USAAMRDL TECHNICAL REPORT 72-9

A STATISTICAL EVALUATION OF THE INJURY POTENTIAL OF A "SQUARE WAVE" ENERGY ABSORBER

By

Norman S. Phillips

Richard W. Carr

William B. Walcott

June 1972

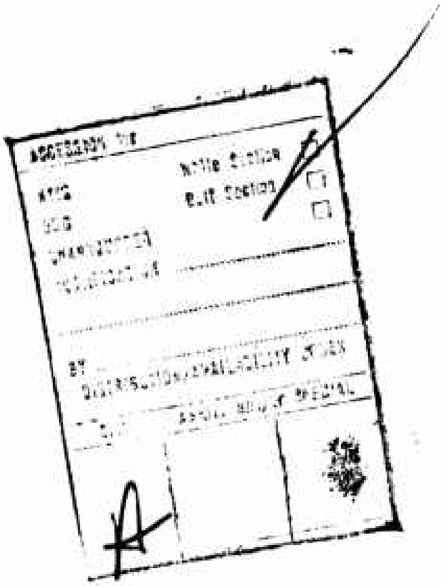
EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-70-C-0055

BETA INDUSTRIES, INC.

DAYTON, OHIO

Approved for public release; distribution unlimited.



Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Beta Industries, Inc. 2763 Culver Avenue Dayton, Ohio	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
A STATISTICAL EVALUATION OF THE INJURY POTENTIAL OF A "SQUARE WAVE" ENERGY ABSORBER

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report

5. AUTHOR(S) (First name, middle initial, last name)
Norman S. Phillips
Richard W. Carr
William B. Walcott

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1972	56	8

8a. CONTRACT OR GRANT NO. DAAJ02-70-C-0055 b. PROJECT NO. 1F162203A529 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) USAAMRDL Technical Report 72-9 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Eustis Directorate U.S. Army Air Mobility R&D Laboratory Fort Eustis, Virginia

13. ABSTRACT
This report presents a quantitative measure of the effects of energy absorber stroke length upon cumulative probability of injury. The response of a seated subject to a vertical deceleration pulse representing a helicopter crash was calculated for a given seat and clothing weight. The seat-man system was analytically supported by a "square wave" energy absorber selected to generate no greater than 23 G for a 5th percentile man. The calculated response, DRI, provides a probability of spinal injury for the seated occupant. Since all parameters necessary for response computations had known statistical properties, it was possible to calculate the joint probability of injury for a particular deceleration pulse and subject weight. By calculating the statistical values for many deceleration and weight combinations, sufficient to represent the total population of both, a cumulative probability of injury was generated. Stroke length of the energy absorber required for each combination of deceleration and weight was calculated. By examining the effects of a limited stroke length, it was possible to generate a curve of stroke length available versus cumulative probability of injury. The curve indicates that for a realistic stroke length (12 inches), the cumulative probability of injury is 0.119. By doubling the stroke available or by halving it, the cumulative probability is decreased or increased by 7 percent. Comparisons with previously reported data indicate that the injury potential of the square wave is significantly higher than is theoretically achievable.

ia

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Injury potential						
"Square Wave" energy absorber						
Crash acceleration						
Seat occupant weights						

ib

DEPARTMENT OF THE ARMY
U. S. ARMY AIR MOBILITY RESEARCH & DEVELOPMENT LABORATORY
EUSTIS DIRECTORATE
FORT EUSTIS, VIRGINIA 23604

This report was prepared by Beta Industries, Inc., under the terms of Contract DAAJ02-70-C-0055.

The purpose of the effort described herein was to determine the cumulative probability of injury to a helicopter occupant seated in an armored crash-force-attenuating seat when subjected to a range of possible survivable vertical crash forces. The scope of the study was limited by the following: (1) only one energy absorber force-deflection curve was used, but stroking distance was varied; (2) the 5th through 95th percentile population of clothed and equipped Army aviators was studied; (3) seat bucket weight was constant; (4) seat cushion characteristics were not varied; and (5) only vertical crash forces were considered. Crash pulse data and energy absorber performance criteria were extracted from USAAVLABS Technical Report 70-22, "Crash Survival Design Guide."

As a result of this effort, a plot of cumulative probability of injury versus energy absorber limit stroke length is presented. Correlation with previous energy absorber efforts indicates that for the seat-man system studied, probability of occupant injury may be reduced by (1) replacing the "square wave" energy absorber with an energy absorber having a "notched" force-deflection curve, (2) lowering the "square wave" energy absorber limit load below that used in this study, or (3) using an energy absorber with multiple load limit settings as discussed in USAAMRDL Technical Report 71-22.

The results of this effort were incorporated in the recent revision of the "Crash Survival Design Guide," USAAMRDL Technical Report 71-22, revised October 1971.

The Eustis Directorate technical monitor for this effort was Mr. G. T. Singley, III, of the Safety and Survivability Division.

Project 1F162203A529
Contract DAAJ02-70-C-0055
USAAMRDL Technical Report 72-9
June 1972

A STATISTICAL EVALUATION OF THE INJURY POTENTIAL OF A "SQUARE WAVE" ENERGY ABSORBER

Final Report

Beta Industries Report 214-5

By

Norman S. Phillips
Richard W. Carr
William B. Walcott

Prepared by

Beta Industries, Inc.
Dayton, Ohio

For

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY
RESEARCH AND DEVELOPMENT LABORATORY
FORT EUSTIS, VIRGINIA

ii

SUMMARY

This report presents a quantitative measure of the effect of energy-absorber stroke length upon cumulative probability of injury. If a helicopter crashes with an energy absorber beneath the seated occupant, the acceleration transmitted to him will generate a response that is indicative of the probability of injury. If all possible crash acceleration environments and seat occupant weights are examined, this probability can be calculated for all crashes. Since the crash environment can be described statistically, and since the subject weight is a statistical parameter, the cumulative probability of injury can be calculated.

A digital program was available to calculate the probability of injury for a subject sitting within a seat supported by an energy absorber subjected to vertical crash impact forces. The program was capable of accepting variable weights and input vertical accelerations; hence, it was possible to calculate the subject's response for all necessary combinations of inputs and weights. The data were collected for discrete combinations such that the cumulative probability at each point could be calculated as the product of the individual probabilities. At each point, stroke length was another calculated output. By summing the probabilities over given stroke lengths, it is then possible to determine the effect of stroke length upon cumulative probability of injury for a given seat energy absorber.

The curve generated indicates that for a realistic stroke length (12 inches), the cumulative probability of injury is 0.119. By doubling the stroke length, the cumulative probability is decreased by 7 percent to 0.111. Halving the stroke increases the probability by the same value to 0.127. Correlation with previously developed data contained in Reference 3 indicate that the injury potential of the square wave absorber is significantly higher than is theoretically achievable.

The data presented have inherent limitations and restrictions. The results were computed assuming a triangular vertical deceleration waveform as specified in the Crash Survival Design Guide.[2] The subject weights were based upon U. S. Army Aviator distribution, and a fixed number was used for seat, equipment, and clothing weight. A nonlinear representation of a polyurethane foam seat cushion is included in the calculation. The DRI concept is strictly applicable to spinal injury only as a result of vertical impacts. Additionally, only one selected energy absorber waveform is used for all cases examined.

FOREWORD

The statistical study reported is a portion of an overall program designed to develop criteria for energy-abosrbing landing gear as required under Contract DAAJ02-70-C-0055, Project 1F162203A529. This particular portion was concerned with the effect of a square-wave energy absorption waveform upon the cumulative probability of injury. The computer program required for this effort was available and the calculations generated data indicative of human response to input acceleration waveform. Hence, it was possible to evaluate a crash condition independent of development of a particular energy-absorbing landing gear, and to infer seat-mounted energy-absorbing capability.

Many individuals made this program possible. The anthropometric data were provided by Mr. George Singley, USAAMRDL; the DRI data were provided by Mr. J. W. Brinkley, U.S. Air Force Aerospace Medical Research Laboratories; and the computer time was supplied by Mr. R. L. Peterson, Air Force Flight Dynamics Laboratory.

TABLE OF CONTENTS

Preceding page blank

LIST OF ILLUSTRATIONS

LIST OF SYMBOLS

DRI	Dynamic Response Index
G	Inertial Load Factor
P	Cumulative Probability of Injury
P_A	Probability of Having a Given Deceleration Level
P_{DRI}	Probability of Spinal Injury Associated With a Given DRI Level
P_W	Probability of Having a Given Weight Subject

INTRODUCTION

There has always been a problem in determining the force level for which an energy absorber should be designed in order to protect seated subjects from spinal impact injuries. If the force level is selected assuming that a heavy man is to be protected, the force during impact will be too great for a lightweight man. If the force level is selected for the small man, then the large man will require a greater stroke length. If the stroke length is to be increased to avoid bottoming, for which acceleration input is the stroke to be compatible? The inherent difficulty in determining the force level to be used has been in resolving the amount of injury potential the device possesses.

A recently developed computer program (3) has provided the necessary tool to evaluate the injury potential of a particular energy absorber. The analytical model is shown in Figure 1. The program, listed in Appendix III, consists of nonlinear ordinary differential equations which relate the forces and displacements of a seated subject, structural seat, and energy absorber. Hence, for any given vertical impulse input, it is possible to calculate the response of the seat and the man. Since there exists a means of relating seat vertical acceleration to injury, an additional degree of freedom is added to the "force" model of the man to calculate the Dynamic Response Index (DRI).

The desired quantitative measure of absorber performance is obtained because of the availability of statistical data relative to each model parameter. That is, the crash input acceleration has a statistical distribution associated with it to relate probability of occurrence to deceleration magnitude (see Reference 1). Similarly, the crewmember weight has a statistical value associated with it. And lastly, a given DRI value can be related to a probability of injury (5).

With both deterministic and statistical values available, bandwidth magnitudes of acceleration and subject weights can be used as input to the digital routine to calculate the human response. Since all parameters are statistically independent, it is possible to calculate the joint probability of injury for any particular crash that will occur. By summing over all accelerations and weights, it is possible to calculate one number which indicates the cumulative probability of injury that exists for all possible vertical accelerations and seated subjects. Given that a survivable crash occurs, the cumulative probability of injury for a given absorber is now available.

Another parameter automatically calculated is the stroke length required to dissipate the input energy. If a stroke length is selected as

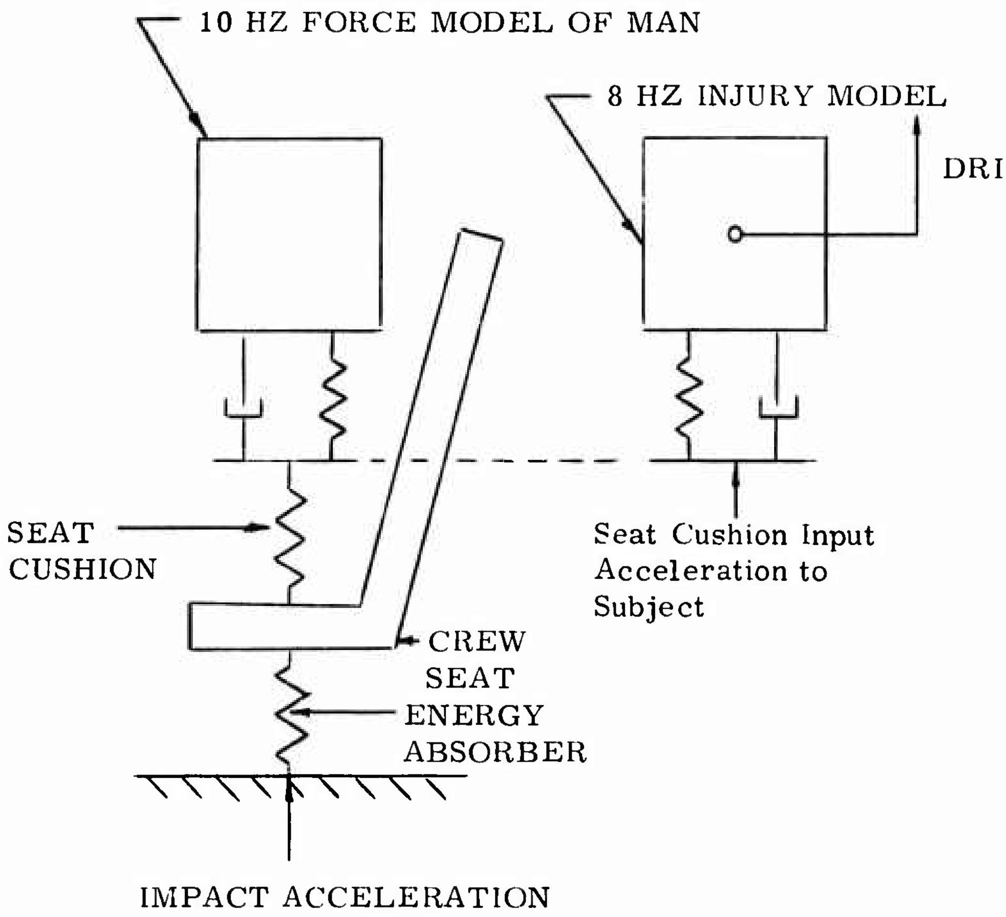


Figure 1. Analytical Representation of Seated Subject.

being the practical limit, it was shown (4) that the impact at bottoming produces a DRI increase sufficient to cause the probability of injury to approximate unity. Therefore, once the array of responses has been generated, the variation of cumulative probability of injury is evaluated by setting the DRI probability to unity and resumming all cell values. This was accomplished to provide a quantitative measure of the effects of changing available stroke length, for a given energy absorber.

CALCULATION OF INJURY POTENTIAL

The purpose of this research was to calculate the variation of cumulative probability of injury for changes in stroke length by implementing an existing digital program. The initial steps required to do this were:

1. Collect the statistical data required
2. Generate the computer input data
3. Determine the force level of the energy absorber
4. Calculate the response of the human to all vertical acceleration inputs and man-weight variations
5. Generate the statistical tables
6. Calculate the cumulative probability of injury as a function of stroke length

These are depicted in Figure 2.

STATISTICAL DATA

Statistical data were collected for the crash deceleration profile, the seated subject weight, and the probability of injury. The statistical data for the crash deceleration pulses were obtained from the "Crash Survival Design Guide", USAAVLABS TR 70-22 (1), Figure 1-11 (Distribution of Vertical Impact Accelerations for Rotary- and Light Fixed-Wing Aircraft). The distribution of personnel weights was determined from "U. S. Army Aviators, 1970" (6) Natick Laboratories. Data for the Dynamic Response Index (DRI) were obtained from the Impact Branch of the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base. These distributions are presented as Figures 6, 7, and 8 in the appendixes.

COMPUTER INPUT DATA

The computer program (see Appendix II) used solves for the injury potential of a particular seated subject responding to a particular input. That is, it is necessary to calculate the response for particular waveforms and particular subject and seat weights. The cumulative probability of injury should theoretically be calculated from continuous distributions of the variable, but this cannot be practically achieved.

I. Collection of Statistical Data
- a) Crash deceleration pulses (USAAVLABS 70-22)
- b) Subject weight distribution (appropriate Army data)
- c) D. R. I. distribution (USAF Impact Branch of AMRL)

II. Generate Computer Input Data
- a) Helicopter crash only
  1. Crash pulse triangular waveform
  2. Man weight
  3. Fixed seat weight (Army specified)
- b) Statistical distributions
  1. Crash pulse into 20 ranges
  2. Man weight into 20 ranges
  3. Revised D. R. I. probability

III. Determine E. A. Waveform (force-displacement)
- a) Helicopter crash only
  1. Maximum acceleration input (48 g peak)
  2. Man weight (80 percent of total weight)
  3. Fixed seat weight (Army specified)
- b) Calculate force-displacement (Chapter 3)

IV. Calculate Response
- a) Variations of acceleration input
- b) Variations of subject weight
- c) Record D. R. I. and stroke length

V. Generate Statistical Tables
- a) A 17 x 20 matrix of probabilities
- b) Cumulative probability of injury versus stroke

VI. Data Presentation
- a) Cumulative probability of injury versus stroke length for USAAVLABS 70-22 criteria
- b) Generate report to detail the results with required assumptions and limitations

Figure 2. Program Flow Chart.

Hence, it is necessary to utilize discrete values of the variable and establish the probability that exists for a particular bandwidth. This was done for both the deceleration profile and the subject weight.

The helicopter crash deceleration G distribution (1) used was:

Mean G	Probability	Mean G	Probability
1.80	0.4700	18.00	0.0133
3.97	0.1700	19.87	0.0107
6.90	0.0900	22.00	0.0080
7.93	0.0700	24.00	0.0080
10.00	0.0400	26.00	0.0080
12.00	0.0400	28.00	0.0080
13.75	0.0267	30.00	0.0080
16.00	0.0133	32.00	0.0080
		34.00	0.0080
			1.0000

The weights of men (without clothing and equipment weight) used were: (6)

Weight (lb)	Probability	Weight (lb)	Probability
128.0	0.05	172.0	0.05
137.5	0.05	175.0	0.05
143.5	0.05	178.5	0.05
148.5	0.05	181.5	0.05
152.5	0.05	184.5	0.05
156.0	0.05	188.0	0.05
159.0	0.05	193.0	0.05
162.0	0.05	198.5	0.05
165.5	0.05	206.5	0.05
169.0	0.05	220.0	0.05

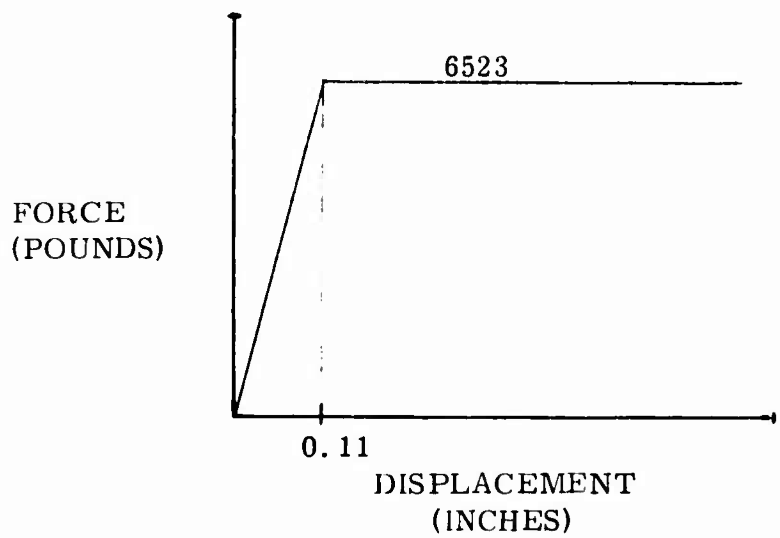
The equipment and clothing weight used in conjunction with the above subject weights was 37.4 pounds. This weight included all clothing and equipment except the boots and was comprised of such items as the armored vest (15.9 to 17.7 pounds), survival vest (5.0 pounds), flight helmet (3.3 pounds), pistol plus twelve rounds (2.5 pounds), and clothing (6.8 pounds). By using one weight, approximately the median based upon size, the variation accepted was approximately 2 pounds. This is negligible when considering the other quantitative aspects that are within the overall computation.

Another input parameter included was the force-displacement curve of the seat cushion. The model represents a 1.0-inch layer of polyurethane foam upon a 0.25-inch layer of closed cell ensolite foam. The force-deflection curve used as input is shown in Figure 9.

The helicopter seat bucket weight used was 147 pounds. This was provided as being indicative of the weight of an energy-absorbing armored seat.

ENERGY ATTENUATION

The energy-absorber force level was dictated by the procedures outlined in Reference 1, Section 3.3.3. That is, it was assumed that the attenuator provided a square wave force-displacement curve and that the force required would not injure the 5th percentile man. Eighty percent of the 5th percentile man with clothing and equipment is 136.6 pounds. This and the seat weight dictate a maximum force level of 6,523 pounds to be used in order not to exceed a 23 G level. Had the heavier man been chosen with a 20 G limit, the force level would have been too great. The force deflection curve used is shown below.



CALCULATION OF INJURY POTENTIAL

The analytical model used in calculating the response of a seated human to spinal impact has been presented and documented in a previous report (3). The program consists of a set of nonlinear ordinary differential equations that are solved using iterative techniques. For any given input vertical acceleration that is specified as a function of time, the time dependent forces, accelerations, and displacements are calculated. The human response is calculated in two ways in order to evaluate the injury level (DRI). The equations of motion are written for a 10 Hz system to duplicate man's force response. This yields the correct seat acceleration that would exist if a human were subjected to the attenuated acceleration pulse. The seat acceleration is then used as the input acceleration to the DRI model, an 8 Hz system. The output of the latter model is then the desired DRI magnitude which is directly related to probability of injury.

For each of the discrete values of input acceleration and man weight, a calculation was made. The DRI value and stroke length for each were recorded.

STATISTICAL TABLES

Each calculation has associated with it three probabilities. The probability of being within that weight bandwidth (P_W), the probability of having a deceleration within the given bandwidth (P_A), and the probability associated with the calculated DRI (P_{DRI}). The computed data were tabulated in the format shown in Figure 8. The upper cell of any one statistical calculation is the cumulative probability of having the acceleration and weight magnitudes occur $(P_A)(P_W)$. The middle cell is the probability of injury (P_{DRI}), and the bottom cell is the cumulative probability of all three variables

$$P = (P_A)(P_W)(P_{DRI})$$

The upper cell of the second table is the magnitude of the DRI, and the lower is the stroke length required to absorb all of the input energy. All tables developed are presented in Appendix III.

DEVELOPMENT OF CUMULATIVE PROBABILITY OF INJURY VERSUS STROKE LENGTH

The generated tables consist of an array of 340 probability/stroke length pairs. If the probabilities for all cells are summed, the cumulative probability is that associated with the largest stroke length obtained. The heaviest man with the greatest deceleration requires nearly 28 inches of stroke. If one absorber of this length were provided, then all crash occurrences examined would be protected as defined by Reference 1; therefore, the cumulative probability of injury (0.109) is plotted on Figure 3 as the injury potential associated with a square wave absorber of at least 28 inches' stroke length. By changing the stroke length, it is apparent that the injury potential changes. If the stroke length were 20 inches, all occurrences examined with stroke lengths calculated at greater than 20 inches would be instances of "bottoming" or impact of seat and floor. For these conditions it is reasonable to assume that the "bottoming" is impulsive. That is, the floor is stiff enough to create a deceleration pulse such that the body responds as a function of the velocity change. Since the DRI is linearly related to the velocity change in feet per second, nearly one to one, a small velocity residue of 1 foot per second increases the DRI by one unit (7). A one-unit change does not create a small change in probability because of the statistical relation of DRI to probability. Hence, even for a small velocity residue at the instant of "bottoming", the probability of injury approaches unity.

The cumulative probability for a given stroke was calculated by selecting a particular stroke length, determining all cells where that stroke was exceeded, setting the DRI probability to unity for those cells, generating a new joint probability table, and resumming all values. Only the DRI probability is set to unity. A given cell has a probability associated with the weight and deceleration magnitude of that cell. Hence, the new cell generated has the joint probability of weight-deceleration as its final value.

The process discussed above was used rather than recalculating on the computer the DRI magnitude that would occur for a restricted stroke length. This was used before and verified as a reasonable approximation technique in previous works (3).

RESULTS

The data of Figure 3 indicate that there would be a possible improvement in cumulative injury probability of 23-1/2 percent if a 27.7-inch stroke were possible. For a more realistic stroke length of 12 inches, the improvement is approximately 17 percent over the no-energy-absorber condition. The variation of percent improvement as a function of stroke length is shown in Figure 4.

The curve shown is relatively flat in that although the maximum stroke required has been determined, only a 23-1/2-percent improvement is possible. The reason for this is apparent in the tabulated data. Although the energy absorber is designed not to exceed 23 G for the 5th percentile man, and to generate only approximately 18 G for the heavy man, the response of the human is much greater than desired. The 95th percentile man and the 95th percentile crash pulse are attenuated over 27.7 inches. The response of the man is a DRI of 20.81, or approximately a 20-percent probability of injury due to an 18 G force level. Similarly, the 5th percentile man attenuates the 95th percentile crash in 17.4 inches while reaching a DRI of 28.58. This is the result of an energy-absorber designed to generate a 23 G force on a rigid mass subject.

The data are indicative of the fact that the human is not a "rigid mass" for the environments considered. Admittedly, the seat cushion is included in the analysis. However, the cushion is a device that is soft only up to full body weight. The one used is thin and is essentially "bottomed out" prior to any great acceleration input. Hence, the data are more indicative of the human response and not the effects of the cushion.

To further demonstrate the effects of body dynamics, the curve developed has been superimposed on data developed under another program (4). The curves shown in Figure 5 are for "optimized", notched energy absorbers.

The "optimized" force levels are those that will not exceed a given DRI for the mean weight subject, a 115-pound seat bucket, and the same deceleration pulse used for the square wave analysis. The "optimization" process is based upon taking advantage of the dynamic nature of man's force and injury response. This creates a "notched" energy-absorber force-displacement curve. The curves are for a theoretical waveform and as such as idealistic or only conceptually attainable. However, they are indicative of possible goals. One particular waveform is shown on the following page.

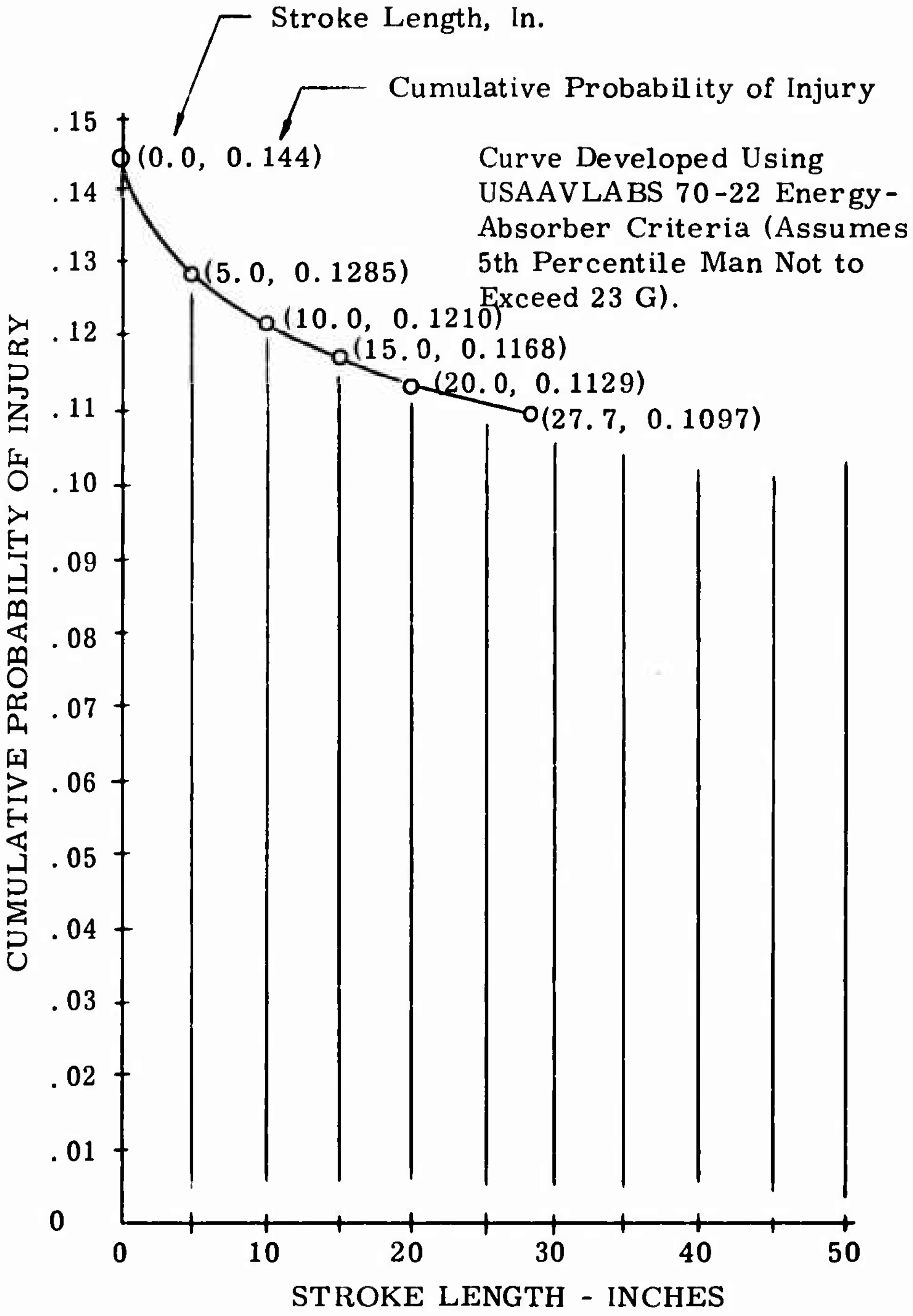


Figure 3. Cumulative Probability of Injury Variation With Energy-Absorber Stroke Length.

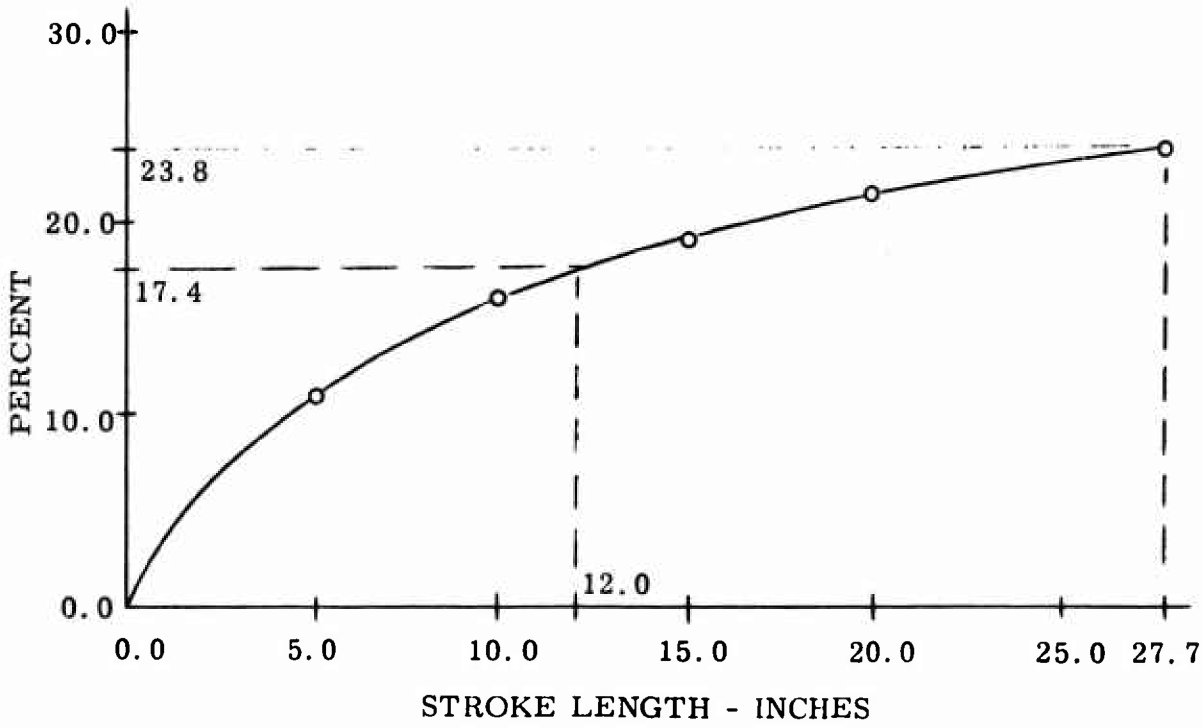


Figure 4. Cumulative Probability of Injury Improvement With Stroke Length.

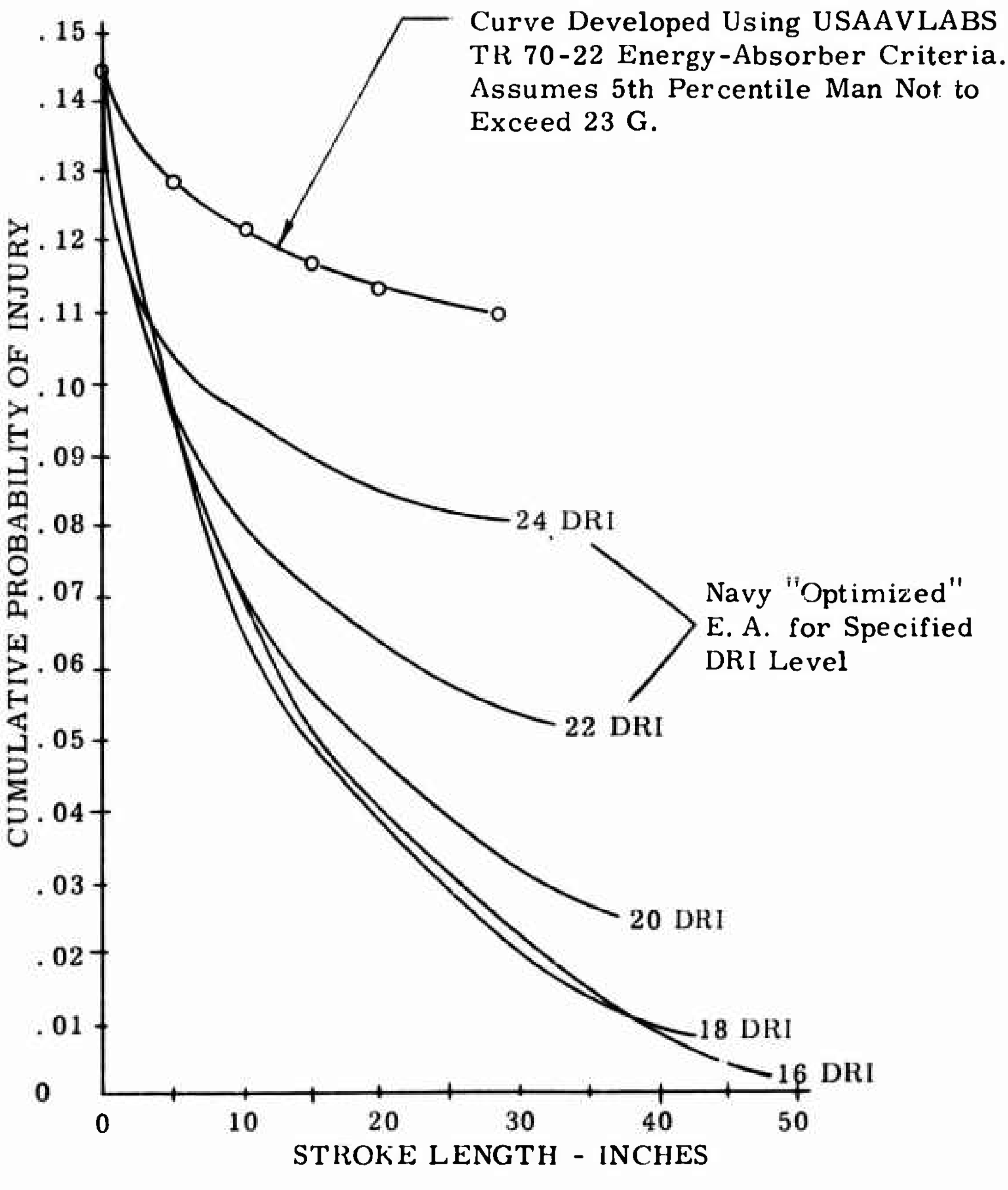
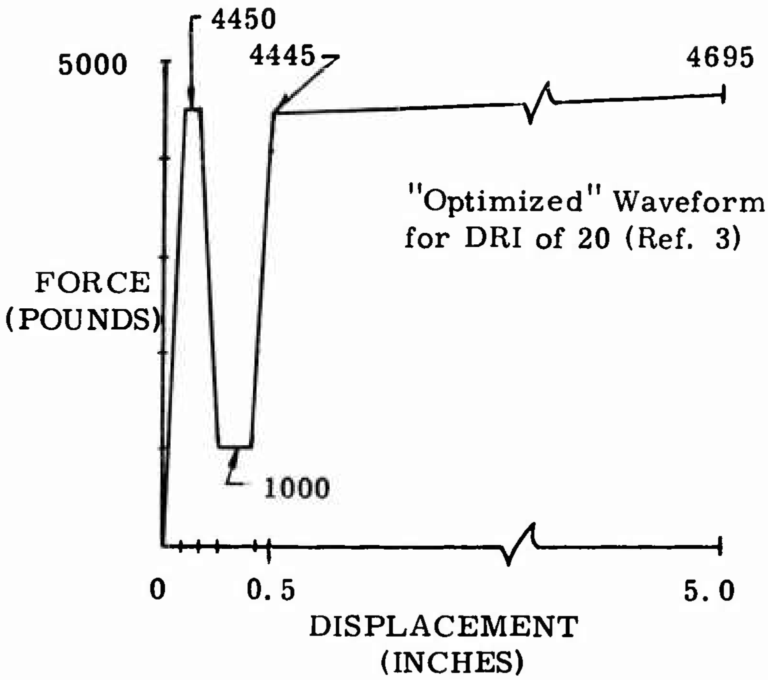


Figure 5. Cumulative Probability of Injury Variation With Comparative Data.



The "optimized" energy absorber curves in Figure 3 indicate that for a 12-inch stroke it is possible to have a 50-percent improvement in cumulative probability of injury, compared with the square wave absorber, by designing for an 18 DRI limit for the mean (170-pound) man. Even if the force level is selected to develop a 23 DRI, instead of 23 G, the improvement in probability from square wave to optimum absorber would be 30 percent.

CONCLUSIONS

Several conclusions can be drawn concerning the curve developed (Figure 3):

1. The cumulative probability of spinal injury for a helicopter crash, with vertical deceleration only, with the selected seat cushion and a 12-inch stroke "square wave" absorber defined on page 7, is 0.119. Given that a vertical deceleration survivable helicopter crash occurs, there is an 11.9 percent probability of spinal injury. This is approximately a 17 percent improvement over the no energy absorber condition (P = 0.124).

2. The stroke required for the most severe condition for the seat/energy absorber system assumed is 27.7 inches.

3. The cumulative probability difference between a no-energy-absorber condition and the maximum stroke condition (27.7 in.) to handle the heaviest man and greatest deceleration is 23.8 percent.

Considering the relative magnitudes of the generated curve and previously reported data, it is concluded that:

1. A cumulative probability of injury lower than that created by the vertical load limiting criteria of Reference 1 is theoretically achievable.

2. For a 12-inch stroke length, a 50-percent improvement in injury probability is theoretically possible if a "notched" energy absorber is used.

3. An improvement in the injury probability for a 12-inch stroke length "square wave" energy absorber is possible if the load level setting would be reduced below that cited in 1*.

4. An improvement in the injury probability for a 12-inch stroke is possible if an energy absorber with a multiple load limit setting capability is used (2).

*Note: Reference 1 has been superseded by Reference 2, which has a lower load limiter setting requirement.

RECOMMENDATIONS

It is recommended that:

1. Additional effort be spent in deriving an acceptable cumulative probability of injury.

2. The energy-absorber force level criteria of Reference 1 be revised to reflect the available injury potential data. Some level of DRI should be selected to dictate a particular design condition, or a cumulative probability injury level.

LITERATURE CITED

1. Turnbow, J. W., Carroll, D. F., Haley, J. L. Jr., Robertson, S. H., CRASH SURVIVAL DESIGN GUIDE, USAAVLABS Technical Report 70-22, U. S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, Revised August 1969, AD 695 648.

2. CRASH SURVIVAL DESIGN GUIDE, USAAMRDL Technical Report 71-22, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, Revised October 1971, AD 733358.

3. Carr, Richard W., and Phillips, Norman S., DEFINITION OF DESIGN CRITERIA FOR ENERGY ABSORPTION SYSTEMS, Beta Industries, Inc.; NADC Report AC-7010, Naval Air Development Center, Johnsville, Warminster, Pennsylvania, June 1970, AD 871-040.

4. Phillips, N. S., Carr, R. W., and Scranton, R. S., A STATISTICAL INVESTIGATION INTO THE DEVELOPMENT OF ENERGY ABSORBER DESIGN CRITERIA, Beta Industries, Inc., NADC Report CS-7122, Naval Air Development Center, Johnsville, Warminster, Pennsylvania, November 1971.

5. Brinkley, James W., DEVELOPMENT OF AEROSPACE ESCAPE SYSTEMS, Air University Review, Vol XIX (5), 34-49, July-August 1968.

6. U. S. ARMY AVIATORS, 1970, Natick Laboratories.

7. Carr, R. W., and Walcott, W. B., DESIGN CRITERIA FOR ENERGY ABSORBERS, RESTRAINT SYSTEM, SEAT CUSHION, and HEAD REST, FOR A HIGH STRENGTH ARMORED CREW SEAT, Beta Industries, Inc., Report BII 220-3 prepared under Contract F33165-71-R-1411, for The Budd Company, August 1971.

APPENDIX I

INPUT DATA

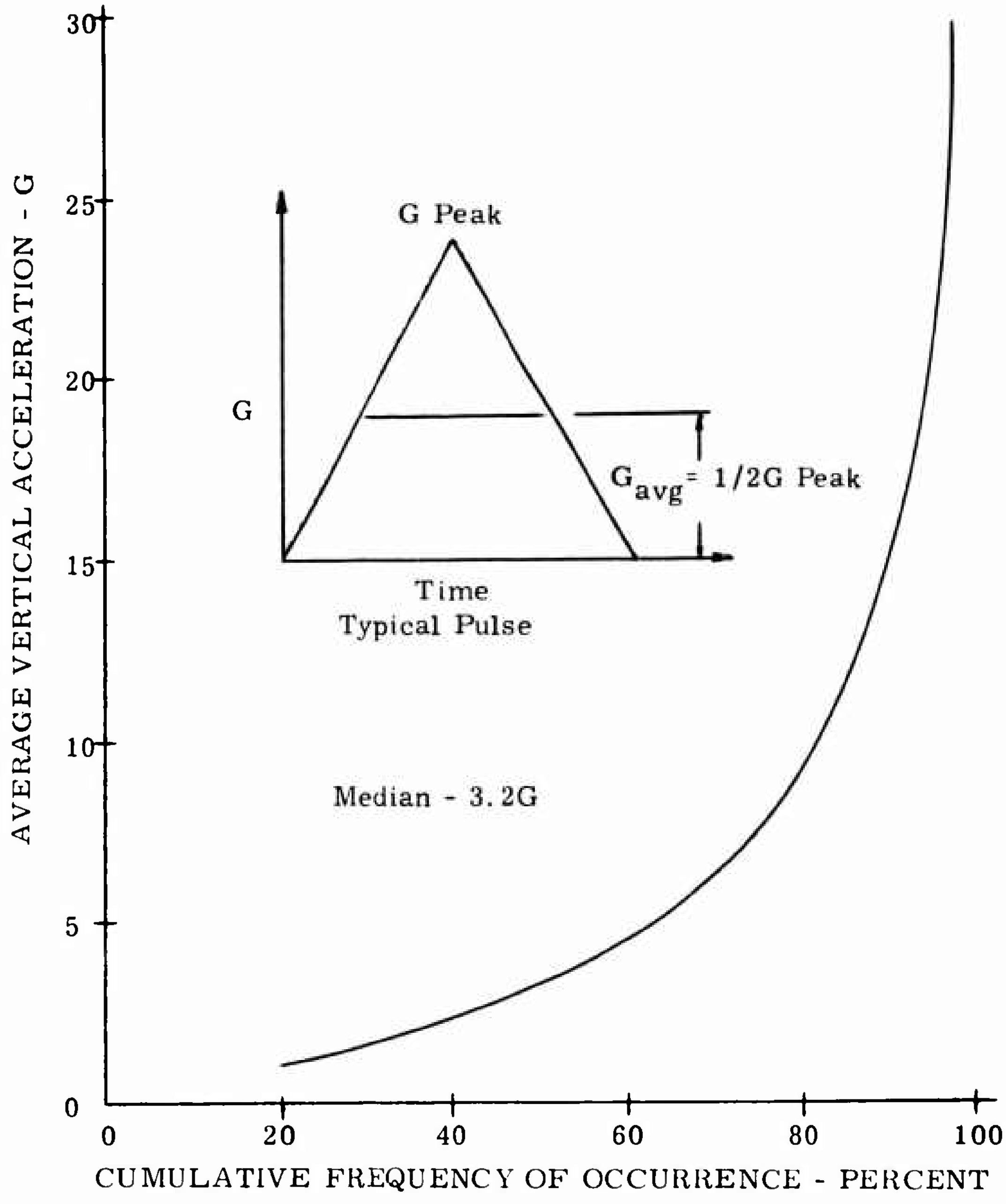


Figure 6. Distribution of Vertical Impact Accelerations for Rotary-and Light Fixed-Wing Aircraft.

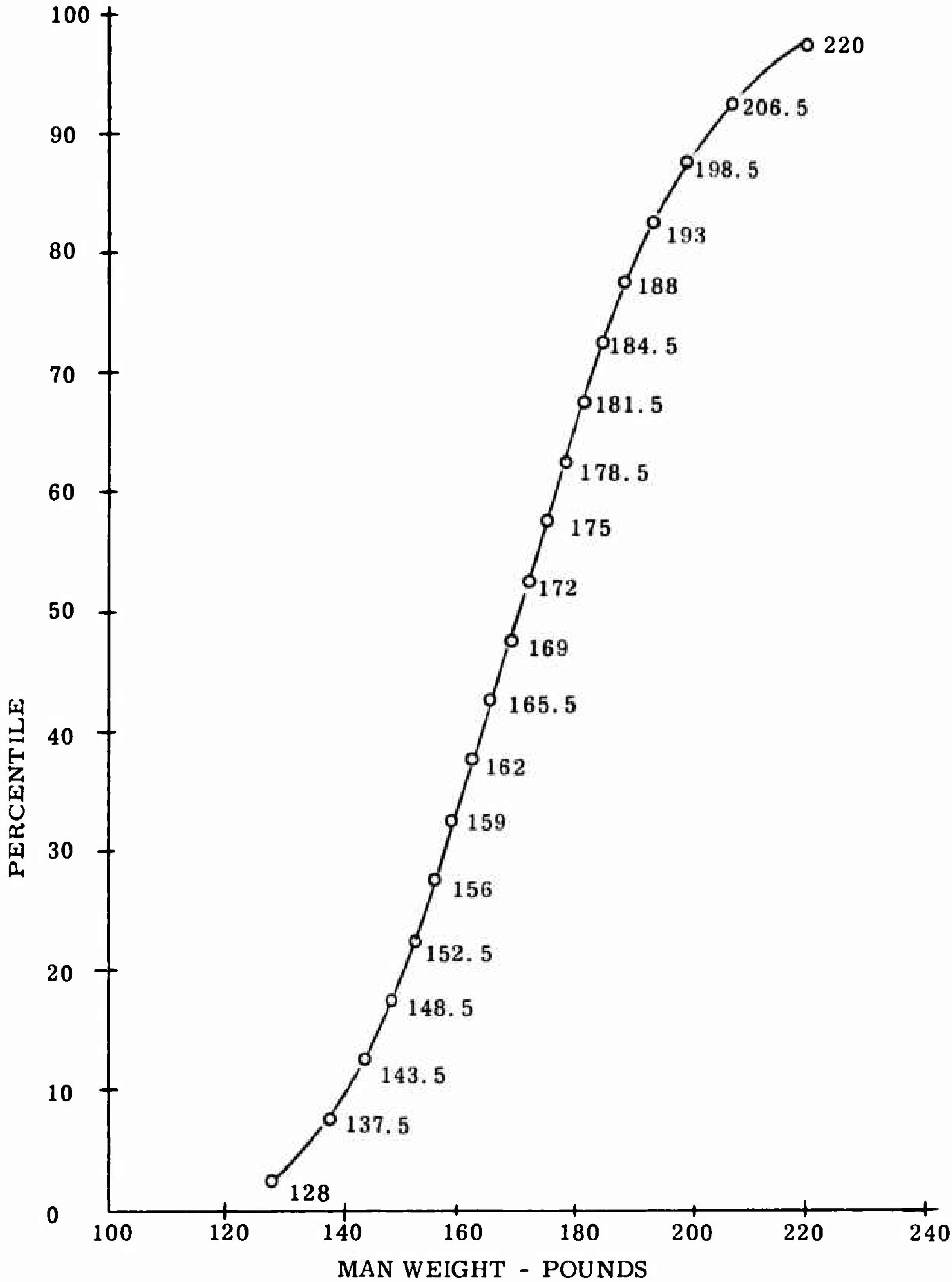


Figure 7. Weight Distribution of U. S. Army Aviators (Ref. 3).

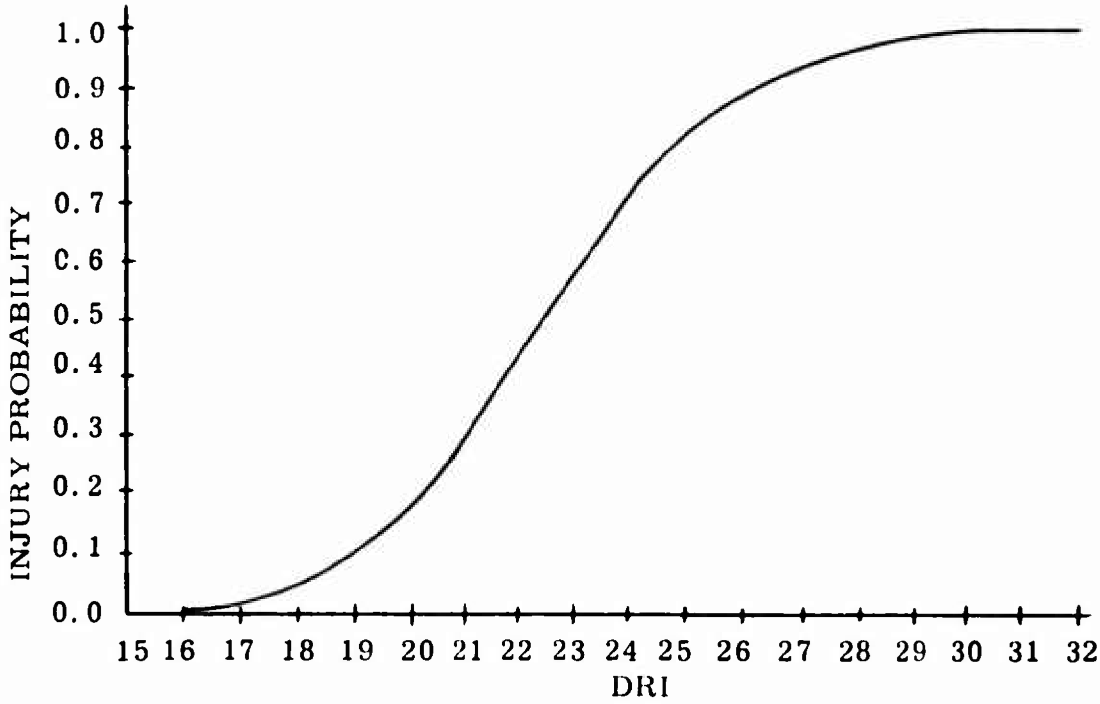


Figure 8. Injury Probability Curve.

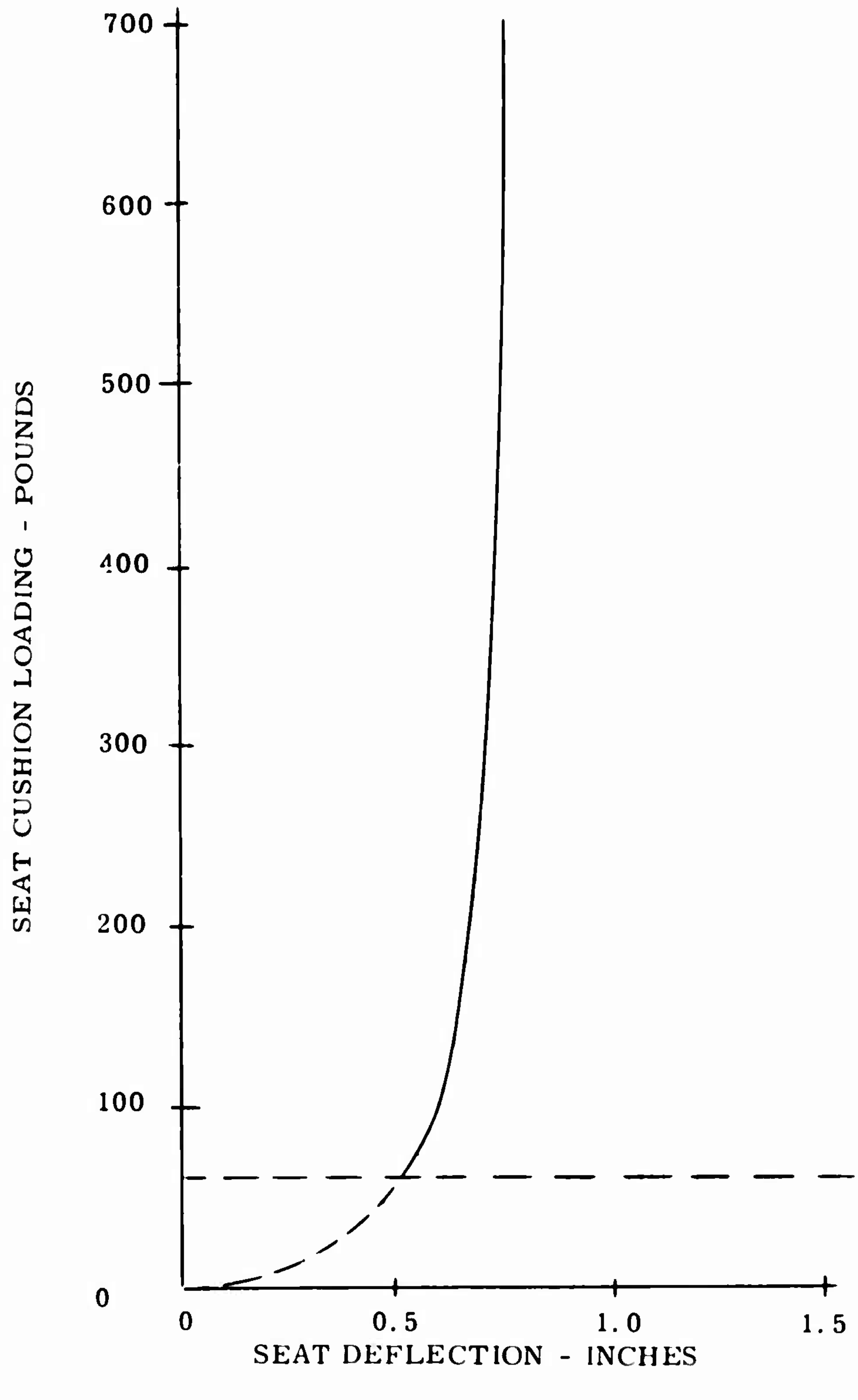


Figure 9. Seat Cushion Force-Displacement Curve.

APPENDIX II

COMPUTER PROGRAM USERS GUIDE

The computer program used for this study is listed on the following two pages and is discussed in the subsequent paragraphs with a complete listing of the terms following the discussion.

The initial cards (CON) establish the constants to be used in specifying the structural constants. The aircraft floor stiffness is (K6) and damping is (C6). The impact velocities for acceleration waveforms are A1, A2, and A3.

The first constant function cards, CFN, represent the acceleration waveform used as an input. The number within the field indicates the number of time data points within the field. If it takes 10 points to describe the acceleration input, CFN (10.0) would be required. The next CFN card represents the energy absorber as a function of displacement and a series of three points. The next two CFN cards describe the seat cushion characteristics. SC is the force-deflection curve for the seat cushion and ISC is the inverse function or deflection-force curve. This curve is required in the program to determine the initial deflection of the seat cushion.

The seat weight (W2), aircraft type (AC), energy absorber stroke (SL) and number of energy absorbers (NE) are read in as constants. If it is desired to vary these quantities, they can easily be read as parameters. The weight of the seated man (W1) and the input reduction factor vary from run to run and are read in as parameters.

The function cards establish the functional relationship between the parameters on the constant function cards. That is, FUN (AJ, T) indicates that the data on the CFN card AJ is a function of time, T. The computer will establish linear relations between the points given and interpolate as required.

The next series of cards merely evaluate the stiffness and damping coefficients for the models. Since the man models are fixed, 10 HZ and ζ =0.3 for the force model and 8 HZ and ζ =0.22 for the injury model; the coefficients are calculated by inserting the given body weight.

The remainder of the program is the coding of the differential equations of motion previously mentioned. For example, the differential equation for the seat is initially written:

$$M_2 \ddot{X}_{51} = F_{ea} + F_{st} + W_2 + F_{sc}.$$

MIMIC SOURCE-LANGUAGE PROGRAM

```
                 IMPACT RESPONSE OF SEATED MAN
                 CON(K6,C6,K7)
                 CON(A1,A2,A3)
HELICOPTER
  AH             CFN(3.0)
  EA             CFN(3.0)
  SC             CFN(10.C)
  ISC            CFN(10.C)
                 CON(W2,AC,SL,NE)
                 PAR(W1,RA)
  M1             W1/386.
  K1             M1*3950.
  C1             0.6*M1*62.8
  M2             W2/386.
  M3             M1
  K3             M3*2500.
  C3             C.44*M3*50.
  RA             FUN(AH,T)
  FORCEA         FUN(EA,X6)
  FSC            FUN(SC,XSC)
  AD             AC-2.
  ARR            FSW(AD,A1,A2,A3)
  AR             RA*ARR
  SCD            .785
  LV1            FSW(XSC-SCD,TRUE,FALSE,FALSE)
  I1             LSW(LV1,C.,1.)
  I2             LSW(LV1,1.,0.)
  INXSC          FUN(ISC,W1)
  DXSC           1DX5-1DX2
  XSC            X5-X2+INXSC
  2DX1           (-C1*1DX1-K1*X1+C1*1DX2+K1*X2-W1)/M1
  1DX1           INT(2DX1,AR)
  X1             INT(1DX1,0.)
  1DX2           (FSC-W1-K1*X2+K1*X1+C1*1DX1)*I2/C1+I1*1DX5
  X2             INT(1DX2,0.)
  1DX21          1DX5-1DX1
  X21            X2-X1
  2DX51          I1*(C1*1DX1+K1*X1-C1*1DX2-K1*X2+ENAR+STR-W2)/M2
  2DX52          I2*(ENAB+STR-W2-FSC)/M2
  2DX5           2DX51+2DX52
  1DX5           INT(2DX5,AR)
  X5             INT(1DX5,0.)
  2DX3           (C3*1DX2+K3*X2-C3*1DX3-K3*X3-W1)/M3
```

```
10X3      INT(20X3,AR)
X3        INT(10X3,0.)
DRI       (K3*(X2-X3))/(M3*365.)
FA        0.
TA        0.
ARS       FSW(AD,FA,HA,TA)
20X4      RA*ARS
10X4      INT(20X4,AR)
X4        INT(10X4,0.)
20X6      20X4-20X5
10X6      10X4-10X5
X6        X4-X5
10X7      AF*10X6
X7        INT(10X7,0.)
AM        FSW(T-.005,1.,1.,0.)
AN        FSW(AM+10X6,FALSE,FALSE,TRUE)
AB        FSW(AM+10X6,TRUE,TRUE,FALSE)
DISP      TAS(X6,AN,0.)
FORED     TAS(ENAC,AN,0.)
DIS2      TAS(X6,AB,0.)
FORE2     TAS(ENAC,AB,0.)
STR       K6*X8+C6*10X8
AY        FSW(X6-SL,FALSE,FALSE,TRUE)
AZ        LSW(AY,1.,0.)
10X8      AZ*10X6
X8        INT(10X8,0.,TRUE,AY)
ENAB      NF*ENAC
ENAC      FSW(10X6,FOREB,FOREB,FOREF)
FOREF     FOREA*BN+FORE2*AP
BN        LSW(DIS2,0.,1.)
AP        LSW(DIS2,1.,0.)
B3        FSW(10X7,TRUE,TRUE,FALSE)
B1        LSW(B3,1.,0.)
B4        FSW(10X7,FALSE,TRUE,TRUE)
B2        LSW(B4,1.,0.)
FORS      FOR2*B2+FORED*B1
FOREC     FORS+REBD
FOREB     FSW(FOREA-FOREC,FOREA,FOREA,FOREC)
10X9      B1*10X7
X9        INT(10X9,0.,TRUE,B3)
10X10     B2*10X7
X10       INT(10X10,0.,TRUE,B4)
REB1      K7*X9
REB2      K7*X10
REBD      REB1*B1+REB2*B2
DT        .001
DTMAX     DT
DTMIN     DTMAX
          FIN(T,.2)
          OUT(T,20X1,10X1,X1,ENAB,DRI)
          OUT( , ,10X2,X2,10X21,X21)
          OUT( ,20X5,10X5,X5,XSC,FSC)
          OUT(20X4,10X4,X4,20X6,10X6,X6)
          END
```

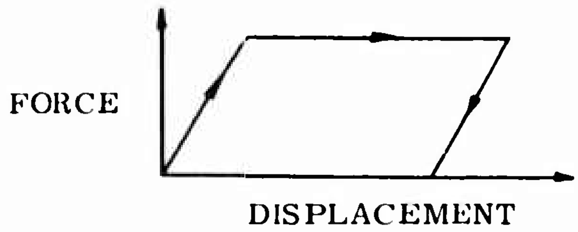
The forces in this equation are due to the energy absorber (F_{ea}), structural loads (F_{st}), inertial force (W_2), and the seat cushion (F_{sc}). The seat cushion force arises from the relative displacement between the man and the seat which causes the seat cushion to be compressed. There is a limit to the amount of compression the seat cushion can withstand; and when it is reached, the cushion is essentially a rigid link between the man and the seat and the equation of motion becomes

$$M_2\ddot{X}_2 = C_1\dot{X}_1 + K_1X_1 - C_1\dot{X}_2 - K_1X_2 + F_{ea} + F_{st} - W_2$$

The first terms are directly from a summation for forces. The last three are the forces due to the energy absorber, forces due to structural response, and the inertial term.

As the energy absorber compresses, the force generated changes with increasing relative displacement. However, it cannot displace an unlimited amount. If an energy absorber is not sufficient to absorb the input energy, it would attempt to travel a distance greater than practically available. Therefore, the stroke limit, SL, is specified. If the device attempts to exceed this limit, it is assumed that the seat impacts on a very rigid structure having stiffness K6. This causes large-magnitude and high-frequency "ringing" to occur, and structural damping C6 is included to limit the ringing.

The other condition is that of seat rebound. If the absorber dissipates the energy properly, a point is reached where the relative velocity between the floor and seat goes to zero. If the seat and man want to rebound, the energy absorber does not necessarily respond as a continuous element. Since rebound data is not available for all types of absorbers, it is assumed the device deforms elastically back to zero force with the same stiffness as the original elastic deformation of the curve. This is shown below. The value used at present is 60, 000 pounds per inch.



The remainder of the program contains the logic required to properly control the energy absorber "rebound" and the structural bottoming. The structural response is the easiest to explain. When the absorber deformation, X6, exceeds the selected stroke, SL, the displacement of the "rigid" link is calculated by integrating the relative velocity starting at the time when X6-SL is greater than zero. This creates a force STR which is added into the differential equation. When the deformation becomes less than the limiting stroke, the integration stops and the force goes to zero. The seat is free to rebound.

The energy absorber action is more complicated. As the displacement, X6, increases; the relative velocity, IDX6, eventually slows to zero. At this point the absorber wants to rebound, but not along the original path. Instead, it wants to unload along a line parallel to the initial elastic portion of the force-displacement curve. There the last value of force and displacement attained at zero relative velocity must be stored as the initial value of the rebound or relaxation portion of the curve. This is the purpose of the "track and store" operations such as:

```
DISP = TAS (X6, AN, O.)
FORED = TAS (ENAC, AN, O.)
```

From these initial conditions we must backtrack along the stiffness curve K7. Therefore, the force in the energy absorber is the stored value minus the product of K7 and X9. When the absorber reaches another zero relative velocity and expands as far as it will go, the deformation may again increase along the elastic curve from the stored values:

```
DIS2 = TAS (X6, AB, O.)
FOR2 = TAS (ENAC, AB, O.)
```

The occurrence of elastic rebound within the elastic range, even though 1DX6 goes positive, is recognized by having the logical test placed upon 1DX7, which detects the first change in relative velocity as positive but the maximum displacement has not occurred to initiate 1DX7. After the peak displacement is once reached, 1DX7 has some value and enables the computer to calculate the relaxation effect rather than return to the original force displacement curve.

The output of the program can be selected by use of header and outs cards in the formats shown. As written, the program prints out and plots the input acceleration, the seat acceleration, the energy absorber crush and the DRI. These provide in one plot the input, the seat response, energy absorber response, and the human physiological response.

COMPUTER PROGRAM GLOSSARY

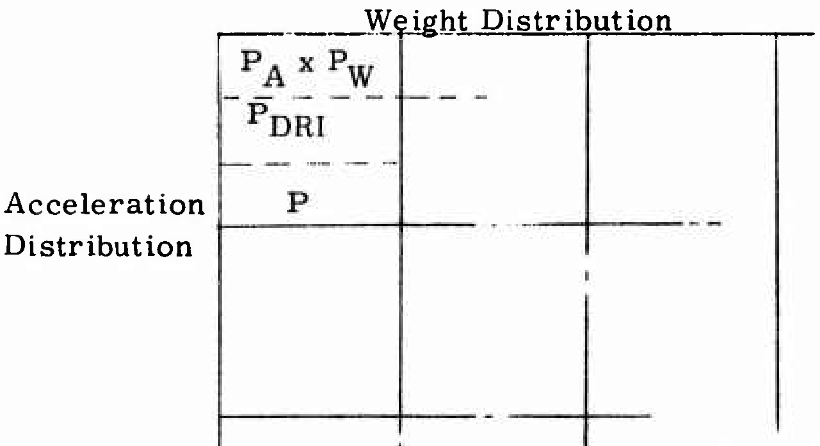
AC	Aircraft control parameter. This is input to the program to select either the fighter, helicopter or transport acceleration input depending upon whether or not the value is 1, 2, or 3 respectively.
AF, AH, AT	Symbols identifying the acceleration data points fo. fighter, helicopter, and transport.
DISP	The displacement of the absorber as long as the relative velocity is positive. The track and store operation causes DISP to track X6 until 1DX6 goes negative and stores that value. When 1DX6 goes positive again, DISP tracks until another velocity reversal. In this manner DISP always contains the initial conditions for displacement when the seat attempts to compress the absorber.
DRI	The Dynamic Response Index which is a measure of vertebral fracture.
EA	Symbol identifying the data points obtained from the energy absorber curve. The number in parentheses establishes the number of points to be used as input. (Force in pounds versus time in seconds)
ENAB	Total force for all absorbers. (pounds)
ENAC	The force developed by one absorber at any time. (pounds)
FA, HA, TA	Symbols identifying the time function generated by the data points AF, AH, and AT.
FOREA	Symbol establishes the relation between the energy absorber curve and calculated relative displacement.
FORED	The force the absorber develops as long as the relative velocity is positive. This duplicates the actions of DISP.
FORS	A stored force at the beginning of expansion or compression.
NE	Number of energy absorbers; also an input.
SL	Stroke limit is included as input. (inches)
STR	The force developed by the structure at impact of the seat when the stroke limit is exceeded.

A1, A2, A3	Velocities of the fighter, helicopter, and transport aircraft respectively. These are used as the initial values of the integrators of the program.
C1	The damping factor of the 10 HZ man model (#/inch/sec.)
C3	The damping factor of the 8 HZ injury model (#/inch/sec.)
C6	Damping coefficient of structural element that is impacted when seat impacts. (#/inch/sec.)
DISC2	The displacement of the absorber as long as the relative velocity is negative. The track and store operation is reversed so that DIS2 will always contain the value of absorber displacement as the absorber attempts to elongate. This provides the initial conditions for absorber displacement during expansion.
FOR2	The value of the force in the energy absorber during expansion. The value is held during compression.
K1	The stiffness of the 10 HZ man model (#/inch)
K3	The stiffness of the 8 HZ injury model (#/inch)
K6	Stiffness of structural element that is impacted when seat impacts after exceeding stroke limit. (#/inch)
K7	Relaxation stiffness of energy absorber. This can be an assumed equal to the initial stiffness of energy absorber force-displacement curve. (#/inch)
M1	The mass of the 10 HZ man model (#/inch/sec^2)
M2	The mass of the seat (#/inch/sec^2)
M3	The mass of the 8 HZ injury model (#/inch/sec^2)
X6	Relative displacement across the energy absorber.
2DX1, 1DX1, X1	The acceleration, velocity and displacement of the force model mass, M1.
2DX3, 1DX3, X3	The acceleration, velocity, and displacement of the injury model mass, M3.
2DX4, 1DX4, X4	The acceleration, velocity, and displacement of the crash input.

RA	Input Reduction Ratio.
SC	Data points describing the force deflection curve of the seat cushions.
ISC	Inverse of SC (deflection force data points).
FSC	Force developed by the seat cushion (pounds).
XSC	Compression of seat cushion (inches).
1DX2, X2	The velocity and displacement of the seat cushion - man interface.
2DX51	Acceleration of seat after the seat cushion is fully compressed.
2DX52	Acceleration of seat before the seat cushion is fully compressed.
2DX5, 1DX5, X5	The acceleration, velocity, and displacement of the seat.

APPENDIX III
COMPUTED DATA

Statistical Tables (Table I)



P_A is the probability of the acceleration occurrence.
P_{DRI} is the probability of injury associated with the calculated DRI.
P is the joint probability of all variables.
P_W is the probability of the weight occurrence.

Response Data (Table II)

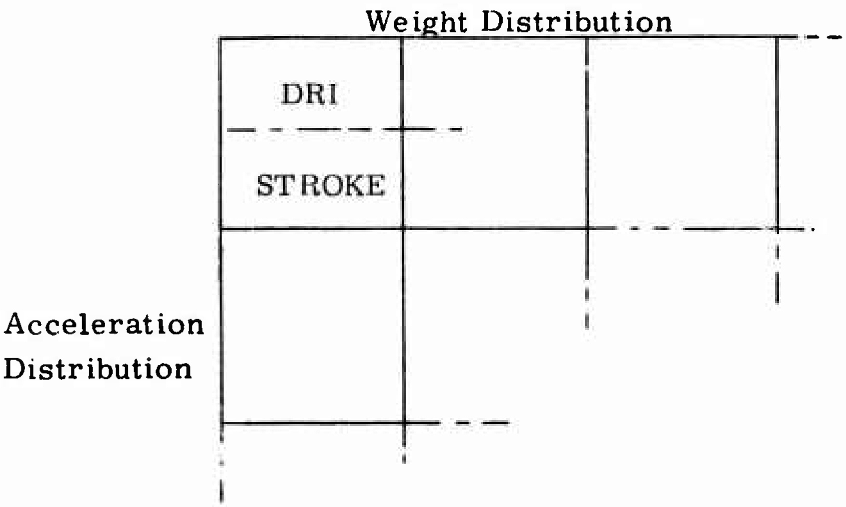


TABLE I. STATISTICAL DATA

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 128.0	137.5	143.5	148.5	152.5	156.0	1
1.80	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	1
3.97	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	2
	7.167×10^{-7}	6.184×10^{-7}	6.184×10^{-7}	4.827×10^{-7}	4.327×10^{-7}	4.399×10^{-7}	
	6.092×10^{-9}	5.256×10^{-9}	5.256×10^{-9}	4.093×10^{-9}	3.678×10^{-9}	3.739×10^{-9}	
6.00	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	3
	1.094×10^{-4}	3.241×10^{-5}	1.094×10^{-4}	9.375×10^{-5}	9.375×10^{-5}	1.498×10^{-4}	
	4.923×10^{-7}	1.458×10^{-7}	4.923×10^{-7}	4.219×10^{-7}	4.219×10^{-7}	6.741×10^{-7}	
7.93	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	4
	9.430×10^{-7}	9.874×10^{-4}	2.448×10^{-3}	5.151×10^{-3}	5.151×10^{-3}	5.210×10^{-3}	
	3.301×10^{-6}	3.456×10^{-6}	7.868×10^{-6}	1.803×10^{-5}	1.803×10^{-5}	1.824×10^{-5}	
10.00	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	5
	1.379×10^{-1}	1.136×10^{-1}	6.453×10^{-2}	1.876×10^{-2}	3.117×10^{-2}	6.218×10^{-4}	
	2.758×10^{-4}	2.272×10^{-4}	1.291×10^{-4}	3.752×10^{-5}	6.234×10^{-5}	1.244×10^{-6}	
12.00	2.0×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	6
	5.406×10^{-1}	5.469×10^{-1}	5.454×10^{-1}	5.406×10^{-1}	5.326×10^{-1}	5.231×10^{-1}	
	1.081×10^{-3}	1.094×10^{-3}	1.091×10^{-3}	1.081×10^{-3}	1.065×10^{-3}	1.046×10^{-3}	
13.75	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	7
	8.621×10^{-1}	8.329×10^{-1}	8.073×10^{-1}	7.811×10^{-1}	7.539×10^{-1}	7.340×10^{-1}	
	1.151×10^{-3}	1.112×10^{-3}	1.078×10^{-3}	1.043×10^{-3}	1.006×10^{-3}	9.799×10^{-4}	
16.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	8
	9.583×10^{-1}	9.299×10^{-1}	9.044×10^{-1}	8.790×10^{-1}	8.545×10^{-1}	8.309×10^{-1}	
	6.373×10^{-4}	6.184×10^{-4}	6.014×10^{-4}	5.845×10^{-4}	5.682×10^{-4}	5.525×10^{-4}	
18.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	9
	9.764×10^{-1}	9.519×10^{-1}	9.273×10^{-1}	9.017×10^{-1}	8.765×10^{-1}	8.517×10^{-1}	
	6.492×10^{-4}	6.330×10^{-4}	6.166×10^{-4}	5.996×10^{-4}	5.829×10^{-4}	5.664×10^{-4}	
19.87	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	10
	9.810×10^{-1}	9.564×10^{-1}	9.325×10^{-1}	9.049×10^{-1}	8.808×10^{-1}	8.561×10^{-1}	
	5.248×10^{-4}	5.117×10^{-4}	4.989×10^{-4}	4.841×10^{-4}	4.712×10^{-4}	4.580×10^{-4}	

Table I. Continued

INPUT DECELERATION (AVG. G)		MAN WEIGHT (LB) 128.0	137.5	143.5	148.5	152.5	156.0	2
22.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	11
		9.819x10^{-1}	9.583x10^{-1}	9x342x10^{-1}	9.075x10^{-1}	8.853x10^{-1}	8.582x10^{-1}	
		3.928x10^{-4}	3.833x10^{-4}	3.737x10^{-4}	3.630x10^{-4}	3.541x10^{-4}	3.433x10^{-4}	
24.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	12
		9.827x10^{-1}	9.588x10^{-1}	9.350x10^{-1}	9.088x10^{-1}	8.843x10^{-1}	8.594x10^{-1}	
		3.931x10^{-4}	3.835x10^{-4}	3.740x10^{-4}	3.635x10^{-4}	3.537x10^{-4}	3.438x10^{-4}	
26.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	13
		9.830x10^{-1}	9.593x10^{-1}	9.358x10^{-1}	9.102x10^{-1}	8.849x10^{-1}	8.601x10^{-1}	
		3.932x10^{-4}	3.837x10^{-4}	3.743x10^{-4}	3.641x10^{-4}	3.540x10^{-4}	3.440x10^{-4}	
28.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	14
		9.831x10^{-1}	9.597x10^{-1}	9.361x10^{-1}	9.102x10^{-1}	8.849x10^{-1}	8.608x10^{-1}	
		3.932x10^{-4}	3.839x10^{-4}	3.744x10^{-4}	3.641x10^{-4}	3.540x10^{-4}	3.443x10^{-4}	
30.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	15
		9.832x10^{-1}	9.597x10^{-1}	9.361x10^{-1}	9.107x10^{-1}	8.857x10^{-1}	8.614x10^{-1}	
		3.933x10^{-4}	3.839x10^{-4}	3.744x10^{-4}	3.643x10^{-4}	3.543x10^{-4}	3.446x10^{-4}	
32.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	16
		9.834x10^{-1}	9.599x10^{-1}	9.365x10^{-1}	9.115x10^{-1}	8.864x10^{-1}	8.614x10^{-1}	
		3.934x10^{-4}	3.840x10^{-4}	3.746x10^{-4}	3.646x10^{-4}	3.546x10^{-4}	3.446x10^{-4}	
34.00		4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	4.00x10^{-4}	17
		9.834x10^{-1}	9.599x10^{-1}	9.365x10^{-1}	9.115x10^{-1}	8.864x10^{-1}	8.621x10^{-1}	
		3.934x10^{-4}	3.840x10^{-4}	3.746x10^{-4}	3.646x10^{-4}	3.546x10^{-4}	3.448x10^{-4}	
	Σ	7.075x10^{-3}	6.886x10^{-3}	6.643x10^{-3}	6.396x10^{-3}	6.253x10^{-3}	6.032x10^{-3}	

Table I. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 159.0	162.0	165.5	169.0	172.0	175.0	3
1.80	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	1
3.97	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	2
	4.899×10^{-7}	4.899×10^{-7}	3.926×10^{-7}	4.006×10^{-7}	4.470×10^{-7}	$4.541.\,10^{-7}$	
	4.164×10^{-9}	4.164×10^{-9}	3.337×10^{-9}	3.405×10^{-9}	3.800×10^{-9}	3.860×10^{-9}	
6.00	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	3
	1.498×10^{-4}	1.498×10^{-4}	1.473×10^{-4}	7.079×10^{-5}	7.079×10^{-5}	7.079×10^{-5}	
	6.741×10^{-7}	6.741×10^{-7}	6.629×10^{-7}	3.186×10^{-7}	3.186×10^{-7}	3.186×10^{-7}	
7.93	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	4
	6.626×10^{-3}	6.626×10^{-3}	6.626×10^{-3}	6.569×10^{-3}	6.569×10^{-3}	6.569×10^{-3}	
	2.319×10^{-5}	2.319×10^{-5}	2.319×10^{-5}	2.299×10^{-5}	2.299×10^{-5}	2.299×10^{-5}	
10.00	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	5
	3.062×10^{-2}	1.090×10^{-1}	1.083×10^{-1}	1.075×10^{-1}	1.083×10^{-1}	1.115×10^{-1}	
	6.124×10^{-5}	2.180×10^{-4}	2.166×10^{-4}	2.150×10^{-4}	2.166×10^{-4}	2.230×10^{-4}	
12.00	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	6
	5.144×10^{-1}	5.016×10^{-1}	4.888×10^{-1}	4.733×10^{-1}	4.578×10^{-1}	4.420×10^{-1}	
	1.029×10^{-3}	1.003×10^{-3}	9.776×10^{-4}	9.466×10^{-4}	9.156×10^{-4}	8.840×10^{-4}	
13.75	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	7
	7.139×10^{-1}	7.088×10^{-1}	$6.797.\,10^{-1}$	6.554×10^{-1}	6.304×10^{-1}	6.064×10^{-1}	
	9.531×10^{-4}	9.462×10^{-4}	9.074×10^{-4}	8.750×10^{-4}	8.416×10^{-4}	8.095×10^{-4}	
16.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	8
	8.095×10^{-1}	7.846×10^{-1}	7.539×10^{-1}	7.217×10^{-1}	7.088×10^{-1}	6.765×10^{-1}	
	5.382×10^{-4}	5.218×10^{-4}	5.012×10^{-4}	4.799×10^{-4}	4.712×10^{-4}	4.499×10^{-4}	
18.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	9
	8.289×10^{-1}	8.039×10^{-1}	7.721×10^{-1}	7.389×10^{-1}	7.098×10^{-1}	6.907×10^{-1}	
	5.512×10^{-4}	5.346×10^{-4}	5.134×10^{-4}	4.914×10^{-4}	4.717×10^{-4}	4.593×10^{-4}	
19.87	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	10
	8.329×10^{-1}	8.084×10^{-1}	7.770×10^{-1}	7.441×10^{-1}	7.129×10^{-1}	6.950×10^{-1}	
	4.456×10^{-4}	4.324×10^{-4}	4.156×10^{-4}	3.981×10^{-4}	3.814×10^{-4}	3.717×10^{-4}	

Table I. Continued

INPUT DECELERATION (AVG. G)		MAN WEIGHT (LB) 159.0	162.0	165.5	169.0	172.0	175.0	4
22.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	11
		8.359×10^{-1}	8.114×10^{-1}	7.804×10^{-1}	7.464×10^{-1}	7.159×10^{-1}	6.991×10^{-1}	
		3.344×10^{-4}	3.246×10^{-4}	3.122×10^{-4}	2.986×10^{-4}	2.864×10^{-4}	2.796×10^{-4}	
24.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	12
		8.379×10^{-1}	8.130×10^{-1}	7.822×10^{-1}	7.483×10^{-1}	7.170×10^{-1}	7.005×10^{-1}	
		3.352×10^{-4}	3.252×10^{-4}	3.129×10^{-4}	2.993×10^{-4}	2.868×10^{-4}	2.802×10^{-4}	
26.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	13
		8.389×10^{-1}	8.138×10^{-1}	7.831×10^{-1}	7.492×10^{-1}	7.180×10^{-1}	7.019×10^{-1}	
		3.356×10^{-4}	3.255×10^{-4}	3.132×10^{-4}	2.997×10^{-4}	2.872×10^{-4}	2.808×10^{-4}	
28.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	14
		8.396×10^{-1}	8.138×10^{-1}	7.831×10^{-1}	7.502×10^{-1}	7.190×10^{-1}	7.033×10^{-1}	
		3.358×10^{-4}	3.255×10^{-4}	3.132×10^{-4}	3.001×10^{-4}	2.876×10^{-4}	2.813×10^{-4}	
30.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	15
		8.403×10^{-1}	8.146×10^{-1}	7.841×10^{-1}	7.502×10^{-1}	7.190×10^{-1}	7.033×10^{-1}	
		3.361×10^{-4}	3.258×10^{-4}	3.136×10^{-4}	3.001×10^{-4}	2.876×10^{-4}	2.813×10^{-4}	
32.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	16
		8.403×10^{-1}	8.154×10^{-1}	7.841×10^{-1}	7.511×10^{-1}	7.203×10^{-1}	7.033×10^{-1}	
		3.361×10^{-4}	3.262×10^{-4}	3.136×10^{-4}	3.004×10^{-4}	2.881×10^{-4}	2.813×10^{-4}	
34.00		4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	4.00×10^{-4}	17
		8.403×10^{-1}	8.154×10^{-1}	7.841×10^{-1}	7.511×10^{-1}	7.203×10^{-1}	7.047×10^{-1}	
		3.361×10^{-4}	3.262×10^{-4}	3.136×10^{-4}	3.004×10^{-4}	2.881×10^{-4}	2.819×10^{-4}	
	Σ	5.952×10^{-3}	5.959×10^{-3}	5.748×10^{-3}	5.528×10^{-3}	5.333×10^{-3}	5.187×10^{-3}	

Table I. Continued

	MAN WEIGHT (LB)						
	178.5	181.5	184.5	188.0	193.0	198.5	5
1.80	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	2.35×10^{-2}	1
3.97	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	8.50×10^{-3}	2
	6.060×10^{-7}	5.947×10^{-7}	5.721×10^{-7}	6.173×10^{-7}	5.947×10^{-7}	5.947×10^{-7}	
	5.131×10^{-9}	5.045×10^{-9}	4.863×10^{-9}	5.247×10^{-9}	5.045×10^{-9}	5.045×10^{-9}	
6.00	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	4.50×10^{-3}	3
	7.079×10^{-5}	7.079×10^{-5}	7.152×10^{-5}	9.084×10^{-5}	9.084×10^{-5}	8.936×10^{-5}	
	3.186×10^{-7}	3.186×10^{-7}	3.208×10^{-7}	4.088×10^{-7}	4.088×10^{-7}	4.021×10^{-7}	
7.93	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	3.50×10^{-3}	4
	6.499×10^{-3}	7.143×10^{-3}	7.143×10^{-3}	3.151×10^{-3}	3.191×10^{-3}	2.147×10^{-3}	
	2.265×10^{-5}	2.500×10^{-5}	2.500×10^{-5}	1.093×10^{-5}	1.107×10^{-5}	7.515×10^{-6}	
10.00	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	5
	1.151×10^{-1}	1.185×10^{-1}	1.218×10^{-1}	1.235×10^{-1}	1.235×10^{-1}	1.218×10^{-1}	
	2.302×10^{-4}	2.370×10^{-4}	2.436×10^{-4}	2.470×10^{-4}	2.470×10^{-4}	2.436×10^{-4}	
12.00	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	2.00×10^{-3}	6
	4.255×10^{-1}	4.067×10^{-1}	3.905×10^{-1}	3.684×10^{-1}	3.402×10^{-1}	3.107×10^{-1}	
	8.510×10^{-4}	8.134×10^{-4}	7.810×10^{-4}	7.368×10^{-4}	6.804×10^{-4}	6.214×10^{-4}	
13.75	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	1.335×10^{-3}	7
	5.631×10^{-1}	5.390×10^{-1}	5.128×10^{-1}	4.816×10^{-1}	4.380×10^{-1}	3.928×10^{-1}	
	7.517×10^{-4}	7.196×10^{-4}	6.846×10^{-4}	6.429×10^{-4}	5.847×10^{-4}	5.244×10^{-4}	
16.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	8
	6.435×10^{-1}	6.141×10^{-1}	5.816×10^{-1}	5.327×10^{-1}	4.828×10^{-1}	4.298×10^{-1}	
	4.279×10^{-4}	4.084×10^{-4}	3.868×10^{-4}	3.542×10^{-4}	3.211×10^{-4}	2.854×10^{-4}	
18.00	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	6.65×10^{-4}	9
	6.539×10^{-1}	6.247×10^{-1}	5.917×10^{-1}	5.406×10^{-1}	4.888×10^{-1}	4.345×10^{-1}	
	4.347×10^{-4}	4.154×10^{-4}	3.935×10^{-4}	3.595×10^{-4}	3.251×10^{-4}	2.889×10^{-4}	
19.87	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	5.35×10^{-4}	10
	6.583×10^{-1}	6.278×10^{-1}	5.951×10^{-1}	5.454×10^{-1}	4.920×10^{-1}	4.369×10^{-1}	
	3.520×10^{-4}	3.359×10^{-4}	3.184×10^{-4}	2.918×10^{-4}	2.632×10^{-4}	2.337×10^{-4}	

Table I. Continued

	MAN WEIGHT (LB)						
	178.5	181.5	184.5	188.0	193.0	198.5	6
22.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	11
	$6.627x10^{-1}$	$6.316x10^{-1}$	$5.975x10^{-1}$	$5.485x10^{-1}$	$4.952x10^{-1}$	$4.392x10^{-1}$	
	$2.651x10^{-4}$	$2.526x10^{-4}$	$2.390x10^{-4}$	$2.194x10^{-4}$	$1.981x10^{-4}$	$1.757x10^{-4}$	
24.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	12
	$6.642x10^{-1}$	$6.327x10^{-1}$	$5.987x10^{-1}$	$5.501x10^{-1}$	$4.968x10^{-1}$	$4.404x10^{-1}$	
	$2.657x10^{-4}$	$2.531x10^{-4}$	$2.395x10^{-4}$	$2.200x10^{-4}$	$1.987x10^{-4}$	$1.762x10^{-4}$	
26.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	13
	$6.656x10^{-1}$	$6.338x10^{-1}$	$6.002x10^{-1}$	$5.513x10^{-1}$	$4.984x10^{-1}$	$4.404x10^{-1}$	
	$2.662x10^{-4}$	$2.535x10^{-4}$	$2.401x10^{-4}$	$2.205x10^{-4}$	$1.994x10^{-4}$	$1.762x10^{-4}$	
28.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	14
	$6.671x10^{-1}$	$6.338x10^{-1}$	$6.017x10^{-1}$	$5.533x10^{-1}$	$4.98x10^{-1}$	$4.420x10^{-1}$	
	$2.668x10^{-4}$	$2.535x10^{-4}$	$2.407x10^{-4}$	$2.213x10^{-4}$	$1.994x10^{-4}$	$1.768x10^{-4}$	
30.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	15
	$6.671x10^{-1}$	$6.350x10^{-1}$	$6.017x10^{-1}$	$5.533x10^{-1}$	$5.000x10^{-1}$	$4.420x10^{-1}$	
	$2.668x10^{-4}$	$2.540x10^{-4}$	$2.407x10^{-4}$	$2.213x10^{-4}$	$2.000x10^{-4}$	$1.768x10^{-4}$	
32.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	16
	$6.685x10^{-1}$	$6.350x10^{-1}$	$6.017x10^{-1}$	$5.533x10^{-1}$	$5.000x10^{-1}$	$4.420x10^{-1}$	
	$2.674x10^{-4}$	$2.540x10^{-4}$	$2.407x10^{-4}$	$2.213x10^{-4}$	$2.000x10^{-4}$	$1.768x10^{-4}$	
34.00	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	$4.00x10^{-4}$	17
	$6.685x10^{-1}$	$6.361x10^{-1}$	$6.032x10^{-1}$	$5.549x10^{-1}$	$5.000x10^{-1}$	$4.436x10^{-1}$	
	$2.674x10^{-4}$	$2.544x10^{-4}$	$2.413x10^{-4}$	$2.220x10^{-4}$	$2.000x10^{-4}$	$1.774x10^{-4}$	
Σ	$4.936x10^{-3}$	$4.730x10^{-3}$	$4.515x10^{-3}$	$4.189x10^{-3}$	$3.829x10^{-3}$	$3.441x10^{-3}$	

Table I. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 206.5	220.0					7
1.80	2.35×10^{-2}	2.35×10^{-2}					1
3.97	8.50×10^{-3}	8.50×10^{-3}					2
	3.926×10^{-7}	5.381×10^{-7}					
	3.337×10^{-9}	4.574×10^{-9}					
6.00	4.50×10^{-3}	4.50×10^{-3}					3
	8.936×10^{-5}	9.375×10^{-5}					
	4.021×10^{-7}	4.219×10^{-7}					
7.93	3.50×10^{-3}	3.50×10^{-3}					4
	1.774×10^{-3}	1.917×10^{-3}					
	6.209×10^{-6}	6.710×10^{-6}					
10.00	2.00×10^{-3}	2.00×10^{-3}					5
	1.169×10^{-1}	9.541×10^{-2}					
	2.338×10^{-4}	1.908×10^{-4}					
12.00	2.00×10^{-3}	2.00×10^{-3}					6
	2.637×10^{-1}	1.950×10^{-1}					
	5.274×10^{-4}	3.900×10^{-4}					
13.75	1.335×10^{-3}	1.335×10^{-3}					7
	3.289×10^{-1}	2.372×10^{-1}					
	4.390×10^{-4}	3.167×10^{-4}					
16.00	6.65×10^{-4}	6.65×10^{-4}					8
	3.564×10^{-1}	2.499×10^{-1}					
	2.369×10^{-4}	1.662×10^{-4}					
18.00	6.65×10^{-4}	6.65×10^{-4}					9
	3.617×10^{-1}	2.527×10^{-1}					
	2.404×10^{-4}	1.680×10^{-4}					
19.87	5.35×10^{-4}	5.35×10^{-4}					10
	3.628×10^{-1}	2.536×10^{-1}					
	1.941×10^{-4}	1.357×10^{-4}					

Table I. Concluded

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 206.5	220.0				
22.00	4.00×10^{-4}	4.00×10^{-4}				
	3.651×10^{-1}	2.559×10^{-1}				
	1.460×10^{-4}	1.024×10^{-4}				
24.00	4.00×10^{-4}	4.00×10^{-4}				
	3.664×10^{-1}	2.559×10^{-1}				
	1.466×10^{-4}	1.024×10^{-4}				
26.00	4.00×10^{-4}	4.00×10^{-4}				
	3.675×10^{-1}	2.572×10^{-1}				
	1.470×10^{-4}	1.029×10^{-4}				
28.00	4.00×10^{-4}	4.00×10^{-4}				
	3.675×10^{-1}	2.572×10^{-1}				
	1.470×10^{-4}	1.029×10^{-4}				
30.00	4.00×10^{-4}	4.00×10^{-4}				
	3.675×10^{-1}	2.572×10^{-1}				
	1.470×10^{-4}	1.029×10^{-4}				
32.00	4.00×10^{-4}	4.00×10^{-4}				
	3.684×10^{-1}	2.585×10^{-1}				
	1.474×10^{-4}	1.034×10^{-4}				
34.00	4.00×10^{-4}	4.00×10^{-4}				
	3.684×10^{-1}	2.585×10^{-1}				
	1.474×10^{-4}	1.034×10^{-4}				
Σ	2.907×10^{-3}	2.095×10^{-3}				

TABLE II. RESPONSE DATA

INPUT DECELERATION (AVG	MAN WEIGHT (LB) 128.0	137.5	143.4	148.5	152.5	156.0	1
1.80	5.46	5.52	5.48	5.48	5.27	5.25	
	1.154×10^{-2}	1.165×10^{-2}	1.172×10^{-2}	1.179×10^{-2}	1.185×10^{-2}	1.191×10^{-2}	
3.97	9.29	9.21	9.21	9.07	9.00	9.01	
	4.584×10^{-2}	4.695×10^{-2}	4.768×10^{-2}	4.829×10^{-2}	4.879×10^{-2}	4.921×10^{-2}	
6.00	12.37	11.55	12.37	12.26	12.26	12.61	
	6.641×10^{-2}	6.806×10^{-2}	6.910×10^{-2}	6.997×10^{-2}	7.066×10^{-2}	7.127×10^{-2}	
7.93	13.98	14.05	14.79	15.46	15.46	15.47	
	8.582×10^{-2}	8.793×10^{-2}	8.926×10^{-2}	9.036×10^{-2}	9.125×10^{-2}	9.202×10^{-2}	
10.00	19.50	19.18	18.34	16.80	17.39	15.65	
	1.069×10^{-1}	1.095×10^{-1}	1.112×10^{-1}	1.127×10^{-1}	1.140×10^{-1}	1.155×10^{-1}	
12.00	22.78	22.82	22.81	22.78	22.73	22.66	
	1.596×10^{-1}	1.939×10^{-1}	2.243×10^{-1}	2.552×10^{-1}	2.832×10^{-1}	3.100×10^{-1}	
13.75	25.50	25.14	24.87	24.62	24.39	24.22	
	4.464×10^{-1}	5.596×10^{-1}	6.389×10^{-1}	7.083×10^{-1}	7.666×10^{-1}	8.189×10^{-1}	
16.00	27.24	26.54	26.09	25.70	25.39	25.12	
	1.170	1.369	1.500	1.612	1.703	1.784	
18.00	27.95	27.06	26.49	26.04	25.67	25.36	
	2.059	2.334	2.512	2.662	2.783	2.891	
19.87	28.19	27.19	26.59	26.10	25.73	25.41	
	3.362	3.414	3.637	3.825	3.976	4.108	
22.00	28.25	27.24	26.63	26.14	25.77	25.44	
	4.506	4.948	5.227	5.462	5.650	5.814	
24.00	28.28	27.26	26.65	26.16	25.79	25.46	
	6.110	6.639	6.974	7.252	7.475	7.669	
26.00	28.30	27.28	26.67	26.18	25.80	25.47	
	7.931	8.548	8.938	9.262	9.520	9.746	
28.00	28.31	27.29	26.68	26.18	25.80	25.48	
	9.999	1.070×10^{1}	1.115×10^{1}	1.152×10^{1}	1.182×10^{1}	1.208×10^{1}	
30.00	28.32	27.29	26.68	26.19	25.81	25.49	
	1.225×10^{1}	1.306×10^{1}	1.357×10^{1}	1.399×10^{1}	1.433×10^{1}	1.463×10^{1}	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB)						
	128.0	137.5	143.4	148.5	152.5	156.0	2
32.00	28.33	27.30	26.69	26.20	25.82	25.49	
	1.472×10^1	1.563×10^1	1.621×10^1	1.669×10^1	1.708×10^1	1.742×10^1	
34.00	28.33	27.30	26.69	26.20	25.82	25.50	
	1.746×10^1	1.849×10^1	1.915×10^1	1.970×10^1	2.013×10^1	2.052×10^1	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB)						
	159.0	162.0	165.5	169.0	72.0	175.0	3
1.80	5.26	5.28	4.84	4.83	4.81	4.81	
	1.195×10^{-2}	1.200×10^{-2}	1.205×10^{-2}	1.211×10^{-2}	1.215×10^{-2}	1.220×10^{-2}	
3.97	9.08	9.08	8.95	8.96	9.02	9.03	
	4.958×10^{-2}	4.995×10^{-2}	5.038×10^{-2}	5.081×10^{-2}	5.117×10^{-2}	5.154×10^{-2}	
6.00	12.61	12.61	12.60	12.08	12.08	12.08	
	7.178×10^{-2}	7.230×10^{-2}	7.291×10^{-2}	7.352×10^{-2}	7.403×10^{-2}	7.455×10^{-2}	
7.93	15.71	15.71	15.71	15.70	15.70	15.70	
	9.268×10^{-2}	9.334×10^{-2}	9.412×10^{-2}	9.489×10^{-2}	9.555×10^{-2}	9.621×10^{-2}	
10.00	17.37	19.12	19.11	19.10	19.11	19.14	
	1.168×10^{-1}	1.182×10^{-1}	1.203×10^{-1}	1.225×10^{-1}	1.250×10^{-1}	1.280×10^{-1}	
12.00	22.59	22.51	22.43	22.31	22.21	22.11	
	3.340×10^{-1}	3.604×10^{-1}	3.925×10^{-1}	4.262×10^{-1}	4.562×10^{-1}	4.876×10^{-1}	
13.75	24.05	23.90	23.69	23.50	23.31	23.15	
	8.643×10^{-1}	9.110×10^{-1}	9.659×10^{-1}	1.022	1.071	1.121	
16.00	24.89	24.66	24.39	24.12	23.90	23.68	
	1.854	1.925	2.007	2.092	2.164	2.237	
18.00	25.10	24.84	24.54	24.25	24.01	23.77	
	2.982	3.076	3.184	3.293	3.387	3.481	
19.87	25.14	24.88	24.58	24.29	24.04	23.80	
	4.222	4.336	4.469	4.603	4.717	4.832	
22.00	25.17	24.91	24.61	24.31	24.07	23.83	
	5.954	6.095	6.259	6.424	6.564	6.705	
24.00	25.19	24.93	24.63	24.33	24.08	23.84	
	7.837	8.004	8.197	1.058×10^{1}	8.559	8.725	
26.00	25.20	24.94	24.6[illegible]	24.34	24.09	23.85	
	9.941	1.013×10^{1}	1.036×10^{1}	1.058×10^{1}	1.078×10^{1}	1.097×10^{1}	
28.00	25.21	24.94	24.64	24.35	24.10	23.86	
	$1.231. \times 10^{1}$	1.253×10^{1}	1.279×10^{1}	1.305×10^{1}	1.328×10^{1}	1.350×10^{1}	
30.00	25.22	24.95	24.65	24.35	24.10	23.86	
	1.489	1.514×10^{1}	1.544×10^{1}	1.574×10^{1}	1.600×10^{1}	1.626×10^{1}	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB)						
	159.0	162.0	165.5	169.0	172.0	175.0	4
32.00	25.22	24.96	24.65	24.36	24.11	23.86	
	1.771×10^{1}	1.800×10^{1}	1.834×10^{1}	1.868×10^{1}	1.898×10^{1}	1.927×10^{1}	
34.00	25.22	24.96	24.65	24.36	24.11	23.87	
	2.085×10^{1}	2.118×10^{1}	2.157×10^{1}	2.196×10^{1}	2.229×10^{1}	2.263×10^{1}	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 178.5	181.5	184.5	188.0	193.0	198.5	5
1.80	5.27	5.44	5.50	5.39	5.35	5.15	
	2.749×10^{-2}	2.768×10^{-2}	2.787×10^{-2}	2.809×10^{-2}	2.841×10^{-2}	2.879×10^{-2}	
3.97	9.19	9.18	9.16	9.20	9.18	9.18	
	5.197×10^{-2}	5.233×10^{-2}	5.270×10^{-2}	5.313×10^{-2}	5.374×10^{-2}	5.441×10^{-2}	
6.00	12.08	12.08	12.09	12.24	12.24	12.23	
	7.516×10^{-2}	7.568×10^{-2}	7.619×10^{-2}	7.680×10^{-2}	7.766×10^{-2}	7.861×10^{-2}	
7.93	15.69	15.80	15.80	15.02	15.03	14.68	
	9.698×10^{-2}	9.764×10^{-2}	9.830×10^{-2}	9.907×10^{-2}	1.002×10^{-1}	1.015×10^{-1}	
10.00	19.20	19.26	19.31	19.33	19.33	19.31	
	1.324×10^{-1}	1.373×10^{-1}	1.436×10^{-1}	1.528×10^{-1}	1.698×10^{-1}	1.933×10^{-1}	
12.00	21.98	21.86	21.74	21.58	21.37	21.14	
	5.249×10^{-1}	5.586×10^{-1}	5.924×10^{-1}	6.336×10^{-1}	6.934×10^{-1}	7.612×10^{-1}	
13.75	22.92	22.77	22.58	22.38	22.08	21.76	
	1.180	1.231	1.282	1.343	1.431	1.530	
16.00	23.42	23.20	22.98	22.73	22.39	22.01	
	2.322	2.396	2.470	2.557	2.681	2.818	
18.00	23.49	23.27	23.04	22.78	22.43	22.05	
	3.591	3.685	3.780	3.890	4.049	4.222	
19.87	23.52	23.29	23.07	22.81	22.45	22.07	
	4.966	5.080	5.195	5.329	5.520	5.730	
22.00	23.55	23.32	23.09	22.83	22.47	22.09	
	6.869	7.009	7.150	7.314	7.548	7.805	
24.00	23.56	23.33	23.10	22.83	22.48	22.10	
	8.920	9.086	9.252	9.447	9.724	1.003×10^{1}	
26.00	23.57	23.34	23.11	22.85	22.49	22.10	
	1.120×10^{1}	1.139×10^{1}	1.159×10^{1}	1.181×10^{1}	1.214×10^{1}	1.250×10^{1}	
28.00	23.58	23.34	23.12	22.86	22.49	22.11	
	1.377×10^{1}	1.399×10^{1}	1.422×10^{1}	1.448×10^{1}	1.485×10^{1}	1.527×10^{1}	
30.00	23.58	23.35	23.12	22.86	22.50	22.11	
	1.656×10^{1}	1.682×10^{1}	1.708×10^{1}	1.738×10^{1}	1.782×10^{1}	1.830×10^{1}	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB)						
	178.5	181.5	184.5	188.0	193.0	198.5	6.
32.00	23.59	23.35	23.12	22.86	22.50	22.11	
	1.962×10^1	1.991×10^1	2.021×10^1	2.056×10^1	2.105×10^1	2.160×10^1	
34.00	23.59	23.36	23.13	22.87	22.50	22.12	
	2.302×10^1	2.335×10^1	2.369	2.409×10^1	2.465×10^1	2.527×10^1	

Table II. Continued

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB) 206.5	220.0					7
1.80	5.25 2.933×10^{-2}	4.92 3.026×10^{-2}					
3.97	8.95 5.538×10^{-2}	9.13 5.709×10^{-2}					
6.00	12.23 8.009×10^{-2}	12.26 8.259×10^{-2}					
7.93	14.51 1.034×10^{-1}	14.57 1.065×10^{-1}					
10.00	19.23 2.358×10^{-1}	18.96 3.253×10^{-1}					
12.00	20.77 8.634×10^{-1}	20.15 1.042					
13.75	21.29 1.675	20.54 1.924					
16.00	21.48 3.019	20.65 3.360					
18.00	21.52 4.476	20.68 4.904					
19.87	21.53 6.037	20.69 6.553					
22.00	21.55 8.180	20.71 8.813					
24.00	21.56 1.047×10^{1}	20.71 1.122×10^{0}					
26.00	21.57 1.302×10^{1}	20.72 1.391×10^{1}					
28.00	21.57 1.588×10^{1}	20.72 1.692×10^{1}					
30.00	21.57 1.900×10^{1}	20.72 2.020×10^{1}					

Table II. Concluded

INPUT DECELERATION (AVG. G)	MAN WEIGHT (LB)						
	206.5	220.0					8
32.00	21.58	20.73					
	2.240×10^{1}	2.337×10^{1}					
34.00	21.58	20.73					
	2.618×10^{1}	2.773×10^{1}					