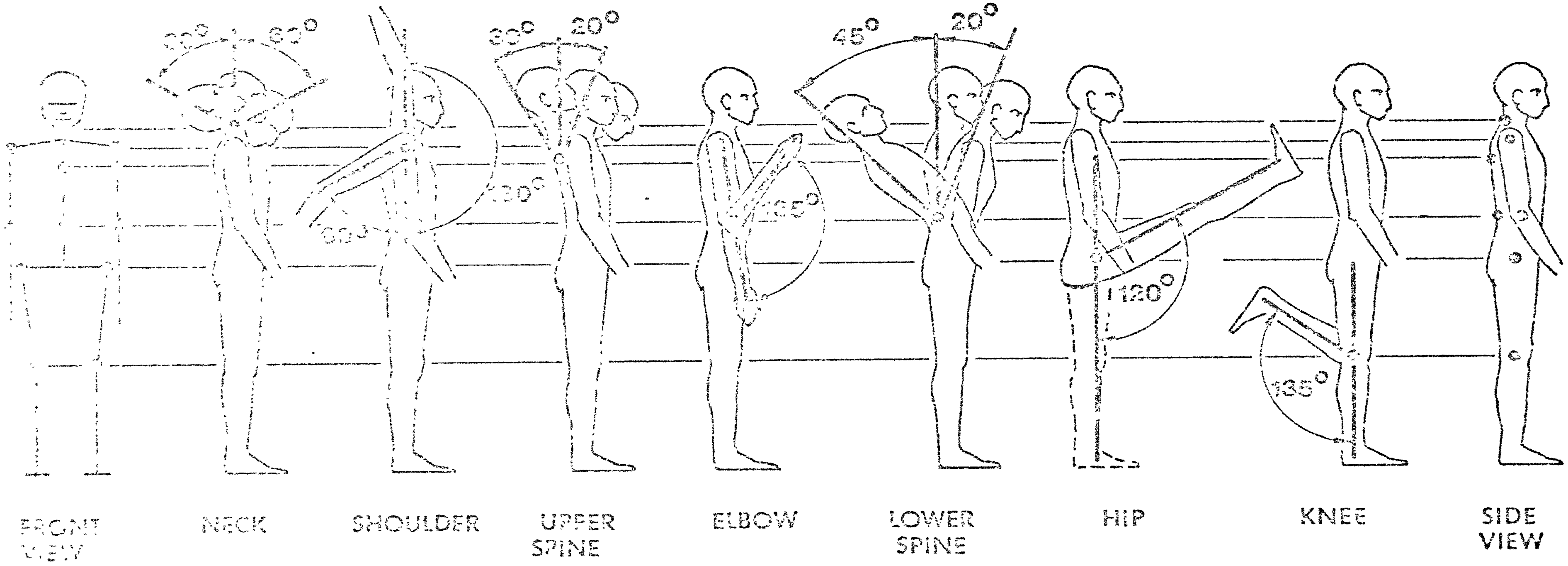
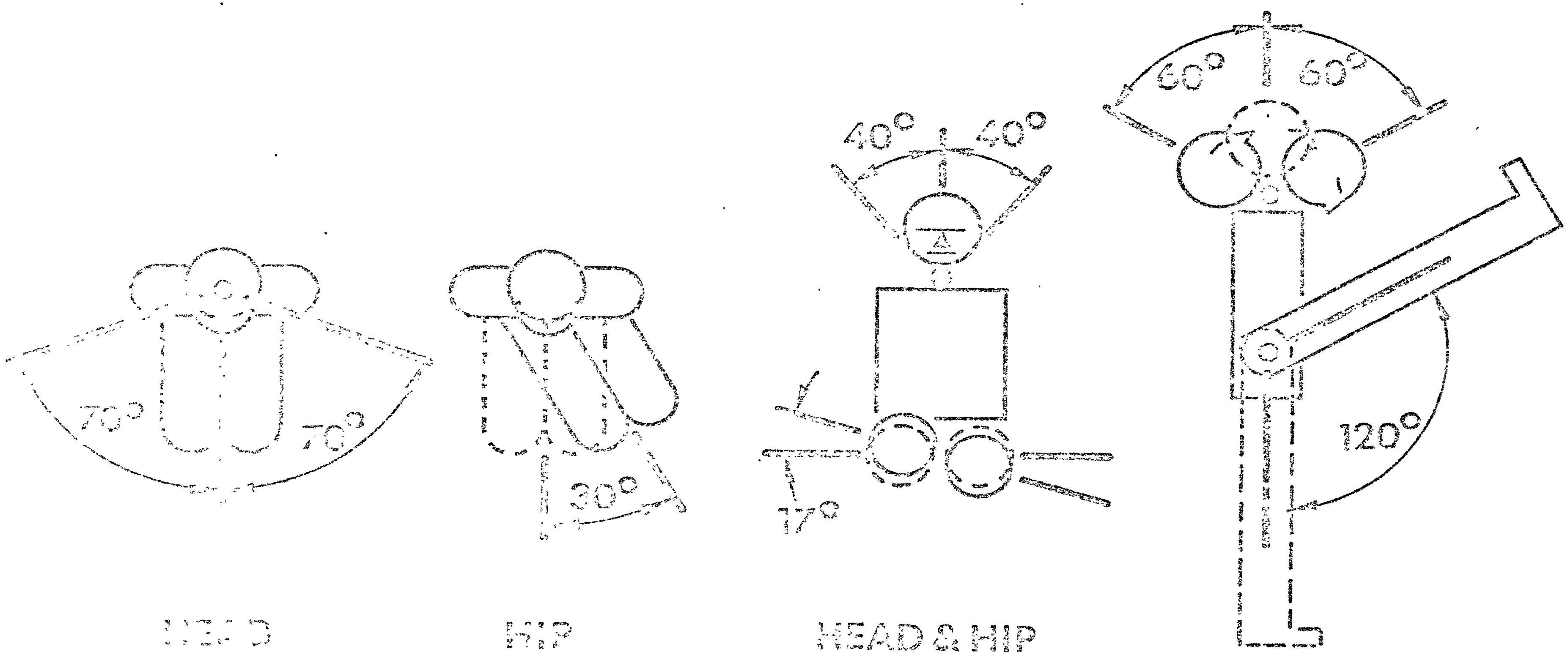


Figure 1. Schematic of angular motion limits used in Seven-Joint Model.



HEAD YAW

HIP YAW

HEAD & HIP ROLL

HEAD & HIP PITCH

Figure 2. Schematic of angular motion limits used in Two-Joint Model.

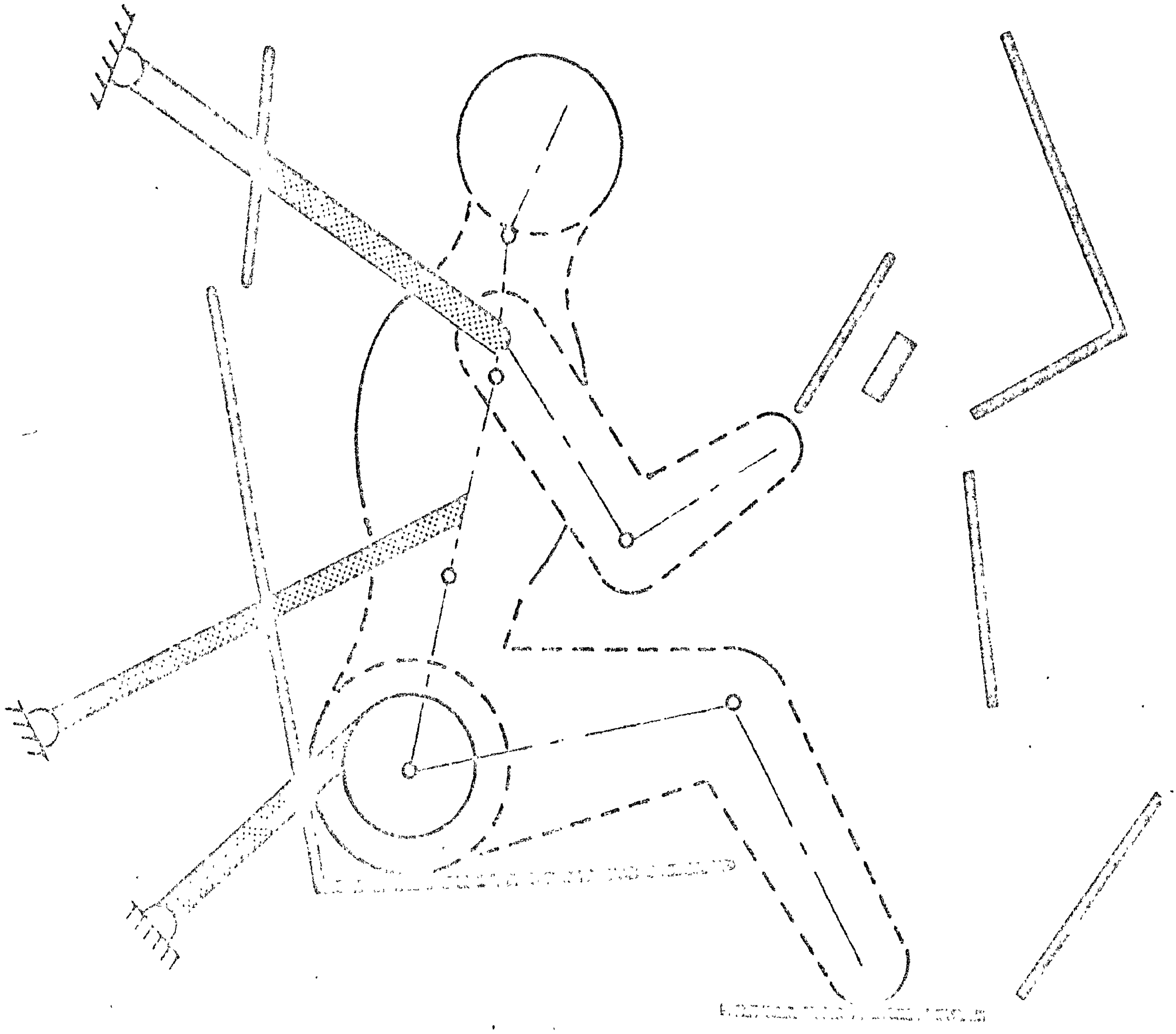


Figure 3. Two-Dimensional, Seven Joint Model of Body Motions.

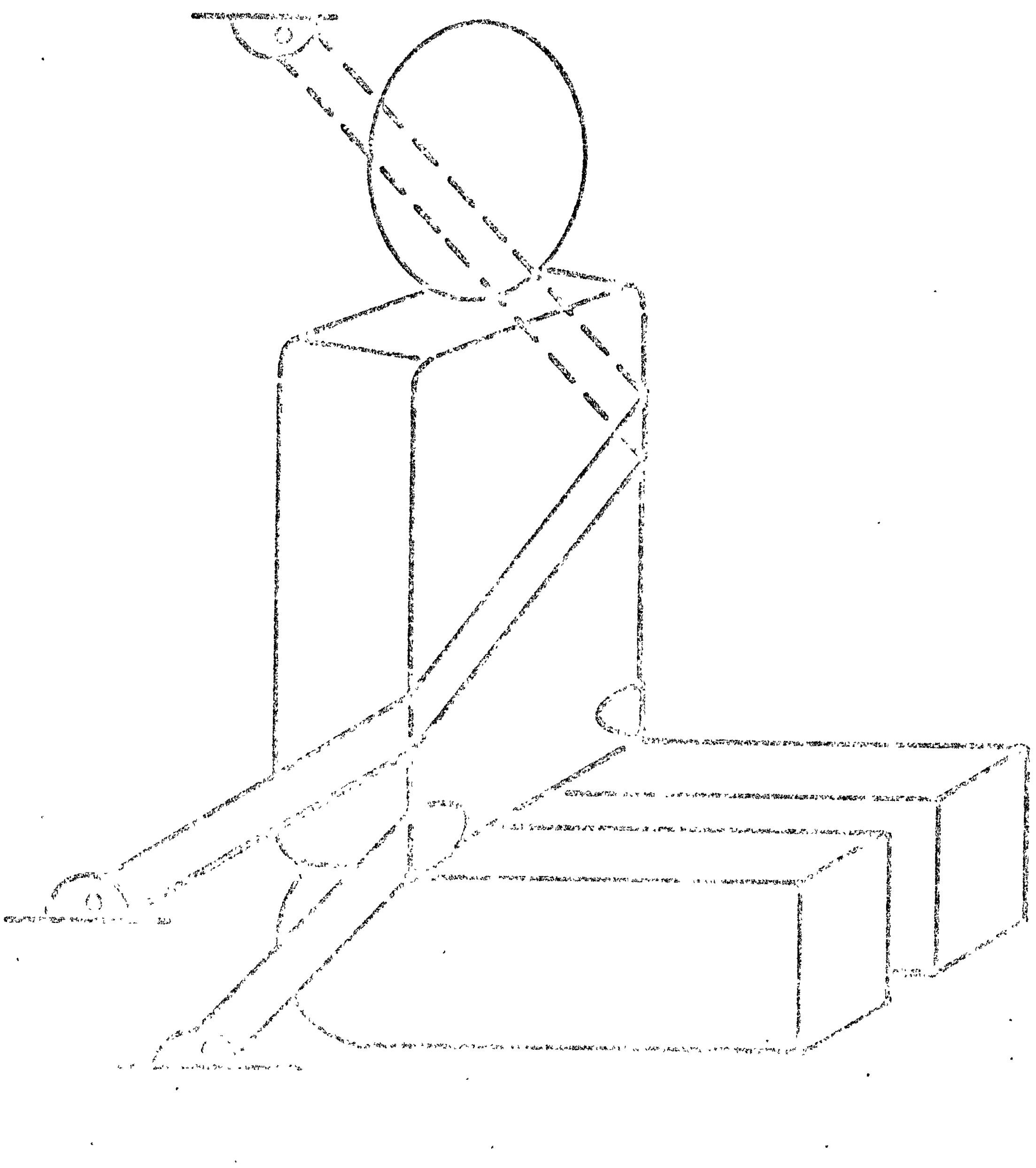


Figure 4. Three-Dimensional, Two-Joint Model of Body Motions.

the direction of impact, his position in the vehicle, and the use of restraint systems. These quantities have been carefully compiled and documented in many accident investigation studies. The most recent statistical data which are available to this project have been gathered by HSRI and used to compute the percentages given in the table. A more detailed discussion of this data is included in part 4.0 of this report.

Eight directions or regions of impact are included in the list of accident type probabilities. The vehicles involved received extensive damage in these areas. It should be noted that the sum of probabilities does not add up to 100%. In additional accident cases, the vehicle was totally destroyed making identification of the region of primary impact impossible. This category also includes rollovers and multiple impact collisions.

This data has not been weighted to reflect the velocity of impact because no accurate technique is yet available for estimating impact velocity after a collision. A suitable crash recorder certainly would be helpful.

The probability of restraint use was based on a smaller sample (523 cases) of injury producing accidents. For lap belts, only occupied seating positions equipped with lap belts were considered. Likewise in computing the percentage of lap belt plus shoulder harness usage, only seating positions equipped with this system were included in the sample. Thus, of the occupants having this system available only 4.6% chose to use it. Figures for airbag usage are not yet available but it is estimated that usage of a purely passive airbag system will be essentially 100%. No attempt was made to correlate injury with restraint system use; rather, the purpose was to determine the level of restraint system usage.

## 3.0 DISCUSSION OF DATA BASE FOR INJURY CRITERIA

The literature on injuries related to restraint system performance is of two types. One deals with individual case studies of injury and gives impact tolerance estimates for restrained occupants. Rarely are injuries which occur under test conditions reported to human volunteers. The other class of publications discusses the effectiveness of restraint systems in reducing injury and sometimes presents the results of a group of case studies which are not individually reported. A total of 74 papers (references 12-85) in the first category and 43 in the second (references 86-128) have been reviewed.

The experimental and clinical cases reported individually in the literature can be broken into three major categories: (1) human clinical studies; (2) human volunteer tests; and, (3) animal subjects. Each of these categories can be further divided into frontal, lateral, and rear collisions. These cases can be summarized as follows:

1. Human clinical studies
    a. Frontal impact - 253 cases
    b. Side impact - 46 cases
    c. Rear impact - 13 cases
2. Human volunteer subjects
    a. Frontal impact - 145 tests
    b. Side impact - 164 tests
    c. Rear impact - 33 tests
3. Animal subjects
    a. Frontal impact - 68 tests
    b. Side impact - 22 tests
    c. Rear impact - 10 tests

In order to evaluate and compare the data gathered in the various studies on injuries related to restraint system performance, the individual human volunteer tests listed above have been reviewed and assembled into the master collection of data included as Appendix A of this report. As much data as was available in the original published reports are included in these tables. The description of the type of test is summarized in the first few columns and includes test location, type of restraint system, age and weight of subject, and the test number. The input sled deceleration experienced by the occupant is described in the next set of columns and includes the angle which the seat cushion makes with a horizontal surface, the impact velocity, the peak g-level of the applied deceleration, the onset rate of the deceleration, and the distance required by the sled to stop. Any injury or discomfort which was experienced by the subject, and the literature source from which this information was taken, are listed in the last two columns.

If all these quantities were accurately recorded and evaluated for each of the tests listed, there would be a bare minimum of information available for estimating body tolerance levels, particularly for belt loads as well as head and chest g-levels. However, there are many blank spaces in these tables indicating the small amount of information which was gathered in most of the test programs. In addition to this, different physical quantities were measured in different test programs making comparisons of results and establishment of well-defined impact tolerance levels extremely difficult. Finally, it should be observed that injury to the subject is recorded in only a small minority of the tests and in most cases this is limited to subject discomfort.

Even with these problems, human volunteer data remain the most reliable source of information for the development of injury criteria models. The purpose of the present compilation has been to bring together from all published sources the results of all individual tests carried out. These tables should be updated as new data become available in order to provide a continuing source of information for students of injury mechanism and writers of performance standards concerned with impact protection.

A compilation of individual case studies involving human clinical subjects (accident victims) and animal test subjects was not made. The elimination of this rather large body of data from the current compilations was done for two reasons. First, for the human clinical studies, the physical parameters which describe each accident are largely unknown. This limits the value of the excellent and detailed medical studies which have been carried out on accident victims in establishing injury criteria models. The speed and direction of impact are very hard to document and the decelerative loads which can cause injury must be guessed. This fact illustrates the need for vehicle crash recorders and physician-engineer accident investigation teams.

For impact studies involving animal test subjects, instrumentation can be as good or better than that used with human volunteer subjects. Also, it is possible with humanely anesthetized animals to conduct testing at injury levels far in excess of those which can be reached using human test subjects. However, there is little geometric similarity between laboratory animals and humans. Therefore, the second reason for not including human clinical and animal test subject data in this study was the lack of techniques for scaling injury from animal subjects to humans. This fact illustrates the need for detailed analytical studies to be carried out in order to develop the geometrical scaling laws governing injury as it relates to man or animal. Tissue properties (hard and soft tissues) are similar in the two cases. It remains to collect appropriate anthropological data and develop the analytical scaling techniques before animal subject data can become useful in the development of injury criteria models.

Three sources of information on which injury models can be based have been discussed in the previous paragraphs. In clinical studies of accident victims, an inadequate supply of physical data defining the crash environment is available. Also, abundant animal subject impact test data will remain generally unused until scaling laws are developed and verified. This leaves only human volunteer data as the base on which injury criteria models can be formulated and this information is limited by the fact that impact levels must be kept below estimated injury levels.

Therefore, in order to increase the data base and improve the injury criteria model which has been presented in this report, considerable research must be carried out. Receiving high priority should be: (1) more complete documentation in order to define the physical quantities of the crash such as velocity, impact direction, and contacts between body parts and items in the vehicle interior, etc.; (2) development of a crash recorder to measure impact g-levels and direction; (3) development of analytical scaling laws to relate human injury to animal test subject data based on detailed anthropometric studies on both humans and animals; (4) improvement of technique for measuring linear and angular acceleration, velocities and positions in human volunteers; and, (5) correlation between human subject and anthropometric dummy data in order to reduce the need for volunteer testing, and development of scaling laws to compare dummy and animal test data.

# 4.0 EVENT PROBABILITY DATA BASE

The statistical data base used to determine the probability of a given collision event is outlined and discussed in this part of the report. All data has been retrieved from the HSRI Accident Data Bank[129]. Because the data files are continually updated, this is the most current information available.

The probability of particular accident types is outlined in Table IV. Two data sets are used. The first set covers a five-year period from 1965 to 1970 and is based on Ann Arbor, Michigan, a medium-sized city with a population of approximately 100,000. The second data set covers a two-year period from 1968 to 1970 and is based on Washtenaw County, Michigan, a primarily rural area with an extensive network of paved county roads and high-speed expressways. Data for the City of Ann Arbor is included with the county data.

The impact damage zones used in compiling this data are shown in Figure 5. Each of the eight zones is defined by a 45° arc. Of the total 10,686 recorded accidents in Ann Arbor, 555 of these are included in a ninth category entitled "total," in which vehicle damage was so severe that identification of a primary impact region was impossible. This category also includes rollovers and multiple impact collisions. The increased incidence of "totalled" vehicles in the county data should be noted. This reflects the increased speeds and increased accident severity which occurs outside the city limits on county roads and expressways.

The probability that a particular occupant position is being used is outlined in Table V. The six standard occupant positions comprise the bulk of the data. The same data files which were used to prepare Table IV were again used in this case. It should be noted that there is a higher occupancy rate for vehicles involved in county accidents than for city vehicles.

TABLE IV. PROBABILITY OF PARTICULAR ACCIDENT TYPE

| Impact Location | City of Ann Arbor, Mich.* | Percent | Washtenaw County, Mich.** | Percent |
|---|---|---|---|---|
| front | 4730 | 44.3 | 3836 | 39.0 |
| right front oblique | 2169 | 20.3 | 1552 | 15.8 |
| left front oblique | 1858 | 17.4 | 1395 | 14.2 |
| right side | 452 | 4.2 | 532 | 5.4 |
| left side | 332 | 3.1 | 431 | 4.9 |
| right rear oblique | 213 | 2.0 | 235 | 2.4 |
| left rear oblique | 186 | 1.7 | 241 | 2.4 |
| rear | 191 | 1.8 | 229 | 2.3 |
| undetermined | 555 | 5.2 | 1339 | 13.6 |
| TOTALS | 10686 | 100.0 | 9840 | 100.0 |

*Data for City of Ann Arbor obtained from HSRI Accident Data Bank covering period from 1965-1970.

**Data for Washtenaw County obtained from HSRI Accident Data Bank covering period from 1968-1970.

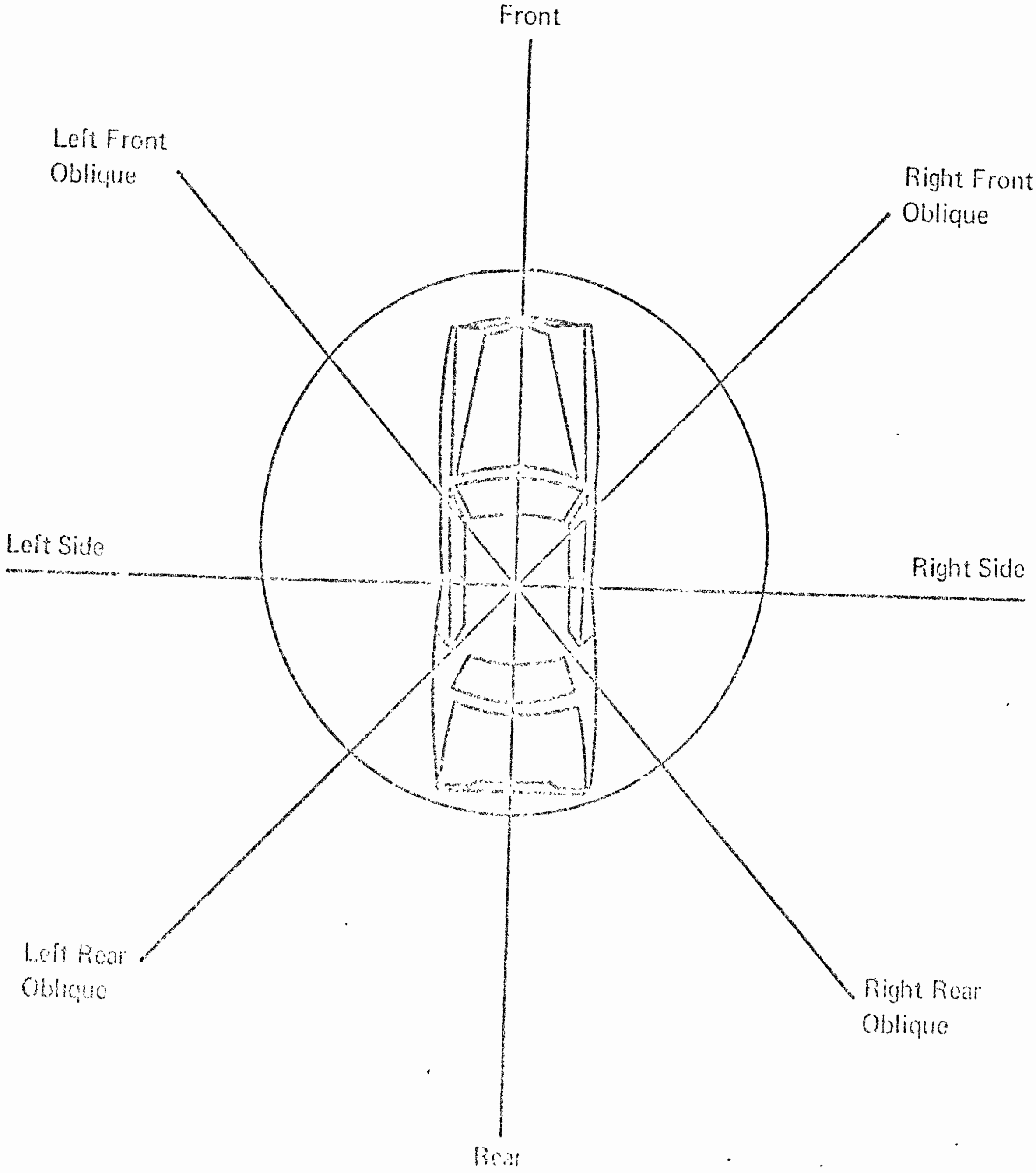


Figure 5. Impact Damage Zones Used in Compiling Probability Data

## TABLE V. PROBABILITY OF PARTICULAR OCCUPANT LOCATION

| Location in Vehicle | Ann Arbor, Mich.* - % | Washtenaw County, Mich.** - % |
|---|---|---|
| driver | 100% | 100% |
| center front | 5.7 | 6.9 |
| right front | 27.5 | 29.2 |
| left rear | 5.3 | 6.2 |
| center rear | 3.4 | 3.7 |
| right rear | 6.2 | 7.1 |
| 4th in front | .2 | .1 |

*Data for City of Ann Arbor obtained from HSRI Accident Data Bank covering period from 1965-1970.

**Data for Washtenaw County obtained from HSRI Accident Data Bank covering period from 1968-1970.

Restraint system use is summarized in Table VI. The detailed data sample is smaller in this case and is composed of 521 lap belt and 505 upper torso restraint analyses. Current indications are that less than 20% of occupants are using lap belts and less than 5% are using upper torso restraints. Also noted in this study was that improper use of active restraint systems can lead to very inefficient system performance and can even be dangerous. A slack restraint system can increase belt loads[130] and body g-levels significantly and thus result in an increased injury incidence. Table VI shows that 69% of the occupants were wearing snug lap belts, whereas, in a much more limited sample, only 33.3% were wearing their upper torso systems correctly.

## TABLE VI. RESTRAINT SYSTEM USE SUMMARY

### Lap Belt

| | |
|---|---|
| Number of accident cases | 521 |
| Occupant positions equipped with lap belt | 441 |
| Occupant positions not equipped with lap belt | 50 |
| Not known whether equipped with lap belt | 30 |
| Lap belt used by occupant | 87 |
| Occupants wearing lap belt snuggly* | 60 |

### Lap Belt Plus Upper Torso Harness

| | |
|---|---|
| Number of accident cases | 505 |
| No upper torso restraint for occupant | 310 |
| Lap belt plus upper torso restraint for occupant | 195 |
| Occupants using restraint system | 9 |
| Occupants using restraint system correctly * | 3 |

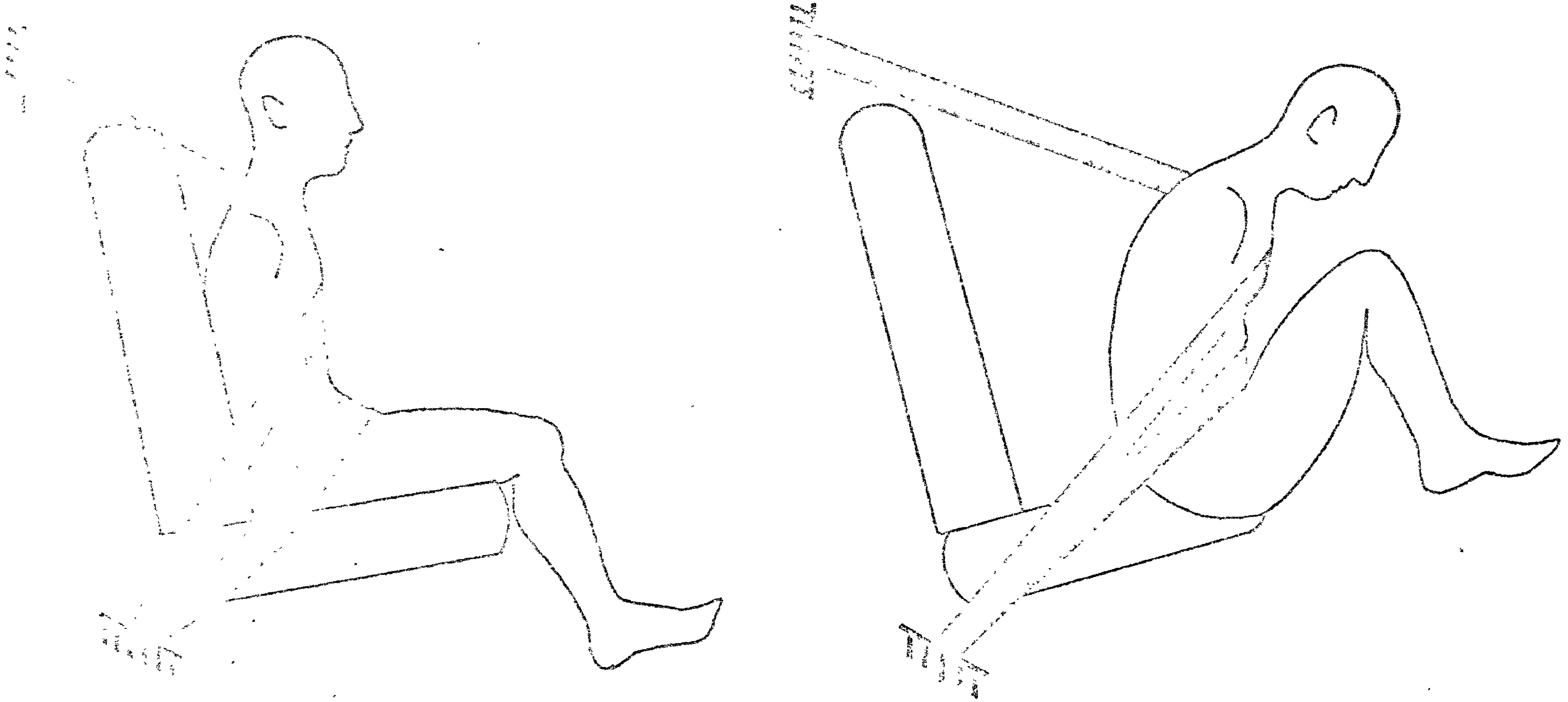
*This data was gathered by questioning the occupant concerning his use of restraints.

# 5.0 SAMPLE APPLICATIONS OF THE INJURY CRITERIA MODEL

The application and use of the injury criteria model is discussed in this part of the report. Two types of applications for models of this type are apparent. The first of these is in conjunction with the HSRI Two- and Three-Dimensional Mathematical Crash Victim Simulators, where the computer programs are supplemented by subroutines which automatically compare the motions, forces, and accelerations experienced by the crash victim with acceptable levels as defined in the injury criteria model. The second type of application is to actual impact sled or full-scale vehicle crash tests. In this case, motions must be determined from high speed motion pictures of the event while the appropriate forces and accelerations are found from oscillographic or tape recordings of transducer data. Both types of applications are demonstrated in the three samples which follow, the first two using the HSRI mathematical models and the third using the results of an HSRI impact sled test. It should be noted that these applications do not represent optimum restraint system configurations. Rather, for the purpose of demonstrating the use of the injury criteria model, examples of inferior restraint system performance have been chosen from the viewpoint that well-designed restraint systems will not produce injuries and hence would not demonstrate the injury criteria model.

## 5.1 APPLICATION NO. 1 - TWO-DIMENSIONAL MATHEMATICAL CRASH VICTIM SIMULATOR

This case represents an improperly used belt restraint system consisting of a slack lap belt (4 inches) and a slack single diagonal shoulder harness (10 inches). A sketch of occupant position is shown in Figure 6 and a description of the computer input and output is given in Table VII.



Initial Position

Maximum Forward Motion

Figure 5. Occupant Motions in Two-Dimensional Crash Simulation.

## TABLE VII. SUMMARY OF TWO-DIMENSIONAL CRASH SIMULATION INPUT DATA

occupant - 50th percentile male
restraint - slack lap belt and single diagonal torso harness
position - front occupant
type of crash - frontal impact
initial velocity - 30 mph
acceleration level - 25 g peak

The next four tables (VIII-XI) show the output generated by the injury criteria model section of the Two-Dimensional Crash Victim Simulator. The first two of these tables tabulate the input data on which the injury criteria model is based.

Table X summarizes in seven columns those quantities which exceed tolerance levels. The quantity is identified in the first column, its peak value given in the second, the time of occurrence of the peak in the third, the time duration while the quantity remains above the tolerance level in the fourth, the points in time when the quantity rises above the tolerance level and then falls below in the fifth and sixth, and the weighting code for the injury which has been identified with a particular tolerance level in the seventh column.

In this example the occupant slides forward, contacts the slack restraints, and then rebounds into the seat back. Because of the large amount of slack in the upper torso belt, the hip begins to rebound before the upper torso has moved the maximum distance forward. As a result of this, the head and upper portion of the chest pitch forward over the upper torso belt.

Head pitch acceleration exceeds specified tolerance levels twice as the head is slowed down in its forward pitching motion over the upper torso belt. During this same period high upper torso belt loads are observed. These loads are much higher than would occur with a properly adjusted tight belt restraint

```
TWO DIMENSIONAL CRASH VICTIM SIMULATOR    OUTPUT DATA                    NOV  3, 1970            PAGE  7

                          SUMMARY OF TOLERANCE DATA USED IN INJURY CRITERIA

      QUANTITY                MAXIMUM ACCEPTABLE VALUE             NATURE OF INJURY OR DATA            WEIGHTING CODE

1. SEVERITY INDEX                1. 1000                    1. INTERNAL HEAD INJURY, DANGEROUS TO LIFE.       1. 22/26
2. HEAD PITCH ACCELERATION       2. 2000 RAD/SEC/SEC        2. 50% CHANCE OF CEREBRAL CONCUSSION.             2. 17/26
3. CHEST LOAD                    3. 1000 LB                 3. RIB FRACTURE OF CADAVER.                       3. 13/26
4. SHOULDER BELT LOAD            4. 1800 LB COMBINED        4. PREDICTED TOLERANCE LEVEL WITHOUT INJURY.      4.  1/26
5. PELVIC BELT LOAD              5. 5000 LB                 5. MAX MAN VOLUNTARY LOAD.                        5.  1/26
6. KNEE LOAD (EACH)              6. 1500 LB                 6. COMMINUTED PATELLA FRACTURE.                   6. 12/26
7. CHEST A-P G-LOAD              7.   45 G-PEAK             7. VOLUNTEER DATA WITH NO INJURY.                 7.  4/26
                                                               (DURATION=.09 SEC, RISE TIME=500 G/SEC)
                                                               HIGHER RISE TIMES OR LONGER DURATIONS CAN
                                                               DECREASE THIS VALUE SIGNIFICANTLY.
8. CHEST S-I G-LOAD              8.   25 G-PEAK             8. VOLUNTEER DATA, FRACTURED VERTEBRAE            8. 16/26

                                          LIST OF REFERENCES

1. GADD, C.W., "USE OF A WEIGHTED-IMPULSE CRITERION FOR ESTIMATING INJURY HAZARD", PROC. 10TH. STAPP CAR CRASH CONF.,
   NEW YORK 1966, P.95-100.
2. OMMAYA, A.K. ET AL, "COMPARATIVE TOLERANCES FOR CEREBRAL CONCUSSION BY HEAD IMPACT AND WHIPLASH INJURY IN
   PRIMATES", 1970 INTERNATIONAL AUTOMOBILE SAFETY CONFERENCE COMPENDIUM, SAE PUB. NO. P-30, P.808-817.
3. GADD, C.W. AND PATRICK, L.M., "SYSTEM VERSUS LABORATORY IMPACT TESTS FOR ESTIMATING INJURY HAZARD", SAE PAPER
   680053, JAN. 1968.
4. AN ESTIMATED PROBABLE THRESHOLD OF INJURY BY BIOMECHANICS TASK FORCE OF SAE OCCUPANT RESTRAINT SYSTEMS SUBCOMMITTEE.
5. STAPP, J.P. AND ENFIELD, S.A., "EVALUATION OF THE LAP-TYPE AUTOMOBILE SAFETY BELT WITH REFERENCE TO HUMAN
   TOLERANCE", SAE PAPER NO. 62A, 1958.
6. SNYDER, R.G., "HUMAN IMPACT TOLERANCE", 1970 INTERNATIONAL AUTOMOBILE SAFETY CONFERENCE COMPENDIUM, SAE PUB. NO.
   P-30, P.712-7[illegible].
7. IBID.
8. IBID.

NOTE: THE WEIGHTING CODE IS BASED ON VAN KIRK, D.J. AND LANGE, W.A., "A DETAILED INJURY SCALE FOR ACCIDENT
      INVESTIGATION", PROC. OF THE 12TH. STAPP CAR CRASH CONFERENCE, OCT. 1968, P.240-259.
      MINOR INJURY = 1-4/26, MODERATE INJURY = 8-10/26, MODERATELY SEVERE INJURY = 12-14/26,
      SEVERE INJURY = 15-19/26, CRITICAL INJURY = 20-22/26, FATAL INJURY = 24-26/26.
```

TABLE VIII. Summary of Tolerance Data Used with Two-Dimensional Crash Victim Simulator.

```
TWO DIMENSIONAL CRASH VICTIM SIMULATOR   OUTPUT DATA                NOV  3, 1970            PAGE  8

        SUMMARY OF ANGULAR MOTION LIMITS USED IN INJURY CRITERIA

            JOINT                     FLEXION           HYPEREXTENSION

        1.  HIP                        0 DEG               120 DEG
        2.  LOWER SPINE               45 DEG                20 DEG
        3.  UPPER SPINE               30 DEG                20 DEG
        4.  NECK                      60 DEG                60 DEG
        5.  SHOULDER                  60 DEG               180 DEG
        6.  ELBOW                      0 DEG               135 DEG
        7.  KNEE                       0 DEG               135 DEG

NOTE: ALL QUANTITIES MEASURED FROM AN ERECT STANDING POSITION WITH ARMS AT SIDES.
```

TABLE IX. Summary of Angular Motion Limits Used with Two-Dimensional Crash Victim Simulator.

```
TWO DIMENSIONAL CRASH VICTIM SIMULATOR    OUTPUT DATA                    NOV  3, 1970           PAGE  9

                                 SUMMARY OF QUANTITIES EXCEEDING TOLERANCES

       QUANTITY               PEAK    TIME OF OCCURRENCE   DURATION      TIME START      TIME END    WEIGHTING CODE

HEAD [illegible] ACCELERATION   3579.      0.070000          0.008730      0.065005       0.073735        12/26
HEAD PITCH ACCELERATION         2565.      0.115000          0.002624      0.113569       0.116193        12/26
[illegible] BELT LOAD           4405.      0.090000          0.061679      0.062607       0.124287         1/26
CHEST UP G-LOAD                  -46.      0.095000          0.002445      0.092756       0.095201         4/26
CHEST AFT G-LOAD                -179.      0.170000          0.014210      0.163452       0.177662         4/26
CHEST [illegible] G-LOAD         -49.      0.075000          0.018906      0.072483       0.091389        16/26
CHEST [illegible] G-LOAD          37.      0.100000          0.009241      0.097164       0.106405        16/26
CHEST [illegible] G-LOAD          39.      0.170000          0.009821      0.163851       0.173672        16/26
[illegible] SPINE FLEXION         38.      0.160000          0.086774      0.104902       0.191676        -----
```

TABLE X. Summary of Quantities Exceeding Tolerances in Two-Dimensional Simulation.

```
TWO DIMENSIONAL CRASH VICTIM SIMULATOR   OUTPUT DATA                    NOV  3, 1970           PAGE 10

                          PROBABILITY OF OCCURRENCE

                  THE PROBABILITY OF OCCURRENCE IS BASED ON:

     1. PROBABILITY OF FRONT COLLISION         =  0.3900
     2. PROBABILITY OF RIGHT FRONT PASSENGER   =  0.2920
     3. PROBABILITY OF SHOULDER & LAP BELT USE =  0.0440

               PROBABILITY OF OCCURRENCE =    0.0052
```

TABLE XI.  Probability of Occurrence in Two-Dimensional Sample Case.

system. As a result of the large belt force applied to the chest, the anterior-posterior g-loading of the upper torso exceeds tolerance levels at nearly the same time. An additional large chest anterior-posterior g-load is applied to the chest late in the simulation when the upper torso rebounds into the seat back structures.

Excessive superior-inferior chest g-loadings are observed three times during the simulation. The first of these results because of an upward push caused by contact between the buttocks of the occupant and the seat cushion. The second is a downward pull on the torso and results at that point in time when the lap belt force is a maximum. The third peak occurs as the buttocks of the occupant interact with seat back structures during the rebound phase of the simulation.

Upper spine flexion is the final quantity exceeding specified voluntary motion ranges. This occurs as a result of the high chest loads caused by the upper torso belt as the head and upper chest pitch forward over the belt.

Table XI demonstrates the computations of the probability that this event would occur. In Washtenaw County data the probability that a given collision will be a front collision is .39 and the probability that there will be a right front passenger seat occupant is .292. The low probability of shoulder and lap belt use (.046) indicates that this injury pattern could occur in less than 1% of accident cases.

## 5.2 APPLICATION NO. 2 - THREE-DIMENSIONAL MATHEMATICAL CRASH VICTIM SIMULATOR

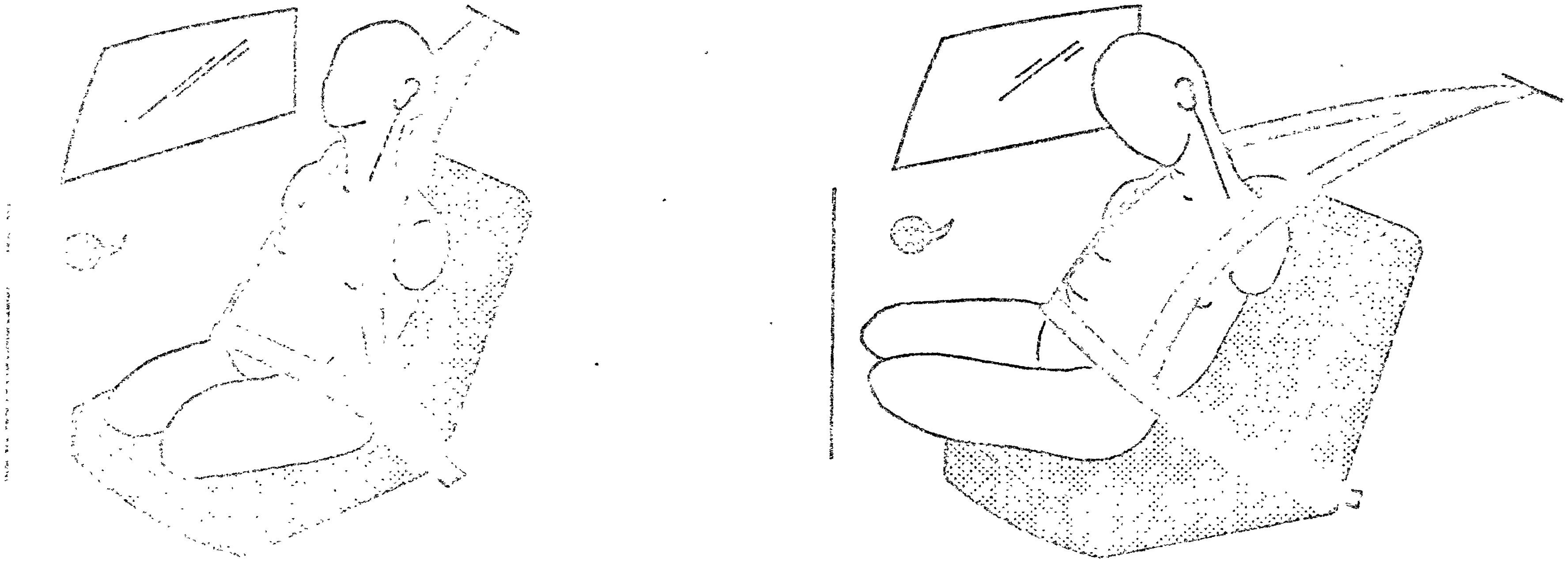
This case represents a center right side impact. The 50th percentile male right front passenger using a bucket seat is restrained by an inverted y-yoke harness and a lap belt. A sketch of occupant position is shown in Figure 7 and a description of the computer input and output is given in Table XII. The next four tables (XIII-XVI) show the output generated by the injury criteria model section of the Three-Dimensional Crash Victim Simulator. The first two of these tables tabulate the input data on which the injury criteria model is based.

## TABLE XII. SUMMARY OF THREE-DIMENSIONAL CRASH SIMULATION INPUT DATA

occupant - 50th percentile male
restraint - inverted y-yoke harness
position - right front occupant
type of crash - right front oblique impact
initial velocity - 0 mph
forward acceleration - 3.4 g peak
side acceleration - 15 g peak

Table XV summarizes those quantities which exceed tolerance levels in seven columns as was done in the Two-Dimensional Crash Victim Simulator. As this computer excercise involves a mild right front collision, the passenger is observed to slide forward and to the right in his seat. He contacts door side panels and the window lightly with his right shoulder and knee and is well restrained by the restraint system and bucket seat combination.

Several angles are observed to exceed voluntary range of motion limits, partially due to the selection of the stiff torso option for the injury criteria model printout. The head yaw angle reaches a peak of 71.2 degrees to the right as the occupant reaches his maximum forward motion. Likewise head roll to the right side reaches a maximum at 0.115 sec. and rebounds to the left reaching a peak of 41.8 degrees near the end of the collision. As the legs swing toward the door, hip yaw reaches a peak of 36 deg. at 0.100 sec. Hip pitch angle becomes large as the legs rebound upward at the end of the simulation. The fact that hip roll angle is reported several times reflects the stiff torso option used in this printout with any nonzero values being listed. Head pitch acceleration (in deg/sec$^2$) is also reported to exceed tolerance levels. The first peak occurs as the head pitches forward over the restraint system. The remaining values are observed to occur during the rebound phase of the simulation.



Right front occupant
in initial position

Occupant contacts door
lightly with knee and
shoulder — restraint is
tight — occupant has
slid on seat to side

Figure 7. Occupant Motions in Three-Dimensional Crash Simulation

```
                          THREE DIMENSIONAL CRASH VICTIM SIMULATOR   INJURY DATA                 OCT  5, 1970  PAGE 20
                          CENTER SIDE IMPACT, 50% MALE, BUCKET SEAT, Y-YOKE
                          UNITS ARE INCHES, DEGREES, POUNDS, AND SECONDS UNLESS NOTED.

                          SUMMARY OF TOLERANCE DATA USED IN INJURY CRITERIA

      QUANTITY                MAXIMUM ACCEPTABLE VALUE      NATURE OF INJURY OR DATA                   WEIGHTING CODE

   1. SEVERITY INDEX          1. [illegible]                1. INTERNAL HEAD INJURY, DANGEROUS TO LIFE.    1. 22/26
   2. HEAD PITCH ACCELERATION 2. [illegible] RAD/SEC/SEC    2. 50% CHANCE OF CEREBRAL CONCUSSION".         2. 12/26
   3. [illegible]             3.   36 G PEAK                3. HUMAN VOLUNTEER SUBJECT EXPERIENCED         3.  1/26
                                                               HEADACHE AND SORE NECK FOR 3 DAYS.
   4. [illegible]             4. [illegible] LB             4. RIB FRACTURE OF CADAVER.                    4. 13/26
   5. [illegible] BELT LOAD   5. 3000 LB COMBINED           5. PREDICTED TOLERANCE LEVEL WITHOUT INJURY.   5.  1/26
   6. [illegible] LOAD        6. [illegible] LB             6. MAXIMUM VOLUNTARY LOAD.                     6.  1/26
   7. [illegible] LOAD        7. [illegible] LB             7. [illegible] PATELLA FRACTURE.               7. 12/26
   8. [illegible]             8.   45 G PEAK                8. VOLUNTEER DATA WITH NO INJURY.              8.  4/26
                                                               (DURATION=.04 SEC, RISE TIME=500 G/SEC)
                                                               HIGHER RISE TIMES OR LONGER DURATIONS CAN
                                                               DECREASE THIS VALUE SIGNIFICANTLY.
   9. [illegible]             9.   25 G PEAK                9. VOLUNTEER DATA. FRACTURED VERTEBRAE         9. 16/26
                                                               OBSERVED AT THIS LEVEL.

                                     LIST OF REFERENCES

   1. [illegible] "USE OF A WEIGHTED-IMPULSE CRITERION FOR ESTIMATING INJURY HAZARD", PROC. 10TH. STAPP CAR CRASH CONF.,
        [illegible]
   2. [illegible] ET AL, "[illegible] TOLERANCES FOR CEREBRAL CONCUSSION BY HEAD IMPACT AND WHIPLASH INJURY IN
        [illegible] INTERNATIONAL AUTOMOBILE SAFETY CONFERENCE COMPENDIUM, SAE PUB. NO. P-30, P.808-817.
   3. [illegible] "[illegible] TOLERANCE TO LATERAL IMPACT WITH LAP BELT ONLY", PROC. 8TH. STAPP CAR CRASH CONF.,
        [illegible]
   4. [illegible] "SYSTEM VERSUS LABORATORY IMPACT TESTS FOR ESTIMATING INJURY HAZARD", SAE PAPER
        [illegible]
   5. [illegible] THRESHOLD OF INJURY BY BIOMECHANICS TASK FORCE OF SAE OCCUPANT RESTRAINT SYSTEMS SUBCOMMITTEE.
   6. [illegible] "EVALUATION OF THE LAP-TYPE AUTOMOBILE SAFETY BELT WITH REFERENCE TO HUMAN
        TOLERANCE", [illegible] 1958.
   7. [illegible] IMPACT TOLERANCES", 1970 INTERNATIONAL AUTOMOBILE SAFETY CONFERENCE COMPENDIUM, SAE PUB. NO.
        [illegible]
   8. [illegible]
   9. [illegible]

   NOTE: THE WEIGHTING CODE IS BASED ON VAN KIRK, D.J. AND LANGE, W.A., "A DETAILED INJURY SCALE FOR ACCIDENT
         [illegible]", PROC. OF THE 12TH. STAPP CAR CRASH CONFERENCE, OCT. 1968, P.240-252.
         [illegible] = 2-4/26, MODERATE INJURY = 8-10/26, MODERATELY SEVERE INJURY = 12-14/26,
         SEVERE INJURY = [illegible]/26, CRITICAL INJURY = 20-22/26, FATAL INJURY = 24-26/26.
```

TABLE XIII. Summary of Tolerance Data Used with Three-Dimensional Crash Victim Simulator.

```
               THREE DIMENSIONAL CRASH VICTIM SIMULATOR   INJURY DATA                   OCT  5, 1970  PAGE 21
                 CENTER SIDE IMPACT. 50% MALE. BUCKET SEAT, Y-YOKE
               UNITS ARE INCHES, DEGREES, POUNDS, AND SECONDS UNLESS NOTED.

            SUMMARY OF ANGULAR MOTION LIMITS USED IN INJURY CRITERIA

            JOINT      MOTION        DIRECTION             STIFF TORSO

          1. NECK      PITCH       HYPEREXTENSION            60 DEG
                       PITCH          FLEXION                60 DEG
                       ROLL        LATERAL FLEXION           40 DEG
                       YAW            ROTATION               70 DEG
          2. HIP       PITCH       HYPEREXTENSION             0 DEG
                       PITCH          FLEXION               120 DEG
                       ROLL        LATERAL FLEXION            0 DEG
                       YAW           LEG SPREAD              30 DEG

   NOTE: ALL QUANTITIES MEASURED FROM AN ERECT STANDING POSITION EXCEPT LEG SPREAD.

   NOTE: THESE DATA ARE DERIVED FROM SAE J963 AND REPRESENT VOLUNTARY MOTION RANGES.
```

TABLE XIV. Summary of Angular Motion Limits Used with Three-Dimensional Crash Victim Simulator.

```
                    THREE DIMENSIONAL CRASH VICTIM SIMULATOR   INJURY DATA                  OCT  5, 1970  PAGE 22
                     CENTER SIDE IMPACT, 50% MALE, BUCKET SEAT, Y-YOKE
                UNITS ARE INCHES, DEGREES, POUNDS, AND SECONDS UNLESS NOTED.

                    SUMMARY OF QUANTITIES EXCEEDING TOLERANCES
     QUANTITY               PEAK     TIME OF OCCURRENCE  DURATION    TIME START    TIME END   WEIGHTING CODE
  [illegible]               21.2         0.1350          0.0023       0.1334       0.1357         0
  [illegible]              -41.2         0.1900          0.0265       0.1666       0.1931         0
  [illegible]        [illegible]         0.1150          0.0063       0.1097       0.1161         0
  [illegible]        [illegible]         0.1000          0.0159       0.0944       0.1103         0
  [illegible]               52.5         0.2000          0.0442       0.1558       0.2000         0
  [illegible]               -1.7         0.0750          0.0277       0.0586       0.0863         0
  [illegible]        [illegible]         0.1700          0.0491       0.1437       0.1928         0
  [illegible]                0.1         0.0550          0.0436       0.0150       0.0586         0
  [illegible]        [illegible]         0.1200          0.0574       0.0863       0.1437         0
  [illegible]               10.9         0.2050          0.0072       0.1928       0.2000         0
  [illegible]        [illegible]         0.1150          0.0222       0.1105       0.1327        12
  [illegible]        [illegible]         0.1450          0.0142       0.1365       0.1507        12
  [illegible]        [illegible]         0.1650          0.0159       0.1579       0.1738        12
  [illegible]           209176.3         0.1900          0.0057       0.1866       0.1923        12
```

TABLE XV. Summary of Quantities Exceeding Tolerances in Three-Dimensional Simulation.

```
                      THREE DIMENSIONAL CRASH VICTIM SIMULATOR  INJURY DATA          OCT 5, 1973 PAGE 23
                              CENTER SIDE IMPACT, 50% MALE, BUCKET SEAT, Y-YOKE
                        UNITS ARE INCHES, DEGREES, POUNDS, AND SECONDS UNLESS NOTED.

                                        PROBABILITY OF OCCURRENCE
                THE PROBABILITY OF OCCURRENCE IS BASED ON:

                1.  PROBABILITY OF RIGHT FRONT OCCUPANT     =  0.292
                2.  PROBABILITY OF RIGHT FRONT COLLISION    =  0.158
                3.  PROBABILITY OF Y-YOKE HARNESS USE       =  0.200

  EXECUTION TERMINATED                    PROBABILITY OF OCCURRENCE = 0.0092
```

TABLE XVI.  Probability of Occurrence in Three-Dimensional Sample Case.

Table XVI shows the probability of occurrence of this event. The accident and occupant position probabilities are based on Washtenaw County, Michigan, data. Since no data is available on usage of inverted y-yoke harnesses, their probability of use is arbitrarily assumed to be equal to seat belts.

## 5.3 APPLICATION NO. 3 - IMPACT SLED TEST EVALUATION

This case represents a frontal impact involving a 50th percentile male Sierra dummy restrained only by a lap belt. A tracing of part of the oscillographic data recorded in this test is shown in Figure 8 and a photograph of occupant motions at maximum forward excursion in Figure 9. The impact velocity was 43 ft/sec with a trapezoidal deceleration pulse with an 18 g peak and a total duration of 0.110 sec.

In order to evaluate this data, reference is made to Tables I and II which summarize the tolerance and angular motion data used in the injury criteria model. The value of the severity index is 856 based on integration of the head anterior-posterior g-pulse. It should be noted, however, that this pulse does have peaks over 100 g's and exceeds 80 g's for more than 3 ms. Based on the severity index, the value is below a tolerance level of 1000. Other accelerometer data exceed tolerance levels used in the injury criteria model including chest superior-inferior g-loading (32 g's), chest anterior-posterior g-loading (60 g peak and over 45 g's for 8 ms), head lateral g-loading (70 g peak). The lap belt total peak load is 3300 lb. and is within tolerance levels used in the injury criteria model. Based on the photographic data it is observed that the head is bent back (hyperextension) relative to the torso approximately 90°, a value exceeding the angular motion limits given in the injury criteria model, and potentially fatal to the occupant.

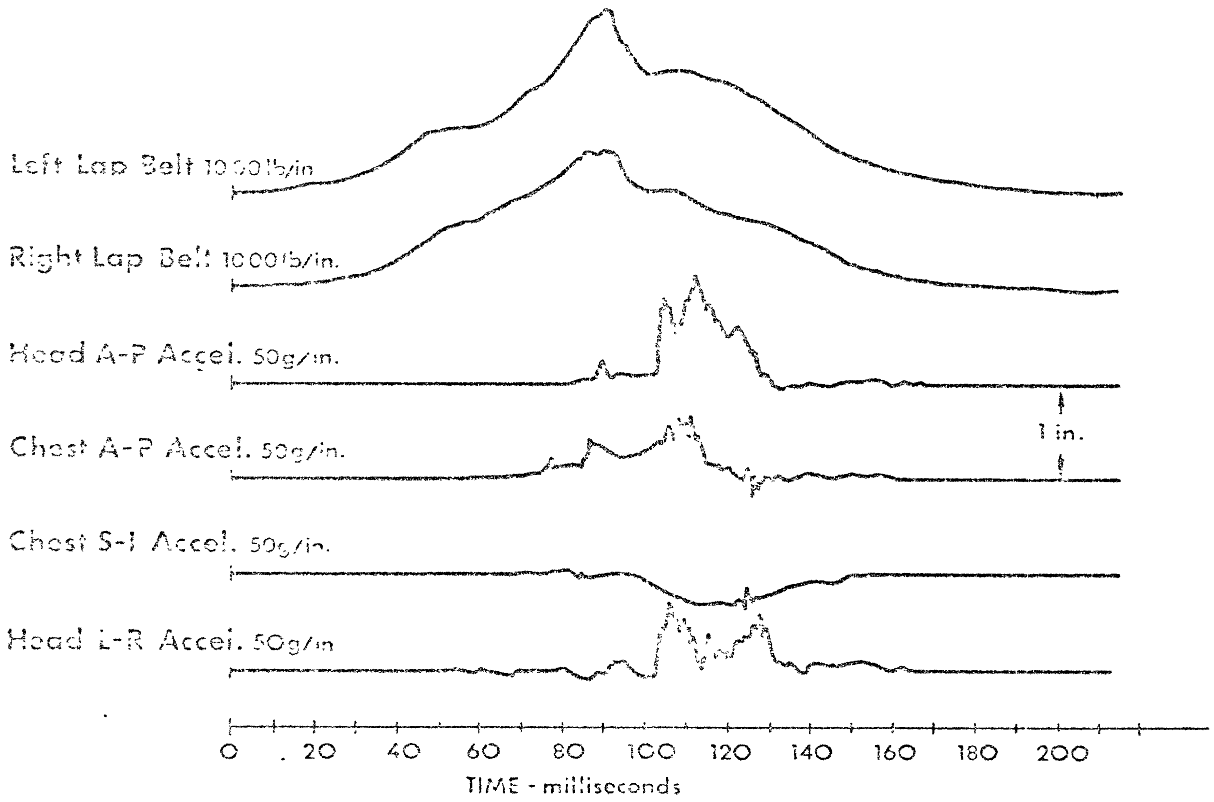


Figure 8. Tracing of Oscillographic Data from HSRI Sled Test No. A=247.

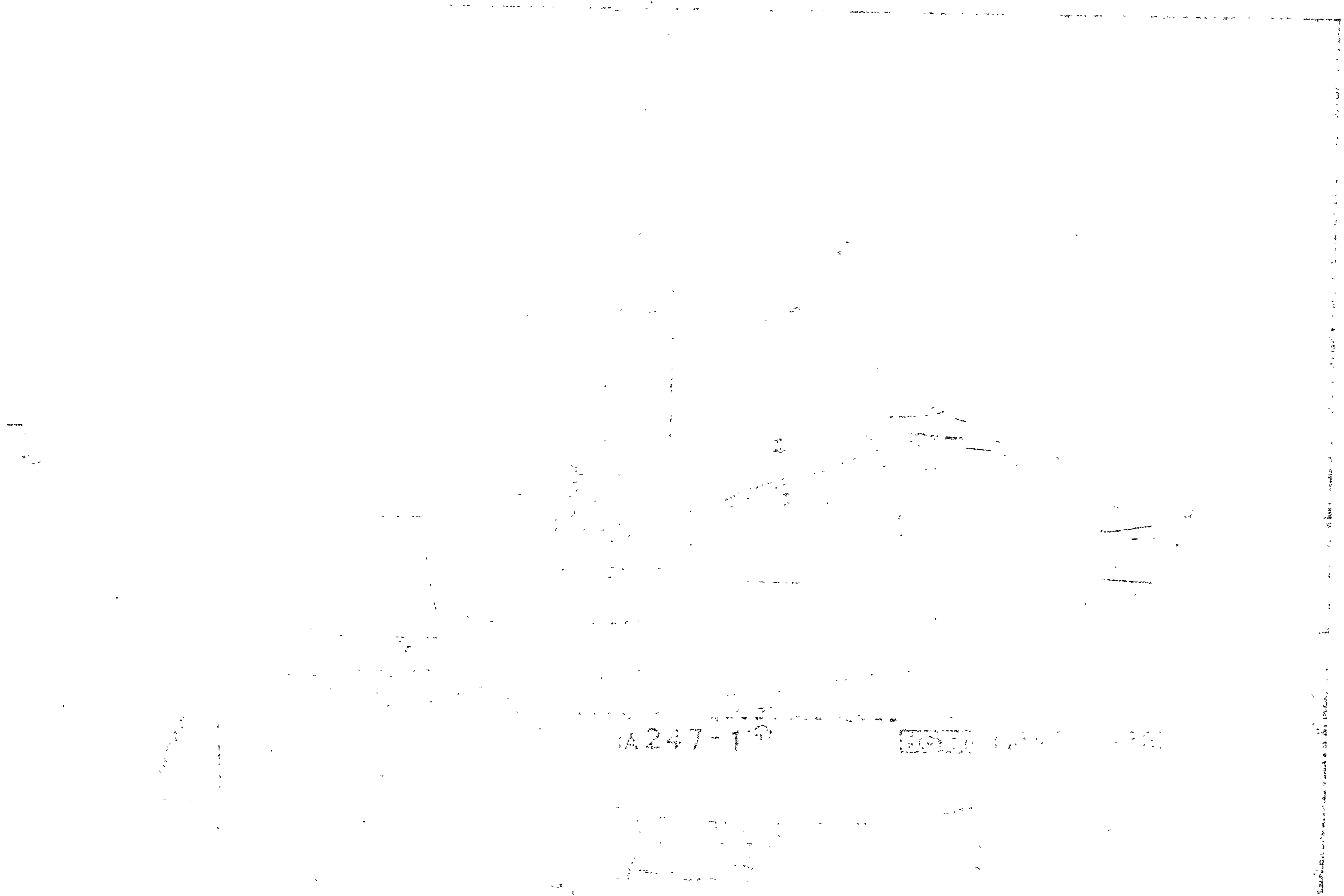


Figure 2

## 6.0 PERFORMANCE EVALUATION OF RESTRAINT SYSTEMS

In order to rate the overall protective capacity of a restraint system, it is necessary to apply the injury criteria model which has been proposed in this report to various occupant sizes, impact velocities, impact directions, etc. Thus, the effectiveness is based on multiple applications of the injury criteria model; individual samples of which have been given in Part V of this report. An analytical effectiveness index (M) is presented in this part of the report which allows the user to estimate the performance potential offered by a restraint system based on the totality of occupant sizes, impact directions, probabilities of usage etc., which might be encountered in actual use. In conclusion, applications of this index are made to general restraint system performance evaluation, to use in connection with estimating compliance to motor vehicle safety standards, to estimation of the protective payoff offered by the introduction of safety-related motor vehicle hardware as a function of the probability of use of such hardware, and to updating of the injury criteria model.

The analytical effectiveness index (M) is hypothesized to be a function of the three sets of physical parameters which define a restraint environment (the occupant, the vehicle interior and physical properties of the restraint system, and the velocity as well as direction of the impact), the probability that an occupant will be using the vehicle location for which the restraint system is provided, and the probability that the restraint system will be in use by the occupant.

This may be formulated as

$$M = f_1\ (O,\ R,\ D,\ P_O,\ P_U) \qquad (1)$$

where

$O$ = occupant weight and geometry

$R$ - physical definition of restraint environment

D = definition of deceleration time history, impact velocity, and direction of impact

$P_\sigma$ = probability that an occupant will occupy the seating location for which the restraint system is provided

$P_u$ = probability that the occupant will use the system

As the intent of the index (M) is to provide a measure of effectiveness for individual restraint concepts, the quantity R may be separated from the functional relationship and redefined as a scaling function to be used with baseline data to set the value of M to unity. In this case M>1 would indicate a restraint device more effective than the baseline whereas M<1 would indicate a less effective device. Likewise, the two probabilities are numbers independent of the restraint system and the quantities describing the various types of collision events. As such they can also be separated from the functional relationship. Hence, Eq. 1 may be rewritten

$$M = R\, P_\sigma\, P_u\, f_2\,(O,\, D) \tag{2}$$

That part of the function which describes the occupant should apply to the entire size range of occupants for which the restraint system is expected to offer protection. Representative occupants are those modeled by anthropometric test dummies and include a six year old child, a 5th percentile adult female, and 50th as well as 95th percentile adult male dummies. It should be noted at this point that parameters describing the occupant(O) have been separated from probability that an occupant will be using the location where the restraint system is provided. For example, it is unlikely that a 6 year old child will occupy the drivers seat and it is most likely that the driver will be an adult male. Therefore, in addition to representing the size range of possible occupants, the functional relationship must include the probability that the occupant is a particular size.

The relationship

$$f_3(O) = a_1 + a_2 + a_3 + a_4 \tag{3}$$

where

$\sigma_1$ = probability of use by 6-year-old child

$\sigma_2$ = probability of use by 5th percentile female

$\sigma_3$ = probability of use by 50th percentile male

$\sigma_4$ = probability of use by 95th percentile male,

accomplishes both these objectives and also increases as the variety of occupant sizes offered protection increases. If sufficient data have not been gathered to define these probabilities, the quantities could be set to 0 or 1 to cover the range of occupants for which the restraint system is intended to be effective. A more general form of the equation describing the range of occupant sizes which may use a particular restraint system is

$$f_3(0) = \sum_{i=1}^{n} \sigma_i \tag{4}$$

where "n" is the number of occupant sizes or combination of sizes for which the restraint system is designed. This formulation may be useful when a combination of occupants may be offered protection by a single restraint system.

That portion of $f_1$ which describes the velocity and direction of impact should increase as effectiveness increases and include the range of velocities over which the level of protection is satisfactory, impact direction, the probability that a particular type of accident event will occur, and the distribution of impact speeds from a given direction. The relationship which accomplishes this is

$$f\ (D) = \sum_{j=1}^{m} (v_{j1} - v_{j2}) d_j\ a_j \tag{5}$$

where

$v_{j1}$ = the maximum velocity for which protection is offered to the occupant under the injury criteria model for a particular impact direction

$v_{j2}$ = the minimum velocity (in most cases $v_{j2}$ = 0 mph) for which protection is offered to the occupant under the injury criteria model for a particular impact direction

$d_j$ = the probability of an impact from a particular direction

$a_j$ = the percentage of accidents occurring in the speed range covered by the difference in maximum and minimum threshold velocities

m = the number of types of collisions to be included in the index.

The maximum and minimum threshold velocities are chosen either as a requirement to be met by a restraint system under evaluation or as the result of testing and analysis. The subscripting scheme in Table XVII is suggested for use in the index.

TABLE XVII. SUBSCRIPTING IN RESTRAINT SYSTEM EFFECTIVENESS INDEX

| Subscript j | Definition |
|---|---|
| 1 | front |
| 2 | right front oblique |
| 3 | left front oblique |
| 4 | right side |
| 5 | left side |
| 6 | right rear oblique |
| 7 | left rear oblique |
| 8 | rear |
| 9 | rollover |
| 10 | other |

The probabilities for most of these events are given in Table IV.

Less information is available describing the percentage of accidents occurring in the speed range covered by the difference in maximum and minimum threshold velocities. The most up-to-date information known to the authors is that contained in the HSRI Hit Lab files[129] and gathered at the Research Triangle Institute.[131] This information could be modified for use with the present effectiveness index. A preliminary study based on HSRI Hit Lab files is given in Table XVIII showing the percentage of accidents occurring at increasing velocities. No correlation with impact direction is available.

TABLE XVIII. PERCENTAGE OF ACCIDENTS AS A FUNCTION OF VELOCITY

| Velocity Range (mph) | Percentage of Accidents |
|---|---|
| 0-5 | 14.5 |
| 5-10 | 6.6 |
| 10-15 | 4.0 |
| 15-20 | 15.8 |
| 20-25 | 14.5 |
| 25-30 | 9.2 |
| 30-35 | 13.2 |
| 35-40 | 3.9 |
| 40-45 | 9.2 |
| 45-50 | 2.6 |
| 50-55 | 4.0 |
| above 55 | 2.6 |

Combining Equations (2), (4) and (5) the general form proposed for the complete restraint system effectiveness index can be written

$$\Pi = K\, p_i\, P_u \sum_{i=1}^{n} a_i \sum_{j=1}^{m} (v_{ij} - v_{ji}) d_j a_j \qquad (6)$$

If the subscripting schemes proposed in Evaluation (3) and in Table XVII are applied, Equation (6) can be rewritten

$$M = R\, P_\sigma\, P_u(\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4)[(v_{1,1} - v_{1,2})d_1\, a_1$$

$$+ (v_{2,1} - v_{2,2})d_2\, a_2 + \cdots + (v_{10,1} - v_{10,2})d_{10}\, a_{10}] \qquad (7)$$

The first sample hypothetical application of the effectiveness index compares a lap belt-shoulder harness combination with an airbag for a right front passenger. Ordinarily, an impact sled or full-scale crash test matrix for such a system includes frontal, right lateral, and rear-end tests and involves various sizes of adult dummies. The 5th percentile female, 50th percentile male, and 95th percentile male will be assumed for this case. The airbag will be assumed to: (1) have a 100% probability of use; (2) be effective from 0 to a maximum of 40 mph in a frontal collision; and, (3) be effective in 20 mph right side impact and 40 mph rear impact when supplemented by appropriate vehicle side door and seat back design features. The belt combination will: (1) have a 5% probability of usage; (2) be effective from 0 to 40 mph in a frontal collision; and, (3) be effective in 20 mph right side impact and in a 40 mph rear collision when supplemented by appropriate vehicle side door and seat back design features. The probability of occupancy of the right front passenger position will be assumed to be 29.2% (See Table V) and the percentage of accidents occurring in the speed range will be assumed to be 100% for the purposes of this example. Both the airbag and the belt combination are assumed to protect all three occupant sizes leading to the assumption that the threshold velocity is independent of occupant size. Thus, in this example, $\sigma_5 = \sigma_{50} = \sigma_{95} = 1$. Equation (7) is simplified for the example to

$$M = P_\sigma P_u (\sigma_5 + \sigma_{50} + \sigma_{95})(v_f d_f + v_{rl} d_{rl} + v_r d_r)$$

For the airbag restraint system,

$$M = .292 \times 1. \times 3.(40 \times .39 + 20 \times .054 + 40 \times .023) = 15.4$$

For the lap belt and shoulder harness combination,

$$M = .292 \times .05 \times 3.(40 \times .39 + 20 \times .054 + 40 \times .023) = .8$$

The advantage of the airbag is clearly demonstrated because of its passive deployment.

The second example of possible use of the index is related to its application as a compliance tool. The revised form of MVSS 208 (November 3, 1970) involves frontal, lateral and rollover compliance tests involving dummies in all seating locations. Because there are six seating locations the index may be written

$$M = M_1 + M_2 + \cdots + M_6 \qquad (9)$$

where 1, 2, ..., 6 represent separate applications of the index. Expanding this,

$$\begin{aligned} M = {} & P_d P_u \sigma_{50} (v_f d_f) \\ & + P_{cf} P_u \sigma_{50} (v_f d_f) \\ & + P_{rf} P_u \sigma_{50} (v_f d_f + v_{rl} d_{rl} + v_{r\sigma} d_{r\sigma}) \\ & + P_{lr} P_u \sigma_{50} (v_f d_f) \\ & + P_{cr} P_u \sigma_{50} (v_f d_f) \\ & + P_{rr} P_u \sigma_{50} (v_f d_f + v_{rl} d_{rl} + v_{r\sigma} d_{r\sigma}) \end{aligned}$$

where

subscripts d, cf, rf, lr, cr, rr refer to occupant locations with d = driver, cf = center front, rf = right front, lr = left rear, cr = center rear, and rr = right rear

$P_u$ = probability of use

$\sigma_{50}$ = 50th percentile male dummy

Subscripts f, rl, and rσ refer to front, right lateral, and rollover accidents when subscripted to velocity or probability. Because the test matrix will be carried out in the same manner each time the probability of use of the occupant positions, the probability of use of the restraint systems, the probability of a 50th percentile male dummy and the probabilities of the accident type and velocity range will all be unity. The test velocities as stated in the standard are

$$v_f = 30 \text{ mph}, \; v_{rl} = 20 \text{ mph}, \; v_{r\sigma} = 30 \text{ mph}$$

In order to comply with the standard, the injury criteria (in this case the one specified in MVSS 208) must be met for

$$M = 280$$

with the stipulation that no test velocity be below these listed in the standard.

The third example of potential use for the index (M) is concerned with its use in the determination of research priority and potential payoff. It should be noted in Equation (6) that the effectiveness varies directly with both the probability of restraint system use and the probability that a particular seating location is occupied, emphasizing that protecting the driver and right front seat passengers with effective passive restraint systems would lead to a greater reduction of injuries than protecting all other potential occupants combined. Likewise, protecting the driver in frontal collisions would be a more effective measure in injury reduction than protecting him from all left rear oblique collisions.

The fourth example of the application of the index (M) has to do with its use in updating the injury criteria model. In order to determine the velocity (v) for use in the index it is necessary to apply an injury criteria model such as the one proposed in this report. When this is done repeatedly it is likely that some types of tolerance levels will be exceeded more often than others.

For instance, knee loadings will show up as an important limiting factor in most passive restraint systems which are being proposed at the present time. Likewise, head lateral g-loading will very likely be a limiting factor in evaluating door crashworthiness structures. Thus, during application of the index (M), the need for refining specific tolerance data and for determining new information should be isolated.

In this part of the report a restraint system effectiveness index (M) has been introduced for use with the injury criteria model. Its use has been demonstrated in four examples to provide the researcher and developer of standards with a consistent tool for comparing the protective level of restraint systems.

# 7.0 REFERENCES

1. Gadd, C.W. 1966. "Use of a weighted-impulse for estimating injury hazard," Proc. 10th Stapp Car Crash Conf., Nov., pp. 95-100.

2. Ommaya, A.K., et al. 1970. "Comparative tolerances for cerebral concussion by head impact and whiplash injury in primates." 1970 International Automobile Safety Conference Compendium, SAE Pub. No. P-30, pp. 808-817.

3. Zaborowski, A.B. 1964. "Human tolerance to lateral impact with lap belt only," Proc. 8th Stapp Car Crash Conf., Oct., pp. 34-71.

4. Gadd, C.W. and Patrick, L.M. 1968. "System versus laboratory impact tests for estimating injury hazard." SAE Paper No. 680053, Jan.

5. "Estimated probable threshold of injury." Biomechanics Task Force of SAE Occupant Restraint Systems Subcommittee.

6. Stapp, J.P. and Enfield, D.L. 1958. "Evaluation of the lap-type automobile safety belt with reference to human tolerance." SAE Paper No. 62A.

7. Snyder, R.G. 1970. "Human Impact Tolerance." 1970 International Automobile Safety Conference Compendium, SAE Publ. No. P-30, pp. 712-782.

8. Van Kirk, D.J. and Lange, W.A. 1968. "A detailed injury scale for accident investigation," Proc. 12th Stapp Car Crash Conf. pp. 237-259.

9. Patrick, L.M., Kroell, C.K., and Mertz, H.J. 1966 "Force on the human body in simulated crashes." Proc. 9th Stapp Car Crash Conf. pp. 237-259.

10. Robbins, D.H., Bennett, R.O. and Roberts, V.L. 1970. "Development of two- and three-dimensional crash victim simulators." HSRI Report No. Bio M-70-3, p. 80.

11. Robbins, D.H. "Three-dimensional simulation of advanced automotive restraint systems." 1970 International Automobile Safety Conference Compendium, SAE Pub. No. P-30, pp. 1008-1023.

12. Winquist, P.G., Stumm, P.W. and Hanson, R. 1953. "Crash injury experiments with monorail decelerator." AFFTC Report No. 53-7, Edwards AFB, Calif.

13. Campbell, H.E. 1955. "Role of the safety belt in nineteen auto crashes." Bull. Amer. Coll. Surgeons 40:155-158 (May-June).

14. Kulowski, J. and Rost, W.B. 1956. "Intra-abdominal injury from safety belt in auto accident. Report of a case." Arch. Surg. 73:970-971.

15. Beeding, E.L. and Hessberg, R.R. 1958. "Daisy test tracks 271-337." AFMDC Holloman AFB, November.

16. Lewis, S.T. and Stapp, J.P. 1958. "Human tolerance of aircraft seat belt restraint." J. Aviation Med. 29:[illegible].

17. Beeding, E.L. 1959. "Daisy track tests 338-519." AFMDC, Holloman AFB, Test Report No. 59-14, Dec.

18. Beeding, E.L. 1960. "Daisy decelerator tests 13 July 1959-13 April 1960." AFMDC, Holloman AFB, Test Report No. 60-4, July.

19. Cook, J.E. and Mosely, J.D. 1960. "Visceral displacement in black bears subjected to abrupt deceleration." Aerospace Med. 31(1):1-8.

20. Beeding, E.L. 1961. "Human forward facing impact tolerance." Presented to the Thirty-Second Annual Aerospace Medical Association Convention Chicago, Illinois, 24-27 April.

21. Bergstrom, J. 1961. "Neck injury from a safety belt." Svensk. Lakartidn. 58:3100-1, 27 October.

22. Bruggenk, G.M. and Schneider, D.J. 1961. "Limits of seat belt protection during crash decelerations." TREC Technical Report 61-115, Sept.

23. Brunius, U. and Lindgren, S. "The effectiveness of safety belts. An analysis of 210 belts cases." Nord. Med. 66(44):1500-1503.

24. Engberg, A. 1961. "Injuries caused by safety belts. A contribution to the discussion with reference to an unusual case." Svensk. Lakartidn. 58:884-886.

25. von Bahr, V. and Friksson, F. 1961. "Injuries caused by safety belts." Svensk. Lakartidn. 58:141-143.

26. Ebbetts, J. 1962. "Seat belts and cervical spondylosis." Practitioner 188-802.

27. Garrett, J.W. and Braunstein, P.W. 1962. "The seat belt syndrome." J. Trauma 2:220-238.

28. Lindgren, S. and Warg, E. 1962. "Seat belts and accident prevention." Practitioner 188:467-473.

29. Moreland, J.D. 1962. "Safety belts in motor cars, an assessment of their effectiveness." Ann. Occup. Hyg. 5:95.

30. Aiken, D.W. 1963. "Intestinal perforation and facial fractures in an automobile accident victim wearing a seat belt." J. Louisiana State Med. Soc. 115(7):235-236.

31. Backstrom, C. 1963. "Traffic injuries in south Sweden with special reference to medico-legal autopsies of car occupants and value of safety belts." Acta Chirurg. Scand., Suppl. 308.

32. Cocke, W.H., Jr. and Meyer, K.K. 1963. "Splenic rupture due to improper placement of automotive safety belt." JAMA 183(8):693.

33. Hansen, O.M. and Rasumussen, P.S. 1963. "Traffic accident with a spleen injury associated with the use of a safety belt." Ugeskr. Laeg. 125:771-773.

34. Birrel, J.H. 1964. "Safety belts for motor vehicles in Victoria." Med. J. Australia 1:67.

35. Melhom, G. 1964. "Contribution to the subject of safety belts." [Beitrag Zum Thema Sicherheits-gurte] Landarzt 40:114-116, 31 Jan.

36. Rubovits, F.E. 1964. "Traumatic rupture of the pregnant uterus from seat belt injury." Amer. J. Ob. Gyn. 90(6):828-829.

37. States, J.D. 1964. "Case studies of racing accidents." Proc. 8th Stapp Car Crash Conf.

38. Tolins, S.H. 1964. "An unusual injury due to the seat belt." J. Trauma 4:397-399.

39. Fish, J. and Wright, R.H. 1965. "The seat belt syndrome - does it exist?" J. Trauma 5(6):746-750.

40. Fisher, P. 1965. "Injury produced by seat belts: report of 2 cases." J. Occup. Med. 7:211-212.

41. Howland, W.J., Curry, J.L. and Buffington, C.B. 1965. "Fulcrum fractures of the lumbar spine." JAMA 193(3):240-241.

42. Hurwitt, E.S. and Silver, C.E. 1965. "A ventral hernia following an automotive crash." JAMA 194(7):829-831.

43. McRoberts, J.W. 1965. "Seat belt injuries and legal aspects." Indust. Med. and Surg. 34:866-869.

44. Nahum, A.M. 1965. "Facial trauma in automobile collisions." Am. Acad. OPHTH. & OTOL. 69:396-404, May-June.

45. Sharp, J.E., Campbell, H.E., and Utans, P. 1965. "Analysis of lap shoulder belt effectiveness in accidents." Proc. 9th Stapp Car Crash Conf. Univ. of Minnesota, 20-21 October, pp. 65-75.

46. Schneider, R.C., Livingston, K.E., Cave, A.J.E. and Hamilton, G. 1965. "Hangman's Fracture" of the cervical spine." J. Neurosur. 22 (2):141-154.

47. States, J.D. and Benedict, J.F. 1965. "Safe and unsafe upper torso restraints for occupant protection in motor vehicles." Proc. 7th Stapp Car Crash Conf. pp. 312-323. Springfield, Ill. C.C. Thomas.

48. Gerritsen, R. Frobese, A.S., and Pazzi, P.J. 1966. "Unusual abdominal injuries due to seat belts." J. of the Albert Einstein Medical Center 14(1):63-66.

49. Hilton, B.C. 1966. "The development of vehicle safety seating for injury protection." Presented at the American Association for Automotive Medicine Holloman AFB. Alamogordo, New Mexico, Nov. 10-11.

50. Snyder, R.G. 1966. "Civil pilot accident experience with high performance single engine light executive type aircraft." Presented at International Air Safety Seminar, Flight Safety Seminar, Madrid, Spain, Nov.

52. Snyder, R.G., Crosby, W., Hanson, P., Snow, C.C., Chandler, R. and Fineg, J. 1966. "Impact injury to the pregnant female and fetus in lap belt restraint." Presented at 10th Stapp Car Crash Conference, Holloman AFB, New Mexico, 8 Nov., (in press).

53. Stapp, J.P. 1966. "Part II. Effects of seat belts: man." *Environmental Biol.*, p. 229. Bethesda: Federation of American Society for Experimental Biology.

54. Williams, J.S., Lies, B.A., and Hale, H.W. 1966. "Intra-abdominal injury from seat belts." *J. Trauma* 6:303-315.

55. Zabrowski, A.D. 1966. "Human tolerance to lateral impact with lap belt only." *8th Stapp Car Crash Conf.* Detroit: Wayne State University Press.

56. Zabrowski, A.B. 1966. "Lateral impact studies. Lap belt-shoulder harness investigations." *Proc. 9th Stapp Car Crash Conf.*

57. Blumenberg, R.M. 1967. "The seat belt syndrome: Sigmoid colon perforation." *Annals of Surg.* 65(4):637-639, April.

58. Connor, R.W. 1967. "Personal communication."

59. Fletcher, B.D. and Bragdon, B.G. 1967. "Seat-belt fractures of the spine and sternum." *JAMA* 200(2):177-178, 10 April.

60. Lemire, J.R., Earley D.E. and Hawley, C. 1967. "Intra-abdominal injuries caused by automotive seat belts." *JAMA* 201(10):109-111, 4 Sept.

61. Reader, D.C. 1967. "The restraint afforded by the USAF and proposed RAF IAM seat harnesses for the F111 under high forward and lateral decelerations. IAM Report No. 421, Sept.

62. Saldeen, T. 1967. "Fatal neck injuries caused by use of diagonal safety belts." *J. Trauma* 7(6):856-862.

63. Smith, W.S. and Kaufer, H. 1967. "A new pattern of spine injuries associated with lap type seat belts." *Univ. of Mich. Med. Center J.* Vol. 33, May-June.

64. Snyder, R.G., Snow, C.C., Young, J.W., Price, G.T., and Hanson, P. 1967. "Experimental comparison of trauma in lateral ($-G_y$), rearward facing ($-G_x$) and forward facing ($-G_x$) body orientations when restrained by lap belt only." *Aerospace Med.* (in press).

65. Snyder, R.G., Crosby, W.M., Snow, C.C., Young, J.W., and Hanson, P. 1967. "Seat belt injuries in impact." *Proceedings of Symposium* held in honor of Univ. of Mich. Sesquicentennial, 19-21 April.

66. Sube, J., Ziperman, H.H. and McIver, W.J. 1967. "Seat belt trauma to the abdomen." *Amer. J. of Surg.* 113(3):346-350, March.

67. Tampen, I.D. 1967. "The effectiveness of seat belts." Road Accident Research Report #3. Ford Motor Company. Aug.

68. Backwinkel, K.D. 1968. "Injuries from seat belts" JAMA 205(2):107-110, 29 July.

69. Carroll, T.B. and Bruber, F.H. 1968. "Seat belt fractures." Radiology 91(3):517-518, Sept.

70. Crosby, W.M., Snyder, R.G., Snow, C.C., and Hanson, Peter G. 1967. "Impact injuries in the pregnant female: 1. Experimental studies." Presented at the Central Association of Obstetricians and Gynecologists Annual Meeting 14-16 Sept., 1967; Amer. J. Ob. Gyn. 101(1):100-110; also FAA Report AM 68-6, March 1968.

71. Kear, J.E. 1968. Personal communication.

72. Jalley, F.L. and Wright, P.H. 1968. "A study of severe vehicular accidents phase 1: Medico-engineering trauma program." Report for FHA School of Civil Engineering, Georgia Institute of Technology.

73. Nahum, A.M., Siegel, A.W., Hight, P.V. and Brooks, S.H. 1968. "Lower Extremity Injuries of Front Seat Occupants." SAE Paper #680483.

74. Porter, S.D. and Green, E.W. 1968. "Seat belt injuries." Arch. Surg. 96:242-246, Feb.

75. Schneider, R.C., Smith, W.S., Grabb, W.C., Turcotte, J.G., and Huelke, D.F., 1968. "Lap seat belt injuries; the treatment of the fortunate survivor." Michigan Med. 67(3):171-186, Feb.

76. States, J.D. and States, D.J. 1968. "Pathology and Pathogenesis of injuries caused by lateral impacts' accidents." 12th Stapp Car Crash Conf. Detroit, Mich. 22-23 Oct., 1968.

77. Armstrong, R.W. and Waters, H.P. 1969. "Testing programs and research on restraint systems." SAE Paper No. 690247.

78. Huelke, D.F. and Chewning, W.A. 1969. "Comparison of occupant injuries with and without seat belts." Prepared for International Automotive Engineers Congress, Detroit.

79. Johannessen, H.G. 1969. "Personal communication."

80. Siegel, A.W., Van Wagoner, W.T., and Nahum, A. 1969. "Case comparisons of restrained and non-restrained occupants and related injury patterns." Presented at the International Automotive Engineering Company, Detroit, Mich. 13-17 January, 1969.

81. Siegel, A.W., Nahum, A.M. and Appleby, M.R. 1969. "Injuries to children in automobile collisions." SAE Paper No. 680771.

82. Snyder, R.G., Young, J.W., and Snow C.C. 1969. "Experimental impact protection with advanced restraint systems, preliminary primate tests with air bag and inertia reel, inverted Y yoke torso harness." Report No. AM 69-[illegible]. Federal Aviation Administration Civil Aeromedical Institute, Oklahoma City, Okla. 20 pp.

83. Snyder, R.G., Snow, C.C., Young, J.W., Crosby, W.M., and Price, G.T. 1969. "Pathology of trauma attributed to restraint systems in crash impacts." Report No. AM 69-3. Federal Aviation Administration Civil Aeromedical Institute, Oklahoma City, Okla. 29 pp.

84. States, J.D. and Ryon, D. 1969. SAE Paper No. 690246.

85. Van Kirk, D.J. and King, A.I. 1969. "A prelimnnary study of an effective restraint system for pregnant women and children." Proc. 13th Stapp Car Crash Conf., Boston, Mass. 2-4 Dec.

86. Aldman, B., 1962. "Biodynamic studies on impact protection." Acta Physiologica Scand. Stockholm 56 (Suppl. 192).

87. Anonymous. 1967. "Nearly two-thirds of drivers in survey do not use seat belts." Traffic Safety 67(4):42.

88. Bastiannse, J.C. and Bouwman, A.A. 1966. Statistical study. Effectiveness (of) seatbelts." Rapport. RAI-TNO, Instituut Voor Wegtransport Middelen, Netherlands.

89. Bourke, G.J., 1965. "The efficiency of car safety belts." J. Irish Med. Assoc. 57:110-117.

90. Campbell, B.J. and Kihlberg, J.K. 1964. "Seat belt effectiveness in the non-ejection situation." Proc. 7th Stapp Car Crash Conf. Charles C. Thomas Springfield, Ill.

91. Campbell, H.E. 1964a. "The automotive seat belt and abdominal injury." Surgery 119-591-592.

92. DeHaven, H., Tourin, B., and Marcri, S. 1953. "Aircraft safety belts: their injury effect on the human body." Crash Injury Research of Cornell University Medical College.

93. DuBois, F.F. 1952. "Safety belts are not dangerous." Brit. Med. J. 2:605. (Discussion of Teare's Paper).

94. Elias, M. 1950. "Rupture of pregnant uterus by external violence." Lancet, 2:253-254, August. (No Seat Belts - 1950).

95. Frazier, R.G. 1961. "Effectiveness of Seat Belts in Preventing Motor Vehicle Injuries." New England J. Med. 264:1254-1256.

96. Fredericks, R.H., 1961. "Progress in Safe Vehicle Design." The Fifth Stapp Automotive Crash and Field Demonstration Conference, The University of Minnesota, 14-16 September, pp. [illegible].

97. Fredericks, R.H. 1961. "Barrier Collision Investigation of Harness Restraining Systems." Proc. Seventh Stapp Car Crash Conf., Springfield, Ill., C.C. Thomas.

98. Garrett, J.W., [illegible]. "A Study of Seat Belts in Wisconsin Automobile Accidents." Cornell Aeronautical Laboratory, Inc., Rept. No. VJ-1823-R[illegible], Sept.

99. Gissane, W. and Bull, J. 1961. "A study of motor-way fatalities." Brit. Med. J. 1:75.

100. Gogler, E. 1965. Road Accidents. Basle, Switzerland: Geigy. ("Unfallopfer im Strassenverkehr." Series Chirurgica Geigy No. 5)(1962).

101. Haley, J.L. 1962. "Personnel restraint systems study, basic concepts." AvCIR 62-12. U.S. Army Transportation Research Command, Fort Eustis, Virginia. Dec.

102. Hasbrook, A.H. 1956. "Design of passenger "tie-down; some factors for consideration in the crash-survival design of passenger seats in transport aircraft." Report AvCIR 44-9-66. Aviation Crash Injury Research of Cornell University, Flushing, N.Y.

103. Herbert, D.D. 1964. Med. J. Austr. 1:61.

104. Huelke, D.F. and Gikas, P.W. 1966. "Ejection - the leading cause of death in automobile accidents." Proc. 10th Stapp Car Crash Conf. Holloman AFB, 8-9 Nov. pp. 156-181.

105. Lawrence, J.M. 1966. "Seat belt liability: Texas." Defense Memo 7(7):52-53.

106. Life, J.S., Pince, B.W., Brian, M., Herberlein, P.J. and Gesink, J.W. 1966. "Comparative responses of live anesthetized and dead embalmed monkeys exposed to impact stress. Phase I." Space/Defense TR 66-107, 16 Sept. (Submitted to Science as "Comparative pathology of live and embalmed monkeys exposed to impact.")

107. Lister, R.D. and Milson, B.M. 1963. "Car seat belts: an anlaysis of the injuries sustained by car occupants." Practitioner 191:332-340.

108. Lombard, C.F. and Advani, S.H. 1966. "Impact protection by isovolumetric containment of the torso." Proc. 10th Stapp Car Crash Conf., Holloman AFB.

109. MacVean, S.S. 1966. "Seat belt usage and vehicle occupancy data." Ford Motor Co. Technical Memo, PRM 66-26. 9 Aug.

110. McHenry, R.R. 1965. "Analysis of the dynamics of automobile passenger-restraint systems." Proc 7th Stapp Car Crash Conf. Springfield, Ill: Charles C. Thomas.

111. Michelsen, K., Aldman, B., Tourin, B., and Mitchell, J. 1964. "Dynamic tests of restraining devices for automobile passengers." Public Health Reports 79:125.

112. Moseley, A. 1963. "Research on fatal highway collisions papers 1962-1963." Harvard Medical School.

113. Patrick, L.M. and Daniel, R.P. 1966. "Comparison of Standard and Experimental Windshields." L.M. Patrick, ed., Proc. 8th Stapp Car Crash and Field Demonstration Conf., 1964. (Detroit, Mich.: Wayne State University Press, 1966).

114. Patrick, L.M., Mertz, H.J. and Kroell, C.K. 1966. "Impact dynamics of unrestrained, lap belted, and lap and diagonal chest belted vehicle occupants." Proc. 10th Stapp Car Crash Conf., Holloman AFB, 8-9 Nov. pp. 27-52.

115. Quinn, F.C., Jr. 1962. "Are seat belts enough?" Gen. Pract. 26:101.

116. Schwimmer, S. and Wolf, R.A. 1962. "Leading causes of injury in automobile accidents." Automotive Crash Injury Research of Cornell University, Ithaca.

117. Severy, D.M. 1950. "Photographic instrumentation for collision injury research." J. Soc. Motion Picture and Television Engineers 67(2):69-77.

118. Severy, D.M. 1950. "Human simulation techniques by collision researchers." Proc. 8th Stapp Car Crash and Field Demonstration Conf., Detroit: Wayne State University Press.

119. Swearingen, J.J., Hasbrook, A.H., Snyder, R.G. and McFadden, E.B. 1963. "Kinematic behavior of the human body during deceleration." Aerospace Medicine 32(2):249 (Abstract). Civil Aeromedical Research Institute Report 62-13, Oklahoma City.

120. Swearingen, J.J. and Morrow, D.J. 1956. "Motion of the head and trunk allowed by safety belt restraint during impact." Civil Aeronautics Medical Research Laboratory, Columbus, Ohio.

121. Taylor, E.R., Chandler, R.F., Rhein, L.W., Edwards, R.H., and Carter, V.L. 1963. "The effects of severe impact on bears." Presented at the 34th Annual Meeting of Aerospace Medical Association, Los Angeles, 29 April-2 May.

122. Teare, D. 1951. "Post-mortem examination on air crash victims." Brit. Med. J. 2:707-708.

123. Tourin, B. and Garrett, J. 1960. "Safety belt effectiveness in rural California automotive accidents." Automotive Crash Research of Cornell University.

124. von Gierke, H.E. 1964. "Biodynamic response of the human body." Appl. Mech. Rev. 17(2):951-958. Dec.

125. Williams, R.D. and Sargent, F.T. 1963. "The mechanism of intestinal injury in trauma." J. Trauma 3:288-294.

126. Wolf, R.A. "The discovery and control of ejection in automobile accidents." JAMA 180:114.

127. Woodhull, R.B. 1942. "Traumatic rupture of pregnant uterus resulting from automobile accident." Surgery 12:615-620 Oct.

128. Young, J.W. 1967. "A functional comparison of basic restraint systems." OAM Report, Federal Aviation Agency., (in press).

129. Highway Safety Research Institute, 1970. "HIT Lap Report." September, The University of Michigan, Ann Arbor.

130. Roberts, V.L. and Robbins D.H. 1969. "Multidimensional mathematical modeling of occupant dynamics under crash conditions." SAE Paper No. 690248, 10 p.

131. Research Triangle Institute, 1970. "Speed and Accidents," Final Report on U.S. Department of Transportation Contract No. FH-11-6965.

# APPENDIX A

# HUMAN VOLUNTEER TEST SUMMARIES

# HUMAN SUBJECTS - FOREWARD FACING IMPACTS

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Impact | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 1) Daisy | lap belt | | M | 145 | 3485 | -5° | 8.5 | 3.1 | | | .75 | 125 | 100 | | | | | | | | | | 77 |
| 2) Daisy | lap belt | | M | 145 | 3486 | -5° | 12.3 | 7.2 | | | .75 | 300 | 250 | | | | | | | | | | 77 |
| 3) Daisy | lap belt | | M | 175 | 3490 | -5 | 15.2 | 9.8 | | | .75 | 480 | 180 | | | | | | | | | | 77 |
| 4) Daisy | lap belt | | M | 160 | 3491 | -5 | 14.5 | 8.9 | | | .75 | 300 | 290 | | | | | | | | | | 77 |
| 5) Daisy | lap belt & upper torso | | M | 130 | 3492 | -5 | 14.1 | 8.1 | | | .75 | 290 | 280 | 100 | 140 | | | | | | | | 77 |
| 6) Daisy | lap and upper torso | | M | [illegible] | 3493 | -5 | 14.5 | 8.7 | | | .75 | 300 | 250 | 220 | 330 | | | | | | | | |
| 7 Daisy | lap belt | | M | 130 | 3495 | -5 | 13.7 | 7.7 | | | .75 | 180 | 150 | | | | | | | | | | 77 |
| 8) Daisy | lap belt | | M | 155 | 3496 | -5 | 17.5 | 12.3 | | | .75 | 450 | 410 | | | | | | | | | pain lower abdomen & hip | 77 |
| 9) Daisy | 3 point | | M | 155 | 3497 | -5 | 17.4 | 12.2 | | | .75 | 360 | 400 | 230 | 300 | | | | | | | | 77 |
| 10) Daisy | lap and upper torso | | M | 175 | 3498 | -5 | 20.7 | 16.3 | | | 1.58 | 520 | 590 | 550 | 770 | | | | | | | pain & burns on neck | 77 |
| 11) Daisy | lap belt | | M | 155 | 3505 | -5 | 18.6 | 13.3 | | | .75 | 540 | 460 | | | | | | | | | pain in lower right ribcage | 77 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 12) Daisy | lap and upper torso |  | M | 135 | 3506 | -5 | 17.8 | 12.3 |  |  | .75 | 470 | 500 | 410 | 690 |  |  |  |  |  |  | pain and bruise on left hip-bone | 77 |
| 13) Daisy | lap belt |  | M | 180 | 3507 | -5 | 19.9 | 15.4 |  |  | .75 | 750 | 510 |  |  |  |  |  |  |  |  |  | 77 |
| 14) Daisy | lap and upper torso |  | M | 175 | 3508 | -5 | 19.5 | 15.1 |  |  | .75 | 280 | 300 | 510 | 710 |  |  |  |  |  |  | bruises on arms | 77 |
| 15) Daisy | lap and upper torso |  | [illegible] | [illegible] | 3509 | -5 | 19.4 | 13.2 |  |  | .75 | [illegible] | 540 | 330 | 570 |  |  |  |  |  |  |  | 77 |
| 16) Daisy | lap belt |  | M | 150 | 3511 | -5 | 19.2 | 14.3 |  |  | .75 | 590 | 520 |  |  |  |  |  |  |  |  |  | 77 |
| 17) Daisy | lap belt |  | [illegible] | 116 | 3512 | -5 | 20.1 | 15.9 |  |  | 1.58 | 560 | 550 |  |  |  |  |  |  |  |  |  | 77 |
| 18) Daisy | lap belt & upper torso |  | M | [illegible] | 3513 | -5 | 19.0 | 15.0 |  |  | .75 | 425 | 390 | 250 | 375 |  |  |  |  |  |  |  | 77 |
| 19) Daisy | lap belt |  | M | 180 | 3514 | -5 | 20.2 | 16.0 |  |  | 1.58 | 800 | 700 |  |  |  |  |  |  |  |  |  | 77 |
| 20) Daisy | lap belt & shoulder |  | M | 197 | 3515 | -5 | 20.3 | 16.0 |  |  | 1.58 | 650 | 660 | 400 | 590 |  |  |  |  |  |  |  | 77 |
| 21) Daisy | lap belt & shoulder |  | [illegible] | 135 | 3516 | -5 | 18.7 | 13.2 |  |  | .75 | 499 | 490 | 275 | 500 |  |  |  |  |  |  |  | 77 |

| Location of Testing | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED<br>Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | BELT LOADS (lb.)<br>Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | CHEST LOAD<br>g-level | Onset rate g/sec. | Time Duration sec. | HEAD LOAD<br>g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22) Daisy | Lap belt | | M | 150 | 3517 | -5 | 14.0 | 8.1 | | | .73 | 175 | 300 | | | | | | | | | | 77 |
| 23) Daisy | Lap belt | | M | 159 | 3518 | -5 | 13.5 | 9.9 | | | .75 | 109 | 299 | | | | | | | | | | 77 |
| 24) Daisy | Lap belt | 24 | M | 150 | 3519 | -5 | 13.2 | 11.9 | | | .75 | 430 | 380 | | | | | | | | | | 77 |
| 25) Daisy | Lap belt | | M | 130 | 3520 | -5 | 14.8 | 10.7 | | | .75 | 260 | 200 | | | | | | | | | | 77 |
| 26) Daisy | Lap belt | 20 | M | 214 | 3521 | -5 | 13.3 | 9.3 | | | .75 | 240 | 230 | | | | | | | | | | 77 |
| 27) Daisy | Lap belt | 22 | M | 147 | 3523 | -5 | 14.6 | 8.2 | | | .75 | 260 | 300 | | | | | | | | | | 77 |
| 28) Daisy | Lap belt | 25 | M | 177 | 3524 | -5 | 15.0 | 8.7 | | | .75 | 300 | 390 | | | | | | | | | | 77 |
| 29) Daisy | Lap belt | | M | 159 | 3525 | -5 | 15.1 | 8.5 | | | .73 | 260 | 300 | | | | | | | | | | 77 |
| 30) Daisy | Lap belt | 22 | M | 157 | 3526 | -5 | 19.3 | 15.9 | | | .75 | 540 | 440 | | | | | | | | | | 77 |
| 31) Daisy | Lap belt | 23 | M | 166 | 3527 | -5 | 17.4 | 12.8 | | | .75 | 400 | 460 | | | | | | | | | | 77 |
| 32) Daisy | Lap and upper torso | 31 | M | 160 | 3528 | -5 | 16.9 | 11.3 | | | .75 | 250 | 260 | 40 | 130 | | | | | | | | 77 |
| 33) Daisy | Lap and upper torso | 26 | M | 133 | 3530 | -5 | 17.3 | 12.4 | | | .75 | 240 | 360 | 100 | 230 | | | | | | | | 77 |
| 34) Daisy | Lap and upper torso | 21 | M | 114 | 3531 | -5 | 20.4 | 15.5 | | | 1.38 | 500 | 460 | 140 | 220 | | | | | | | | 77 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity f+/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| [illegible] Daisy | Lap belt & upper torso | 22 | M | [illegible] | 6932 | -5 | 15.0 | 9.7 |  |  | .75 | 180 | 220 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt & upper torso |  | M | 130 | 6933 | -5 | 11.8 | 9.1 |  |  | .75 | 280 | 300 | 70 | 120 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt & upper torso | 24 | M | 155 | 6934 | -5 | 15.1 | 9.2 |  |  | .75 | 400 | 390 | 120 | 200 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt & upper torso | 25 | M | 106 | 6935 | -5 | 20.1 | 15.2 |  |  | 1.58 | 360 | 440 | 220 | 460 |  |  |  |  |  |  |  | 77 |
| 31, Daisy | Lap belt & upper torso | 26 | M | 178 | 6936 | -5 | 17.5 | 12.2 |  |  | .75 | 360 | 420 | 220 | 440 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt & upper torso | 24 | M | 191 | 6937 | -5 | 16.5 | 13.3 |  |  | .75 | 280 | 400 | 140 | 340 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt | 24 | M | 191 | 6939 | -5 | 17.5 | 12.4 |  |  | .75 | 260 | 420 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | Lap belt & upper torso | 29 | M | 147 | 6940 | -5 | 17.3 | 12.2 |  |  | .75 | 400 | 440 | 100 | 340 |  |  |  |  |  |  |  | 77 |
| 43, Daisy | Lap belt & upper torso | 31 | M | 160 | 6941 | -5 | 19.3 | 13.0 |  |  | .75 | 260 | 360 | 220 | 430 |  |  |  |  |  |  |  | 77 |
| 41, Daisy | Lap belt & upper torso |  | M | 155 | 6942 | -5 | 13.6 | 7.8 |  |  | .75 | 280 | 300 | 200 | 340 |  |  |  |  |  |  |  | 77 |

| [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 45) Daisy | lap belt & upper torso | 26 | M | 137 | 3943 | -5 | 15.6 | 10.2 |  |  | .75 | 320 | 300 | 80 | 100 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 24 | M | 155 | 1059 | -5 | 13.9 | 8.3 |  |  | .75 | 330 | 390 | 190 | 280 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 22 | M | 147 | 1060 | -5 | 8.9 | 3.1 |  |  | .75 | 100 | 80 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 22 | M | 141 | 1061 | -5 | 11.1 | 5.2 |  |  | .75 | 100 | 110 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 25 | M | 177 | 1062 | -5 | 11.3 | 5.7 |  |  | .75 | 130 | 160 | 30 | 30 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 38 | M | 163 | 4065 | -5 | 15.1 | 9.7 |  |  | .75 | 210 | 250 | 190 | 340 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt | 38 | M | 165 | 4066 | -5 | 14.0 | 8.2 |  |  | .75 | 330 | 260 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt | 25 | M | 173 | 1067 | -5 | 14.7 | 9.2 |  |  | .75 | 250 | 360 |  |  |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 35 | M | 175 | 1068 | -5 | 13.3 | 7.5 |  |  | .75 | 160 | 210 | 110 | 160 |  |  |  |  |  |  |  | 77 |
| [illegible] Daisy | lap belt & upper torso | 21 | M | 114 | 4070 | -5 | 16.8 | 12.1 |  |  | .75 | 340 | 370 | 70 | 130 |  |  |  |  |  |  |  | 77 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 55) Daisy | Lap belt & upper torso | 25 | M | 136 | 4071 | -5 | 13.5 | 11.6 |  |  | .75 | 240 | 310 | 220 | 310 |  |  |  |  |  |  |  | 77 |
| 56) Daisy | Lap belt & upper torso | 23 | M | 178 | 4072 | -5 | 17.9 | 14.0 |  |  | .75 | 360 | 370 | 360 | 500 |  |  |  |  |  |  |  | 77 |
| 57) Daisy | Lap belt & upper torso | 24 | M | 191 | 4073 | -5 | 16.0 | 10.9 |  |  | .75 | 230 | 290 | 210 | 320 |  |  |  |  |  |  |  | 77 |
| 58) Daisy | Lap belt & upper torso | 31 | M | 160 | 4074 | -5 | 15.1 | 9.9 |  |  | .75 | 160 | 170 | 200 | 320 |  |  |  |  |  |  |  | 77 |
| 59) Daisy | Lap belt & upper torso | 26 | M | 137 | 4075 | -5 | 15.4 | 10.3 |  |  | .75 | 310 | 240 | 160 | 190 |  |  |  |  |  |  |  | 77 |
| 60) Daisy | Lap belt & upper torso | 23 | M | 166 | 4076 | -5 | 18.0 | 14.2 |  |  | .75 | 510 | 610 | 240 | 460 |  |  |  |  |  |  |  | 77 |
| 61) Daisy | Lap belt & upper torso | 29 | M | 136 | 4077 | -5 | 17.5 | 13.6 |  |  | .75 | 280 | 320 | 200 | 370 |  |  |  |  |  |  |  | 77 |
| 62) Daisy | Lap belt | 24 | M | 155 | 4079 | -5 | 8.8 | 3.7 |  |  | .75 | 170 | 170 |  |  |  |  |  |  |  |  |  | 77 |
| 63) Daisy | Lap belt | 24 | M | 155 | 4080 | -5 | 17.6 | 13.3 |  |  | .75 | 610 | 630 |  |  |  |  |  |  |  |  |  | 77 |
| 64) Daisy | Lap belt | 32 | M | 147 | 4081 | -5 | 16.1 | 11.5 |  |  | .75 | 330 | 350 |  |  |  |  |  |  |  |  |  | 77 |

| [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Seat Pitch deg. | Entrance Velocity f'/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. | | |
| 65) Daisy | Lap belt | 22 | M | 114 | 4082 | -5 | 15.2 | 10.1 | | | .75 | 190 | 250 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 25 | M | 177 | 4083 | -5 | 9.7 | 4.4 | | | .75 | 130 | 120 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 24 | M | 159 | 4084 | -5 | 13.8 | 8.3 | | | .75 | 220 | 260 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt & upper torso | 24 | M | 159 | 4085 | -5 | 14.5 | 9.1 | | | .75 | 240 | 330 | 310 | 380 | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 25 | M | 136 | 4089 | -5 | 19.0 | 15.5 | | | .75 | 260 | 390 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 20 | M | 175 | 4090 | -5 | 18.3 | 15.2 | | | .75 | 620 | 600 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 24 | " | 191 | 4091 | -5 | 15.5 | 10.7 | | | .75 | 290 | 230 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | [illegible] | [illegible] | [illegible] | 4092 | -5 | 14.5 | 9.1 | | | .75 | 270 | 280 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 23 | M | 160 | 4093 | -5 | 17.6 | 13.9 | | | 75 | 480 | 430 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 31 | M | 160 | 4094 | -5 | 13.4 | 12.4 | | | .75 | 250 | 270 | | | | | | | | | | 77 |
| [illegible] Daisy | Lap belt | 28 | M | 103 | 4095 | -5 | 10.0 | 11.8 | | | .75 | 170 | 200 | | | | | | | | | | 77 |
| 73) R.A.F. (F-111) | R.A.F. Harness | | M | 186 | 89 | | | 6.6 | 83 | | | 21 | 32 | 108 | 127 | | | | | | | | 61 |
| 77) R.A.F. (F-111) | R.A.F. Harness | | M | 159 | 64 | | | 7.5 | 64 | | | 98 | 32 | 148 | 234 | | | | | | | | 61 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-Level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 7a) R.A.F. (F-111) | R.A.F. Harness |  | M | 147 | 87 |  |  | 7.8 | 310 |  |  | 78 | 126 | 96 | 123 |  |  |  |  |  |  |  | 61 |
| [illegible] R.A.F. (F-111) | U.S.A.F. Harness |  | M | 147 | 90 |  |  | 7.9 | 175 |  |  | 83 | 47 | 154 | 145 |  |  |  |  |  |  |  | 61 |
| [illegible] R.A.F. (F-111) | U.S.A.F. Harness |  | M | 153 | 93 |  |  | 6.5 | 118 |  |  | 69 | 54 | 161 | 166 |  |  |  |  |  |  |  | 61 |
| [illegible] R.A.F. (F-111) | U.S.A.F. Harness |  | M | 226 | 95 |  |  | 6 | 110 |  |  | 135 | 70 | 216 | 197 |  |  |  |  |  |  |  | 61 |
| [illegible] Daisy |  | 22 | M |  |  |  |  | 38.6 | 331 | 253 |  |  |  |  |  |  |  |  |  |  |  |  | 53 |
| [illegible] Daisy |  | 59 | M |  |  |  |  | 45.4 | 494 | .228 |  |  |  |  |  |  |  |  |  |  |  |  | 53 |
| [illegible] Daisy |  | 24 | M | 220 |  |  | 19.5 | 16.0 | 540 | .01 | .56 |  |  |  |  | 19.0 |  | .004 |  |  |  | mild abdominal pain for several minutes | 53 |
| [illegible] Daisy |  | 29 | M | 162 |  |  | 19.0 | 17.0 | 576 | .007 | .56 |  |  |  |  | 18.0 |  | .003 |  |  |  | mild abdominal pain for several minutes | 53 |
| [illegible] Daisy |  | 25 | M | 163 |  |  | 19.0 | 18.9 | 523 | .005 | .52 |  |  |  |  | 25.0 |  | .01 |  |  |  | mild abdominal pain for several minutes | 53 |

| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | | |
| 57) Daisy | | 24 | M | 165 | | | 19.0 | 20.0 | 740 | 002 | .46 | | | | | 26.0 | | .003 | | | | severe upper abdominal pain for 30 sec. - upper back pain & stiffness for 48 hours | 53 |
| [illegible]) Daisy | | 22 | M | 165 | | 5 | 30.8 | 23.5 | 920 | .107 | .83 | | | | | | 1000 | | | | | no injury | 53 |
| [illegible]) Daisy | | 2[illegible] | M | 162 | | 5 | 43 9 | 21.0 | 1040 | .140 | 1 98 | | | | | | 1533 | | | | | no injury | 53 |
| [illegible]) Daisy | | 22 | M | 147 | | 5 | 48.2 | 22 0 | 1880 | .16 | 2 23 | | | | | | 2240 | | | | | no injury | 53 |
| 91) Daisy | | 22 | M | 147 | | 5 | 32.0 | 25.6 | 1030 | .101 | .99 | | | | | | 1110 | | | | | moderate pain-recuperation in + 21 hours | 53 |
| [illegible] Daisy | | 25 | M | 205 | | 35 | 21.4 | 24.5 | 1000 | .112 | .85 | | | | | | 1460 | | | | | mild pain-recuperation in + 72 hours | 53 |
| 93) Daisy | | 23 | M | 166 | | 35 | 45.9 | 22.0 | 2130 | .19 | 2 07 | | | | | | 1430 | | | | | no injury | 53 |
| [illegible]) Daisy | | 22 | M | 133 | | 35 | 45.5 | 23.5 | 2120 | .14 | 2.14 | | | | | | 1120 | | | | | mild pain-mild breathing difficulty-recuperation in 3 hrs. | 53 |

| [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED<br>Seat Pitch deg. | SLED<br>Entrance Velocity ft/sec | SLED<br>Peak g's | SLED<br>Onset rate g/sec | SLED<br>Pulse Duration sec | SLED<br>Stopping Distance Feet | BELT LOADS (lb.)<br>Right Lap Belt | BELT LOADS (lb.)<br>Left Lap Belt | BELT LOADS (lb.)<br>Right Upper Torso Belt | BELT LOADS (lb.)<br>Left Upper Torso Belt | CHEST LOAD<br>g-level | CHEST LOAD<br>Onset rate g/sec. | CHEST LOAD<br>Time Duration sec | HEAD LOAD<br>g-level | HEAD LOAD<br>Onset rate g/sec. | HEAD LOAD<br>Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95) Daisy | | 21 | M | 165 | | 35 | 31.5 | 25.0 | 1020 | .092 | .83 | | | | | | 1300 | | | | | severe pain-recuperation in 15 minutes | 53 |
| [illegible] | | 29 | M | [illegible] | | 45 | 31.4 | 25.1 | 960 | .12 | .90 | | | | | | 900 | | | | | severe pain-severe breathing difficulty mild faintness recuperation in 60 days | 53 |
| [illegible] Daisy | | 23 | M | 174 | | 45 | 45.8 | 22.5 | 2110 | .18 | 2.14 | | | | | | 1275 | | | | | mild pain, mild breathing difficulty-recuperation in 5 minutes | 53 |
| [illegible] | | 30 | [illegible] | 179 | | 315 | 31.1 | 24.6 | 980 | .12 | .83 | | | | | | 1370 | | | | | mild pain-recuperation in 14 days | 53 |
| [illegible] Daisy | | 25 | M | 205 | | 315 | 45.1 | 21.0 | 1530 | .165 | 2.29 | | | | | | 1710 | | | | | no injury | 53 |
| [illegible] Daisy | | 23 | M | 134 | | 335 | 31.3 | 24.7 | 1300 | .150 | .74 | | | | | | 1100 | | | | | mild pain-recuperation in 12 hours | 53 |
| [illegible] Daisy | | 25 | M | 173 | | 335 | 45.6 | 21.7 | 1530 | 170 | 2.07 | | | | | | 1450 | | | | | mild breathing difficulty - 1 minute | 53 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED<br>Seat Pitch deg. | SLED<br>Entrance Velocity ft/sec | SLED<br>Peak g's | SLED<br>Onset rate g/sec | SLED<br>Pulse Duration sec. | SLED<br>Stopping Distance Feet | BELT LOADS (lb.)<br>Right Lap Belt | BELT LOADS (lb.)<br>Left Lap Belt | BELT LOADS (lb.)<br>Right Upper Torso Belt | BELT LOADS (lb.)<br>Left Upper Torso Belt | CHEST LOAD<br>g-level | CHEST LOAD<br>Onset rate g/sec. | CHEST LOAD<br>Time Duration sec. | HEAD LOAD<br>g-level | HEAD LOAD<br>Onset rate g/sec. | HEAD LOAD<br>Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] Daisy | | 26 | M | 194 | | 325 | 44.2 | 20.0 | 1970 | .192 | 2.14 | | | | | | 1950 | | | | | no injury | 53 |
| 102) Daisy | | 19 | M | 177 | | 335 | 29.1 | 20.0 | 1330 | .120 | .83 | | | | | | 1100 | | | | | mild pain - 3 minutes | .53 |
| [illegible] Daisy | | 22 | M | | | | | 39.[illegible] | | | | | | | | | | | | | | anterior compression of 5th & 6th thoracic vertebral- linear fracture of 5th lumbar vetebrae | 53 |
| [illegible] Daisy | full harness | 24 | M | 163 | 1 | | 19.6 | 13.9 | 300 | .006 | .65 | | | | | | | | | | | | 16 |
| [illegible] Daisy | lap belt | 23 | F | 163 | 2 | | 19.0 | 18.9 | 52[illegible] | .005 | 52 | | | | | 25.0 | 320 | .010 | | | | | 16 |
| [illegible] Daisy | lap belt | 24 | M | 130 | 3 | | 19.5 | 16.0 | 540 | .010 | .58 | | | | | 17.0 | 250 | .004 | | | | | 16 |
| [illegible] Daisy | lap belt | 2[illegible] | M | 162 | 4 | | 19.0 | 17.0 | 576 | .007 | .57 | | | | | 18.0 | 240 | .003 | | | | | 15 |
| [illegible] Daisy | full harness | 28 | M | 123 | 5 | | 20.0 | 18.0 | 610 | .01 | .51 | | | | | 25.0 | 1000 | .02 | | | | | 16 |
| [illegible] Daisy | full harness | 19 | [illegible] | 155 | 6 | | 20.0 | 15.0 | 600 | 01 | .52 | | | | | 22.0 | 800 | .02 | | | | | 16 |

| Location of Subject | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 11) Daisy | Lap belt | 24 | F | 165 | 7 |  | 19.0 | 20.0 | 740 | .002 | .46 |  |  |  |  | 26.0 | 260 | .003 |  |  |  | back injury | 16 |
| 12) Daisy | Lap belt-shoulder harness-Y leg strap |  | M |  | 338 |  |  | 14.0 | 1200 | .140 |  |  |  |  |  | 12.6 | 560 | 080 |  |  |  |  | 17 |
| 13) Daisy | Lap belt-shoulder harness-Y leg strap |  | M |  | 339 |  |  | 13.9 | 1100 | .174 |  |  |  |  |  | 16.9 | 530 | .071 |  |  |  |  | 17 |
| 14) Daisy | Lap belt - shoulder harness-Y leg strap |  | M |  | 340 |  |  | 15.2 | 1200 | .187 |  |  |  |  |  | 17.4 | 400 | .087 |  |  |  |  | 17 |
| 15) Daisy | Lap belt - shoulder harness-Y leg strap |  | M |  | 341 |  |  | 22.3 | 1100 | .125 |  |  |  |  |  | 27.8 | 775 | 075 |  |  |  |  | 17 |
| 16) Daisy | Lap belt - shoulder harness-Y leg strap |  | M |  | 342 |  |  | 22.9 | 1200 | .134 |  |  |  |  |  | 22.8 | 550 | 073 |  |  |  |  | 17 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 117) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 343 | | | 23.0 | 1200 | .130 | | | | | | 28.7 | 825 | .065 | | | | | 17 |
| 118) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 345 | | | 28.3 | 1200 | .123 | | | | | | 34.6 | 1000 | .079 | | | | | 17 |
| 119) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 346 | | | 28.1 | 1150 | .123 | | | | | | 47.2 | 2500 | .062 | | | | | 17 |
| 120) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 347 | | | 28.7 | 1300 | .122 | | | | | | 48.0 | 1730 | .066 | | | | | 17 |
| 121) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 348 | | | 29.2 | 1400 | .112 | | | | | | 25.4 | 1225 | .100 | | | | | 17 |
| 122) Daisy | Lap belt - shoulder harness-V leg strap | | M | | 349 | | | 23.3 | 1500 | .120 | | | | | | 36.5 | 1030 | .061 | | | | | 17 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 120) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 370 |  |  | 29.0 | 1325 | 124 |  |  |  |  |  | 39 5 | 900 | .072 |  |  |  |  | 17 |
| 121) Daisy | lap belt - shoulder harness-V leg strap |  | M |  | 379 |  |  | 28.1 | 1350 | .110 |  |  |  |  |  | 36.6 | 1100 | .055 |  |  |  |  | 17 |
| 123) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 380 |  |  | 29.6 | 1475 | .113 |  |  |  |  |  | 36.9 | 1075 | 051 |  |  |  |  | 17 |
| 124) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 381 |  |  | 28.9 | 1375 | .114 |  |  |  |  |  | 37.6 | 1200 | 066 |  |  |  |  | 17 |
| 127) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 383 |  |  | 27.5 | 1250 |  |  |  |  |  |  | 42.0 | 1325 | .063 |  |  |  |  | 17 |
| 128) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 387 |  |  | 26.1 | 1200 |  |  |  |  |  |  | 37.3 | 1210 | .061 |  |  |  |  | 17 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 129) Daisy | lap belt-shoulder harness-V leg strap | | M | | 356 | | | 23.0 | 1270 | .113 | | | | | | 34.1 | 1035 | .065 | | | | | 17 |
| 130) Daisy | lap belt-shoulder harness-V leg strap | 22 | M | 173 | | | 43.0 | 39.8 | | | | | | | | | | | | | | anterior compression fracture thoracic vetebrae 5-6-linear fractures of anterior superior border of lumbar vertebrae 3 | 20 |
| 131) Daisy | lap belt-shoulder harness-V leg strap | | M | | 661 | | | 34 0 | 743 | | | | | | | 32 0 | 959 | .071 | | | | cervical spine pain-partial loss of vision in left eye for 3 min -beginning syncope | 18 |
| 132) Daisy | lap belt-shoulder harness-V leg strap | | M | | 662 | | | 28.2 | 708 | | | | | | | 30.5 | 769 | .070 | | | | coccygeal pain | 18 |
| 133) Daisy | lap belt-shoulder harness-V leg strap | | M | | 663 | | | 27 4 | 874 | | | | | | | 32.7 | 652 | .084 | | | | | 18 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| (134) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 664 |  |  | 27.4 | 875 |  |  |  |  |  |  | 32.0 | 868 | .072 |  |  |  | coccygeal pain | 18 |
| (135) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 665 |  |  | 26.0 | 775 |  |  |  |  |  |  | 29.8 | 725 | .068 |  |  |  |  | 18 |
| (136) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 666 |  |  | 23.7 | 859 |  |  |  |  |  |  | 32.3 | 966 | .078 |  |  |  |  | 18 |
| (137) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 667 |  |  | 30.4 | 942 |  |  |  |  |  |  | 32.3 | 974 | .068 |  |  |  |  | 18 |
| (138) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 668 |  |  | 30.5 | 813 |  |  |  |  |  |  | 32.9 | 521 | .080 |  |  |  | cervical spine pain | 18 |
| (139) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 669 |  |  | 29.8 | 776 |  |  |  |  |  |  | 29.5 | 654 | .076 |  |  |  |  | 18 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 140) Daisy | lap belt-shoulder harness-V leg strap |  | M |  | 670 |  |  | 18.0 | 480 |  |  |  |  |  |  | 14.9 | 273 | .056 |  |  |  |  | 18 |
| 141) Daisy | lap belt - shoulder harness-V leg strap |  | M |  | 671 |  |  | 28.7 | 678 |  |  |  |  |  |  | 34.5 | 785 | .072 |  |  |  |  | 18 |
| 142) Daisy | lap belt - shoulder harness-V leg strap |  | M |  | 674 |  |  | 33 7 | 1036 |  |  |  |  |  |  | 35.2 | 849 | .066 |  |  |  | cervical pain | 18 |
| 143) Daisy | lap belt - shoulder harness-V leg strap |  | M |  | 675 |  |  | 34.4 | 1031 |  |  |  |  |  |  | 38.9 | 930 | .065 |  |  |  | anterior compression fracture of 5th thoracic vertebra-slight compression of 6th thoracic vertebra-linear fracture of anterior superior border of 5th lumbar vertebra |  |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Type of | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 144) Daisy | lap belt - shoulder harness-V leg strap | | M | | 376 | | | 29.6 | 1073 | | | | | | | 29.9 | 808 | .065 | | | | | 18 |
| 145) Daisy | lap belt - shoulder harness-V leg strap | | M | | 677 | | | 30.2 | 1111 | | | | | | | 33.4 | 1100 | .065 | | | | | 18 |

## HUMAN SUBJECTS - REARWARD FACING IMPACTS

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec | Stopping Distance feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 1) Daisy | | 29 | M | 152 | | | | 35.0 | 1156 | | | | | | | | | | | | | | 53 |
| 2) Daisy | | [illegible] | M | 153 | | | | 34.8 | 1130 | | | | | | | | | | | | | | 53 |
| 3) Daisy | | | M | | | | | 25.0 | 1000 | .08 | | | | | | | | | | | | no injuries | 53 |
| 4) Daisy | lap belt - shoulder harness & V leg strap | | M | | 300 | | | 25.5 | 1072 | .044 | | | | | | 37.8 | 1710 | | | | | back pains from L-3 to Coccyx | 15 |
| 5) Daisy | lap belt - shoulder harness & V leg strap | | M | | 318 | | | 25.5 | 1237 | .040 | | | | | | 45.7 | 2427 | | | | | back pains from L-3 to Coccyx | 15 |
| 6) Daisy | lap belt - shoulder harness & V leg strap | | M | | 313 | | | 25.4 | 1547 | .044 | | | | | | 67.3 | 1724 | | | | | back pains from L-3 to Coccyx | 15 |
| 7) Daisy | lap belt - shoulder harness & V leg strap | | M | | 320 | | | 23.8 | 1120 | .051 | | | | | | 44.3 | 1888 | | | | | | 15 |
| 8) Daisy | lap belt - shoulder harness & V leg strap | | M | | 321 | | | 25.8 | 1333 | .044 | | | | | | 58.5 | 2324 | | | | | | 15 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 9) Daisy | lap belt - shoulder harness & V leg strap | | M | | 322 | | | 26.9 | 1852 | .052 | | | | | | 41.1 | 2102 | | | | | | 15 |
| 10) Daisy | lap belt - shoulder harness & V leg strap | | M | | 329 | | | 31.1 | 1187 | .048 | | | | | | 49.9 | 1653 | | | | | back pains from L-3 to Coccyx | 15 |
| 11) Daisy | lap belt - shoulder harness & V leg strap | | M | | 330 | | | 31.5 | 1224 | .042 | | | | | | 52.4 | 1953 | | | | | back pain from L-3 to Coccyx | 15 |
| 12) Daisy | lap belt - shoulder harness & V leg strap | | M | | 331 | | | 30.1 | 1284 | .052 | | | | | | 39.3 | 1603 | | | | | back pain from L-3 to Coccyx | 15 |
| 13) Daisy | lap belt - shoulder harness & V leg strap | 27 | M | 115 | 332 | | | 37.5 | 1517 | .044 | | | | | | 52.6 | 2156 | | | | | back pain from L-3 to Coccyx-Dyspnea for 4 min. post run | 15 |
| 14) Daisy | lap belt shoulder harness & V leg strap | 34 | M | 192 | 333 | | | 35.4 | 1351 | .042 | | | | | | 67.0 | 2594 | | | | | back pain from L-3 to Coccyx-Dyspnea post run | 15 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 15) Daisy | lap belt - shoulder harness & V leg strap |  | M |  | 534 |  |  | 34.3 | 1336 | .048 |  |  |  |  |  | 45.8 | 1637 |  |  |  |  |  | 15 |
| 16) Daisy | lap belt - shoulder harness & V leg strap | 29 | M | 150 | 535 |  |  | 40.4 | 2139 | .040 |  |  |  |  |  | 82.6 | 3826 |  |  |  |  | no blood pressure 20 sec. post impact-severe pain from L-2 to Coccyx-albumin of +3 for 3 hours | 15 |
| 17) Daisy | lap belt - shoulder harness & V leg strap |  | M |  | 559 |  |  | 18.0 | 1774 | .099 |  |  |  |  |  | 21.9 | 1031 |  |  |  |  |  | 18 |
| 18) Daisy | lap belt - shoulder harness & V leg strap |  | M |  | 590 |  |  | 16.2 | 1194 | .104 |  |  |  |  |  | 21.3 | 855 |  |  |  |  |  | 18 |
| 19) Daisy | lap belt shoulder harness & V leg strap |  | M |  | 591 |  |  | 18.0 | 1961 | .099 |  |  |  |  |  | 21.5 | 1164 |  |  |  |  |  | 18 |
| 20) Daisy | lap belt shoulder harness & V leg strap |  | M |  | 592 |  |  | 18.9 | 1378 | .108 |  |  |  |  |  | 21.9 | 935 |  |  |  |  |  | 18 |

| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | | |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 593 | | | 16.4 | 1243 | .104 | | | | | | 23.2 | 932 | | | | | | 18 |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 594 | | | 18.0 | 1283 | .109 | | | | | | 24.1 | 939 | | | | | | 18 |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 606 | | | 17.4 | 2273 | .106 | | | | | | 27.5 | 1178 | | | | | | 18 |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 607 | | | 16.4 | 2220 | .108 | | | | | | 24.7 | 1105 | | | | | | 18 |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 608 | | | 17.8 | 2659 | .106 | | | | | | 27.3 | 1302 | | | | | | 18 |
| 22) Daisy | Lap belt shoulder harness & V leg strap | | M | | 609 | | | 18.3 | 2543 | .111 | | | | | | 23.8 | 1032 | | | | | | 18 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED<br>Seat Pitch deg. | SLED<br>Entrance Velocity ft/sec | SLED<br>Peak g's | SLED<br>Onset rate g/sec | SLED<br>Pulse Duration sec. | SLED<br>Stopping Distance Feet | BELT LOADS (lb.)<br>Right Lap Belt | BELT LOADS (lb.)<br>Left Lap Belt | BELT LOADS (lb.)<br>Right Upper Torso Belt | BELT LOADS (lb.)<br>Left Upper Torso Belt | CHEST LOAD<br>g-level | CHEST LOAD<br>Onset rate g/sec. | CHEST LOAD<br>Time Duration sec. | HEAD LOAD<br>g-level | HEAD LOAD<br>Onset rate g/sec. | HEAD LOAD<br>Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27) Daisy | lap belt shoulder harness & V leg strap | | M | | 610 | | | 18.2 | 2719 | .110 | | | | | | 23.1 | 884 | | | | | | 18 |
| 28) Daisy | lap belt shoulder harness & V leg strap | | M | | 611 | | | 18.2 | 2190 | .108 | | | | | | 24.5 | 945 | | | | | | 18 |
| 29) Daisy | lap belt shoulder harness & V leg strap | | M | | 612 | | | 16.8 | 3034 | .102 | | | | | | 23.6 | 1126 | | | | | | 18 |
| 30) Daisy | lap belt shoulder harness & V leg strap | | M | | 613 | | | 17.0 | 2266 | .102 | | | | | | 23.3 | 1177 | | | | | | 18 |
| 31) Daisy | lap belt shoulder harness & V leg strap | | M | | 614 | | | 16.0 | 3590 | .104 | | | | | | 25.3 | 1033 | | | | | | 18 |
| 32) Daisy | lap belt shoulder harness & V leg strap | | M | | 615 | | | 17.8 | 2487 | .100 | | | | | | 23.9 | 1129 | | | | | | 18 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| [illegible] Daisy | lap belt shoulder harness & [illegible] leg strap | | M | | 616 | | | 17.5 | 2499 | .103 | | | | | | 26.5 | 1102 | | | | | | 18 |

# HUMAN SUBJECTS - SIDE FACING IMPACTS

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED Seat Pitch deg | SLED Entrance Velocity ft/sec | SLED Peak g's | SLED Onset rate g/sec | SLED Pulse Duration sec. | SLED Stopping Distance Feet | BELT LOADS (lb.) Right Lap Belt | BELT LOADS (lb.) Left Lap Belt | BELT LOADS (lb.) Right Upper Torso Belt | BELT LOADS (lb.) Left Upper Torso Belt | CHEST LOAD g-level | CHEST LOAD Onset rate g/sec. | CHEST LOAD Time Duration sec. | HEAD LOAD g-level | HEAD LOAD Onset rate g/sec | HEAD LOAD Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) R.A.F. (F111) | R.A.F. Harness | | M | 159 | 120 | | | 13.8 | 212 | | | 25 | 34 | 69 | 444 | | | | | | | | 61 |
| 2) R.A.F. (F111) | R.A.F. Harness | | M | 147 | 124 | | | 15.4 | 280 | | | 73 | 113 | 12 | 487 | | | | | | | | 61 |
| 3) R.A.F. (F111) | R.A.F. Harness | | M | 186 | 129 | | | 12.5 | 257 | | | 91 | 193 | 52 | 433 | | | | | | | | 61 |
| 4) R.A.F. (F111) | U.S.A.F. Harness | | M | 186 | 131 | | | 10.5 | 93 | | | 177 | 114 | 315 | 225 | | | | | | | | 61 |
| 5) R.A.F. (F111) | U.S.A.F. Harness | | M | 147 | 132 | | | 17.7 | 390 | | | 36 | 55 | 330 | 208 | | | | | | | | 61 |
| 6) R.A.F. (F111) | U.S.A.F. Harness | | M | 159 | 133 | | | 17.2 | 360 | | | 124 | 100 | 360 | 313 | | | | | | | | 61 |
| 7) Daisy | lap belt | 34 | M | 197 | 2432 | | 13.5 | 2.93 | 191 | | 2.46 | | | | | 10.02 | 181 | | 3.74 | 51 | | | 55 |
| 8) Daisy | lap belt | 39 | M | 159 | 2433 | | 14.8 | 2.98 | 159 | | 2.46 | | | | | 4.70 | 131 | | 3.04 | 65 | | | 55 |
| 9) Daisy | lap belt | 41 | M | 140 | 2434 | | 14.4 | 3.41 | 151 | | 2.46 | | | | | 10.14 | 211 | | 3.34 | 52 | | | 55 |
| 10) Daisy | lap belt | 31 | M | 165 | 2435 | | 14.0 | 3.44 | 150 | | 2.46 | | | | | 11.01 | 246 | | 4.2 | 54 | | | 55 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 11) Daisy | lap belt | 36 | M | [illegible] | 243[illegible] | | 13.9 | 3.14 | 223 | | 2.46 | | | | | 8.94 | 174 | | 3.4 | 30 | | | 55 |
| 12) Daisy | lap belt | 26 | M | 157 | 2433 | | 14.2 | 3.35 | 146 | | 2.42 | | | | | 12.2 | 155 | | 4.3 | 46 | | | 55 |
| 13) Daisy | lap belt | 22 | M | 159 | 2439 | | 14.2 | 3.20 | 153 | | 2.44 | | | | | 7.56 | 90 | | 3.36 | 20 | | | 55 |
| 14) Daisy | lap belt | 24 | M | 180 | 2440 | | 13.7 | 3.34 | 78 | | 2.44 | | | | | 9.08 | 50 | | 3.97 | 46 | | | 55 |
| 15) Daisy | lap belt | 24 | M | 167 | 2441 | | 14.2 | 3.21 | 93 | | 2.44 | | | | | 6.69 | 141 | | 4.30 | 37 | | | 55 |
| 16) Daisy | lap belt | 23 | M | 125 | 2442 | | 14.8 | 3.26 | 90 | | 2.42 | | | | | 20.72 | 487 | | 6.20 | 36 | | | 55 |
| 17) Daisy | lap belt | 24 | M | [illegible] | 2443 | | 14.1 | 3.50 | 130 | | 2.44 | | | | | 13.89 | 185 | | 5.41 | 60 | | | 55 |
| 18) Daisy | lap belt | 20 | M | [illegible] | 2444 | | 14.5 | 3.22 | 95 | | 2.44 | | | | | 8.52 | 135 | | 2.33 | 30 | | | 55 |
| 19) Daisy | lap belt | 24 | M | 150 | 2453 | | 15.7 | 5.79 | 341 | | 1.33 | | | | | 21.39 | 824 | | 6.59 | 275 | | | 55 |
| 20) Daisy | lap belt | 22 | M | 135 | 2454 | | 15.0 | 7.06 | 315 | | 1.21 | | | | | 30.78 | 436 | | 46.40 | 115.7 | | sorness and stiffness in hips and neck + 72 hours | 55 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 21) Daisy | lap belt | 28 | M | 120 | 2455 | | 15.1 | 6.38 | 427 | | 1.29 | | | | | 21.23 | 911 | | 10.67 | 319 | | | 55 |
| 22) Daisy | lap belt | 32 | M | 182 | 2456 | | 14.4 | 5.48 | 318 | | 1.20 | | | | | 14.28 | 369 | | 9.51 | 115 | | | 55 |
| 23) Daisy | lap belt | 31 | M | 163 | 2457 | | 14.7 | 6.64 | 290 | | 1.25 | | | | | 19.82 | 674 | | 12.40 | 170 | | | 55 |
| 24) Daisy | lap belt | 23 | M | 130 | 2458 | | 15.6 | 6.94 | 336 | | 1.27 | | | | | 27.75 | 405 | | 17.37 | 175 | | | 55 |
| 25) Daisy | lap belt | 22 | M | 133 | 2459 | | 15.2 | 6.25 | 258 | | 1.29 | | | | | 25.22 | 522 | | 3.82 | 129 | | | 55 |
| 26) Daisy | lap belt | 27 | M | 182 | 2460 | | 14.6 | 6.64 | 384 | | 1.25 | | | | | 22.34 | 287 | | 11.32 | 122 | | | 55 |
| 27) Daisy | lap belt | 25 | M | 209 | 2461 | | 14.4 | 6.65 | 265 | | 1.25 | | | | | 17.30 | 233 | | 11.19 | 271 | | | 55 |
| 28) Daisy | lap belt | 22 | M | 151 | 2462 | | 14.8 | 6.40 | 431 | | 1.29 | | | | | 22.05 | 1769 | | 8.51 | 207 | | | 55 |
| 29) Daisy | lap belt | 31 | M | 171 | 2476 | | 15.1 | 5.77 | 182 | | 1.35 | | | | | 20.14 | 383 | | 9.81 | 88 | | | 55 |
| 30) Daisy | lap belt | 33 | M | 152 | 2477 | | 14.8 | 6.25 | 252 | | 1.33 | | | | | 20.76 | 392 | | 9.59 | 95 | | | 55 |
| 31) Daisy | lap belt | 33 | M | 163 | 2478 | | 14.9 | 5.82 | 142 | | 1.40 | | | | | 14.99 | 101 | | 9.20 | 88 | | | 55 |
| 32) Daisy | lap belt | 42 | M | 141 | 2479 | | 15.6 | 6.13 | 227 | | 1.16 | | | | | 21.73 | 323 | | 15.11 | 222 | | | 55 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Typ. of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 33) Daisy | lap belt | 24 | M | 157 | 2483 | | 15.3 | 6.43 | 160 | | 1.40 | | | | | 10.34 | 362 | | 9.66 | 149 | | | 55 |
| 34) Daisy | lap belt | 23 | M | 159 | 2481 | | 15.2 | 5.74 | 182 | | 1.21 | | | | | 17.84 | 252 | | 9.21 | 130 | | | 55 |
| 35) Daisy | lap belt | 22 | M | 125 | 2483 | | 15.9 | 5.70 | 317 | | 1.33 | | | | | 23.63 | 305 | | 11.02 | 115 | | | 55 |
| 36) Daisy | lap belt | 27 | M | 183 | 2482 | | 15.6 | 6.31 | 185.3 | | 1.25 | | | | | 25.41 | 200 | | 22.05 | 762 | | | 55 |
| 37) Daisy | lap belt | 22 | M | 151 | 2491 | | 15.4 | 7.85 | 347 | | 1.10 | | | | | 25.23 | 1100 | | 8.10 | 195 | | | 55 |
| 38) Daisy | lap belt | 23 | M | 125 | 2492 | | 15.8 | 8.83 | 348 | | 1.06 | | | | | 41.31 | 810 | | | | | | 55 |
| 39) Daisy | lap belt | 30 | M | 148 | 2493 | | | 7.41 | 345 | | 1.15 | | | | | 26.90 | 593 | | 7.90 | 145 | | | 55 |
| 40) Daisy | lap belt | 41 | M | 140 | 2494 | | 15.2 | 7.95 | 333 | | 1.10 | | | | | 31.77 | 1110 | | 22.72 | 424 | | | 55 |
| 41) Da'sy | lap belt | 26 | M | 191 | 2495 | | 14.4 | 7.52 | 341 | | 1.08 | | | | | 26.96 | 770 | | 20.25 | 739 | | | 55 |
| 42) Daisy | lap belt | 31 | M | 171 | 2496 | | 14.8 | 7.37 | 298 | | 1.12 | | | | | 22.21 | 458 | | 8.54 | 93 | | | 55 |
| 43) Daisy | lap belt | 31 | M | 185 | 2497 | | 14.9 | 8.02 | 362 | | 1.15 | | | | | 22.93 | 500 | | 7.05 | 129 | | | 55 |
| 44) Daisy | lap belt | 37 | M | 131 | 2498 | | 16.1 | 8.48 | 423 | | 1.06 | | | | | 50.82 | 1471 | | | | | | 55 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 57) Daisy | lap belt | 42 | M | 141 | 2526 |  | 14.35 | 9.70 | 359 |  | 1.22 |  |  |  |  | 24.50 | 266 |  | 11.12 | 134 |  |  | 55 |
| 58) Daisy | lap belt | 21 | M | 193 | 2527 |  | 14.4 | 8.90 | 284 |  | .96 |  |  |  |  | 13.90 | 209 |  | 8.33 | 103 |  |  | 55 |
| 59) Daisy | lap belt | 23 | M | 164 | 2528 |  | 15.1 | 9.95 | 300 |  | .96 |  |  |  |  | 19.90 | 265 |  | 14.38 | 162 |  |  | 55 |
| 60) Daisy | lap belt | 29 | M | 203 | 2529 |  | 14.4 | 9.32 | 312 |  | .96 |  |  |  |  | 30.38 | 879 |  | 22.16 | 394 |  |  | 55 |
| 61) Daisy | lap belt | 24 | M | 180 | 2530 |  | 14.8 | 8.48 | 271 |  | .96 |  |  |  |  | 14.47 | 215 |  | 22.04 | 321 |  |  | 55 |
| 62) Daisy | lap belt | 22 | M | 134 | 2531 |  | 14.7 | 9.06 | 311 |  | .96 |  |  |  |  | 17.70 | 190 |  | 9.34 | 143 |  |  | 55 |
| 63) Daisy | lap belt | 22 | M | 163 | 2532 |  | 15.2 | 9.24 | 379 |  | .94 |  |  |  |  | 23.15 | 588 |  | 16.10 | 322 |  |  | 55 |
| 64) Daisy | lap belt | 21 | M | 167 | 2533 |  | 14.5 | 8.88 | 315 |  | .99 |  |  |  |  | 16.44 | 285 |  | 9.69 | 160 |  |  | 55 |
| 65) Daisy | lap belt | 27 | M | 182 | 2534 |  | 14.9 | 8.82 | 207 |  | .98 |  |  |  |  | 16.09 | 281 |  | 11.59 | 239 |  |  | 55 |
| 66) Daisy | lap belt |  | M |  | 2535 |  | 15.7 | 9.16 | 322 |  | 1.04 |  |  |  |  | 24.15 | 420 |  | 9.41 | 150 |  |  | 55 |
| 67) Daisy | lap belt | 26 | M | 174 | 2537 |  | 14.4 | 8.53 | 316 |  | .98 |  |  |  |  | 17.10 | 483 |  | 16.48 | 476 |  |  | 55 |
| 68) Daisy | lap belt | 20 | M | 173 | 2538 |  | 15.1 | 9.44 | 355 |  | .98 |  |  |  |  | 21.77 | 345 |  |  |  |  |  | 55 |

| Location of Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 69) Daisy | lap belt | 33 | M | 163 | 2539 |  | 14.7 | 9.02 | 338 |  | .96 |  |  |  |  | 18.02 | 353 |  | 12.78 | 27[illegible] |  |  | 55 |
| 70) Daisy | lap belt | 23 | M | 191 | 2540 |  | 14.3 | 8.83 | 311 |  | .96 |  |  |  |  | 17.05 | 333 |  | 20.92 | [illegible] |  |  | 55 |
| 71) Daisy | lap belt | [illegible] | M | 186 | 2541 |  | 15.3 | 8.83 | 291 |  | .99 |  |  |  |  | 18.14 | 272 |  | 19.97 | 693 |  |  | 55 |
| 72) Daisy | lap belt | 25 | M | 209 | 2542 |  | 13.7 | 9.14 | 319 |  | .99 |  |  |  |  | 16.10 | 499 |  | 13.50 | 177 |  |  | 55 |
| 73) Daisy | lap belt | 27 | M | 182 | 2543 |  | 14.5 | 8.97 | 336 |  | 99 |  |  |  |  | 21.20 | 225 |  | 1661 | 455 |  |  | 55 |
| 74) Daisy | lap belt | 27 | M | 131 | 2544 |  | 16.0 | 8.81 | 356 |  | .99 |  |  |  |  | 33.31 | 390 |  | 31.61 | 142 |  |  | 55 |
| 75) Daisy | lap belt | 24 | M | 166 | 2545 |  | 15.3 | 8.92 | 357 |  | 1.02 |  |  |  |  | 2290 | 470 |  | 13.30 | 205 |  |  | 55 |
| 76) Daisy | lap belt | 23 | M | 159 | 2546 |  | 15.4 | 8.94 | 330 |  | 1.04 |  |  |  |  | 2091 | 171 |  | 25.19 | 333 |  |  | 55 |
| 77) Daisy | lap belt - [illegible] | 23 | M | 135 | 2708 |  | 15.3 | 5.05 | 228 |  | 2.09 |  |  |  |  | 5.71 | 179 |  | 7.89 | 77 |  |  | 56 |
| 78) Daisy | lap belt - [illegible] | 42 | M | 140 | 2709 |  | 15.1 | 4.95 | 256 |  | 2.10 |  |  |  |  | 4.87 | 114 |  | 6.31 | 71 |  |  | 56 |
| 79) DELETE |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 80) Daisy | lap belt - harness | 25 | M | 157 | 2710 |  | 14.7 | 5.15 | 284 |  | 2.08 |  |  |  |  | 3.80 | 100 |  | 6.05 | 60 |  |  | 56 |
| 81) Daisy | lap belt - harness | [illegible] | M | 161 | 2711 |  | 13.0 | 4.59 | 256 |  | 2.1 |  |  |  |  | 6.50 | 143 |  | 7.81 | 82 |  |  | 56 |
| 82) Daisy | lap belt - harness | 33 | M | 182 | 2712 |  | 13.9 | 3.69 | 200 |  | 2.1 |  |  |  |  | 5.88 | 116 |  | 7.21 | 61 |  |  | 56 |
| 83) Daisy | lap belt - harness | 23 | M | 159 | 2713 |  | 14.8 | 4.65 | 230 |  | 2.06 |  |  |  |  | 5.79 | 114 |  | 10.24 | 139 |  |  | 56 |
| 84) Daisy | lap belt - harness | 22 | M | 164 | 2714 |  | 14.4 | 4.51 | 234 |  | 2.1 |  |  |  |  | 5.73 | 134 |  | 3.33 | 76 |  |  | 56 |
| 85) Daisy | lap belt - harness | 21 | M | 175 | 2715 |  | 14.2 | 4.20 | 217 |  | 2.09 |  |  |  |  | 5.86 | 84 |  | 6.45 | 107 |  |  | 55 |
| 86) Daisy | lap belt - harness | 26 | M | 209 | 2716 |  | 13.8 | 3.71 | 215 |  | 2.13 |  |  |  |  | 4.65 | 54 |  | 5.51 | 79 |  |  | 56 |
| 87) Daisy | lap belt - harness | 23 | M | 166 | 2717 |  | 14.8 | 4.89 | 257 |  | 2.1 |  |  |  |  | 5.90 | 126 |  | 7.43 | 112 |  |  | 56 |
| 88) Daisy | lap and harness | 21 | M | 147 | 2719 |  | 15.3 | 4.88 | 140 |  | 2.1 |  |  |  |  | 6.72 | 144 |  | 7.61 | 76 |  |  | 55 |
| 89) Daisy | lap and harness | 32 | M | 163 | 2720 |  | 14.0 | 4.36 | 259 |  | 2.09 |  |  |  |  | 5.94 | 75 |  | 6.01 | 81 |  |  | 56 |
| 90) Daisy | lap and harness | 26 | M | 119 | 2721 |  | 15.8 | 4.8[illegible] | 283 |  | 2.09 |  |  |  |  | 6.34 | 86 |  | 9.14 | 113 |  |  | 56 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED: Seat Pitch deg. | SLED: Entrance Velocity ft/sec | SLED: Peak g's | SLED: Onset rate g/sec | SLED: Pulse Duration sec. | SLED: Stopping Distance Feet | BELT LOADS (lb.): Right Lap Belt | BELT LOADS (lb.): Left Lap Belt | BELT LOADS (lb.): Right Upper Torso Belt | BELT LOADS (lb.): Left Upper Torso Belt | CHEST LOAD: g-level | CHEST LOAD: Onset rate g/sec. | CHEST LOAD: Time Duration sec. | HEAD LOAD: g-level | HEAD LOAD: Onset rate g/sec. | HEAD LOAD: Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91) Daisy | lap and harness | 27 | M | 203 | 2722 | | 13.9 | 3.95 | 231 | | 2.08 | | | | | 4.98 | 69 | | 5.84 | 88 | | | 56 |
| 92) Daisy | lap and harness | 26 | M | 175 | 2723 | | 14.5 | 3.69 | 199 | | 2.1 | | | | | 5.11 | 78 | | 7.05 | 121 | | | 56 |
| 93) Daisy | lap and harness | 30 | M | 130 | 2726 | | 14.7 | 4.40 | 189 | | 2.08 | | | | | 5.75 | 208 | | 5.70 | 84 | | | 56 |
| 94) Daisy | lap and harness | 27 | M | 137 | 2727 | | 14.9 | 3.90 | 221 | | 2.06 | | | | | 5.65 | 121 | | 8.03 | 26 | | | 56 |
| 95) Daisy | lap and harness | 31 | M | 141 | 2728 | | 14.8 | 4.77 | 250 | | 2.1 | | | | | 6.23 | 159 | | 7.20 | 85 | | | 56 |
| 96) Daisy | lap and harness | 24 | M | 130 | 2729 | | 15.3 | 4.59 | 199 | | 2.1 | | | | | 6.09 | 101 | | 7.82 | 79 | | | 56 |
| 97) Daisy | lap and harness | 25 | [illegible] | [illegible] | 2730 | | | 4.50 | 234 | | 2.1 | | | | | 6.63 | 216 | | 6.27 | 80 | | | 56 |
| 98) Daisy | lap and harness | 23 | M | 154 | 2741 | | 13.0 | 8.41 | 227 | | 1.08 | | | | | 13.72 | 513 | | 13.47 | 499 | | | 56 |
| 99) Daisy | lap and harness | 22 | M | 171 | 2742 | | 14.7 | 8.03 | 241 | | 1.06 | | | | | 13.32 | 262 | | 21.16 | 932 | | | 56 |
| 100) Daisy | lap and harness | 28 | M | 173 | 2743 | | 14.5 | 7.40 | 203 | | 1.08 | | | | | 11.41 | 188 | | 13.60 | 255 | | | 56 |
| 101) Daisy | lap and harness | 25 | M | 135 | 2750 | | 15.5 | 6.90 | 183 | | 1.31 | | | | | 8.67 | 652 | | 8.19 | 105 | | | 56 |
| 102) Daisy | lap and harness | 25 | M | 195 | 2751 | | 14.4 | 6.87 | 238 | | 1.29 | | | | | 8.46 | 155 | | 8.51 | 156 | | | 56 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 103) Daisy | lap and harness | 23 | M | 129 | 2752 |  | 15.6 | 7.16 | 426 |  | 1.23 |  |  |  |  | 10.94 | 251 |  | 10.21 | 395 |  |  | 56 |
| 104) Daisy | lap and harness | 20 | M | 156 | 2753 |  | 15.2 | 6.80 | 391 |  | 1.29 |  |  |  |  | 9.85 | 375 |  | 9.10 | 411 |  |  | 56 |
| 105) Daisy | lap and harness | 23 | M | 179 | 2754 |  | 15.7 | 6.88 | 425 |  | 1.29 |  |  |  |  | 10.58 | 172 |  | 9.66 | 110 |  |  | 56 |
| 106) Daisy | lap and harness | 22 | M | 163 | 2755 |  | 15.0 | 7.30 | 575 |  | 1.31 |  |  |  |  | 10.07 | 261 |  | 13.48 | 324 |  |  | 56 |
| 107) Daisy | lap and harness | 20 | M | 135 | 2756 |  | 15.5 | 7.06 | 422 |  | 1.31 |  |  |  |  | 9.35 | 339 |  | 9.37 | 241 |  |  | 56 |
| 108) Daisy | lap and harness | 27 | M | 178 | 2760 |  | 14.3 | 5.72 | 356 |  | 1.46 |  |  |  |  | 6.07 | 670 |  | 6.92 | 40 |  |  | 56 |
| 109) Daisy | lap and harness | 27 | M | 137 | 2761 |  | 15.1 | 5.86 | 377 |  | 1.44 |  |  |  |  | 7.87 | 291 |  | 9.44 | 165 |  |  | 56 |
| 110) Daisy | lap and harness | 27 | M | 169 | 2762 |  | 14.6 | 6.01 | 411 |  | 1.45 |  |  |  |  | 7.97 | 546 |  | 10.45 | 356 |  |  | 56 |
| 111) Daisy | lap and harness | 31 | M | 190 | 2763 |  | 13.7 | 6.37 | 380 |  | 1.44 |  |  |  |  | 5.35 | 114 |  | 7.89 | 46 |  |  | 56 |
| 112) Daisy | lap belt & harness | 23 | M | 179 | 2764 |  | 14.2 | 5.81 | 400 |  | 1.48 |  |  |  |  | 6.13 | 94 |  | 4.44 | 95 |  |  | 56 |
| 113) Daisy | lap belt & harness | 23 | M | 165 | 2765 |  | 14.0 | 6.18 | 367 |  | 1.44 |  |  |  |  | 7.84 | 188 |  | 7.80 | 285 |  |  | 56 |
| 114) Daisy | lap belt & harness | 22 | M | 169 | 2766 |  | 14.8 | 6.02 | 408 |  | 1.48 |  |  |  |  | 7.17 | 99 |  | 9.66 | 937 |  |  | 56 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec | g-level | Onset rate g/sec. | Time Duration sec. |  |  |
| 115) Daisy | lap belt & harness | 22 | M | 184 | 2767 |  | 13.9 | 6.19 | 430 |  | 1.14 |  |  |  |  | 8.31 | 377 |  | 11.73 | 354 |  |  | 55 |
| 116) Daisy | lap belt & harness | 20 | M | 154 | 2768 |  | 14.6 | 5.97 | 417 |  | 1.52 |  |  |  |  | 6.89 | 287 |  | 9.17 | 256 |  |  | 55 |
| 117) Daisy | lap belt & harness | 22 | M | 180 | 2771 |  | 14.4 | 6.12 | 331 |  | 1.48 |  |  |  |  | 7.12 | 219 |  | 7.56 | 113 |  |  | 55 |
| 118) Daisy | lap belt & harness | 23 | M | 197 | 2783 |  | 15.1 | 8.50 | 433 |  | .92 |  |  |  |  | 10.79 | 414 |  | 13.16 | 346 |  |  | 56 |
| 119) Daisy | lap belt & harness | 25 | M | 180 | 2784 |  | 14.4 | 8.68 | 316 |  | .92 |  |  |  |  | 12.17 | 269 |  | 11.39 | 321 |  |  | 56 |
| 120) Daisy | lap belt & harness | 34 | M | 152 | 2785 |  | 15.1 | 9.42 | 356 |  | .91 |  |  |  |  | 14.31 | 499 |  | 14.46 | 239 |  |  | 56 |
| 121) Daisy | lap belt & harness | 42 | M | 140 | 2786 |  | 14.8 | 8.29 | 596 |  | .94 |  |  |  |  | 13.06 | 499 |  | 15.63 | 352 |  |  | 56 |
| 122) Daisy | lap belt & harness | 29 | M | 129 | 2787 |  | 14.9 | 8.74 | 615 |  | .94 |  |  |  |  | 13.58 | 363 |  | 23.10 | 1444 |  |  | 56 |
| 123) Daisy | lap belt & harness | 32 | M | 185 | 2788 |  | 13.9 | 8.57 | 491 |  | .98 |  |  |  |  | 11.06 | 1150 |  | 12.03 | 220 |  |  | 56 |
| 124) Daisy | lap belt & harness | 25 | M | 166 | 2789 |  | 14.6 | 8.32 | 557 |  | .92 |  |  |  |  | 9.92 | 553 |  | 14.90 | 373 |  |  | 56 |
| 125) Daisy | lap belt & harness | 43 | M | 141 | 2790 |  | 14.6 | 9.58 | 521 |  | .88 |  |  |  |  | 14.83 | 372 |  | 16.37 | 427 |  |  | 55 |

| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | SLED<br>Seat Pitch deg. | SLED<br>Entrance Velocity ft/sec | SLED<br>Peak g's | SLED<br>Onset rate g/sec | SLED<br>Pulse Duration sec. | SLED<br>Stopping Distance Feet | BELT LOADS (lb.)<br>Right Lap Belt | BELT LOADS (lb.)<br>Left Lap Belt | BELT LOADS (lb.)<br>Right Upper Torso Belt | BELT LOADS (lb.)<br>Left Upper Torso Belt | CHEST LOAD<br>g-level | CHEST LOAD<br>Onset rate g/sec. | CHEST LOAD<br>Time Duration sec. | HEAD LOAD<br>g-level | HEAD LOAD<br>Onset rate g/sec. | HEAD LOAD<br>Time Duration sec. | Injury to Subject | Reference Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 126) Daisy | lap belt & harness | 26 | M | 119 | 2791 | | 15.5 | 9.31 | 584 | | .96 | | | | | 12.26 | 868 | | 18.91 | 391 | | | 56 |
| 127) Daisy | lap belt & harness | 21 | M | 175 | 2792 | | 14.4 | 8.71 | 519 | | .94 | | | | | 10.84 | 344 | | 13.01 | 275 | | | 56 |
| 128) Daisy | lap belt & harness | 26 | M | 160 | 2793 | | 14.6 | 8.96 | 611 | | .92 | | | | | 14.13 | 453 | | 24.78 | 651 | | | 55 |
| 129) Daisy | lap belt & harness | 25 | M | 157 | 2794 | | 14.6 | 8.62 | 570 | | .92 | | | | | 13.91 | 574 | | 13.84 | 289 | | | 56 |
| 130) Daisy | lap belt & harness | 23 | M | 151 | 2795 | | 14.7 | 8.66 | 521 | | .94 | | | | | 12.78 | 411 | | 12.00 | 175 | | | 56 |
| 131) Daisy | lap belt & harness | 30 | M | 136 | 2800 | | 14.9 | 8.43 | 554 | | .94 | | | | | 11.57 | 176 | | 12.45 | 203 | | | 55 |
| 132) Daisy | lap belt & harness | 22 | M | 164 | 2801 | | 14.2 | 8.57 | 332 | | .96 | | | | | 13.32 | 403 | | 9.55 | 84 | | | 56 |
| 133) Daisy | lap belt & harness | 33 | M | 132 | 2802 | | 14.8 | 7.70 | 267 | | .94 | | | | | 9.40 | 140 | | 12.55 | 120 | | | 56 |
| 134) Daisy | lap belt & harness | 22 | M | 147 | 2803 | | 15.3 | 9.20 | 374 | | .94 | | | | | 14.67 | 348 | | 14.48 | 189 | | | 56 |
| 135) Daisy | lap belt & harness | 20 | M | 135 | 2804 | | 15.4 | 9.62 | 383 | | .93 | | | | | 14.65 | 266 | | 12.15 | 128 | | | 56 |
| 136) Daisy | lap belt & harness | 32 | M | 163 | 2805 | | 14.6 | 9.34 | 268 | | .92 | | | | | 13.34 | 196 | | 19.05 | 281 | | | 55 |

|  |  |  |  |  |  | SLED |  |  |  |  |  | BELT LOADS (lb.) |  |  |  | CHEST LOAD |  |  | HEAD LOAD |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 137) Daisy | lap belt & harness | 22 | M | 140 | 2806 |  | 14.8 | 9.00 | 268 |  | .94 |  |  |  |  | 13.50 | 236 |  | 16.71 | 194 |  |  | 56 |
| 138) Daisy | lap belt & harness | 23 | M | 159 | 2807 |  | 14.7 | 8.81 | 263 |  | .94 |  |  |  |  | 11.01 | 172 |  | 12.23 | 170 |  |  | 55 |
| 139) Daisy | lap belt & harness | 26 | M | 209 | 2808 |  | 13.8 | 8.36 | 302 |  | .92 |  |  |  |  | 10.61 | 150 |  | 14.33 | 193 |  |  | 56 |
| 140) Daisy | lap belt & harness | 27 | M | 182 | 2809 |  | 14.5 | 9.18 | 340 |  | 92 |  |  |  |  | 12.88 | 325 |  | 14.68 | 163 |  |  | 55 |
| 141) Daisy | lap belt & harness | 22 | M | 125 | 2810 |  | 15.3 | 8.63 | 249 |  | .94 |  |  |  |  | 13.51 | 230 |  | 14.91 | 149 |  |  | 56 |
| 142) Daisy | lap belt & harness | 26 | M | 160 | 2811 |  | 14.6 | 8.84 | 314 |  | .94 |  |  |  |  | 12.38 | 212 |  | 19.01 | 200 |  |  | 56 |
| 143) Daisy | lap belt & harness | 25 | M | 123 | 3069 |  | 14.2 | 9.40 | 332 |  | 79 |  |  |  |  | 15.83 | 330 |  | 17.16 | 1597 |  |  | 56 |
| 144) Daisy | lap belt & harness | 20 | M | 150 | 3072 |  | 14.2 | 10.37 | 548 |  | 75 |  |  |  |  | 17.83 | 1012 |  | 14.83 | 1041 |  |  | 56 |
| 145) Daisy | lap belt & harness | 27 | M | 182 | 3073 |  | 13.4 | 10.28 | 537 |  | 71 |  |  |  |  | 18.31 | 393 |  | 23.35 | 857 |  |  | 56 |
| 146) Daisy | lap belt & harness | 22 | M | 164 | 3074 |  | 13.8 | 9.92 | 534 |  | .75 |  |  |  |  | 19.83 | 554 |  | 17.68 | 615 |  |  | 56 |
| 147) Daisy | lap belt & harness | 31 | M | 190 | 3075 |  | 13.6 | 9.46 | 499 |  | .73 |  |  |  |  | 14.92 | 855 |  | 26.23 | 1642 |  |  | 56 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Sponsor | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec. | Stopping Distance Feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 148) Daisy | lap belt & harness | 29 | M | 173 | 3076 | | 13.6 | 9.92 | 354 | | .73 | | | | | 15.80 | 412 | | 18.80 | 516 | | | 56 |
| 149) Daisy | lap belt & harness | 23 | M | 179 | 3077 | | 13.5 | 10.19 | 444 | | .73 | | | | | 16.21 | 486 | | 16.06 | 503 | | | 56 |
| 150) Daisy | lap belt & harness | 22 | M | 172 | 3078 | | 13.4 | 10.54 | 501 | | .73 | | | | | 15.44 | 979 | | 19.17 | 449 | | | 55 |
| 151) Daisy | lap belt & harness | 22 | M | 147 | 3079 | | 14.4 | 11.51 | 364 | | .73 | | | | | 23.15 | 517 | | 17.08 | 210 | | | 56 |
| 152) Daisy | lap belt & harness | 25 | M | 135 | 3080 | | 14.4 | 11.60 | 391 | | .73 | | | | | 23.84 | 603 | | 24.37 | 375 | | | 56 |
| 153) Daisy | lap belt & harness | 25 | M | 195 | 3081 | | 13.5 | 10.28 | 310 | | .71 | | | | | 16.71 | 470 | | 15.72 | 295 | | | 56 |
| 154) Daisy | lap belt & harness | 32 | M | 171 | 3082 | | 13.4 | 11.33 | 317 | | .73 | | | | | 19.97 | 234 | | 21.42 | 602 | | | 55 |
| 155) Daisy | lap belt & harness | 43 | M | 141 | 3083 | | | 12.18 | 360 | | .73 | | | | | 23.21 | 772 | | 45.41 | 1230 | | | 56 |
| 156) Daisy | lap belt & harness | 25 | M | 135 | 3084 | | 14.1 | 10.83 | 353 | | .75 | | | | | 19.22 | 548 | | 15.14 | 171 | | | 55 |
| 157) Daisy | lap belt & harness | 22 | M | 163 | 3085 | | 13.7 | 10.34 | 310 | | .73 | | | | | 17.65 | 295 | | 17.26 | 245 | | | 56 |
| 158) Daisy | lap belt & harness | 24 | M | 130 | 3086 | | 14.5 | 11.37 | 354 | | .75 | | | | | 21.80 | 1200 | | 18.08 | 476 | | | 56 |
| 159) Daisy | lap belt & harness | 22 | M | 150 | 3087 | | 13.4 | 9.79 | 386 | | .73 | | | | | 17.10 | 279 | | 17.12 | 485 | | | 56 |

| | | | | | | SLED | | | | | | BELT LOADS (lb.) | | | | CHEST LOAD | | | HEAD LOAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location or Type of [illegible] | Type of Restraint | Age | Sex | Weight (lb.) | Test No. | Seat Pitch deg. | Entrance Velocity ft/sec | Peak g's | Onset rate g/sec | Pulse Duration sec | Stopping Distance feet | Right Lap Belt | Left Lap Belt | Right Upper Torso Belt | Left Upper Torso Belt | g-level | Onset rate g/sec. | Time Duration sec. | g-level | Onset rate g/sec. | Time Duration sec. | Injury to Subject | Reference Number |
| 160) Daisy | lap belt & harness | 26 | M | 209 | 3088 | | 12.6 | 9.49 | 275 | | .75 | | | | | 13.63 | 190 | | 12.45 | 125 | | | 56 |
| 161) Daisy | lap belt & harness | 22 | M | 184 | 3039 | | 13.6 | 11.21 | 342 | | .73 | | | | | 18.25 | 406 | | 21.22 | 243 | | | 56 |
| 162) Daisy | lap belt & harness | 22 | M | 140 | 3090 | | 14.3 | 11.18 | 383 | | .73 | | | | | 22.30 | 378 | | 18.82 | 237 | | | 56 |
| 163) Daisy | lap belt & harness | 27 | M | 191 | 3108 | | 13.3 | 11.41 | 1015 | | .63 | | | | | 17.55 | 141 | | 24.72 | 625 | | | 56 |
| 164) Daisy | lap belt & harness | 23 | M | 125 | 3109 | | 14.6 | 11.74 | 1162 | | .60 | | | | | 26.71 | 800 | | 18.63 | 1050 | | | 55 |