UMTRI-88-23-2

MVMA TWO-DIMENSIONAL CRASH VICTIM SIMULATION, VERSION 6

VOLUME 2

The User's Manual

B. M. Bowman, Research Scientist
R. O. Bennett, Senior Research Associate

Transportation Research Institute
The University of Michigan
2901 Baxter Road
Ann Arbor, Michigan 48109-2150

June 30, 1988

Technical Report Documentation Page

1. Report No. UMTRI-88-23	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle MVMA Two-Dimensional Crash Victim Simulation, Version 6. Volume 2.		5. Report Date June 30, 1988
		6. Performing Organization Code
7. Author(s) B. M. Bowman and R. O. Bennett		8. Performing Organization Report No. UMTRI-88-23
9. Performing Organization Name and Address Transportation Research Institute The University of Michigan Huron Parkway and Baxter Roads Ann Arbor, Michigan 48109-2150		10. Work Unit No. (TRAIS) 302743
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Motor Vehicle Manufacturers Association 320 New Center Building Detroit, Michigan		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes This report is an update of the report released June 28, 1985, titled "MVMA Two-Dimensional Crash Victim Simulation, Version 5." This report is for Version 6.

16. Abstract Volume Two is intended primarily as a guide to the day-to-day usage of the MVMA Two-Dimensional Crash Victim Simulator.

This volume contains specifications for the input data cards together with a detailed description of input data quantities. Normal output options and certain normal output quantities are described. Input and output are presented for two example exercises of the computer model.

Volume One presents the analytical formulation of the equations describing the crash dynamics. Volume Three provides detailed information relating to program design and implementation.

17. Key Words Automotive Safety Design Crash Dynamics Occupant Dynamics, Restraint Systems Whole-Body Response	18. Distribution Statement UNLIMITED

19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages 402 (p. 215 - p. 488)

TABLE OF CONTENTS

Page

4/3/87

Page

VOLUME 2

VOLUME 3 Page

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

Acknowledgements

UMTRI expresses its gratitude to the Motor Vehicle Manufacturers Association, which has provided financial support for development of the MVMA 2-D Crash Victim Simulation model. The authors would also like to thank the numerous other organizations that have supported various model development and applications projects at UMTRI. These projects have made possible the refinements which have made the MVMA 2-D model a powerful, user oriented tool for automotive safety design and diverse other applications.

We thank Dr. D. Hurley Robbins, co-author of MVMA 2-D CVS releases prior to Version 6, for his many contributions toward the development of the model. Dr. Robbins was responsible for obtaining the funding that made the initial development work possible and was part of the team that has nurtured the model since 1972.

We are also most appreciative of the careful, and tedious, work done by Donna Head, Jeannette Leveille, and Carol Sobecki in typing the manuscript for these manuals.

PART 3 USERS' GUIDE

This part of the report contains a detailed description of the data required to operate the MVMA 2-D model and program output generated using sample data sets. The first section contains a tabular listing of all data required, the format of the cards, and the units of physical quantities. The second section supplements this table with text to provide the user with information concerning particular data quantities which may not be easily chosen (e.g., sign conventions on joint angles, integration control parameters, etc.). The third section describes normal output.

Section 3.4 discusses two example simulations, including preparation of the data sets. It is highly recommended that all MVMA 2-D users read this section completely and carefully.

3.1 DESCRIPTION OF THE INPUT DATA CARDS

Two data decks are required for computer simulations made with the MVMA 2-D model. (See Figure 64.) Each data deck consists of a series of eighty-character lines which will be called "cards" in this discussion. The first data deck is read by the input pre-processor "INP," and the cards are identified by numbers 100 through 1000 in columns 78-80 or 77-80.* Primarily, these cards contain data which describe the crash event, the occupant, the vehicle interior, and the restraint systems. The second data deck is read by the output pre-processor "OUTP."** Each card is identified by a number 1001 through 1600 in columns 77-80. These cards contain data which control printout and various post-processing functions. In general, data cards can be in any order within a data deck. Cards which control model options not used for a particular simulation need not be present. Also, various quantities can be defaulted to constants stored within the program by omitting their cards from the data deck(s).

---

*There are a few cases of tabular input where no identification numbers are included (vehicle accelerations, energy-absorbing steering column parameters, airbag parameters).

**"INP" and "OUTP" are two of the five major parts of the computer model, discussed in Volume 3.

DATA DECKS

Card Number	
100	Cards read by IN
101	100, 200,..., 900 content used for
102	automatic titling of pages
¦	
1000	1000 (blank) marks end of data deck
1001	
1002	Cards read by OUT
1003	
¦	
1600	1600 (blank) marks end of data deck

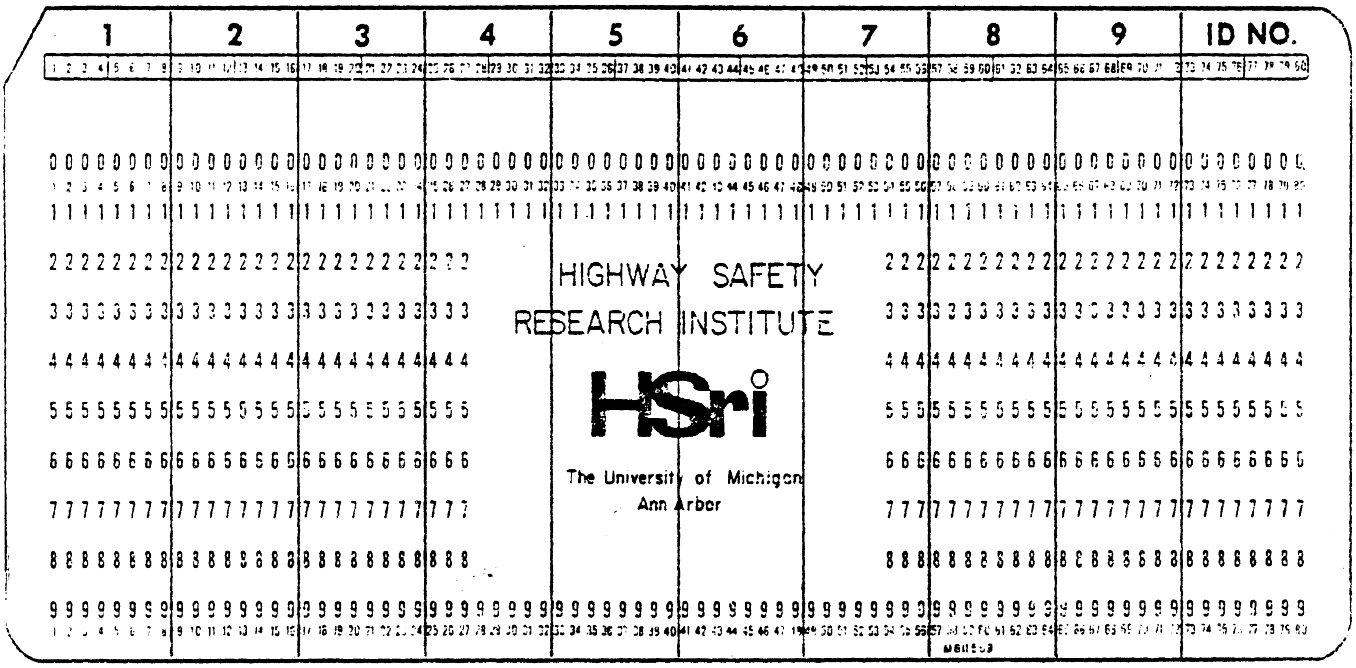
FIGURE 64 Data Decks

6/30/88

Each card consists of ten fields. (See Figure 65.) The tenth field is reserved for the previously mentioned card identification number. The first nine fields, consisting of eight columns each, are data fields. Thus, up to nine numbers may be required per card although most cards make use of a smaller number of fields. Numerical data must be specified in either F, E, or D format, examples of which are given with Figure 65. Blanks in numeric fields are treated as zeros by most computer systems, so E- and D-format numbers must be right-adjusted within data fields. Alphanumeric data are required on some cards; blanks within an alphanumeric field will not be ignored since a blank is a legitimate alphanumeric character.

A summary of the cards required to exercise the MVMA 2-D model is included here as Table 6. This table contains a card identification number in the first column, a general description of data contents in the second, and the number of cards which may contain a particular identification number in the third. A detailed description of all data cards and their content, card by card and field by field, is given in Table 7. This table, which includes over 100 card layouts, is the primary reference for preparation of data sets. In addition to collecting in one place a description of all required input data, the table includes information regarding default values for fields of cards omitted from the data deck(s) and also information regarding required units for data, field by field. The units required for running the model with metric-system or English-system data are indicated separately.

Following Table 7, Section 3.2 contains input data descriptions that are more detailed than those included on the card layouts in Table 7. Section 3.2 also includes many figures and tables which should be useful in the preparation of input data sets. This section will answer many of the questions that are likely to arise during input data set development. However, the



Acceptable data formats

F	E	D
123.4	1.234E2	1.234D2

FIGURE 65 A Data Card

user may sometimes find it necessary to refer to Volume 1 or to the Tutorial System Self-Study Guide [8], which contains the most complete description available of input quantities needed by the MVMA 2-D model.

Supplemental information of wide variety pertaining to input data, modeling considerations, etc., can be found in Section 3.2-A.

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Control Block	
100	Computer run title	1
101	Simulation Controls (Card 1)	1
102	Simulation Controls (Card 2)	1
103	Simulation Controls (Card 3)	1
104	Debugging controls	1
105	Debugging controls	1
106	Contact interaction controls	up to 100
107	Stored output specifications (Card 1)	1
108	Stored output specifications (Card 2)	1
109	Stored output specifications (Card 3)	1
110	Stored output specifications (Card 4)	1
111	Stored output specifications (Card 5)	1
112	Stored output specifications for Advanced Airbag (Card 1)	1
113	Stored output specifications for Advanced Airbag (Card 2)	1
	Occupant Parameter Input Block	
200	Occupant parameter subtitle	1
201	Occupant body segment lengths	1
202	End of link to center-of-mass lengths	1
203	Mass of body segments	1
204	Moments of inertia	1
205	Head-Neck joint parameters (forward)	1
206	Neck-Upper Torso joint parameters (forward)	1
207	Upper spine joint parameters	1
208	Lower spine joint parameters	1
209	Hip joint parameters	1
210	Knee joint parameters	1
211	Upper Arm-Upper Torso joint parameters	1
212	Elbow joint parameters	1
213	Neck element parameters (for elongation)	1
214	Shoulder element parameters (for elongation)	1

11/29/83

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Occupant Parameter Input Block	
215	Head-Neck joint parameters (rearward)	1
216	Neck-Upper Torso joint parameters (rearward)	1
217	"Natural" link displacements	1
218	Occupant accelerometer and belt attachment parameters	1
219	Contact ellipse specifications (Card 1)	1 for each ellipse
220	Contact ellipse specifications (Card 2)	1 for each ellipse
221-226	Contact ellipse material cards (Same as 403-408)	1 set for each ellipse material
227	Head-Neck joint muscle tension coefficients	1
228	Neck-Upper Torso joint muscle tension coefficients	1
229	Upper Spine joint muscle tension coefficients	1
230	Lower Spine joint muscle tension coefficients	1
231	Hip joint muscle tension coefficients	1
232	Knee joint muscle tension coefficients	1
233	Upper Torso-Upper Arm muscle tension coefficients	1
234	Elbow joint muscle tension coefficients	1
235	Shoulder-Upper Torso joint muscle tension coefficients	1
236	Neck element elongation muscle tension coefficients	1
237	Shoulder element elongation muscle tension coefficients	1
238	Muscle tension versus time	1 for each point in each muscle tension table
239	Radial shoulder joint stiffness (elastic)	1 for each point in table
240	Radial shoulder joint stiffness (quadratic)	1 for each point in table
241	Radial shoulder joint stiffness (cubic)	1 for each point in table
242	Neck element parameters (for compression)	1
243	Material names for neck joints	1
244	Material names for torso joints	1
245	Material names for hip and knee joints	1
246	Material names for shoulder and elbow joints	1
247	Material names for neck (axial) and shoulder	1

11/29/83

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Occupant Parameter Input Block	
248	Ellipse material bilinear unloading curves	n + 1, where n is number of bilinear curves for the material
	Occupant Description Input Block	
300	Occupant description subtitle	1
301	Initial body link angles relative to vehicle	1
302	Initial body link angular velocities relative to vehicle	1
303	Initial conditions for upper torso and neck	1
304	Initial shoulder location and velocity relative to upper torso attachment	1
	Vehicle Interior Input Block	
400	Vehicle Interior Characteristics subtitle	1
401-402	Description of real line contact regions	2 cards for each region
403-408	Material property specifications	1 set for each material
409-410	Line parameters within a region	1 set for each line within region
411	Line segment location	1 set for each line segment in a region ordered on time.
412	Friction coefficients	1 card for each friction combination
413	Material bilinear unloading curves	n + 1, where n is number of bilinear curves for the material
	Vehicle Interior Belt Anchors Input Block	
500	Vehicle interior configuration subtitle	1
501	MODROS belt anchor points relative to vehicle origin	1

11/29/83

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Impact Specification Input Block	
600	Vehicle impact subtitle	1
601	Vehicle initial conditions and accelerometer location	1
602	Vehicle horizontal acceleration versus time	1
-	Acceleration versus time	Several cards, 4 time points per card
603	Vehicle vertical acceleration versus time	1
-	Acceleration versus time	Several cards, 4 time points per card
604	Vehicle angular acceleration versus time	1
-	Acceleration versus time	Several cards, 4 time points per card
605	Head applied force specifications	1
606	Head applied force component versus time	1 for each point in head force table
	Belt Restraint System Input Block	
700	Belt restraint system subtitle	1
701-703	MODROS belt system parameters	3
704-709	Belt material cards for MODROS and advanced belt systems	1 set for each material name used for belts
710-719	Advanced belt system parameters	10
720	Advanced belt system and ring parameters	1
721-723	Advanced belt system inertia reel parameters	3
724	Belt material bilinear unloading curves	n + 1, where n is number of bilinear curves for the material
725	Out-of-plane belt system dimensions	1

11/29/83

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Belt Restraint System Input Block	
726	Unstrained belt lengths	1
727	Belt retractor parameters	n + 2, where n is number of time-length pairs
	Energy Absorbing Steering Assembly Input Block	
800	Energy absorbing steering assembly system subtitle	1
801-803	EA steering assembly parameters	3
804	Gearbox position versus time	1
-	Position versus time	Several cards, 4 time points per card
805	Head/steering system properties	1
806	Upper torso/steering system properties	1
807	Middle torso/steering system properties	1
808	Lower torso/steering system properties	1
809	Front line intersection points	1
810	Steering wheel material card	1
811	Reaction material names	1
812-817	Steering assembly system and body material properties	1 set for each material name used on Cards 805-811
	Airbag Restraint System Input Block	
900	Airbag system subtitle	1
901-903	Airbag system parameters	3
904	Airbag mass influx rate versus time	1
-	Rate versus time	Several cards, 4 time points per card
905	Supply gas temperature versus time	1
-	Temperature versus time	Several cards, 4 time points per card

TABLE 6. SUMMARY OF REQUIRED INPUT DATA CARDS

I.D.	Card Contents	Number of Cards
	Airbag Restraint System Input Block	
906	Bag porosity versus pressure differential	1
-	Porosity versus temperature	Several cards, 4 time points per card
907-909	Airbag occupant contact reference points	3
910-929	Advanced airbag system parameters	See AAS manual.
	Direct Input Block	
999	Constant values	Up to 100
	Execution and Output Block	
1000	"Go" Card for model execution	1
1001-1002	Category selection and ordering specification	2
1003	Printout controls	1
1004	Filter and HIC controls	1
1100-1107	Joint relative angle test values	8
1200-1201	Standard list test values	2
1202	Face and chest ellipse designation	1
1300	Type A comparisons	1
1400-1401	Type B comparisons	2
1500-1501	Stick figure control parameters	2
1502	Stick figure time point specifications	1
1600	"Go" Card for output processor	1

11/29/83

TABLE 7 INPUT DATA

COMPUTER RUN TITLE

Field	Name of Quantity	Units	Definition
	HTITLE(1 - 18)		Run Title Centered in columns 1 to 72

NOTE: The content of this card is printed in the first line of each page of output. Cards 200, 300, 400, 500, 600, 700, 800, and 900 may be used for a subtitle line, the second line on each page. See the notes for Card 200.

TABLE 7 INPUT DATA

SIMULATION CONTROLS (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	MKSSWT		Switch = 0. Metric units ≠ 0. English units	0.
2			Ellipse man graphics postprocessor plot record increment. If ≥0, no graphics postprocessor recording. (Integral multiple of Field 8, negative to be effective.)	1.
3	G,g	ft/sec^2 (m/sec^2)	Gravity	32.174 9.80665
4	INTOP		Switch =1. Runge-Kutta fixed-step integration (any Sw≠2.) =2. Adams Moulton predictor-corrector fixed-step	1.
5	TB	msec	Beginning Time	0.
6	TF	msec	Final Time	200.
7	DT, Δt	msec	Numerical Integration Step Size	.5
8	PTINC	msec	Output Print Increment (must be an integral multiple of Field 7)	5.
9	PLINC	msec	Output Plot Increment (must be an integral multiple of Field 8) for printer plot recording. If zero, no plot recording for stick figures.	10.

NOTE: TB must be less than TF. DT and PTINC must be non-zero. A sufficiently small DT (usually .25 or .5) is important.

NOTE: The Adams Moulton predictor-corrector integration requires two evaluations per time step in comparison with four for Runge-Kutta and therefore results in shorter execution times. The methods are both fourth-order integrations and are of comparable accuracy. Runga-Kutta is slightly more stable, however, and in some cases can be used with a larger time step than the predictor-corrector integration.

NOTE: See Section 3.2-A.1 regarding the effect on run cost of the values in fields 4, 6, 7, and 8.

MVMA 2-D Model
Card 101

TABLE 2 INPUT DATA

SIMULATION CONTROLS (CARD 2)

Field	Name of Quantity	Units	Description	Defaults
1	NBELT		Switch = 0. no belts = 1. standard (MODROS) lap belt, no shoulder harness (BELT) = 2. standard (MODROS) lap belt plus shoulder harness (BELT) = 3. advanced belt system (BELT2)	0.
2	NBAG		Switch = 0. airbag interaction not desired = 1. simple airbag model (AIRBAG) = 2. advanced airbag model (ADVBAG)	0.
3	NSTCOL		Switch = 0. steering column interaction not desired ≠ 0. steering column interaction desired	0.
4	LHIB		Switch = 0., Ellipse-ellipse contacts on 106 cards are allowable 1., Ellipse-ellipse contacts on 106 cards are inhibited	0.
5	KHIB		Switch = 0., Ellipse-region contacts on 106 cards are allowable 1., Ellipse-region contacts on 106 cards are inhibited	1.
6	ILL		Switch = 0., Ellipse-ellipse contacts can occur 1., Global control to override LHIB.No ellipse-ellipse contacts are allowed despite LHIB and 106 cards.	1.
7	FNU	in/sec (m/sec)	Length of scaling ramp to insure friction force continuity	10. .254

Note: See Section 3.2 for additional information about LHIB on 106-Cards.

Card 102

TABLE 7 INPUT DATA

SIMULATION CONTROLS (CARD 3)

(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	DSTEPX	in(cm)	Maximum step to search for balance in shared deflection.	.2 .5
2	DSTEPN	in(cm)	Minimum step to search for balance in shared deflection.	.02 .05
3	FORLIM	lbs(N)	Maximum force for rigid-rigid contact.	100,000. 450,000.
4	HARDCN	lb/in(N/cm)	Linear elastic coefficient for rigid-rigid contact.	15000. 26269.
5	LIMCNT		Maximum number of iterations for finding force balance.	20.
6	TPC		Fraction of current ramp length for velocity change in moving contact lines.	.05
7	EPSFAC		Number of integration steps for maximum ramp length for velocity change in moving contact lines.	10.
8	BETELP, β		Minimum ratio of shorter to longer semi axis for ellipse to be treated as circle.	.75
9	GAMELP, γ		Fractional position of circle center along semi-major axis relative to position for circle-ellipse tangency at end of axis.	.9

Notes: See Section 2.6.4 for Fields 8, 9. If Field 9 is zero, all ellipses must be circles, or "circle-like," in the sense of Field 8.

TABLE 7 INPUT DATA

DEBUGGING CONTROLS (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	THEX (1)	msec	Time to set debug switches	0.
2	HEX (1)		Debug switch settings in hexadecimal format	00000000
3	THEX (2)	msec	Same as field 1	5000.
4	HEX (2)		Same as field 2	00000000
5	THEX (3)	msec	Same as field 1	
6	HEX (3)		Same as field 2	
7	THEX (4)	msec	Same as field 1	
8	HEX (4)		Same as field 2	
9	KONSIS		*Switch = -1. Debug controls to operate for all integration evaluations at each time ≥0. Debug controls to operate only at final evaluation at each time	0.

NOTE: Cards 104 and 105 allow specification of the hexadecimal debug switch at eight time points. The first time (0 ms) will be THEX (1), etc.

*NOTE: A value of 1. should normally be used for field 9. Debug printout for intermediate evaluations is seldom useful and can be voluminous.

NOTE: See the note on Card 105 for information about a debug switch which controls printout from INP and OUTP.

NOTE: See unnumbered card following layout for Card 999 for information about special control over debug printout for ellipse-ellipse or ellipse-line interactions.

TABLE 7 INPUT DATA

DEBUGGING CONTROLS (CARD 2)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	THEX (5)	msec	Time to set debug switches	
2	HEX (5)		Debug switch settings in hexadecimal format	
3	THEX (6)	msec	Same as field 1	
4	HEX (6)		Same as field 2	
5	THEX (7)	msec	Same as field 1	
6	HEX (7)		Same as field 2	
7	THEX (8)	msec	Same as field 1	
8	HEX (8)		Same as field 2	
9	KDICTP		Switch = 1. Do not print 0. Print packing debug dictionary and binary file index summary	0.

NOTE: There is an additional debug switch which controls debug printout from INP and OUTP. This switch is specified by inclusion in the INP and/or OUTP data decks of any number of cards with negative numbers in their card ID fields. This switch is automatically intialized in INP for no debug printout and may be set anywhere in the data deck before Card 1000 by a card with -2, -3, or -4 in the ID field. These values correspond to debug levels 1, 2, and 3 as discussed in Section 4.2.4 of Volume 3. Debug level can be re-set to 0, 1, 2, or 3 by additional cards with values -1, -2, -3, or -4 in the ID field. If the debug level is not 0 when the 1000-Card is processed, then its current value will be used in OUTP until it is changed in the OUTP data deck.

MVMA 2-D Model
Card 105

TABLE 7 INPUT DATA

CONTACT INTERACTION CONTROLS
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Ellipse Name
3-4			Ellipse Name or Region Name

NOTE: Each card specifies a combination which will be interpreted according to the settings of KHIB, LHIB, and ILL on Card 102.

NOTE: See Section 2.10.4 for information regarding implicitly defined disallowed interactions.

NOTE: See Section 3.2-A.1 regarding the effect on run cost of 106-Card contact interaction control specifications.

NOTE: See Section 3.2-A.2 regarding modeling the head-windshield interaction. Also see Card 412.

NOTE: See Section 3.2-A.3 regarding interpretation of ellipse-line Category 4 output quantities.

TABLE 7 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	Category 1		Switch = {0., Store vehicle response; 1., Inhibit}	0.
2	Category 2		Switch = {0., Store region parameters; 1., Inhibit}	0.
3	Category 3		Switch = {0., Store region segment movement; 1., Inhibit}	0.
4	Category 4		Switch = {0., Store occupant-vehicle contacts, including belts; 1., Inhibit}	0.
5	Category 5		Switch = {0., Store neck reaction forces; 1., Inhibit}	0.
6	Category 6		Switch = {0., Store unfiltered body accelerations; 1., Inhibit}	0.
7	Category 7		Switch = {0., Store filtered body accelerations; 1., Inhibit}	1.
8	Category 8		Switch = {0., Store severity indices calculated from unfiltered data; 1., Inhibit}	0.
9.	Category 9		Switch = 0., Store severity indices calculated from filtered data; 1., Inhibit	1.

NOTE: Use Cards 1001 and 1002 to specify desired printed output

NOTE: Use field 8 of Card 1003 to request Summary Page output for maximum line segment deflections.

NOTE: See Section 3.2-A.1 regarding the effect on run cost of specifications on Cards 107-113 for selection of output categories.

NOTE: See Section 3.2-A.3 regarding integration monitor warning output.

TABLE 7 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 2)
(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	Category 10		Switch = 0., Store body link angles 1., Inhibit	0.
2	Category 11		Switch = 0., Store body link angular velocities 1., Inhibit	0.
3	Category 12		Switch = 0., Store body link angular accelerations 1., Inhibit	0.
4	Category 13		Switch = 0., Store body joint coordinates 1., Inhibit	0.
5	Category 14		Switch = 0., Store body joint velocities 1., Inhibit	0.
6	Category 15		Switch = 0., Store body joint torques 1., Inhibit	0.
7	Category 16		Switch = 0., Store body joint absorbed energies 1., Inhibit	0.
8	Category 17		Switch = 0., Store body kinetic energies 1., Inhibit	0.
9	Category 18		Switch = 0., Store airbag variables 1., Inhibit	0.

NOTE: Use Cards 1001 and 1002 to specify desired printed output

MVMA 2-D Model
Card 108

TABLE 7 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 3)
(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	Category 19		Switch = 0., Store airbag contact forces 1., Inhibit	0.
2	Category 20		Switch = 0., Store airbag center of mass forces and moments 1., Inhibit	0.
3	Category 21		Switch = 0., Store neck joint coordinates 1., Inhibit	0.
4	Category 22		Switch = 0., Store shoulder joint coordinates 1., Inhibit	0.
5	Category 23		Switch = 0., Store joint torque linear components 1., Inhibit	0.
6	Category 24		Switch = 0., Store joint torque nonlinear components 1., Inhibit	0.
7	Category 25		Switch = 0., Store joint torque friction components 1., Inhibit	0.
8	Category 26		Switch = 0., Store joint torque viscosity components 1., Inhibit	0.
9	Category 27		Switch = 0., Store joint absorbed energy,joint stop components 1., Inhibit	0.

NOTE: Use Cards 1001 and 1002 to specify desired printed output

MVMA 2-D Model
Card 109

TABLE 7 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 4)
(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	Category 28		Switch = 0., Store joint absorbed energy, friction components 1., Inhibit	0.
2	Category 29		Switch = 0., Store joint absorbed energy, viscosity components 1., Inhibit	0.
3	Category 30		Switch = 0., Store center of mass x-component forces 1., Inhibit (includes head applied forces)	0.
4	Category 31		Switch = 0., Store center of mass z-component forces 1., Inhibit (includes head applied forces)	0.
5	Category 32		Switch = 0., Store center of mass resultant moments 1., Inhibit	0.
6	Category 33		Switch = 0., Store steering column coordinates 1., Inhibit	0.
7	Category 34		Switch = 0., Store steering column generalized coordinates 1., Inhibit	0.
8	Category 35		Switch = 0., Store Steering column forces and moments 1., Inhibit	0.
9	Category 36		Switch = 0., Store forces and moments on body due to steering column 1., Inhibit	0.

NOTE: Use Cards 1001 and 1002 to specify desired printed output.

MVMA 2-D Model
Card 110

TABLE 2. INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 5)
(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	Category 37		Switch = 0., Store neck and shoulder forces 1., Inhibit	0.
2	Category 38		Switch = 0., Store muscle tension forces 1., Inhibit	0.
3	Category 39		Switch = 0., Store muscle tension energy absorption 1., Inhibit	0.
4	Category 40		Switch = 0., Store femur and tibia loads 1., Inhibit	0.
5	Category 46		Switch = 0., Store head c.g. motion 1., Inhibit	0.
6	Category 47		Switch = 0., Store chest c.g. motion 1., Inhibit	0.
7	Category 48		Switch = 0., Store hip motion 1., Inhibit	0.
8	Category 49		Switch = 0., Store joint relative angles 1., Inhibit	0.
9	Category 50		Switch = 0., Store joint relative angle velocities 1., Inhibit	0.

Note: Use Cards 1001 and 1002 to specify desired printed output.

Note: Categories 41-45 are for quantities determined by the output processor. See Table 11 and Cards 1001 and 1002.

NOTE: See Section 3.2-A.3 regarding interpretation of femur and tibia load output quantities.

MVMA 2-D Model
Card 111

TABLE 2 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 6)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	Category 51		Switch = 0., Store advanced airbag system thermodynamic variables. 1., Inhibit.	0.
2	Category 52		Switch = 0., Store pressure forces on body. 1., Inhibit.	0.
3	Category 53		Switch = 0., Store occupant-plane normal flotation forces. 1., Inhibit.	0.
4	Category 54		Switch = 0., Store occupant-plane tangential flotation forces. 1., Inhibit.	0.
5	Category 55		Switch = 0., Store off-occupant plane normal flotation forces. 1., Inhibit.	0.
6	Category 56		Switch = 0., Store off-occupant plane tangential flotation forces. 1., Inhibit.	0.
7	Category 57		Switch = 0., Store bag slap forces on body. 1., Inhibit.	0.
8	Category 58		Switch = 0., Store airbag equilibrium and contact conditions. 1., Inhibit.	0.
9	Category 59		Switch = 0., Store airbag-deformable segment motions. 1., Inhibit.	0.

Card 112

TABLE 2 INPUT DATA

STORED OUTPUT SPECIFICATIONS (CARD 7)
(3 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	Category 60		Switch = 0., Store total bag forces on body. 1., Inhibit.	0.
2	Category 61		Switch = 0., Store total inertial x-component bag forces. 1., Inhibit.	0.
3	Category 62		Switch = 0., Store total inertial ~~z~~-component bag forces. 1., Inhibit.	0.
4.	Category 63		Switch = 0., Store kinematics for non-body links 1., Inhibit.	0.
5.	Category 64		Switch = 0., Store resistance forces and moments for non-body links 1., Inhibit.	0.

TABLE 7 INPUT DATA

OCCUPANT PARAMETER SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1(1:19) or STITL1(1:72)		Run subtitle for Occupant Parameters Input Block. Columns 1-19 will become columns 1-19 of subtitle.

NOTES: Cards 200, 300, 400, 500, 600, 700, 800, and 900 may be used in two different modes to produce a subtitle line, the second line printed at the top of each page of output.

Mode 1: This is a revised implementation of the mode of use of Cards 200, 300, 400, 500, 600, 700, 800, and 900 that has been available in Versions of MVMA 2-D prior to Version 6. The model constructs a subtitle line from the first 19 columns of Cards 200, 300, 400, 500, 600, and 700 and the first 17 columns of Card 800 or 900. The model will treat these 19-column fields (or 17) as blocks to be assembled contiguously. If the joining of two contiguous fields would result in three or more successive blanks, the model will sometimes adjust spacing to accommodate an MVMA 2-D version designation at the end of the subtitle line. (Adjustment of trailing blanks for any particular block can be disallowed by entering "#" in column 20.)

Mode 2: This option normally utilizes only Cards 200 and 300. Mode 2 is made active simply by having at least 10 non-blank characters in the column range 20-72 of Card 200 or 20-53 of Card 300. (If only one of these cards meets this criterion, it must precede the other one in the data set.) The subtitle is constructed by appending the first 53 columns of Card 300 to the 72 columns of Card 200. For Mode 2, a Card 400, 500, ..., or 900 is ignored unless it has "#" in column 20, in which case its characters in columns 1-19 (or (1-17) will overlay the corresponding columns of the Mode 2 "200/300" subtitle which are not "#".

TABLE 7 INPUT DATA

OCCUPANT BODY-SEGMENT LENGTHS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	CONDYL, c	inches (cm)	A-P offset of upper neck joint from head c.g. (positive rearward)	1.68 4.27
2	L23, L_{23} FLJI(3)	inches (cm)	Upper Torso Length	7.09 18.01
.3	L34, L_{34} FLJI(4)	inches (cm)	Middle Torso Length	5.95 15.11
4	L45, L_{45} FLJI(5)	inches (cm)	Lower Torso Length	7.28 18.49
5	L56, L_{56} FLJI(6)	inches (cm)	Hip-Knee Length	17.1 43.43
6	L27, L_{27} FLJI(7)	inches (cm)	(not used)	
7	L78, L_{78} FLJI(8)	inches (cm)	Shoulder-Elbow Length	11.91 30.25
8	ASH, a	inches (cm)	Rest point x of shoulder joint relative to upper torso C.G., pos. along centerline toward joint 2 from C.G.	1.84, 4.67
9	BSH, b	inches (cm)	Rest point z of shoulder joint relative to upper torso C.G., pos. toward front of body.	0.

NOTE: See Section 2.1, Figures 2 and 6 or Figures 66 and 67.

FLJI(I-1) = length of Ith segment

TABLE 7 INPUT DATA

END OF LINK TO CENTER-OF-MASS LENGTHS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	L1, ℓ_1	inches (cm)	Head / neck joint -head C-M length (component along inferior-superior axis)	6.14 15.6
2	L2, ℓ_2	inches (cm)	Neck-Chest C-M Length	4.02 10.21
3	L3, ℓ_3	inches (cm)	Upper Torso Joint - Middle Torso C-M Length	2.45 6.22
4	L4, ℓ_4	inches (cm)	Lower Torso Joint - Lower Torso C-M Length	3.03 7.70
5	L5, ℓ_5	inches (cm)	Hip-Upper Leg C-M Length	7.41 18.82
6	L6, ℓ_6	inches (cm)	Knee-Lower Leg C-M Length	7.08 18.0
7	L7, ℓ_7	inches (cm)	Shoulder-Upper Arm C-M Length	5.2 13.21
8	L8, ℓ_8	inches (cm)	Elbow-Lower Arm C-M Length	4.56 11.58
9	ALF, α		Proportion of neck mass at upper joint	0.5

NOTES: 1. See Figure 66 and Sections 2.1 and 2.2 for definitions.

2. $(1-\alpha)m_n$ will be at the lower neck joint.

MVMA 2-D Model
Card 202

TABLE 7 INPUT DATA

MASS OF BODY SEGMENTS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	M1, M_1	lb sec^2/in (kg)	Head Mass	0.0242 4.238
2	M2, M_2	lb sec^2/in (kg)	Chest Mass	0.0641 11.226
3	M3, M_3	lb sec^2/in (kg)	Middle Torso Mass	0.0613 10.735
4	M4, M_4	lb sec^2/in (kg)	Lower Torso Mass	0.0734 12.854
5	M5, M_5	lb sec^2/in (kg)	Upper Leg Mass (Both Legs)	0.0839 14.693
6	M6, M_6	lb sec^2/in (kg)	Lower Leg Mass (Both Legs)	0.0532 9.317
7	M7, M_7	lb sec^2/in (kg)	Upper Arm Mass (Both Arms)	0.029 5.079
8	M8, M_8	lb sec^2/in (kg)	Lower Arm Mass (Both Arms)	0.0214 3.748
9	EM9, M_n	lb sec^2/in (kg)	Total Neck Mass	0.009 1.576

NOTE: See Sections 2.1 and 2.2 and Figure 66 for definitions.

TABLE 7 INPUT DATA

MOMENTS OF INERTIA
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	I1, I_1	lbs-sec^2-in(kg-m^2)	Head	0.325 0.0367
2	I2, I_2	lbs-sec^2-in(kg-m^2)	Chest	3.04 0.344
3	I3, I_3	lbs-sec^2-in(kg-m^2)	Middle Torso	2.39 0.27
4	I4, I_4	lbs-sec^2-in(kg-m^2)	Lower Torso	4.6 0.52
5	I5, I_5	lbs-sec^2-in(kg-m^2)	Upper Leg	2.341 0.2645
6	I6, I_6	lbs-sec^2-in(kg-m^2)	Lower Leg	1.259 0.1422
7	I7, I_7	lbs-sec^2-in(kg-m^2)	Upper Arm	0.383 0.04327
8	I8, I_8	lbs-sec^2-in(kg-m^2)	Lower Arm	0.223 0.0252

MVMA 2-D Model
Card 204

TABLE 7 INPUT DATA

OCCUPANT JOINT PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	KJI (I,1), $K_{i,1}$	in-lb/deg (N-m/deg)	*Linear Angular Deflection Coefficient (elastic or joint stop)
2	KJI (I,2), $K_{i,2}$	in-lb/deg^2 (N-m/deg^2)	Quadratic Angular Deflection Coefficient (joint stop)
3	KJI (I,3), $K_{i,3}$	in-lb/deg^3 (N-m/deg^3)	Cubic Angular Deflection Coefficient (joint stop)
4	CJI (I), C_i^J	in-lb-sec/deg (N-m-sec/deg)	*Viscous Friction Coefficient (elastic; also joint stop unless mat'l name is specified)
5	FJI, F_i^J	in-lb (N-m)	*Constant Friction
6	VJI, V_i^J	deg/sec	*Velocity Threshold for Constant Friction
7	THSI (I,1), $\theta_{i,1}^S$	deg	**Positive -Most Joint Stop (not used for 205 and 206)(or 999.)
8	THSI (I,2), $\theta_{i,2}^S$	deg	**Negative -Most Joint Stop (or -999.)
9	RJI (I), R_i^J		Conserved-Absorbed energy ratio

NOTES:

1. Card 205 I = i = 1 Head-Neck Forward (flexion)
   206 I = i = 2 Neck-Upper Torso Forward (flexion)
   207 I = i = 3 Upper Spine
   208 I = i = 4 Lower Spine
   209 I = i = 5 Hip
   210 I = i = 6 Knee
   211 I = i = 7 Upper Arm-Upper Torso
   212 I = i = 8 Elbow (relative angle $\theta_7^R = \theta_7 - \theta_2$)
2. See Figure 2, Section 2.1, and Section 2.3 for definitions
3. Field 1: $K_{i,1} > 0$ means elastic coefficient is $K_{i,1}$, and linear joint stop torque coefficient is 0; $K_{i,1} < 0$ means elastic coefficient is 0 and linear joint stop torque coefficient is $|K_{i,1}|$.

*4. For a neck joint, flexion-range values for KJI(I,1), CJI(I), and FJI(I) will be used from Card 205 or 206 whenever the joint is in flexion w.r.t. the equilibrium angle on Card 217. Values from Card 215 or 216 will be used for extension.

5. These cards may be supplemented by Cards 243 to 246.
6. Rate-dependent viscous damping may be specified for joint stops if Cards 243-246 are used.

**7. Specify joint stop angles at +/- 999. to request values that bracket the time zero relative angle by +/- .001 degrees.

8. See Cards 215-216 for neck rearward bending (extension).

MVMA 2-D Model
Cards 205-212

TABLE 7 INPUT DATA

OCCUPANT JOINT PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	KJI (I,1), $K_{i,1}$	lb/in (N/cm)	Linear Deflection Coefficient
2	KJI (I,2), $K_{i,2}$	lb/in^2 (N/cm^2)	Quadratic Deflection Coefficient
3	KJI (I,3), $K_{i,3}$	lb/in^3 (N/cm^3)	Cubic Deflection Coefficient
4	CJI (I), C_i^J	lb sec/in (N sec/cm)	Viscous Friction Coefficient
5			(not used)
6			(not used)
7	RSH	in (cm)	Shoulder Stop Circle Radius (not used for Card 213)
8			(not used)
9	RJI (I), R_i^J		Conserved-Absorbed energy ratio (not used for Card 213)

NOTES:

1. Card 213 I = i = 9 Neck (stretching of element; also see Card 242)
   214 I = i = 10 Shoulder (extensible element)
2. See Figure 2, Section 2.1 and Section 2.3 for definitions.
3. Field 1, Card 214: See Note 3, Cards 205-212.
4. These cards may be supplemented by Card 247.
5. Rate-dependent viscous damping may be specified for neck link and for shoulder stop circle if Card 247 is used.

TABLE 7 INPUT DATA

OCCUPANT JOINT PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	KJI (I,1), $K_{i,1}$	in-lb/deg (N-m/deg)	*Linear Angular Deflection Coefficient
2	KJI (I,2), $K_{i,2}$	in-lb/deg^2 (N-m/deg^2)	Quadratic Angular Deflection Coefficient
3	KJI (I,3), $K_{i,3}$	in-lb/deg^3 (N-m/deg^3)	Cubic Angular Deflection Coefficient
4	CJI (I), C_i^J	in-lb-sec/deg (N-m-sec /deg)	*Viscous Friction Coefficient (elastic; also joint stop unless material name is specified)
5	FJI, F_i^J	in-lb (N-m)	*Constant Friction
6	VJI, V_i^J	deg/sec	*Velocity Threshold for Constant Friction
7	THSI (I,1), $\theta_{i,1}^S$	deg	**Positive-Most Joint Stop (or 999.)
8			
9	RJI (I), R_i^J		Conserved-Absorbed energy ratio

NOTES: 1. Card 215 I = i = 11 Head-Neck Rear (extension)
216 I = i = 12 Neck-Upper Torso Rear (extension)

2. See Figure 2, Section 2.1, and Section 2.3 for definitions

3. Field 1: See Note 3, Cards 205-212.

4. These cards may be supplemented by Card 243.

5. Rate-dependent viscous damping may be specified for joint stops if Card 243 is used.

*6. See Note 4 for Cards 205 and 206 and check field 1 and 2 of Card 217.

**7. Specify joint stop angle as 999. to request a value that is .001 degrees greater than the time zero value of the relative angle. Use a similar specification on Card 205-206 to bracket the initial relative angle.

MVMA 2-D Model
Cards 215-216

TABLE 7 INPUT DATA

"NATURAL" LINK DISPLACEMENTS (ZETAS)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults**
1	THROI(1), θ_1^R	Degrees	*Upper neck joint angle for zero "elastic" torque.	999.
2	THROI(2), θ_2^R	Degrees	*Lower neck joint angle for zero "elastic" torque.	999.
3	THROI(3), θ_3^R	Degrees	Upper spine angle for zero torque.	999.
4	THROI(4), θ_4^R	Degrees	Lower spine angle for zero torque.	999.
5	THROI(5) θ_5^R	Degrees	Hip angle for zero torque.	999.
6	THROI(6) θ_6^R	Degrees	Knee angle for zero torque.	999.
7	THROI(7) θ_7^R	Degrees	Shoulder angle for zero torque.	999.
8	THROI(8) θ_8^R	Degrees	Elbow angle for zero torque.	999.

NOTE: See Figures 8, 73, and/or 74 and Section 2.3 for definitions.

*NOTE: These values should be properly defined for neck joints if any of the quantities KJI(I,1), CJI(I), or FJI(I) for neck joints on Cards 205, 206, 215, or 216 are non-zero. See Note 4 for Cards 205 and 206.

**NOTE: Any or all zero elastic torque angles may be entered as 999. to specify that the time zero value of the relative angle(s) should be used. If Card 217 is omitted from the data set, all 999.'s will be assumed.

TABLE 7 INPUT DATA

OCCUPANT ACCELEROMETER AND BELT ATTACHMENT PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	AH	Inches (cm)	Offset to head accelerometer, measured upward from upper neck joint and parallel to vertical (S-I) head axis.
2	AC	inches (cm)	Directed distance along upper torso centerline to chest accelerometer measured from lower neck joint.
3	AHH	inches (cm)	Offset to head accelerometer, measured forward from upper neck joint and parallel to horizontal (A-P) head axis.
4	CSIB1, ξ_1^B	inches (cm)	Distance along centerline of lower torso from joint 4 for Lap belt reference point.
5	ZETAB1, ζ_1^B	inches (cm)	Distance perpendicular to centerline of lower torso for Lap belt reference point.
6	CSIB2, ξ_2^B	inches (cm)	Distance along centerline of upper torso from joint 2 for upper torso belt reference point.
7	ZETAB2, ζ_2^B	inches (cm)	Distance perpendicular to centerline of upper torso for upper torso belt reference point.
8	CSIB3, ξ_3^B	inches (cm)	Distance along centerline of torso from upper joint of torso element for lower torso belt reference point.*
9	ZETAB3, ζ_3^B	inches (cm)	Distance perpendicular to centerline of torso for lower torso belt reference point.

NOTE: See Figure 75 and Section 2.5.1 for definitions.

NOTE: Fields 4 to 9 are not needed if the advanced belt system BELT2 has been selected. See Cards 710-723.

*The lower torso belt may be attached to the upper, middle or lower torso link (+ξ downward along body, +ζ toward back of body). See Field 7 of Card 702. Figure 75 illustrates attachment to the middle link.

TABLE 7 INPUT DATA
CONTACT ELLIPSE SPECIFICATIONS (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of Ellipse (also name for non-body link) (up to 16 characters)
3-4			Material of Ellipse (up to 16 characters) Blank if rigid.
5	KSEG		Ellipse Attachment Indicator Reference System Designations: 1. = Head; 2. = Upper Torso; 3. = Middle Torso; 4. = Lower Torso; 5. = Upper legs; 6. = Lower legs; 7. = Upper arms; 8. = Lower arms; 9. = Vehicle; 10. = Inertial; >10. = user-specified link number for attachment of secondary ellipse (See Card 249, field 9)
	Pos.(+)		If Reference System Designation is supplied as a positive number, the ellipse is rigidly attached (i.e., "fixed") to the designated system. If greater than 10., then this is a "secondary" ellipse and the Reference System Designation refers to a link number previously defined on a 249-Card for a non-body link.
	Neg.(-)		If Reference System Designation is supplied as a negative number, then a non-body link with mass and moment of inertia is defined. The link can move with respect to the designated reference system. The Name of Ellipse refers to both the non-body link and a "primary" ellipse fixed to it. Link initial position/orientation is determined from required user specifications for primary ellipse position/orientation with respect to the link system (on Card 220) and with respect to the Designated Reference System (on Card 305). A 249-Card is also required. Only -1., -2., ..., -10. are allowed, i.e., non-body links cannot be referenced (connected) to other non-body links.
6			Ellipse friction class (1-5)
7	XEQ	in (cm)	Equilibrium position x-coordinate for CG of user-defined non-body link w.r.t. Designated Reference System (needed only if field 5 is negative)
8	ZEQ	in (cm)	Equilibrium position z-coordinate for CG of user-defined non-body link
9	THEQ	degrees	Equilibrium orientation angle of user-defined non-body link

See NOTES for Card 219 on the next page. See schematic for non-body links on the following page.

TABLE 7 INPUT DATA
CONTACT ELLIPSE SPECIFICATIONS (CARD 1, CONTINUED)

CARD 219 NOTES:

1. If field 5 is positive, a matching Card 220 is required but Cards 249 and 305 cannot be used.

2. If field 5 is negative, matching Cards 220, 249, and 305 are all required.

3. See Section 2.10 for discussion of ellipses that are not rigidly attached to any reference system.

4. See schematic for non-body link ellipses on the next page.

5. One additional non-body link segment is defined for each link with field 5 negative. If regions or secondary ellipses are to be attached to the link, then the link must be assigned a link number in field 9 of the corresponding 249-Card. (Also see Note 6.)

6. A value greater than +10 must be specified in field 5 of a 219-Card in order to attach a secondary ellipse to a non-body link. A value less than -10 must be specified in field 6 of a 402-Card in order to attach a region to a non-body link.

7. If femur and tibia load are of interest, a knee ellipse should be attached to the upper legs and a foot ellipse should be attached to the lower legs. A hip ellipse, if used, should be assigned to the lower torso element. See Section 4.6.2.5.

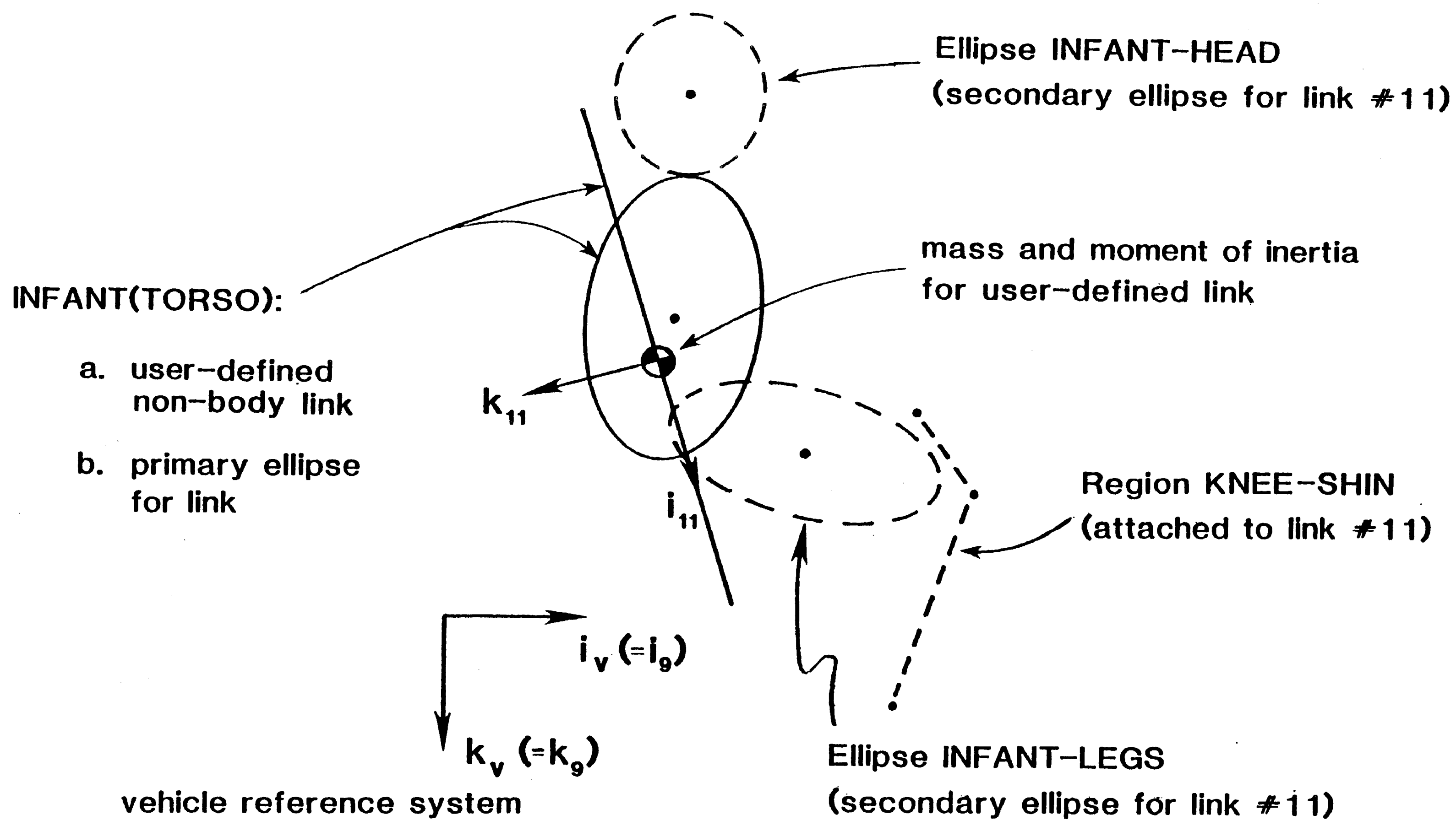
8. Secondary ellipses on a non-body link do not articulate with respect to the primary ellipse for that link. They serve only to provide a more complex profile for interaction with other ellipses and line segments.

9. Fields 7-9 are used only if field 5 is negative. The absolute value of field 5 indicates the coordinate system in which the equilibrium position is defined.

EXAMPLE SPECIFICATIONS FOR A NON-BODY LINK ELLIPSE
(CARD 219 AND CARD 249)

CARD	FIELD	ENTRY	DESCRIPTION/EXPLANATION
219	1-2	INFANT(TORSO)	Name of Ellipse
	5	-9.	Reference System Designation. "9" indicates that position data are referenced to the vehicle coordinate frame. Minus sign indicates that this ellipse is not rigidly attached but instead is attached to a non-body link that can move (with respect to system 9, the vehicle. The ellipse INFANT(TORSO) is the "primary" ellipse for the non-body link of like name -- INFANT(TORSO) -- thus defined.
249	1-2	INFANT(TORSO)	Name of Ellipse
	9	11.	User-defined segment number. Any number greater than 10 which is not used on any other 249-Card can be used. This is the number assigned to the INFANT(TORSO) non-body link reference system.
219	1-2	INFANT-HEAD	Name of Ellipse
	5	11.	Reference System Designation -- segment number for secondary ellipse. An ellipse of name INFANT-HEAD is fixed, as a "secondary ellipse", to the non-body link designated by "11", i.e., to the INFANT(TORSO) link.
219	1-2	INFANT-LEGS	Name of Ellipse
	5	11.	Reference System Designation -- segment number for secondary ellipse. An ellipse of name INFANT-LEGS is fixed, as a "secondary ellipse", to the non-body link designated by "11", i.e., to the INFANT(TORSO) link.
402	1-2	KNEE-SHIN	Name of Region
	6	-11.	KPATCH -- negative segment number for attachment of region. A contact region of name KNEE-SHIN is attached to the non-body link designated by "11", i.e., to the INFANT(TORSO) link.

SCHEMATIC FOR EXAMPLE NON-BODY LINK WITH PRIMARY AND SECONDARY ELLIPSES AND AN ATTACHED CONTACT REGION



NOTE: The ellipses illustrated do not articulate at neck and hip joints. Thus a three-ellipse profile may not be appropriate for a model of a lap-held infant unless compensation is made in assignment of ellipse material properties. (That is, a one-ellipse profile may be a preferable, simple model.)

TABLE 7 INPUT DATA

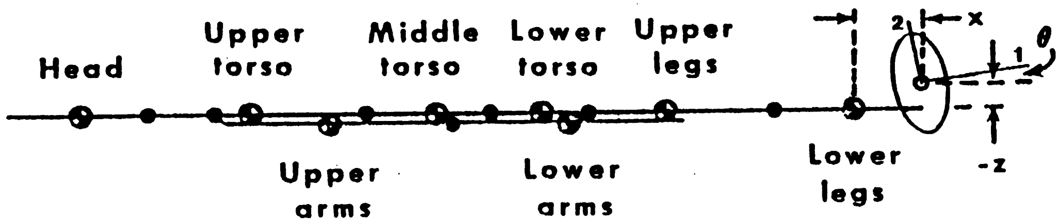
CONTACT ELLIPSE SPECIFICATIONS (Card 2)
(9 fields of 8)

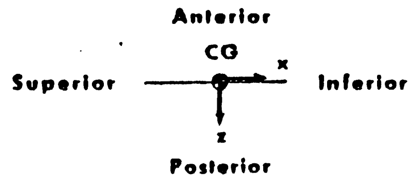
Field	Name of Quantity	Units	Description
1-2			Name of ellipse (Up to 16 characters)
3	XEM, xem	inches(cm)	Fixed x-coordinate of ellipse center on segment, vehicle, or inertial frame (See Notes 2 and 3.)
4	ZEM, zem	inches(cm)	Fixed z-coordinate of ellipse center on segment, vehicle, or inertial frame (See Notes 2 and 3.)
5	a	inches(cm)	Semi-axis length along ellipse axis number one
6	c	inches(cm)	Semi-axis length along ellipse axis number two
7	THEM	degrees	Fixed orientation angle of ellipse axis number one w.r.t. x-axis of segment, veh., or iner. frame (pos. c-clockwise) See Notes 2/3.
* 8	ISEGB		Link (a value 4.-8.) which shares ellipse with reference system link. Normally for hip, knee, or elbow. Leave blank if not shared. See Note 6. Valid pairs: (4.,5.) (5.,6.) (7.,8.)

NOTES:

1. See Section 2.6.1 and figure below for body segment reference system definitions.
2. The reference system for fields 3,4,7 is specified on Card 219, field 5, if this ellipse is fixed to a body link (1-8) or to the vehicle or inertial system (9 or 10). If field 5 of Card 219 is negative, then the ellipse is fixed to the user-defined segment with segment number indicated in field 9 of the 249-Card.
3. The x, z, and angle values give the fixed position in its reference system if the ellipse is rigidly attached. But if the ellipse is the "primary ellipse" for a user-defined non-body link, which can move with respect to its reference frame, these values are for its equilibrium position.
4. Fields 5 and 6 may not both be zero. If only one of the two fields is nonzero, that value is used for both.
5. For every Card 219, there must be a Card 220 with matching ellipse name.

* 6. Ellipse sharing (field 8) is recommended for hip, knee, and elbow ellipses and is ignored for link pairs other than (4.,5.), (5.,6.), and (7.,8.). Ellipse sharing is used to cause an ellipse attached at or near a joint to rotate, for the purpose of calculating contact slip velocities, with an "averaged" angular velocity of the adjoined links. Without ellipse sharing (blank field), the ellipse will rotate with the velocity of the body link to which it is attached (field 5, Card 219).





Example for a "foot" ellipse

* 7. See Section 3.2-A.2.

MVMA 2-D Model
Card 220

TABLE 7 INPUT DATA

CONTACT ELLIPSE MATERIAL CARDS
(9 Fields of 8)

NOTE: Contact ellipse material properties are specified in the same manner as contact region material properties. See Cards 403-408 for format.

MVMA 2-D Model
Cards 221-226
(403-408)

TABLE 7 INPUT DATA

MUSCLE TENSION COEFFICIENTS
(5 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	AMUS (I,1), a_1	I = 1-9 lb in/deg (N·m/deg) I = 10, 11 lb/in (N/cm)	*Stiffness coefficient a_1 $(k = \|a_1\| + a_2\ \|M\|)$	0.
2	AMUS (I,2), a_2	I = 1-9 deg^{-1} I = 10,11 in^{-1} (cm^{-1})	Stiffness coefficient a_2 $(k = \|a_1\| + a_2\ \|M\|)$	0.
3	AMUS (I,3), a_3	I = 1-9 sec/deg I = 10,11 sec/in (sec/cm)	Damping coefficient $(c = a_3\|M\|)$	0.
4	TMUS (I)	I = 1-9 lb in (N.m) I = 10,11 lb (N)	Initial value of muscle force or moment resultant (normally zero)	0.
5	MUSNAM (1-2,I)		Name assigned to muscle tension table |M| vs. time. (up to 8 characters)	

NOTES:

Card 227 I = 1 Head-Neck Joint (θ_1^R)
228 I = 2 Neck-Upper Torso Joint (θ_2^R)
229 I = 3 Upper Spine Joint (θ_3^R)
230 I = 4 Lower Spine Joint (θ_4^R)
231 I = 5 Hip (θ_5^R)
232 I = 6 Knee (θ_6^R)
233 I = 7 Upper Torso - Upper Arm Joint (θ_7^R)
234 I = 8 Elbow (θ_8^R)
235 I = 9 Shoulder-Upper Torso Joint (θ_s)
236 I = 10 Neck (extensible element) (L_n)
237 I = 11 Shoulder (extensible element) (L_s)

*NOTE: Set a_1 negative if non-zero Maxwell element force should be allowed in compression.

TABLE 7 INPUT DATA

MUSCLE TENSION VERSUS TIME
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			NAME assigned to muscle tension table $\lvert M \rvert$ vs. time.
2	t	msec	Time associated with a specified muscle tension value.
3	TENSE (I), $\lvert M \rvert$, $\lvert T \rvert$	lb (N) or lb in (N.m)	Muscle contraction force or moment (should be $\geq 0.$)

MVMA 2-D Model
Card 238

TABLE 7 INPUT DATA

RADIAL SHOULDER JOINT STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	θ_s	deg	Relative shoulder angle associated with specified linear stiffness.
2	KJI (10,1), $K_{10,1}$	$\frac{lb}{in}$ $(\frac{N}{cm})$	Linear radial shoulder joint stiffness coefficient.

NOTE: If $K_{10,1}$ is desired to be constant, then the value in field 1 of the 214 Card will suffice. Only if $K_{10,1}$ is to be tabular must 239 Cards be present, one card per point. $K_{10,1}$ is assumed periodic, with period of 360°. Points at θ_s= 0° and 360° and desired intermediate abscissa values are entered.

TABLE 7 INPUT DATA

RADIAL SHOULDER JOINT STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	θ_s	deg	Relative shoulder angle associated with specified quadratic stiffness.
2	KJI (10,2), $K_{10,2}$	$\frac{lb}{in}$ $(\frac{N}{cm})$	Quadratic radial shoulder joint stiffness coefficient.

NOTE: A table for $K_{10,2}$ is optional. See note for Card 239.

TABLE 7 INPUT DATA

RADIAL SHOULDER JOINT STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	θ_s	deg	Relative shoulder angle associated with specified cubic stiffness.
2	KJI (10,3), $K_{10,3}$	$\frac{lb}{in}$ $(\frac{N}{cm})$	Cubic radial shoulder joint stiffness coefficient.

NOTE: A table for $K_{10,3}$ is optional. See note for Card 239.

TABLE 7 INPUT DATA

OCCUPANT NECK COMPRESSION PARAMETERS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1	KJI(13,1), $K_{13,1}$	lb/in(N/cm)	Linear Compression Coefficient
2	KJI(13,2), $K_{13,2}$	$lb/in^2(N/cm^2)$	Quadratic Compression Coefficient
3	KJI(13,3) $K_{13,3}$	$lb/in^3(N/cm^3)$	Cubic Compression Coefficient
4	CJI(13), C^J_{13}	lb sec/in (N sec/cm)	Viscous friction coefficient

NOTES: 1. This card contains neck compression parameters; see Card 213 for neck elongation parameters.

2. This card may be supplemented by Card 247.

TABLE 7 INPUT DATA

OCCUPANT JOINT-STOP MATERIAL NAMES
(8 Fields of 8)

Field	Card Reference	Definition
1-2	205	Material name for upper neck joint flexion.
3-4	215	Material name for upper neck joint extension.
5-6	206	Material name for lower neck joint flexion.
7-8	216	Material name for lower neck joint extension.

NOTES:
1. These materials are used only for joint stops.
2. Neck flexion is forward bending; extension is rearward.
3. Fields 1 (if negative), 2, 3, 4, and 9 of the indicated joint parameter cards are not used for stop if material name is specified. Leave the material name fields blank if polynomial coefficients on the reference card are to be used.
4. Material specifications are made on Cards 403-408.

TABLE 7 INPUT DATA

OCCUPANT JOINT-STOP MATERIAL NAMES
(8 Fields of 8)

Field	Card Reference	Definition
1-2	207	Material name for upper torso joint flexion.
3-4	207	Material name for upper torso joint extension.
5-6	208	Material name for lower torso joint flexion.
7-8	208	Material name for lower torso joint extension.

NOTES:
1. Torso flexion is forward bending; extension is rearward.
2. See Notes for Card 243.

TABLE 7 INPUT DATA

OCCUPANT JOINT-STOP MATERIAL NAMES
(8 Fields of 8)

Field	Card Reference	Definition
1-2	209	Material name for hip joint forward bending.
3-4	209	Material name for hip joint rearward bending.
5-6	210	Material name for knee joint flexion (bending).
7-8	210	Material name for knee joint extension (straightening).

NOTES:

1. The order of material names for the knee are reversed, in a sense, from the other joints since for this joint, flexion corresponds to rearward bending (into "upper" stop) and extension corresponds to forward bending (into "lower" stop).
2. See Notes for Card 243.

TABLE 7 INPUT DATA

OCCUPANT JOINT-STOP MATERIAL NAMES
(8 Fields of 8)

Field	Card Reference	Definition
1-2	211	Material name for shoulder joint, forward arm rotation.
3-4	211	Material name for shoulder joint, rearward arm rotation.
5-6	212	Material name for elbow flexion (bending).
7-8	212	Material name for elbow extension (straightening).

NOTE : See Notes for Card 243.

TABLE 7 INPUT DATA

OCCUPANT JOINT-STOP MATERIAL NAMES
(6 Fields of 8)

Field	Card Reference	Definition
1-2	213	Material name for neck link elongation.
3-4	242	Material name for neck link compression.
5-6	214	Material name for shoulder link elongation.
7-8	-	(Unused material name)

NOTES:
1. The "stop" locations for neck link elongation and compression are not specified by the user. They are determined as the initial neck link length.
2. The shoulder link "stop" locations are specified by the shoulder stop circle radius in field 7 of Card 214.
3. See Notes for Card 243.

TABLE 7 INPUT DATA

UNLOADING CURVES
(3 Fields of 8)

NOTE: Contact ellipse material unloading curves are specified in the same manner as curves for contact region materials. See Card 413 for format.

MVMA 2-D Model
Card 248
(413)

TABLE 7 INPUT DATA

PRIMARY ELLIPSE/NON-BODY LINK SPECIFICATIONS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name of Ellipse/Link (primary ellipse/non-body link)
3-4			Torsional Material Name (blank for null material)
5			Radial Resistance Name (blank for null resistance)
6			Tangential Resistance Name (blank for null resistance)
7		lb-sec**2/in (kg)	Non-body link mass
8		lb-sec**2-in (kg m**2)	Non-body link moment of inertia
9			User-defined segment number (>10) for this non-body link (See Note 2.)

NOTES:
1. Neither field 7 nor field 8 may be zero or negative.
2. Field 9 must be unique and greater than 10 if specified but is not required unless a secondary ellipse or a contact region is attached to this non-body link. The model will renumber consecutively in ascending order of given values.
3. Fields 3-6 are optional. Normally either all or none should be specified for a reasonable physical model. Exercise caution with partial specifications.
4. Material and resistance names in fields 3-6 relate to primary ellipse displacements away from the equilibrium position/orientation specified on Card 220 in the reference system of field 5 of Card 219.
5. If a resistance name is entered in field 5, then Cards 250, 251, or 252 must be included. Card 253 is optional.
6. If a resistance name is entered in field 6, then Cards 254 must be included.

TABLE 7 INPUT DATA

ELLIPSE ATTACHMENT RADIAL STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name for radial stiffness/damping coefficients table.
2		degrees	Circumferential Angle.
3	K1	lb/in (N/cm)	Linear stiffness coefficient for radial attachment of ellipse.

NOTES: 1. A quadratic and a cubic stiffness coefficient and a damping coefficient can be specified to be used in concert with the linear coefficient specified on this card. If this is desired, Cards 251, 252, and/or 253 may also appear and must have an identical table name specified in field 1.

2. Resistance force for ellipse radial motion away from the initial position of the ellipse center is determined from F = K1 * d + K2 * d**2 + K3 * d**3 + K4 * r where d is the deflection, r is the deflection rate, and K1, K2, K3, K4 are the circumferential angle-dependent resistance coefficients.

3. Circumferential angle is defined as the angle between the x-axis of the ellipse attachment reference system and the vector from the initial position of the ellipse center to its current position. The circumferential angle in field 2 is positive counterclockwise.

4. The attachment reference system for each ellipse is specified in field 5 of Card 219.

5. Each Card 250 specifies one point for a table relating circumferential angle and linear stiffness. At least two points are required to define a table.

TABLE 7 INPUT DATA

ELLIPSE ATTACHMENT RADIAL STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name for radial stiffness/damping coefficients table.
2		degrees	Circumferential angle.
3	K2	lb/in**2 (N/cm**2)	Quadratic stiffness coefficient for radial attachment of ellipse.

NOTES: 1. A linear and a cubic stiffness coefficient and a damping coefficient can be specified to be used in concert with the quadratic coefficient specified on this card. If this is desired, Cards 250, 252, and/or 253 may also appear and must have an identical table name specified in field 1.

2. See Notes 2 through 4 of Card 250.

3. Each Card 251 specifies one point for a table relating circumferential angle and quadratic stiffness. At least two points are required to define a table.

TABLE 7 INPUT DATA

ELLIPSE ATTACHMENT RADIAL STIFFNESS TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name for radial stiffness/damping coefficients table.
2		degrees	Circumferential angle.
3	K3	lb/in**3 (N/cm**3)	Cubic stiffness coefficient for radial attachment of ellipse.

NOTES: 1. A linear and a quadratic stiffness coefficient and a damping coefficient can be specified to be used in concert with the cubic coefficient specified on this card. If this is desired, Cards 250, 251, and/or 253 may also appear and must have an identical table name specified in field 1.

2. See Notes 2 through 4 of Card 250.

3. Each Card 252 specifies one point for a table relating circumferential angle and cubic stiffness. At least two points are required to define a table.

TABLE 7 INPUT DATA

ELLIPSE ATTACHMENT RADIAL DAMPING TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name for radial stiffness/damping coefficients table.
2		degrees	Circumferential angle.
3	K4	lb sec/in (N sec/cm)	Damping coefficient for radial attachment of ellipse.

NOTES: 1. This card is optional and is used to specify a damping coefficient for use with the stiffness coefficients provided on Cards 250-252. This card may not be included in a data deck which does not have one or more of Cards 250-252 for same table name.

2. See Notes 2 through 4 of Card 250.

3. Each Card 253 specifies one point for a table relating circumferential angle and damping coefficient. At least two points are required to define a table.

TABLE 7 INPUT DATA

ELLIPSE TANGENTIAL DAMPING TABLES
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name for tangential damping coefficient table.
2		degrees	Circumferential angle.
3	CT	lb sec/in (N sec/cm)	Damping coefficient for tangential motion of ellipse. (Tangential motion is perpendicular to radial motion.)

NOTES: 1. See Note 3 of Card 250.

2. "Frictional" or "plowing" resistance force to tangential motion of ellipse is determined as F = CT * d * THETADOT, where d is radial distance of ellipse center from its initial position and THETADOT is circumferential velocity (See Notes 2-3 of Card 250).

3. Each Card 254 specifies one point for a table relating circumferential angle and tangential damping. At least two points are required to define a table.

TABLE 7 INPUT DATA

OCCUPANT DESCRIPTION SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (20:38) or STITL1 (73:125)		Run subtitle for Occupant Orientation Input Block. Columns 1 to 19 of this card become columns 20 to 38 in subtitle.

Note: See Mode 2 note on the page for Card 200 for description of an alternate method of specifying run subtitle data.

TABLE 7 INPUT DATA

INITIAL BODY LINK ANGLES (RELATIVE TO VEHICLE)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	TH1, θ_1	deg.	Head Angle
2	TH2, θ_2	deg.	Upper Torso Angle
3	TH3, θ_3	deg.	Middle Torso Angle
4	TH4, θ_4	deg.	Lower Torso Angle
5	TH5, θ_5	deg.	Upper Leg Angle
6	TH6, θ_6	deg.	Lower Leg Angle
7	TH7, θ_7	deg.	Upper Arm Angle
8	TH8, θ_8	deg.	Lower Arm Angle
9	TH9, θ_9, θ_n	deg.	Neck angle

NOTE: See Figure 78 for definition.

TABLE 7 INPUT DATA

INITIAL BODY LINK ANGULAR VELOCITIES (RELATIVE TO VEHICLE)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	TH1D, $\dot{\theta}_1$	deg/sec	Head Angular Velocity	0.
2	TH2D, $\dot{\theta}_2$	deg/sec	Upper torso Angular Velocity	0.
3	TH3D, $\dot{\theta}_3$	deg/sec	Middle torso Angular Velocity	0.
4	TH4D, $\dot{\theta}_4$	deg/sec	Lower torso Angular Velocity	0.
5	TH5D, $\dot{\theta}_5$	deg/sec	Upper leg Angular Velocity	0.
6	TH6D, $\dot{\theta}_6$	deg/sec	Lower leg Angular Velocity	0.
7	TH7D, $\dot{\theta}_7$	deg/sec	Upper Arm Angular Velocity	0.
8	TH8D, $\dot{\theta}_8$	deg/sec	Lower Arm Angular Velocity	0.
9	TH9D, $\dot{\theta}_9$, $\dot{\theta}_n$	deg/sec	Neck Angular Velocity	0.

MVMA 2-D Model
Card 302

TABLE 7 INPUT DATA

INITIAL CONDITIONS FOR UPPER TORSO AND NECK
(6 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	XH, x_2	inches (cm)	Initial X coordinate of upper torso C-G relative to vehicle origin.	0.
2	XHD, $\dot{x}_2$	ft/sec (m/sec)	Initial X velocity of upper torso C-G relative to initial vehicle X velocity.	0.
3	ZH, z_2	inches (cm)	Initial Z coordinate of upper torso C-G relative to vehicle origin.	0.
4	ZHD, $\dot{z}_2$	ft/sec (m/sec)	Initial Z velocity of upper torso C-G relative to initial vehicle Z velocity.	0.
5	ELN, L_n	inches (cm)	Initial length of neck.	4.
6	ELND, $\dot{L}_n$	in/sec (cm/sec)	Initial rate of extension of neck.	0.

NOTE: 1. See Figure 2 for definitions of (x_2, z_2) and L_n.

2. L_n cannot be 0. Further, a small value for L_n will necessitate a small integration time step. Δt must be no larger than about 0.5 msec if L_n is 0.1 inches.

3. Note that x_2 is in "inches" while $\dot{x}_2$ is in "ft"/sec, etc.

TABLE 7 INPUT DATA

INITIAL SHOULDER LOCATION AND VELOCITY RELATIVE TO UPPER TORSO ATTACHMENT

Field	Name	Units	Definition	Defaults
1	XS, x_s	in (cm)	Initial X coordinate of shoulder joint relative to upper torso attachment point.	0.
2	XSD, $\dot{x}_s$	in/sec (cm/sec)	Initial X velocity in upper torso system.	0.
3	ZS, z_s	in (cm)	Initial Z coordinate of shoulder joint relative to upper torso attachment point.	0.
4	ZSD, $\dot{z}_s$	in/sec (cm/sec)	Initial Z velocity in upper torso system.	0.

NOTE: See Figure 67 for definition of (x_s, z_s).

MVMA 2-D Model
Card 304

TABLE 7 INPUT DATA

INITIAL LOCATION AND ORIENTATION ANGLE
OF NON-BODY LINK
(9 fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of primary ellipse / non-body link
3	XEMO	in (cm)	Initial value of x-coordinate of non-body link CG relative to Designated Reference System.
4	XEMOD	in/s (cm/s)	Initial x velocity of non-body link CG relative to Designated Reference System.
5	ZEMO	in (cm)	Initial value of z-coordinate of non-body link CG relative to Designated Reference System.
6	ZEMOD	in/s (cm/s)	Initial z velocity of non-body link CG relative to Designated Reference System.
7	THEMO	degrees	Initial value of non-body link orientation angle relative to Designated Reference System.
8	THEMOD	deg/sec	Initial velocity of non-body link orientation angle relative to Designated Reference System.

NOTES:

1. This card is used only for non-body links. (See Cards 219 and 249.)
2. For every Card 219 for which field 5 is negative, a Card 305 with matching ellipse name is required.
3. Values on this card are with respect to the Designated Reference System on Card 219, field 5.

TABLE 7 INPUT DATA

VEHICLE INTERIOR CHARACTERISTICS SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (39:57)		Run subtitle. Used to describe general character of interior panels used to simulate the interior. Columns 1 to 19 of this card become 39 to 57 of subtitle.

TABLE 7 INPUT DATA

DESCRIPTION OF REAL LINE CONTACT REGIONS (CARD 1)
(2 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of region.
3-4			Name of material (Blank if rigid).

NOTE: This is the first of two descriptive cards which must be supplied for each contact region.

TABLE 7 INPUT DATA

DESCRIPTION OF REAL LINE CONTACT REGIONS (Card 2)
(9 fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of Contact Region
3	NSR		Number of line segments in region.
4			Region friction class (1. to 10.)
5	IMIG		Switch: = 0., Structural deformation allowed. This switch controls use of the migration rules Section 2.6.8. 1., Structural deformation not used.
6	KPATCH		KPATCH > 0., Region attached to inertial system KPATCH = 0., Region attached to vehicle system KPATCH < 0., Region attached to system |KPATCH|
7			Switch: = 0., Segment endpoints printed in vehicle coordinates 1., Segment endpoints printed in inertial coordinates

NOTES:

1. Field 6 refers to segment position data on 411-Cards.
2. Field 7 refers to output categories 2 and 3.
3. Contact regions can be attached to any reference system 1. to 10. or to any user-defined (non-body segment) reference system. KPATCH < 0 can be used to designate any system:

-1. = Head	-5. = Upper legs	-9. = Vehicle
-2. = Upper Torso	-6. = Lower legs	-10. = Inertial
-3. = Middle Torso	-7. = Upper arms	-n. = non-body segment number (n>10) for attachment of region
-4. = Lower Torso	-8. = Lower arms	

   If n>10, then associated 219- and 249-Cards are required in the data deck. See the next Note.
4. (Reference Note 3.) A value n>10 indicates that the region is to be attached to a user-defined non-body link in the same manner that a secondary ellipse can be attached by use of a 219-Card. That is, -n (n>10) here corresponds to +n (n>10) on Card 219. Thus, KPATCH < -10. here is allowable only when the data deck includes a 219-Card with a negative value in field 5 and a corresponding 249-Card for user-defined link number |KPATCH| (i.e., value |KPATCH| in field 9).
5. (Reference Notes 3 and 4.) An example pertinent to the case KPATCH < -10. (attachment to non-body segment) is given following Card 219.
6. If -11. < KPATCH < 0., then 219- and 249-Cards are not pertinent.

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of material.
3	DA, δ_A	inches (cm)	*Maximum deflection that allows second loading of inertial spike curve. (normally at peak of curve).
4	DB, δ_B	inches (cm)	*Deflection at cutoff of inertial spike curve. (Should be at F=0)
5	DC, δ_C	inches (cm)	*Deflection at yield point.
6	DE, δ_D	inches (cm)	*Deflection at beginning of breakdown.
7	DF, δ_F	inches (cm)	*Deflection at breaking point.
8	FM, F_{max}	pounds (N)	**Force saturation level (If this quantity is zero, force saturation is not used).
9	DM, β	lbs/in (N/cm)	*Slope of unloading curve from saturation state. (or negative)

NOTES:
1. See Section 2.4.1 and Figures 12 and 81 to 85 for definitions.
2. This is the first of six cards which must be entered for each material specification (vehicle region, ellipse, belt).
3. Required conditions: $0 \leq \delta_A \leq \delta_B \leq \delta_D < \delta_F$; $\delta_C \geq 0$. See Section 2.4.1 regarding definitions.

*4. Belts may have material properties defined optionally in terms of strain. (See Cards 702 and 717.) In this case all δ's in Fields 3 to 7 will have strain units (in/in) and Field 9 will be in force per unit strain.

5. Field 9: If a negative value is in Field 9, then the unloading curve is determined from the G-ratio.

*6. All δ's for joint stop materials are in degrees and unloading slope from saturation is in in-lb/deg or N-m/deg. Units for neck and shoulder link elongation and compression are inches or cm.

**7. "Force saturation level" for joint stop materials has units in-lb or N-M. Units for neck and shoulder link elongation and compression are lbs or N.

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 2)

Field	Name of Quantity	Units	Description
1-2			Name of material.
3	FOREPS, ε_p	pounds(N)	Epsilon for shared-deflection force balancing (allowed error)
*4		lb-sec/in (N-sec/ cm)	Viscous damping coefficient for loading (positive deflection rate)
*5		lb-sec/in (N-sec/ cm)	Viscous damping coefficient for unloading (negative deflection rate)
6			(blank--not used)
7			Name assigned to static curve
8			Name assigned to inertial spike
9			Name assigned to G and R ratios

NOTES:
1. See Section 2.4.1 for fields 2, 7, 8, 9
2. See Section 2.6.10 for fields 4, 5, 6
3. Field 3 applies to contact regions and ellipses and also to belts if body deformations are allowed.
4. Fields 4, 5, (6) may now used for viscous damping parameters. The earlier use was for cavity coefficients $\lambda_1, \lambda_2, \lambda_3$, which are not currently defined on any card in the input data deck. Since the cavity option is not functional, $\lambda_1, \lambda_2, \lambda_3$ are not currently needed, but an input data card will have to be provided for them if the cavity option is made operative.

*5. Joint stop viscous damping coefficients for joint materials have units in-lb-sec/deg or N-m-sec/deg. Damping coefficients for force-strain belt materials have units lb-sec/deg or N-sec/deg.

*6. Joint stop viscous damping coefficients replace, rather than add to, elastic range viscous damping coefficients when deflections are into the joint stops.

7. No viscous damping force will be generated in the absence of an associated deflection-dependent force.

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 3)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1			Name assigned to G and R ratios (See Card 404, Field 9)
2	D, δ	inches (cm)	*Deflection associated with a specified G-ratio. If a negative value is given, G is assumed constant.
3	GEE, G		Ratio of permanent deformation to maximum deflection.

NOTES: 1. See Section 2.4.1 and Figure 12.
2. At least one 405 and one 406 card must be included for each name occurring in field 9 of 404 cards.
*3. Belts may have material properties defined optionally in terms of strain.(See cards 702 and 717.) In this case Field 2 will have strain units (in/in).
4. G should not be 1.
5. Deflection is in degrees for joint stop materials (inches or cm for neck and shoulder link elongation and compression).

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 4)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1			Name assigned to G and R ratios (See Card 404, field 9).
2	D, δ	inches (cm)	*Deflection associated with a specified R-ratio. If a negative value is given, R is assumed constant.
3	ARE, R		Ratio of conserved energy to total energy.

NOTES:
1. See Section 2.4.1 and Figures 12 and 85.
2. At least one 405 and one 406 card must be included for each name occurring in field 9 of 404 cards.

*3. See Note 3 of Card 405.

4. R should not be 0.
5. Deflection is in degrees for joint stop materials (inches or cm for neck and shoulder link elongation and compression).

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 5)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1			Name assigned to static curve (See Card 404, Field 7).
2	D,	inches (cm)	*Deflection at which a value of force is specified. If a negative value is given, polynomial coefficients are to be specified in Fields 3-8.
3	F or C_1	lbs or (N or lbs/in N/cm)	*Force or linear spring constant.
4	C_2	lbs/in^2(N/cm^2)	*Second order polynomial coefficient.
5	C_3	lbs/in^3(N/cm^3)	*Third order polynomial coefficient.
6	C_4	lbs/in^4(N/cm^4)	*Fourth order polynomial coefficient.
7	C_5	lbs/in^5(N/cm^5)	*Fifth order polynomial coefficient.
8	C_6	lbs/in^6(N/cm^6)	*Sixth order polynomial coefficient.

NOTES:
1. See Section 2.4.1 and Figures 12 and 81.
2. At least one 407 card must be included for each name in Field 7 of 404 cards.
3. If a polynomial is selected, force is computed by:

$$F = C_1\delta + C_2\delta^2 + C_3\delta^3 + C_4\delta^4 + C_5\delta^5 + C_6\delta^6$$

If tabular input is selected, more than one 407 card must be supplied.

*4. Belts may have material properties defined optionally in terms of strain. (See Cards 702 and 717.) In this case Field 2 must have strain units and spring coefficients in Fields 3-8 are defined accordingly.

5. Deflection is in degrees for joint stop materials, "force" units are in-lb or N-m, and polynomial coefficients have units in-lb/deg or N-m/deg, etc. Units for neck and shoulder link elongation and compression are as indicated in the eight-field layout above.

MVMA 2-D Model
Card 407 (225,708,816)

TABLE 7 INPUT DATA

MATERIAL PROPERTIES (CARD 6)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1			Name assigned to inertial spike (See Card 404, Field 8)
2	D,	inches (cm)	* Deflection at which a value of force is specified. If a negative value is given, polynomial coefficients are to be specified in Fields 4-9.
3	F or C_1	lbs or (N or lbs/in N/cm)	* Force or linear spring constant.
4	C_2	lbs/in^2 (N/cm^2)	* Second order polynomial coefficient.
5	C_3	lbs/in^3 (N/cm^3)	* Third order polynomial coefficient.
6	C_4	lbs/in^4 (N/cm^4)	* Fourth order polynomial coefficient.
7	C_5	lbs/in^5 (N/cm^5)	* Fifth order polynomial coefficient.
8	C_6	lbs/in^6 (N/cm^6)	* Sixth order polynomial coefficient.

NOTES:
1. See Section 2.4.1 and Figures 12 and 82.
2. At least one 408 card must be included for each name in Field 8 of 404 cards.
3. If a polynomial is selected, force is computed by:

$$F = C_1\delta + C_2\delta^2 + C_3\delta^3 + C_4\delta^4 + C_5\delta^5 + C_6\delta^6$$

If tabular input is selected, more than one 408 card must be supplied.

*4. See Note 4 of Card 407.

5. The inertial spike curve should be zero at δ_B. See Card 403.

6. See Note 5 of Card 407 for joint stop materials.

TABLE 7. INPUT DATA

LINE PARAMETERS WITHIN A REGION (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to line segment.
3-4			Name assigned to region.
5		inches(cm)	Penetration limit.
6			Edge constant.
7			Direction factor (defines front and rear of segment).
8			Line segment position within the region, from 1. to NSR where 1. = segment at one end of region and NSR = segment at other end of region (See Card 402, Field 3).

NOTES:
1. See Section 2.6.3 for Field 8. Also Figure 89.
2. See Section 2.6.2 for Field 6. Also Figures 87 and 88.
3. See Section 2.6.3 for Field 5.
4. The first endpoint of the first segment in a region is numbered "1." The remaining segments are numbered consecutively.
5. This is the first of three cards which must be included for each line segment.

MVMA 2-D Model
Card 409

TABLE 7 INPUT DATA

LINE PARAMETERS WITHIN A REGION (CARD 2)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to line segment
3			Number of time points for which the location of this line segment is to be specified.
4	XG(I+1), γ_{i+1}	in/lb sec^2 or 1/mass(1/kg)	Mass compliance at second endpoint.
5	XK(I+1), k_{i+1}	in lbs/deg(N-m/deg)	Bending constant at second endpoint.
6	XG(I), γ_i	in/lb sec^2 or 1/mass(1/kg)	Mass compliance at first endpoint
7	XK(I), k_i	in lbs/deg(N-m/kg)	Bending constant at first endpoint.

NOTES:
1. The last two fields are used only when Card 409, field 8 = 1.
2. I = 1, ..., NSR (See Card 402, Field 3).
3. See Section 2.6.8 for Fields 4-7.
4. This is the second of three cards which must be included for each line segment.

MVMA 2-D Model
Card 410

TABLE 7 INPUT DATA

LINE SEGMENT LOCATION
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to line segment.
3	T, t	msec	Time at which line segment location is specified. If a negative number is entered, line segment location is time-independent and only one 411 card need be entered.
4	XHAT(1), x_i	inches (cm)	x-coordinate of first endpoint.
5	XHAT(2), z_i	inches (cm)	z-coordinate of first endpoint.
6	XHAT(3), x_{i+1}	inches (cm)	x-coordinate of second endpoint.
7	XHAT(4), z_{i+1}	inches (cm)	z-coordinate of second endpoint.
8	II		Enter 1., 2., 3., 4., 5., or 6. on t=0 cards to indicate that first endpoint is a point of the frontal interior outline for airbag contact.

Notes:
1. All coordinates should be given with respect to the coordinate system specified on Card 402, Field 6 for the corresponding region (Inertial or vehicle).
2. All values must be filled in through field 7.
3. These cards must be ordered with respect to time for each line segment.
4. Field 8: Two to six points must be indicated if airbag is present. 1. should be for bottom of toeboard. Numbers must be used sequentially and the largest number should be for a point near the top of the windshield. Number of points minus one equals number of lines.
5. No line segment should pass exactly through the inertial origin at t=0.
6. See Section 2.6.8 and Figure 27 for definitions.
7. The coordinates of the first endpoint of the second segment in a region must be identical to the coordinates of the second endpoint of the first segment, etc.

MVMA 2-D Model
Card 411

TABLE 7 INPUT DATA

FRICTION AND PLOWING CONSTANTS
(9 fields of 8)

Field	Name of Quantity	Units	Description	Default
1	I	-	Magnitude is ellipse friction class (1. to 5.). If <0, then plowing resistance is desired in negative line direction (see Notes 1-4).	
2	J	-	Magnitude is region friction class (1. to 10.). If <0, then plowing resistance is desired in positive line direction (see Notes 1-4).	
3	CMU1	-	Constant friction coefficient	0.
4	CMU2	1/in (1/cm)	Linear friction coefficient	0.
5	CMU3 or PMAX	1/in**2 (1/cm**2) or lb (N)	Quadratic friction coefficient if KONTLP=0 (see Note 3). *Full value for plowing force (constant) if KONTLP<>0.	0.
6	PMIN	lb (N)	Static, or residual, plowing force (tangential force from broken surface against non-moving ellipse)	
*7	PNU	in (cm)	Deflection (normal to surface) at which full plowing resistance PMAX is applied. Plowing force is ramped linearly for deflection < PNU.	
8	PBETA	lb/in (N/cm) -	If >0, unloading slope from plowing at turnaround. If <0, magnitude is G-ratio for permanent plowing deformation.	
*9	YNU	in/sec (cm/s) sec/in (s/cm)	If >0, plowing velocity at which full resistance is applied; plowing is ramped linearly for plowing velocity < YNU. If <0, magnitude is slope of velocity-ramp factor; force>PMAX allowed.	

NOTES:

1. Friction force for any ellipse/line interaction allowed by 106-Card specification will be zero unless (nonlinear) coefficient of friction data are given on this card for the ellipse/region friction class combination. (See Cards 219/402.) Plowing force parameters for the interaction are specified on the same 412-Card. [There must be only one 412-Card for any interaction].

2. Friction force is computed as the product of the normal force and a nonlinear friction coefficient CMU, where DEL is deflection normal to the surface and

   CMU = CMU1 + CMU2 * DEL + CMU3 * DEL**2 . (CMU3 = 0 if plowing has been selected.)

3. The value KONTLP (plowing resistance control) is determined from the signs of fields 1 and 2.

		Field 1 +	Field 1 -
Field 2	+	0	-1
	-	+1	2

   Table for KONTLP [Note that plowing can be specified for either direction, both, or neither.]

4. Positive line direction is clockwise around the vehicle interior; negative is counterclockwise.

*5. Normally, the plowing force (in loading) is: (deflection-ramp factor) x (velocity-ramp factor) x PMAX, where the ramp factors become 1.0 for normal deflection and plowing velocity greater than PNU and YNU.

6. Typical plowing parameter values for windshield: PMAX = xxxx N, PMIN = xx N, PNU = x cm, PBETA = +xxxxx N/cm, YNU = +xxx cm/sec

TABLE 7 INPUT DATA

UNLOADING CURVES
(3 Fields of 8)

Fields	Name of Quantity	Units	Description
1-2			Name of Material
3	NBI		Number of unloading curves to be specified for this material

NOTES: 1. NBI cards with unloading curve specifications must immediately follow this card.

2. G- and R- ratios are ignored for a material for which unloading curves are specified.

TABLE 7 INPUT DATA

UNLOADING CURVES
(5 Fields of 8)

Fields	Name of Quantity	Units	Description
1	δ_1	in (cm)	Deflection for complete unloading, δ_1
2	δ_2	in (cm)	Deflection at break in bilinear curve, δ_2
3	δ_3	in (cm)	Deflection at beginning of unloading, δ_3
4	S_1	lb/in (N/cm)	Slope of lower segment of bilinear unloading curve, S_1
5	S_2	lb/in (N/cm)	Slope of upper segment of bilinear unloading curve, S_2

NOTES: 1. For each material, prescribed unloading curves must be in order of increasing deflection at beginning of unloading (δ_3).

2. See field 3 and notes for Card 413.

TABLE 7 INPUT DATA

VEHICLE INTERIOR CONFIGURATION SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (58:76)		Run subtitle for Vehicle Interior Configuration Input Block. Columns 1 to 19 of this card become columns 58 to 76 of subtitle.

NOTE: See note on Card 200.

TABLE 7 INPUT DATA

BELT ANCHOR POINTS (RELATIVE TO VEHICLE ORIGIN)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	XVAI (1), X_1^{VA}	inches (cm)	Lap belt inboard anchor point. (x-coordinate)
2	ZVAI (1), Z_1^{VA}	inches (cm)	Lap belt inboard anchor point. (z-coordinate)
3	XVAI (2), X_2^{VA}	inches (cm)	Lap belt outboard anchor point. (x-coordinate)
4	ZVAI (2), Z_2^{VA}	inches (cm)	Lap belt outboard anchor point. (z-coordinate)
5	XVAI (3), X_3^{VA}	inches (cm)	Torso belt upper anchor point. (x-coordinate)
6	ZVAI (3), Z_3^{VA}	inches (cm)	Torso belt upper anchor point. (z-coordinate)
7	XVAI (4), X_4^{VA}	inches (cm)	Torso belt lower anchor point. (x-coordinate)
8	ZVAI (4), Z_4^{VA}	inches (cm)	Torso belt lower anchor point. (z-coordinate)

NOTE: See Section 2.5.1 and Figure 16 for definitions.

NOTE: This card is not needed if the advanced belt system BELT2 has been selected. See Cards 710-723.

TABLE 7 INPUT DATA

VEHICLE IMPACT SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (77:95)		Run subtitle for Vehicle Impact Specification Input Block. Columns 1 to 19 of this card become columns 77 to 95 of subtitle.

NOTE: See note on Card 200.

TABLE 7 INPUT DATA

VEHICLE INITIAL CONDITIONS AND ACCELEROMETER LOCATION
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	XV, X_v	inches (cm)	X coordinate of vehicle origin	0.
2	XVD, $\dot{X}_v$	ft/sec (m/sec)	X component of initial vehicle velocity	0.
3	ZV, Z_v	inches (cm)	Z coordinate of vehicle origin	0.
4	ZVD, $\dot{Z}_v$	ft/sec (m/sec)	Z component of initial vehicle velocity	0.
5	THV, θ_v	degrees	Initial vehicle pitch angle	0.
6	THVD, $\dot{\theta}_v$	deg/sec	Initial vehicle pitch angular velocity	0.
7	AA, a	inches (cm)	X coordinate of vehicle accelerometer in vehicle frame	0.
8	C , c	inches (cm)	Z coordinate of vehicle accelerometer in vehicle frame	0.
9	VM		0. = vehicle motion data are specified as x- and z-accelerometer readings 1. = inertial x and z accelerations are specified for the vehicle origin 2. = inertial x and z positions are specified for the vehicle origin 3. = inertial x acceleration and inertial z position are specified for the vehicle origin 4. = inertial x position and inertial z acceleration are specified for the vehicle origin -1. = translational vehicle motion is defined by x-accelerometer reading data and the time-varying position of a pivot point	1.

NOTES:
1. See Section 2.9 for discussion of vehicle motion.
2. For Version 3, Card 601 must precede Cards 602, 603, and 604 in the data deck unless Card 601 is defaulted.
3. Field 9 is not used for Version 4.
4. If position points are to be specified (field 9 = 2.,3.,4., or -1., or field 2 of Card 604 = 2. or 3.), the integration time step on Card 101 should be no greater than half the minimum difference between any two successive time coordinates in the time-position tables. Equivalently, for a given integration time step Δt, the minimum spacing in the position tables should be at least 2Δt.
5. See Note 9 on Card 603.
6. See Section 3.2-A.2 with regard to specifying vehicle pitching motion with the pivot point method (field 9 of Card 601 equal to -1.).

TABLE 7 INPUT DATA

VEHICLE HORIZONTAL ACCELERATION VERSUS TIME
(4 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults**
1	NPX		Number of time-acceleration or time-position pairs.	24.
2	HEAD (1)		Acceleration or position indicator 0. = in/sec^2 or in (m/sec^2 or cm) 1. = g's	1.
3	DCONTL(1)		For position input only. The fraction of current position ramp length over which full velocity change takes place. (See Note 7.)	0.
*4	DCONTL(2)	in/sec^2(cm/sec^2)	For position input, estimated maximum magnitude for the inertial x-acceleration. (See Note 5.)	10000.(25400.)

NOTES:
1. The type of motion specified must be as indicated in field 9 of Card 601.
2. Acceleration (or position) data follow on succeeding unnumbered cards, four time (MSEC) - acceleration (or position) pairs per card starting in field 1 and filling eight fields.
3. Summed field 1 values for Cards 602, 603, and 604 cannot exceed 903.
4. See Note 2 on Card 601.

*5. Note that the required metric system units for DCONTL(2) are cm/sec^2, not m/sec^2 or g's. Must be greater than zero.

6. Position specification is not allowed for Version 4.
7. For each position ramp, of time length t_2-t_1, velocity ramps to full values over DCONTL (1)*(t_2-t_1) and then remains constant through t_2. Acceleration is slope of velocity curve. (See Figure 32.) A good value for DCONTL(1) may be selected in the following manner: a) Let n be the number of integration time steps within the smallest difference between any two successive time coordinates in the time-position table. (n should be at least 2.); b) Take DCONTL(1) as ≈ 8/3n, or ≈ 3/n.

** The "AMA Frontal Barrier Profile" is used for default. The twenty-four time-acceleration pairs for the 30 mph frontal collision are as follows:

(0.,0.)(5.,-.5)(10.,-2.)(15.,-4.)(20.,-9.5)(25.,-16.5)(30.,-15.5)
(35.,-15.)(40.,-15.)(45.,-15.5)(50.,-15.)(60.,-15.)(65.,-14.5)(70.,-15.5)
(75.,-18.5)(80.,-19.)(85.,-19.)(90.,-17.)(95.,-14.7)(100.,-11.7)
(105.,-8.5)(110.,-4.5)(115.,0.)(2000.,0.)

Default times are in milliseconds and accelerations are in g's.

MVMA 2-D Model
Card 602

TABLE 7 INPUT DATA
VEHICLE VERTICAL ACCELERATION VERSUS TIME
(7 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults**
1	NPZ		Number of time-acceleration or time-position pairs if field 9 Card 601 is non-negative. Otherwise, the number NPZ of timepoints for which the inertial Z position of a "pivot point" is specified.	2.
2	HEAD(2)		Acceleration or position units indicator 0. = in/sec^2 or in (m/sec^2 or cm) 1. = g's	0.
3	NPP		Number of time-position pairs for instantaneous x position (in vehicle frame) of the "pivot point"	0.
4	NPQ		Number of time-position pairs for instantaneous z position (in vehicle frame) of the "pivot point"	0.
5	DCONTL(3)		For position input only (including pivot coordinates). Time interval fraction for velocity ramping. See Note 7, Card 602.	0.
*6	DCONTL(4)	in/sec^2(cm/sec^2)	For position input (including pivot), estimated maximum magnitude for the inertial acceleration. (See Note 5.)	5000. (12700.)
*7	DCONTL(5)	in/sec^2(cm/sec^2)	For pivot input, estimated maximum magnitude for the rate of velocity change (x- or z-acceleration) within the vehicle frame for the changing location of the pivot point. (See Note 5.)	2000. (5080.)

NOTES:
1. The type of motion specified must be as indicated in field 9 of Card 601. Also see Section 2.9.
2. Acceleration (or position) data follow on succeeding unnumbered cards, four time (msec)-acceleration (or position) pairs per card starting in field 1 and filling eight fields. For pivot data there must be three sets of unnumbered cards, for NPZ, NPP, and NPQ points.
3. Fields 3 and 4 are not used if field 9 of Card 601 is non-negative.
4. If pivot point data are specified, this card is followed by three sets of unnumbered cards. The first set is for the NPZ time-position pairs described for field 1. The second and third sets are for the NPP and NPQ time-position pairs described for fields 3 and 4.

*5. Note that the required metric system units for DCONTL(4) and DCONTL(5) are cm/sec^2, not m/sec^2 or g's. Must be greater than zero.

6. See Note 2 on Card 601.
7. See Note 3 on Card 602.
8. For input of pivot data, z-accelerometer printout calculated by the program will be "jumpy" (although not necessarily inaccurate) unless all of the following are smooth: a) X-accelerometer input; b) angular acceleration (from direct entry or numerical differentiation of tabular $\theta_Y(t)$); c) inertial Z-acceleration of pivot point (second derivative of Z input). Even when z-accelerometer calculations are unreliable, vehicle inertial velocities and displacements will be good, and only these terms enter the equations of motion.
9. Take care to prescribe compatible time zero values for the inertial and vehicle relative pivot point coordinates and the vehicle pitch angle and z coordinate of the vehicle origin on Card 601. These five values should satisfy equation (314.1) of Volume 1. If they do not, ZV (for Card 601) will be adjusted by the program and a warning will be printed.

** The default time-acceleration pairs are: (0.,0.) (2000.0.)

10. See Section 3.2-A.2 with regard to specifying vehicle pitching motion with the pivot point method (field 9 of Card 601 equal to -1.).

TABLE 7 INPUT DATA
VEHICLE ANGULAR ACCELERATION VERSUS TIME
(4 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults*
1	NPTH		Number of time - acceleration or time-angle pairs	2.
2	TRAD		0. = deg/sec^2 2. = deg (angle input) 1. = rad/sec^2 3. = rad (angle input)	0.
3	DCONTL(6)		For angle input only. Time interval fraction for velocity ramping. See Note 7, Card 602.	0.
4	DCONTL(7)	(units--see Note 2)	For angle input, estimated maximum magnitude for the angular acceleration.	5000.

NOTES:
1. Acceleration (or angle) data follow on succeeding unnumbered cards, four time (MSEC) - acceleration (or angle) pairs per card starting in Field 1.
2. Units for DCONTL(7) must be deg/sec^2 if field 2 is 2. and rad/sec^2 if field 2 is 3.
3. See Note 3 on Card 602 and Note 2 of Card 601.
4. A value of 3000. to 7000. is recommended for field 4.

*5. The default time-acceleration pairs are: (0.,0.) (5000.,0.)

6. See Section 3.2-A.2 with regard to specifying vehicle pitching motion with the pivot point method (field 9 of Card 601 equal to -1.).

TABLE 7 INPUT DATA

HEAD APPLIED FORCE SPECIFICATIONS

Field	Name of Quantity	Units	Definition
1	MUSNAM (1-2, 12)		Name assigned to applied force table F_x vs time (up to 8 characters); leave blank if no F_x table.
2	MUSNAM (1-2, 13)		Name assigned to applied force table F_z vs time (up to 8 characters); leave blank if no F_z table.
3	JFORCE		0. if applied force components are in the inertial frame; non-zero if in the head coordinate system
4	AF, a	in (cm)	X coordinate in head system of point of application of force vector (positive toward feet from head c.g.).
5	CF, c	in (cm)	Z coordinate in head system of point of application of force vector (positive rearward from head c.g.).

NOTE: Printout for head applied forces is obtained by requesting Categories 30 and 31 on Cards 110 and 1001/1002.

TABLE 7 INPUT DATA

HEAD APPLIED FORCE COMPONENT VERSUS TIME

Field	Name of Quantity	Units	Definition
1			NAME assigned to applied force table (F_x or F_z) vs. time.
2	t	msec	Time associated with a specified force value.
3	FORCEX, FORCEZ, F_x, F_z	lb (N)	Component of applied force vector.

NOTE: Printout for head applied forces is obtained by requesting Categories 30 and 31 on Cards 110 and 1001/1002.

MVMA 2-D Model
Card 606

TABLE 7 INPUT DATA

BELT RESTRAINT SYSTEM SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (96:114)		Run Subtitle for Belt Restraint System Input Block. Columns 1 to 19 of this card become columns 96 to 114 of subtitle.

NOTE: See note on Card 200.

TABLE 7 INPUT DATA

BELT SYSTEM PARAMETERS (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	LBLO, l_o^{BL}	inches(cm)	Total lap belt length.
2	DELBL, Δ^{BL}	inches(cm)	Total lap belt slack.
3	LBTUO, ℓ^{BU}	inches(cm)	Total upper torso belt length.
4	DELBTU, Δ^{BU}	inches(cm)	Total upper torso belt slack.
5	FBLMAX, F_{MAX}^{BL}	lbs(N)	Lap belt breaking force.
6	FBTMAX, F_{MAX}^{BT}	lbs(N)	Torso belt breaking force.
7	DELTB, Δt_B	msec	Time duration for belt failure.

NOTE: See Section 2.5.1 for analysis.

NOTE: This card is not needed if the advanced belt system BELT2 has been selected. See Cards 710-723.

TABLE 7 INPUT DATA

BELT SYSTEM PARAMETERS (CARD 2)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to lap belt material.
3-4			Name assigned to body material for shared deflection with lap belt (or blank if shared deflection with belt is not desired).
5	LBTLO, ℓ^{BT}	inches (cm)	Total lower torso belt length.
6	DELBTL, Δ^{BT}	inches (cm)	Total lower torso belt slack.
7	LBTLA		Lower torso belt attachment indicator 2. = upper torso link 4. = lower torso link otherwise = middle torso link
8	LBSTAN		Switch = { 0, Force-strain input data. 1, Force-deflection input data.

NOTE: See Section 2.5.1 for analysis.

NOTE: This card is not needed if the advanced belt system BELT2 has been selected. See Cards 710-723.

MVMA 2-D Model
Card 702

TABLE 7 INPUT DATA

BELT SYSTEM PARAMETERS (CARD 3)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to upper torso belt material
3-4			Name assigned to body material for shared deflection with upper torso belt (or blank if shared deflection with belt is not desired).
5-6			Name assigned to lower torso belt material.
7-8			Name assigned to body material for shared deflection with lower torso belt (or blank if shared deflection with belt is not desired).

NOTE: See Section 2.5.1 for analysis.

NOTE: This card is not needed if the advanced belt system BELT2 has been selected. See Cards 710-723.

TABLE 7 INPUT DATA

BELT MATERIAL CARDS
(9 Fields of 8)

Field	Name of Quantity	Units	Description

NOTES:

1. Belt material properties are specified in the same manner as contact region material properties. See Cards 403-408 for format. These cards must be present for either the MODROS belt option (BELT) or the advanced belt system (BELT2).

2. (BELT option) If Card 702, Field 8 is set for force-strain, all deflections will be interpreted as strains.

3. (BELT2 option) If Card 717, Field 8 is set for force-strain, all deflections will be interpreted as strains.

4. See notes for Cards 704-709 in Section 3.2.

5. With regard to assigning belt material names for the belt segments in the advanced belt system, see Note 2 of Card 720.

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1	ATTANC(1,1,J)	in(cm)	X-coordinate on body segment of belt attachment point (along centerline from upper joint of torso segment of attachment)
2	ATTANC(1,2,J)	in(cm)	Z-coordinate on body segment of belt attachment point (measured perpendicular to torso segment toward front of body)
3	ATTANC(2,1,J)	in(cm)	X-coordinate in vehicle of belt anchor
4	ATTANC(2,2,J)	in(cm)	Z-coordinate in vehicle of belt anchor
5	SLAK(J) (J=1-4) BL(J) (J=5-7)	in(cm)	Initial belt slack (negative if initial tension) for belts 1-4 or total initial unstrained belt length for belts 5-7
6-7	-	-	Belt material name (see cards 704-709)
8-9	-	-	Force-deflection material name for body segment, anchor deformation/belt spoolout, or composite (body and anchor/spoolout).

NOTES:

1. See Figures 90 and 91.
2. Anchor point for belt 1 is not needed if belt 6 is present.
3. Anchor points for belts 2 & 3 are not needed if belt 5 is present.
4. Fields 1, 2, 8, 9 not used for belts 5,6,7 (Cards 714-716)
5. Attachment points for belts 3 and 4 should be coincident.
6. The attachment point for belts 3 and 4 is adjusted at each time step. See Section 2.5.2.7.
7. Card 710 = belt 1 = upper torso belt
   Card 711 = belt 2 = lower torso belt
   Card 712 = belt 3 = inboard lap belt
   Card 713 = belt 4 = outboard lap belt
   Card 714 = belt 5 = lower ring strap
   Card 715 = belt 6 = upper ring strap
   Card 716 = belt 7 = upper torso belt extension
8. With regard to material names, see Note 2 of Card 720.
9. Belts 5 and 6 cannot both be specified.
10. Fields 8-9 not needed if body and anchor are both rigid for belt interactions. Material properties, if specified, are for deflections in the direction of belt loading. (See Section 3.2-A.2.)

MVMA 2-D Model
Card 710-716

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM PARAMETERS
(7 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	INFLNC	_	Type of interbelt influence adjustment for torso belt tensions: 0. = no adjustment, 1. = normal-force friction, 2. = saturation based on force difference, 3. = percent influence	1.
2	MBELT	-	0. = Force-deflection material properties for all belts ≠ 0. = Force-strain material properties for all belts	1.
3	LBTLA	-	Lower torso belt attachment indicator 2. = upper torso segment 3. = middle torso segment 4. = lower torso segment	4.
4	YSEP(1)	in(cm)	*Out-of-plane separation between torso belt attachment points	0.
5	YSEP(2)	in(cm)	*Out-of-plane separation between lap belt attachment points	0.
6	II(1)		Method for calculating first estimate of torso belt forces: 0. = fixed attachment, 1. = free slipping ("force equalization")	1.
7	II(3)		Same except for lap belt.	1.

NOTES:
1. For Fields 6 and 7, "free slipping" means force equalization in the two torso or lap belt segments by considering a single deflection for the combined length of these two and all other belt segments acting together.
2. Fields 1, 6, and 7 should be nonzero for most realistic results in normal operation.
3. If Field 1 is 1., two different approaches to calculation of belt friction across the torso may be used. 1) If Field 6 is zero, the first estimate to torso belt tensions (unadjusted for friction) is based on the assumption of no-slip belts ($\mu=\infty$). 2) If Field 6 is nonzero, the first estimate is based on free slipping ($\mu=0$). The second approach is preferred. See Note 2 on Card 719.
4. Regarding fields 1, 6, and 7, see Note 2 of Card 720.
5. Field 2 must be set non-zero.
*6. See Figure 93-A.
7. All non-zero Field 1 options represent methods of adjusting torso belt forces for the effects of slippage, with friction, across the torso.

MVMA 2-D Model
Card 717

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM: RING FORCE EQUILIBRIUM PARAMETERS

(5 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	IPRMT(2)		1. = program is allowed to reset user-specified ring strap stiffness if it is too large relative to stiffnesses of other belts at ring (warning is printed). -1. = program is not allowed to reset stiffness	1.
2	IPRMT(3)	-	Maximum number of iterations allowed per evaluation for force balance at ring	30.
3	REPS	lbs(N)	Force epsilon for x-, y-, and z-force balance	11.2405 50.
4	-	-	(unused)	
5	XLAPAJ	-	≥ 0. = for system without ring strap, lap belt attachment points on lower torso link is allowed to adjust as links angle change < 0. = adjustment of lap belt attachment point not allowed	0.

NOTES:
1. If belts 5 and 6 are absent, this card is not needed.
2. If a ring strap is present, the program determines its deflection stiffness (strain stiffness divided by unstrained length) and that of other belts leading to the ring. Since the program may not be able to determine a ring position for which there is a force equilibrium if the ring strap stiffness is greater than about ten times the maximum stiffness of the other belts, it is set to that limit if this is allowed by the switch in field 1 of this card. A warning is printed regardless of the switch setting if the ring strap stiffness is too large.
3. Field 2 should have a value between 10. and 30. Field 3 should be greater than 20N (4.49618 lb).

TABLE 7 INPUT DATA

TORSO INTERBELT INFLUENCE
(7 Fields of 8)

Field	Name of Quantity	Units	Description
1	BMUK	-	Kinetic friction coefficient for torso belt with body
2	BMUS	-	Static friction coefficient for torso belt with body
3	ZINFL, ζ	-	*Fraction of total friction force adjustment to be apportioned to lower tensioned torso belt (influencee). (Value .5 is recommended.)
4	INF(1,2)	-	1. = tension in belt 1 (influencer) causes adjustment in tension for belt 2 (influencee) -1. = belt 2 is influencer, belt 1 is influencee
5	RFSAT, F_S	lbs(N)	Force difference saturation level for torso belts
6	AFSAT, F_B	lbs(N)	Maximum force influence for influencer or influencee
7	PERCNT, p_{ij}	-	Positive or negative percent influence (fractional) for modification of influencee by influencer

NOTES: 1. Certain fields of this card are needed only for certain values of INFLNC , Field 1 of Card 717.

INFLNC	Fields of Card 719 Needed
0.	none (leave out card)
1.	1,2,3,(4)
2.	5
3.	4,6,7

2. For the case INFLNC=1., field 4 of this card is used only if field 6 of Card 717 is nonzero. In this case, the value for INF should normally be 1. since the upper torso belt tension may normally be expected to exceed the lower torso belt tension.

3. For field 4, the influencer should normally be selected as the belt expected to have the greater tension.

*4. The fraction (1 - ζ) is apportioned to the higher tensioned torso belt (influencer). (See Section 2.5.2.3.)

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM ANCHOR AND RING PARAMETERS
(8 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	ANCHOR(1)	-	Anchor 1 type: 0. = free (absent or broken) 1. = belt 4, 5, 6, or 7 fixed to anchor (ring is present) 2. = belt 5, 6, or 7 with inertia reel 3. = anchored ring (ring strap absent) or belt 1, 2, 3, or 4 fixed at anchor	3.
2	ANCHOR(2)		Anchor 2 type (See Field 1)	3.
3	ANCHOR(3)		Anchor 3 type (See Field 1)	3.
4	ANCHOR(4)		Anchor 4 type (See Field 1)	1.
5	RING(1)		Belt influence type for upper harness ring: 1. = fixed to (torso) belt or ring absent 2. = friction with belt 3. = free (belt slips freely, no friction)	1.
6	RING(2)		Belt influence type for lower harness ring	1.
7	RINGMU(1)		Coefficient of friction for belt slipping at upper harness ring (needed only if RING(1) = 2.)	0.
8	RINGMU(2)		Coefficient of friction for belt slipping at lower harness ring (needed only if RING(2) = 2.)	0.

NOTES:
1. See Figures 90, 92, and 93.
2. Specification of RING( )=1. makes the parts of the belt system on either side of the ring independent. In general, parts of the belt system are independent if separated by no-slip specifications at ring or body. Any belt segments that should be treated as parts of a common strap should be assigned the same material. Whenever belts should be treated as a common strap but the materials for the separate segments are different, the program arbitrarily uses the material for one of the members. (Version 3 prints a warning message.) Specifically, the conditions that make contiguous parts of the system independent are: 1) RING( )=1.; 2) II(3)=0. for lap belts (field 7 of Card 717); 3) INFLNC=0. and II(1)=0. for torso belts (fields 1 and 6 of Card 717).
3. If Ring( ) = 3., then RINGMU( ) is ignored.

MVMA 2-D Model
Card 720

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM SPOOL LOCKUP

(6 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	REEL(1)	-	1. = inertia reel at anchor 1 is vehicle sensitive 0. = inertia reel at anchor 1 is webbing sensitive	1.
2	TLOCK(1)	msec	Time at which reel 1 locks (vehicle sensitive)(or -1.)	-1.
3	ALOCK(1)	g's	Value for resultant acceleration at reel 1 which will cause it to lock (vehicle sensitive)	.4
4	PLOCK(1)	deg	Value of vehicle pitch angle which will cause reel 1 to lock (vehicle sensitive)	14.
5	VLOCK(1)	in/sec (cm/sec)	Velocity for belt feed-out which will cause reel 1 to lock (webbing sensitive) (or -1.)	-1.
6	ALOCK(1)	g's	Acceleration for belt feed-out which will cause reel 1 to lock (webbing sensitive) (or -1.)	.75

NOTE: Use only Field 2 or Fields 3 and 4 if Field 1 is 1. (enter -1. in field 2 if fields 3 & 4 are used)
Use only Field 5 or Field 6 if Field 1 is 0. (enter -1. in Field 5 or 6, whichever is not used)

NOTE: This card is needed only if Field 1 of Card 720 is 2.

MVMA 2-D Model
Card 721

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM SPOOL LOCKUP
(6 Fields of 8)

Field	Name of Quantity	Units	Description
1	REEL(2)	-	
2	TLOCK(2)	msec	
3	ALOCK(2)	g's	same as Card 721 except for lockup at anchor 2
4	PLOCK(2)	deg	
5	VLOCK(2)	in/sec(cm/sec)	
6	ALOCK(2)	g's	

NOTE: Use only Field 2 or Fields 3 and 4 if Field 1 is 1. (enter -1. in field 2 if fields 3 & 4 are used)
Use only Field 5 or Field 6 if Field 1 is 0. (enter -1. in Field 5 or 6, whichever is not used)

NOTE: This card is needed only if Field 2 of Card 720 is 2.

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM SPOOL LOCKUP
(6 Fields of 8)

Field	Name of Quantity	Units	Description
1	REEL(3)	-	Same as Card 721 except for lockup at anchor 3.
2	TLOCK(3)	msec	
3	ALOCK(3)	g's	
4	PLOCK(3)	deg	
5	VLOCK(3)	in/sec(cm/sec)	
6	ALOCK(3)	g's	

NOTE: Use only Field 2 <u>or</u> Fields 3 and 4 if Field 1 is 1. (enter -1. in Field 2 if Fields 3 & 4 are used)
Use only Field 5 <u>or</u> Field 6 if Field 1 is 0. (enter -1. in Field 5 or 6, whichever is not used)

NOTE: This card is needed only if Field 3 of Card 720 is 2.

TABLE 7 INPUT DATA

UNLOADING CURVES
(3 Fields of 8)

NOTE: Belt material unloading curves are specified in the same manner as curves for contact region materials. See Card 413 for format.

MVMA 2-D Model
Card 724
(413)

TABLE 7 INPUT DATA

OUT-OF-PLANE BELT SYSTEM DIMENSIONS
(7 Fields of 8)

Field	Name of Quantity	Units	Description
1	YDEL(1)	in(cm)	y-separation between anchor (or ring) and attachment for belt 1
2	YDEL(2)	in(cm)	y-separation between anchor (or ring) and attachment for belt 2
3	YDEL(3)	in(cm)	y-separation between anchor (or ring) and attachment for belt 3
4	YDEL(4)	in(cm)	y-separation between anchor and attachment for belt 4
5	YDEL(5)	in(cm)	y-separation between ring and anchor for belt 5
6	YDEL(6)	in(cm)	y-separation between ring and anchor for belt 6
7	YDEL(7)	in(cm)	y-separation between ring and anchor for belt 7

Notes:

1. Out-of-plane separations between torso belt attachments and lap belt attachments are entered in fields 4 and 5 of Card 717 (YSEP(1) and YSEP(2)).
2. ---
3. YDEL(1-4) positive if anchor (ring) is farther from the occupant's mid-plane than is the belt attachment. YDEL(5-7) positive if belt anchor is farther from the occupant's mid-plane than is the ring.
4. See Figure 93-A.

TABLE 7 INPUT DATA

BELT LENGTHS **
(7 Fields of 8)

Field	Name of Quantity	Units	Description
1	BELTL(1)	in(cm)	Unstrained length of belt 1 (upper torso belt)
2	BELTL(2)	in(cm)	Unstrained length of belt 2 (lower torso belt)
3	BELTL(3)	in(cm)	Unstrained length of belt 3 (inboard lap belt)
4	BELTL(4)	in(cm)	Unstrained length of belt 4 (outboard lap belt)
5	BELTL(5)	in(cm)	Unstrained length of belt 5 (lower ring strap)
6	BELTL(6)	in(cm)	Unstrained length of belt 6 (upper ring strap)
7	BELTL(7)	in(cm)	Unstrained length of belt 7 (upper torso belt extension)

NOTES:

1. This card is optional for all simulations. Unstrained belt lengths are normally calculated by the model from endpoint coordinates and slack. However, those calculations will be omitted for any belt for which a nonzero length is entered on this card. The calculation is omitted also for one case of a zero entry: in the case that a belt pair participates in free slipping (see Note 4) and/or is not (for torso belts only) an "independent "belt pair (i.e., INFLNC is not zero--Card 717), then if one BELTL( ) is zero and the other is nonzero, the nonzero value is assumed to be the total length for the pair.

**2. Unstrained lengths are the webbing lengths in three dimensions (including slack).

3. If the force equalization option is selected for the lap belt (Card 717, field 7), then the individual lap belt segment lengths are not important, only their sum. This sum should include any out-of-plane separation between attachment points since YSEP(2) on Card 717 will be ignored if BELTL(3) and/or BELTL(4) are nonzero and force equalization has been selected. Similar considerations apply for the torso belts if force equalization is selected (Card 717, field 6). YSEP(1) will be ignored if BELTL(1) and/or BELTL(2) are nonzero. Webbing between the attachment points for belts 1 and 2 should be included in BELTL(1) and/or BELT2(2) if force equivalization is selected.

4. Unstrained belt lengths, whether calculated or specified, are used for calculating belt strain: $\varepsilon/\delta/L_o$, where δ is deflection and L_o is unstrained webbing length.

**5. Use of this card is recommended. Lengths specified are for webbing lengths (without hardware) in three-dimensional space and they must account for all acting, unspooled webbing.

MVMA 2-D Model
Card 726

TABLE 7 INPUT DATA

ADVANCED BELT SYSTEM BELT RETRACTOR PARAMETERS
(2 Fields of 8)

Field	Name of Quantity	Units	Description
1	n	-	Belt Number (1., 2., ..., or, 7.)
2	FMAXRT(n)	lbs(N)	Maximum belt tension allowed during retraction (lock-up force)

NOTE: This card is followed by a sequence of unlabeled cards which specify as a tabular function of time the amount of belt retraction caused by an actuator in the belt reel. Each card contains a time-retraction length pair. The time value in field 1 is in msec and the retraction length value in field 2 is in inches or cm. The sequence is terminated by a negative value for time.

TABLE 7 INPUT DATA

ENERGY ABSORBING STEERING ASSEMBLY SYSTEM SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1 (115:131)		Run subtitle for Steering Column System Input Block. Columns 1 to 17 of this card become columns 115 to 131 of subtitle.

NOTE: Energy Absorbing Steering Assembly System Subtitle and Airbag System Subtitle are mutually exclusive. If only one of them is present in the data deck, that one will appear. If both are present, the one occurring last will appear.

NOTE: Also see note on Card 200.

TABLE 7 INPUT DATA

ENERGY ABSORBING STEERING ASSEMBLY SYSTEM PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1	HL, ℓ	inches (cm)	Length of steering column from instrument panel to steering wheel attachment.
2	HLD, $\dot{\ell}$	in/sec (cm/sec)	Time rate of HL (See Field 1).
3	HAL1, α_1	deg	Initial angle of steering column measured clockwise from horizontal.
4	HAL1D, $\dot{\alpha}_1$	deg/sec	Time rate of HAL1 (See Field 3).
5	HAL2, α_2	deg	Initial angle of steering wheel measured clockwise from horizontal to steering wheel axis.
6	HAL2D, $\dot{\alpha}_2$	deg/sec	Time rate of HAL2, (See Field 5).
7	HH, h	inches (cm)	Initial distance between the steering column attachment point on the instrument panel and the place of the steering wheel.
8	HHD, $\dot{h}$	in/sec (cm/sec)	Time rate of HH (See Field 7).

MVMA 2-D Model
Card 801

TABLE 7 INPUT DATA

ENERGY ABSORBING STEERING ASSEMBLY SYSTEM PARAMETERS

Field	Name of Quantity	Units	Description
1	HA, a	inches(cm)	Distance between upper hinge and steering column center of gravity.
2	HRω, r_ω	inches(cm)	Steering wheel radius.
3	HLOC, ℓ_c	inches(cm)	Length of lower column from steering gear box to attachment point.
4	HLI, ℓ_o	inches(cm)	Initial value of ℓ.
5	HH1, h_1	inches(cm)	Distance between upper hinge and the steering column hub constant point.
6	HS1, s_1	inches(cm)	Reference coordinates to orient the steering assembly with respect to the vehicle reference point (X_v, Z_v).
7	HS2, s_2	inches(cm)	
8	HS5, s_5	inches(cm)	

MVMA 2-D Model
Card 802

TABLE 7 INPUT DATA

ENERGY ABSORBING STEERING ASSEMBLY SYSTEM PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1	HI1, I_1	lb sec^2in ($kgin^2$)	Moment of inertia of segment 1 of steering assembly.
2	HI2, I_2	lb sec^2in ($kgin^2$)	Moment of inertia of segment 2 of steering assembly.
3	HM1, m_1	lb sec^2/in (kg)	Mass of segment 1 of steering assembly.
4	HM2, m_2	lb sec^2/in (kg)	Mass of segment 2 of steering assembly.

MVMA 2-D Model
Card 803

TABLE 7 INPUT DATA

GEARBOX POSITION VERSUS TIME
(1 Field of 8)

Field	Name of Quantity	Units	Definition
1	HTX11(n), HX11I(n)		Number of time-position pairs

NOTES: 1. Data follows on succeeding cards, four time-position pairs per card starting on Field 1.
2. Time in msec and position in inches (cm).

MVMA 2-D Model
Card 804

TABLE 7 INPUT DATA

HEAD/STEERING SYSTEM PROPERTIES
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to head material (blank if rigid)
3	RHOI(1), ρ_1	inches (cm)	Radius of circle for head contact surface.
4	SCMU(1,1), μ_0		Constant friction coefficient.
5	SCMU(1,2), μ_1	1/in (1/cm)	Linear friction coefficient.
6	SCMU(1,3), μ_2	$1/in^2$ ($1/cm^2$)	Second order friction coefficient.

NOTE: A non-linear friction coefficient is computed to simulate "plowing" $\mu = \mu_0 + \mu_1\delta + \mu_2\delta^2$

MVMA 2-D Model
Card 805

TABLE 7 INPUT DATA

UPPER TORSO/STEERING SYSTEM PROPERTIES
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to upper torso material (blank if rigid)
3	SCENTX	inches (cm)	Distance from center of semicircle of upper torso to the center line (negative if the center is in front of center line).
4	SCENTZ	inches (cm)	Along center line distance (from joint 2) to the center of upper torso semicircle.
5	RHOI(2), ρ_2	inches (cm)	Radius of semicircle of the top of upper torso for contact surface.
6	SZETAI(1), ξ_{10}	inches (cm)	Distance from center line to contact surface of upper torso (negative value).
7	SCMU(2,1), μ_0		Constant friction coefficient.
8	SCMU(2,2), μ_1	1/in (1/cm)	Linear friction coefficient.
9	SCMU(2,3), μ_2	$1/in^2 (1/cm^2)$	Second order friction coefficient.

NOTE: 1. See Card 805 Note.
2. See Figure 62 for definition of SCENTX, SCENTZ, ρ_2, ξ_{10}.

TABLE 7 INPUT DATA

MIDDLE TORSO/STEERING SYSTEM PROPERTIES
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to middle torso material (blank if rigid)
3	SZETAI(2), ξ_{12}	inches (cm)	Distance from center line to contact surface of middle torso (negative value).
4	SCMU(3,1), μ_0		Constant friction coefficient.
5	SCMU(3,2), μ_1	1/in (1/cm)	Linear friction coefficient.
6	SCMU(3,3), μ_2	$1/in^2$ $(1/cm^2)$	Second order friction coefficient.

NOTE: 1. See Card 805 Note.
2. See Figure 62 for definition of ξ_{12}.

TABLE 7 INPUT DATA

LOWER TORSO/STEERING SYSTEM PROPERTIES
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to lower torso material (blank if rigid)
3	SZETAI(3), ξ_{14}	inches (cm)	Distance from center line to contact surface of lower torso (Negative).
4	SCMU(4,1), μ_0		Constant friction coefficient.
5	SCMU(4,2), μ_1	1/in (1/cm)	Linear friction coefficient.
6	SCMU(4,3), μ_2	$1/in^2$ ($1/cm^2$)	Second order friction coefficient.

NOTE: 1. See Card 805 Note.
2. See Figure 62 for definition of ξ_{14}.

MVMA 2-D Model
Card 808

TABLE 7 INPUT DATA

FRONT LINE INTERSECTION POINTS
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1	SCSI(1), x_1	inches (cm)	Distance from point 1 to the center line of the upper torso.
2	SZETA(1), ξ_1	inches (cm)	Distance from joint 2 along the center line of upper torso to point 1.
3	SCSI(2), x_2	inches (cm)	Distance from point 2 to the center line of the middle torso.
4	SZETA(2), ξ_2	inches (cm)	Distance from joint 3 along the center line of the middle torso to point 2.
5	SCSI(3), x_3	inches (cm)	Distance from point 3 to the center line of the lower torso.
6	SZETA(3), ξ_3	inches (cm)	Distance from joint 4 along the center line of the lower torso to point 3.
7	SCSI(4), x_4	inches (cm)	Distance from point 4 to the center line of lower torso.
8	SZETA(4), ξ_4	inches (cm)	Distance from joint 5 along the center line of the lower torso to point 4.

NOTE: Points 1, 2, 3 and 4 and the signs of x_i, ξ_i see Figure 62.

MVMA 2-D Model
Card 809

TABLE 7 INPUT DATA

STEERING WHEEL MATERIAL CARD
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to material of steering wheel edge (for F_1, F_3)
3-4			Name assigned to material of steering wheel center (for F_2)
5-6			Name assigned to material of hub (for K_H, F_4)

NOTE: Leave field blank for rigid material.

TABLE 7 INPUT DATA

REACTION MATERIAL NAMES

(9 Fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name assigned to material for force resistance at F_{A1}.
3-4			Name assigned to material for moment resistance at M_{J1}.
5-6			Name assigned to material for force resistance at F_{A2}.
7-8			Name assigned to material for moment resistance at M_J2.

NOTE: Leave field blank for rigid material.

MVMA 2-D Model
Card 811

TABLE 7 INPUT DATA

STEERING ASSEMBLY SYSTEM AND BODY MATERIAL PROPERTIES

Field	Name of Quantity	Units	Description

NOTE: Reaction material properties are specified in the same manner as contact region material properties. See cards 403-408 for format.

TABLE 7 INPUT DATA

UNLOADING CURVES
(3 Fields of 8)

NOTE: Steering system material unloading curves are specified in the same manner as curves for contact region materials. See Card 413 for format.

MVMA 2-D Model
Card 818
(413)

TABLE 7 INPUT DATA

AIRBAG SYSTEM SUBTITLE

Field	Name of Quantity	Units	Definition
	STITL1(115:131)		Run subtitle for Airbag Restraint System Input Block. Columns 1-17 of this card become columns 115 to 131 of subtitle.

NOTE: See note on Card 800

NOTE: Also see note on Card 200.

TABLE 7 INPUT DATA

AIRBAG SYSTEM PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	NGLSW		*RLTHET switch. 1. = constant angle, 0. = adjusted at each t	1.
2	RLTHET	Degrees	Angle of reference line, counterclockwise from +x	161.
3	WIDTH	inches (cm)	Bag width.	36. 91.44
4	PRMTOL	inches (cm)	Perimeter iteration tolerance.	1. 2.54
5	ITRTOP		Maximum iteration count.	30.
6	BPERIM	inches (cm)	Bag perimeter when fully inflated.	75.4 191.5
7	BGPRSS	lbs/in^2 (N/cm^2)	Pressure differential necessary to burst membrane.	2. 1.38
8	ORFICE	in^2 (cm^2)	Area of one deflation membrane (Two orifices assumed).	12. 71.4
9	BGXCOR	inches (cm)	X coordinate of bag attachment point in vehicle system.	20. 50.8

NOTES: 1) Airbag contact forces are zero until the bag is both in contact with the occupant and "full." The bag becomes "full" before contact if the thermodynamic volume becomes greater than the full geometric volume, which is $\pi r^2 w$, where $r = BPERIM/2\pi$ and w = width. The bag becomes "full" after contact if the calculated perimeter of the deformed bag is greater than BPERIM.

*2) If field 1 is 0., the angular location of the center of the full bag will be adjusted at each time step to be at the center of pressure. If field 1 is 1., the center will always be on the fixed RLTHET deployment line.

TABLE 7 INPUT DATA

AIRBAG SYSTEM PARAMETERS CONTINUED
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	BGZCOR	inches(cm)	Z coordinate of bag attachment point in vehicle system	-14. -35.56
2	GASTMP	Fahrenheit deg.(Celsius deg.)	Temperature of supply gas.	40. 4.44
3	OCCWID(1)	inches(cm)	Occupant head width.	8. 20.32
4	OCCWID(2)	inches(cm)	Occupant shoulder width.	20. 50.8
5	OCCWID(3)	inches(cm)	Occupant torso width.	20. 50.8
6	OCCWID(4)	inches(cm)	Occupant hip width.	20. 50.8
7	OCCWID(5)	inches(cm)	Occupant thigh width.	20. 50.8
8			(not used)	
9	TBGFR	msec	Bag fire time.	0.

TABLE 7 INPUT DATA

AIRBAG SYSTEM PARAMETERS CONTINUED
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	RX	ft-lb/lbm°F(Joules/kg°C)	Gas Constant	55.15 296.7
2	PEX	lb/in^2 (N/cm^2)	Exhaust Pressure (one atmosphere)	14.7 10.135
3	GAMMB		Ratio of Specific Heats (C_p/C_v)	1.4
4	TAU	sec	Decay Time (not used)	1.
5	CP	BTU/lbm°F(Joules/gm°C)	Specific Heat at Constant Pressure	0.25 1.0465
6	SPSI	deg	Roof angle with respect to vehicle X-axis.	150.
7	RHEAD	in(cm)	Average head radius.	6. 15.24

MVMA 2-D Model
Card 903

TABLE 7 INPUT DATA

AIRBAG MASS INFLUX RATE VERSUS TIME
(1 Field of 8)

Field	Name of Quantity	Units	Definition
1			Number of time - rate pairs

NOTES: 1. Data follows on succeeding cards, four time - rate pairs per card starting in Field 1, BTIM and MDOT alternating in the first eight fields.

2. Mass rate units are lbm/sec (kg/sec) and time is msec.

3. Time zero for these data corresponds to the bag fire time, which may be nonzero.

TABLE 7 INPUT DATA

SUPPLY GAS TEMPERATURE VERSUS TIME
(1 Field of 8)

Field	Name of Quantity	Units	Definition
1			Number of time-temperature pairs.

NOTES: 1. Data follows on succeeding cards, four time-temperature pairs per card starting in Field 1, TTIM and TEMPS alternating in the first eight fields.

2. Temperature in °F(°C) versus time in msec (temperature of supply gas as it passes through inlet orifice)

3. Time zero for these data corresponds to the bag fire time, which may be nonzero.

TABLE 7 INPUT DATA

BAG POROSITY VERSUS PRESSURE DIFFERENTIAL
(1 Field of 8)

Field	Name of Quantity	Units	Definition
1			Number of pressure-porosity pairs.

NOTES:

1. Data follows on succeeding cards, four pressure-porosity pairs per card starting in Field 1, DELTAP and PERM alternating in the first eight fields.
2. Pressure units are lb/ft^2 (N/cm^2). Porosity units are $ft^3/ft^2/min$ $(m^3/m^2/min)$.

MVMA 2-D Model
Card 906

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 1)
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(1), ξ_1	inches(cm)	Distance along centerline from reference joint (see card 909) to contact reference point 1.
2	ZETAI(1), ζ_1	inches(cm)	Distance perpendicular to centerline from reference joint (see card 909) to contact reference point 1.
3	CSI(2), ξ_2	inches(cm)	See Field 1 (Reference Point 2)
4	ZETAI(2), ζ_2	inches(cm)	See Field 2 (Reference Point 2)
5	CSI(3), ξ_3	inches(cm)	(Not used.)
6	ZETAI(3), ζ_3	inches(cm)	(Not used.)
7	CSI(4), ξ_4	inches(cm)	See Field 1 (Reference Point 4)
8	ZETAI(4), ζ_4	inches(cm)	See Field 2 (Reference Point 4)

NOTE: See Figure 46 and figure on Card 909.

MVMA 2-D Model
Card 907

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 2)
(8 Fields of 8)

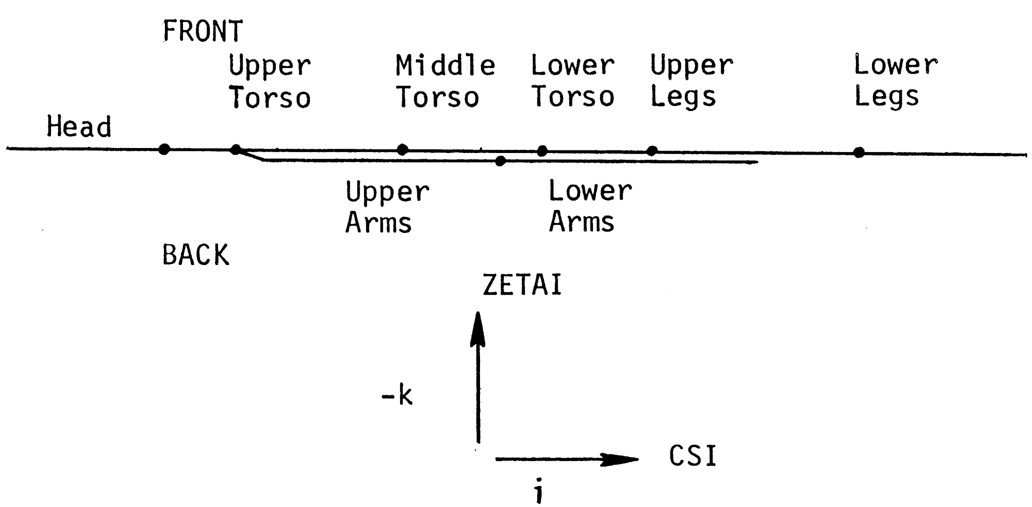
Field	Name of Quantity	Units	Definition
1	CSI(5), ξ_5	inches (cm)	(Not used)
2	ZETAI(5), ζ_5	inches (cm)	(Not used)
3	CSI(6), ξ_6	inches (cm)	See Card 907. Reference Points 6 to 8.
4	ZETAI(6), ζ_6	inches (cm)	
5	CSI(7), ξ_7	inches (cm)	
6	ZETAI(7), ζ_7	inches (cm)	
7	CSI(8), ξ_8	inches (cm)	
8	ZETAI(8), ζ_8	inches (cm)	

MVMA 2-D Model
Card 908

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 3)
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(9), ξ_9	inches (cm)	See Card 907 Reference Points 9 and 10
2	ZETAI(9), ζ_9	inches (cm)	
3	CSI(10), ξ_{10}	inches (cm)	
4	ZETAI(10), ζ_{10}	inches (cm)	



Reference Point	Definition	Reference Joint
1	Top of Chest Line	Neck
2	Bottom of Chest Line	Neck
3	Top of Gut Line	Upper Torso
4	Bottom of Gut Line	Upper Torso
5	Top of Pelvis Line	Lower Torso
6	Bottom of Pelvis Line	Lower Torso
7	Top of Upper Leg Line	Hip
8	Bottom of Upper Leg Line	Hip
9	Top of Lower Leg Line	Knee
10	Bottom of Lower Leg Line	Knee

MVMA 2-D Model
Card 909

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM CONTROLS
(5 Fields of 8)

Field	Name of Quantity	Units	Definition
1	NBAGS		Number of Airbags
2	NENCV		Number of vehicle interior enclosure segments
3	NABOVE		Number of vehicle interior enclosure segments above attachment point for airbag number 1 (must be at least one)
4-5			Name assigned to airbag number 1 (see note 1)

NOTES:

1. Airbag number 1, identified in fields 4-5, cannot be inside any other bag.
2. The number of airbags must be no greater than 20.
3. This card must be followed by "NENCV" unnumbered cards, one for each vehicle interior enclosure segment. Each segment must be one named on a 409 - Card, and the "NENCV" segments must be connected, one to another, at their endpoints. The first card following Card 910 must be for the "lowest" in line (~ floor), or most clockwise. The NENCV-th must be for the highest in line (~ roofheader), or most counterclockwise.

Card 910

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM VEHICLE ENCLOSURE SEGMENTS
(2 Fields of 8)

Field	Name of Quantity	Units	Definition
1 - 2			Contact segment name from 409 -Card of segment included in airbag "enclosure"

NOTE:

"NENCV" unnumbered cards follow Card 910. See note on Card 910.

(follows Card 910)

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM INFLATION GAS PROPERTIES
(7 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	RGAS	$\frac{ft\ lb}{lbm\ F^\circ}$ $\left(\frac{joules}{kg\ C^\circ}\right)$	Gas constant for inflation [or 0.]	55.15 (296.7)
2	MOLEWT	-	Molecular weight (average) for inflation gas [or 0.]	28.02
3	GAMMG	-	Ratio of specific heats for inflation gas	1.4
4	CPG	$\frac{BTU}{lbm\ ^\circ F}$ $\left(\frac{joules}{gm\ ^\circ C}\right)$	Specific heat at constant pressure	0.25 (1.0465)
5	PATM	$\frac{lb}{in^2}$ $\left(\frac{N}{cm^2}\right)$	Pressure of external medium (atmosphere)	14.7 (10.135)
6	TATM	°F (°C)	Temperature of external medium (atmosphere)	68. (20.)
7	RHEAD	in (cm)	Head radius for airbag contacts	5. (12.7)

NOTE:

Field 1 or Field 2 is needed, not both. Enter a "0." (or blank) in the field not used. If non-zero fields are present in both fields, Field 2 will be used.

Card 911

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM CONVERGENCE EPSILONS AND ITERATION LIMITS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	EPSP	$\frac{lb}{in^2}$ $\left(\frac{N}{cm^2}\right)$	Convergence epsilon for testing pressure in pressure-volume iteration	.1 (.068948)
2	EPSM	lb in (N-m)	Convergence epsilon for testing unbalanced moment on bag in bag position iteration	50. (5.6492)
3	EP1	in^2 (cm^2)	Distance-squared epsilon for distinguishing between cases of 1) real (small) difference between two distances and 2) an apparent difference due to roundoff	.0005 (.0032258)
4	EP2	in^2 (cm^2)	Distance-squared epsilon for distinguishing between cases of 1) non-coincident (but near) points and 2) coincident points made "non-coincident" by roundoff	.0001 (.00064516)
5	EP3	in (cm)	X- (or Z-) position epsilon for determining if two straight-line segments interact	.000001 (.00000254)
6	EP4	in (cm)	X- (or Z-) position epsilon for distinguishing between cases of 1) non-coincident (but near) points and 2) coincident points made "non-coincident" by roundoff	.001 (.00254)
7	DMIN	in (cm)	Minimum allowed chord length for arc (bulge) of bag in occupant plane; smaller arcs are replaced by the chord	.3 (.762)
8	ITPMAX	-	Maximum number of iterations allowed for each bag at each time for pressure and volume determination	20.
9	ITMMAX	-	Maximum number of iterations allowed for each bag at each time for adjustment of bag position for moment balance (2. or 3.)	3.

Card 912

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 1)
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(1), ξ_1	inches(cm)	Distance along centerline from reference joint (see card 915) to contact reference point 1.
2	ZETAI(1), ζ_1	inches(cm)	Distance perpendicular to centerline from reference joint (see card 915) to contact reference point 1.
3	CSI(2), ξ_2	inches(cm)	See Field 1 (Reference Point 2)
4	ZETAI(2), ζ_2	inches(cm)	See Field 2 (Reference Point 2)
5	CSI(3), ξ_3	inches(cm)	(Not used.)
6	ZETAI(3), ζ_3	inches(cm)	(Not used.)
7	CSI(4), ξ_4	inches(cm)	See Field 1 (Reference Point 4)
8	ZETAI(4), ζ_4	inches(cm)	See Field 2 (Reference Point 4)

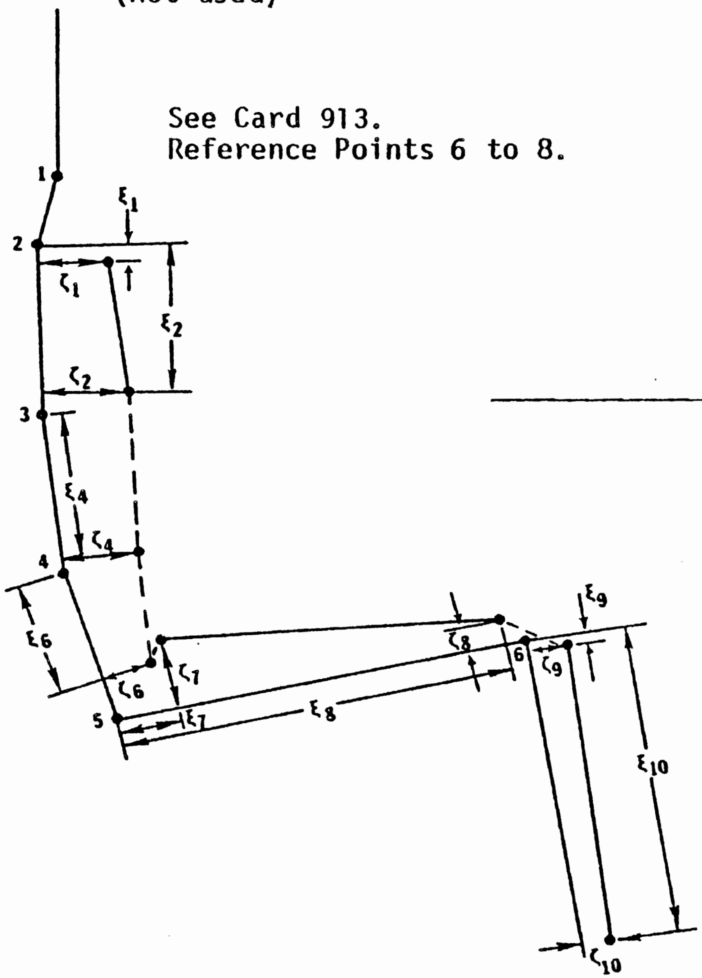
NOTE: See figures on Cards 914 and 915.

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 2)
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(5), ξ_5	inches (cm)	(Not used)
2	ZETAI(5), ζ_5	inches (cm)	(Not used)
3	CSI(6), ξ_6	inches (cm)	See Card 913. Reference Points 6 to 8.
4	ZETAI(6), ζ_6	inches (cm)	
5	CSI(7), ξ_7	inches (cm)	
6	ZETAI(7), ζ_7	inches (cm)	
7	CSI(8), ξ_8	inches (cm)	
8	ZETAI(8), ζ_8	inches (cm)	

NOTE: Also see figures on Card 915.



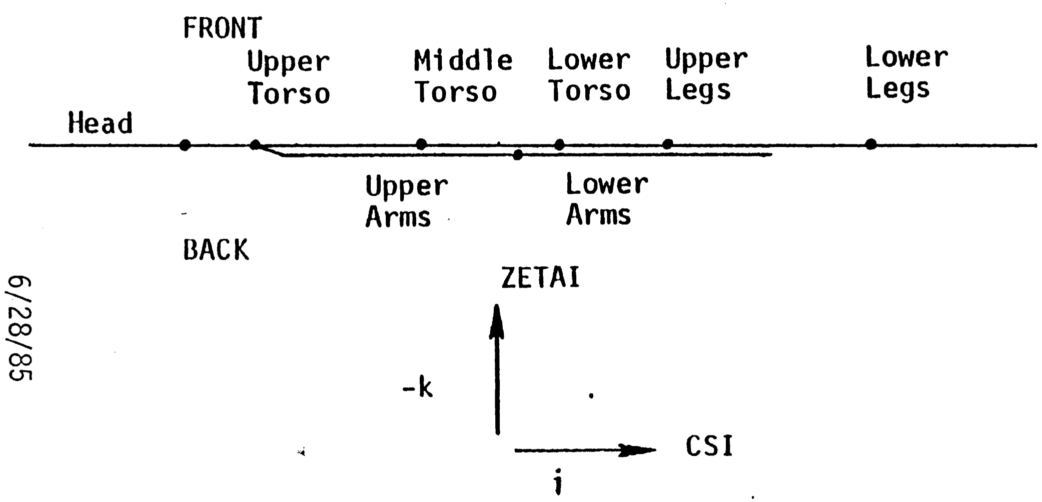
Card 914

TABLE 7 INPUT DATA

AIRBAG OCCUPANT CONTACT REFERENCE POINTS (CARD 3)
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1	CSI(9), ξ_9	inches (cm)	See Card 913 Reference Points 9 and 10
2	ZETAI(9), ζ_9	inches (cm)	
3	CSI(10), ξ_{10}	inches (cm)	
4	ZETAI(10), ζ_{10}	inches (cm)	

NOTE: Also see figure on Card 914.



Reference Point	Definition	Reference Joint
1	Top of Chest Line	Neck
2	Bottom of Chest Line	Neck
3	Top of Gut Line	Upper Torso
4	Bottom of Gut Line	Upper Torso
5	Top of Pelvis Line	Lower Torso
6	Bottom of Pelvis Line	Lower Torso
7	Top of Upper Leg Line	Hip
8	Bottom of Upper Leg Line	Hip
9	Top of Lower Leg Line	Knee
10	Bottom of Lower Leg Line	Knee

Card 915

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM AIRBAG CONSTANTS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3	WBAG	in (cm)	Side-to-side width of deflated bag
4	SURFCE	ft^2 (m^2)	Total surface area of porous fabric (or negative surface area - see Note 1)
5	TBGFR	msec	Bag fire time
6	T_S	^oF (^oC)	Constant source gas temperature (see note 2)
7		$\frac{deg}{in\ lb}$ $\left(\frac{deg}{N\text{-}m}\right)$ or deg	Bag equilibrium adjustment parameter: compliance for initial θ-adjustment of bag if negative, angle adjustment if positive (+15. is suggested)
8			Number of vehicle interior segments between bag #1 attachment point and attachment point for this bag. (Attachments must be at endpoints of vehicle interior segments of the enclosure.) Number should be positive if counterclockwise from bag # 1 and negative if clockwise. If this airbag is bag # 1, the number entered here will be 0.

NOTES:

1. If the bag is constructed such that none (or little) of the porous venting surface will be in contact with the occupant or vehicle interior surfaces, enter the negative of the porous surface area in Field 4.

2. Field 6 is needed only if no table for source gas temperature vs. time is included for this airbag in the data set.

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM INTERIOR BAGS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Name of one of the airbags immediately inside this bag

NOTES:

1. Omit 917-Cards if there are no airbags immediately inside.
2. There can be up to twenty airbags total, but no string of successively nested bags can be greater than five bags in length.

Card 917

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFLATION VENTS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3		in^2 (cm^2)	Area of one of the deflation vents (membranes) for this bag
4		$\frac{lbs}{in^2}$ $\left(\frac{N}{cm^2}\right)$	Pressure differential necessary to burst membrane

NOTE:

Use one 918-Card for each deflation vent (omit cards if no vents).

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG SLAP PARAMETERS
(9 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3	BMASS	lbm (kg)	Bag/gas mass for bag slap
4	FLUIDK	$\frac{lb}{in}$ $\left(\frac{N}{cm}\right)$	Fluid k for bag-slap 4-parameter viscoelastic model
5	FLUIDC	$\frac{lb\ sec}{in}$ $\left(\frac{N\text{-}sec}{cm}\right)$	Fluid c for bag-slap 4-parameter viscoelastic model
6	SOLIDK	$\frac{lb}{in}$ $\left(\frac{N}{cm}\right)$	Solid k for bag-slap 4-parameter viscoelastic model
7	SOLIDC	$\frac{lb\ sec}{in}$ $\left(\frac{N\text{-}sec}{cm}\right)$	Solid c for bag-slap 4-parameter viscoelastic model
8	VFACTR	-	Velocity factor
9			Switch which indicates whether specified enclosure segments (Cards 920) are allowed or disallowed for bag slap interaction with this bag: 0. if all are allowed (no 920-Cards needed), -1. if allowed are specified, 1. if disallowed are specified.

NOTE:

Field 8 (VFACTR) is reasonably from 1. to 2. VFACTR = 1. means that the leading surface of the deploying bag moves with constant velocity from "fire" time until contact; VFACTR = 2. means it moves with constant acceleration. Values between 1. and 2. indicate intermediate conditions.

NOTE:

Omit card if no slap forces are desired from this bag.

Card 919

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM ENCLOSURE SEGMENTS FOR BAG SLAP
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Enclosure segment name allowed or disallowed for bag slap interaction with this bag. See Notes and Card 919.

NOTES:

1. Cards 920 are unneeded if field 9 of Card 919 for this bag is 0 or if Card 919 for this bag is absent.

2. The enclosure segment name in fields 3 and 4 may be either one of the vehicle-interior enclosure segment names on the unnumbered cards following Card 910 or it may be an occupant body element name. Allowed entries for body element names are as follows, where "b" indicates "blank" and all names begin in column 17: HEAD, CHEST, MIDSECTION, PELVIS, UPPERbLEG, KNEE, LOWERbLEG.

3. The bag slap model may perform better if segments allowed for bag slap interaction are restricted to the body element names listed in Note 2, i.e., if no vehicle-interior enclosure segments are allowed for interaction.

Card 920

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM TABLE NAMES
(6 Fields of 8)

Field	Names of Quantity	Units	Definition
1-2			Name assigned to airbag
3			Name assigned to collective V vs. A tables for this bag ($\frac{P}{T}$ is constant for each tabular curve)
4			Name assigned to table for mass influx rate vs. t
5			Name assigned to table for source gas temperatures vs. t (blank if none)
6			Name assigned to table for bag porosity vs. pressure differential (blank if none)

NOTES:

1. There must be one 921-Card for each airbag.

2. Names in fields 3-6 may be used for more than one bag.

3. Tables are entered with cards indicated:

Card 921 Field	Card for Table Entries
3	922
4	923
5	924
6	925

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM V vs. A FOR CROSS-SECTION OF BAG CONTACT
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to collective V vs. A tables for an airbag
2		$\frac{lb}{in^2\ R^\circ}$ $\left(\frac{N}{cm^2 K^\circ}\right)$	Constant P/T value for a tabular curve, V= V(A)
3		ft^2 (m^2)	Area A of cross-section of airbag in occupant plane
4		ft^3 (m^3)	Airbag volume, V

NOTES:

1. Use one card for each point on a tabular curve.
2. At least two V vs. A curves along which P/T is constant must be defined for each airbag. At least two points must be specified to define each curve (one being for A = 0.). There must therefore be at least four 922-Cards for each airbag unless the same collective V vs. A tables name (field 1) is used for more than one bag.

Card 922

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM MASS INFLUX RATE VS. TIME
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for mass influx rate vs. t for an airbag
2		msec	Time relative to "fire" time (i.e., 0. at t = TBGFR)
3	MNDOT	$\frac{lbm}{sec}$ $\left(\frac{kg}{sec}\right)$	Mass influx rate for primary-source inflation gas

NOTES:

1. Mass influx table must be defined.

2. Use one card for each point in table.

Card 923

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM SOURCE GAS TEMPERATURE VS. TIME
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for source gas temperature vs. t for an airbag
2		msec	Time relative to "fire" time (i.e., 0. at t = TBGFR)
3		°F (°C)	Source gas temperature

NOTES:

1. Omit 924-Cards if no source gas temperature table.
2. Use one card for each point in table.

Card 924

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG FABRIC POROSITY VS. PRESSURE DIFFERENTIAL
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to table for porosity vs. pressure differential for an airbag
2		$\frac{lb}{in^2}$ $\left(\frac{N}{cm^2}\right)$	Pressure differential
3		$ft^3/ft^2/min$ $(m^3/m^2/min)$	Porosity (volume of gas at atmospheric temperature and pressure which will pass through unit area of bag fabric in unit time)

NOTES:

1. Omit 925-Cards if no porosity table.

2. Use one card for each point in table.

Card 925

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG PROFILE CONTROLS
(5 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3			Time relative to "fire" time (i.e., 0. at t = TBGFR)
4	NPPTS		Number of points specified on bag profile
5	NREF		Point number of a reference point, counting counter-clockwise from bag attachment point = 1. (see Note 3)

NOTES:

1. At least one 926-Card must included for each airbag.

2. Point number 1 is the bag attachment point. This point (coordinates entered on the first following unnumbered card) must be at least slightly inside the enclosure (Card 910).

3. One particular material point, called the "reference point," must be present in each profile for the expanding bag. NREF should be in the range [1/4 NPPTS, 3/4 NPPTS] if possible, and as near the center as possible. Since NPPTS is not necessarily the same for each profile, NREF will not necessarily be the same either.

4. This card is followed by a block of unnumbered cards. The block consists of as many cards as necessary to give x and z coordinates of the NPPTS successive points on the bag profile (4 points, i.e., 4 coordinate pairs per card). For each bag, 926-Cards with their blocks of unnumbered cards must appear in the data deck in order of increasing time for profiles of the expanding bag.

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM BAG PROFILE POINTS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1	x_i	in (cm)	x- and z- coordinates of points on airbag profile, relative to an axis system located at the bag attachment point and parallel to the vehicle-fixed coordinate system
2	z_i	in (cm)	
3	$x_i +1$	in (cm)	
4	$z_i + 1$	in (cm)	
5	$x_i + 2$	in (cm)	
6	$z_i + 2$	in (cm)	
7	$x_i + 3$	in (cm)	
8	$z_i + 3$	in (cm)	

NOTE:

See notes on Card 926.

(follows Card 926)

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE ENCLOSURE SEGMENTS
(4 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name assigned to airbag
3-4			Name of an enclosure segment which can deform (yield) in response to contact by this bag (see Note)

NOTES:

1. Omit 927-Cards if no deformations from contacts by this bag.
2. Fields 3-4 contain the name of a vehicle-interior enclosure segment. It will be the name on one of the unnumbered cards which follow Card 910.

Card 927

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE ENCLOSURE SEGMENT PROPERTIES

(8 Fields of 8)

Field	Name of Quantity	Units	Definition
1-2			Name of airbag-deformable enclosure segment (See Note 1)
3			Name assigned to tabular static force-deflection curve (See Note 2)
4	m	lbm (kg)	Effective inertial resistance (mass) of segment (greater than 0.)
5	Y	lb (N)	Bag force required to cause initial movement of segment
6	C	$\frac{\text{lb in}}{\text{sec}}$ $\frac{(\text{N cm})}{(\text{sec})}$	Viscous damping coefficient
7	G	-	G - ratio for segment displacements
8	τ	msec	Segment rebound duration time ($\neq$ 0.) from maximum displacement

NOTES:

1. Fields 1-2 must contain a vehicle-interior enclosure segment name which appears on an unnumbered card following the 910-Card . Also, see Card 927.
2. The static curve name in field 3 must be different from names appearing on 225-, 407-, 708-, and 816-Cards.
3. Omit 928-Cards for vehicle-interior enclosure segments not named on any 927-Card.

TABLE 7 INPUT DATA

ADVANCED AIRBAG SYSTEM DEFORMABLE SEGMENT LOADING CURVE DATA
(3 Fields of 8)

Field	Name of Quantity	Units	Definition
1			Name assigned to static curve for airbag-deformable segment (See Card 928, field 3)
2		in (cm)	Deflection
3		lb (N)	Force

NOTES:

1. Use one card for each point for tabular curve.
2. Tabular static force-deflection curve must start at (0., 0.).

TABLE 7 INPUT DATA

CONSTANT VALUES
(2 Fields of 8)

Fields	Name of Quantity	Units	Description
1	n		Decimal number for n, $1 \le n \le 100$
2	CVALUE(n)		A constant which is to be used directly in the Input, Execution, or Output Processors

NOTES:

1. Cards 999 provide a means for the user to enter values in a standard manner via the Input Processor for use by user-modified program code in subroutines of the Input, Execution, or Output Processors. It is necessary only to add the common block COMMON/VALUES/CVALUE(100) to the affected routines. Comment statements in subroutines INMVMA, READIN, and OUTMVM regarding definition of elements of the CVALUE array should be kept up to date as uses of the array are changed.

2. Units for all CVALUE entries should be in Newtons, meters, and seconds for metric system simulations and in pounds, inches, and seconds for English system simulations.

UNNUMBERED CARDS READ BY "GO" TO CONTROL CASES FOR DEBUGGING PRINTOUT

(Not required) (maximum of 20 such cards)

Field	Columns	Description *
1	1-8	Debug Switch Number (1-16)
2	9-16	Case Identifier A
3	17-24	Case Identifier B

Notes:

1. These cards must be read from logical device number 5.
2. Currently implemented for switches 9 and 10. Ignored by all others.
3. If switch 9 or 10 is specified in Field 1, values are applied to both 9 and 10.
4. If -9999999 is specified in Field 2 or Field 3, any value matches. Otherwise, only cases with matching identifiers will produce debugging output for that debugging switch.
5. For switches 9 and 10, the two identifiers correspond to the interaction IA and IB fed into SETACT.

* 6. All values must be entered with a decimal point.

TABLE 7 INPUT DATA

"GO CARD" DESCRIPTION

This "Go-Card" has no fields. It serves to let the model know that a complete data set has been submitted and to start model execution. This card must be present in the deck.

MVMA 2-D Model
Card 1000

TABLE 7 INPUT DATA

CATEGORY SELECTION AND ORDERING SPECIFICATION
(Free Format, Columns 1-72)

Specifications are made by using a string of intermixed entries which are either individual listings ("a" below) or contiguous range listings ("b" below) ordered as desired.

(a) "NN," where NN is a one or two digit number in the range 0 to 50 with or without leading zeroes. The comma appears literally for punctuation.

(b) "NN-NN," where NN is as above and the hyphen appears for punctuation. The first number may be larger or smaller than the second.

NOTES

1. Blanks are ignored
2. If card 1001 and 1002 are both missing, the default cards below are used.
3. If card 1001 is present but blank, then no categories are printed. Only Category 45 (stick figures) and the Summary Page (see Card 1003, field 8) will be printed.
4. If card 1001 has -1bb (b=blank) in first four columns, the default ordering is used minus printout of input data summary (category 0).
5. Cols. 1 to 72 of Card 1002 are treated as 73 to 144 of Card 1001.
6. The comma is not necessary in the last specification on the two cards.
7. See Card 1001, 1002 writeup in Section 3.2 and Tables 11 and 113.
8. See information following Table 11 for a description of Summary Page output, which can be obtained in addition to Categories 0-64.

DEFAULTS

1001 0,1,46-48,10-14,21,22,37,5,38,49,50,15,23-26,2-4,18-20,51-64,33-36,

1002 30-32,16,27-29,39,17,40,6-9,45

TABLE 7 INPUT DATA

PRINTOUT CONTROLS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	IDB		Switch = 0. no detailed HIC printout 1. print details of HIC scan.	0.
2	KO		Switch = 0. if separate printout of peak and 3 msec accel calculation is not desired. ≠0. is logical device number that this information is to be put on.	0.
3	NIXP		Switch = 1. Do not repeat filtering or computation of special indices in "OUT" rerun if previously done. 0. Repeat using new specifications.	0.
4	FEMSOR	in (cm)	Distance from hip joint to sensor located on upper leg center-line.	13.5 (34.29)
5	SKMASS	lb sec^2/in (kg)	Upper leg mass between sensor and knee.	.015 (2.627)
6	TYPEPR		*Number of characters per horizontal inch in printout (used for computing stick figure scale factor)	13.6
7	MVSSDB		Switch = 0. no debug for MVSS 201/208 calculations ≠ 0. print debug for MVSS response parameters	0.
8	KSUMRY		Switch = 0. no Maximum Deflections Summary Page output ≠ 0. logical device number for Summary Page output	

*Notes: 1. A standard line printer gives 132 characters in 13.2 inches (10/in). TYPEPR is normally 13.6 (the default) since xerographic page printers give an image with about 13.6 characters per inch.

2. For TYPEPR the number of printed characters per centimeter (instead of number per inch) may be specified if the value is entered as a negative number.

3. See pages 352.1 to 352.3 regarding summary page.

MVMA 2-D Model
Card 1003

TABLE 7 INPUT DATA

FILTER AND HIC CONTROLS
(8 Fields of 8)

Field	Name of Quantity	Units	Definition	Defaults
1	NPP		NPP is number of filter weights. Number of points used in filtering each point is 2*NPP + 1.	40.
2	FC	Hz	Filter Cut-Off Frequency	500.
3	FT	Hz	Filter Roll-Off Frequency	560.
4	MIRROR	-	Switch = 0. if extension for filtering at data endpoints is by polar image; Switch ≠ 0. if extension is by mirror image	0.
5	FRAK	-	Fraction of max HIC below which scanning is stopped.	0.65
6	DURMAX	ms	Switch: 0. if any HIC duration is allowed; a nonzero value is maximum allowed duration (ms)	0.
7	NFLT	-	No. of points the T1 of a HIC duration is indexed	1.
8	NSCN	-	No. of points the T2 of a HIC duration is indexed	1.

NOTE: The supplied values of NPP, FT, FC must satisfy the following relationships:

1. $FC \leqq \frac{.5}{DT}$

2. $NPP * DT * (FT - FC) \geqq$ 2 for 1%, 3 for 1/2% expected error

3. $NPP \leqq 500$

where DT is the value specified in the original input deck on Card 101, field 7 converted to seconds.

NOTE: Digital filtering is not considered to be necessary for simulation results since normal integration time steps (.25 or .5 ms) effectively "remove" all high frequency content of the response.

MVMA 2-D Model
Card 1004

6/30/88

TABLE 7 INPUT DATA

JOINT RELATIVE ANGLE TEST VALUES
(2 Fields of 8)

Field	Name of Quantity	Units	Definition
1	RAH (I)	deg	High Test Value
2	RAL (I)	deg	Lower Test Value

NOTE:

1. Card 1100 I=1 Head-Neck (Upper Neck)
   1101 I=2 Neck-upper Torso (Lower Neck)
   1102 I=3 Upper Torso-Middle Torso (Upper Spine)
   1103 I=4 Middle Torso-Lower Torso (Lower Spine)
   1104 I=5 Upper Leg-Lower Torso (Hip)
   1105 I=6 Lower Leg-Upper Leg (Knee)
   1106 I=7 Upper Arm-Upper Torso (Shoulder)
   1107 I=8 Lower Arm-Upper Arm (Elbow)

2. No defaults

TABLE 7 INPUT DATA

STANDARD LIST TEST VALUES (CARD 1)
(9 Fields of 8)

Field	Name of Quantity	Units	Description
1	TESTV(1)	g's	Head frontal acceleration test value
2	TESTV(2)	g's	Head vertical acceleration test value
3	TESTV(3)	g's	Head resultant acceleration test value
4	TESTV(4)	deg/sec^2	Head angular acceleration test value
5	TESTV(5)	sec	HIC test value
6	TESTV(6)	lbs(N)	Face load test value
7	TESTV(7)	in(cm)	Chest deflection test value
8	TESTV(8)	lbs(N)	Chest load test value
9	TESTV(9)	g's	Chest frontal acceleration test value

NOTE: 1. If a test value is set zero or left blank, the corresponding comparison will not be made.

2. No defaults.

MVMA 2-D Model
Card 1200

TABLE 7 INPUT DATA

STANDARD LIST TEST VALUES (CARD 2)

(9 fields of 8)

Field	Name of Quantity	Units	Description
1	TESTV(10)	g's	Chest vertical acceleration test value
2	TESTV(11)	g's	Chest resultant acceleration test value (3 msec. average)
3	TESTV(12)	sec	Chest frontal Severity Index test value
4	TESTV(13)	sec	Chest vertical Severity Index test value
5	TESTV(14)	sec	Chest resultant Severity Index test value
6	TESTV(15)	g's	Pelvic Horizontal acceleration test value
7	TESTV(16)	g's	Pelvic vertical acceleration test value
8	TESTV(17)	g's	Pelvic resultant acceleration test value
9	TESTV(18)	lbs(N)	Femur load at sensor test value

NOTE: See note for card 1200.

MVMA 2-D Model
Card 1201

TABLE 7 INPUT DATA

STANDARD LIST ELLIPSE SPECIFICATIONS
(4 fields of 8)

Field	Name of Quantity	Units	Description
1-2			Name of 'face' ellipse
3-4			Name of 'chest' ellipse

Note: No Defaults

MVMA 2-D Model
Card 1202

TABLE 7 INPUT DATA

TYPE A COMPARISONS
(8 Fields of 8)

Field	Name of Quantity	Units	Description
1		-	Category number of quantity
2		-	Column number of quantity
3-4		-	Name of first identifier
5-6		-	Name of second identifier
7		various	High test value
8		various	Low test value

Note: See Table 114 for Category 4. Values needed for Field 2 range from 1 to 31 and are equal to an offset plus the true column number (excluding the time column). Offsets for ellipse-line, ellipse-ellipse, and belt interactions are 0, 12, and 23, respectively.

TABLE 7 INPUT DATA

TYPE B COMPARISON (CARD 1)
(7 Fields of 8)

Field	Name of Quantity	Units	Description
1		-	Category Number of First Quantity
2		-	Column Number of First Quantity
3-4		-	Name of first identifier of First Quantity
5-6		-	Name of second identifier of First Quantity
7		-	Number used to match with 1401 Card and order pair in printout. If left zero, assigned in order of physical position among no match 1400 cards

Note: See Table 114 for Category 4. Values needed for Field 2 range from 1 to 31 and are equal to an offset plus the true column number (excluding the time column). Offsets for ellipse-line, ellipse-ellipse, and belt interactions are 0,12, and 23, respectively.

TABLE 7 INPUT DATA

TYPE B COMPARISON (CARD 2)
(7 Fields of 8)

Field	Name of Quantity	Units	Description
1		-	Category Number of Second Quantity
2		-	Column Number of Second Quantity
3-4		-	Name of First Identifier of Second Quantity
5-6		-	Name of Second Identifier of Second Quantity
7		-	Number used to match with 1400 Card and order pair in printout. If left zero, assigned in order of physical position among no match 1400 cards

Note: See Table 114 for Category 4. Values needed for Field 2 range from 1 to 31 and are equal to an offset plus the true column number (excluding the time column). Offsets for ellipse-line, ellipse-ellipse, and belt interactions are 0, 12, and 23, respectively.

TABLE 7 INPUT DATA

STICK FIGURE CONTROL PARAMETERS (CARD 1)

(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	IZERO	-	Switch = 0. if zero coordinate lines desired 1. if not desired	0.
2			UNUSED	
3	XLEFT	in (cm)	Value of X at left margin of plots.	-33.(-83.8)
4	XRIGHT	in (cm)	Value of X at right margin of plots.	70. (177.8)
5	ZBOT	in (cm)	Value of Z at bottom margin of plots	20. (50.8)
6	ZTOP	in (cm)	Value of Z at top margin of plots	-50. (-127.)
7	NOP	in (cm)	Switch = 0. if no filler points to be plotted >0. = number of filler symbols to be plotted every 10 in. (10 cm) of scaled length.	5.
8	IBELT	-	Switch = 0. to plot belt anchors and attachments ≠ 0. for no plot of belt anchors and attachments.	0.

NOTE: XMAX > XMIN and ZMIN < ZMAX since the x-axis points right and the z-axis points down. If the respective condition is not met; XMAX and/or ZMIN is adjusted to provide the default plot range (103 in. (261.6 cm) for X and 70 in (177.8 cm) for Z).

TABLE 7 INPUT DATA

STICK FIGURE CONTROL PARAMETERS (Card 2)
(9 Fields of 8)

Field	Name of Quantity	Units	Description	Defaults
1	ISTEP	-	Number of plots to be printed. The maximum number is 31 (not including plots based on input).	11.
2	IELLP	-	Switch = 0. if contact ellipse positions are desired 1. if not desired	0.
3	HEDRAD	in(cm)	Switch = 0. do not plot circle around head c.g. >0. radius of circle around head c.g.	6. (15.24)
4	IBAG	-	Switch = 0. plot airbag perimeter if present 1. do not plot airbag perimeter	0.
5	IWHEEL	-	Switch = 0. plot steering col outline if present 1. do not plot steering col outline	0.
6	ICNTCT	-	Switch = 0. plot line segments of contacts 1. do not plot contactline segments	0.
7	METH	-	Switch = 0. if time points to be specified on 1502 cards 1. if time points to be generated.	1.
8	FIRST	msec	Time at which first plot is desired.	0.
9	DELTA	msec	Time increment between plots. (if zero, all recorded plots will be made.)	0.

NOTE: Fields 8 & 9 ignored if field 7 = 0. If field 7 = 0, the time points specified on 1502 cards must be integral multiples of the output plot increment in field 9 of Card 101.

MVMA 2-D Model
Card 1501

TABLE 7 INPUT DATA

STICK FIGURE TIME POINT SPECIFICATION
(9 Fields of 8)

Field	Name of Quantity	Units	Description
I = 1,..,9	POINTS (9N+I-1)	msec	Time at which plot desired

where I = field number
N = total number of 1502 cards occurring in the deck before this card.

NOTE: 1. Limit of 81 time points can be specified and they must be specified in order.

2. No defaults

3. Time points must be integral multiples of the output plot increment in field 9 of Card 101.

MVMA 2-D Model
Card 1502

3/10/87

TABLE 7 INPUT DATA

PLOT VARIABLE SPECIFICATIONS

(1 field of 8)

Field	Name of Quantity	Units	Description
1	NUMVPL		Number of output variables to be recorded for plotting or to be used for generation of time history plots

NOTES:

1. NUMVPL pairs of unnumbered cards must follow immediately after this card. The first card specifies the MVMA 2-D output variable that is to be recorded. The second card specifies the time increment for recording, etc.

2. Recorded time histories are written to the indexed (random access) file attached to logical device number 3. The layout of the written file is described in the table which immediately follows the 1503-Card specifications.

TABLE 7 INPUT DATA

PLOT VARIABLE SPECIFICATIONS
(first unnumbered card)
(9 fields of 8)

Field	Name of Quantity	Units	Description
1	KATG, KONVP(1,-)	-	Category number of quantity to be recorded
2	KOL, KONVP(2,-)	-	* Column number of quantity to be recorded
3-4	VPNAME(1-4,-)	-	** Name of first identifier of quantity to be recorded (if Category 2, 3, 4, 63, or 64)
5-6	VPNAME(5-8,-)	-	** Name of second identifier of quantity to be recorded (if Category 4)
7-9	VPLEGD(1-6,-)	-	User name for this quantity (curve legend if this time history is plotted, up to 24 characters)

* NOTE: Column 1 is always the first column after the TIME column. [To record TIME as a plot variable, select Category 1 (Vehicle Response) and Column 0.]

** NOTE: Fields 3-4 are needed only for output quantities from Categories 2, 3, 4, 63, or 64. The "first identifier" for Category 4 is an ellipse or belt name. For Categories 63 and 64 it is a non-body link name.

Fields 5-6 are needed only for output quantities from Category 4. The "second identifier" is an ellipse name or a line segment name. The second identifier is not needed unless the first identifier is an ellipse name.

Allowed belt names for first identifier:
UPPER TORSO BELT
LOWER TORSO BELT
INBOARD LAP BELT
OUTBOARD LAP BLT
LOWER RING STRAP
UPPER RING STRAP
TORSO BELT EXT.

TABLE 7 INPUT DATA

PLOT VARIABLE SPECIFICATIONS
(second unnumbered card)
(6 fields of 8)

Field	Name of Quantity	Units	Description
1	VPRFID	-	* User's assigned curve reference identification (8 characters)
2	XBEG, VPBEI(1,-)	msec	Beginning time for recording of quantity to be recorded
3	XEND, VPBEI(2,-)	msec	Ending time for recording of quantity to be recorded
4	XINC, VPBEI(3,-)	msec	Time increment at which the quantity is to be recorded. Must be an integral multiple of PTINC (Card 101, field 8).
5	A		** Multiplication factor for category/column quantity
6	B		** Addition term for category/column quantity

* NOTE: A unique curve name (reference identification) must be assigned to each plot variable.

** NOTE: The recorded value will be (Ax + B) , where x is the printout value for column KOL of category KATG. If A is zero (or blank), then the recorded value will be x, not (Ax + B).

EXAMPLE PLOT VARIABLE SPECIFICATIONS

FOR CARD 1503 (and following unnumbered cards)

```
14.                                                                     1503
1.        3.                                     Vehicle X-acceleration
XVDD      0.      40.      1.      -9.80665
46.       1.                                     Head CG x-position
X.HEAD    0.      40.      1.
46.       4.                                     Head CG z-position
Z.HEAD    0.      40.      1.
12.       1.                                     Head angle acceleration
TH1DD     0.      40.      1.
48.       2.                                     Hip x-velocity
XD.HIP    0.      40.      1.      .01     0.
48.       5.                                     Hip z-velocity
ZD.HIP    0.      40.      1.      .01     0.
49.       6.                                     Relative angle at knee
RELANGKNO.        40.      1.      -1.     90.
49.       5.                                     Relative angle at hip
RELANGHPO.        40.      1.
4.        1.      HIP              SEATCUSHION SEG4Deflection
D.HPSC4   0.      40.      1.
4.        5.      HIP              SEATCUSHION SEG4Normal force
FN.HPSC40.        40.      1.
4.        6.      HIP              SEATCUSHION SEG4Tangential force
FT.HPSC40.        40.      1.
4.        8.      HIP              SEATCUSHION SEG4Slip velocity
SV.HPSC40.        40.      1.
63.       2.      FOOT                            Foot x-velocity
FOOTXVELO.        40.      1.
64.       10.     FOOT                            Foot circumferential vel
FOOTCVELO.        40.      1.
```

The example 1503-Card specifications in this table illustrate the manner in which time history information for response variables selected from categories of standard output can be directed to a file (logical device number 3) for post-processing. Typically, the purpose would be to plot time history response curves, but various other types of post-processing might be of interest in any particular instance. The user must provide post-processing code for his particular need which will read the time history data from file 3. The layout of file 3 is shown on the three pages that follow this one.

<u>Notes</u>: 1) Use of fields 7-9 of the first unnumbered card for a curve legend is optional; these fields can, in fact, be used to communicate any alphameric data from the MVMA 2-D data set to the plotting (or other post-processor) program by way of file 3.

2) The use of optional multiplication factors and addition terms for output quantities is illustrated for the time histories identified by user names "XVDD", "XD.HIP" and "ZD.HIP", and "RELANGKN". Respectively, these: a) convert vehicle x-acceleration from g's to m/s**2 and change the sign; b) convert hip x- and z- velocity components from cm/s to m/s; and c) redefine the relative angle at the knee so that it is zero when the upper and lower leg link lines are perpendicular, not in-line (and for the knee in flexion, i.e., for a normal "seated occupant" configuration).

LAYOUT FOR PLOT VARIABLE DATA

ON LOGICAL DEVICE NUMBER 3

The file attached to logical device number 3 is generated via specifications on Card 1503 and following unnumbered cards. The file is a character file consisting of records of 24-character length (maximum). It must be accessed via indexed, i.e., random access, input-output commands.

A time-history curve directory is located at the top of the file. It contains the beginning index values for the sections in this file for all of the time-history variables recorded for plotting (or other post-processing).

The directory is followed by sections containing the data for each time-history variable. Each of those sections begins with a six-record header containing control and description data for the time-history variable. The ordinate data for the time-history curve follows the six-record header.

DIRECTORY SECTION

Record 1: Length of Table of Contents Card

Field	Column Range	Description
1	01 - 16	Table of Contents Identifier: E.g., "MVMA 2-D PLOTS " Format (A16)
2	17 - 20	Number of Variable Curves (NUMVPL) Format (I4)

Record 2 through Record NUMVPL + 1:

Typical Table of Contents of Recorded Variable Entry

Field	Column Range	Description
1	01 - 20	Beginning Index in this file for the first of the recorded curve entries for the respective variable curve Format (I20)

TYPICAL TIME-HISTORY CURVE HEADER SECTION

Record NUMVPL + 2 through Last line of file:

Typical Recorded Variable Curve Entry 1

Field	Column Range	Description
1	01 - 16	Curve Entry Identifier: "VAR. CURVE ENTRY" Format (A16)

Typical Recorded Variable Curve Entry 2

Field	Column Range	Description
1	01	Data Type Indicator: S=Simulation data (not used currently) Format (A1)
2	09 - 16	User's Curve Reference ID (VPRFID) Format (A8)

Typical Recorded Variable Curve Entry 3

Field	Column Range	Description
1	01 - 24	User's Variable Curve Legend (VPLEGD) Format (A24)

Typical Recorded Variable Curve Entry 4

Field	Column Range	Description
1	01 - 16	Beginning Abscissa Value for Curve (XBEG) Format (G16.7)
2	17 - 24	Abscissa Units Designation: "MSEC" Format (A8)

Note: No attempt is made at the present time to automatically control units, but this would be a useful feature at some time in the future. For now the units designation fields may be used as "comments."

Typical Recorded Variable Curve Entry 5

Field	Column Range	Description
1	01 - 16	Abscissa Spacing for Recorded Curve Ordinates (XINC) Format (G16.7)

Typical Recorded Variable Curve Entry 6

Field	Column Range	Description
1	01 - 04	Number of Recorded Points (NRKURV) Format (I4)
2	17 - 24	Ordinate Units Designation: "????" Format (A8)

TYPICAL TIME-HISTORY CURVE ORDINATE DATA SECTION

There follow NRKURV Typical Ordinate Records in order of increasing abscissas.

Typical Recorded Curve Ordinate Entry
(for XINC abscissa spacing)

Field	Column Range	Description
1	01 - 16	Ordinate Value Format (G16.7)

TABLE 7 INPUT DATA

"GO CARD" DESCRIPTION

This "Go-Card" has no fields. It serves to let the output processor know that the input data is complete and start execution. This card must be present in the deck.

MVMA 2-D Model
Card 1600

3.2 DETAILED DESCRIPTION OF INPUT DATA QUANTITIES

This section of the report includes material to supplement Table 7 of Section 3.1. Answers to many questions that will arise during preparation of input data sets will be found here. This section is necessarily relatively brief, however. If a user's question is not adequately answered in this section, it is suggested that reference be made to the 397-page Tutorial System Self-Study Guide [8]. The focus of the Tutorial System is preparation of input data sets. It provides the user with detailed information about all aspects of the simulation model and also gives general guidance in proper use of the model for predicting occupant dynamics. Tables 8 and 9, which follow, are an index to use of the Tutorial System Self-Study Guide.

DATA CARDS REFERENCED BY MODULES

Module	Data Cards Referenced
2	201-217, 303, 227-238
3	201-203, 205-217, 227, 228, 233, 235-242, 303
4	102, 103, 106, 219-226, 402, 412, 903, 907-909
5	102, 103, 106, 219, 401-412
6-1	103, 219, 221-226, 401, 403-408, 702-716
6-2	102, 103, 219, 222, 401, 402, 404, 409, 410, 412, 605, 606, 705
7	205, 206, 215, 216, 301-304, 409, 1501, 1502
8	601-606
9	102, 218, 501, 701-723
10	102, 411, 901-909
11	-
12	101, 102, 104, 105, 107-111, 218, 1000-1004, 1100-1107, 1200-1202, 1300, 1400, 1401, 1500-1502, 1600

Table 8. Data Cards Referenced By Tutorial System Modules.

DATA CARD FIELDS

AND REFERENCING MODULES

Card	Field								
	1	2	3	4	5	6	7	8	9
101	12	12	12	12	12	12	12	12	12
102	9,12	10,12	12	4	4,5	4	6-2	12	12
103	6-2	6-2	6-1	6-1	6-2	5	5	4	4
104	12	12	12	12	12	12	12	12	12
105	12	12	12	12	12	12	12	12	12
106	4,5	4,5	4,5	4,5					
107	12	12	12	12	12	12	12	12	12
108	12	12	12	12	12	12	12	12	12
109	12	12	12	12	12	12	12	12	12
110	12	12	12	12	12	12	12	12	12
111	12	12	12	12					
201	2,3	2	2	2	2		2	3	3
202	2,3	2,3	2	2	2	2	2	2	3
203	2	2	2	2	2	2	2	2	2,3
204	2	2	2	2	2	2	2	2	
205	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3,7	2,3
206	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3,7	2,3
207	2	2	2	2	2	2	2	2	2
208	2	2	2	2	2	2	2	2	2
209	2	2	2	2	2	2	2	2	2
210	2	2	2	2	2	2	2	2	2
211	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
212	2	2	2	2	2	2	2	2	2

Table 9. Data Card Fields Referencing Modules (Page 1 of 6) (Tutorial System)

Card	Field								
	1	2	3	4	5	6	7	8	9
213	3	3	3	3					
214	3	3	3	3			3		3
215	2,3	2,3	2,3	2,3	2,3	2,3	2,3,7	2,3	2,3
216	2,3	2,3	2,3	2,3	2,3	2,3	2,3,7	2,3	2,3
217	2	2	2	2	2	2	2,3	2	
218	12	12	12	9	9	9	9	9	9
219	4	4	4,6-1	4,6-1	4	4,5,6-2			
220	4	4	4	4	4	4			
221	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1
222	4,6-1	4,6-1	4,6-2				4,6-1	4,6-1	4,6-1
223	4,6-1	4,6-1	4,6-1						
224	4,6-1	4,6-1	4,6-1						
225	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	
226	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	4,6-1	
227	2,3	2,3	2,3	2,3	2,3				
228	2,3	2,3	2,3	2,3	2,3				
229	2	2	2	2	2				
230	2	2	2	2	2				
231	2	2	2	2	2				
232	2	2	2	2	2				
233	2,3	2,3	2,3	2,3	2,3				
234	2	2	2	2	2				
235	2,3	2,3	2,3	2,3	2,3				

Table 9. Data Card Fields Referencing Modules (page 2 of 6)

Card	Field								
	1	2	3	4	5	6	7	8	9
236	2,3	2,3	2,3	2,3	2,3				
237	2,3	2,3	2,3	2,3	2,3				
238	2,3	2,3	2,3						
239	3	3							
240	3	3							
241	3	3							
242	3	3	3	3					
301	7	7	7	7	7	7	7	7	7
302	7	7	7	7	7	7	7	7	7
303	7	7	7	7	2,3,7	3,7			
304	3,7	7	3,7	7					
401	5	5	5,6-1	5,6-1	5,6-2	5,6-2	5,6-2	5,6-2	
402	5	5	5	4,5,6-2	5,6-2	5	5		
403	5,6-1	5,6-1	5,6-1	5,6-1	5,6-1	5,6-1	5,6-1	5,6-1	5,6-1
404	5,6-1	5,6-1	5,6-2	6-2	6-2	6-2	5,6-1	5,6-1	5,6-1
405	6-1	6-1	6-1						
406	6-1	6-1	6-1						
407	6-1	6-1	6-1	6-1	6-1	6-1	6-1	6-1	
408	6-1	6-1	6-1	6-1	6-1	6-1	6-1	6-1	
409	5	5	5	5	5,6-2,7	6-2	5	5	
410	5	5	5	6-2	6-2	6-2	6-2		
411	5	5	5	5,10	5,10	5	5	10	
412	4,5,6-2	4,5,6-2	4,5,6-2	5,6-2	5,6-2				

Table 9. Data Card Fields Referencing Modules (page 3 of 6)

Card	Field								
	1	2	3	4	5	6	7	8	9
501	9	9	9	9	9	9	9	9	
601	8	8	8	8	8	8	8	8	
602	8	8	8						
603	8	8	8						
604	8	8							
605	6-2,8	6-2,8	6-2,8	6-2,8	6-2,8				
606	6-2,8	6-2,8	6-2,8						
701	9	9	9	9	9	9	9		
702	6-1,9	6-1,9	9	9	9	9	9	9	
703	6-1,9	6-1,9	9	9	6-1,9	6-1,9	9	9	
704	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9
705	6-1,9	6-1,9	6-2,9				6-1,9	6-1,9	6-1,9
706	6-1,9	6-1,9	6-1,9						
707	6-1,9	6-1,9	6-1,9						
708	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	
709	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	6-1,9	
710	9	9	9	9	9	6-1,9	6-1,9	9	9
711	9	9	9	9	9	6-1,9	6-1,9	9	9
712	9	9	9	9	9	6-1,9	6-1,9	9	9
713	9	9	9	9	9	6-1,9	6-1,9	9	9
714	9	9	9	9	9	6-1,9	6-1,9	9	9
715	9	9	9	9	9	6-1,9	6-1,9	9	9
716	9	9	9	9	9	6-1,9	6-1,9	9	9

Table 9. Data Card Fields Referencing Modules (page 4 of 6)

Card	Field								
	1	2	3	4	5	6	7	8	9
717	9	9	9	9	9	9	9		
718		9	9						
719	9	9	9	9	9	9	9		
720	9	9	9	9	9	9	9	9	
721	9	9	9	9	9	9			
722	9	9	9	9	9	9			
723	9	9	9	9	9	9			
901	10	10	10	10	10	10	10	10	10
902	10	10	10	10	10	10	10		10
903	10	10	10		10	10	4,10		
904	10								
905	10								
906	10								
907	4,10	4,10	4,10	4,10			4,10	4,10	
908			4,10	4,10	4,10	4,10	4,10	4,10	
909	4,10	4,10	4,10	4,10					
1000	12								
1001	12								
1002	12								
1003	12	12	12	12	12				
1004	12	12	12	12	12	12	12	12	
1100	12	12							
1101	12	12							

Table 9. Data Card Fields Referencing Modules (page 5 of 6)

Card	Field								
	1	2	3	4	5	6	7	8	9
1102	12	12							
1103	12	12							
1104	12	12							
1105	12	12							
1106	12	12							
1107	12	12							
1200	12	12	12	12	12	12	12	12	12
1201	12	12	12	12	12	12	12	12	12
1202	12	12	12	12					
1300	12	12	12	12	12	12	12	12	
1400	12	12	12	12	12	12	12		
1401	12	12	12	12	12	12	12		
1500	12	7,12	12	12	12	12	12	12	
1501	12	12	12	12	12	12	12	12	12
1502	12	12	12	12	12	12	12	12	12
1600	12								

Table 9. Data Card Fields Referencing Modules (page 6 of 6)

INPUT DATA CARDS

Card 100

This card contains the run title. It is used by the program in the automatic preparation of headings for each page of printed output.

Card 101

The switch MKSSWT instructs the program to interpret input data from all following cards in metric units or English units. The required units for all input values, whether metric or English, are indicated in Table 7. Input units are mixed, e.g., "in" (or "cm") might be required for one value while "ft" (or "m") will be required for another. Internal units, however, are in-lb-sec for a run made in English system units and m-N-sec for a metric system run. See Table 10 for conversion constants.

The integration option indicator, INTOP, should be set equal to 1. or 2. at present. The integration subroutine which has been supplied with this program uses a fixed-step Runge-Kutta integration if INTOP≠2. and a fixed-step Adams-Moulton predictor-corrector integration if INTOP=2. Both integration methods are fourth order.

METRIC/ENGLISH SYSTEM CONVERSION CONSTANTS

PHYSICAL QUANTITY	CONVERSION RELATION
Length	1 in. = 2.54 cm*
Length	1 ft. = .3048 m*
Length	39.370075 in. = 1 m
Force	1 lb. = 4.4482216 N
Mass	1 lbm = .45359237 kg*
Mass	1 lb-sec^2/in. = 175.12684 kg
Mass	1 slug = 14.593903 kg.
Moment of Inertia	1 lb-sec^2-in = 0.11298483 kg-m^2
Torque	1 lb-in = 0.11298483 N-m
Energy	1 in-lb = 0.11298483 N-m
Linear Spring Coefficient	1 lb/in. = 1.7512684 N/cm
Second Order Coefficient	1 lb/in^2 = 0.68947573 N/cm^2
Third Order Coefficient	1 lb/in^3 = 0.27144714 N/cm^3
Fourth Order Coefficient	1 lb/in^4 = 0.10686895 N/cm^4
Fifth Order Coefficient	1 lb/in^5 = 0.042074390 N/cm^5
Sixth Order Coefficient	1 lb/in^6 = 0.016564721 N/cm^6
Pressure	1 lb/in^2 = 0.68947573 N/cm^2
Pressure	1 atm. = 14.696 lb/in^2 = 1.0132535 x 10^5 N/m^2
Gas Constant	1 ft-lb/(lbm °F) = 5.38032 Joules/(kg °C)
Specific Heat	1 BTU/lb-°F = 1 kg-cal/kg-°C = 4.1868 Joules/gm-°C*
Earth Standard Gravity	1 E.S.G. = 9.80665 m/sec^2* = 32.174049 ft/sec^2 = 386.08858 in/sec^2

* Exact conversion

Table 10. Metric/English System Conversion Constants

Beginning time, TB, is usually chosen to be 0.0 msec unless the exercise is a restart. The final time, TF, usually ranges from 150-250 msec for vehicle occupant studies and up to 1 second for pedestrian studies.

The numerical integration step size, DT, is usually selected as 0.001 sec. Smaller sizes have been used in particularly violent dynamic events.

The print time increment, PTINC, in Field 8 is sometimes set to 0.001 sec. For applications where the increment is not so critical, PTINC = 0.005 sec. will produce a complete record of an output subject on one sheet of printed paper for a 200-msec simulation.

Card 102

The first three fields of Card 102 indicate whether belt, airbag, and energy-absorbing steering assembly submodels are to be used. If an option is not desired, it is necessary only to enter a 0. here; the associated submodel parameter cards need not be removed from the data deck.

The fourth, fifth, and sixth fields of Card 102 control inhibitions of contact between body segments and the various regions describing the vehicle. Field 6, ILL, should be selected first. If it is set to 1., contact between body ellipses is not sensed in the program. If it is set to 0, then the setting of LHIB in field 4 controls ellipse contact inhibitions. Some of the Cards 106 contain two ellipse names. If LHIB = 0, these potential contacts are allowed; if LHIB ≠ 0, these contacts are not considered. Field 5 controls the meaning of Cards 106 for region-ellipse contacts. It should be noted that only those contacts which are likely to be important should be included. The more contacts which must be tested, the more complex the algorithm and costly the computer run.

Field 7 contains FNU. This quantity attempts to soften the effect of a discontinuous frictional force. Assume that a normal force begins to move tangentially over a surface. Theory states that a friction force exists the moment this tangential motion starts. FNU defines a velocity ramp. For zero velocity, tangential friction is zero. For the velocity, FNU, the friction force attains its full value. For tangential velocities between 0 and FNU, the tangential force behaves as a linear function of velocity. (See Section 2.6.6). Values from 1.0 to 10 in/sec are reasonable.

Field 8 contains EPSINV. This quantity is used to sense errors introduced during matrix inversion due to singularity conditions. The quantity is particularly tuned to matrix diagonal quantities which are very small compared with their neighbors. If the matrix tends to singularity, this check will register as a fatal error and execution will be terminated. This value which has been used successfully in HSRI crash victim simulators is 0.000001.

Field 9 contains MX, the execution CPU time limit. This quantity will depend on user experience with the particular simulation event which is being conducted. It is estimated that 2 min. should be sufficient for most purposes.

Card 103

The first, second, and fifth fields define DSTEPX, DSTEPN, and LIMCNT which are used when deflection is shared between a contact ellipse and a region (or other ellipse). The shared deflection problem can be stated as

$$F_1(\delta_1) = F_2(\delta_2)$$
$$\delta_1 + \delta_2 = \delta$$

where

F_1, F_2 are the forces on the contacting elements,

δ is the total deflection

δ_1, δ_2 are the deflections of the individual elements.

Without including an elaborate formulation, the shared deflection algorithm can be described as follows. First, a non-zero δ is sensed. It is necessary to balance forces and solve the individual deflections, δ_1 and δ_2. A function G is defined as follows:

$$G(\delta_1) = F_1(\delta_1) - F_2(\delta - \delta_1)$$

and the algorithm attempts to find δ_1 in the range 0 to δ for which $G(\delta_1) = 0$.

For initial contact, two δ's are estimated.

$$\delta_{11} = \frac{\delta}{2} \quad , \quad \delta_{12} = \frac{\delta}{4}$$

The quantity G is computed for both. If both G's have the same sign, δ_1 does not lie between δ_{11} and δ_{12} and new δ_{1i}'s must be selected until δ_1 is trapped. When the two G's are of the same sign, then δ_1 is trapped and an interval halving procedure is used to isolate it.

For the case of continuing contact, the following information is available to the program: a new δ as well as δ_1 and δ_2 for the previous time step. In this case new δ_{1i}'s must be estimated until δ_1 is trapped as described above.

The quantities, δ_{1i}, are estimated using a classical Newton's method.

DSTEPX and DSTEPN are the maximum and minimum allowed trial adjustments of the component deflection values at any iteration step. Values of .2 and .02 are virtually always suitable. The number of iterations allowed, LIMCNT, should be about 20. The zero of $G(\delta_1)$ is usually found in fewer than 10 iterations. LIMCNT is essentially the limit of the subscript i in δ_{1i}.

Fields 3 and 4 contain FORLIM and HARDCN which relate to the contact between two elements specified to be "rigid." In reality the model treats rigid members as extremely stiff elastic-plastic solids. The linear elastic constant, HARDCN, is usually chosen to be 15,000 lb/in while FORLIM often limits the value of the resulting contact force to 100,000 lb.

Fields 6 and 7 contain TPC and EPSFAC which are used when contact region line segments are specified to move as a function of time (See Figure 32). They are introduced to avoid abrupt changes in velocity at line segment corner points. The quantity EPSFAC is the number of integration time steps over which the maximum ramp length connecting the two velocity levels is specified. The quantity TPC defines the ramp length on the basis of a percentage of the time between t_1 and t_2. The quantity, ε, shown in Figure 32 is defined as

$$\varepsilon = \min \left\{ \text{TPC} \times (t_2 - t_1),\ \text{EPSFAC} \times \Delta t \right\}$$

The usual value for TPC is 0.05 (5% of the ramp) and 10 for EPSFAC which allows a change of velocity to become complete within 5 msec if the integration time step is selected to be 0.5 msec.

Fields 8 and 9 contain the geometric quantities BETELP and GAMELP which relate to ellipse contact. Because the true ellipse contact problem involves an extremely complex algorithm, HSRI has chosen to replace all ellipses by special circles thus leading to an important reduction in computer exercise costs. If the ellipse is nearly a circle (if the ratio of the shorter to the longer semi- axis is nearly unity), the ellipse is simply replaced by a circle placed at the ellipse center. The ratio of axis lengths (the level of the desired approximation) is controlled by the input quantity BETELP. HSRI usually sets BETELP at least as large as 0.75, usually 1.0.

If the ratio of the semi- axes is less than BETELP, a circle with a radius equal to the shorter semi- axis is allowed to migrate along the major axis essentially sweeping out a rectangle capped with semi-circular ends. This geometric figure replaces the ellipse. In a way this is similar to the straight line techniques used in ROS but without the attendant analytical problems. The quantity GAMELP controls the extent of the excursion of the circle. When GAMELP = 1, the circle can travel to a point where it is tangent with the end of the ellipse. HSRI practice is to choose GAMELP = 0.9 or higher. See Section 2.6.7 for the analysis and Figure 35 for a schematic.

Cards 104-105

Auxiliary or debugging printout for this program is organized in terms of sixteen four-level switches. Each switch corresponds to a particular section of the program. The levels of a particular switch control the depth of detail of the debugging printout. Examples of hexadecimal debug words for use on the 104-105 cards as well as a complete description of the output available using this technique are included as Section 4.3.5 of this report. Because debug printout is specified as a function of time, it is possible to isolate very small time domains for detailed study. This is usually necessary because of the immense amount of printout which can be generated by the debug commands.

Debug printout can be obtained for all four evaluations of derivatives required by the Runge-Kutta integration or only at the final evaluation (at the full time step Δt). If debug printout for the intermediate evaluations is felt unlikely to be of value for a particular run, then the total amount of debug printout can be reduced to one fourth by setting Field 9 of Card 104 to 1. While it is generally true that intermediate evaluations are not important for uncovering a program bug, they can in some cases be of value. A value of 1. is recommended.

Field 9 of Card 105 contains KDICTP. The packing debug dictionary contains internal references to storage of contact force information and connects these references to external alphabetic titles of contact ellipses and regions. Although this material is not useful in the case of routine exercises, it should be obtained when new simulation problems are initiated or when debug printout is required. A value of 0. is recommended.

Card 106

Each of these cards contains the name of an ellipse attached to the body of the crash victim and either another ellipse or one of the contact regions describing the vehicle. Depending on the settings of KHIB, LHIB, and ILL on Card 102, they may refer to contacts which are allowed or which are disallowed. The most customary practice is to select desired or anticipated contacts and include them on these cards. The general operational philosophy is to use as few contacts as possible thus minimizing run costs.

Cards 107-111

These cards contain switches controlling storage of potential program output quantities. The amount of storage should be kept at a minimum to reduce costs. The actual printout of these classes of variables is controlled by Card 1001 and 1002. Table 11 provides a listing of all output categories.

Category Number	Description
0	Formatted Printout of Input Quantities
1	Vehicle Response
2	Real Line Region Parameters
3	Real Line Region Individual Line Segment Movement
4	Contact Forces Including Occupant-Vehicle, Occupant-Belt, Occupant-Occupant
5	Neck Reaction Forces
6	Unfiltered Body Accelerations (Head, Chest, Pelvis)
7	Filtered Body Accelerations (Head, Chest, Pelvis)
8	Severity indices from unfiltered accelerations
9	Severity indices from filtered accelerations
10	Body Link Angles
11	Body Link Angular Velocities
12	Body Link Angular Accelerations
13	Body Joint Coordinates
14	Body Joint Velocities
15	Body Joint Torques
16	Body Joint Absorbed Energies
17	Body Kinetic Energies
18	Airbag Variables
19	Airbag Contact Forces
20	Airbag Center of Mass Forces and Moments
21	Neck Joint Coordinates
22	Shoulder Joint Coordinates
23	Joint Torque Elastic Components
24	Joint Torque Joint-Stop Components
25	Joint Torque Friction Components
26	Joint Torque Viscosity Components
27	Joint Absorbed Energy Joint Stop Components
28	Joint Absorbed Energy Friction Components
29	Joint Absorbed Energy Viscosity Components
30	Center of Mass X-Component Forces
31	Center of Mass Z-Component Forces

Table 11 List of Output Categories

Category Number	Description
32	Center of Mass Resultant Moments
33	Steering Column Coordinates
34	Steering Column Generalized Coordinates
35	Steering Column Forces and Moments
36	Forces and Moments on Body Due to Steering Column
37	Neck and Shoulder Forces
38	Muscle Tension Forces
39	Muscle Tension Energy Absorption
40	Femur and Tibia Accelerations and Loads
41	Joint Relative Angle Comparisons Against Upper and Lower Test Values
42	Standard List of Quantities to be Compared Against Test Values
43	Individual Type A Comparisons
44	Individual Type B Comparisons
45	Printer-Plots of Stick Figures
46	Head Center-of-Gravity Motion
47	Chest Center-of-Gravity Motion
48	Hip Motion
49	Joint Relative Angles
50	Joint Relative Angle Velocities
51	Advanced Airbag System Thermodynamic Variables
52	Pressure Forces on Body (AAS*)
53	Occupant-Plane Normal Flotation Forces (AAS)
54	Occupant-Plane Tangential Flotation Forces (AAS)
55	Off-Occupant-Plane Normal Flotation Forces (AAS)
56	Off-Occupant-Plane Tangential Flotation Forces (AAS)
57	Bag Slap Forces on Body (AAS)
58	Airbag Equilibrium and Contact Conditions (AAS)
59	Airbag-Deformable Segment Motions (AAS)
60	Total Bag Forces on Body (AAS)
61	Total Inertial X-Component Bag Forces (AAS)
62	Total Inertial Z-Component Bag Forces (AAS)
63	Non-body link motion
64	Non-body link resistance forces and moments

Table 11 List of Output Categories

*AAS = Advanced Airbag System

SUMMARY PAGE FOR MAXIMUM LINE SEGMENT DEFLECTIONS

Standard Summary Page Output

An option that can be selected through field 8 of Card 1003 of the Output Processor data set provides for printout of a single page of summary data relating to ellipse-line interactions. This option serves the following purposes:

1) to identify the maximum line segment deflection, and associated quantities, for each ellipse-line interaction occurring in an MVMA 2-D CVS simulation

2) to identify specifically the maximum deflection of the windshield together with associated quantities

3) to identify specifically the maximum chest deflection occurring in any ellipse-line interaction, together with associated quantities

Special data set specifications are required if printouts for items 2 and/or 3 above are to be obtained. Program code identifies windshield and chest interactions on the basis of names specified by the user in the data set. Thus, some care must be taken in specification of pertinent names if there is intention to make use of established maximum deflection data. In particular:

a) A windshield interaction is identified if either the region name or the segment name for an ellipse-line interaction begins with the four characters "WIND". It is best not to have more than one such segment or region in the data set.

b) A chest interaction is identified if either the ellipse name or the ellipse material name for an ellipse-line interaction begins with the four characters "CHES". It is best not to have more than one such ellipse or material in the data set.

Special Uses of Related Output Processor Code

Standard Summary Page printout is obtained by using the 1003-Card. Users may, however, generate related output in whatever form they choose by making program modifications. Data pertinent to maximum ellipse-line deflections are found in common block /MAXDEF/, which is described below. These data may be referenced from any subroutine in the Output Processor to which the /MAXDEF/ common block is added. References to maximum deflection data and associated quantities should be made as follows:

Windshield — If IWIND is 0, there was no windshield interaction. If IWIND is not zero, then use it as an index to find desired values. (See Definitions below.) For example, the maximum windshield deflection is DELLMX(IWIND), occurring at time TIMEDL(IWIND).

Chest -- If IACTC is 0, there was no chest interaction. If IACTC is not zero, then maximum chest deflection and associated quantities are DELCMX, DELLIN, TIMEDC, FORCDC, ELLC(1-4), and SEGC(1-4).

Line segments other than the windshield -- If NINTLE is 0, no ellipse-line interaction occurred. Otherwise, NINTLE is the number of occurring interactions and an interaction I of interest is identified by its INTACT() index, which is stored by CATG1 in IACTLE(I), and also by the ellipse and line segment names, which are stored in ELLPSE(1-4,I) and SEGMNT(1-4,I).

DEFINITIONS

The common block /MAXDEF/ is defined as follows in Subroutine CATG1:

```
 COMMON/MAXDEF/DELLMX(100),DELELL(100),TIMEDL(100),FORCDL(100),
1 ELLPSE(4,100),SEGMNT(4,100),IACTLE(100),NINTLE,IWIND,
2 DELCMX,DELLIN,TIMEDC,FORCDC,ELLC(4),SEGC(4),IACTC
```

Definitions of quantities in /MAXDEF/ are given in the table below. The index I ranges from 1 to the number of occurring ellipse-line interactions, NINTLE (100 maximum).

Quantity	Definition
DELLMX(I)	Maximum deflection of line for ellipse-line interaction I
DELELL(I)	Ellipse deflection for interaction I at time of maximum line deflection
TIMEDL(I)	Time of maximum deflection of line for interaction I
FORCDL(I)	Force for interaction I at time of maximum line deflection
ELLPSE(1-4,I)	Name of ellipse (4A4) in interaction I
SEGMNT(1-4,I)	Name of line segment (4A4) in interaction I
IACTLE(I)	Index for interaction I in INTACT array of common block /PREP/ (probably not needed for summary page printout application)
NINTLE	Number of ellipse-line interactions occurring in the simulation
IWIND	Index in /MAXDEF/-arrays for interaction data relating to maximum windshield deflection
DELCMX	Maximum deflection of chest

DELLIN	Line segment deflection at time of maximum chest deflection
TIMEDC	Time of maximum deflection of chest
FORCDC	Chest force at time of maximum chest deflection
ELLC(1-4)	Name of chest ellipse (CHES..., 4A4) with maximum chest deflection
SEGC(1-4)	Name of line segment which produces maximum chest deflection (4A4)
IACTC	Index for chest interaction in INTACT array of common block /PREP/ (probably not needed for summary page printout application)

3/19/86

Card 200

This card contains the run subtitle for the occupant parameter input block. It is used by the program in the automatic preparation of headings for each page of printed output.

Cards 201-204

Useful schematics are included as Figures 66 and 67.

Cards 205-216 (plus Card 242)

There are a variety of quantities on these cards which define the geometry and torsional strength properties of the various joint structures. Joint geometry will be discussed followed by a discussion of joint torque generation.

Figure 68 is a sketch of a human in a standing position. His body links have been sketched in to show that they are not necessarily in alignment. This factor becomes important in auxiliary programs which compute body link dimensions on the basis of external anthropometric data.

Figure 69 is a schematic representation of the standing man represented by his links and contact circles. In this diagram the misalignment of the links is shown and the misalignment on angular displacement between the upper torso link and the neck link is labeled ZETA.

Figure 70 is a sketch of a human in a seated position. His body links as required for input to the program have been superimposed on the body outline to show their positions. The same considerations apply to sitting position as were discussed for the standing position in Figure 68.

Figure 71 is similar to Figure 69 except that the occupant is seated. It is apparent that the natural angular displacement of the links at the knee and hip are different for the seated position and the standing position. Distinction between seated and standing positions becomes necessary when the simulation is used to characterize vehicle occupants and pedestrians.

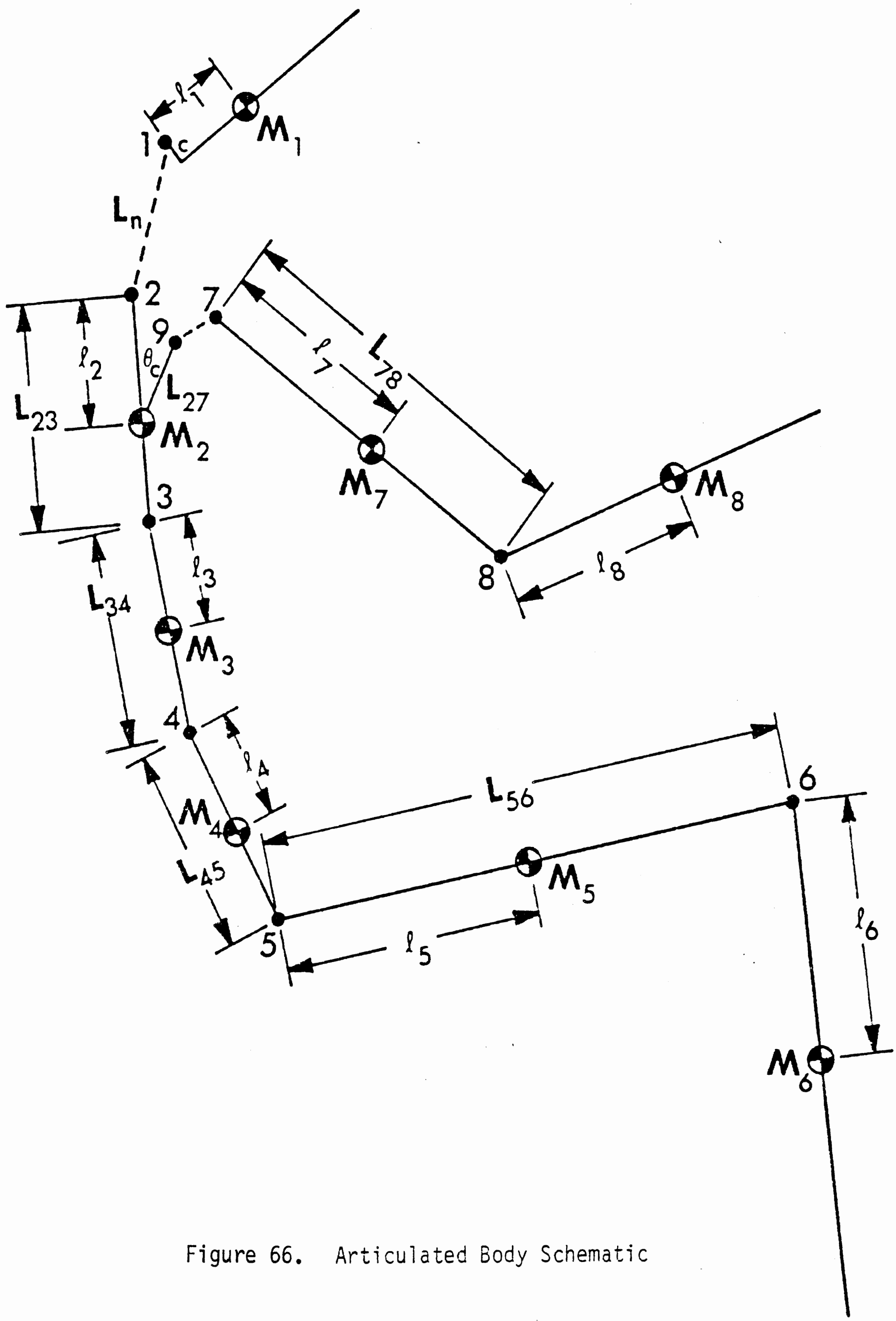
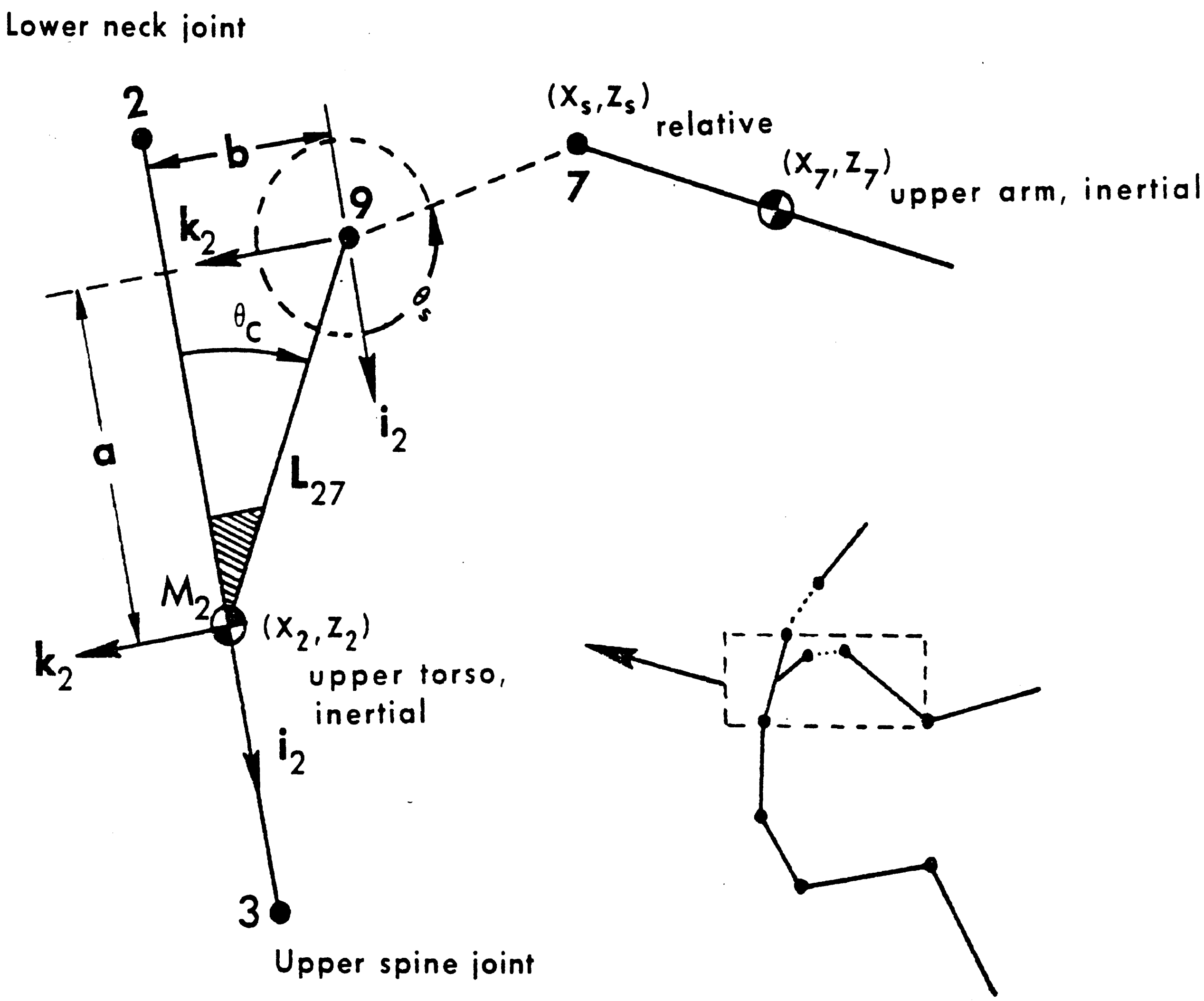


Figure 66. Articulated Body Schematic



$$\vec{\ell}_{9\to7} = \mathbf{x}_s\mathbf{i}_2 + \mathbf{z}_s\mathbf{k}_2$$

$$\theta_C = \text{constant}$$

$$L_{27} = \text{constant}$$

Figure 67. Shoulder Joint

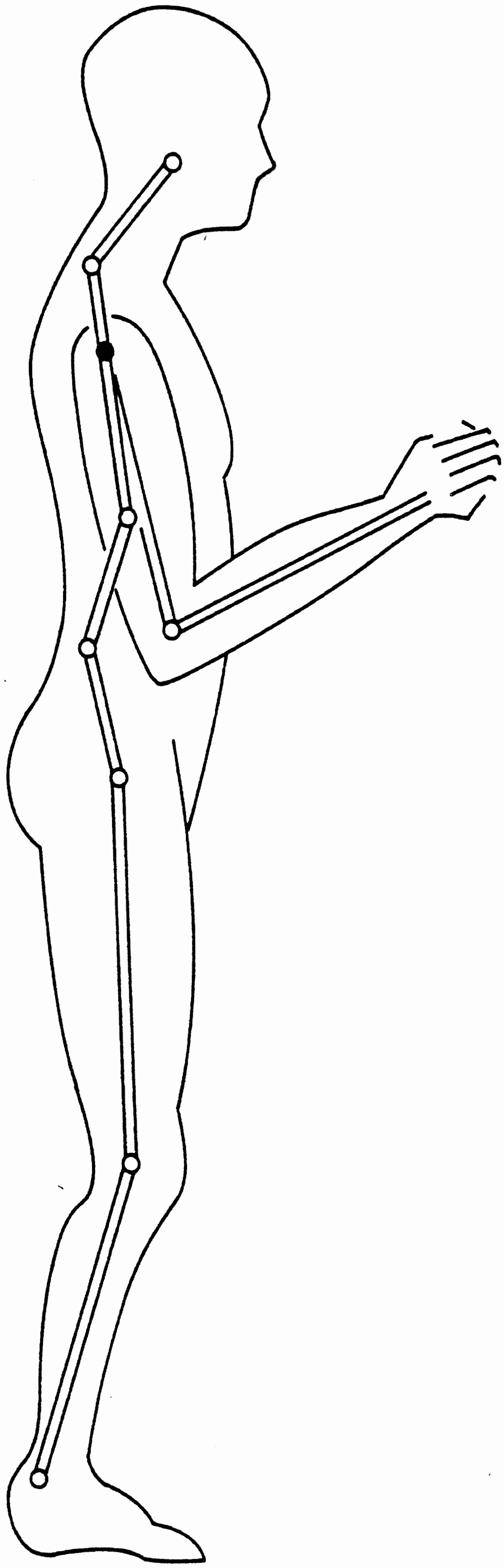


Figure 68. Standing Position

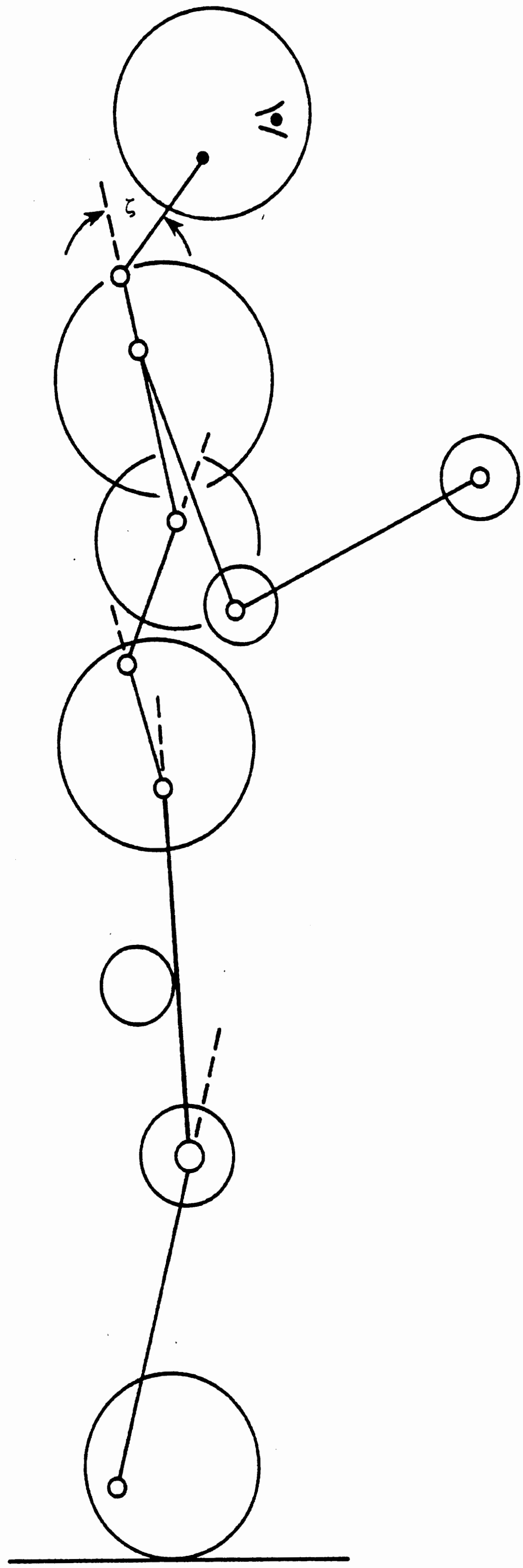


Figure 69. Schematic Representation of Man

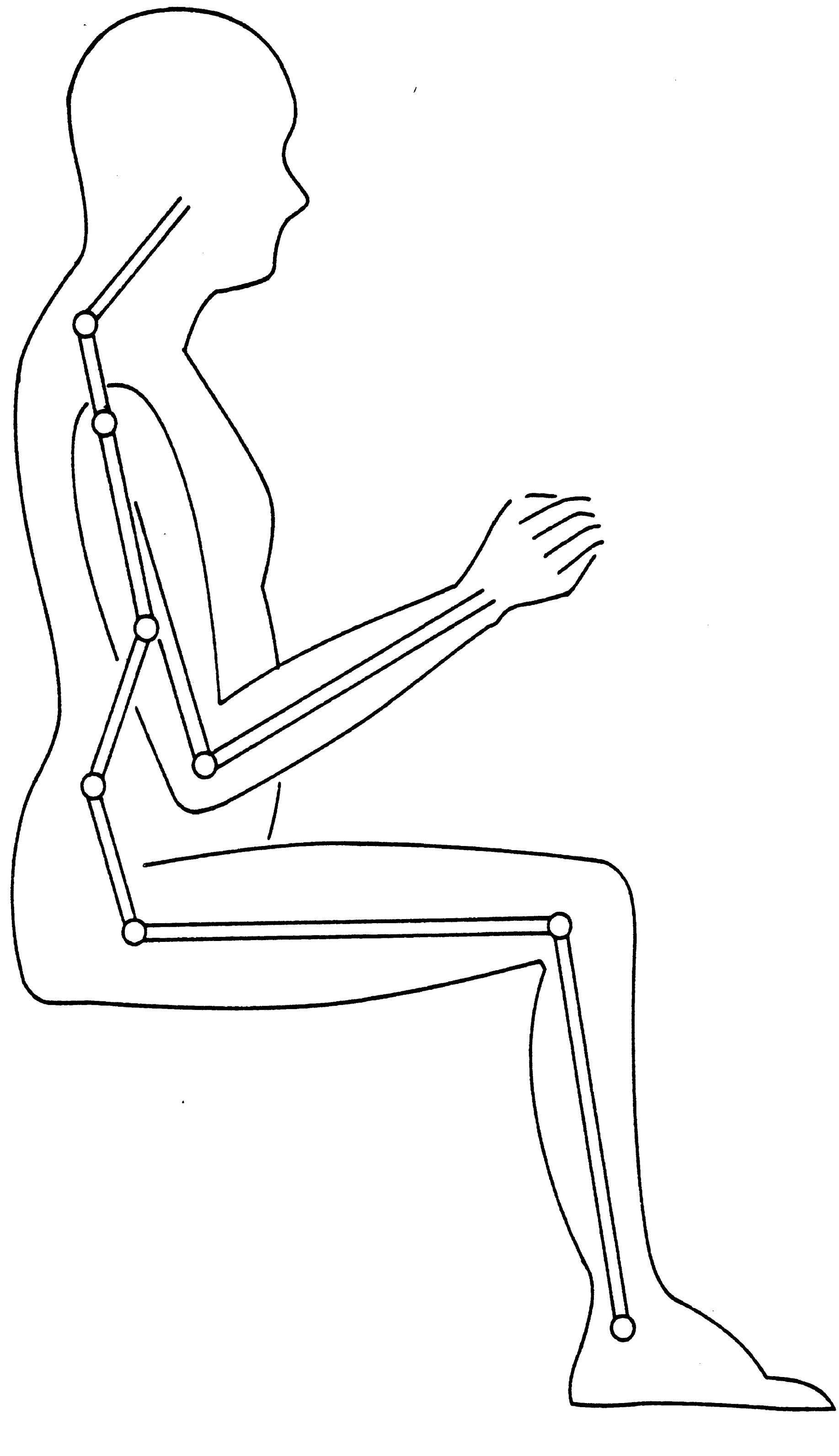


Figure 70. Sitting Position

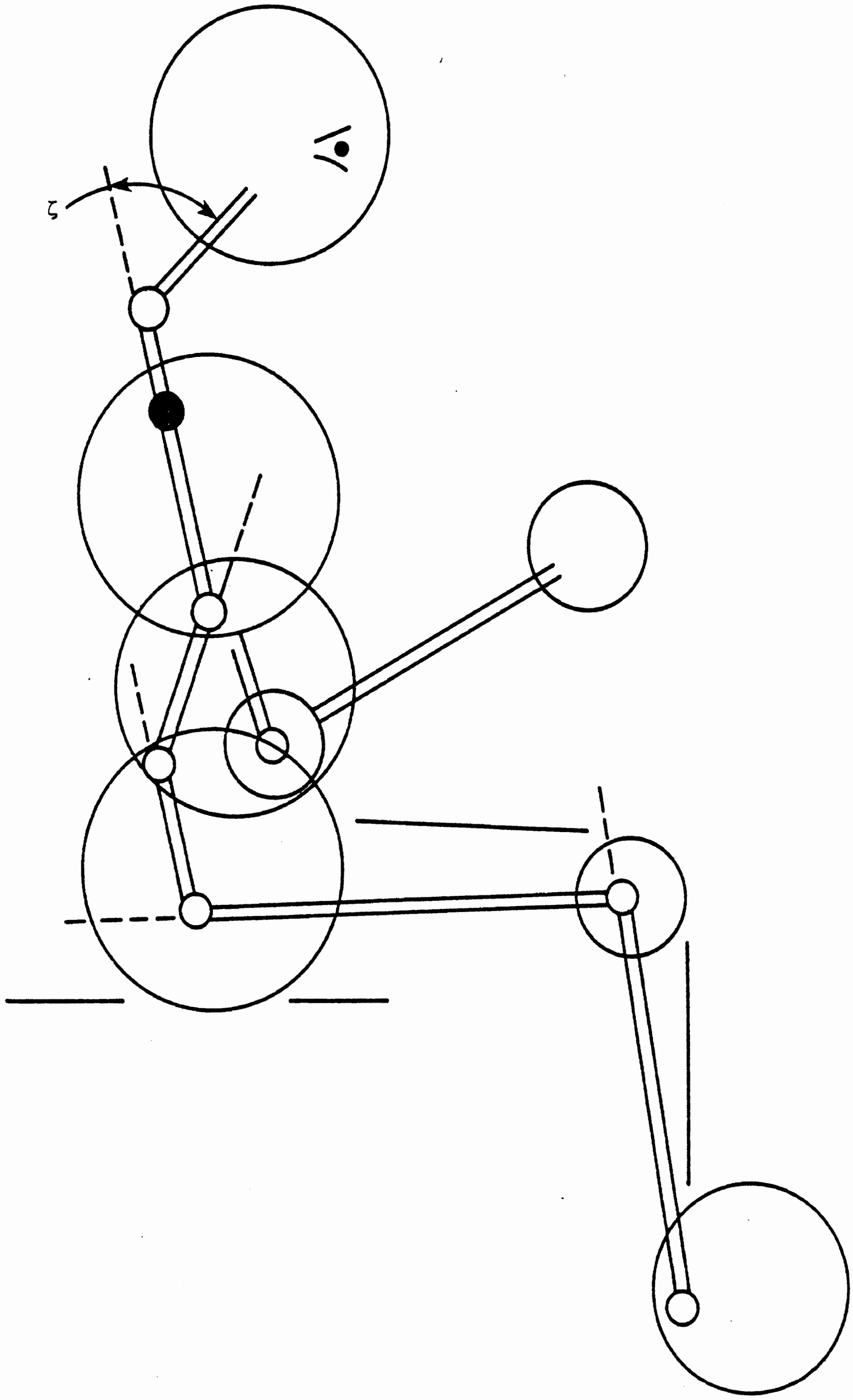


Figure 71. Schematic Sitting Position

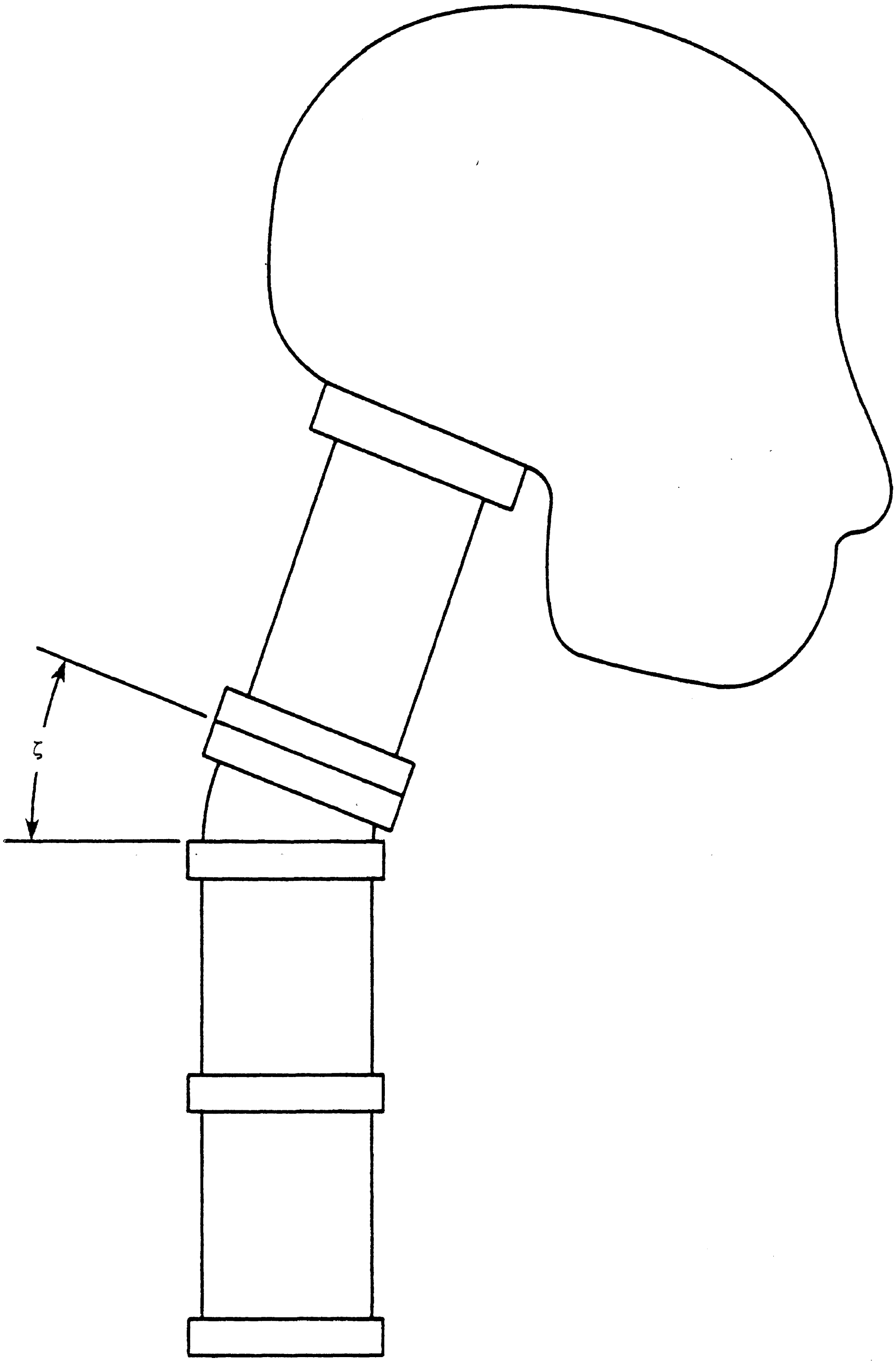


Figure 72. Provision for "Natural" Link Orientation

Figure 72 shows how natural link orientation might be obtained in the construction of a dummy which employs an assemblage of symmetrical jointed links. Namely, interconnecting flanges of appropriate angular sweep could be used between the links. This feature would allow the joint to be at rest in a natural position without exerting a torque. In actual dummy construction, the individual links might incorporate the angular characteristics required at each end. This figure is included only to point out that both dummies and the mathematical models of humans must accommodate the natural angular displacement of the links when the human is at rest.

On Cards 205-216, joint-stop angles and a "natural link angle" must be prescribed for each joint. All are prescribed as "relative angles."

Figure 73 defines, for the purposes of this discussion, the relative angular displacements between two adjacent links. Figure 74 illustrates the definitions of joint-stop angles and the "natural link angle." Consider the joint between body links "L_α" and "L_β." Here, "α" shall designate the link nearer to the head and "β" the link nearer to the feet. The upper and lower joint-stop angles and the "natural link angle" are defined by counterclockwise (positive) rotation of L_α with respect to L_β, as shown in the Figures. Positions of L_α requiring clockwise rotation are described by negative angles.

Field 1 of Cards 205-212 and 215-216 contains KJI(I,1). If positive, this is the linear coefficient of an elastic torque generated when two links move away from their "natural" link orientation defined above. If negative, the magnitude is taken as a linear joint-stop spring stiffness. Quadratic and cubic joint-stop stiffnesses are in fields 2 and 3.

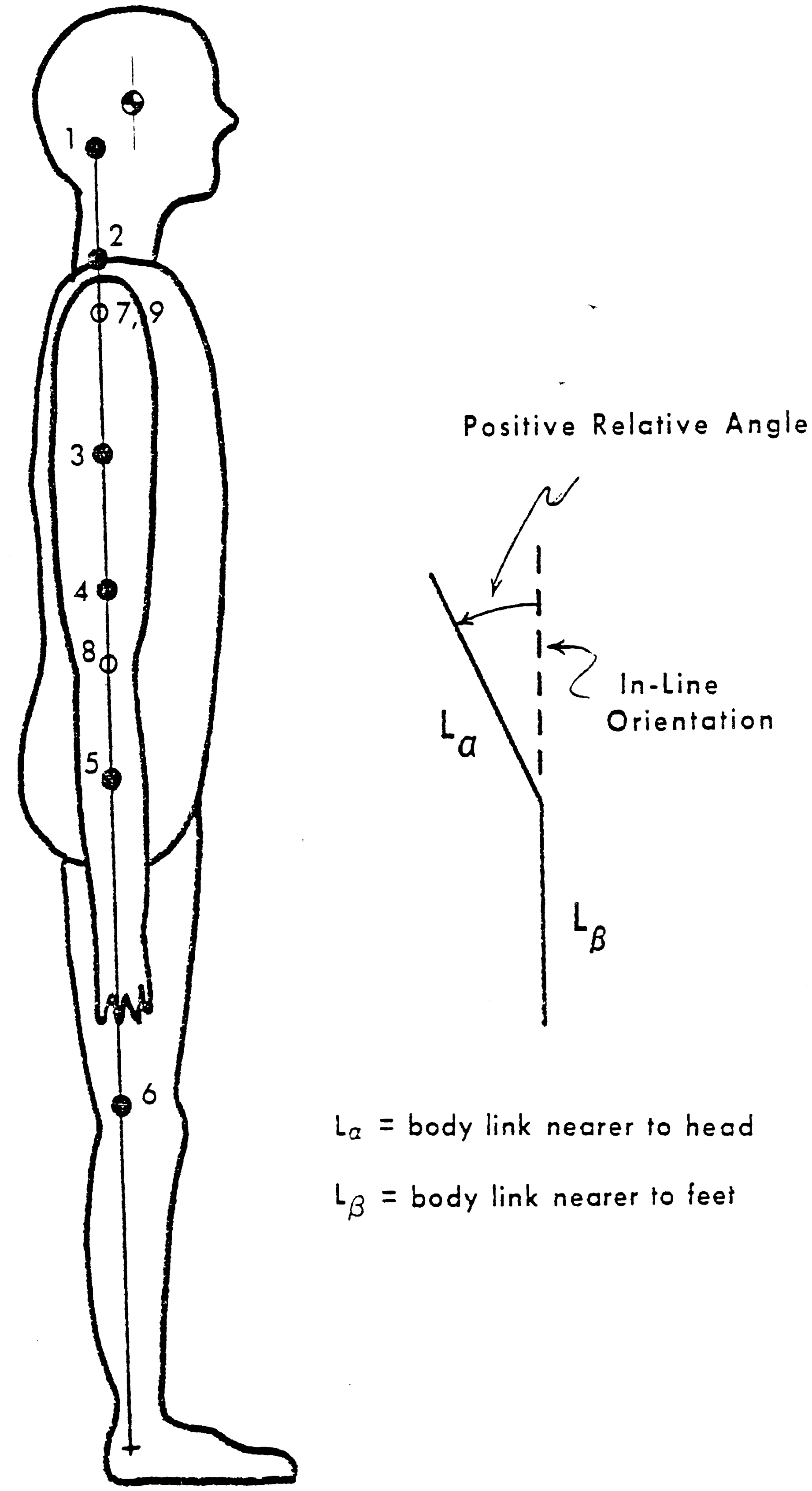


Figure 73. In-line Orientation

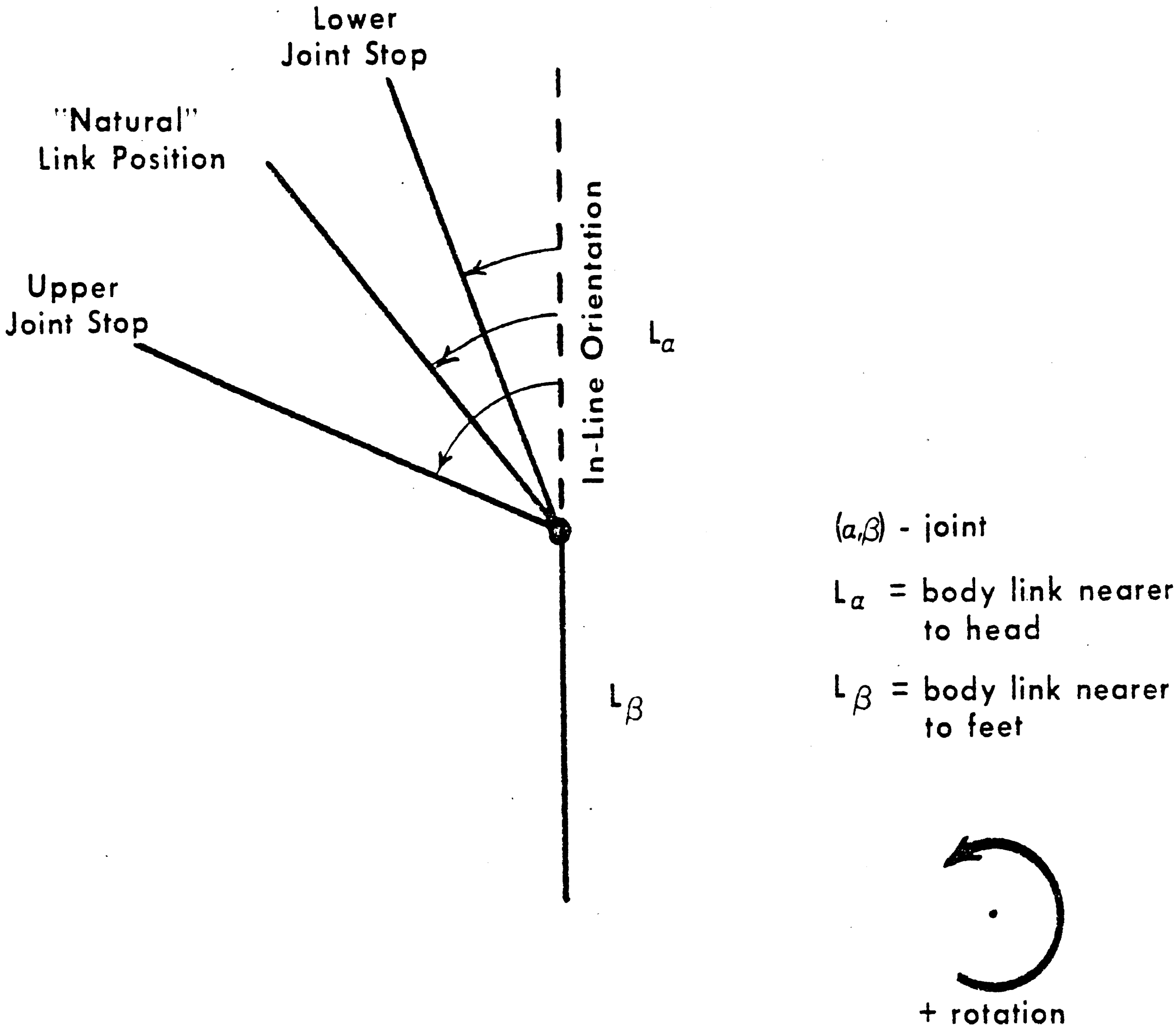


Figure 74. Definition of joint stop angles and natural link position

Field 4 on these cards contains a viscous damping constant. The damping torque generated at a joint is

$$T_i^v = C_i^j \theta_i^v \quad ,$$

where T_i^v is the torque, C_i^j is the damping constant, and θ_i^v is the relative angular velocity between the two adjacent body elements.

Fields 5 and 6 define the joint constant friction properties of the crash victim as shown in Figure 7. When the relative angular velocity between the two adjacent body segments exceeds the threshold velocity V_i^J, the frictional torque, F_i^J, is applied to resist the motion.

Fields 7 and 8 on cards 205-212 and 215-216 define the location of upper and lower joint stops. Field 9 defines the ratio of conserved to stored energy in the stops. It is used in the computation of an unloading curve.

Cards 213, 214, and 242 contain similar quantities for elongation and compression of the neck and shoulder elements. Analogies with the quantities on Cards 205-212 and 215-216 do not always hold strictly. First, there is no "stop" for the neck element. It might be considered that there is a stop at zero elongation since the quadratic and cubic deflection coefficients take effect immediately with deviation from the initial neck length (Field 5 of Card 303), but no conserved-absorbed energy ratio (Field 9) is used. Energy can be dissipated through viscous damping for both the neck and shoulder element, but there is no constant friction. The shoulder element does have a stop (RSH), i.e., an elongation at which a conserved-absorbed energy ratio takes effect along with a stiffening of the deflection curve (the quadratic and cubic deflection coefficients). The neck element behaves differently in elongation and compression if the coefficients on Cards 213 and 242 differ.

Card 217

Fields 1-7 on Card 217 define the "natural" link displacements for the joints. When relative joint angles equal these "rest angles," the joint torques due to linear spring forces are zero. It should be noted that this natural angle does not have to correspond to the initial position of the crash victim. The "natural" angle is described in Figure 74.

Card 218

Self-contained. (See Figure 75.)

Card 219

This card and at least two following it should be included for each contact-sensing ellipse attached to the crash victim. This first contains an ellipse name used in output headings, the name of the material defining the force-deformation characteristics of the ellipse, the body element on which the ellipse is attached, and the friction class. A friction class number is assigned to each ellipse and each contact region. For each pair of friction class numbers, a friction constant is assigned (see Card 412).

Card 220

This card locates the ellipse with respect to the center of gravity of the particular body segment to which it is attached. Fields 3 and 4 locate the center of the ellipse while fields 4 and 6 determine the semi-axes of the ellipse which are located parallel to the moving coordinate system attached to each body element. Figure 76 illustrates the definition of these various parameters.

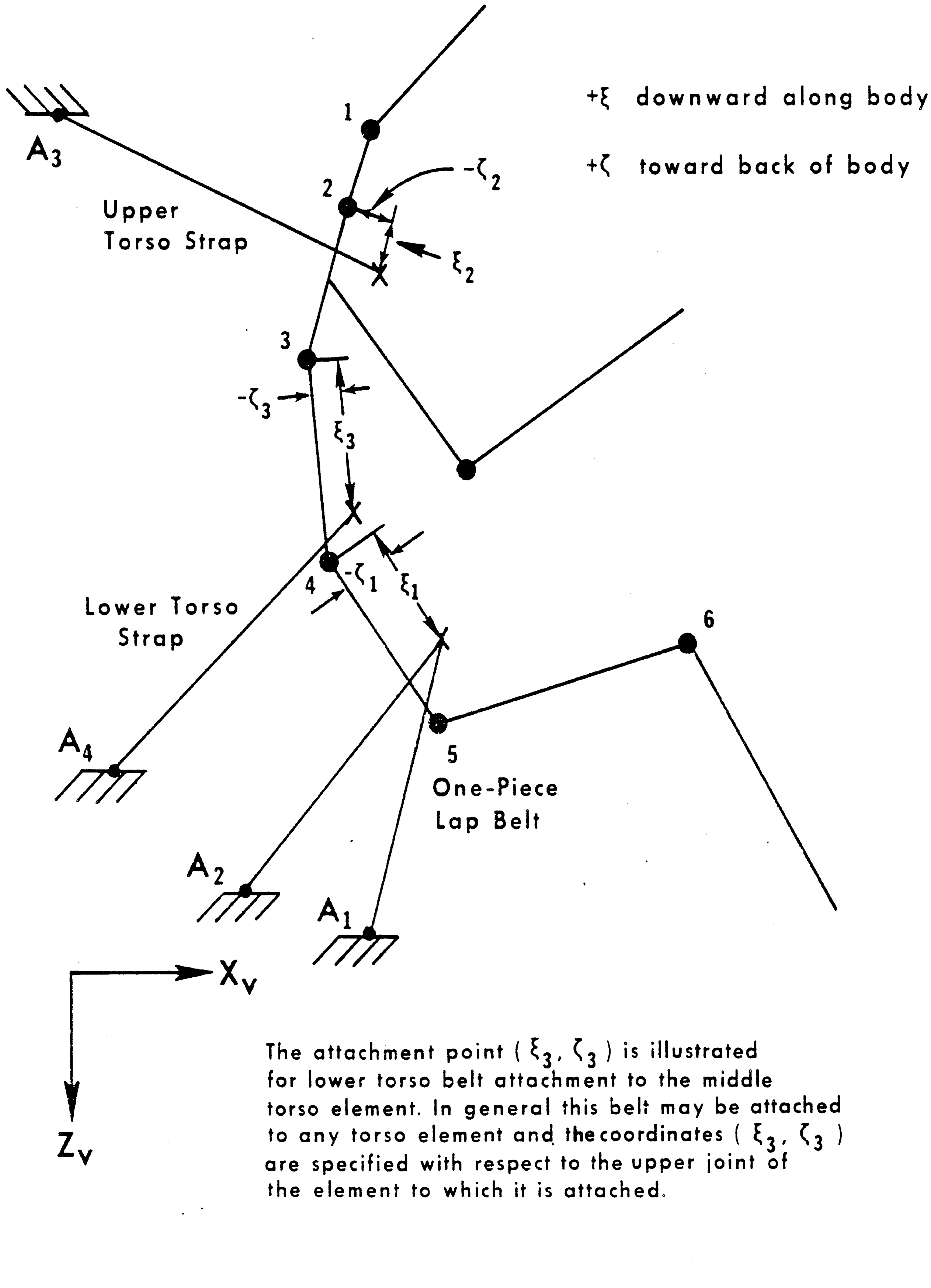


Figure 75. Three-Belt System Geometry

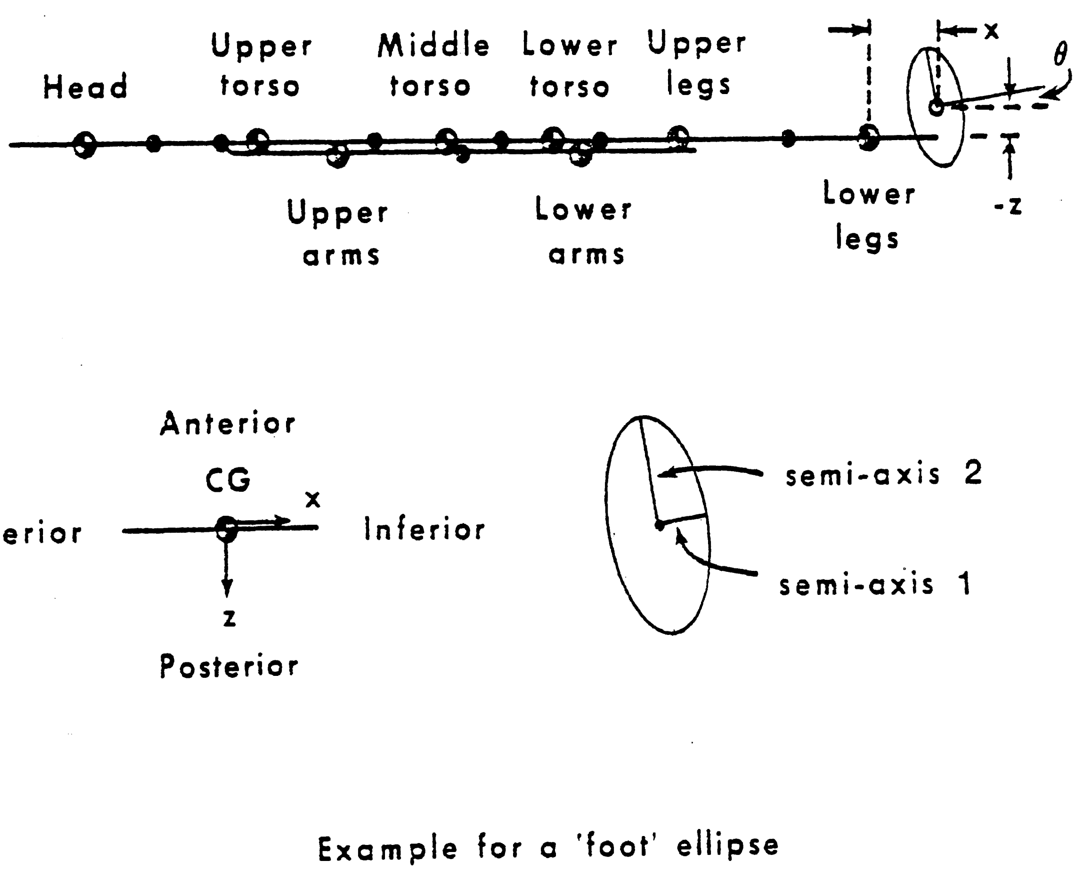


Figure 76. Definition of Location and Dimensions of Contact-Sensing Ellipses

Cards 221-226

See Cards 403-408.

Cards 227-238

Cards 227-237 contain the muscle element coefficients a_1, a_2, a_3, which, together with the tabular time-dependent muscle tensions $|M|$ from 238-Cards, define the Maxwell coefficients of the composite musculature at a joint. This is discussed in Section 2.3.2.

The literature does not at present contain a great deal of experimental information relating to the values a_1, a_2, a_3, and $M(t)$. HSRI has successfully used values determined by Bowman [10] from certain published data for the knee and by scaling on the basis of available anthropometric data. The available values which are pertinent to the MVMA 2-D simulation are given below. $|M|_{max}$ in each instance is the maximum degree of muscle contraction by an average man. Figure 77 pertains to scaling of these data.*

Upper neck joint and lower neck:

a_1 = 1.476 lb in/deg

a_2 = 0.153 deg^{-1}

a_3 = 0.0129 sec/deg

$|M|_{max}$ = 210 lb in

Shoulder-upper torso joint:

a_1 = 0.15 lb in/deg

a_2 = 0.153 deg^{-1}

a_3 = 0.0129 sec/deg

$|M|_{max}$ = 5 lb in

Neck element elongation:

a_1 = 42.3 lb/in

a_2 = 4.4 in^{-1}

---

*L is the effective moment arm at a joint for action of a muscle.

a_3 = 0.37 sec/in

$|M|_{max}$ = 210 lb

*Shoulder-upper torso joint:

a_1 = 0.15 lb in/deg

a_2 = 0.153 deg^{-1}

a_3 = 0.0129 sec/deg

$|M|_{max}$ = 5 lb in

*Shoulder element elongation:

a_1 = 4.23 lb/in

a_2 = 4.4 in^{-1}

a_3 = 0.37 sec/in

$|M|_{max}$ = 200 lb

Knee:

a_1 = 10.44 lb in/deg

a_2 = 0.105 deg^{-1}

a_3 = 0.0088 sec/deg

$|M|_{max}$ = 4320 lb in (two knees together)

Cards 239-241

Since shoulder flexibility may be more restricted in some directions than in others (See Section 2.3.1) allowance has been made for angular dependence of the stiffness coefficients for elongation of the shoulder element. Periodic tables may be entered by use of Cards 239-241.

Card 242

See the last paragraph of the section describing Cards 205-216.

Card 300

This card contains the run subtitle for the occupant orientation input block. It is used by the program in the automatic preparation of headings for each page of printed output.

* The shoulder muscle tension parameter values are little better than guesses.

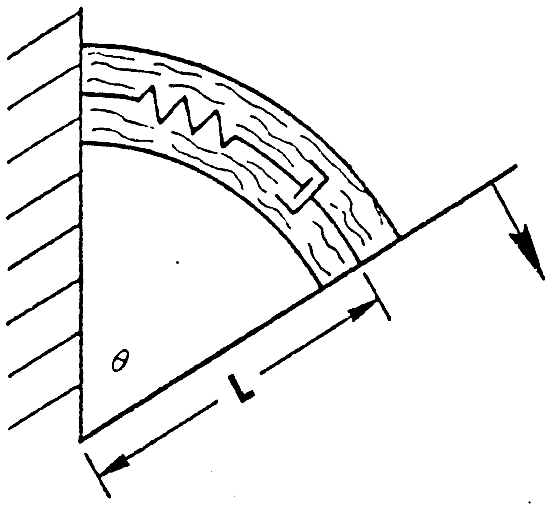


Figure 77. Muscle at a joint

SCALING LAWS RELATING MUSCLE PARAMETERS

FOR JOINTS I AND II:

$$a_{1,II} = \left(\frac{L_{II}}{L_I}\right)^2 a_{1,I} \quad \frac{|F_{max,II}|}{|F_{max,I}|}$$

$$a_{2,II} = \left(\frac{L_{II}}{L_I}\right) a_{2,I}$$

$$a_{3,II} = \left(\frac{L_{II}}{L_I}\right) a_{3,I}$$

where $|F_{max,j}| = |M_{max,j}| \,/\, L_j$.

NOTE: I and II indicate either two joints for the same individual or the same joint for two individuals. $M_{max,j}$ is the maximum static torque that can be voluntarily generated at joint j. $F_{max,j}$ is the maximum static tension that can be generated in the muscle element under the same conditions. For scaling from individual to individual for the same joint, $|F_{II}|/|F_I|$ can reasonably be taken as $(m_{II}/m_I)^{\frac{2}{3}}$, where m is total body mass.

Card 301

This card contains the initial body link angles. They are computed relative to the null position shown in Figures 78 and 79. Two examples are also shown in Figure 79, an upright occupant position with arms extended and a representative seated position. The angles included in the tabular output use this same convention.

In auxiliary debug output, the angles are computed using a different convention. The null position is shown in Figure 80 as well as the values corresponding to the seated example of Figure 79.

Card 302

Self-contained (See Card 301)

Cards 303-304

Self-contained. (See Figure 67 for X_s and Z_s.)

Card 400

This card contains the run subtitle for the input block used to describe the shape and physical properties of the vehicle interior. It is used by the program for the automatic preparation of headings for each page of printed output.

Cards 401-402

These two cards which must be supplied for each contact region contain the control switches which select the various contact force generation options available with the program.

Each contact region is given a region name and a name for the material properties as specified in Fields 1-4 of Card 401. The switch in Field 5 selects the force generation model to be used. The standard model (switch = 0) uses techniques similar to MODROS and older HSRI models. That is, line segments within a region deform independently for each impinging contact-sensing ellipse and continuity is not maintained between adjacent line segments within a region. The force-deformation curve may be tabular, polynomial or a combination. The standard force-deformation model does have the advantages of the real-line

$\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7, \theta_8, \theta_n = 0$ (input or output)

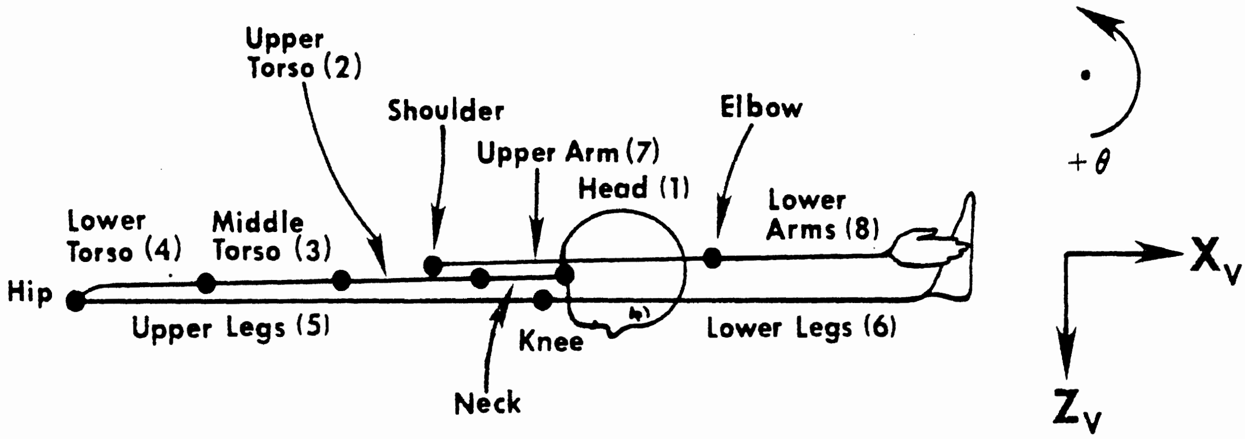


Figure 78. Occupant Model Configuration with all Body Link Angles Equal to Zero, for INPUT or OUTPUT

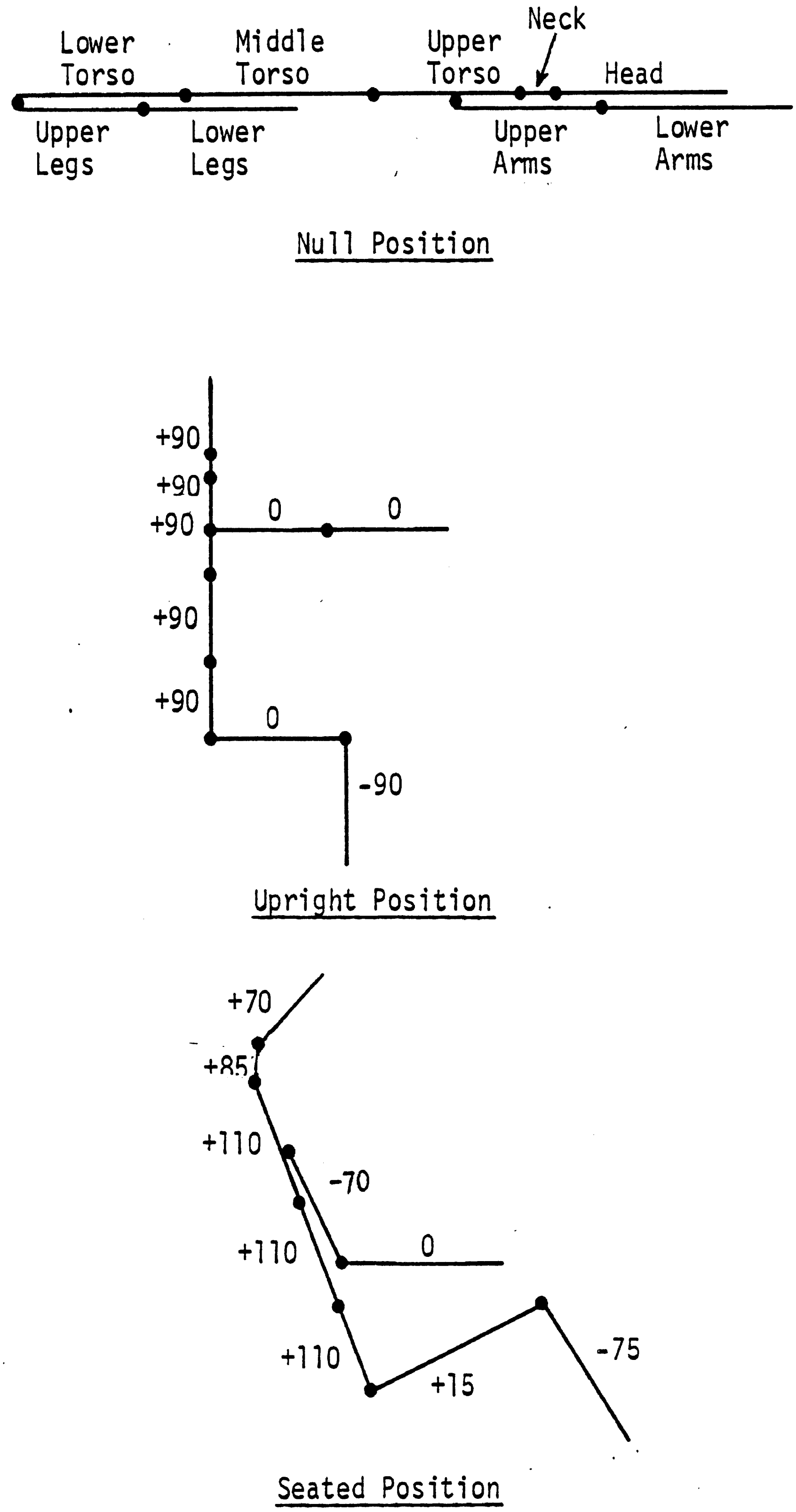
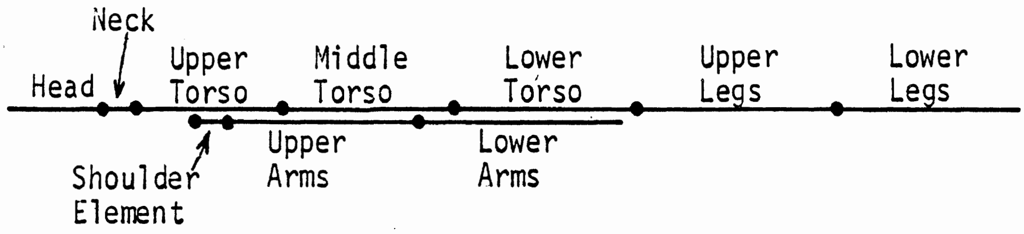
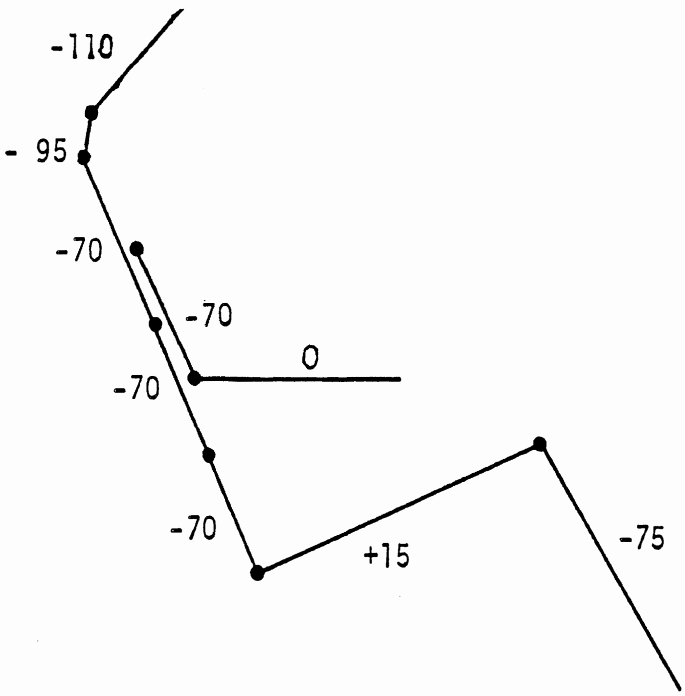


Figure 79. Body Link Angle Conventions for Input Data and Tabular Output



Null Position



Seated Position

Figure 80. Body Link Angle Conventions for Auxiliary Debug Output.

interior model in the sense that resultant forces are computed in a direction perpendicular to the particular line segments of the region which are contacted.

If the switch = 1 in Field 5, a model of material response coupled with structural deformation is used. The force-deformation properties for the region are applicable for all line segments. However, continuity of the line segments is maintained and permanent deformation of one segment will result in permanent deformation for all. This permanent deformation also affects the location of the region for contacts involving additional ellipses. In addition, the use of this structural model allows variable stiffness within a contact region. A use of this is to simulate exactly the force-deformation curve of a region in the place where test data is available and to provide stiffer response near support structure for the region.

Field 6 of Card 401 supplements the contact model. If the switch = 0, multiple ellipses interacting with one line segment are not considered independently. Rather, the sum of their independent forces is required to equal the maximum of the forces generated if they are all considered independently. This effectively distributes the loading of several contact ellipses over the surface and improves the model of contact. If the switch = 1, the older technique is used where each contact-sensing ellipse interacts independently with the contact line segments. For this option to work the cavity analysis must be used as specified by the switch in Field 8 of Card 401.

The switch in Field 7 of card 401 considers the case where a large contact-sensing ellipse interacts with a curved area within a region including several line segments. When the switch = 0, the forces generated by all the involved line segments are combined to yield a resultant force acting in the appropriate direction. When the switch = 1, the forces act independently on the ellipse as is the case with older HSRI models and MODROS.

The switch in Field 8 of Card 401 controls the use of a "cavity analysis" for line segments within a region. Individual contact ellipses yield a "dent" when they impinge on a surface. The shape of this dent is controlled by parameters on Card 404, the "cavity coefficients." The purpose of these dents is to control the phasing of contact ellipse interactions with a surface. If one ellipse interacts, a dent is formed with deformation of the surface existing away from the area of contact. If a second ellipse begins to impinge, it should see this dent rather than the original contact surface for proper phasing of contact forces. This refinement of the analysis is not included in MODROS or older HSRI models.

Field 3 of card 402 includes the number of individual line segments in the contact region. The location and properties of each of the line segments are included on 409-411 cards.

Field 4 of Card 402 identifies the friction class of the contact region. A friction class number is attached to each ellipse and each contact region. For each pair of friction class numbers, friction coefficients are assigned (see Card 412).

The switch in Field 5 of Card 402 controls use of the structural deformation model. If the switch is 0, structural deformation is allowed. If the switch is 1, it is not.

The switches in Fields 6 and 7 of Card 402 define the coordinate systems used in the input data and in the printed output. Vehicle coordinates will most often be selected for occupant protection studies while inertial coordinates will be mostly used in pedestrian studies.

Cards 403-408 (221-226) (704-709) (812-817)

These six cards are used to describe material properties for regions, contact ellipses, belts, and steering assembly components. A set must be included for each material property name included elsewhere in the input data.

Card 403 (221, 704, 812)

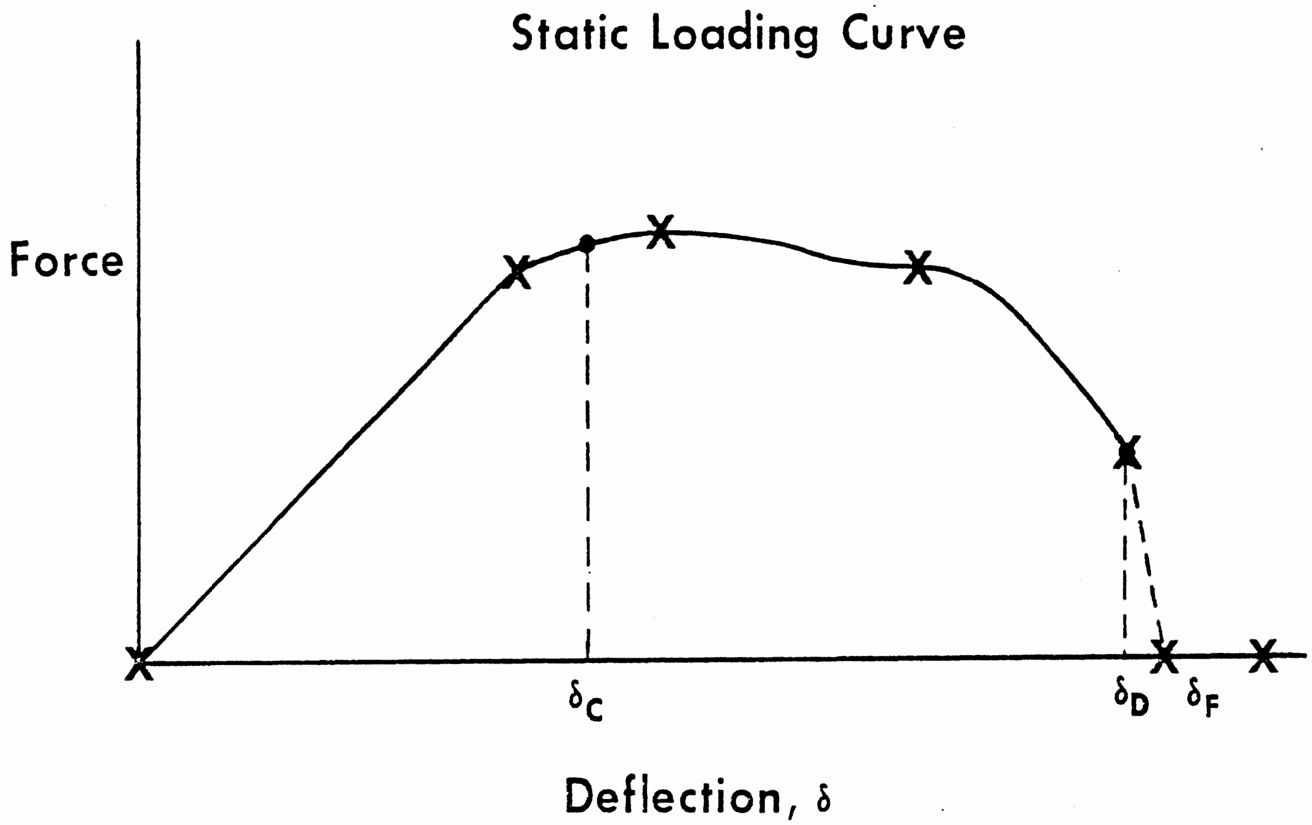
The quantities included in Fields 3-9 determine key points on the force-deformation curve shown as Figures 12, 81, 82, 83, 84, and 85.

Card 404 (222, 705, 813)

Field 3 contains the quantity FOREPS. When shared deflection is used, it is necessary to solve for a deflection in two elements such that the force is the same acting on both. Because exact solution is not possible, a range of error must be specified. This range of error is specified on the applied force. For most problems an error range of 5 lb. is felt to be adequate.

Fields 4, 5, and 6 contain cavity coefficients which are read if this option is selected. The quantity λ_1 controls the extent of the dent due to the deflection. The quantity λ_2 controls the extent of the dent due to the size of the impinging ellipse and λ_3 controls the shape of the dent under the contact ellipse. The action of these coefficients is shown in Figure 86. Their values should be selected based on the size of the dent observed when a ball impinges into the contact surface during an experimental impact. The smallest possible cavity is given by $\lambda_1 = \lambda_2 = \lambda_3 = 0$.

Fields 7, 8, and 9 specify names for various material properties specified in detail on other cards.

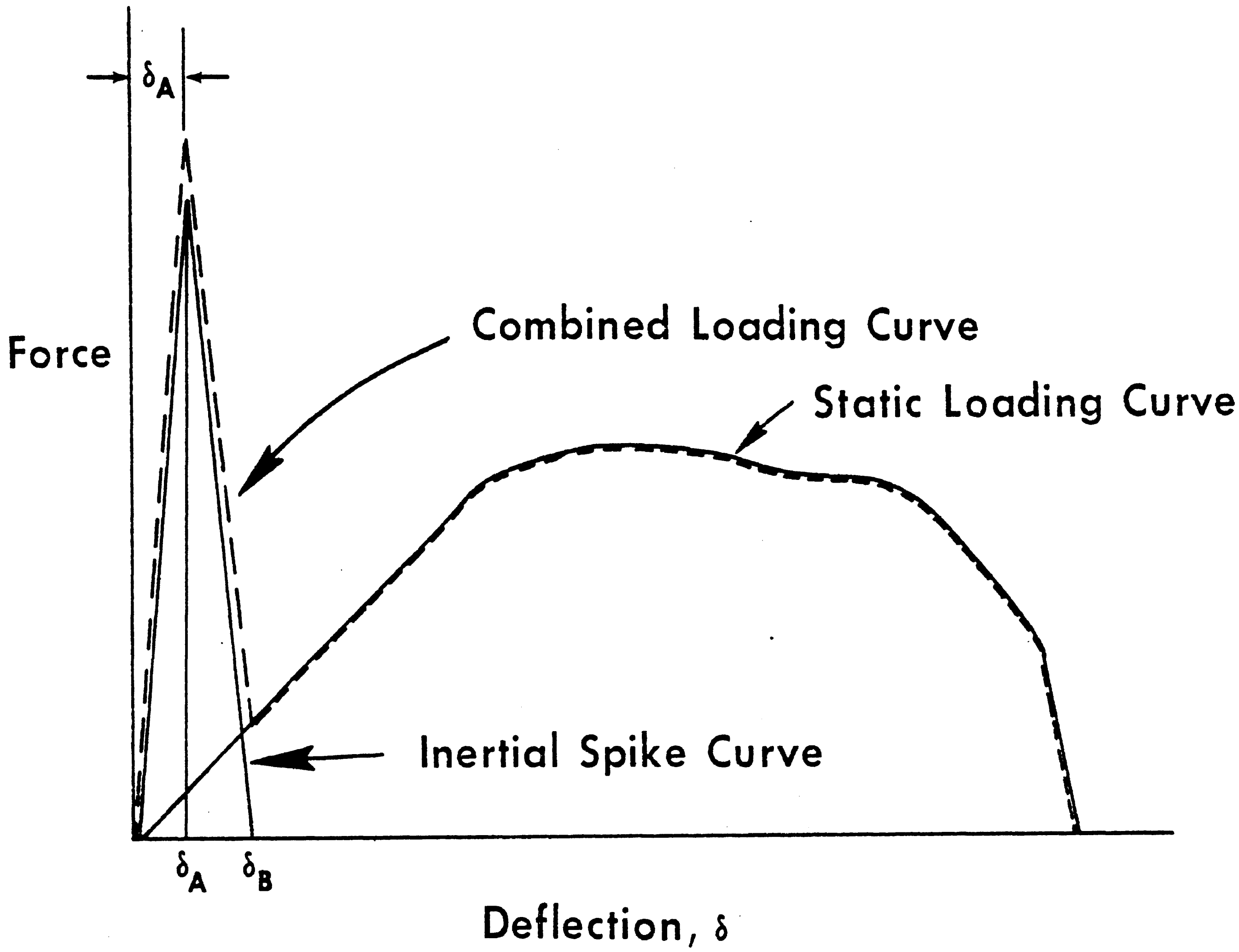


δ_C = yield point (elastic limit)

δ_D = breaking point

δ_F = end of breakdown curve

Figure 81. Static Loading Curve



δ_A = deflection at peak of inertial spike curve

δ_B = deflection at cutoff of inertial spike curve

Figure 82. Inertial Spike Curve

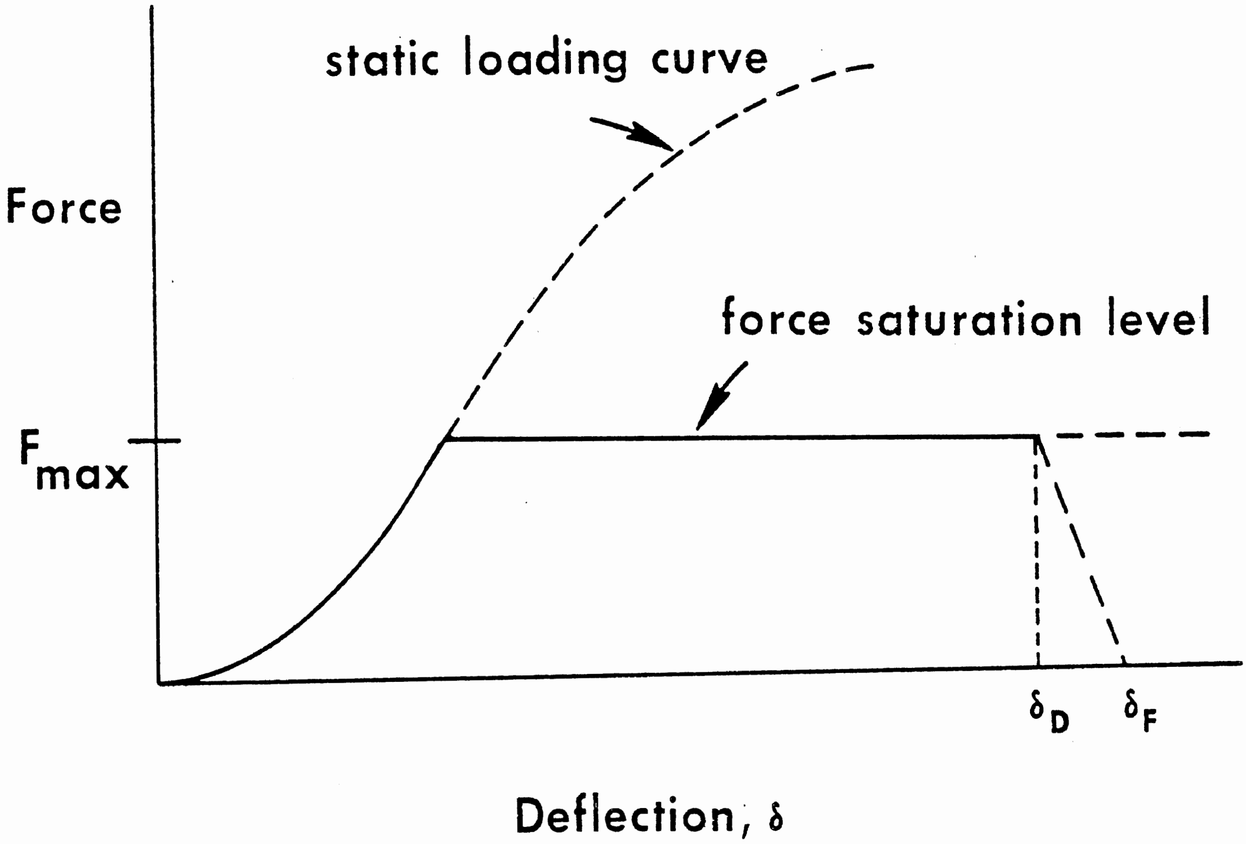


Figure 83. Static Loading Curve with Force Saturation

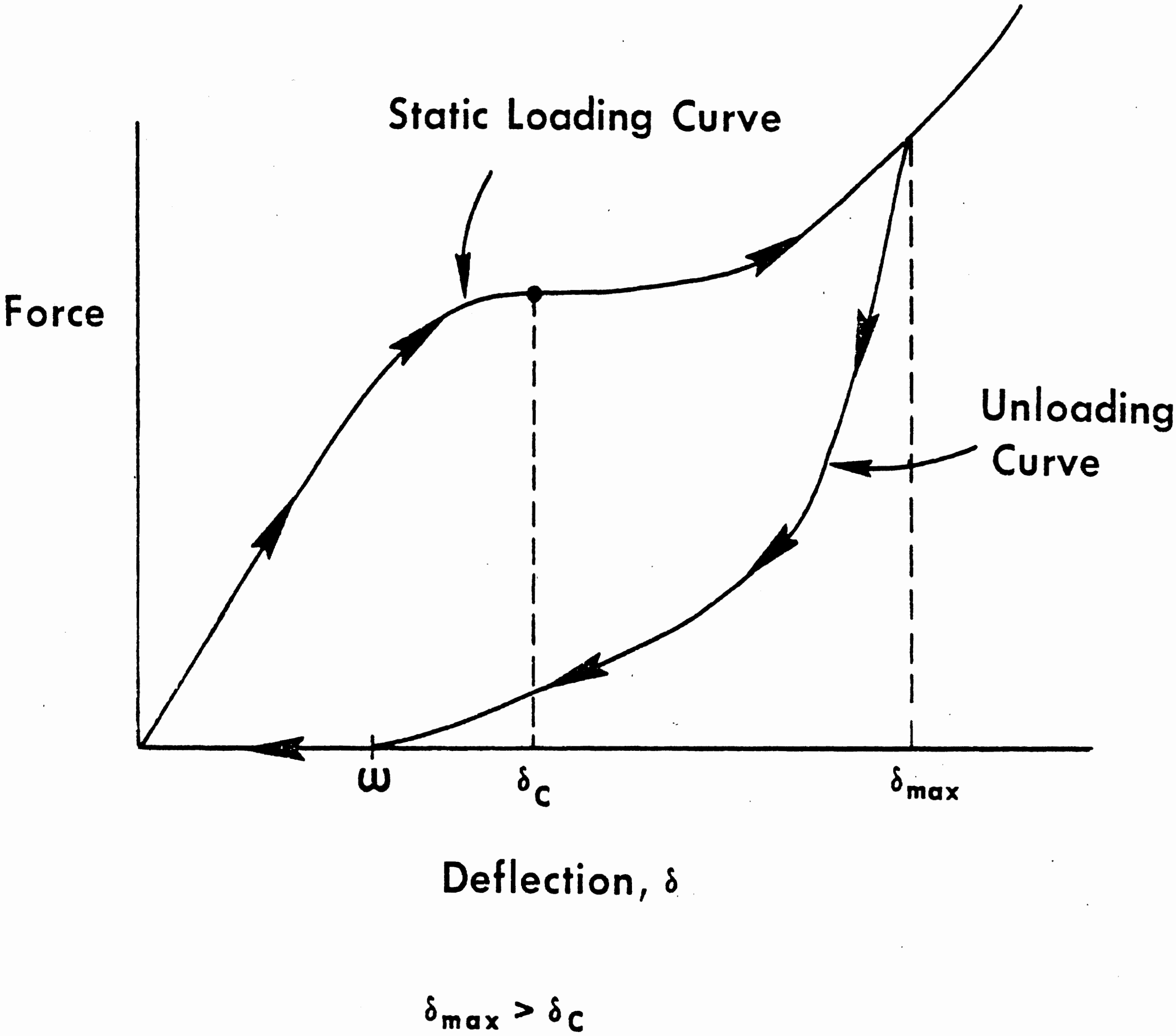


Figure 84. Unloading With Permanent Deformation from Deflections Greater Than δ_c

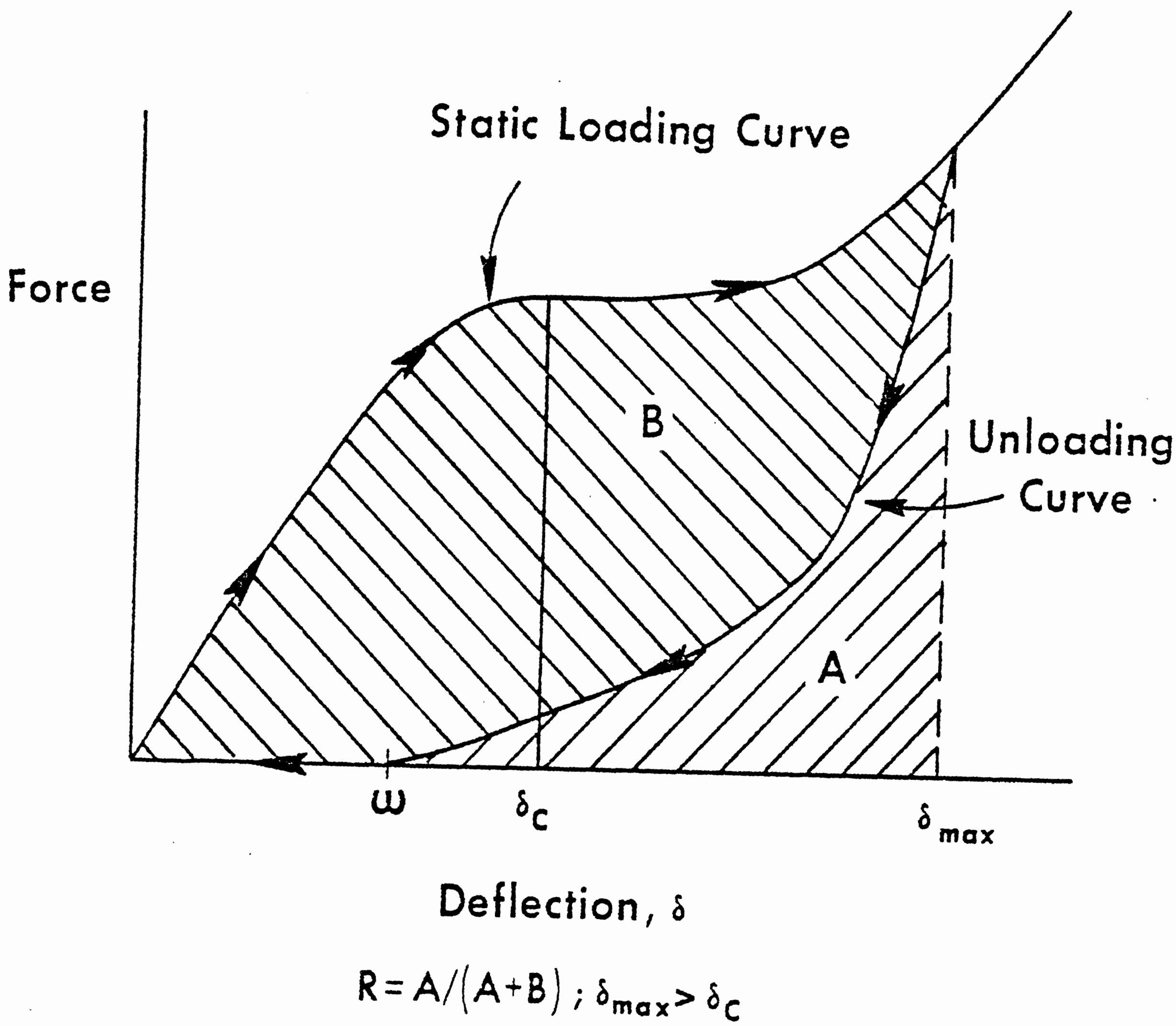
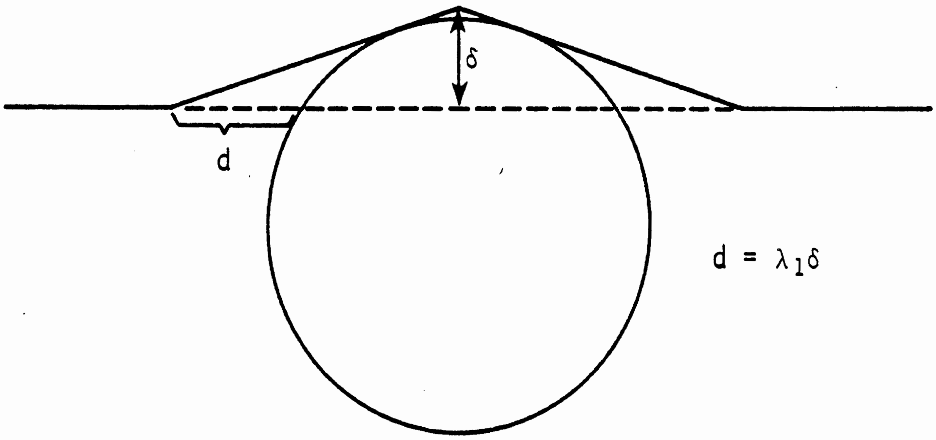
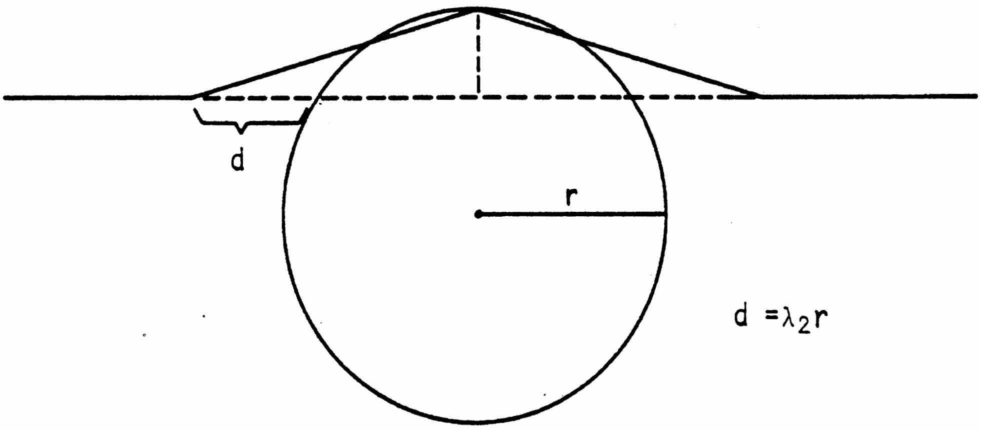


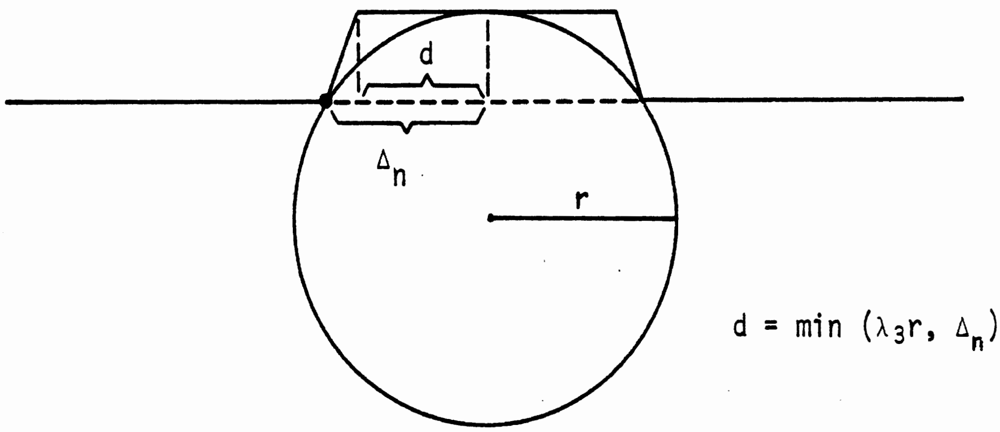
Figure 85. Unloading with Energy Loss from Deflections Greater Than δ_c



Cavity for $\lambda_1 \neq 0$, $\lambda_2 = 0$ $\lambda_3 = 0$



Cavity for $\lambda_1 = 0$, $\lambda_2 \neq 0$, $\lambda_3 = 0$



Cavity for $\lambda_1 = 0$, $\lambda_2 = 0$, $\lambda_3 \neq 0$

Figure 86. Cavity Coefficients

Card 405 (223, 706, 814)

This card or cards defines the ratio of permanent deflection to maximum deflection used in computing material unloading force-deflection curves. Field 2 contains a deflection or a negative number. If a negative number is given, there is only one 405 card for this material and G is assumed to be constant. See Figure 84.

Card 406 (224, 707, 815)

This card or cards defines the ratio of conserved energy to total energy used in computing material unloading force-deflection curves. Field 2 contains a deflection or a negative number. If a negative number is given, there is only one 406 card for this material and R is assumed to be constant. See Figure 85.

Card 407 (225, 708, 816) (See Figures 81 through 85.)

This card defines the static force-deflection curve for a material (Field 1) either as a polynomial or as a table of force versus deflection. If Field 2 contains a negative number, then force is given by

$$F = C_1\delta + C_2\delta^2 + C_3\delta^3 + C_4\delta^4 + C_5\delta^5 + C_6\delta^6$$

If Field 2 contains a deflection and Field 3 contains a force, then multiple 407 cards must be included to build a force-deflection table.

Card 408 (226, 709, 817)

The comments given for Card 407 apply except that the specified curve is the inertial spike shown in Figure 82 and discussed in Section 2.4.1.

Cards 409 and 410

These two cards must be included for each line segment and contain several required and optional quantities. Fields 5, 6, and 7 of Card 409 refer to the penetration limit, edge constant, and direction factors which are defined as in previous HSRI models. The penetration limit is needed to avoid force generation when a contact ellipse is legitimately under a contact surface. For example, the knee is often placed under the plane of the upper instrument panel. The value for this number should be selected larger than the amount of deflection which is expected of the surface in one time integration step.

The edge constant has been defined to handle cases where a contact ellipse interacts at the edge of a region or at a corner where two line segments meet. Its effect is shown in Figures 87 and 88. The force calculated based on a deflection, δ, is reduced from its full value where the ellipse is in full contact with the surface, to zero when the ellipse has slid to the side off the edge of the surface. The value for this constant should be chosen

$$0 \leq \lambda \leq 0.5$$

An example of the selection of a particular value is included in Section 2.6.2.

The direction factor indicates which side of a surface should be contacted. It is selected based on a determination of whether the time-zero inertial origin lies behind or in front of the contact surface. If the inertial origin is on the same side of the surface which should be contacted, 1. should be entered. Otherwise -1. should be entered.* See Figure 89.

The third field of Card 410 determines whether the contact line segment is programmed to move as a predetermined function of time thus representing events such as vehicle collapse or motion of a deployable restraint system. If the region does not move, 1. should be entered.

---

*No line segment defined by 411-Cards is allowed to pass through the inertial origin at t=0.

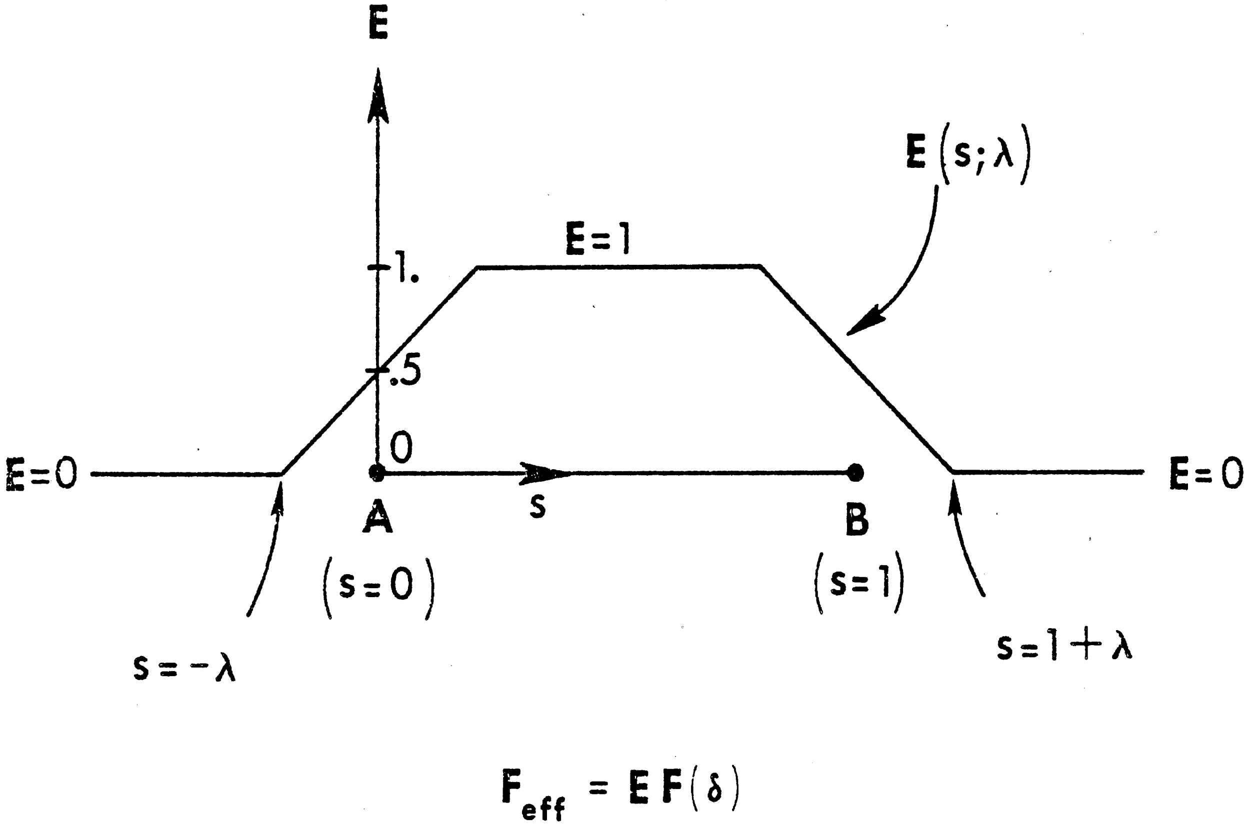
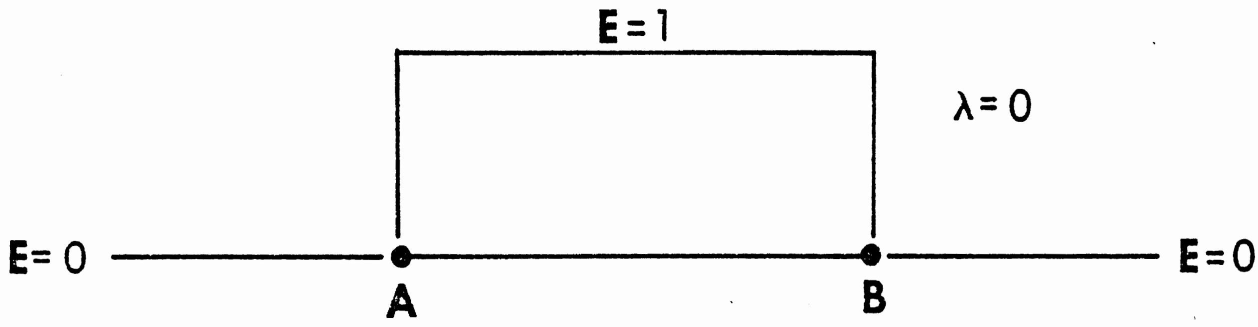


Figure 87. Effectiveness Factor E as a Function of s, the Position of Contact Point with Respect to Line Segment, With Edge Constant λ as a Parameter



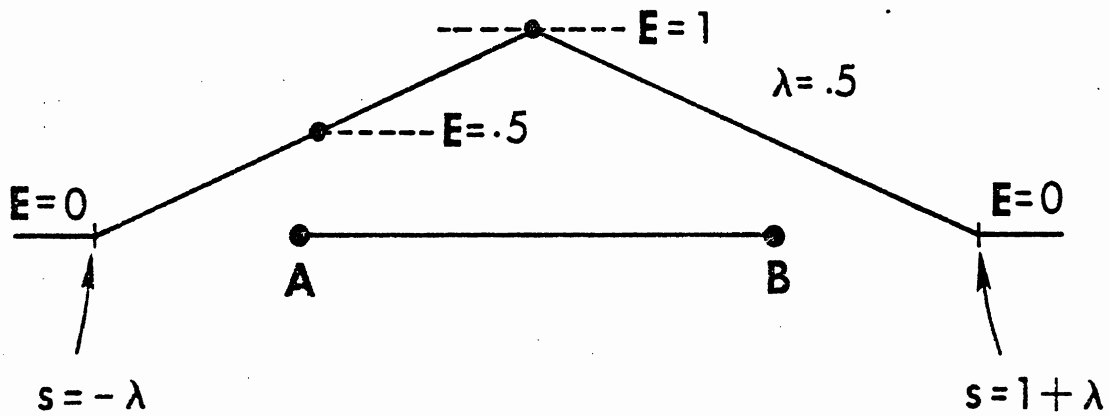


Figure 88. Effectiveness Factors for Edge Constant Values of 0. and .5

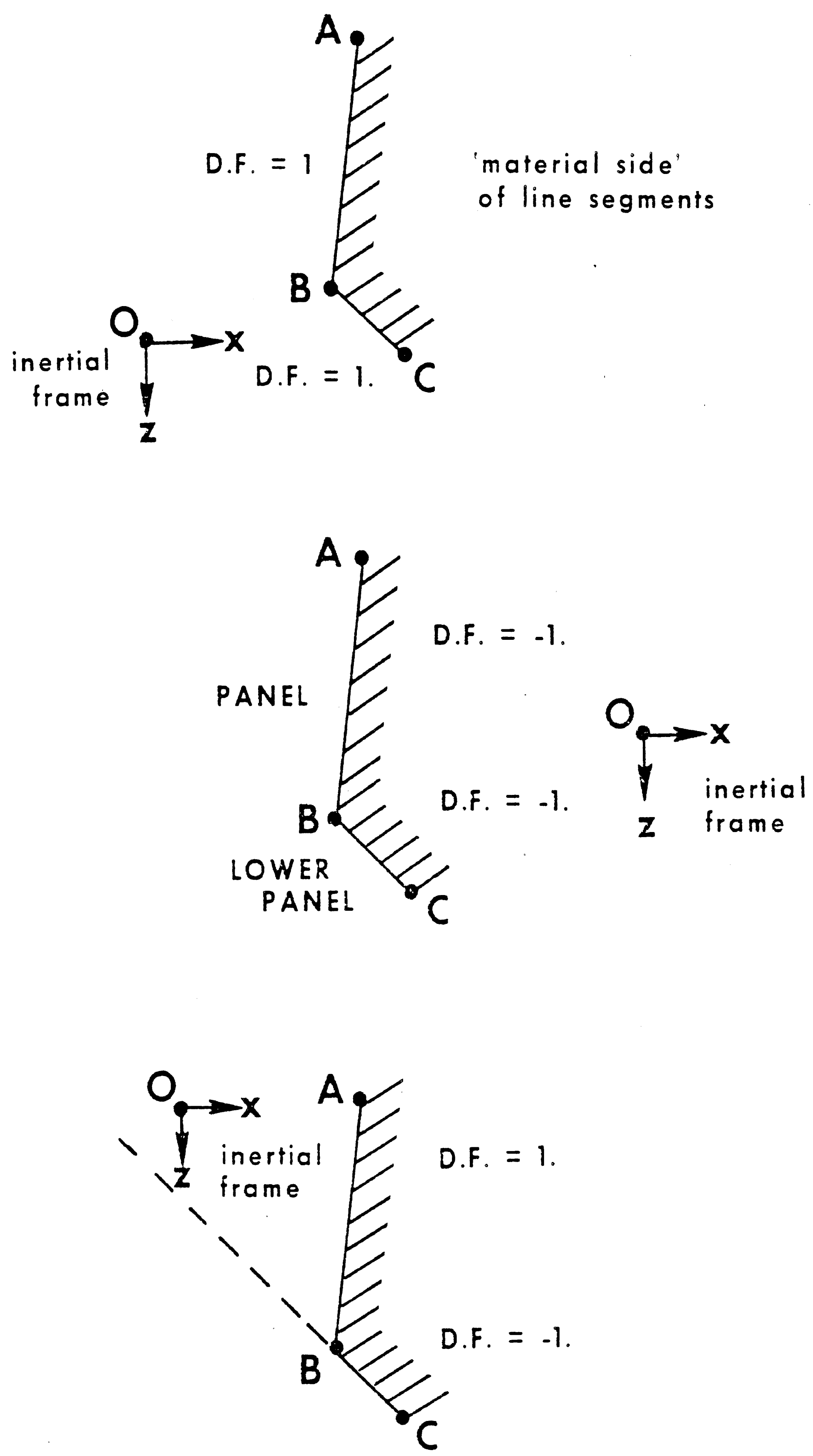


Figure 89. Line-Segment Direction Factors, Defined at t = 0

The fourth through seventh fields of Card 410 are used to simulate structural response of a contact region. The gamma (γ) quantities have the units of inverse mass and are therefore called "mass impedance." Their effect is to influence the amount a line segment can be pushed out of the way during the force action of a contact ellipse. When $\gamma = 0$, the end point of a line segment cannot be pushed out of the way. When γ is a very large number, the line segment can be pushed out of the way without generating a substantial force. Therefore, it is apparent that γ quantities must be selected while developing force-deformation curves and can probably be used to simulate the inertial spike.

The k's relate to the structural connection between the line segments within a region. When k = 0, the line segments within a region are connected, but only for the purpose of maintaining continuity. As k is increased, the coupling of line segments with respect to one another becomes more apparent. The effect of the k's is that of a torsional spring at the points where line segments meet. Hence, they are called "bending constants."

The main use of the k and γ quantities which is obvious at this early stage of their development is to allow variation of material properties within a region. Let us assume that a force-deformation curve is determined from a single test such as a pendulum test of an instrument panel. Most likely this test is conducted at a "soft" part of the instrument panel. Where the panel is more curved or where it is supported by substructure, it will be stiffer. The γ quantities should be chosen $\gamma > 0$ for the line segments where the "soft" test result is measured. For sharp corners and for substructure, values of $\gamma \simeq 0$ should be chosen. The effect of γ is governed by

$$\Delta\delta = \gamma F\ (\Delta t)^2 + \Delta\delta_{\text{permanent}}$$

where $\Delta\delta$ is the total permanent motion of the line segment during a time integration step.

$\Delta\delta_{permanent}$ is the permanent motion of the line segment due to permanent deformation resulting from the force-deformation curve

F is the force at the beginning of the time integration step

Δt is the size of the time integration step.

Therefore, the value of γ may be estimated on the basis of the relationship desired between the measured force-deformation curve, the expected applied force and the time duration during which the force acts.

Card 411

At least one 411 card must be included for each line segment of each region. The identification name is given in the first field. The remaining fields locate the line segment as a function of time.* Although the line segments will move with the vehicle to simulate a non-deforming occupant compartment or vehicle exterior surface, it is also possible to specify their location as a function of time with respect to the vehicular or inertial coordinate systems in order to model such physical events as predetermined vehicle collapse or deployment of a restraint system. This motion is then superimposed upon any of the types of structural deformation which may occur during occupant-vehicle contact. The third field specifies the point in time at which position is specified while the 4th through 7th fields specify location of the endpoints. If the location of the line segment is time independent, a negative number should be entered in Field 3.

*It is not allowed for a line segment or its extension to pass exactly through the inertial origin at t=0.

Field 8 is used to define a point of a frontal interior outline for air-bag contact. This usage is described completely in footnotes for Card 411.

Card 412

Card 412 contains friction coefficients for ellipse-region contact. It should be recalled that a friction class has been assigned to each region and to each ellipse. These cards match regions and ellipses for which non-zero friction is desired in the first two fields while the last three fields contain the linear and nonlinear friction coefficients.

Card 500

This card contains the run subtitle for the vehicle interior configuration input block. It is used by the program for automatic preparation of headings for each page of printed output.

Card 501

This card contains anchor points for the belt restraint systems as defined in Figure 16, all relative to the vehicle-fixed coordinate frame.

Card 600

This card contains the run subtitle for the vehicle impact specification input block. It is used by the program for the automatic preparation of headings for each page of printed output.

Card 601

Fields 1-6 give the vehicle x, y, and θ position and initial velocity with respect to the inertial coordinate system. Because it is possible to use accelerometer data from a test as input to this program, accelerometer location in vehicle coordinates is specified in Fields 7 and 8. If deceleration force is given instead of acceleration, vehicle or sled mass must be included in Field 9.

Cards 602, 603, 604, 605, 606

These sets of cards define vehicle horizontal, vertical, and angular accelerations as functions of time and also head-applied forces. Card content is self-explanatory.

Card 700

This card contains the run subtitle for the belt restraint system input block. It is used by the program for the automatic preparation of headings for each page of printed output.

Card 701 (See Figure 75 for Simple Belt System schematic.)

Card 701 contains physical parameters relating to the lap belt and the upper torso belt attached to the upper spine body segment. Belt length and slack quantities are self-explanatory. The breaking force features available with the HSRI force-deformation routines are duplicated in the belt routine using Fields 5, 6, and 7 of this card. The time duration, DELTB, insures that the belt force will gradually be reduced to zero rather than undergo a step-function dropoff, a potential source of solution instability. This technique differs from that available with the force-deformation routines where force dropoff occurs over a small change in deformation. The technique used in preparing input data may well depend on the availability of experimental data. If a force-deformation curve of the belt material is available, that technique would probably be easiest. Where a dynamic break test is available the 701 Card would probably be best.

Card 702

Fields 1-4 represent an attempt to uncouple compliance of a lap belt structure with compliance of the vehicle occupant whether it be dummy, cadaver, or human. In otherwords, physical properties may be determined separately for the belt structure and for the occupant. The material names for occupant and belt materials are included in these four fields.

Fields 5-7 refer to the lower torso belt element. Field 7 allows the belt to be attached on any of the three torso elements.

Field 8 allows the user to supply either force-strain or force-deflection input data for the three belt segments. The two types of data may not be mixed.

Card 703

The eight fields of this card contain the material names for the torso belts. Belt material properties are again uncoupled from occupant deformation properties.

Cards 704-709

See Cards 403-408. Note: Belts B_1 and B_7 (see Figure 90) should have the same material unless they are made independent by the conditions at the upper ring (viz. RING(1) = 1; see Card 720). This holds in addition for belts B_2 and B_3 at the lower ring. It also applies for pairs B_1 - B_2 and B_3 - B_4 if the force equalization options are selected (Card 717). Whenever a belt pair must be treated as a common strap but the materials for the separate segments are different, the program arbitrarily uses the material for the first member of the pair.

Cards 710-716

Figures 90 and 91 illustrate the Advanced Belt System and the definition of attachment points on the occupant. (Note that while belt attachment points are measured from joints for input, the internal values are with respect to torso segment CG's.)

Card 717

Field 1 allows the user to specify and of three types of interbelt influence for the belt segments passing over the torso. If zero is entered, then the belt segments are considered independent (as in the MODROS belt option) and no adjustment of torso belt forces is made. Interbelt influence is discussed in Section 2.5.2.3.

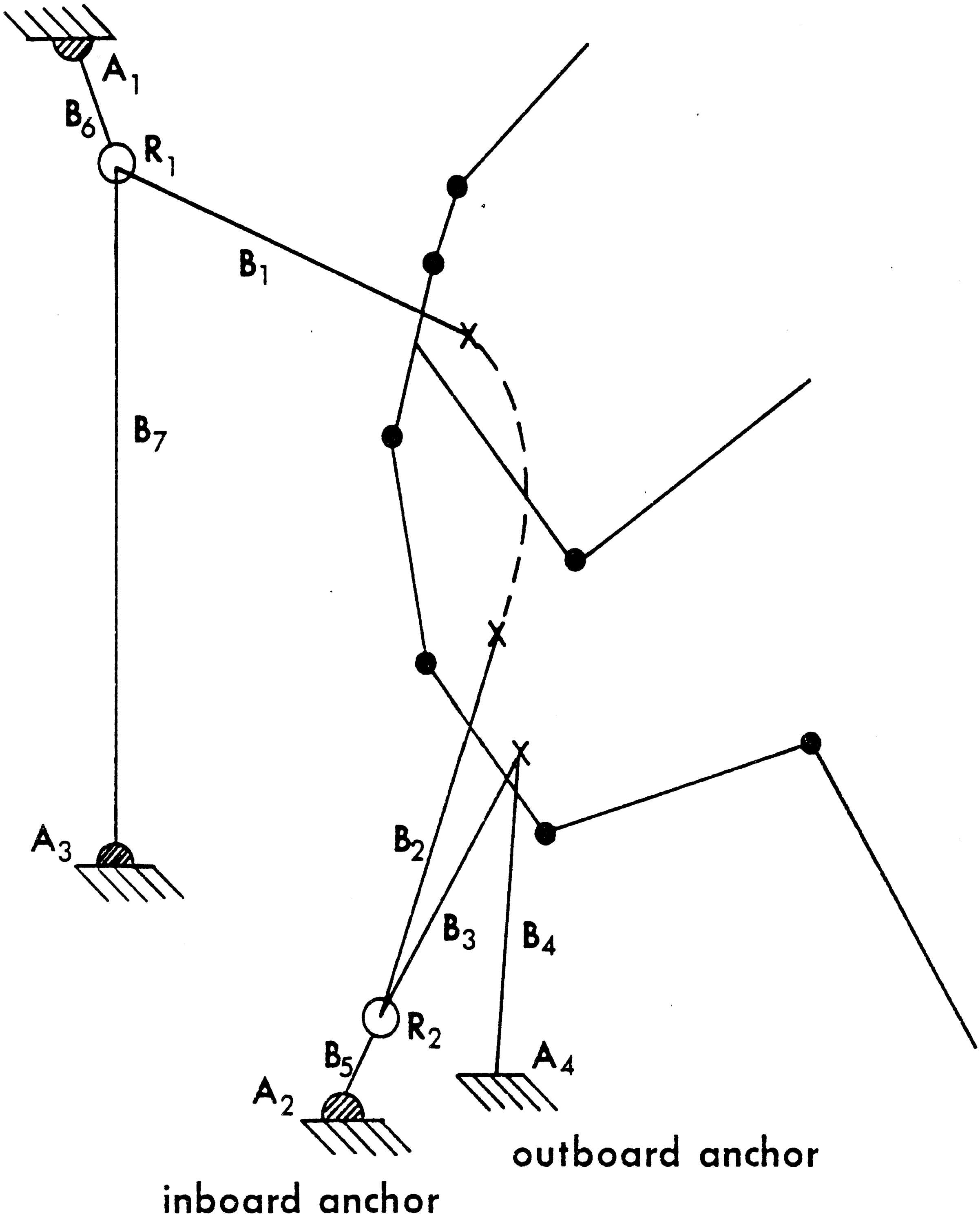


Figure 90. Advanced Belt System

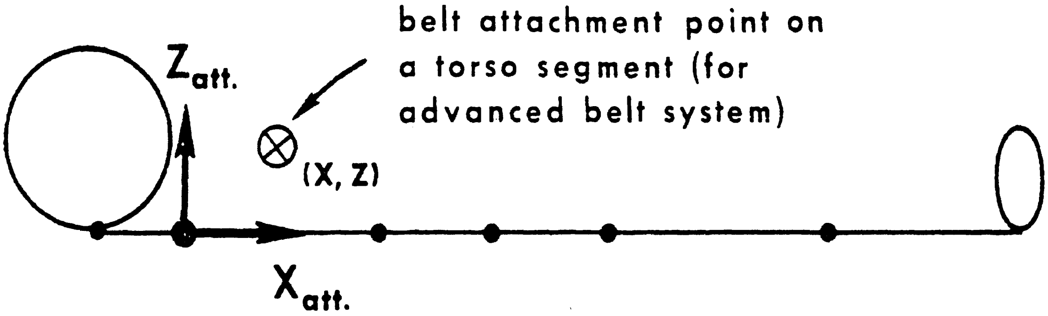


Figure 91. Belt Attachment Point Coordinates for Advanced Belt-Restraint Submodel

Field 2 allows the user to supply either force-strain or force deflection input data for the belt segments of the advanced belt system. The two types of data may not be mixed.

The value in Field 3 indicates which torso segment is attached to by the lower torso belt. Fields 4 and 5 define out-of-plane separations for the torso belt and lap belt attachment points. These values are needed only if the "free slipping" options are turned "on" by the values in Fields 6 and 7; in this case the out-of-plane length is used in order to determine total belt length.

Card 718

This card is needed whenever the rings of the defined belt system have the possibility of moving within the vehicle. The values in the two fields of this card are control parameters for the subroutine (RELAX) which determines the ring location for a force balance at any instant of time. The method of relaxation [19, 20, 21] is used to solve a system, in this case of order 2, of simultaneous, nonlinear algebraic equations. The general method is to systematically reduce to zero a set of functions of the unknowns—in this case, cart-relative x and z ring coordinates—by adjusting the values of the unknowns. When the functions, called residuals, have been reduced to zero, the current values of the unknowns constitute the solution vector. Convergence is tested by examining the nearness to zero of the sum of the squares of the residuals.

Field 2 should contain an upper limit on the number of relaxation steps allowed per ring per evaluation. (This value should probably be at least 10.)

If convergence is not attained within this number of steps, then the calling program (BELT2) is returned to and the best solution vector obtained through this number of steps will be used. Execution is not terminated but a warning is printed out.

Field 3 contains a value for the maximum acceptable force imbalance at the ring for either the x or z direction (in the vehicle system).

Card 719

No more than three values will ever be needed on this card. All quantities relate to interbelt influence for the torso belts. A footnote on Card 719 summarizes which fields are required for the four possible INFLNC options.

Fields 1 and 2 contain friction coefficients for the normal-force friction option. Field 3 also is used for this option. The larger of the torso belt forces will always be reduced by a calculated adjustment (see Section 2.5.2.3 for analysis pertaining to all parameters on this card); the smaller force will be increased by any fraction of this amount depending on the value, from 0. to 1., entered in Field 3.

For the normal-force friction option, the belt subroutine chooses the influencer and influencee at each time evaluation on the basis of which torso belt force is larger or smaller. This is true also of the force difference saturation option. In contrast, if the percentage influence option is selected, the user must specify which of the torso belts is the influencer and influencee. Field 4 controls this. Fields 5-7 are used for these alternate options and the meanings of the parameters are fully explained in Section 2.5.2.3.

Card 720

The four vehicle anchors (see Figure 90) for the advanced belt system may be of several types. The first four fields of this card specify the anchor type for anchors 1 to 4, respectively. A zero means that the anchor is free. Normally, this would mean that either the anchor or the associated belt is absent or "pre-broken." If a 1. is entered, then belt 4, 5, 6, or 7 fastens securely to the anchor. If a 2. is entered, then belt 5, 6, or 7 leads to an inertia reel fixed at the anchor location. Only anchors 1-3 may be of this type. The reel may be of the webbing-sensitive or vehicle-sensitive type, as specified on Cards 721-723. A 3. means that belts 1, 2, or 3 leading to the anchor are either fixed to the frame or ring or instead pass through a ring which is fixed to the vehicle frame at the anchor location. Note that if the ring is not fixed to the vehicle frame, then it is of necessity fixed to one end of a "ring strap" belt segment (belt number 5 or 6), i.e., the associated ring strap must in such case be present.

There are two rings in the system. Lengths of webbing pass through the rings but may be considered: 1) to be fixed to the ring; 2) to slide with normal-force friction through the ring; or, 3) to slip freely. These options are controlled by Fields 5 and 6. Options 2 and 3 should give equivalent results if the friction coefficient for option 2 is zero. If the normal friction option has been selected for a ring, then the friction coefficient must be entered in Field 7 or 8.

Figures 92 and 93 illustrate all possible ANCHOR and RING specifications.

Cards 721-723

If an inertia reel has been requested for anchor 1, 2, or 3, then properties of the inertia reel are entered on one of these cards. The reels may be either vehicle sensitive or webbing sensitive. If vehicle sensitive, then the "lock" condition can be specified either as a lock time or as a

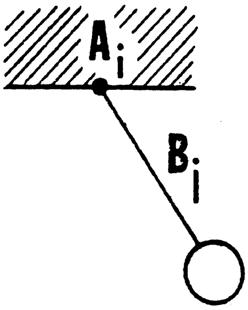
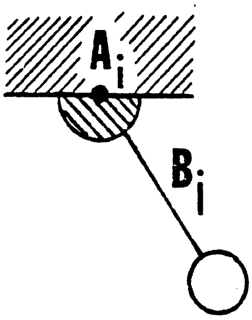
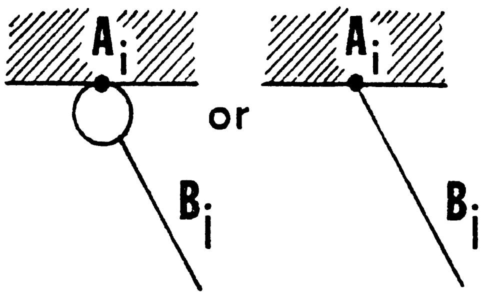
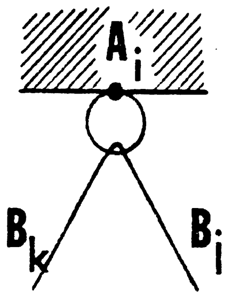
SCHEMATIC	ANCHOR TYPE DESIGNATION	ALLOWED INDEX VALUES
 no belt	$ANCHOR_i = 0$	i = 1, 2, 3, 4
	$ANCHOR_i = 1$	i = 1, j = 6 i = 2, j = 5 i = 3, j = 7 i = 4, j = 4 (no ring)
	$ANCHOR_i = 2$	i = 1, j = 6 i = 2, j = 5 i = 3, j = 7
	$ANCHOR_i = 3$	i = 1 or 3, j = 1, $RING_1 = 1$ i = 2, j = 2 and/or 3, $RING_2 = 1$ i = 4, j = 4
	$ANCHOR_i = 3$	i = 1, j = 1, k = 7, $RING_1$ = 2 or 3 i = 2, j = 2, k = 3, $RING_2$ = 2 or 3

Figure 92. Belt Anchor Type Designation for Anchor "i"

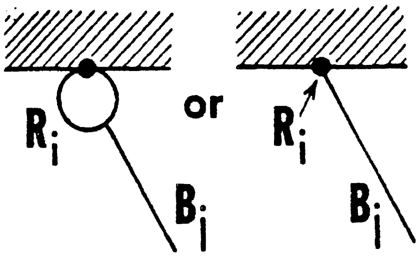
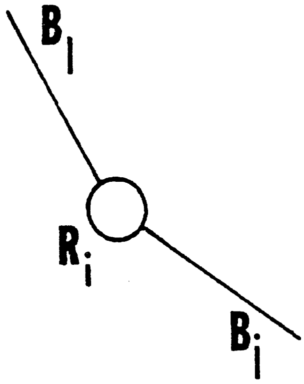
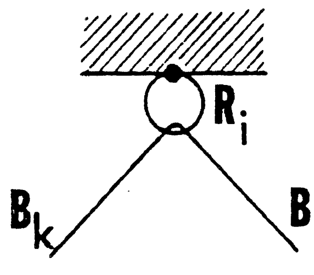
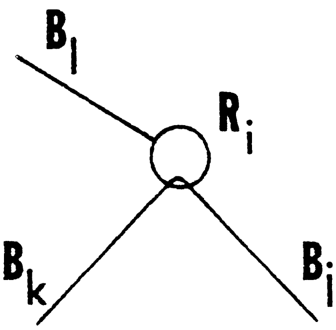
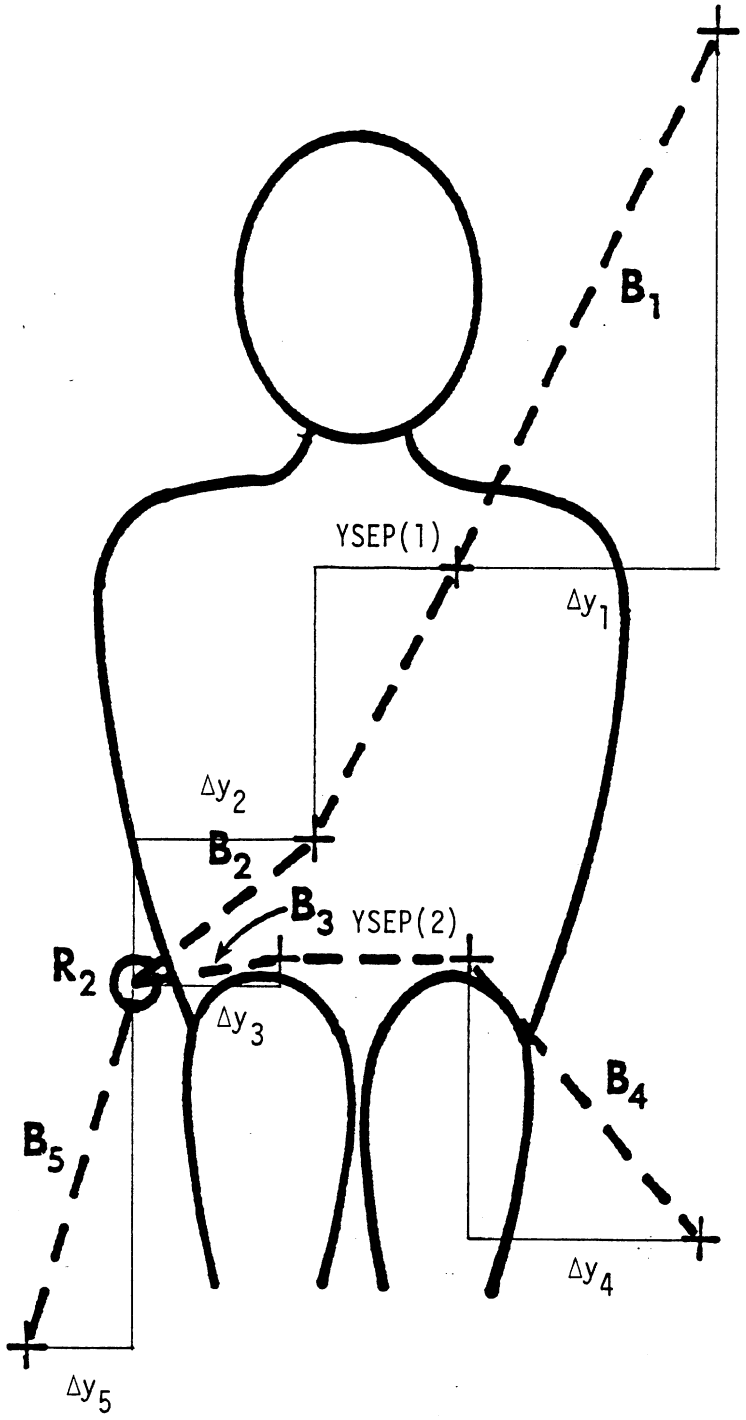
SCHEMATIC	RING TYPE DESIGNATION	ALLOWED INDEX VALUES
	$RING_i = 1$	$i = 1$, $j = 1$, $ANCHOR_1 = 3$ $i = 2$, $j = 2$ or 3, $ANCHOR_2 = 3$ $i = 2$, $j = 2$ and 3, $ANCHOR_2 = 3$
	$RING_i = 1$	$i = 1$, $j = 1$, $\ell = 6$, $ANCHOR_1 = 1$ or 2 $i = 1$, $j = 1$, $\ell = 7$, $ANCHOR_3 = 1$ or 2 $i = 1$, $j = 1$, $\ell = 6$ and 7, $ANCHOR_1$ and $ANCHOR_3 = 1$ or 2 $i = 2$, $j = 2$, $\ell = 5$, $ANCHOR_2 = 1$ or 2 $i = 2$, $j = 2$, $\ell = 3$ and 5, $ANCHOR_2 = 1$ or 2
	$RING_i = 2$ or 3	$i = 1$, $j = 1$, $k = 7$, $ANCHOR_1 = 3$ (or 0) $i = 2$, $j = 2$, $k = 3$, $ANCHOR_2 = 3$
	$RING_i = 2$ or 3	$i = 1$, $j = 1$, $k = 7$, $\ell = 6$, $ANCHOR_1 = 1$ or 2 $i = 2$, $j = 2$, $k = 3$, $\ell = 5$, $ANCHOR_2 = 1$ or 2

Figure 93. Designation of Ring-Belt Relationship for Slip Point "i"



MVMA 2-D BELT SYSTEM: FRONT VIEW

Figure 93-A. Schematic for Out-of-Plane Belt System Dimensions (Δy_i)

pair of values for maximum vehicle pitch and maximum resultant acceleration at the anchor location. If webbing sensitive, then the reel can be made to lock either on the basis of a limiting velocity or acceleration for belt feed-out.

Standard values for some of these lock-condition parameters are: vehicle sensitive resultant acceleration, 0.4 g, and pitch angle, 14°; webbing sensitive belt feed-out acceleration, 0.6 to 0.9 g's. (See References 15 through 18.)

Cards 800-817

The energy-absorbing steering assembly system cards are mostly self-contained. But the analytical symbols used for all quantities in Section 2.8 are given on these cards so easy reference may be made if necessary to the figures and text for the analysis.

Cards 900-909

The airbag system cards are likewise mostly self-contained. References may be made to figures in the analysis section and to the one on Card 909. Reasonable values for all parameters on Cards 901-903 are indicated in the Defaults column. See Figure 94 for definition of occupant contact lines.

Card 1000

This card marks the end of the input data deck which is supplied to the input processor and signifies that work on the input deck is to begin.

Card 1001, 1002

These two cards together with the other cards numbered greater than 1000 comprise the control information to the output processor. The function of the first two cards is to specify the output subjects or categories which are desired and the order in which these are to appear. This is accomplished by listing the categories desired in the order desired using a series of possibly mixed individual listings and group listings. An individual listing consists of a

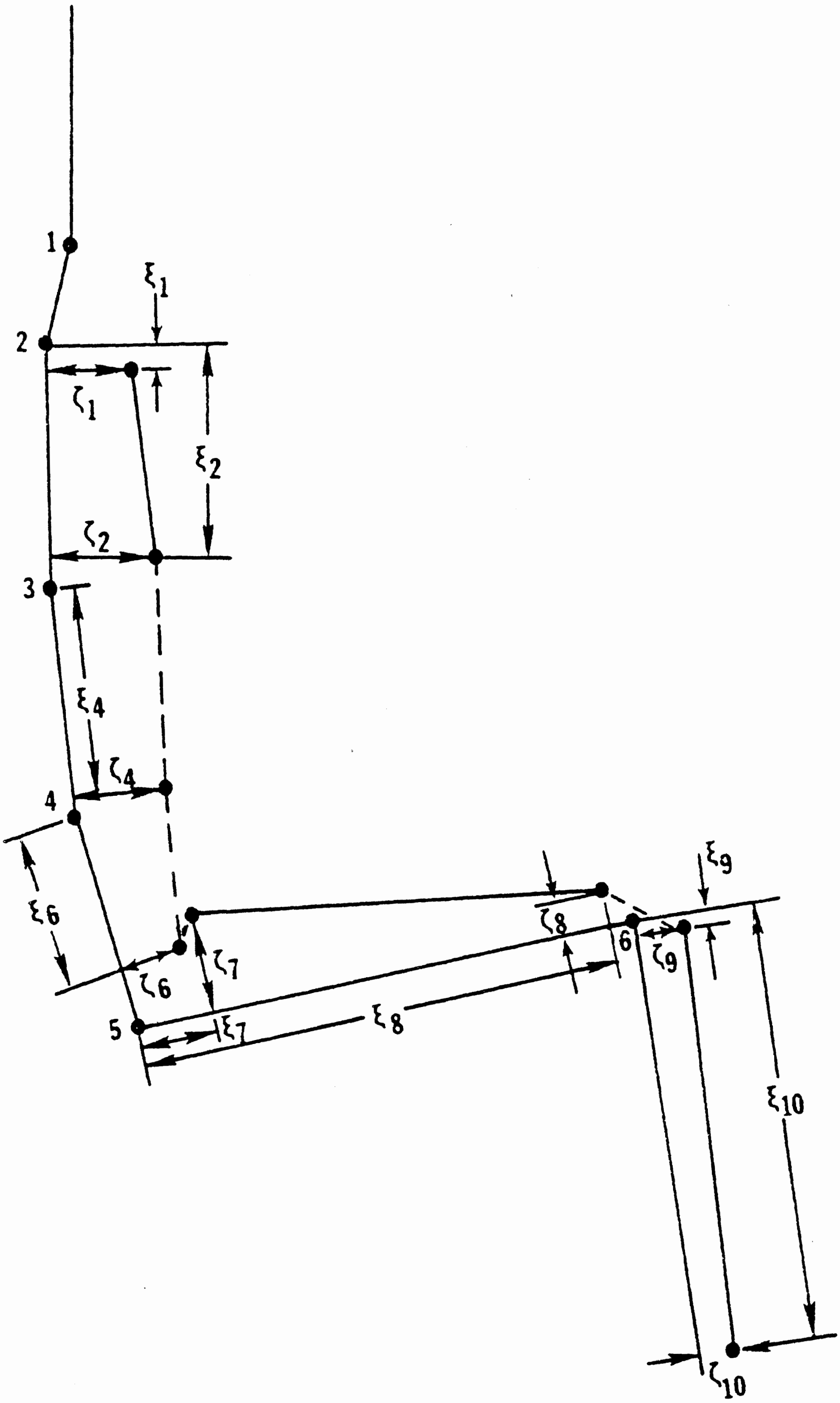


Figure 94. Airbag Contact Lines on Occupant

one- or two-digit category number followed by a comma. Leading zeros may be present and blanks are ignored. As many of these listings as needed may be used. Numbered categories are listed in Table 11 following the description of Cards 107-111.

If there is a group of category numbers in either ascending or descending order which are contiguous, a group listing may be employed to streamline the specification of the string of numbers. The group listing consists of the category number of the end of the string which is to be printed first followed by a dash, hyphen, or negative sign (card 11 punch) followed by the category number which is to appear last. Again, leading zeros may be present and blanks are ignored wherever they appear. Card 1002 is treated as an extension of Card 1001 using only the first seventy-two columns of both cards. If these cards are omitted, all categories are requested in the default ordering indicated on the 1001-card layout in Table 7. If columns 1 and 2 contain "-1", the default ordering minus category 0 will result. The terminating comma on the final listing may optionally be omitted.

Card 1003

This card controls the auxiliary output from the output processor. The first field (IDB) controls auxiliary printout from the HIC routine concerning all the scans made in determining a HIC value. The second field (KO) doubles as a switch and a specification of the Fortran logical device number for a separate printout of peak and three-millisecond average acceleration calculation values. If zero, it is interpreted as a switch which is off. If non-zero, it is interpreted as a switch which is on and its value used for the logical device number.

The third field controls a forced recomputation of filtered accelerations and special indices. Normally, these computations take place only in the first run of OUT after a run of GO.

The fourth and fifth fields describe the particulars of an accelerometer mounted on the upper leg centerline. (See Section 4.6.2.5.)

Card 1004

The first four fields of this card contain information governing the application of numerical filters to head, chest, and hip accelerations. A detailed explanation of the operation of the digital filter employed in this model is found in Section 4.6.2.3. The first three fields are filtering parameters used to control the filter operation. The fourth parameter controls the method of extension of the acceleration data beyond the run time span. The mirror image causes the completed data to be an even function around the end points. The polar image causes the completed data to be odd at each end point if the function value at the endpoint is considered zero. (See Figure 142.) The polar image is thought to be superior normally.

The last four fields of this card control the calculation of the HIC Index. An explanation of these parameters will be found in Section 4.6.2.4.

Cards 1100-1107

Specification of the test values used to determine violations of joint range of motion limitations. The high test value must not be less than the low test value algebraically. If both high and low values are zero, the test is not carried out.

Cards 1200-1201

Specification of the test values used to determine violations of a standard range of values for each individual quantity. A complete list of the quantities together with an explanation will be found in Section 4.6.2.1. The testing is carried out only if the test value is greater than zero.

Cards 1202

Specification of the names of the ellipses which will represent the face and chest for purposes of the standard tests.

Card 1300

A general explanation of the Type A Comparison together with a complete list of variables to which it may be applied will be found in Section 4.6.2.2. The first two fields are filled with the category and column numbers found in Table 114 in Section 4.6.2.2. The two identifiers are the names which are required to make unique a request for a contact variable. In the case that a category 2 or 3 variable has been requested, the first identifier must be the name of the region for which the particular variable is to be tested. In the case a category 4 variable has been requested, the identifiers must be set to the ellipse and line names, the two ellipse names, or the belt name and blanks for each case respectively. Belt names are assigned by the model and are listed in Table 115 found in Section 4.6.2.2. The high test value must be greater than or equal to the low test value. Negative values are allowed.

Cards 1400-1401

A general explanation of the Type B Comparison will be found in Section 4.6.2.2. The first six fields of each of these cards are filled in the same manner as the corresponding six fields on Card 1300 and all comments apply. The seventh field of each of these cards is used to match the 1400 Card to the 1401 Card. Each card specifies a variable for a Type B comparison, which tests one variable against another variable. Hence it is necessary to supply a matched Card 1400 and Card 1401 set in order to complete the specification of a Type B comparison. If Field seven in both cards is left blank, then the number used to match is assigned based on the number of occurrences of that type of card. All the instances of Card 1400 for which Field seven is blank are numbered in the order read and likewise with Card 1401, and the matching is done on the assigned occurrence number. The numbers for matching need not be consecutive, only the same.

Cards 1500-1501

These two cards contain the various switches and parameters which control the production of the stick figure printer plots. Figure 95 is an example of printer-plot output. Up to 27 such plots can be obtained for a simulation. These will be in a time sequence similar to frames of a motion-picture film.

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 60.00 MSEC.

Coordinate ranges for plot are X = 0.0 (at left) to 64.00 (at right) and Z = 2.24 (at bottom) to -41.24 (at top). Scale factor is (in) = 4.923 (in), X and Z point resolution errors equal respectively 0.246 and 0.410 (in) in scale.

Figure 95. Example of Printer Plot Output

6/30/88

The switch in Field one of Card 1500 causes horizontal and vertical lines to be plotted through the origin of the vehicle system. If field two is zero, and the input and output processors are run without "GO," the user will get a printer plot based on the input data alone. Fields three through six define the area in vehicle coordinates to be plotted.

On Card 1501, Fields one, seven, eight, and nine deserve special comment. The number of plots in Field one together with the values in Fields eight and nine are ignored if Field seven is left blank or zero. In this case only the times specifically listed on Card 1502 (of which there may be up to three in the deck) are plotted. If Field seven is non-zero, Field one contains the number of plots, Field eight contains the first time to be plotted and Field nine contains the time increment to be applied to obtain the plot time until the number of plots is reached.

Card 1502

This card is used to specify individual time points at which plots are to be produced. There may be up to three instances of this card containing a maximum of twenty-seven values. The values must be in ascending order in time.

Card 1600

This card marks the end of the input data deck which is supplied to the output processor and signifies that work on the production of output is to begin.

3.2-A. MISCELLANEOUS MODEL USE CONSIDERATIONS

This section consists of copies of an assortment of memos and other documents that pertain to use of the MVMA 2-D CVS model, new features, interpretation of output, and other things. Thus, in various regards, the material in this section relates to both Section 3.2 and Section 3.3, which immediately precede and follow it; those sections describe input data quantities and normal output.

This section is divided into the following subsections:

3.2-A.1. <u>General Information</u>

MEMO TO: MVMA 2-D CVS Users

FROM: Bruce M. Bowman, UMTRI

SUBJECT: New Release of the MVMA 2-D Model:
MVMA 2-D CVS, Version 6

DATE: June 30, 1988

This memo announces the release of Version 6 of the MVMA 2-D CVS model. It also describes features that are new in Version 6 and features that were new in Version 5. Version 5 of the MVMA 2-D CVS immediately followed Version 3. There was a "Version 4," but there were no releases of the Version 4 code even though titles on manuals from 1979 reference "Version 4"; those manuals were for use of Version 3.

VERSION 5

Version 5, released in August 1986, was the first major release of the model since June 1984. Users of Version 5 (and 6) will need MVMA 2-D manuals dated June 28, 1985 (not 1986) or later if they intend use features that are new in Version 5. Version 3 data sets are completely compatible with Version 5, however, so lack of new manuals will not prevent use of Version 5. (Note: Some users of the model have June 28, 1985, manuals that are identified as being for Version 3. Those manuals are, however, completely up-to-date with respect to use of Version 5 features.)

An important difference between Versions 3 and 5 is that calculations in Version 5 are made in double precision. ("GO" in Version 5 is in double precision; the input and output processors, "IN" and "OUT", remain in single precision.) Additionally, users should be aware of the primary features first available in Version 5. (See Cards 219, 220, 249-254, and 305.) They include the following:

1. internal organ elements

2. independent masses, free or attached rigidly or non-rigidly to the vehicle or the inertial frame

3. curved vehicle interior contact surfaces

4. straight-line contact surfaces on the occupant

5. occupant profile ellipses attached with arbitrary orientation to their body links

Applications of the features above are illustrated in a demonstration data set (DEMODAT) that is included on the release tape. The demonstration run includes:

a. a steering column that has mass characteristics and associated degrees of freedom

b. a curved panel for knee interaction

c. a knob ellipse on the dash

d. straight-line contact surfaces on the occupant

e. brain and heart masses

f. body ellipses that are rotated with respect to their body segment link lines

g. a free mass representing a package on the back seat

Varied applications of the new features are possible. One not represented in the demonstration data set, but easily accomplished, is simulation of a simple second occupant for interaction with the primary occupant. Such an occupant might be a rear-seat passenger, a child held on a parent's lap, or a second front-seat occupant (in a side impact simulation). Another application that will surely be useful but which is not represented in the demonstration data set is the modeling of front-seat seatbacks which can flex, i.e., pivot, about a point near the bottom of the seat.

In addition Version 5 includes a variety of general improvements relating to both format and content of output, recognition of data set errors, user conveniences, and accuracy of solution of the equations of motion. Significant improvements were made in the calculation and application of friction forces.

The latest releases of Version 5 (5.3 and 5.4) include additional new features and enhancements. Some of particular importance are:

1. a H.I.C. monitor which flags possibly inaccurate H.I.C. values

2. a "link sharing" feature, which allows the model to use an averaged position and orientation for a contact ellipse near a joint (say, the hip) rather than the position and orientation for an ellipse fixed to one or the other of the rotating links (see Card 220); this feature should be used in all simulations

3. signed tangential force values in Category 4 output (to indicate direction)

VERSION 6

Version 6, the current release, differs from Version 5 primarily in that the code is now ANSI standard FORTRAN 77 rather than the FORTRAN 66 (Fortran IV) code in which the model was written and developed between 1971 and 1988. This conversion was important because increasingly more computer facilities are not supporting Fortran IV compilers. The new source code is greatly different from the Version 5 code, but differences will be transparent to users.

Manuals for Version 6 are dated June 30, 1988. Most differences between Version 5 and Version 6 manuals pertain to various features new in Version 6 rather than to changes in program structure or storage use associated with the conversion to FORTRAN 77. Some of the new features (described below) cannot be used without the new manuals, but Version 5 data sets are completely compatible with Version 6 code, so lack of new manuals will not prevent use of Version 6.

New features include the following:

1. "true plowing," which provides for tangential forces that are (almost) independent of deflection; this is potentially most useful for head-windshield interactions (see Card 412)

2. corrections and improvements in the MODROS passenger airbag model

3. automatic adjustment (migration) of the lap belt attachment point (see Card 718)

4. Input Processor testing of static loading curve and unloading data specifications for compatibility

5. automatic calculation (optional) of 217-Card values for initial zero elastic joint torques

6. automatic calculation (optional) of joint stop angles which bracket initial relative angles by +/- 0.001 deg

7. improved efficiency in some Output Processor functions

8. calculation of H.I.C. for a specifiable duration (e.g., 36 ms)

9. additional options for and improved form of printout of user-specified title card data

10. miscellaneous improvements in diagnostics

11. optional generation of a random access character file containing time histories of user-selected response variables for the purpose of plotting or other postprocessing; user specifiable conversion for different units, etc.

****

MVMA 2-D CVS MODEL

****

CONDITIONS OF USE

NEITHER MVMA 2-D CVS SOURCE CODE NOR OBJECT CODE MAY BE DISTRIBUTED EXCEPT BY UMTRI. TO OBTAIN THE MODEL CONTACT:

DR. BRUCE M. BOWMAN
UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE
2901 BAXTER ROAD
ANN ARBOR, MI 48109-2150

PH.: 313-936-1106

****

6/30/88

MVMA 2-D CVS Tape Description

MVMA 2-D CVS, Ver. 6.0
Release Tape, June 30, 1988 -- UMTRI

9 Track, 6250 BPI, EBCDIC, Unlabeled, 45 Files

Files 1-41: RECFM=FB, LRECL=80, BLKSIZE=2400
Files 42-45: RECFM=FB, LRECL=133, BLKSIZE=2660

Table of Contents

\- Sequencing is either excluded or, for MVMA 2-D data sets, determined by data card format.

NOTE: Files 1-6 and 8-28 are documentation files. They should be listed and read before source code and data files from this tape are installed on your computer system.

6/30/88

MEMO TO: MVMA 2-D Model Users

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: The HELPER program: Initial Equilibrium Conditions and Vertical Hip and Foot Forces at Time = 0

DATE: June 6, 1988

The "HELPER" program is an interactive pre-processor program for MVMA 2-D which may be used optionally for assistance in establishing initial conditions for the occupant which will provide an approximate balance against gravity at time zero. The program has other functions as well that relate to preparation of a baseline input data set. Primary inputs are occupant dimension and weight data, the geometric profile and stiffness characteristics of the seat cushion, and initial head, hip, knee, and heel point position data as determined from film analysis or other methods.

The program contains default data for the Hybrid 3 dummy, and its use does not require a manual. Informal documentation is available, however, from UMTRI.

The information below does not provide any specifics regarding options available in HELPER or the way that HELPER calculations are made, but it is nonetheless relevant to HELPER and also to determination of initial equilibrium conditions without the use of HELPER.

- - - - - - - - - - - - - - - -

In a study at UMTRI test measurements for the heel force for five adult males who were approximately the height and weight of a Hybrid 3 dummy were used to calculate an estimate for the ratio

(heel force) / (lower leg weight) .

Subjects were seated in a bucket seat and their feet and legs were positioned to represent normal driving position and posture. The average value of the ratio of heel force to lower leg weight (estimated from anatomical and anthropomorphic data) for the five test subjects was almost exactly 1.0. Therefore, in simulations and for HELPER program calculations a deflection of the floor at the heel point is needed which will produce a force to exactly balance the weight of the lower legs.

The seat position, leg angle, and foot circle attachment location determined by the HELPER program cause the vertical forces on the occupant at t=0 to have the distribution between hip and foot which satisfies the above experimental results. Whether or not HELPER is used for assisting the preparation of equilibrium conditions at t=0, the vertical foot force as calculated above is probably appropriate for the Hybrid 3 dummy as well as for humans. Initial vertical seat force on the hip (and upper leg) should be equal to the total weight of the occupant minus the weight of the lower legs.

MEMO TO: MVMA 2-D CVS Users

FROM: Bruce M. Bowman, UMTRI

SUBJECT: Minimizing Computer Cost for MVMA 2-D Runs

DATE: June 6, 1988

Consideration should be given to several factors that affect run time for MVMA 2-D simulations. The cost of running the model on a mainframe computer (exclusive of any special post-processing costs) can be doubled if no attention is given to any of these factors.

1. CARDS 107-111: In some kinds of simulation studies, users may want to see output categories that would not interest them in other studies. However, in most simulations some specific set of output categories will be of interest. Often, users do not include Cards 107-111 in their data sets, which means that all categories are requested by default for storing at each print time on file 8 (even if they are not requested for printout on the 1001-Card). Write's to file 8 are all indexed I/O write's--which are relatively expensive.

A significant reduction in "GO" cost can be realized by reducing the "requested" output categories to only those actually desired. Develop a standard set of 107-111 cards and include it, with case by case modification, for all of your runs.

2. PRINT TIME STEP: Establish a standard value for the print time increment specified on Card 101 in field 8. If, for example, you feel that printout every 2 ms is adequate, then it is wasteful to obtain printout every 1 ms. A reduction from 2 to 1 will halve the cost of indexed I/O write's to file 8 (as well as halve the required size of the file). H.I.C. will not be less accurately calculated if the print interval is made larger. H.I.C. is always calculated from data in file 7, which contains the head acceleration data for all integration time steps regardless of the print interval.

3. INTEGRATION METHOD: A study has been made of integration with the two available methods--Runge-Kutta (4 evaluations per time step) and Adams-Moulton Predictor-Corrector (2 evaluations per time step). That study indicates that a cost savings can normally be realized by using the Adams-Moulton integration. For a given time step, the Adams-Moulton integration is almost always entirely as accurate as the Runge-Kutta integration. Since the Adams-Moulton integration requires only half as many evaluations of the equations of motions for each time step, this means that use of Adams-Moulton will very nearly reduce integration cost by one half. The Adams-Moulton integration only occasionally becomes unstable and diverges from Runge-Kutta results. Normally, such instability makes itself very evident by causing the run to blow up completely ("FATAL ERROR DUE TO POSSIBLE LOSS OF SIGNIFICANCE AT ELIMINATION STEP nn"--from SMSOL inversion via DAUX).

When cost or run time considerations are important, it is recommended that the Adams-Moulton Predictor-Corrector integrator be used. Regarding time step, the following is suggested: in a simulation where

.25 ms would be used for Runge-Kutta, use .2 ms for Adams-Moulton; where .5 ms would be used for Runge-Kutta, use .4 ms for Adams-Moulton if you decide on a standard print interval that is a multiple of .4 (e.g., 2 ms) or .5 ms if you decide on some other standard print interval (e.g., 1 ms, 3 ms, 5 ms). Use of a step size 20 per cent smaller than the Runge-Kutta step is a hedge against instability.

4. 106-CARDS: The 106-Cards included in your data set should be examined. If the data set includes "allowed" interactions that in fact can never take place, then cards should be removed. This could be done by users separately in their particular applications as well as in a "standard" 106-Card module. Most of the calculation cost involved in investigating an ellipse-line or ellipse-ellipse interaction is incurred only after interaction (geometric overlap) is found to exist, but it also costs something to determine whether there is an interaction.

Different sets of standard cards could be used for restrained and unrestrained occupant simulations.

5. OPTIMIZATION LEVEL: Most compiler programs have an input parameter by which optimization level can be selected. Development and applications work at UMTRI has always been done with optimization level zero (no optimization), and optimization has not been tested at UMTRI. Consequently, UMTRI is not able to state that MVMA 2-D will function properly in all regards when object code optimization is invoked. Nonetheless, since in the general case program execution costs can be reduced by using optimized object code, the user may want to test compilation and use of MVMA 2-D with non-zero optimization levels.

UMTRI takes the conservative view that the user should not consider use of highest level optimization for MVMA 2-D.

The following description of optimization describes IBM VS FORTRAN optimization but should apply generally for all, or most, other FORTRAN 77 compilers as well.

> Through the techniques of optimization the compiler is capable of improving the object code that it generates in order to create a more efficient program, both with respect to execution time and storage space. The OPTIMIZE option indicates which of four levels of optimization is to be in force. The higher the level, the more efficient is the progam, and the slower and more expensive is the compilation.
>
> OPTIMIZE(0): This level does no optimization at all. This level provides the fastest compile time but the least efficient programs. It is a good level to choose when a program is being debugged or for compilations that are intended only to check for correct program syntax.
>
> OPTIMIZE(1): This level provides a moderate level of local register and branch optimization without considering program loops.
>
> OPTIMIZE(2): This level provides full optimization of the whole program but refrains

from moving code outside of loops if there is any possibility of this causing program errors.

OPTIMIZE(3): This level provides full optimization. It is best suited to fully debugged programs ready for production use. This level is safe for most programs, but if problems should arise that do not appear at lower levels of optimization, it may be necessary to reduce the optimization level of some critical modules.

3.2-A.2. Modeling Approaches

MEMO TO: MVMA 2-D Model Users

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: Modeling Belt Spoolout and Anchor Deformation Effects

DATE: April 9, 1987

Loading and unloading "material" properties for combined belt spoolout and anchor deformation can be specified through use of fields 8 and 9 of Cards 710-716 and standard material cards. Belt spoolout/anchor deformation materials are defined independently from webbing material, i.e., no adjustment of webbing material properties is required in relation to adding the effects of spoolout and anchor deformation to your simulations. Webbing properties should still be specified in terms of strain, but spoolout/anchor deformation properties are specified in terms of deflection.

No new feature has been added to the model. The MVMA 2-D has, in fact, had the ability to model spoolout and anchor deformation since about 1974, but that ability was not recognized until recently. Representation of spoolout and anchor deformation is accomplished by using the feature normally used for representing body compliance in shared interaction with a belt. To represent spoolout and/or anchor deformation, the user may simply indicate a "belt reel" material name in fields 8 and 9 of the belt card and include data cards for that material in the data set. (Any series of material specifications cards may be used: 221-226, 403-408, 704-709, or 812-817).

If it is desired to represent body deformation also, then the separate force-deflection type materials for body and reel must be combined analytically, i.e., made into a composite material. It is noted here that in the case that the body material is much stiffer than the reel material (spoolout/anchor deformation), the body material can simply be ignored, i.e., it is not in that case important to combine the materials analytically.

In relation to the foregoing, pages 75, 87, and 288 of Volumes 1 and 2 have been updated.

MEMO TO: Users of the MVMA 2-D CVS Model

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: Specifying Vehicle Motion for Simulation of Barrier Tests

DATE: May 15, 1987

The MVMA 2-D user has several options in relation to specification of vehicle motion. [See pages 211, 211.1, 211.2, and 277 (Card 601).] I recommend that the "pivot point" option be used whenever it is desired to model vehicle pitch, which normally occurs in barrier crash tests.

This option is easy to use. Any point for which motion with respect to both the inertial and vehicle coordinate systems is known is suitable for a "pivot point." A point on the header might be used for barrier tests. Such a point is easily targeted for determination of motion in the inertial system, and its motion in the vehicle coordinate system is simple--it is fixed. Model input data specifications for this example would be: vehicle x-accelerometer data, location of the fixed point ("pivot") on the vehicle, z-displacement time history in the inertial frame for the fixed point, and the vehicle pitch angle displacement time history. (Note: It is not necessary to use a <u>fixed</u> point on the vehicle as the pivot, but it is easier than using a moving point, which requires specification of motion of the point in both the inertial and vehicle systems.)

To use a <u>fixed</u> point on the vehicle as the "pivot point" (or "constraint point")--say, a point on the header--follow these steps:

1. Select the pivot point option by entering "-1." in field 9 of Card 601.

2. Specify x-accelerometer data by using Card 602 and associated unnumbered cards.

3. Specify pivot point option parameters on Card 603 as illustrated in the example below. The values on the card may be interpreted as follows:

   field 1: 49. (example) -- the number of time points that will be given for the inertial z-displacement of the point on the header

   field 2: 0. -- position data for the pivot point are in centimeters

6/30/88

field 3: 2. — two time points will be given for the (fixed) x position in the vehicle frame of the header point, viz., equal values for t=0 and t=240, the beginning and end times for the crash history

field 4: 2. — two time points will be given for the z position (fixed) in the vehicle frame of the header point

field 5: .25 (example) — typical value for control parameter, but see note 7 for Card 602 for method to calculate value

field 6: 12700. -- recommended control value, not critical

field 7: 5080. — recommended control value, not critical

4. Follow Card 603 with as many unnumbered cards as necessary (13 for this example) to specify the time history for inertial z-displacement of the header point. Follow these cards by one unnumbered card that has the two time point values for the fixed x-position of the header point and then a similar card for the z-position of the header point.

5. Specify vehicle pitch motion by using Card 604 and associated unnumbered cards. Motion may be given in terms of either angular accelerations or angular displacements. Displacement data is easier to obtain in most cases. The example 604-Card below is for displacement data.

EXAMPLE VEHICLE MOTION SPECIFICATION BY USE OF THE PIVOT POINT OPTION FOR A FIXED POINT ON THE VEHICLE

```
0.      13.72  0.      0.      0.      0.      -190.   -12.    -1.       601
241.    1.                                                               602
(61 unnumbered cards with time history for x-accelerometer data)
49.     0.     2.      2.      .25     12700.  5080.                     603
0.      -147.5 11.     -147.5  20.     -148.4  25.     -146.9
32.     -146.4 .       .       .       .       .       .       .
.       .      .  (13 unnumbered cards for inertial    .       .
.       .      .   z-displacement of header point)     .       .
.       .      .       .       .       .       .       .       .
240.    -141.5
0.      -282.  240.    -282.           (x position in vehicle)
0.      -147.5 240.    -147.5          (z position in vehicle)
26.     2.     .13     5000.                                             604
(7 unnumbered cards with time history for pitch angle)
```

MEMO TO: Users of the MVMA 2-D CVS Model

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: Link Sharing for Hip, Knee, and Elbow Ellipses: An Improvement in Modeling of Tangential Forces

DATE: June 6, 1988

Important new code pertains to a new feature in which "link-sharing" can be specified for ellipses at the hip, knee, or elbow. Use of this feature is optional but recommended. It is set "on" by specifications in field 8 of Card 220. There is a replacement page for Card 220 in Volume 2.

"Link-sharing" is important in making more realistic the way that an ellipse at (or near) a joint produces tangential (friction) forces with a line segment. [This is allowed ONLY for ellipses at the hip, knee, and elbow joints.] Card 219 is used to specify the link of attachment for each ellipse. When the link rotates, the ellipse rotates with it. Consider the case of a circle attached to the lower torso link and positioned with its center exactly at the hip joint. Consider, also, a similar data set in which the circle is attached instead to the upper leg link--and still positioned exactly at the hip joint. It seems reasonable that these two data sets should produce the same results, but they do not without the new feature since for one the hip circle rotates with the lower torso and for the other it rotates with the upper leg. This means that slip point velocities and therefore also tangential forces will be different. The new feature will cause the hip circle to rotate (in essence) as an average of lower torso and upper leg rotations. This is much more realistic than a rotation with either one or the other of the two links associated with the hip, knee, and elbow joints.

New code allows specification in field 8 (previously blank) of the 220-Cards (hip, knee, and elbow) of values for the link number of the adjoining link, i.e., the link which "shares" the ellipse with regard to calculation of rotational terms for the slip velocity and lever arms for ellipse-line contact. For the case described above, for example, where the 219-Card for the hip ellipse has a "4." in field 5, a "5." can be put in field 8 of the 220-Card to turn on link sharing. The new feature is most reasonably used when the ellipses are circles (or nearly) and are positioned at or near to the joint.

Sharing an ellipse near a joint will produce results that are in general intermediate between results obtained for attachment to one or the other of the two links meeting at the joint. For example, sharing the hip ellipse between the lower torso and upper leg links rather than assigning it solely to one or the other produced the following "averaged" results for H.I.C. in runs based on one typical baseline data set:

HIP Ellipse Attachment	H.I.C. Value
lower torso link (normal standard)	3166
upper leg link	2018
shared attachment	2716

It is seen here that the manner in which the hip ellipse is defined can affect calculation of tangential forces sufficiently to have a significant effect on H.I.C.

To make a similar test with one of your own data sets, it would be necessary for you to prepare sets of 219- and 220-Card data for attaching the hip ellipse to the lower torso link and alternatively to the upper leg link. The resulting ellipse should have the identical locations and orientations in space at time zero for the two data sets. You will adjust values on Cards 219 and 220, making use of data on Cards 201, 202, and 301. Note that a value will be needed for field 7 of Card 220. In runs in which shared attachment is requested, you will also use field 8 of Card 220.

MEMO TO: Users of the MVMA 2-D CVS Model

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: Modeling/Simulation of Head-Windshield Tangential Forces

DATE: June 6, 1988

An improvement has been made in Version 6 (and late Version 5) in the application of friction forces to the occupant. It will generally be of small benefit, but in some circumstances the differences in simulation results may be of significance, particularly in unrestrained occupant simulations.

The modification relates to calculation of lever arms through which friction forces act and it improves upon the method used in Version 3. Specifically, the friction force between an ellipse and a line is now applied to the occupant at the interface point of the deformed ellipse and deformed line rather than at the point of maximum geometric penetration of the ellipse. Note that the new code will have no new effect for any interaction for which the body ellipse is specified as rigid since in that case the interface point IS the point of maximum geometric penetration.

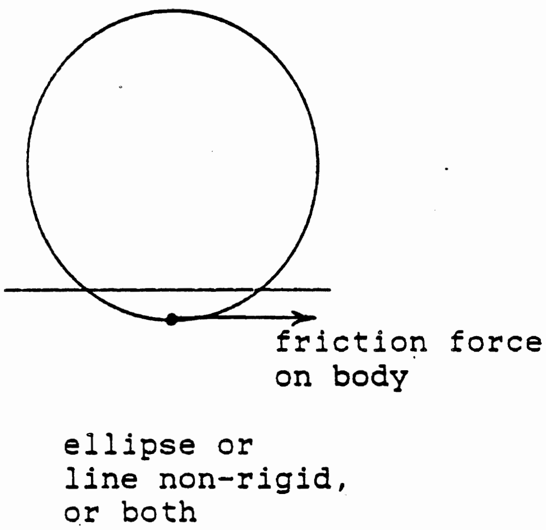
In relation to this new ability of the model, however, I make the following recommendation for modeling/simulation of the head-windshield interaction. [Note: This recommendation does not apply if the "true plowing" option is selected for head-windshield modeling.]

> For HEAD-WINDSHIELD INTERACTIONS, the windshield should be defined as rigid (blank material name on Card 401) and the windshield material should be assigned to a head ellipse (use windshield material name on Card 219). A superimposed rigid head ellipse (with appropriate 106-Cards) should be used for non-windshield interactions.
>
> [Example data may be seen in the DEMODAT data set.]

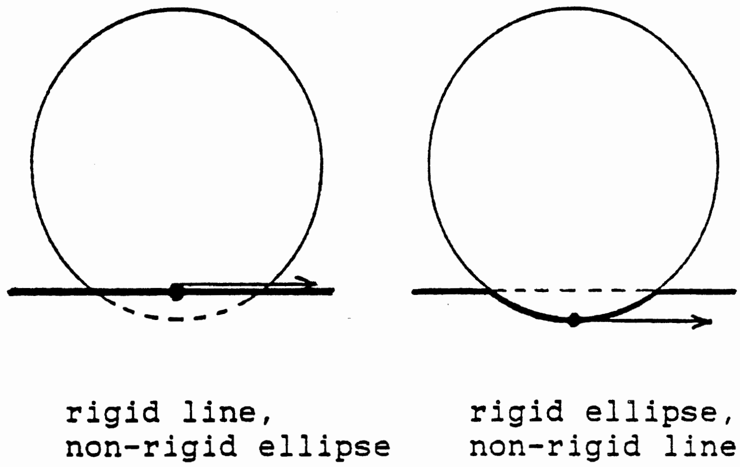
This will cause the friction force to be applied to the head at a more appropriate position. The reason this should be done is that tangential force for the head-windshield interaction is not a true friction force. Rather, this force, when large, results mostly from windshield glass breaking away as the head moves through it in a TANGENTIAL direction. That is, in a barrier test the force acts on the head MOSTLY IN THE PLANE OF THE WINDSHIELD, not at the point of maximum penetration of the head beyond the windshield line. That point, in fact, may actually be completely through the windshield and not experiencing any force at all. While tangential plowing force MAGNITUDE may be modeled reasonably by use of deflection-dependent terms in the coefficient of friction (Card 412), it is not reasonable to apply the force at the "interface" between the rigid head ellipse and the deforming windshield, i.e., at the point of maximum penetration. If, instead, all deformation can be assigned to the head and none to the windshield, then the interface point on the head will be at the windshield line--which is where this particular tangential force SHOULD be applied. Thus, head (normally rigid) and windshield ("soft") materials should be exchanged in data set assignments. [If the "true plowing" option is used instead of normal friction (with deflection dependence), this assignment of materials is unnecessary because MVMA 2-D will apply the plowing force in the line of the windshield plane.]

This will normally reduce HIC's resulting from head-windshield impacts since the smaller lever arm for the friction force vector will reduce the magnitude of associated head angular accelerations and thus angular velocities and their contribution to translational acceleration of the head center of gravity.

Other tangential forces (friction), i.e., those that do not result from plowing away of material of a line element that has been partially broken away, are appropriately applied at the point of maximum penetration if the ellipse is rigid.



VERSION 3



VERSION 6

3.2-A.3. Interpretation of Output

MEMO TO: Users of the MVMA 2-D CVS Model

FROM: Bruce M. Bowman, UMTRI
University of Michigan

SUBJECT: Convention for Interpretation of Ellipse/Line Contact Output

DATE: June 6, 1988

Consistent, easily remembered, and easily applied conventions can be used in interpreting printouts from runs made with Version 6 and late Version 5 code. These conventions relate to ellipse/line tangential force, the position of the contact point on the line (nondimensional), the slip (tangential) velocity, and more generally, the definition of a positive direction around the vehicle interior enclosure. Specifically:

* Tangential (friction) force is positive when the force vector is in the same direction as a right-handed rotation of the normal force vector; i.e., with your right thumb pointing toward you and your curled fingers pointing along the direction of the normal force vector, if you "turn" the normal force vector 90 degrees, it will align with the vector of a positive tangential force.

* Position on the line and slip velocity are positive when in that same direction if the normal force vector is considered to be a force on the occupant (rather than the oppositely directed force on the line segment).

* * Since the occupant is WITHIN the (disconnected) enclosure defined by the 411-Card line segments:

** the above-defined positive direction is **
** always clockwise around the vehicle interior **

Users should be aware that the printed slip velocity is not proportional to the time rate of change of the (nondimensional) position of the contact point on the line. The reason is that the slip velocity is for a material point, not a geometric point, and therefore includes rotational terms.

The figures below illustrate the conventions described.

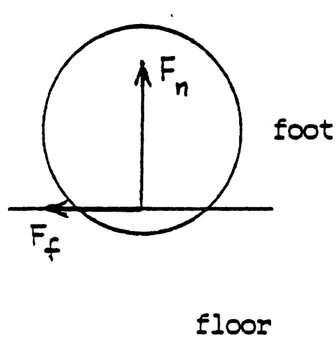


Illustration of positive direction of friction force on ellipse

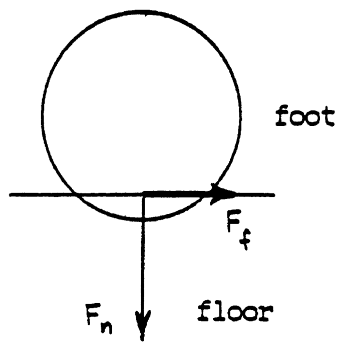


Illustration of positive direction of friction force on line

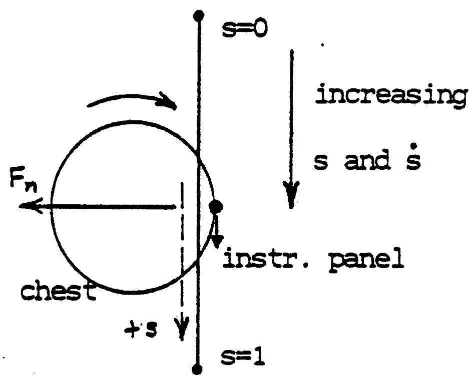


Illustration of positive direction for position on line and slip velocity

6/30/88

INTERPRETATION OF FEMUR AND TIBIA LOADS (CATEGORY 40)

The MVMA 2-D model determines and prints out five components of femur and tibia loads if Category 40 output is requested by the user on Card 111 and on Card 1001. In order that transducer response from anthropomorphic dummy tests may be simulated, the model requires input data for: a) the location along the femur of an axial force transducer, and b) the upper leg mass between the transducer and the knee. The mass is used in calculating a centrifugal force component of femur tension.

Force components printed out are (in order across the page): femur axial forces at transducer (sensor); femur axial force at knee; femur shear force at knee; tibia axial force at knee; tibia axial force at foot. Total leg loads are calculated, so if it is assumed that the loads are shared equally by two legs, the user must divide printout values by two to obtain the load for each leg.

The user should be aware that in order to insure proper calculation of tibia loads, any contact ellipse representing the knee should be attached to the upper leg (link 5) rather than to the lower leg (link 6). The calculation of the tibia axial force at the foot assumes that all external forces on the lower leg are against the foot. If contact ellipses attached to the lower leg other than foot ellipses develop substantial forces then printout for this component will not be accurate.

The equations used for the calculations are given in section 4.6.2.5 in Volume 3 of the MVMA 2-D manuals.

FEMUR LOAD COMPONENTS

AXIAL AT SENSOR (FEMURA) -- positive for compression; FEMUKA adjusted for weight and centrifugal force of upper leg mass between sensor and knee

AXIAL AT KNEE (FEMUKA) -- positive for compression; accounts for all lower leg effects (contacts, weight, centrifugal force) and all contact forces on the upper leg

SHEAR AT KNEE (FEMUKS) -- perpendicular to FEMUKA (i.e., to femur) and positive toward back side of femur, i.e., for "downward" acting lower leg force against the femur; accounts for all lower leg effects and all contact forces on the upper leg

TIBIA LOAD COMPONENTS

AXIAL AT KNEE (TIBIAK) -- positive for compression; TIBIAF adjusted for weight and centrifugal force from lower leg

AXIAL AT FOOT (TIBIAF) -- positive for compression; takes into account all contact forces on the lower leg and can therefore be interpreted as the tibia load AT FOOT only if the foot ellipse is the only ellipse attached to the lower leg that is in contact with the vehicle interior

HIGHWAY SAFETY RESEARCH INSTITUTE
Institute of Science and Technology
Huron Parkway and Baxter Road
Ann Arbor, Michigan 48109

THE UNIVERSITY OF MICHIGAN

MEMO TO: Users of the MVMA 2-D CVS Model

FROM: Bruce M. Bowman
Biomathematics Department
Highway Safety Research Institute
University of Michigan

SUBJECT: MVMA 2-D CVS Integration Monitor

DATE: November 14, 1979

It has come to my attention that there has been a great deal of unnecessary concern regarding warning printouts from the integration monitor of the MVMA 2-D CVS model.* Example printout is shown in Figure 1. The purpose of this memo is to explain the proper manner for interpreting this printout.

There are several ways which an integration algorithm for a simulation model can be overstressed. With regard to crash victim simulation models, the most common causes are: 1) a loading curve for a deforming material which is too steep (For a linear force-deflection curve, this is just the material -- or "spring" -- stiffness, k); 2) a viscous damping coefficient which is too large; 3) a constant (Coulomb) friction which is too large; 4) a too-small velocity ramp for preventing sudden changes in frictional forces when relative velocity is near zero; 5) and, inversely to 1 through 4, an integration time step h which is insufficiently small (for the severity of the impact) for the material property values specified. The material properties mentioned above might be for either contact interactions (forces) or for joint activity (torques).

Experience has shown that when material stiffness or damping is too large, the integration is so unstable that geometric incompatibilities soon result and the run ends in an abort. Conversely, if the run does not abort, the integration is stable and consistent and stiffnesses and damping coefficients are therefore not too large. Thus, an integration monitor is not strictly needed for cases 1 and 2, i.e., the run abort serves the purpose. For cases 3 and 4, however, both of which concern constant friction, it has been found that an instability can result which does not call attention to itself and which should therefore be monitored. In particular, the fourth-order Runge-Kutta integrator used in the MVMA 2-D CVS model can produce large link accelerations which do not satisfy the equations of motion for small ranges of time if the integration time step or constant friction level is too large or if the friction ramp length is too small, and yet a run abort will not occur. Predicted occupant motions are still

*The code which monitors the integration is in Subroutine GOMVMA of the Execution Processor ("GO").

```
***WARNING:  INTEGRATION IS SUSPECT FOR GENERALIZED ACCELERATION.  CONDITION PROBABLY CAUSED BY CONSTANT
FRICTION AT JOINT OR SURFACE OR BY LARGE STIFFNESS, VISCOUS DAMPING, OR DT. (SEE GOMVMA: 1=DTHID,...)

  AT TIME    0.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  2  3  4  5  6  0  0  9 10  0  0  0  0  0  0  0  0  0 20 21
  AT TIME    1.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19  0  0
  AT TIME    2.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19  0  0
  AT TIME    4.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME    5.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME    6.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME    8.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  5  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME    9.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  0  0 11  0  0  0  0  0  0  0  0  0
  AT TIME    9.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19  0  0
  AT TIME   21.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME   22.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19  0  0
  AT TIME   29.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 19  0  0
  AT TIME   29.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 21
  AT TIME   31.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  0  0  0  0  0  0  9  0  0  0  0  0  0  0  0  0  0  0
  AT TIME   33.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME   35.000 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  AT TIME   35.500 INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE (V3-V1)/(T3-T1) FOR VARIABLES NOS.--
      0  0  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

Figure 1. Example Printout from Integration Monitor

basically good, but HIC and SI injury indicators can be in error by five to ten per cent. (Errors in forces and torques are much less.)

The integration monitor warns against the possibility of this occurrence. It employs a relative error test to separate possible inconsistent integration results from consistent results.* At each time point (except t=0 and $t=t_{final}$) and for each degree of freedom "i" in the system, it estimates the acceleration as $\Delta V^{(i)}/\Delta t$, where $V^{(i)}$ is the difference between the predicted velocities one integration time step on either side of t and Δt is the corresponding time interval, i.e., two integration time steps. This is illustrated in Figure 2. The result is

$$A_2^{(i)} = \frac{V_3^{(i)} - V_1^{(i)}}{2h} .$$

Let $A^{(i)}$ be the acceleration for generalized coordinate "i" at time t_2 resulting from the fourth-order Runge-Kutta integration. The integration monitor tests the inequality which follows:

$$\left|(A^{(i)} - A_2^{(i)})/A_2^{(i)}\right| \quad \begin{array}{l} < \varepsilon, \text{ test is satisfied} \\ \geq \varepsilon, \text{ test is not satisfied} \end{array}$$

The test parameter, ε, is set within the program as 0.2. This may seem like a large value to allow for satisfaction of the relative error test, but it is not. It must be kept in mind that $A_2^{(i)}$, against which $A^{(i)}$ is compared, is not the true solution for the differential equations of motion -- the true solution is unknown. Failure to satisfy the relative error test therefore does not necessarily indicate an integration difficulty but instead indicates only that the predicted motion around time t_2 is not smooth, causing the fourth-order integration not to be in close approximation to the secant estimate, $A_2^{(i)}$. Indeed, the fourth-order result can normally be expected to be much more accurate than the simple estimate $A_2^{(i)}$. Thus, the relative error test can serve only to warn that integration difficulties may exist.

The general procedure which should be followed when examining integration monitor printout such as shown in Figure 1 is as follows.

1) Look for rows of numbers which have many non-zero elements (1 through 21). For example, if the numbers printed for, say, t = 113 ms are

1 2 3 0 0 0 7 0 9 10 11 0 0 0 0 0 0 0 19 0 21

then generalized accelerations 1, 2, 3, 7, 9, 10, 11, 19, and 21 fail the relative error test at time 113 ms and the possibility of inaccurate integration should be considered. In particular, the accelerations should be examined in the standard tabular time-history printouts. Reference should be made to Table 95 of Volume 3 of the MVMA 2-D CVS manuals (Error Messages 35 and 36) for definition of the correspondence between numbers and generalized accelerations. That page is included here as Figure 3. For the example given above, most of the coordinates which fail the test are near the head, neck, and upper torso, so one would be led to look closely at

*An absolute error test is first used to filter out close matches.

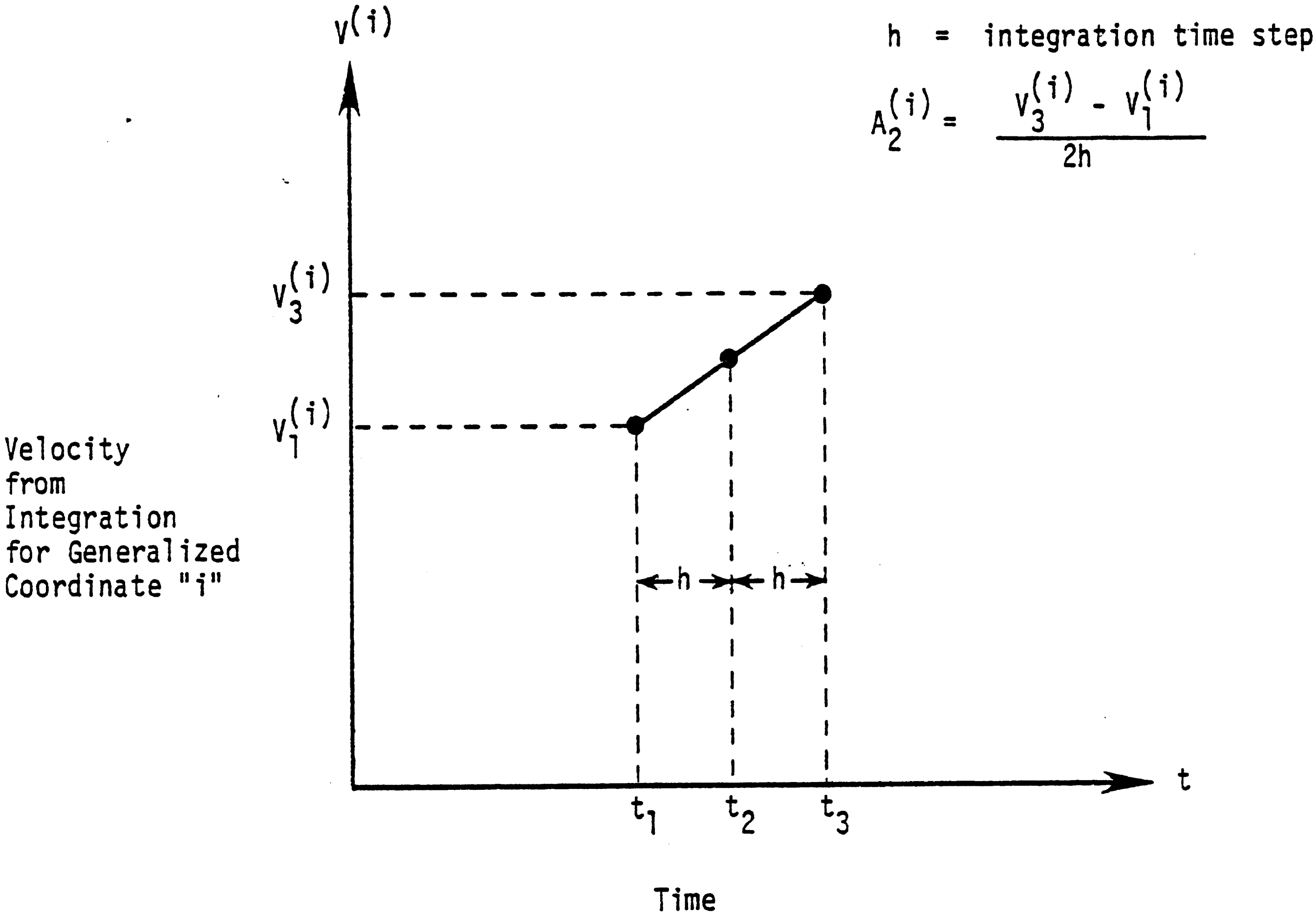


Figure 2. Estimation of Acceleration at Time t_2

TABLE 95. ERROR MESSAGES FROM GO (Page 3 of 4)

Number	Message	Condition and Action Required	Subroutine
29	DF DOES NOT EXCEED DE, RUN ABORTED	Check Cards 221, 403, 704, and 812.	EVAL
30	AT TIME = XX.XXXXX COMPUTED (RELOAD or UNLOAD) CURVE NO GOOD, USE (UNLOAD or STATIC) CURVE. (11 values = DEL and PX(I,1) through PX(I,10) INTERACTION INVOLVES AAAAAAAAAAAAAAA	Program corrective measures are reasonable. No user action required.	EVAL
31	AT TIME = XX.XXXXXX UNLOADING CURVE LIES ABOVE LOADING CURVE. (same variable list as message 33 plus DUM(12) and FOG) INTERACTION INVOLVES AAAAAAAAAAAAAAA	Warning, slope of unloading curve less than slope of loading curve at beginning of unloading. Reduce G-ratio and/or R-ratio, change static curve, or ignore.	EVAL
32	AT TIME X.XXXXXX SLOPE OF CALC'D UNLOAD CURVE WAS NEG. STRAIGHT-LINE UNLOADING USED. MAINTAINS PERM. DEFORMATION, IGNORES ENERGY. INTERACTION INVOLVES AAAAAAAAAAAAAAA	Reduce G-ratio and/or R-ratio, change static curve, or ignore.	EVAL
33	AT TIME = XX.XXXXX BAD UNLOADING CURVE, IIP JJP OG ENERGY NOT RIGHT XXXXX XXXXX XXXXXXXX.XXX BOG FORCE CE DUM(6) XXXXXXXX.XXX XXXXXXXX.XX XXXXXXXX.XX XXXXXXXX.XX INTERACTION INVOLVES AAAAAAAAAAAAAAA	Warning, straight line unloading curve used maintaining permanent deformation but ignoring energy.	EVAL
34	FATAL ERROR --- INTERACTION TABLES EXCEED IN FORCE1	Same as 8.	FORCE1
35	***WARNING: INTEGRATION IS SUSPECT FOR GENERALIZED ACCELERATION. CONDITION PROBABLY CAUSED BY CONSTANT FRICTION AT JOINT OR SURFACE OR BY LARGE STIFFNESS, VISCOUS DAMPING OR DT. (SEE GOMVMA: 1 = DTH1D,....)	1 = DTH1D, 2 = DTH2D, ..., 9 = DTH9D 10 = DXHD, 11 = DZHD, 12 = DXVD, 13 = DZVD, 14 = DTHVD, 15 = DHLD, 16 = DHAL1D, 17 = DHAL2D, 18 = DHHD, 19 = DELND, 20 = DXSD, 21 = DZSD (1-9 = link angle accelerations, 10-11 = chest CG accelerations, 12-14 = vehicle accelerations, 15-18 = steer col. coordinates, 19 = neck length acceleration, 20-21 = shoulder coordinate accelerations.	GOMVMA
36	AT TIME XX.XXX INTEGRATION ACCELERATION DOES NOT APPROXIMATE "3-POINT" ESTIMATE DV/DT FOR VARIABLES NOS. -- XXXXXXXXXXXXXXXXXXXX	A warning only. Often the 4th-order Runge-Kutta integration should not approximate 3-point estimate. Is not of consequence unless most variables are bad or one variable is consistently bad. See message 35.	GOMVMA

Figure 3. Table 95 from Volume 3: Error Messages from GO

material parameters for neck and shoulder joints.

2) Look for particular numbers which appear repeatedly in warning printouts for different times, especially for several successive integration time steps. Examine the tabular time-history printouts and also the values of material parameters for joints and contacts "near" the problem acceleration.

3) As an aid in estimating reasonable extreme sizes for material parameters, refer to Figures 2-11, 3-10, and 3-11 of the MVMA 2-D CVS Tutorial System Self-Study Guide. Those figures are included here as Figures 4, 5 and 6.

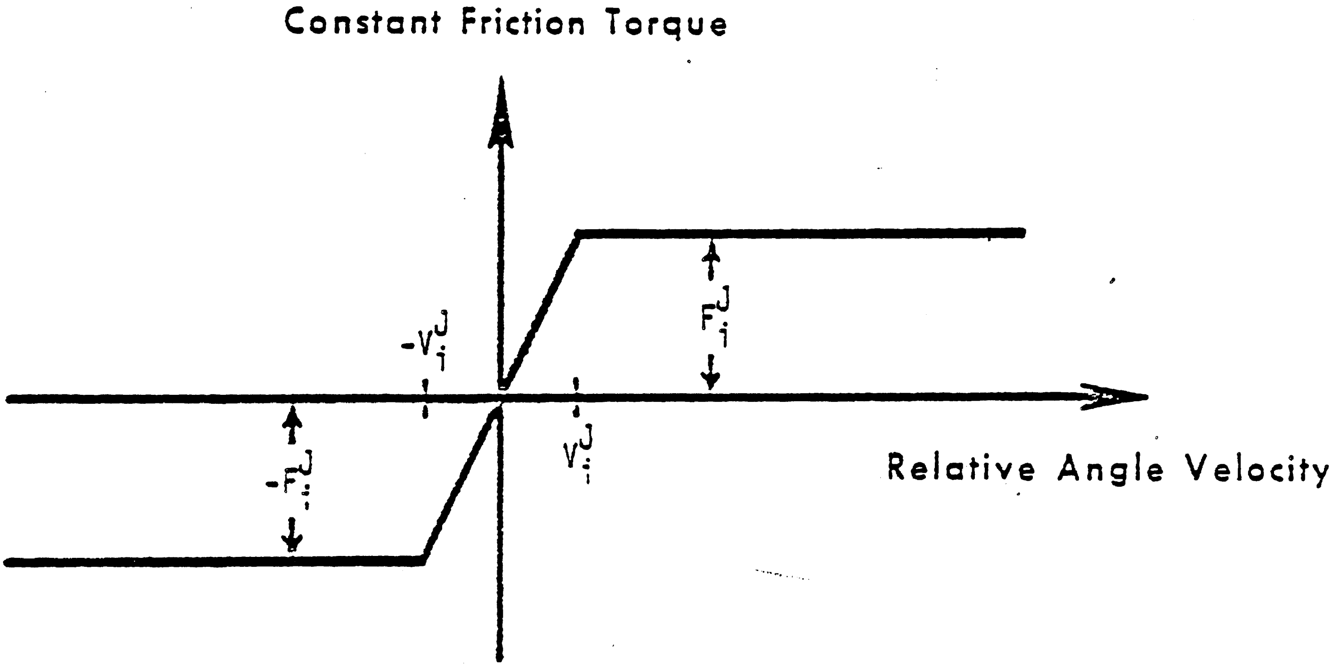
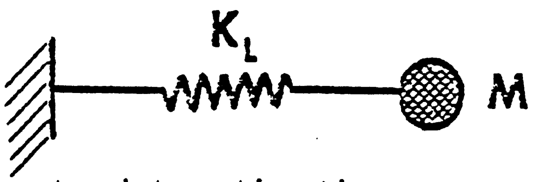


FIGURE 2-11 Joint friction at joint "i"

NOTE: It is estimated for 50th-percentile-male values for mass, moment of inertia, and link lengths and an integration time step of one millisecond that a threshold velocity V_i^J of 300-400 deg/sec or greater should be used for a joint with a constant friction torque of 1000 in-lb or 113 N-m. For greater values of constant friction and time step, proportionately greater values of threshold velocity should be used. Minimum threshold velocities are in inverse proportion to masses and moments of inertia.

Figure 4. Figure 2-11 from Tutorial System Self-Study Guide

6/30/88



Δt = integration time step
T = period of natural frequency

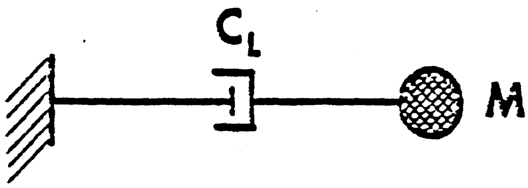
K_L, K_T = linear and torsional spring rates

M, I = mass and moment of inertia

K-rule

$$.05 \text{ (or } .1) \geq \frac{\Delta t}{T} = \frac{\Delta t}{2\pi}\sqrt{\frac{K_L}{M}}$$

$$\longrightarrow \quad \Delta t \leq \frac{\pi}{10\sqrt{\frac{K_L}{M}}} \quad \text{or} \quad \Delta t \leq \frac{\pi}{10\sqrt{\frac{K_T}{I}}}$$



C_L, C_T = linear and torsional damping coefficients

C-rule

For a relative error of less than ε introduced into $\dot{x}$ at each time step,

$$\left| 1 - e^{\frac{-C_L}{M}\Delta t} \Big/ \left(1 - \frac{C_L}{M}\Delta t\right) \right| < \varepsilon . \qquad \text{Therefore,}$$

$$e^{\frac{-C_L}{M}\Delta t} + \frac{C_L}{M}\Delta t\,(1+\varepsilon) < 1 + \varepsilon \text{ or } e^{\frac{-C_T}{I}\Delta t} + \frac{C_T}{I}\Delta t\,(1+\varepsilon) < 1 \div \varepsilon$$

FIGURE 3-10 Maximum stiffness and damping values for numerical stability with integration time step Δt

Figure 5. Figure 3-10 from Tutorial System Self Study Guide 6/30/88

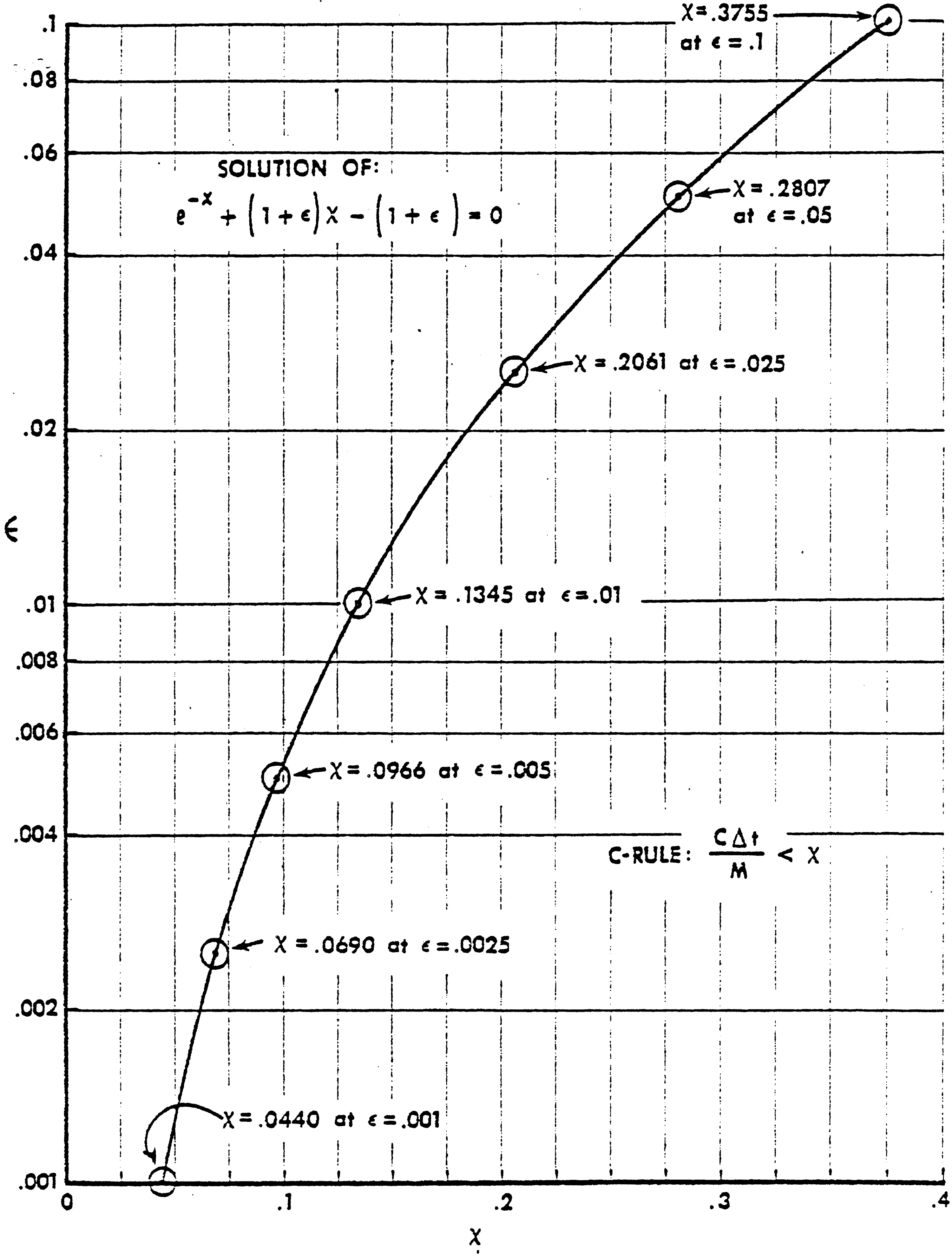


FIGURE 3-11 Solution of $e^{-x} + (1+\varepsilon)x - (1+\varepsilon) = 0$ for x With ε As a Parameter

Figure 6. Figure 3-11 from Tutorial System Self-Study Guide

3.3 DESCRIPTION OF NORMAL OUTPUT **

Section 3.2 describes the use of Cards 107-111 for controlling the storage of potential program output quantities. Potential output is stored or disregarded on the basis of a switch setting for each of 45 normal output categories.* These are listed in Table 11. Section 3.2 also describes the use of Cards 1001 and 1002 for specifying which of the stored output categories are to be printed and in what order. Categories 0 and 41 to 45 constitute special output which is discussed in detail in Section 4.4.2. A brief summary of these options, however, is given in this section after the following discussion of the normal output category options.

Category 1 output consists of the acceleration profiles (input) and the integrated velocities and displacements. Note that x and z output is in a mixture of units— e.g. ,inches for displacements, mph for velocities, and g's for accelerations. X, Z, and velocities are for the vehicle origin motion with respect to the inertial frame regardless of whether input accelerations are accelerometer readings or absolute.

Category 2 output summarizes the "activity" at the defined regions of the vehicle interior. Forces against the region are resolved into special region coordinates (Figure 38) and summed over all segments. If structural deformation is allowed (Card 402), then the third and fourth output items summarize the overall deformation as an average over the segment endpoints. The columns labeled "Endpoint Movement" give the coordinates of the region endpoints in either the vehicle frame or inertial frame, depending on the value of Field 6 of the region 402-Card and as indicated in the Category 2 page heading.

A detailed description of line segment movement is given by Category 3 output. The endpoint coordinates of each of the first five line segments in the region are printed. As for Category 2, coordinates are with respect to the vehicle or inertial frame depending on Field 6 of the region 402-Card.

---

*Categories 1-40 and 46-50.
**Also see Section 3.2-A.

There are three types of Category 4 output. The first describes contact interaction between a line segment and a contact-sensing ellipse. The columns labeled "On Line" give the position (and velocity) of the point of contact measured along the line segment from its first endpoint. The last four columns give the coordinates of the point of maximum penetration by the ellipse in the vehicle and body segment frames. The second type describes contact between body ellipses. Deflections, rates, and force are printed in the first five columns. The remaining columns give the coordinates of the ellipse centers and of the contact point in the inertial and body segment systems, respectively. The third type describes belt forces. Columns one and two are always belt deflection and rate even though belt material properties may have been specified in terms of strain. Column three, with the heading "Ring Equilibrium Tension," is used only for the advanced belt system. This is the belt segment tension for force balance at a slip ring, whether or not the ring is anchored to the vehicle. This force includes the effect of friction at the ring. Column four is labeled "Unadjusted Tension." For the MODROS belt system, this is simply the belt segment tension. For the advanced belts, this is the tension determined from considering the ring positions as quasi-anchor points, without adjustment for friction between occupant and webbing. The positive or negative adjustment for this friction is in column five, labeled, "Tension Adjustment." (This column will contain all zeros for MODROS belts.) For the MODROS system the "Resultant Force" in the next column is the magnitude of the combined lap belt force vectors; it is identical to the belt tension of column four for the torso belts. For the advanced belt system, the resultant belt force is determined from columns 3, 4, and 5. "Resultant Heading" in the next column is the belt angle, measured by counterclockwise rotation from the vehicle x-axis of a line from the anchor point to the attachment point. For the MODROS lap belt combination, the heading is that of the resultant force vector. Advanced belt system tensions and deflections are in three-dimensional space, not merely projections onto the occupant plane.

Neck reaction forces are printed for Category 5. The signs of all shear forces will be consistent with positive shear on the neck for head-neck flexion. Non-zero neck mass causes compressive forces on the neck at the upper and lower neck joints to be different.

Filtered and unfiltered accelerations and injury criteria come from categories 6-9. These output pages are self-explanatory.

Categories 10-12 give body segment angles, velocities, and accelerations in vehicle or inertial frames. Angles are defined in accordance with Figure 78. Categories 13 and 14 give body joint coordinates and velocities relative to the vehicle system. Additional joint coordinates are printed in Categories 21 and 22.

Total torques at the joints are printed for Category 15. It is perhaps worth noting that "Shoulder at Torso" means joint 9 in Figures 1 and 4, and "Shoulder at Arm" means joint 7. The only torque contribution for joint 9 is from muscle tension. All torque components can contribute at joint 7 and the relative angle upon which the torques are based is between the upper arm and upper torso lines, not the shoulder element and upper torso. Absorbed energies for joints and also for the neck and shoulder lengths are printed for Category 16.

Category 17 output consists of body kinetic energies. It should be noted that neck element kinetic energy (if non-zero) is distributed between the head and torso in proportion to α (Card 202).

Categories 18 to 20 print airbag submodel results. Category 18 prints the thermodynamic variables which describe the state of the airbag; the headings are self-explanatory. The airbag generates forces on five body segments which act normal to the contact lines on the occupant (Figure 94). The total force has two components: a) pressure force; b) bag membrane force. These are printed for Category 19. The total force on each of the body elements is resolved into x and z components, relative to the vehicle, and moments about the body element CG's. These are printed for Category 20.

Neck joint coordinates and velocities are printed for Category 21. The neck length is printed also. Similar quantities for the shoulder come from Category 22.

The contents of Categories 23 to 29 are joint torque and absorbed energy components. These pages are self-explanatory.

Categories 30 to 32 give the vehicle-relative x and z components of the total external (non-gravitational) force on each of the body elements. Occupant contact with the vehicle interior can contribute for all eight body elements. The belt restraint forces, whether from the simple or advanced system, contribute to the torso elements only. Airbag contributions are to the head, torso elements, and upper leg. The steering column forces contribute to the head and torso elements. Reaction forces at joints are not included.

The motion of the steering column subsystem is printed for Category 33 and 34. In particular the first six columns for Category 33 locate the points in the system which sense contact by the occupant. (See Figures 55 and 56.) Upper and lower column extensions and angles are printed for Category 34. Category 35 prints body contact forces against the steering wheel and reaction forces within the steering column system. The vehicle-relative force and moment components acting on the occupant result from Category 36.

Category 37 prints all components of internal force in the neck and shoulder length elements. This page is self-explanatory.

Muscle tension may act at nine joints and in both length elements (neck and shoulder). The dynamic muscle tension torques and forces are printed for Category 38. Associated dissipated energy is printed for category 30.

Category 40 output consists of femur and tibia axial and shear forces. These values are determined on the basis of analysis done by Danforth (Ref. 24).

(Also, see Ref. 25.) This analysis is included in Volume 3, Section 4.6.2.5.

Options 41 through 44 constitute an updated version of the parameter assessment capabilities used in earlier HSRI two- and three-dimensional crash victim simulators. Options 41 through 43 yield output which identifies the quantity, the peak value, the time at which the peak occurs, the time duration during which the quantity exceeds an inputted test value together with the points in time at which the quantity exceeds and then returns below the test value. Option 41 causes both a high and low test against upper and lower test values. If a zero test value is specified, the test is not made. Option 45 is for a printer-plot man and vehicle interior presented at specified time points at which regular printout occurs. Details of these options will be found in Section 4.4.2. Figure 95 shows example printer-plot output.

Options 46, 47, and 48 are for head center-of-gravity, chest center-of gravity, and hip-joint motions. x and z displacements, velocities, and accelerations are printed for each category, and rotational motion is also printed for the head and chest segments. Options 49 and 50 yield output of joint relative angles and relative angle velocities, respectively.

3.4 SAMPLE INPUT AND OUTPUT

The purpose of this section is to give the engineer who is learning to use the MVMA 2-D model a "hands-on" feeling for input data sets required by the model. A complete and careful reading of Section 3.4 prior to a first attempt at developing a data set is highly recommended. A careful reading would probably benefit even users already familiar with the MVMA 2-D model.

This section has been reproduced virtually intact from Module 13 of the MVMA 2-D Tutorial System [8]. "Module" references in this section are for the Tutorial System.

Data decks are described and assembled in this section for the following two simulations:

1. a 30-mph frontal barrier crash with vehicle interior deformation and a dummy passenger restrained only by a knee bar; and,

2. a crash with similar occupant and vehicle configurations except that the occupant is restrained additionally by a torso harness.

3.4.1 Introduction

It is normally convenient to construct a data set card by card, beginning with Card 100 and proceeding through Card 1600. However, a complete data set can also be viewed as a collection of subsets which may be dealt with individually. In this section, discussion of the construction of data sets is in terms of eighteen largely independent subsets. These are identified in Figure 96 . Data subsets developed for one simulation can be assembled with subsets developed for other simulations to yield a complete data deck for a new simulation. As long as the user keeps in mind and takes account of the various dependencies between some of the subsets, a completely satisfactory composite data deck will result.

3.4.2 Input Data for Example 1

The first example to be considered is simulation of a 30-mph frontal barrier crash with a dummy passenger restrained only by a knee bar. The frontal portion of the vehicle interior displaces toward the occupant. Figure 97 is a schematic of the occupant and vehicle interior configuration at crash onset. The following sections (3.4.2.1 through 3.4.2.11) discuss the construction of the data set for Example 1, which is shown in its entirety in Figure 109 .

Arbitrary Decomposition of MVMA 2-D Data Set Into Subsets

DATA SUBSET	CARD NUMBERS
Title Cards	100, 200, ..., 900
General Controls for IN and GO	101, 102, 103
Debugging Printout Controls	104, 105
Categories of Output Variables to be Stored	107 - 111
Vehicle Motion	601 - 604
Occupant Description	201 - 242
Occupant Position	217, 301-304
Vehicle Interior	401 - 411
Friction Characteristics	412
Allowed or Disallowed Contact Interactions	106
Belt Restraint System	218, 501, 701-723
Airbag Restraint System	901 - 909
End of Data Deck for IN	1000
Categories of Output Variables to be Printed	1001, 1002
HIC, Femur Loads, and Filtering	1003, 1004
Potential Injury Indicators	1100 - 1401
Printer-Plot Stick Figure Time Sequence	1500 - 1502
End of Data Deck for OUT	1600

FIGURE 96 Arbitrary Decomposition of MVMA 2-D Data Set Into Subsets

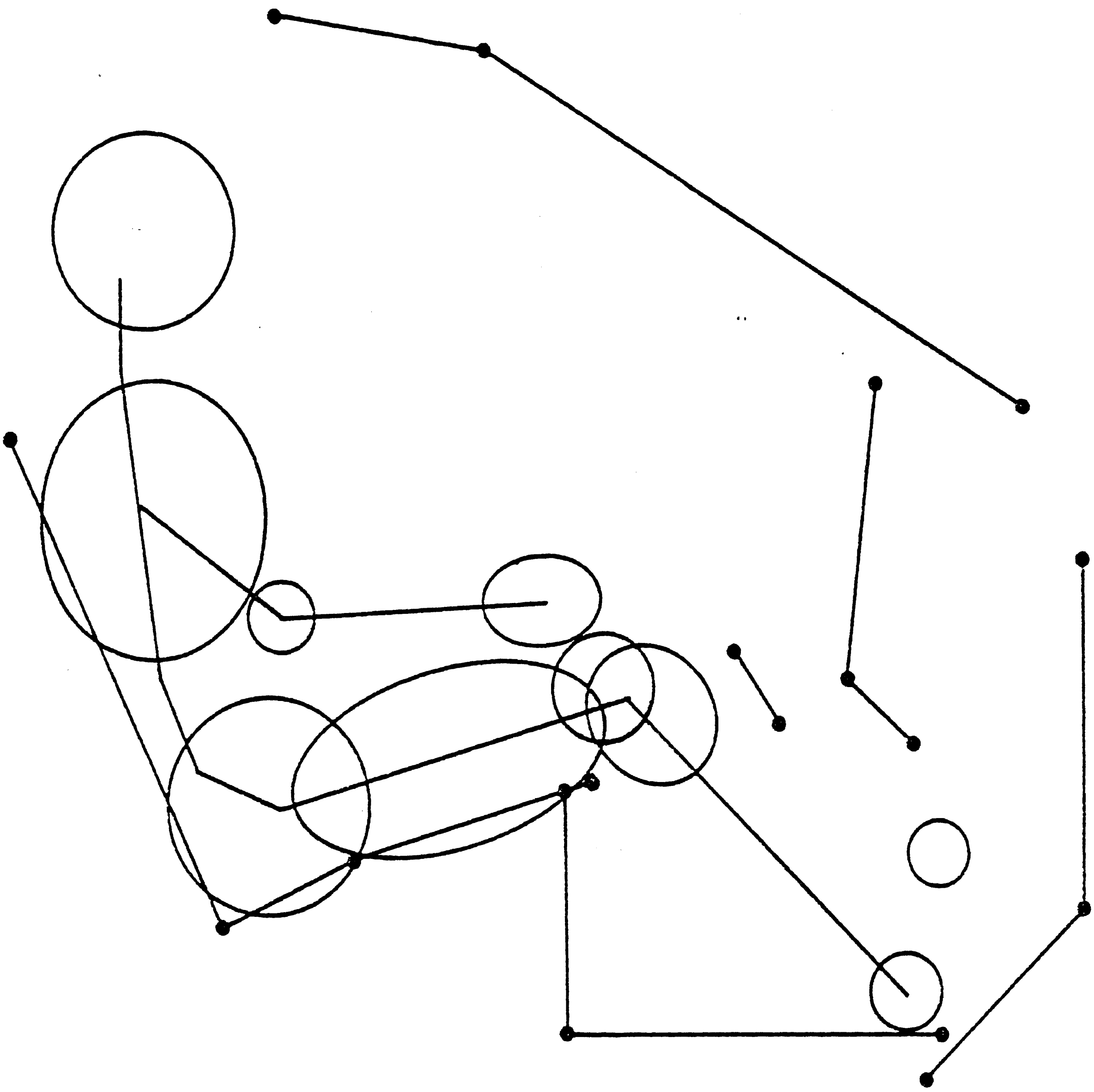


FIGURE 97 Occupant and Vehicle Interior Configuration for Example 1

3.4.2.1 Title Cards. Each page of output for a simulation is headed by titles which may be supplied on Cards 100, 200, 300, ..., 900. These cards are discussed in Module 12. The 100-Card is for a "run title," which should be centered in the first 72 columns and which will appear on the first line of each page of printout. (See Figure 98). The second line of page heading consists of the concatenated content of Cards 200, 300, ..., 900. Each of these cards is normally used for description of a specific simulation characteristic. For example, as indicated in Volume 2 of the MVMA 2-D report, the 700-Card normally describes the type of belt restraint system used. However, there are no restrictions on the content of these cards. The 19-column subtitle fields of Cards 200, 300, ..., 700 plus the 17-column field of either Card 800 or Card 900 (only one may be used) can be used together for any 131-character description of the simulation.

The title cards for Example 1 have been grouped together at the beginning of the data set except for the 200- and 300-cards, which have both been used for occupant description and are placed with the occupant data cards (see Figure 102). It might be again noted, as explained in Module 1, that data cards can be positioned within the data deck in any order, without attention to card identification number. Exceptions to this are the 1000- and 1600-cards, which serve as "end-of-data-deck" markers and must be the last cards of the data decks for the Input and Output Pre-processors INP and OUTP.

3.4.2.2 General Controls for IN and GO. A number of general controls are required for the operation of the Input (IN) and Execution (GO) Processors. These are on Cards 101, 102, and 103, which are discussed in Modules 4, 5, 6, 9, 10, and 12.* Some of the most important of these controls specify: 1) the system of units (metric or English) for the simulation; 2) crash duration, integration time step, and time increment for printing of output; 3) use or non-use of the various restraint system options; 4) interpretation of "inhibition cards" for allowed or disallowed contact interactions; and 5) limits for the algorithm which

*The user is referred to Table 9 for aid in finding discussion in Modules 2 through 12 of the parameter in any data card field.

```
                    MVMA 2-D TUTORIAL EXAMPLE #1                                    100
   KNEE BAR                                                                         400
OCC. COMP. DISPL.                                                                   500
30MPH FRONT BARRIER                                                                 600
    NO BELTS                                                                        700
```

FIGURE 98   Title Cards for Example 1

```
1.       1.       32.174   0.       0.       200.     1.       5.       10.          101
0.       0.       0.       0.       0.       0.       10.      .000001  5.           102
.2       .05      100000.  15000.   10.      .05      10.      1.       1.           103
```

FIGURE 99   General Controls for IN and GO for Example 1 determines shared-deflection force balance. Simulation Examples 1 and 2 of this section are both for 200 msec duration, one msec integration time step, and five msec printout interval. The simulations are made with English system data. Figure 99 shows Cards 101 through 103.

3.4.2.3 Vehicle Motion. The vehicle motion, or more precisely, occupant compartment motion, is described with Cards 601 through 604. This prescription of the "crash history" is the subject of Module 8. Cards for the 30-mph frontal barrier crash of Example 1 are shown in Figure 100. Initial position and velocity values for vehicle horizontal, vertical, and pitch coordinates are on Card 601, together with two coordinates for an accelerometer location. The remaining cards specify acceleration histories for the three vehicle degrees of freedom.

The horizontal motion for this example, illustrated by the acceleration profile in Figure 101, is defined by twenty-three time-acceleration points on cards following the 602-card. The crash represented is for an impact velocity of 30 mph, a ΔV of 32.83 mph, 33.9 g's peak acceleration, and a stopping distance (or "crush") of 21.8 inches.

3.4.2.4 Occupant Description. Most of the Cards 201 through 242 are used for prescribing occupant parameters. Cards 201 through 216 plus 227 through 242 describe mass and moment of inertia properties for the body links, link lengths, and joint properties. Cards 219 and 220 define ellipses which represent the contact-sensing profile of the body. Loading and unloading characteristics of body materials are prescribed on Cards 221 through 226.* The data in Figure 102 are preliminary data compiled by HSRI from several sources for a GM Hybrid II dummy. Toe and heel ellipses have been positioned for a foot in a flexed configuration since the MVMA 2-D model does not include an articulation at the ankle joint.

Values pertinent to initial joint torques are on Card 217 (see Section 3.4.2.5). Head and chest accelerometers are located by values on the 218-Card (see Figure 122).

---

* See Modules 2, 3, 4, and 6 for discussion of occupant parameters.

0.	44.	0.	0.	0.	0.	0.	0.	501
23.	1.	1.						602
0.	-1.7	1.	-1.4	7.	-33.9	12.	2.8	
13.5	3.9	18.	-21.2	21.5	-12.4	28.	-9.2	
32.	-24.0	33.	-24.0	36.	-9.9	37.	-9.9	
42.	-26.9	47.	-31.8	50.	-25.9	54.	-27.2	
58.	-32.2	61.	-29.0	76.	-6.9	90.	-1.4	
100.	-1.4	120.	0.	300.	0.			
2.	1.	1.						603
0.	0.	300.	0.					
2.	1.							504
0.	0.	300.	0.					

FIGURE 100 Vehicle Motion Cards for Example 1

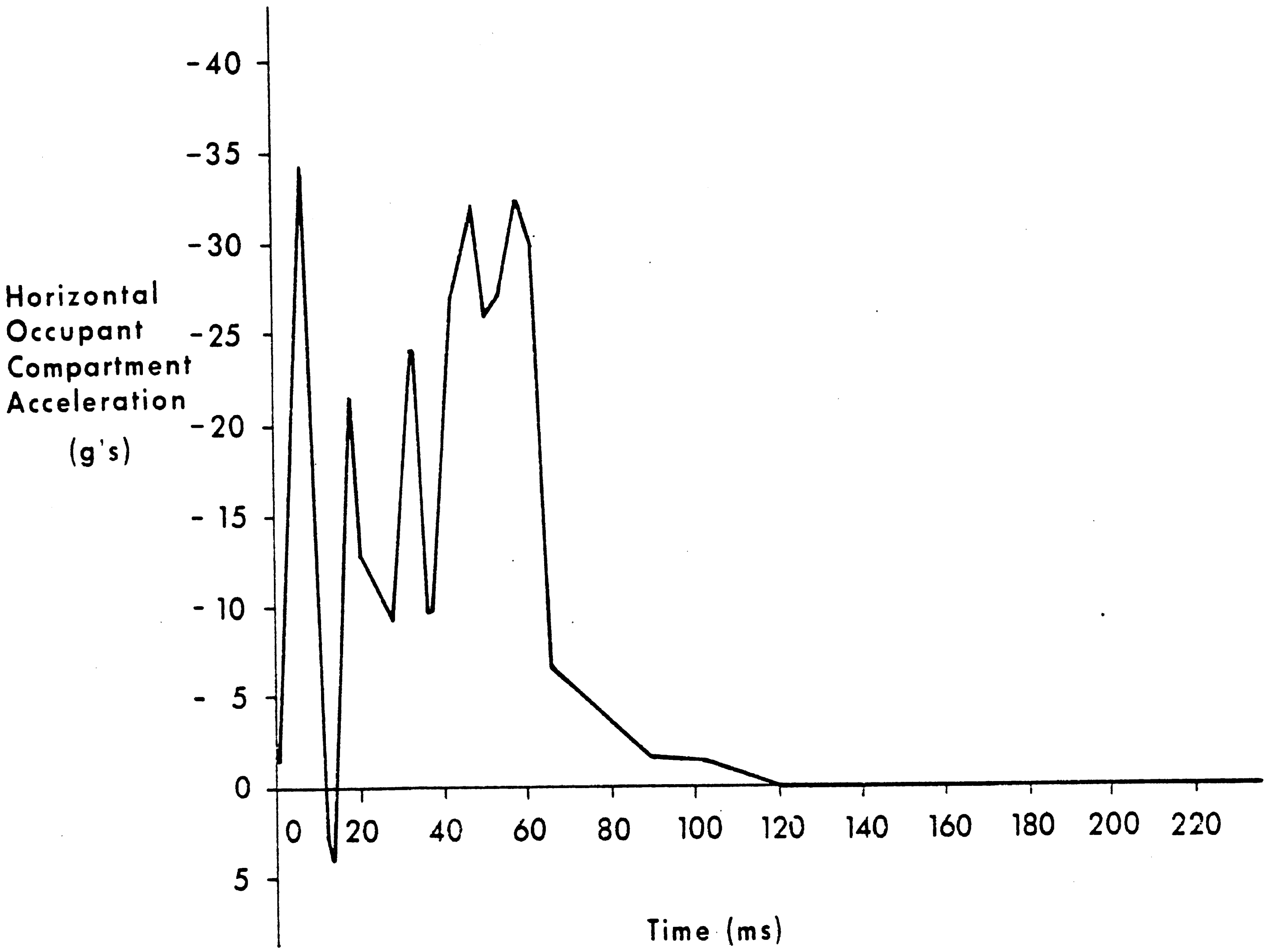


FIGURE 101 Horizontal Component of Vehicle Acceleration for Example 1

```
GM HYBRID II DUMMY                                                                                200
(PRELIMINARY DATA)                                                                                300
1.1       13.44     3.4       5.        15.8                10.3      3.25      -.88              201
2.75      7.        1.7       4.2       8.2       9.3       5.        5.8       .5                202
.0259     .0951     .0052     .0982     .0932     .0518     .022      .0256     .007              203
.198      1.97      .04       1.53      1.38      2.82      .18       .62                         204
12.8      .58       0.        .52       17.4      1.                  -25.      .35               205
12.9      .58       0.        .52       17.4      1.                  -22.      .35               206
72.       15.       0.        .66       1000.     1.        -8.       -25.5     .35               207
102.5     -7.624    .1944     .66       1000.     1.        -33.999   -34.001   .35               208
84.44     -4.810    .1053     0.        850.      1.        -49.999   -50.001   .5                209
0.        29.8      0.        0.        204.      1.        135.      0.        .5                210
0.        10.       0.        0.        222.      1.        28.       -197.     .5                211
0.        10.       0.        0.        64.       1.        0.        -165.     .5                212
751.      0.        757.      1.98                                                                213
20.       230.      0.        0.                            2.                  .5                214
38.       .58       0.        .52       0.        1.        -1.                 .16               215
38.       .58       0.        .52       0.        1.        2.                  .16               216
751.      0.        757.      1.98                                                                242
HEAD                                    1.        3.                                              219
THORAX              CHESTMATL           2.        1.                                              219
HIP                 HIPMATL             4.        1.                                              219
THIGH                                   5.        1.                                              219
KNEE                                    5.        1.                                              219
SHANK                                   6.        1.                                              219
HEEL                                    6.        2.                                              219
TOE                                     6.        2.                                              219
ELBOW                                   7.        1.                                              219
HAND                                    8.        3.                                              219
HEAD                0.        .5        4.        4.                                              220
THORAX              -.5       -.68      5.52      4.44                                            220
HIP                 -.12      0.        4.5       4.5                                             220
THIGH               -.5       -.1       7.        3.                                              220
KNEE                7.        -.4       2.25      2.25                                            220
SHANK               -7.54     0.        3.        2.4                                             220
HEEL                8.57      0.        1.2       1.2                                             220
TOE                 5.61      -5.16     1.2       1.2                                             220
ELBOW               5.3       0.        1.5       1.5                                             220
HAND                5.6       -.4       2.72      1.52                                            220
CHESTMATL           0.        0.        0.        100.      101.      0.        0.                221
CHESTMATL           5.                                      CSTAT     IZERO     CGR               222
CGR       -1.       .1                                                                            223
CGR       0.        1.                                                                            224
CGR       .01       .64                                                                           224
CGR       .3        .5                                                                            224
CGR       1.35      .45                                                                           224
CSTAT     0.        0.                                                                            225
CSTAT     .01       1125.                                                                         225
CSTAT     .05       1460.                                                                         225
CSTAT     .3        1350.                                                                         225
CSTAT     .4        1260.                                                                         225
CSTAT     1.1       1260.                                                                         225
CSTAT     4.25      12600.                                                                        225
IZERO     -1.       0.                                                                            226
HIPMATL             0.        0.        0.        100.      101.      0.        0.                221
HIPMATL             5.                                      CSTAT     IZERO     CGR               222
```

FIGURE 102 Occupant Parameter Cards for Example 1

3.4.2.5 Occupant Position. The seated occupant at "time zero" for Example 1 is shown in Figure 97 . Data are required for initial positioning of the occupant. In addition, a value is needed for the initial velocity for each occupant degree of freedom (see Module 7). As the occupant for Example 1 is initially at rest within the occupant compartment, which is normally the case for crash simulations, these initial velocities -- fourteen fields of Cards 302, 303, and 304 -- are all 0. in the data of Figure 103.

The initial position data are on Cards 217, 301, 303, and 304. First, initial position values are required for the fourteen occupant degrees of freedom. These are the initial link angles (301), neck length (303), shoulder position (304), and horizontal and vertical locations within the occupant compartment of the upper torso center of gravity (303). For the two example simulations, initial link angles and upper torso CG location were estimated from scale drawings of the "time zero" occupant and vehicle-interior configurations, so the values in Figure 103 produce only approximate initial occupant equilibrium. The resulting total initial upward force on the occupant, for example, is 207.1 lb, which does not equal the occupant weight, 163.7 lb. More exact initial z-force balance is recommended. (See "HELPER" information in Section 3.2-A.1.)

Values on Card 217 are for the so-called "joint equilibrium angles." The values in the example data have been selected to equal initial relative joint angles, which may be determined by subtracting link angles on Card 301. As explained in Module 2, this results in zero initial values for the linear components of joint torques.

3.4.2.6 Vehicle Interior. A vehicle interior with which the occupant is to interact must be prescribed by the user. Two types of data are required. The first of these describes the geometrical profile of the interior in the plane of occupant motion. (See Module 5.) The primary elements of this description are the endpoint coordinates of line segments which comprise so-called vehicle-interior "regions," a "region" being a set of connected straight-line segments having the same material properties. Figure 104 shows the vehicle interior profile defined for Example 1. Region and segment names are indicated,

-11.	-8.	-18.	-34.	-50.	0.	0.	0.		217
78.5	97.5	115.5	149.5	19.5	-45.	-41.	3.	89.5	301
0.	0.	0.	0.	0.	0.	0.	0.	0.	302
12.2	0.	-21.4	0.	3.28	0.				303
0.	0.	0.	0.						304

FIGURE 103 Occupant Position Cards for Example 1

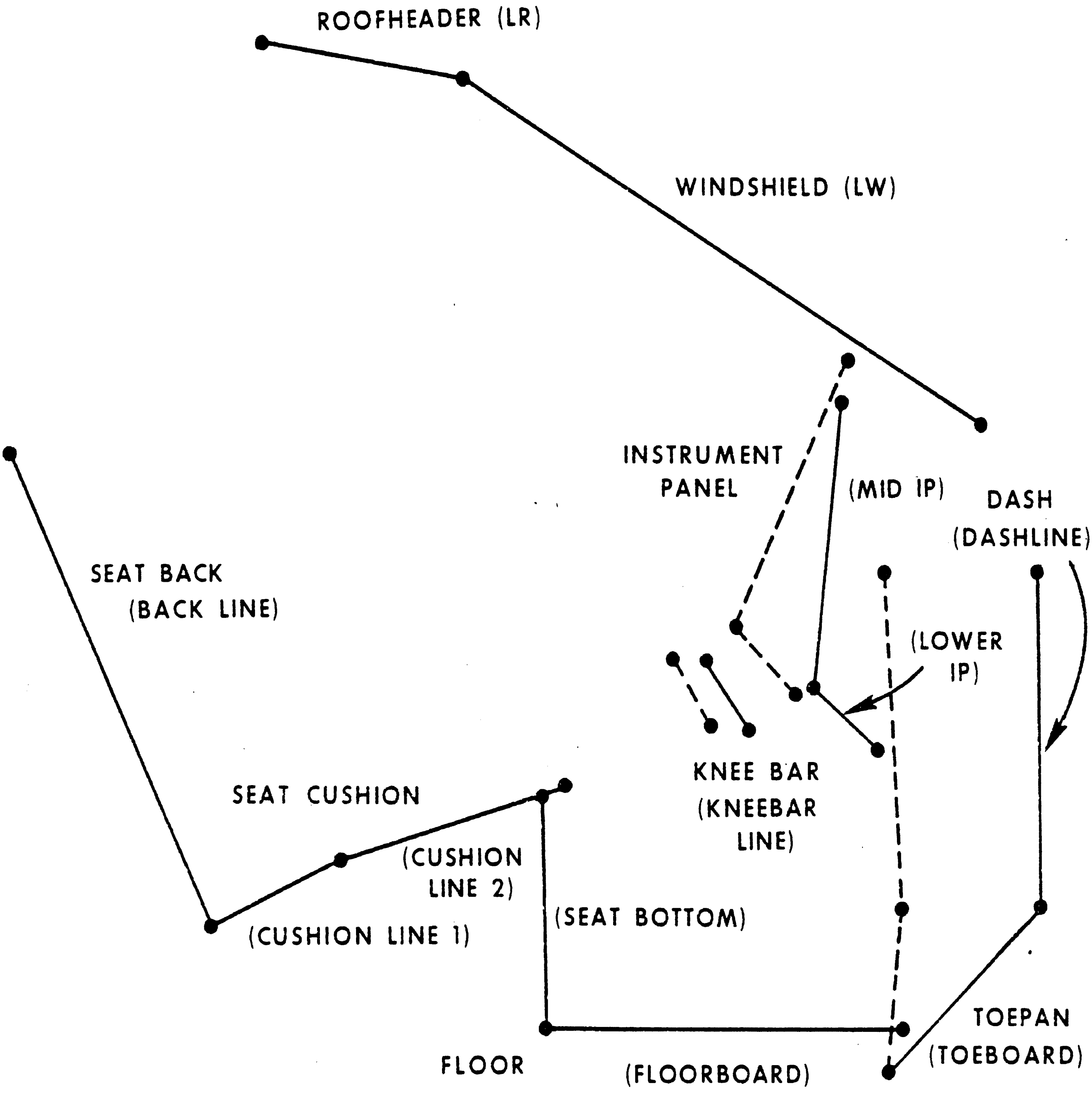


FIGURE 104 Vehicle Interior Profile for Example 1

segment names in parentheses. Solid lines indicate positions of line segments before frontal interior penetration into the occupant compartment, which begins at 40 ms. All penetration occurs between 40 and 80 ms, and the dashed lines represent the deformed vehicle interior. Note that the toeboard segment decreases considerably in length. There is no restriction that segment lengths be held constant while undergoing motion. Data for one of the penetrating regions of the vehicle interior, the INSTRUMENT PANEL region, are illustrated in Figure 105 . The INSTRUMENT PANEL profile is defined entirely by Cards 401, 402, 409, 410, and 411.

The second type of data required for the vehicle interior describes material characteristics, i.e., loading and unloading properties of regions of the defined profile. Data are on Cards 403 through 408. With regard to material specifications in Figure 105 for the INSTRUMENT PANEL, there are two points worthy of note. First, the use of the name IZERO on Card 404 for the inertial spike curve illustrates that curve names may be shared by materials; no inertial spike data (Card 408) appear here for material IPMAT since the inertial spike curve IZERO is defined elsewhere in the data set for a different material (see Card 226 in Figure 102). It is also allowable to specify the same material name for different regions or ellipses while defining the material properties only once within the data set. Second, the dependence of the R-ratio (for energy restitution) on maximum deformation is indicated on the 406-Cards and has been established to be compatible with the G-ratio (for permanent deformation) on Cards 405 and the loading curve from Cards 407. This is important to guarantee proper unloading behavior for the material. Determination of G- and R-ratio compatibility is described in Module 6, Part 2.

3.4.2.7 Friction Characteristics. Frictional forces between the occupant and elements of the vehicle interior can be large enough to have a considerable effect on the magnitude and direction of the resultant force vector at the interaction interface. It is therefore important in simulations to account for frictional forces accurately. The user of the MVMA 2-D model assigns each body ellipse and each vehicle interior region to a "friction class;" this is done with entries on Cards 219 and 402. Coefficients of friction are specified

```
INSTRUMENT PANELIPMAT          0.        1.        1.        1.                             401
INSTRUMENT PANEL2.       4.    1.        0.        0.                                       402
MID IP          INSTRUMENT PANEL5.       0.        1.        1.                             409
MID IP          4.                                                                          410
MID IP          0.       44.9  -27.3     43.7      -15.9                                    411
MID IP          40.      44.9  -27.3     43.7      -15.9                                    411
MID IP          80.      45.6  -29.3     40.6      -18.9                                    411
MID IP          300.     45.6  -29.3     40.6      -18.9                                    411
LOWER IP        INSTRUMENT PANEL5.       .5        1.        2.                             409
LOWER IP        4.                                                                          410
LOWER IP        0.       43.7  -15.9     46.8      -12.8                                    411
LOWER IP        40.      43.7  -15.9     46.8      -12.8                                    411
LOWER IP        80.      40.6  -18.9     42.6      -14.9                                    411
LOWER IP        300.     40.6  -18.9     42.6      -14.9                                    411
```

```
IPMAT           0.       0.    0.        100.      101.      0.        0.                 403
IPMAT           5.       0.    0.        0.        IPSTAT    IZERO     IPGR               404
IPGR     0.     0.                                                                          405
IPGR     2.     .75                                                                         405
IPGR     40.    .75                                                                         405
IPGR     0.     1.                                                                          406
IPGR     1.     .25                                                                         406
IPGR     2.     .1                                                                          406
IPGR     8.     .1                                                                          406
IPGR     8.4    .15                                                                         406
IPSTAT   0.     0.                                                                          407
IPSTAT   .165   80.                                                                         407
IPSTAT   .375   480.                                                                        407
IPSTAT   .665   750.                                                                        407
IPSTAT   .780   760.                                                                        407
IPSTAT   1.25   500.                                                                        407
IPSTAT   1.75   580.                                                                        407
IPSTAT   2.54   225.                                                                        407
IPSTAT   2.87   255.                                                                        407
IPSTAT   3.64   300.                                                                        407
IPSTAT   4.54   380.                                                                        407
IPSTAT   4.63   250.                                                                        407
IPSTAT   8.     250.                                                                        407
IPSTAT   12.    3850.                                                                       407
```

FIGURE 105 Data Cards for Definition of Geometrical Profile and Material Properties for a Typical Region on 412-Cards for combinations of ellipse and region friction classes. Figure 106 shows the 412-Cards in the data set for Example 1. There is one card for each pairing of friction classes represented in the set of contact interactions which can occur in this simulation. For any simulation, coefficients of friction will default to 0. for any pairing not represented by a 412-card. Note that the first data card in Figure 106 includes coefficients for tangential forces proportional to the first and second powers of deflection, as explained in Module 6-2. For this example, the values represent plowing resistance to relative motion between the SEAT CUSHION and SEAT BACK regions and contacting body ellipses.

3.4.2.8 Interaction "Inhibition" Cards. Modules 4 and 5 discuss the use of 106-Cards for specification of allowed or disallowed combinations of potentially-interacting body ellipses and vehicle interior regions. "Allowed" combinations are normally specified when the number of probable interactions is less than the number of improbable interactions. This is judged to be the case for the first simulation example, so twenty-one allowed interactions have been specified between the ten body ellipses and nine vehicle-interior regions. These are shown in Figure 107. One card has been included for an allowed interaction between body ellipses THIGH and THORAX.

3.4.2.9 Belt Restraint System. Example 1 is a simulation for an unrestrained occupant. As an illustration that it is unnecessary to remove restraint system data from the data deck for such a simulation, belt system data cards are included in the complete data deck for Example 1 shown in Figure 109 . (These are Cards 218, 501 and 701 through 709). It is necessary only to set the belt system usage switch in field 1 of Card 102 to its "off" value, zero.

3.4.2.10 End of Data Deck for IN . The last card in the data deck for the Input Processor, IN , must be the 1000-Card. It is blank except for the card identification number in columns 77 through 80. (See Figure 109.)

1.	1.	.25	.125	.125	412
1.	2.	.5			412
1.	3.	.5			412
1.	4.	.4			412
2.	2.	.8			412
3.	1.	.4			412
3.	2.	.5			412
3.	4.	.4			412
3.	5.	.67			412
3.	6.	.9			412

/

FIGURE 106 Data Cards for Coefficients of Friction for Example 1

HEAD	ROOFHEADER	106
HEAD	WINDSHIELD	106
HEAD	INSTRUMENT PANEL	106
THORAX	SEAT BACK	106
THORAX	SEAT CUSHION	106
THORAX	INSTRUMENT PANEL	106
HIP	SEAT BACK	106
HIP	SEAT CUSHION	106
HIP	FLOOR	106
THIGH	SEAT CUSHION	106
KNEE	INSTRUMENT PANEL	106
KNEE	KNEE BAR	106
SHANK	INSTRUMENT PANEL	106
SHANK	KNEE BAR	106
HEEL	FLOOR	106
HEEL	DASH	106
TOE	DASH	106
HEEL	TOEPAN	106
TOE	TOEPAN	106
HAND	SEAT CUSHION	106
HAND	INSTRUMENT PANEL	106
THIGH	THORAX	106

FIGURE 107 Interaction "Inhibition" Cards for Example 1

3.4.2.11 Output Processor Controls. Cards 1001 through 1600 constitute a separate data deck from Cards 100 through 1000, described in the preceding sections and read by the Input Pre-Processor. Cards 1001 through 1600 are read by the Output Pre-Processor. These cards control post-processing and printout of data calculated and stored by the Dynamic Solution Processor (or "Execution Processor," GO). These data and data generated by the Input Processor are stored in four external files (see Module 12); as long as the files are maintained intact, they can be processed by the Output Processor any number of times, using different control Cards 1001 through 1600.

***** Output Categories for Printout. The entire Output Pre-Processor data deck for Example 1 consists of seven cards. These are shown in Figure 108 . The first two cards, 1001 and 1002, are used for specification of categories of calculated data for which printout is desired and the order of printout for these categories. The fifty categories of results which may be printed are identified by Category Number in Table 11. The ordering for printout shown for Example 1 in Figure 108 is identical to the default ordering which would result if the 1001- and 1002-Cards were omitted from the data deck.* All categories are requested for Example 1. Requests for printout for categories for which no data are stored will be ignored by the Output Processor.

***** HIC, Femur Loads, and Filtering. Various data explained in Module 12 are required on Cards 1003 and 1004 for the post-processor functions of filtering of occupant accelerations and determination of HIC and femur loads.

***** Potential Injury Indicators. In addition to HIC and femur loads, other potential injury indicators can be determined and printed by the Output Processor. These are also discussed in Module 12. They are requested by using Cards 1100 through 1401, none of which are included in the data deck for Example 1.

* The default ordering minus printout of the input data summary, Category 0, can be obtained by using a 1001-Card which contains only "-1" in columns one and two.

```
0,1,46-48,10-14,21,22,37,38,49,50,15,23-26,2-5,18-20,33-36,30-32,16,    1001
27-29,39,17,40,6-9,45                                                   1002
0.      0.      0.      11.55   .025                                    1003
40.     500.    560.    0.      .85     201.    5.      5.              1004
0.      0.      -3.     62.     5.      -44.    10.     0.              1500
21.     0.      0.      1.      1.      0.      1.      0.      10.     1501
                                                                        1600
```

FIGURE 108   Output Processor Data Deck for Example 1

***** Printer-Plot Stick Figures. As explained in Module 12, a time sequence of printer-plot pages can be produced which depict the occupant and all lines of the vehicle interior. A control for storing data required for production of this printout is on Card 101, read by the Input Pre-Processor and shown in Figure 99. Controls for producing the printout are read from Cards 1500 through 1502 by the Output Pre-Processor. The most important data on these cards are margin coordinates which frame the printer-plot image within the vehicle coordinate system and the simulation times to be included in the time sequence of printouts.

***** End of Data Deck for OUTP. As for the Input Pre-Processor data deck, a single card is required to mark the end of the Output Pre-Processor data deck. It is Card 1600, which is blank except for the card identification number.

3.4.3 Selected Output from Simulation Example 1

Selected pages of printout from the MVMA 2-D Crash Victim Simulator are shown as Figures 110 through 124. Figure 109 contains the data cards for Example 1 which generated the simulation results shown.

The MVMA 2-D model has undergone continuous development and improvement since its inception, and it is expected that it will continue to undergo change. Consequently, numerical results in Figures 110 through 124 should not be compared with results that MVMA 2-D users might obtain by using the data set for Example 1 for simulation with their own installations of the model. Rather, these figures are to be viewed as illustrative of the format of MVMA 2-D printout.*

3.4.3.1 Data Set Echo. Both the Input and Output Pre-Processors always produce "echoes" of their data decks. An example page from the Input Pre-Processor "echo" for Example 1 is shown as Figure 110. The eight-column data fields are separated by asterisks.

3.4.3.2 Summary of Input Data. Figure 111 is an example page of printout of a summary of the input data. The entire input data summary for Example 1 is 63 pages. This printout is produced whenever category 0 is requested on the 1001-Card.

*Results in Figures 114, 115, 116, 120, and 121 are not consistent with other results since they were taken from a different simulation.

3.4.3.3 Printer-Plot Stick Figure Sequence. The data decks for Example 1 cause printer-plot stick figure output to be generated for each 10 ms of simulation time. Selected "frames" of the time sequence are shown as Figure 112.

3.4.3.4 Printout of Numerical Results. Nine example pages of printout of numerical results are shown in Figures 113 through 124. The definition of most output variables is clear. However, aid is provided for the user in interpreting output in Section 3.3.

Only two special notes will be made here regarding output variables. First, femur and tibia loads (Figure 122) must be interpreted as for two legs combined. That is, values for one leg are obtained by dividing by two. Second, GMR Severity Indices are calculated for head and chest in addition to values for the standard Gadd Severity Index. The GMR index is defined in a section of Volume 3 entitled, "Special Indices." It differs from Gadd index in that its calculation involves raising acceleration values to powers which vary with acceleration level rather than the constant power 2.5.

```
                          MVMA 2-D TUTORIAL EXAMPLE #1                                          100
  KNEE BAR                                                                                      400
OCC. COMP. DISPL.                                                                               500
30MPH FRONT BARRIER                                                                             600
     NO BELTS                                                                                   700
1.         1.         32.174     0.         0.         200.       1.         5.         10.     101
0.         0.         0.         0.         0.         0.         10.        .000001    5.      102
.2         .05        100000.    15000.     10.        .05        10.        1.         1.      103
0.         44.        0.         0.         0.         0.         0.         0.                 501
23.        1.         1.                                                                        602
0.         -1.7       1.         -1.4       7.         -33.9      12.        2.8
13.5       3.9        18.        -21.2      21.5       -12.4      28.        -9.2
32.        -24.0      33.        -24.0      36.        -9.9       37.        -9.9
42.        -26.9      47.        -31.8      50.        -25.9      54.        -27.2
58.        -32.2      61.        -29.0      76.        -6.9       90.        -1.4
100.       -1.4       120.       0.         300.       0.
2.         1.         1.                                                                        603
0.         0.         300.       0.
2.         1.                                                                               604
0.         0.         300.       0.
GM HYBRID II DUMMY                                                                              200
(PRELIMINARY DATA)                                                                              300
1.1        13.44      3.4        5.         15.8                  10.3       3.25       -.88    201
2.75       7.         1.7        4.2        8.2        9.3        5.         5.8        .5      202
.0259      .0951      .0052      .0992      .0932      .0518      .022       .0256      .007    203
.198       1.97       .04        1.53       1.38       2.82       .18        .62                204
12.8       .58        0.         .52        17.4       1.                    -25.       .35     205
12.9       .58        0.         .52        17.4       1.                    -22.       .35     206
72.        15.        0.         .66        1000.      1.         -8.        -25.5      .35     207
102.5      -7.624     .1944      .66        1000.      1.         -33.999    -34.001    .35     208
84.44      -4.810     .1053      0.         850.       1.         -49.999    -50.001    .5      209
0.         29.8       0.         0.         204.       1.         135.       0.         .5      210
0.         10.        0.         0.         222.       1.         28.        -197.      .5      211
0.         10.        0.         0.         64.        1.         0.         -165.      .5      212
751.       0.         757.       1.98                                                           213
20.        230.       0.         0.                               2.                    .5      214
38.        .58        0.         .52        0.         1.         -1.                   .16     215
38.        .58        0.         .52        0.         1.         2.                    .16     216
751.       0.         757.       1.98                                                           242
HEAD                                        1.         3.                                       219
THORAX                CHESTMATL             2.         1.                                       219
HIP                   HIPMATL               4.         1.                                       219
THIGH                                       5.         1.                                       219
KNEE                                        5.         1.                                       219
SHANK                                       6.         1.                                       219
HEEL                                        6.         2.                                       219
TOE                                         6.         2.                                       219
ELBOW                                       7.         1.                                       219
HAND                                        8.         3.                                       219
HEAD                  0.         .5         4.         4.                                       220
THORAX                -.5        -.68       5.52       4.44                                     220
HIP                   -.12       0.         4.5        4.5                                      220
THIGH                 -.5        -.1        7.         3.                                       220
KNEE                  7.         -.4        2.25       2.25                                     220
SHANK                 -7.54      0.         3.         2.4                                      220
HEEL                  8.57       0.         1.2        1.2                                      220
TOE                   5.61       -5.16      1.2        1.2                                      220
ELBOW                 5.3        0.         1.5        1.5                                      220
HAND                  5.6        -.4        2.72       1.52                                     220
CHESTMATL             0.         0.         0.         100.       101.       0.         0.      221
```

FIGURE 109   Complete Data Set for Simulation Example 1 (page 1 of 6)

CHESTMATL		5.				CSTAT	IZERO	CGR	222
CGR	-1.	.1							223
CGR	0.	1.							224
CGR	.01	.64							224
CGR	.3	.5							224
CGR	1.35	.45							224
CSTAT	0.	0.							225
CSTAT	.01	1125.							225
CSTAT	.05	1460.							225
CSTAT	.3	1350.							225
CSTAT	.4	1260.							225
CSTAT	1.1	1260.							225
CSTAT	4.25	12600.							225
IZERO	-1.	0.							226
HIPMATL		0.	0.	0.	100.	101.	0.	0.	221
HIPMATL		5.				CSTAT	IZERO	CGR	222
-11.	-8.	-18.	-34.	-50.	0.	0.	0.		217
78.5	97.5	115.5	149.5	19.5	-45.	-41.	3.	89.5	301
0.	0.	0.	0.	0.	0.	0.	0.	0.	302
12.2	0.	-21.4	0.	3.28	0.				303
0.	0.	0.	0.						304
SEAT BACK		SEAT MATERIAL		0.	1.	1.	1.		401
SEAT BACK		1.	1.	1.	0.	0.			402
SEAT MATERIAL		0.	0.	1.6	3.5	4.	0.	0.	403
SEAT MATERIAL		5.				SSEAT	IZERO	GRSEAT	404
GRSEAT	-1.	.1							405
GRSEAT	-1.	.5							406
SSEAT	0.	0.							407
SSEAT	.8	150.							407
SSEAT	1.6	400.							407
SSEAT	3.	2000.							407
SSEAT	3.5	4000.							407
SSEAT	4.	0.							407
BACK LINE		SEAT BACK		5.	0.	-1.	1.		409
BACK LINE		1.							410
BACK LINE		-1.	6.2	-25.8	15.44	-4.96			411
SEAT CUSHION		SEAT MATERIAL		0.	1.	1.	1.		401
SEAT CUSHION		2.	1.	1.	0.	0.			402
CUSHION LINE 1		SEAT CUSHION		5.	.164	1.	1.		409
CUSHION LINE 1		1.							410
CUSHION LINE 1		-1.	15.44	-4.96	28.	-9.92			411
CUSHION LINE 2		SEAT CUSHION		5.	.5	-1.	2.		409
CUSHION LINE 2		1.							410
CUSHION LINE 2		-1.	28.	-9.92	32.24	-10.64			411
FLOOR		FMATL		0.	1.	1.	1.		401
FLOOR		2.	2.	1.	0.	0.			402
SEAT BOTTOM		FLOOR		5.	0.	-1.	1.		409
SEAT BOTTOM		1.							410
SEAT BOTTOM		-1.	31.2	-8.	31.2	-.84			411
FLOORBOARD		FLOOR		5.	0.	-1.	2.		409
FLOORBOARD		1.							410
FLOORBOARD		-1.	31.2	-.84	49.	-.84			411
TOEPAN		FMATL		0.	1.	1.	1.		401
TOEPAN		1.	2.	1.	0.	0.			402
TOEBOARD		TOEPAN		5.	0.	1.	1.		409
TOEBOARD		4.							410
TOEBOARD		0.	47.3	1.1	54.7	-5.6			411
TOEBOARD		40.	47.3	1.1	54.7	-5.6			411
TOEBOARD		80.	47.3	1.1	47.9	-5.6			411
TOEBOARD		300.	47.3	1.1	47.9	-5.6			411

FIGURE 109 Complete Data Set for Simulation Example 1 (page 2 of 6)

KNEE BAR	SHEET METAL		0.	1.	1.	1.		401
KNEE BAR	1.	3.	1.	0.	0.			402
SHEET METAL	0.	0.	.5	8.	9.	10000.	10000.	403
SHEET METAL	5.				SSHEET	IZERO	GRSHEET	404
GRSHEET 0.	0.							405
GRSHEET 0.5	0.							405
GRSHEET 5.5	0.9							405
GRSHEET 0.	1.							406
GRSHEET .5	1.							406
GRSHEET 2.	.7							406
GRSHEET 4.	.2							406
GRSHEET 5.5	.15							406
GRSHEET 8.	.1							406
GRSHEET 9.	.01							406
SSHEET 0.	0.							407
SSHEET 2.	1500.							407
SSHEET 4.	1500.							407
SSHEET 5.5	10000.							407
SSHEET 8.	10000.							407
SSHEET 9.	0.							407
KNEEBAR LINE	KNEE BAR		5.	0.5	1.	1.		409
KNEEBAR LINE	4.							410
KNEEBAR LINE	0.	40.4	-13.2	38.9	-16.4			411
KNEEBAR LINE	60.	40.4	-13.2	38.9	-16.4			411
KNEEBAR LINE	80.	38.9	-13.2	37.4	-16.4			411
KNEEBAR LINE	300.	38.9	-13.2	37.4	-16.4			411
ROOFHEADER	RMATL		0.	1.	1.	1.		401
ROOFHEADER	1.	6.	1.	0.	0.			402
LR	ROOFHEADER		5.	0.	1.	1.		409
LR	1.							410
LR	-1.	18.2	-43.4	28.0	-41.7			411
WINDSHIELD	WINDSHIELD GLASS		0.	1.	1.	1.		401
WINDSHIELD	1.	5.	1.	0.	0.			402
LW	WINDSHIELD		5.	0.	1.	1.		409
LW	1.							410
LW	-1.	27.8	-41.3	51.6	-26.3			411
INSTRUMENT PANEL	IPMAT		0.	1.	1.	1.		401
INSTRUMENT PANEL	2.	4.	1.	0.	0.			402
MID IP	INSTRUMENT PANEL		5.	0.	1.	1.		409
MID IP	4.							410
MID IP	0.	44.9	-27.3	43.7	-15.9			411
MID IP	40.	44.9	-27.3	43.7	-15.9			411
MID IP	80.	45.6	-29.3	40.6	-18.9			411
MID IP	300.	45.6	-29.3	40.6	-18.9			411
LOWER IP	INSTRUMENT PANEL		5.	.5	1.	2.		409
LOWER IP	4.							410
LOWER IP	0.	43.7	-15.9	46.8	-12.8			411
LOWER IP	40.	43.7	-15.9	46.8	-12.8			411
LOWER IP	80.	40.6	-18.9	42.6	-14.9			411
LOWER IP	300.	40.6	-18.9	42.6	-14.9			411
DASH	DASHMATL		0.	1.	1.	1.		401
DASH	1.	2.	1.	0.	0.			402
DASHLINE	DASH		5.	0.	1.	1.		409
DASHLINE	4.							410
DASHLINE	0.	54.7	-5.6	54.2	-20.1			411
DASHLINE	40.	54.7	-5.6	54.2	-20.1			411
DASHLINE	80.	47.9	-5.6	47.4	-20.1			411
DASHLINE	300.	47.9	-5.6	47.4	-20.1			411
DASHMATL	0.	0.	0.	100.	101.	0.	0.	403
DASHMATL	5.				DSTAT	IZERO	DGR	404

FIGURE 109 Complete Data Set for Simulation Example 1 (page 3 of 6)

```
DGR      0.       0.                                                            405
DGR      .001     .01                                                           405
DGR      10.      .01                                                           405
DGR      0.       1.                                                            406
DGR      .001     .91                                                           406
DGR      .75      .8                                                            406
DGR      1.5      .5                                                            406
DGR      10.      .3                                                            406
DSTAT    0.       0.                                                            407
DSTAT    0.75     2100.                                                         407
DSTAT    1.5      9000.                                                         407
DSTAT    40.      9000.                                                         407
RMATL             0.       0.       0.       100.     101.     0.       0.      403
RMATL             5.       0.       0.       0.       RSTAT    IZERO    DGR     404
RSTAT    -1.      1200.    -65.36   67.38    -29.36   4.78                      407
WINDSHIELD GLASS.5         1.       0.       100.     101.     0.       0.      403
WINDSHIELD GLASS5.         0.       0.       0.       WSTAT    WI       WGR     404
WGR      0.       0.                                                            405
WGR      .5       0.                                                            405
WGR      .51      .65                                                           405
WGR      1.       .75                                                           405
WGR      6.       .8                                                            405
WGR      0.       1.                                                            406
WGR      .5       1.                                                            406
WGR      .51      .1                                                            406
WGR      1.       .05                                                           406
WGR      6.       .01                                                           406
WSTAT    -1.      108.8    50.0     -10.9    1.                                 407
WI       -1.      3000.    1000.    -8000.   4000.                              408
IPMAT             0.       0.       0.       100.     101.     0.       0.      403
IPMAT             5.       0.       0.       0.       IPSTAT   IZERO    IPGR    404
IPGR     0.       0.                                                            405
IPGR     2.       .75                                                           405
IPGR     40.      .75                                                           405
IPGR     0.       1.                                                            406
IPGR     1.       .25                                                           406
IPGR     2.       .1                                                            406
IPGR     8.       .1                                                            406
IPGR     8.4      .15                                                           406
IPSTAT   0.       0.                                                            407
IPSTAT   .165     80.                                                           407
IPSTAT   .375     480.                                                          407
IPSTAT   .665     750.                                                          407
IPSTAT   .780     760.                                                          407
IPSTAT   1.25     500.                                                          407
IPSTAT   1.75     580.                                                          407
IPSTAT   2.54     225.                                                          407
IPSTAT   2.87     255.                                                          407
IPSTAT   3.64     300.                                                          407
IPSTAT   4.54     380.                                                          407
IPSTAT   4.63     250.                                                          407
IPSTAT   8.       250.                                                          407
IPSTAT   12.      3850.                                                         407
FMATL             0.       0.       0.       100.     101.     0.       0.      403
FMATL             5.       0.       0.       0.       FSTAT    IZERO    FGR     404
FGR      0.       0.                                                            405
FGR      2.       .7                                                            405
FGR      0.       1.                                                            406
FGR      2.       .2                                                            406
FSTAT    0.       0.                                                            407
```

FIGURE 109   Complete Data Set for Simulation Example 1 (page 4 of 6)

```
FSTAT     .25      100.                                                                      407
FSTAT     .5       400.                                                                      407
FSTAT     .75      1200.                                                                     407
FSTAT     1.       2400.                                                                     407
FSTAT     1.5      4000.                                                                     407
FSTAT     2.       4600.                                                                     407
FSTAT     3.       5000.                                                                     407
FSTAT     4.       5200.                                                                     407
FSTAT     6.       5400.                                                                     407
FSTAT     10.      5600.                                                                     407
FSTAT     16.      10000.                                                                    407
1.        1.       .25       .125      .125                                                  412
1.        2.       .5                                                                        412
1.        3.       .5                                                                        412
1.        4.       .4                                                                        412
2.        2.       .8                                                                        412
3.        1.       .4                                                                        412
3.        2.       .5                                                                        412
3.        4.       .4                                                                        412
3.        5.       .67                                                                       412
3.        6.       .9                                                                        412
HEAD               ROOFHEADER                                                                106
HEAD               WINDSHIELD                                                                106
HEAD               INSTRUMENT PANEL                                                          106
THORAX             SEAT BACK                                                                 106
THORAX             SEAT CUSHION                                                              106
THORAX             INSTRUMENT PANEL                                                          106
HIP                SEAT BACK                                                                 106
HIP                SEAT CUSHION                                                              106
HIP                FLOOR                                                                     106
THIGH              SEAT CUSHION                                                              106
KNEE               INSTRUMENT PANEL                                                          106
KNEE               KNEE BAR                                                                  106
SHANK              INSTRUMENT PANEL                                                          106
SHANK              KNEE BAR                                                                  106
HEEL               FLOOR                                                                     106
HEEL               DASH                                                                      106
TOE                DASH                                                                      106
HEEL               TOEPAN                                                                    106
TOE                TOEPAN                                                                    106
HAND               SEAT CUSHION                                                              106
HAND               INSTRUMENT PANEL                                                          106
THIGH              THORAX                                                                    106
2.75      7.       0.        0.        0.        1.8       -1.96     14.12     -5.07         218
0.        0.       0.        0.        0.        -33.52    17.       -1.2                    501
100.      0.       15.13     -.00178   6600.     6600.     10.                               701
NO STRENGTH                            14.04     -.00172   2.        1.                      702
6% WEBBING #1                          6% WEBBING #2                                         703
6% WEBBING #1      0.        0.        0.16      14.36     15.04     0.        0.            704
6% WEBBING #1      5.                                      SBELT1    IZERO     GBELT1        705
GBELT1    0.       0.                                                                        706
GBELT1    .16      0.                                                                        706
GBELT1    1.37     .56                                                                       706
GBELT1    6.15     .95                                                                       706
GBELT1    40.      .95                                                                       706
GBELT1    0.       1.                                                                        707
GBELT1    1.37     .33                                                                       707
GBELT1    2.06     .19                                                                       707
GBELT1    6.15     .05                                                                       707
GBELT1    40.      .05                                                                       707
```

FIGURE 109   Complete Data Set for Simulation Example 1 (page 5 of 6)

```
SBELT1   0.       0.                                                                      708
SBELT1   .533     1500.                                                                   708
SBELT1   9.91     2000.                                                                   708
SBELT1   11.28    5300.                                                                   708
SBELT1   14.36    6600.                                                                   708
SBELT1   15.04    0.                                                                      708
6% WEBBING #2     0.       0.       .155     13.85    14.51    0.       0.                704
6% WEBBING #2     5.                                  SBELT2   IZERO    GBELT1            705
SBELT2   0.       0.                                                                      708
SBELT2   .396     1150.                                                                   708
SBELT2   9.56     1650.                                                                   708
SBELT2   10.9     5300.                                                                   708
SBELT2   13.85    6600.                                                                   708
SBELT2   14.51    0.                                                                      708
NO STRENGTH       0.       0.       0.       10.      11.      0.       0.                704
NO STRENGTH       5.                                  SNOSTR   IZERO    GNOSTR            705
GNOSTR   -1.      0.                                                                      706
GNOSTR   -1.      1.                                                                      707
SNOSTR   -1.      0.                                                                      708
                                                                                          1000
0,1,46-48,10-14,21, 22,37,38,49,50,15,23-26, 2-5,18-20,33-36,30-32,16,                    1001
27-29,39,17,40,6-9, 45                                                                    1002
0.       0.       0.       11.55    .025                                                  1003
40.      500.     560.     0.       .85      201.     5.       5.                         1004
0.       0.       -3.      62.      5.       -44.     10.      0.                         1500
21.      0.       0.       1.       1.       0.       1.       0.       10.               1501
                                                                                          1600
```

FIGURE 109   Complete Data Set for Simulation Example 1 (page 6 of 6)

```
100 *         *         *    MVM*A 2-D TU*TORIAL E*XAMPLE #*1       *         *         *
400 *    KNEE *BAR      *         *         *         *         *         *         *
500 *OCC. COM*P. DISPL*.          *         *         *         *         *         *
600 *30MPH FR*ONT BARR*IER        *         *         *         *         *         *
700 *     NO B*ELTS     *         *         *         *         *         *         *
101 *1.       *1.       *32.174   *0.       *0.       *200.     *1.       *5.       *10.      *
102 *0.       *0.       *0.       *0.       *0.       *0.       *10.      *.000001  *5.       *
103 *.2       *.05      *100000.  *15000.   *10.      *.05      *10.      *1.       *1.       *
601 *0.       *44.      *0.       *0.       *0.       *0.       *0.       *0.       *         *
602 *23.      *1.       *1.       *         *         *         *         *         *         *
    *     0.0 *   -1.70*    1.00*    -1.40*     7.00*   -33.90*    12.00*     2.80*      0.0 *
    *   13.50*     3.90*   18.00*   -21.20*    21.50*   -12.40*    28.00*    -9.20*      0.0 *
    *   32.00*   -24.00*   33.00*   -24.00*    36.00*    -9.90*    37.00*    -9.90*      0.0 *
    *   42.00*   -26.90*   47.00*   -31.80*    50.00*   -25.90*    54.00*   -27.20*      0.0 *
    *   58.00*   -32.20*   61.00*   -29.00*    76.00*    -6.90*    90.00*    -1.40*      0.0 *
    *  100.00*    -1.40*  120.00*      0.0 *   300.00*      0.0 *      0.0 *      0.0 *      0.0 *
603 *2.       *1.       *1.       *         *         *         *         *         *         *
    *     0.0 *     0.0 *  300.00*      0.0 *      0.0 *      0.0 *      0.0 *      0.0 *      0.0 *
604 *2.       *1.       *         *         *         *         *         *         *         *
    *     0.0 *     0.0 *  300.00*      0.0 *      0.0 *      0.0 *      0.0 *      0.0 *      0.0 *
200 *GM HYBRI*D II DUM*MY         *         *         *         *         *         *         *
300 *(PRELIMI*NARY DAT*A)         *         *         *         *         *         *         *
201 *1.1      *13.44    *3.4      *5.       *15.8     *         *10.3     *3.25     *-.88     *
202 *2.75     *7.       *1.7      *4.2      *8.2      *9.3      *5.       *5.8      *.5       *
203 *.0259    *.0951    *.0052    *.0982    *.0932    *.0518    *.022     *.0256    *.007     *
204 *.198     *1.97     *.04      *1.53     *1.38     *2.82     *.18      *.62      *         *
205 *12.8     *.58      *0.       *.52      *17.4     *1.       *         *-25.     *.35      *
206 *12.8     *.58      *0.       *.52      *17.4     *1.       *         *-22.     *.35      *
207 *72.      *15.      *0.       *.66      *1000.    *1.       *-8.      *-25.5    *.35      *
208 *102.5    *-7.624   *.1944    *.66      *1000.    *1.       *-33.999  *-34.001  *.35      *
209 *94.44    *-4.810   *.1053    *0.       *850.     *1.       *-49.999  *-50.001  *.5       *
210 *0.       *29.8     *0.       *0.       *204.     *1.       *135.     *0.       *.5       *
211 *0.       *10.      *0.       *0.       *222.     *1.       *28.      *-197.    *.5       *
212 *0.       *10.      *0.       *0.       *64.      *1.       *0.       *-165.    *.5       *
213 *751.     *0.       *757.     *1.98     *         *         *         *         *         *
214 *20.      *230.     *0.       *0.       *         *         *2.       *         *.5       *
215 *38.      *.58      *0.       *.52      *0.       *1.       *-1.      *         *.16      *
216 *38.      *.58      *0.       *.52      *0.       *1.       *2.       *         *.16      *
242 *751.     *0.       *757.     *1.98     *         *         *         *         *         *
219 *HEAD     *         *         *         *1.       *3.       *         *         *         *
219 *THORAX   *         *CHESTMAT*L         *2.       *1.       *         *         *         *
219 *HIP      *         *HIPMATL  *         *4.       *1.       *         *         *         *
219 *THIGH    *         *         *         *5.       *1.       *         *         *         *
219 *KNEE     *         *         *         *5.       *1.       *         *         *         *
219 *SHANK    *         *         *         *6.       *1.       *         *         *         *
219 *HEEL     *         *         *         *6.       *2.       *         *         *         *
219 *TOE      *         *         *         *6.       *2.       *         *         *         *
219 *ELBOW    *         *         *         *7.       *1.       *         *         *         *
219 *HAND     *         *         *         *8.       *3.       *         *         *         *
220 *HEAD     *         *0.       *.5       *4.       *4.       *         *         *         *
220 *THORAX   *         *-.5      *-.68     *5.52     *4.44     *         *         *         *
220 *HIP      *         *-.12     *0.       *4.5      *4.5      *         *         *         *
220 *THIGH    *         *-.5      *-.1      *7.       *3.       *         *         *         *
220 *KNEE     *         *7.       *-.4      *2.25     *2.25     *         *         *         *
220 *SHANK    *         *-7.54    *0.       *3.       *2.4      *         *         *         *
220 *HEEL     *         *8.57     *0.       *1.2      *1.2      *         *         *         *
220 *TOE      *         *5.61     *-5.16    *1.2      *1.2      *         *         *         *
220 *ELBOW    *         *5.3      *0.       *1.5      *1.5      *         *         *         *
220 *HAND     *         *5.6      *-.4      *2.72     *1.52     *         *         *         *
```

FIGURE 110 Input Processor Data Deck Echo for Example 1 (example page)

JUN 24, 1977 02:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 3-00

GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

BODY PARAMETERS

BODY SEGMENT LENGTHS (IN)	
HEAD LENGTH=	1.10
UPPER TORSO LENGTH=	13.44
MIDDLE TORSO LENGTH=	3.40
LOWER TORSO LENGTH=	5.00
HIP-KNEE LENGTH=	15.80
UPPER TORSO-SHOULDER=	0.0
SHOULDER-ELBOW LENGTH=	10.30
X REST POINT OF SHOULDER=	3.25
Z REST POINT OF SHOULDER=	-0.88

END OF LINK TO CENTER-OF-MASS LENGTHS (IN)	
HEAD/NECK JOINT-HEAD CM LENGTH=	2.75
NECK-CHEST CM LENGTHS=	7.00
UPPER TORSO JOINT-MIDDLE TORSO CM LENGTH=	1.70
LOWER TORSO JOINT LOWER TORSO CM LENGTH=	4.20
HIP-UPPER LEG CM LENGTH=	8.20
KNEE-LOWER LEG CM LENGTH=	9.30
SHOULDER-UPPER ARM CM LENGTH=	5.00
ELBOW-LOWER ARM CM LENGTH=	5.80

MASS OF BODY SEGMENTS (LBS SEC**2 IN)	
HEAD MASS=	0.03
CHEST MASS=	0.10
MIDDLE TORSO MASS=	0.01
LOWER TORSO MASS=	0.10
UPPER LEG (BOTH LEGS)=	0.09
LOWER LEG (BOTH LEGS)=	0.05
UPPER ARM (BOTH ARMS)=	0.02
LOWER ARM (BOTH ARMS)=	0.03
HEAD-NECK MASS=	0.00
UPPER TORSO-NECK MASS=	0.00

	MOMENTS OF INERTIA (ABOUT CM) (LBS SEC**2 IN)	"NATURAL" LINK ANGLES (FOR ZERO TORQUE) (DEG)	INITIAL BODY LINK ANGLES (RELATIVE TO VEHICLE) (DEG)	INITIAL ANGULAR VELOCITIES (RELATIVE TO VEHICLE) (DEG/SEC)
HEAD	0.20	-11.00	78.50	0.0
UPPER TORSO	1.97	-8.00	97.50	0.0
MIDDLE TORSO	0.04	-18.00	115.50	0.0
LOWER TORSO	1.53	-34.00	149.50	0.0
UPPER LEG	1.38	-50.00	19.50	0.0
LOWER LEG	2.82	0.0	-45.00	0.0
UPPER ARM	0.18	0.0	-41.00	0.0
LOWER ARM	0.62	0.0	3.00	0.0
NECK	0.0		89.50	0.0

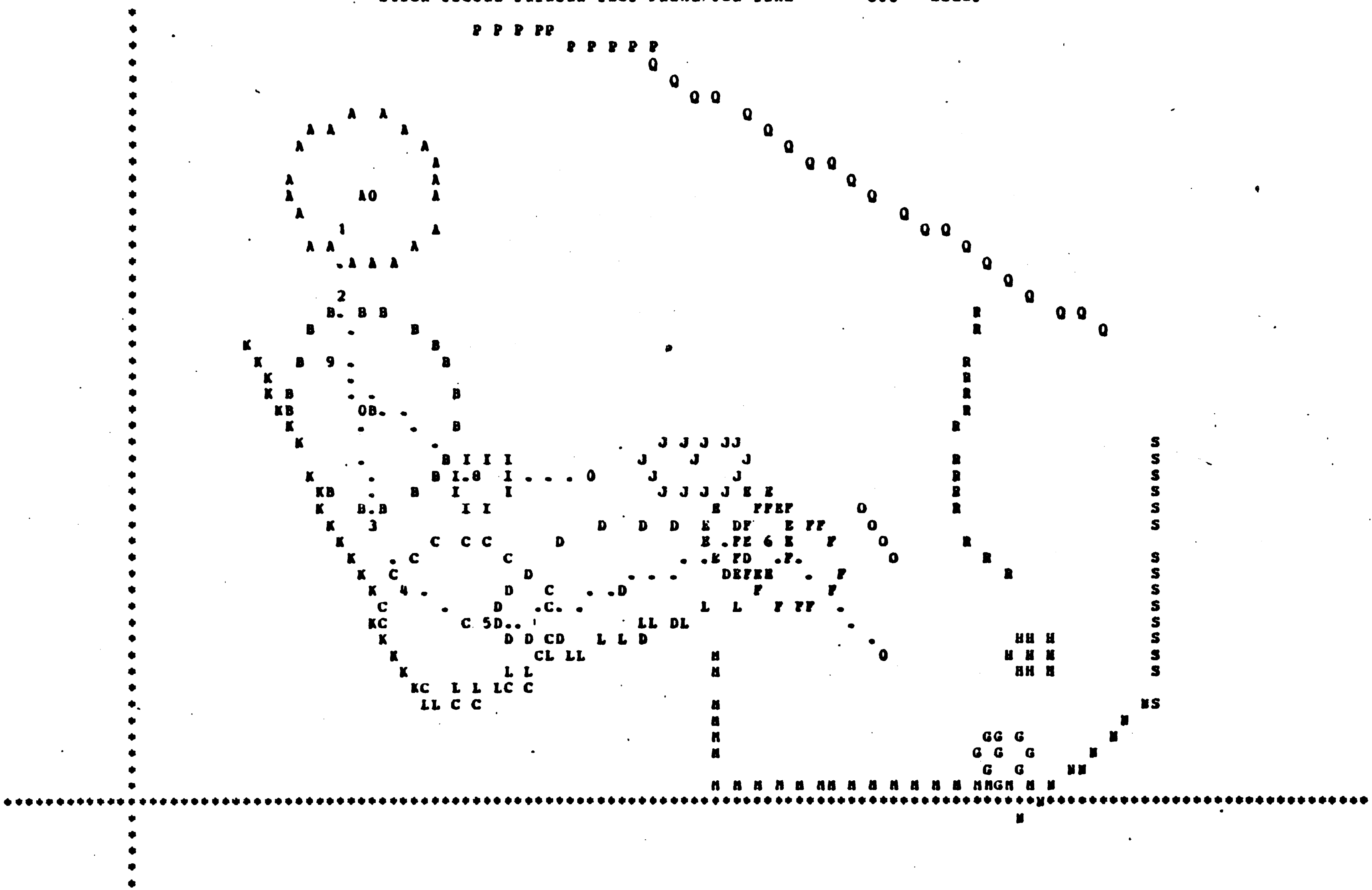
OCCUPANT JOINT PARAMETERS

	LINEAR ANGULAR DEFLECTION COEF. (IN-LBS/DEG)	QUADRATIC ANGULAR DEFLECTION COEF. (IN-LBS/DEG**2)	CUBIC ANGULAR DEFLECTION COEF. (IN-LBS/DEG**3)	CONSERVED-ABSORBED ENERGY RATIO
HEAD-NECK FOWARD	12.80	0.58	0.0	0.35
NECK-UPPER TORSO FORWARD	12.80	0.58	0.0	0.35
UPPER SPINE	72.00	15.00	0.0	0.35
LOWER SPINE	102.50	-7.62	0.19	0.35
HIP	84.44	-4.81	0.11	0.50
KNEE	0.0	29.80	0.0	0.50
UPPER ARM-UPPER TORSO	0.0	10.00	0.0	0.50
ELBOW	0.0	10.00	0.0	0.50
HEAD-NECK REAR	38.00	0.58	0.0	0.16
NECK-UPPER TORSO REAR	38.00	0.58	0.0	0.1C
NECK (EXTENSIBLE) **	751.00	0.0	757.00	NA
SHOULDER (EXTENSIBLE)**	20.00	230.00	0.0	0.50
NECK (COMPRESSIBLE) **	751.00	0.0	757.00	NA
** UNITS FOR THE NECK (EXTENSIBLE),(COMPRESSIBLE) AND SHOULDER (EXTENSIBLE) PARAMETERS ARE GIVEN IN THE ROW BELOW	(LB/IN)	(LB/IN**2)	(LB/IN**3)	

FIGURE 111 Summary of Input Data (example page)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 130-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 0.0 MSEC.

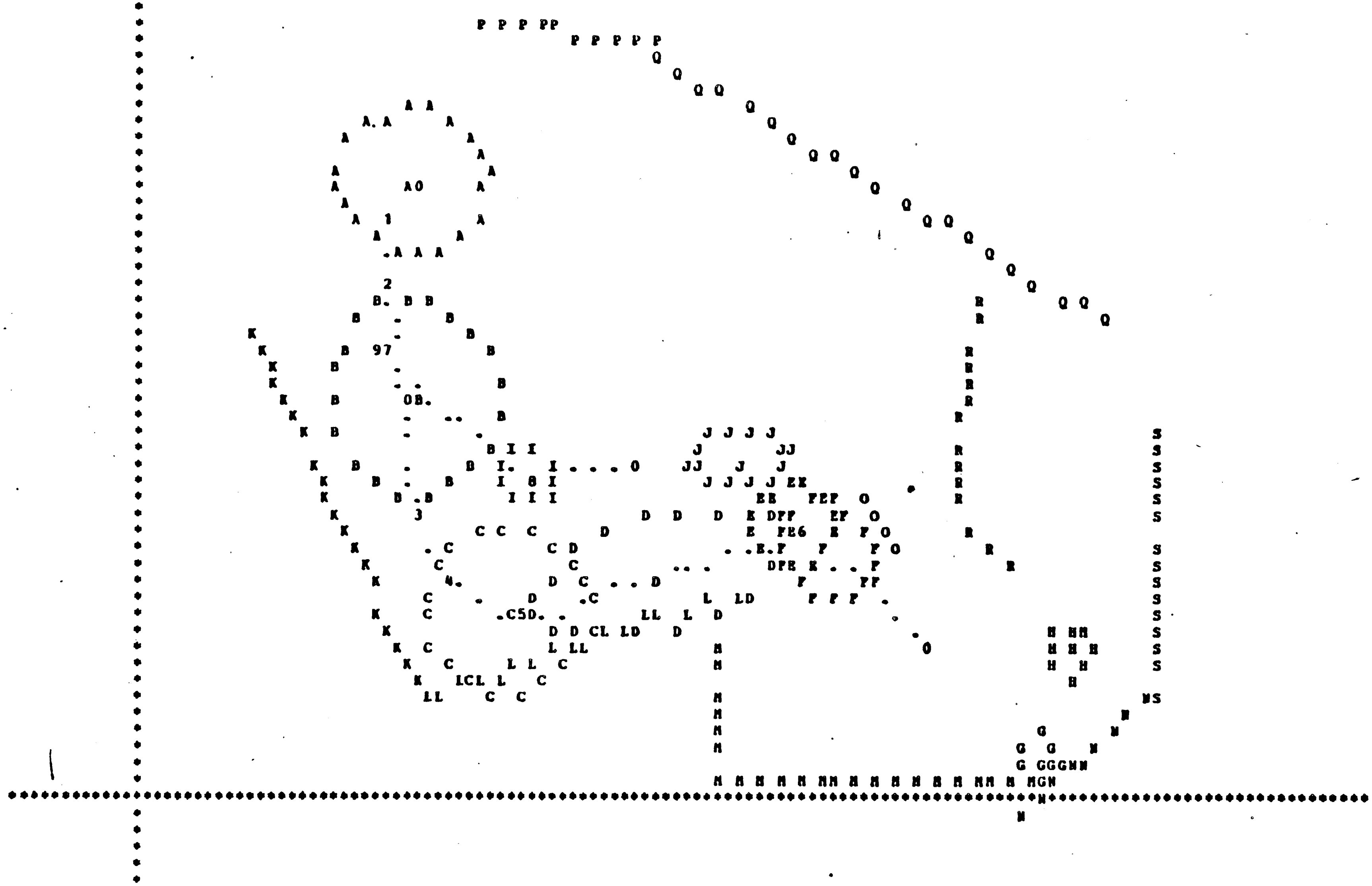


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112a Printer-Plot Time Sequence for Example 1 (0 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 133-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 30.00 MSEC.

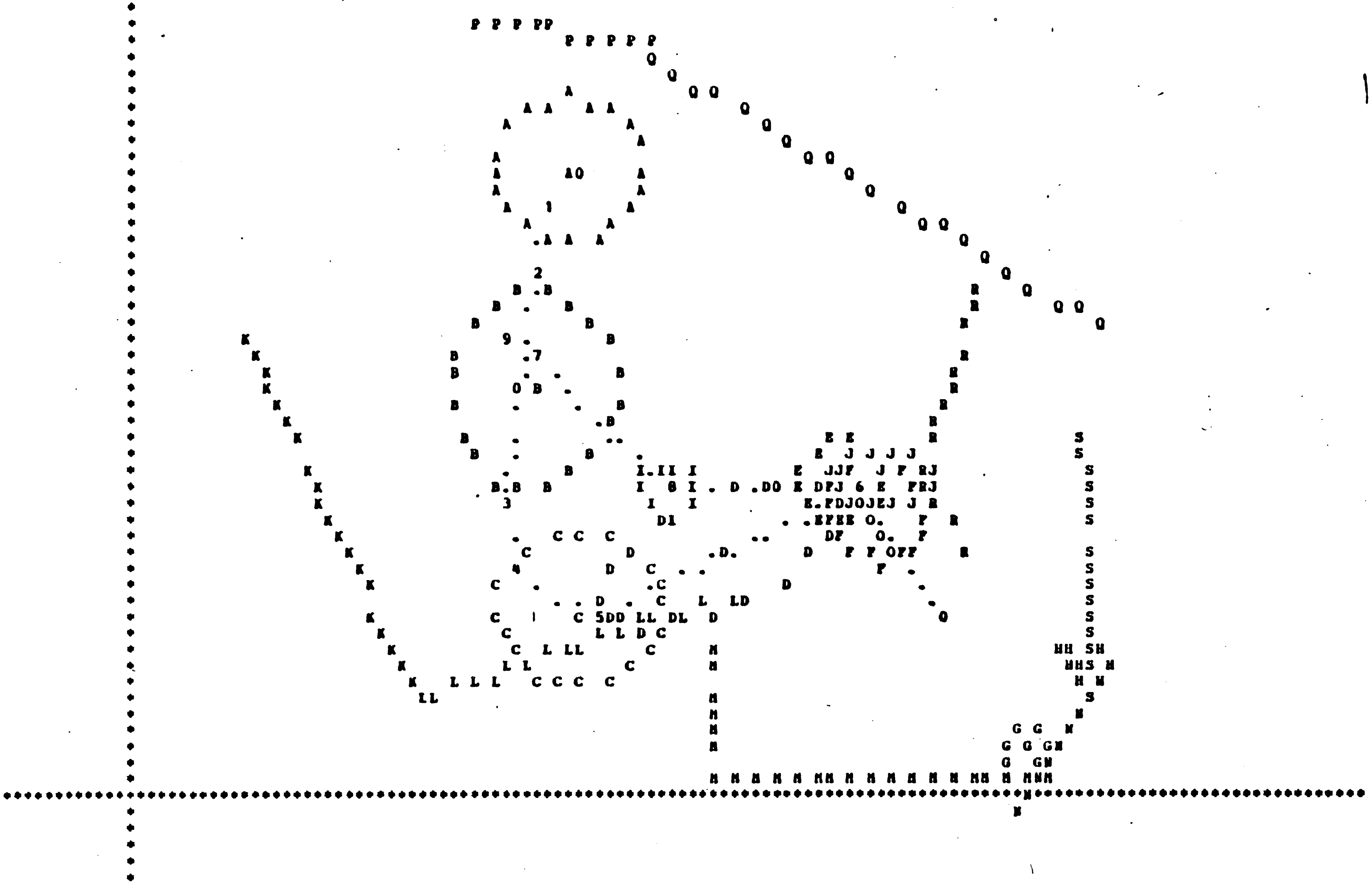


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112b Printer-Plot Time Sequence for Example 1 (30 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 136-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 60.00 MSEC.



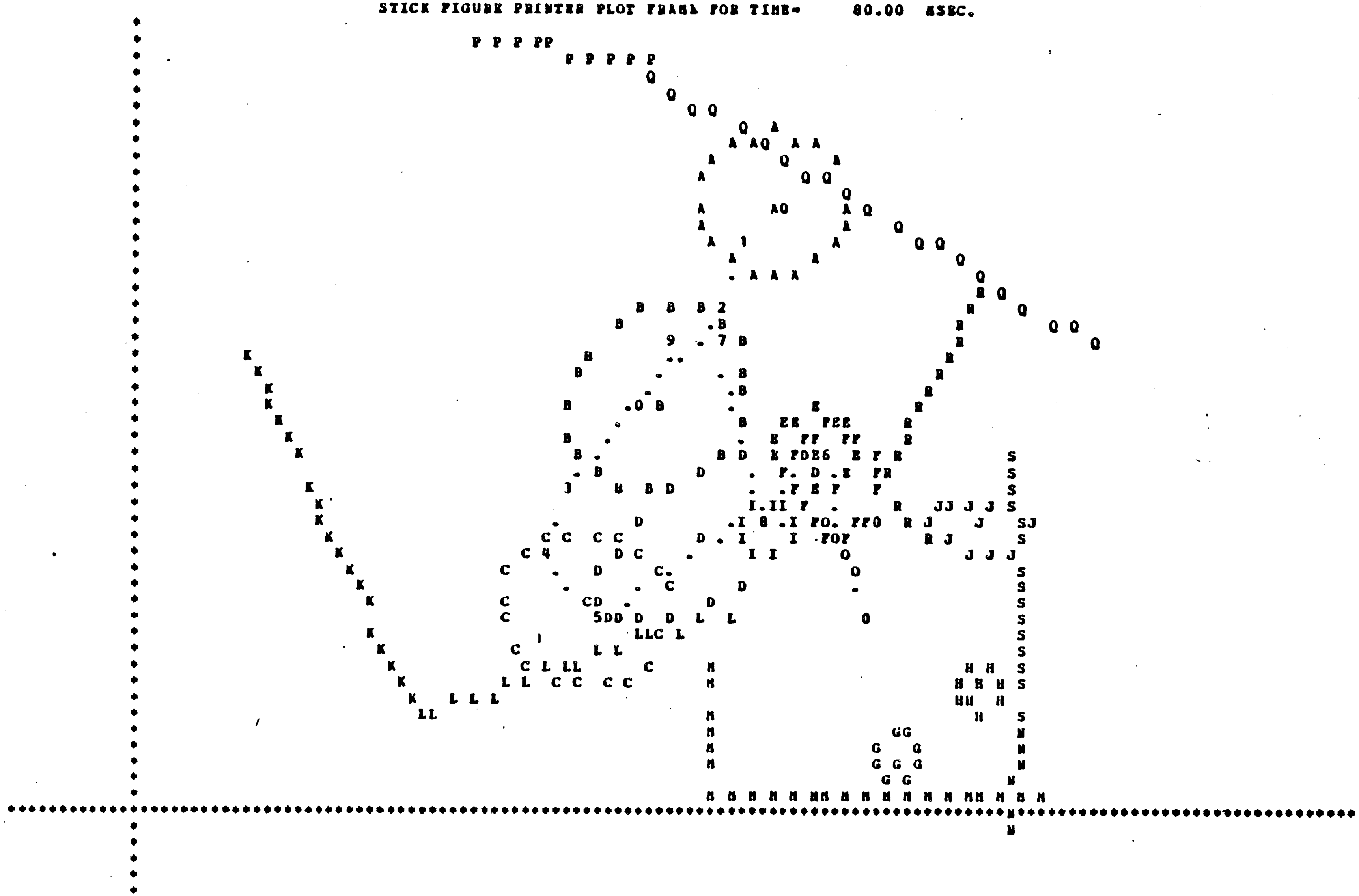
COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (1N) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112c Printer-Plot Time Sequence for Example 1 (60 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 138-45

GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE RAM OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 80.00 MSEC.

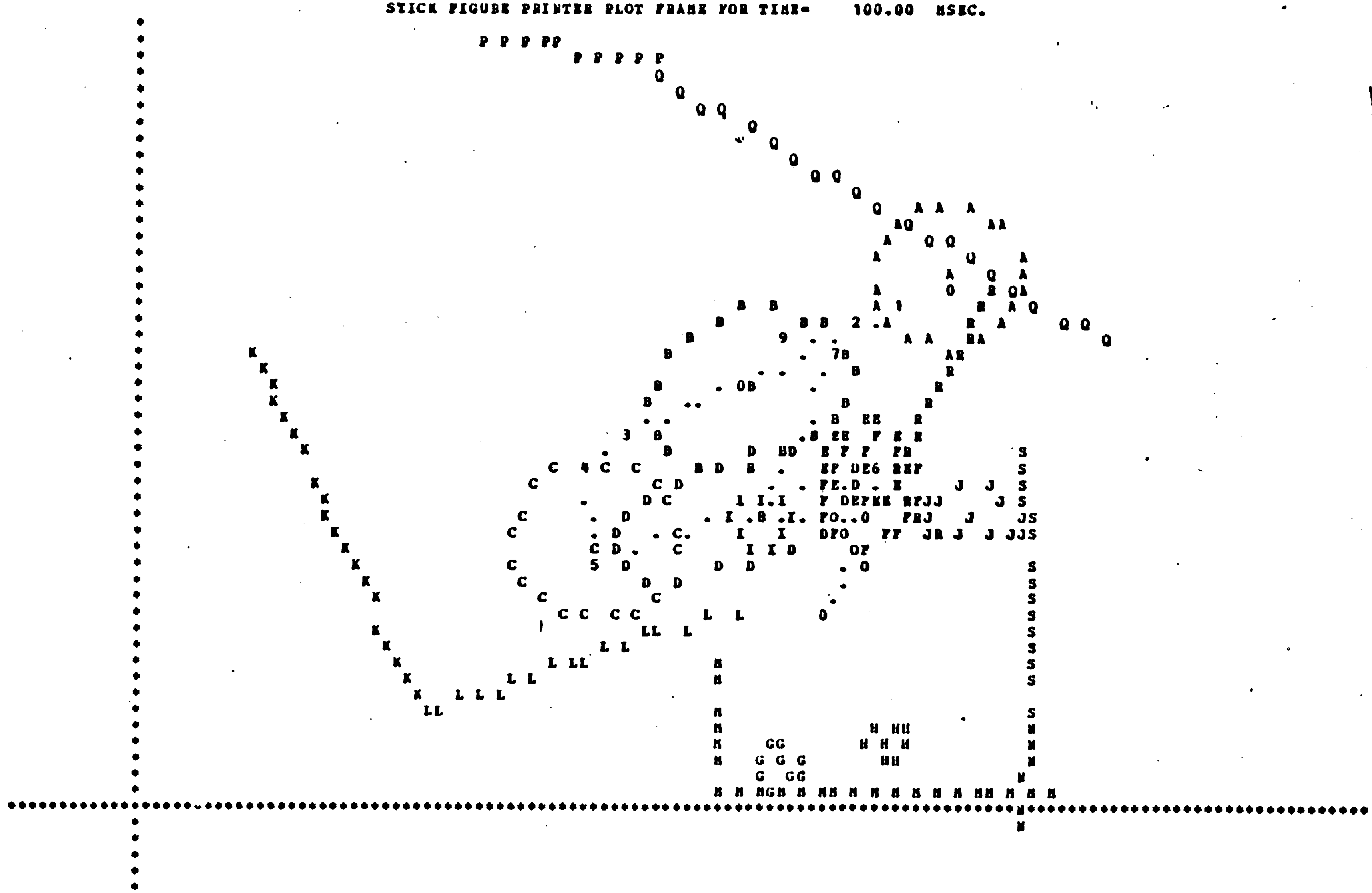


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112d Printer-Plot Time Sequence for Example 1 (80 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 140-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 100.00 MSEC.

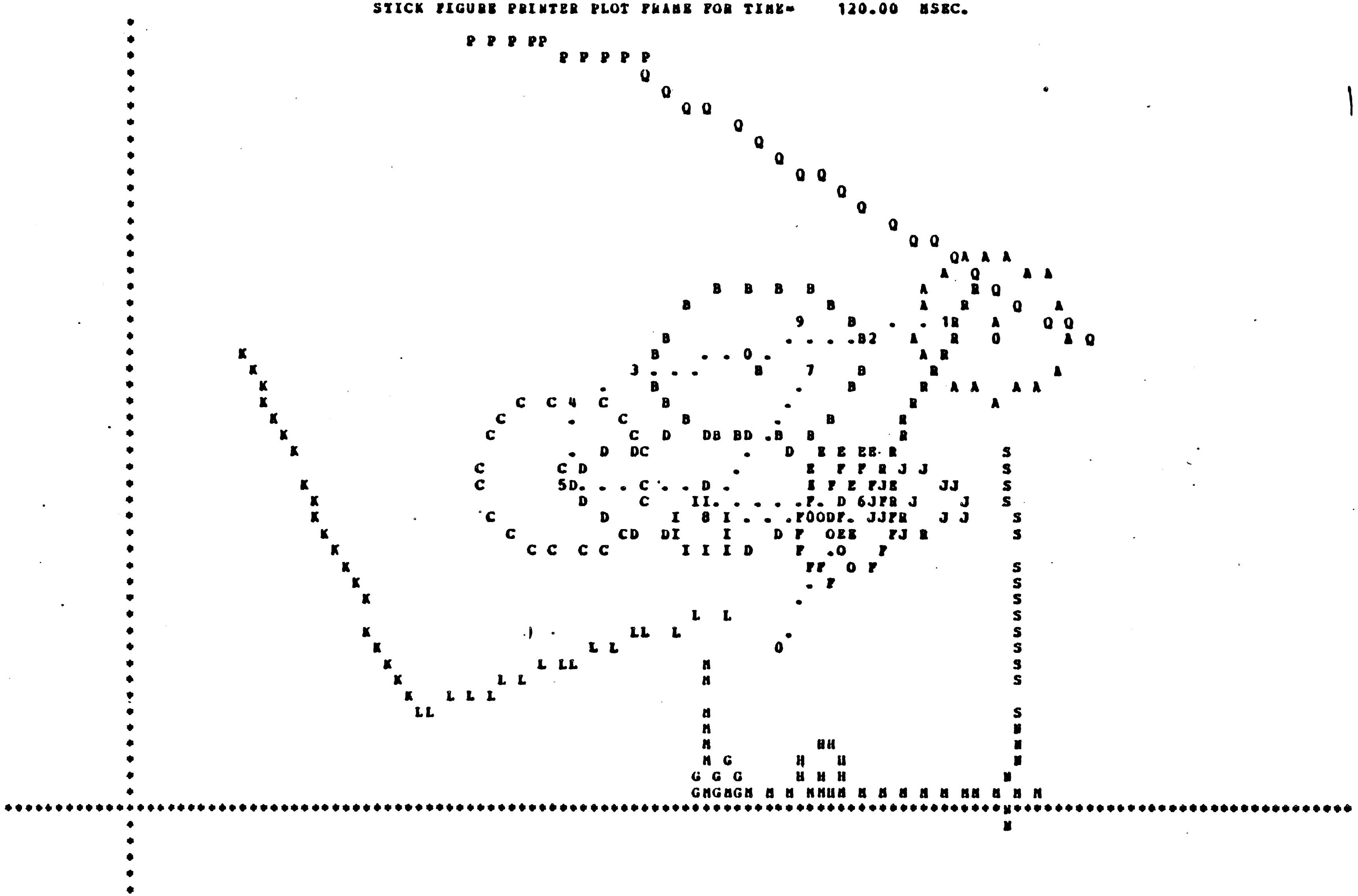


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112e Printer-Plot Time Sequence for Example 1 (100 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 142-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

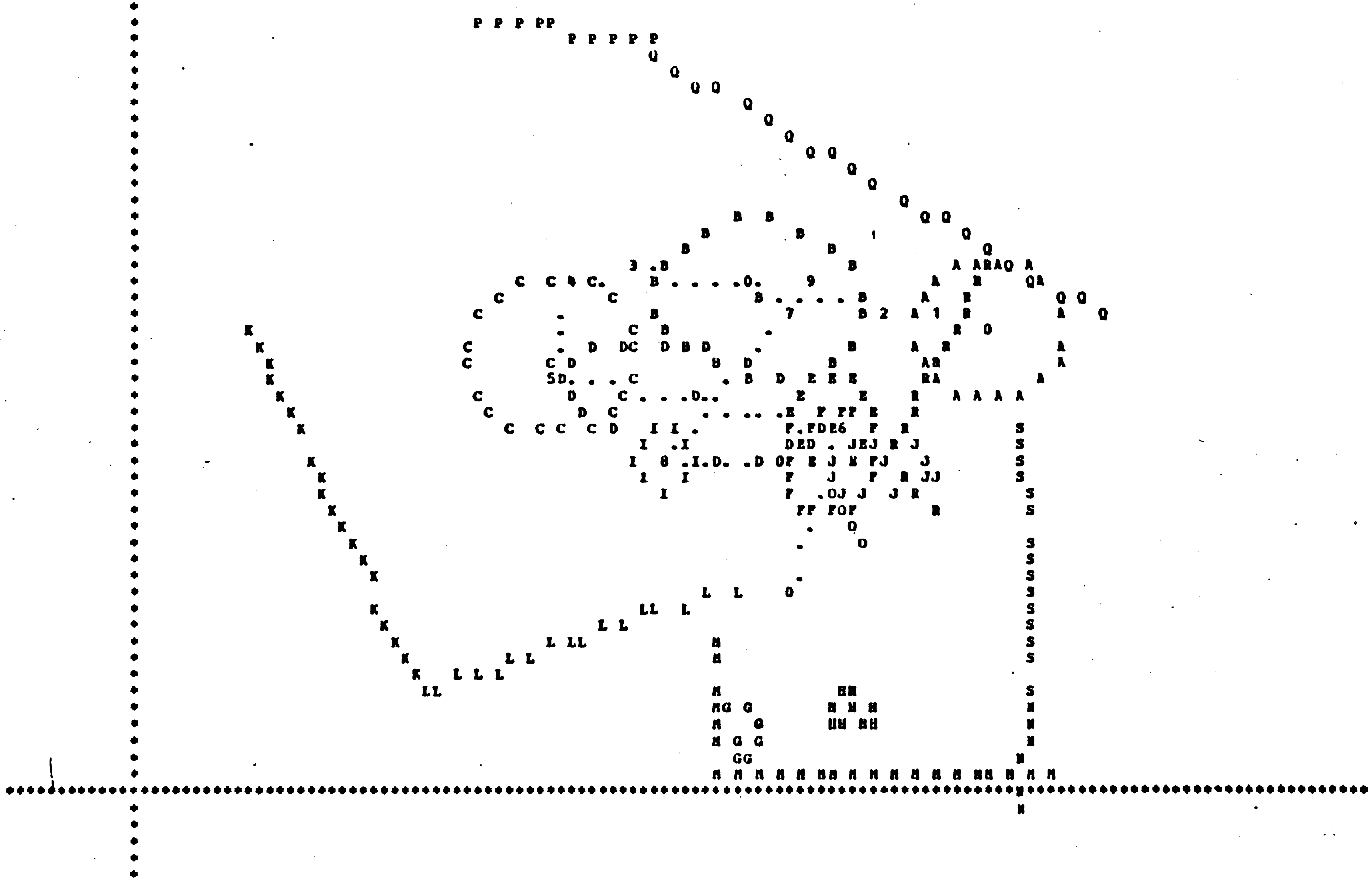
STICK FIGURE PRINTER PLOT FRAME FOR TIME= 120.00 MSEC.



COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112f Printer-Plot Time Sequence for Example 1 (120 ms)

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 150.00 MSEC.



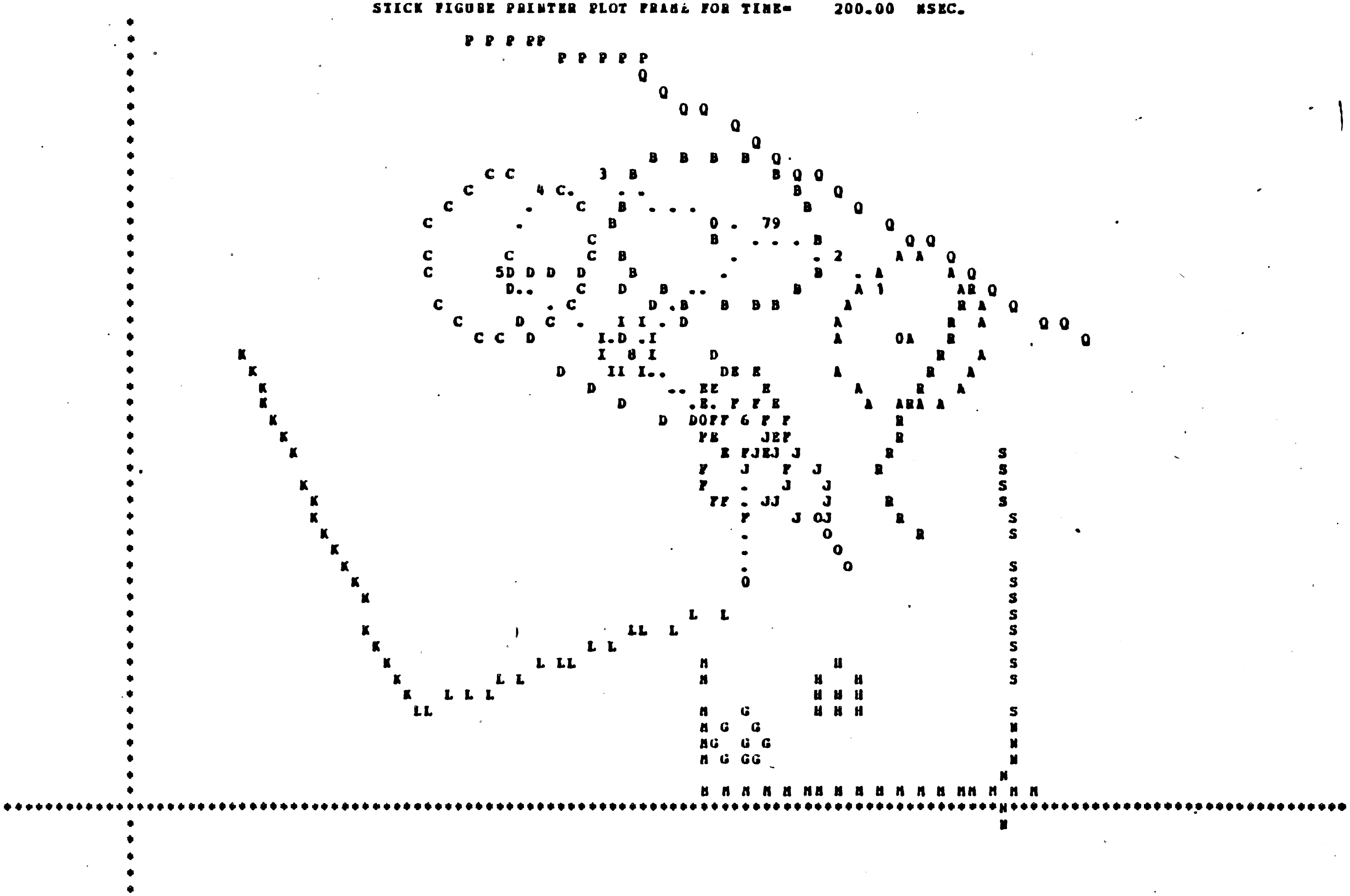
COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112g Printer-Plot Time Sequence for Example 1 (150 ms)

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 150-45

GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 200.00 MSEC.



COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)

SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 112h Printer-Plot Time Sequence for Example 1 (200 ms)

VEHICLE RESPONSE

TIME (MSEC)	DISPL. (INCHES)	HORIZONTAL VELOCITY (MPH)	ACCEL. (G'S)	DISPL. (INCHES)	VERTICAL VELOCITY (FT/SEC)	ACCEL. (G'S)	ANGLE (DEGREES)	PITCH VELOCITY (RAD/SEC)	ACCEL. (RAD/SEC**2)
0.0	0.0	30.00	-1.70	0.0	0.0	0.0	0.0	0.0	0.0
5.00	2.61	28.89	-23.07	0.0	0.0	0.0	0.0	0.0	0.0
10.00	5.02	26.14	-11.88	0.0	0.0	0.0	0.0	0.0	0.0
15.00	7.31	26.04	-4.47	0.0	0.0	0.0	0.0	0.0	0.0
20.00	9.54	24.38	-16.17	0.0	0.0	0.0	0.0	0.0	0.0
25.00	11.62	23.02	-10.68	0.0	0.0	0.0	0.0	0.0	0.0
30.00	13.60	21.80	-16.60	0.0	0.0	0.0	0.0	0.0	0.0
35.00	15.42	19.54	-14.60	0.0	0.0	0.0	0.0	0.0	0.0
40.00	17.08	18.07	-20.10	0.0	0.0	0.0	0.0	0.0	0.0
45.00	18.55	15.17	-29.84	0.0	0.0	0.0	0.0	0.0	0.0
50.00	19.73	11.92	-25.90	0.0	0.0	0.0	0.0	0.0	0.0
55.00	20.66	8.98	-28.45	0.0	0.0	0.0	0.0	0.0	0.0
60.00	21.30	5.62	-30.07	0.0	0.0	0.0	0.0	0.0	0.0
65.00	21.66	2.68	-23.11	0.0	0.0	0.0	0.0	0.0	0.0
70.00	21.79	0.55	-15.74	0.0	0.0	0.0	0.0	0.0	0.0
75.00	21.78	-0.77	-8.37	0.0	0.0	0.0	0.0	0.0	0.0
80.00	21.68	-1.47	-5.33	0.0	0.0	0.0	0.0	0.0	0.0
85.00	21.52	-1.95	-3.36	0.0	0.0	0.0	0.0	0.0	0.0
90.00	21.34	-2.21	-1.40	0.0	0.0	0.0	0.0	0.0	0.0
95.00	21.14	-2.37	-1.40	0.0	0.0	0.0	0.0	0.0	0.0
100.00	20.92	-2.52	-1.40	0.0	0.0	0.0	0.0	0.0	0.0
105.00	20.70	-2.65	-1.05	0.0	0.0	0.0	0.0	0.0	0.0
110.00	20.46	-2.75	-0.70	0.0	0.0	0.0	0.0	0.0	0.0
115.00	20.21	-2.81	-0.35	0.0	0.0	0.0	0.0	0.0	0.0
120.00	19.96	-2.83	-0.00	0.0	0.0	0.0	0.0	0.0	0.0
125.00	19.71	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
130.00	19.47	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
135.00	19.22	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
140.00	18.97	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
145.00	18.72	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150.00	18.47	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
155.00	18.22	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
160.00	17.97	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
165.00	17.72	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
170.00	17.47	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
175.00	17.23	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
180.00	16.98	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
185.00	16.73	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
190.00	16.48	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
195.00	16.23	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200.00	15.98	-2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 113 Vehicle Motion for Example 1

HEAD CENTER OF MASS MOTION

(POSITIONS AND VELOCITIES RELATIVE TO VEHICLE FRAME)
(ACCELERATIONS RELATIVE TO INERTIAL FRAME)

TIME (MSEC)	X (IN)	X-VEL. (IN/SEC)	X-ACCEL. (G'S)	Z (IN)	Z-VEL. (IN/SEC)	Z-ACCEL. (G'S)	HEAD ANGLE (DEG)	ANG. VEL. (DEG/SEC)	ANG. ACC. (RAD/SEC**2)
0.0	12.94	0.0	-0.000	-34.10	0.0	1.000	78.50	0.0	-0.00
5.00	12.97	20.29	-1.965	-34.09	0.94	0.476	78.49	6.59	-551.04
10.00	13.20	69.32	-1.804	-34.09	0.52	-0.148	78.42	-9.45	-556.95
15.00	13.56	71.71	-1.755	-34.09	-0.92	-0.533	78.27	-27.66	-566.14
20.00	13.98	101.85	-1.811	-34.10	-2.82	-0.652	78.02	-44.44	-580.18
25.00	14.55	126.56	-1.830	-34.12	-4.85	-0.705	77.70	-59.41	-588.09
30.00	15.24	149.00	-1.733	-34.14	-7.08	-0.940	77.30	-75.22	-596.04
35.00	16.08	190.11	-1.468	-34.19	-9.96	-1.469	76.81	-94.22	-607.21
40.00	17.10	218.32	-0.517	-34.25	-14.53	-2.648	76.22	-116.07	-584.23
45.00	18.32	275.10	1.907	-34.33	-20.74	-3.291	75.61	-109.48	-450.39
50.00	19.86	341.27	4.840	-34.45	-27.26	-3.151	74.98	-122.48	-243.80
55.00	21.73	406.64	9.350	-34.60	-33.10	-2.312	74.36	-139.87	133.93
60.00	23.95	482.77	9.613	-34.77	-33.12	3.540	73.60	-181.86	13.58
65.00	26.54	548.85	7.028	-34.91	-16.51	14.496	72.55	-249.73	-7.06
70.00	29.40	594.65	2.850	-34.90	22.52	26.240	71.18	-314.76	-88.51
75.00	32.36	541.53	-81.864	-34.61	111.70	61.654	69.79	-37.40	2854.46
80.00	34.96	520.33	-5.805	-33.90	159.05	13.709	69.99	-93.22	-1547.61
85.00	37.54	506.22	-19.047	-33.03	189.55	18.504	68.41	-518.69	-1653.52
90.00	39.98	465.36	-28.412	-31.98	235.22	27.881	64.95	-837.46	-906.97
95.00	42.13	380.94	-62.636	-30.70	259.38	-16.455	58.44	-2474.69	-11601.15
100.00	43.73	260.57	-51.994	-29.54	204.00	-26.712	43.26	-2840.28	3087.70
105.00	44.89	217.67	-10.903	-28.60	173.61	-15.327	30.43	-2415.08	1035.27
110.00	45.90	177.36	-34.519	-27.81	143.79	-12.955	19.37	-1927.01	2419.62
115.00	46.62	107.90	-41.030	-27.12	132.74	-5.796	11.33	-1292.02	2166.98
120.00	46.97	33.86	-33.042	-26.49	117.15	-11.867	6.18	-809.57	817.05
125.00	47.01	-14.06	-16.823	-25.96	94.38	-11.908	2.65	-642.20	242.87
130.00	46.88	-31.99	-2.747	-25.54	73.75	-8.902	-0.45	-600.85	157.31
135.00	46.72	-29.89	3.321	-25.21	59.57	-6.156	-3.34	-558.16	127.29
140.00	46.58	-25.37	0.086	-24.94	48.29	-6.077	-6.04	-525.40	87.96
145.00	46.45	-31.47	-6.088	-24.73	34.14	-8.869	-8.65	-529.89	-160.62
150.00	46.25	-46.01	-8.099	-24.61	15.35	-10.014	-11.44	-590.87	-204.86
155.00	45.99	-59.82	-5.561	-24.58	-2.77	-9.321	-14.53	-642.69	-351.92
160.00	45.67	-66.41	-1.268	-24.63	-17.13	-6.700	-17.95	-708.80	-395.16
165.00	45.34	-66.85	0.717	-24.74	-24.29	-3.194	-21.67	-767.50	-519.80
170.00	45.00	-65.20	0.127	-24.87	-26.84	1.409	-25.72	-846.31	312.56
175.00	44.68	-63.85	0.577	-25.01	-28.43	-1.145	-29.99	-860.65	64.55
180.00	44.36	-63.86	-1.876	-25.16	-32.09	-2.173	-34.16	-803.16	607.71
185.00	44.04	-67.47	-2.649	-25.33	-39.98	-2.702	-37.85	-692.96	792.72
190.00	43.69	-69.37	-0.408	-25.55	-47.34	-1.931	-41.02	-602.64	533.47
195.00	43.35	-66.82	2.711	-25.80	-50.61	-1.326	-43.86	-532.31	47.39
200.00	43.03	-61.20	3.030	-26.05	-49.86	1.500	-46.37	-465.61	327.76

(see footnote, section 3.4.3)

FIGURE 114 Head Center of Mass Motion for Example 1

CHEST CENTER OF MASS MOTION

(POSITIONS AND VELOCITIES RELATIVE TO VEHICLE FRAME)
(ACCELERATIONS RELATIVE TO INERTIAL FRAME)

TIME (MSEC)	X (IN)	X-VEL. (IN/SEC)	X-ACCEL. (G'S)	Z (IN)	Z-VEL. (IN/SEC)	Z-ACCEL. (G'S)
0.0	12.20	0.0	-0.586	-21.40	0.0	-0.603
5.00	12.22	19.09	-13.974	-21.40	-1.30	4.549
10.00	12.44	66.20	-14.432	-21.41	-1.95	4.632
15.00	12.78	65.93	-14.642	-21.42	-3.06	4.429
20.00	13.16	92.93	-14.832	-21.44	-4.57	4.164
25.00	13.68	114.00	-15.116	-21.46	-6.64	3.799
30.00	14.28	132.00	-15.342	-21.50	-9.72	3.212
35.00	15.03	167.34	-16.552	-21.56	-13.89	1.979
40.00	15.90	185.66	-18.230	-21.64	-20.25	3.089
45.00	16.90	218.25	-18.608	-21.75	-24.12	2.277
50.00	18.08	252.02	-22.085	-21.88	-30.31	-0.821
55.00	19.39	271.06	-10.819	-22.06	-40.69	-7.453
60.00	20.81	297.95	-8.731	-22.28	-44.67	-1.530
65.00	22.36	321.35	-6.256	-22.50	-43.57	-1.668
70.00	24.01	336.52	-2.067	-22.72	-44.10	-1.040
75.00	25.72	344.00	-16.667	-22.93	-40.96	4.063
80.00	27.42	333.17	-23.955	-23.10	-23.55	8.101
85.00	29.02	303.03	-29.137	-23.17	-3.04	8.065
90.00	30.42	259.43	-29.820	-23.14	13.40	4.402
95.00	31.51	159.57	-44.250	-23.25	-103.59	-68.862
100.00	32.24	133.70	-16.108	-23.78	-101.82	3.352
105.00	32.83	100.93	-17.277	-24.27	-92.02	6.972
110.00	33.26	68.27	-17.384	-24.68	-74.66	8.514
115.00	33.54	46.58	-8.863	-25.03	-65.55	2.736
120.00	33.74	34.70	-13.138	-25.35	-62.85	-12.330
125.00	33.88	22.06	-3.773	-25.68	-67.94	-3.043
130.00	33.96	12.12	-6.468	-26.03	-71.31	-1.000
135.00	33.99	-1.77	-7.545	-26.39	-74.03	-1.896
140.00	33.95	-15.19	-5.782	-26.77	-78.89	-3.327
145.00	33.85	-22.32	-1.559	-27.19	-87.39	-5.247
150.00	33.73	-23.67	-0.202	-27.65	-95.56	-4.495
155.00	33.61	-24.07	0.078	-28.14	-100.26	-4.891
160.00	33.49	-24.79	0.378	-28.65	-104.73	-5.143
165.00	33.36	-26.84	1.073	-29.19	-108.54	-4.505
170.00	33.23	-28.67	3.600	-29.74	-112.91	12.160
175.00	33.09	-27.36	3.627	-30.29	-109.44	12.303
180.00	32.95	-25.74	4.986	-30.83	-106.75	14.043
185.00	32.83	-22.95	5.411	-31.35	-101.98	15.071
190.00	32.73	-20.27	4.618	-31.84	-95.37	14.219
195.00	32.63	-18.17	-2.294	-32.30	-90.63	0.492
200.00	32.54	-20.58	-1.778	-32.75	-87.06	-0.180

FIGURE 115 Chest Center of Mass Motion for Example 1

(see footnote, section 3.4.3)

OCT 18, 1978 02:51:55 MVMA 2-D TUTORIAL EXAMPLE #1 (7-77) PAGE 67-
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS

HIP MOTION

(POSITIONS AND VELOCITIES RELATIVE TO VEHICLE FRAME)
(ACCELERATIONS RELATIVE TO INERTIAL FRAME)

TIME (MSEC)	X (IN)	X-VEL. (IN/SEC)	X-ACCEL. (G'S)	Z (IN)	Z-VEL. (IN/SEC)	Z-ACCEL. (G'S)
0.0	18.81	0.0	-0.538	-9.41	0.0	-1.626
5.00	18.84	17.57	4.470	-9.41	-1.88	1.380
10.00	19.06	63.13	4.151	-9.42	-2.67	1.484
15.00	19.38	61.15	3.734	-9.44	-2.96	1.319
20.00	19.74	85.98	3.225	-9.45	-3.57	1.136
25.00	20.22	104.15	2.502	-9.47	-4.66	0.893
30.00	20.77	118.39	1.376	-9.49	-5.74	0.460
35.00	21.44	147.88	-1.449	-9.53	-8.98	-0.815
40.00	22.20	151.32	-11.577	-9.58	-11.33	-2.461
45.00	22.97	157.04	-21.461	-9.63	-6.90	1.121
50.00	23.75	145.58	-36.379	-9.65	-1.55	-1.885
55.00	24.39	107.11	-54.473	-9.67	-6.03	0.208
60.00	24.82	67.82	-53.964	-9.69	-4.86	4.745
65.00	25.07	32.35	-44.454	-9.72	-9.86	-8.828
70.00	25.14	-2.29	-36.416	-9.83	-36.74	-18.825
75.00	25.06	-26.37	-10.904	-10.10	-70.61	-14.022
80.00	24.92	-26.54	0.927	-10.52	-99.06	-12.099
85.00	24.80	-19.98	4.790	-11.09	-130.53	-14.423
90.00	24.73	-7.30	9.250	-11.83	-163.72	-14.741
95.00	24.75	13.50	8.292	-12.73	-199.64	-31.099
100.00	24.86	26.66	-7.308	-13.80	-219.61	2.225
105.00	24.91	-16.83	-36.866	-14.86	-199.57	13.978
110.00	24.67	-73.60	-18.051	-15.81	-182.16	2.961
115.00	24.28	-72.53	11.041	-16.73	-186.66	-1.414
120.00	23.97	-49.62	11.304	-17.66	-186.52	11.255
125.00	23.76	-36.83	2.687	-18.59	-187.14	1.924
130.00	23.59	-33.18	1.303	-19.52	-183.81	1.868
135.00	23.43	-31.07	0.751	-20.42	-178.54	3.419
140.00	23.27	-30.51	-0.082	-21.30	-171.31	3.953
145.00	23.12	-31.06	-0.478	-22.13	-163.76	3.774
150.00	22.96	-32.39	-1.025	-22.94	-157.29	3.757
155.00	22.79	-33.75	-1.575	-23.71	-152.67	4.653
160.00	22.62	-35.57	-2.148	-24.46	-147.46	5.091
165.00	22.44	-36.85	-2.458	-25.18	-142.65	4.979
170.00	22.25	-38.29	0.902	-25.88	-136.50	-7.010
175.00	22.06	-38.82	1.003	-26.56	-134.51	-5.740
180.00	21.86	-39.12	1.243	-27.22	-130.59	-6.322
185.00	21.67	-39.33	1.419	-27.87	-127.06	-6.665
190.00	21.47	-39.16	1.387	-28.50	-124.67	-5.968
195.00	21.28	-39.55	1.453	-29.12	-121.55	2.393
200.00	21.09	-36.93	1.256	-29.72	-118.93	2.426

(see footnote, section 3.4.3)

FIGURE 116 Hip Motion for Example 1

BODY LINK ANGLES (DEGREES) (RELATIVE TO VEHICLE)

TIME	HEAD	NECK	UPPER TORSO	MID TORSO	LOW TORSO	UPPER LEG	LOWER LEG	SHOULDER	UPPER ARM	LOWER ARM
0.0	78.50	89.50	97.50	115.50	149.50	19.50	-45.00	---	-41.00	3.00
5.0	78.48	89.46	97.51	115.43	149.54	19.47	-45.00	---	-41.00	3.00
10.0	78.39	89.43	97.46	115.42	149.58	19.38	-45.02	---	-41.02	3.01
15.0	78.24	89.32	97.36	115.43	149.61	19.26	-45.06	---	-41.05	3.02
20.0	78.02	89.15	97.20	115.39	149.61	19.13	-45.11	---	-41.08	3.02
25.0	77.72	88.92	96.97	115.27	149.60	18.99	-45.16	---	-41.12	3.02
30.0	77.36	88.61	96.65	115.04	149.56	18.83	-45.17	---	-41.23	2.99
35.0	76.90	88.18	96.19	114.65	149.50	18.63	-45.14	---	-41.48	2.90
40.0	76.29	87.68	95.47	114.09	149.39	18.45	-45.33	---	-41.93	2.75
45.0	75.61	87.05	94.18	112.98	149.15	19.29	-47.69	---	-42.62	2.53
50.0	74.94	86.10	91.87	110.89	148.49	22.12	-51.13	---	-43.77	2.28
55.0	74.28	84.58	88.20	107.34	147.28	25.68	-54.87	---	-45.34	1.97
60.0	73.52	82.27	82.97	102.13	145.06	28.83	-58.65	---	-47.39	1.54
65.0	72.51	79.00	76.43	95.50	141.16	32.33	-63.13	---	-53.15	1.32
70.0	71.19	74.91	68.79	87.91	135.61	35.73	-68.08	---	-61.29	0.86
75.0	69.89	70.71	60.40	79.37	128.60	37.60	-72.74	---	-69.37	-0.27
80.0	70.18	67.90	52.00	70.76	120.02	38.00	-77.54	---	-75.39	-2.03
85.0	68.66	63.23	43.87	62.39	113.17	37.29	-82.88	---	-82.65	-3.20
90.0	65.21	57.51	35.75	54.07	107.44	34.98	-89.08	---	-94.60	-2.37
95.0	56.91	44.75	29.68	48.51	103.15	29.18	-97.34	---	-105.80	-0.88
100.0	40.47	34.64	25.42	44.61	100.95	19.68	-107.17	---	-112.47	0.60
105.0	27.24	27.16	21.32	40.80	98.68	10.56	-115.53	---	-117.05	1.98
110.0	16.17	20.32	17.67	36.45	93.01	3.65	-120.15	---	-120.35	3.13
115.0	8.62	15.00	14.27	32.64	87.24	0.49	-117.93	---	-122.74	4.06
120.0	4.10	10.96	10.74	28.93	83.56	-1.08	-115.81	---	-123.92	4.73
125.0	1.24	7.92	7.10	25.45	81.21	-2.40	-114.72	---	-123.89	5.04
130.0	-1.05	5.47	3.50	22.02	79.85	-4.12	-113.19	---	-123.29	4.88
135.0	-3.25	3.25	0.04	19.18	79.01	-6.05	-111.70	---	-122.83	3.97
140.0	-5.39	0.96	-3.27	17.17	78.61	-8.09	-110.28	---	-123.38	2.04
145.0	-7.50	-1.56	-6.31	15.95	78.41	-10.17	-108.88	---	-125.40	-0.95
150.0	-9.81	-4.31	-8.94	15.37	78.12	-12.27	-107.46	---	-128.05	-4.50
155.0	-12.67	-7.25	-10.96	14.57	77.76	-14.39	-105.99	---	-130.21	-8.16
160.0	-16.21	-10.21	-12.55	14.00	77.19	-16.50	-104.47	---	-131.81	-11.86
165.0	-20.29	-13.37	-13.80	13.54	76.60	-18.62	-102.90	---	-133.06	-15.61
170.0	-24.84	-16.81	-14.76	13.08	75.89	-20.72	-101.27	---	-133.99	-19.40
175.0	-29.55	-20.37	-15.52	12.54	74.98	-22.83	-99.60	---	-134.74	-23.22
180.0	-33.98	-23.68	-16.23	11.93	73.84	-24.94	-97.89	---	-135.35	-27.08
185.0	-37.96	-26.64	-16.91	11.10	72.48	-27.08	-96.14	---	-135.90	-30.96
190.0	-41.56	-29.22	-17.57	10.12	70.97	-29.22	-94.35	---	-136.44	-34.86
195.0	-44.72	-31.34	-18.35	9.21	69.59	-31.40	-92.55	---	-137.16	-38.77
200.0	-47.47	-33.24	-19.19	8.28	68.38	-33.60	-90.74	---	-137.96	-42.65

FIGURE 117 Body Link Angles for Example 1

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 67-12
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

ACCELERATION OF BODY LINK ANGLES (DEG/SEC**2) (RELATIVE TO INERTIAL FRAME)

TIME	HEAD	NECK	UPPER TORSO	MID TORSO	LOW TORSO	UPPER LEG	LOWER LEG	SHOULDER	UPPER ARM	LOWER ARM
0.0	-0.00	2938.40	-3248.21	2979.45	4793.00	-3645.51	-492.10	---	-0.02	-0.00
5.0	25057.73	-223587.69	127969.00	-527872.88	144861.08	-13590.84	7348.74	---	-38930.38	13606.55
10.0	29682.09	-233848.44	127888.50	-473227.00	90787.13	782.02	5714.10	---	-39166.94	13556.36
15.0	28832.93	-233876.63	127401.56	-475440.25	91681.69	933.72	6171.09	---	-39402.73	13480.65
20.0	30796.70	-237296.81	126878.81	-477046.81	92156.88	1007.69	6765.30	---	-34780.67	10397.41
25.0	31065.69	-237736.81	125688.25	-478322.31	92567.88	613.75	7717.36	---	-40171.68	13262.19
30.0	29287.89	-233934.06	123251.13	-484735.19	99429.08	-1695.69	9112.70	---	-19912.01	566.06
35.0	27216.75	-229205.13	116945.88	-481020.38	96750.88	-4410.46	4634.26	---	-20102.70	261.85
40.0	-33603.26	205130.31	-141076.81	460340.63	-134661.63	48445.68	-112498.75	---	-19932.46	-227.75
45.0	-24479.03	158481.75	-130632.50	315852.69	-80942.63	91546.75	-375308.94	---	-19197.52	-1011.97
50.0	-14550.74	124668.88	-136785.69	244910.44	-70707.81	29565.52	-183277.44	---	-16947.72	-2294.53
55.0	9319.91	-161231.31	7418.38	-317691.06	-7141.34	-1596.45	59359.55	---	-13162.18	-4054.77
60.0	1737.15	-170728.31	22284.50	-306341.13	-40286.15	57256.60	48843.56	---	-245395.88	34988.09
65.0	1548.49	-153355.75	28247.05	-271429.44	-33563.59	19158.34	26113.83	---	-58629.13	-17853.61
70.0	-3805.37	-136127.00	36042.57	-275813.69	-16945.75	-80090.50	23158.45	---	18040.09	-31443.95
75.0	163792.25	205956.06	-50444.42	194833.13	-76379.06	-49146.36	-7571.30	---	106407.75	-26885.63
80.0	-96307.94	7449.24	-49430.32	234451.81	-19378.71	-42686.88	-22981.67	---	-66920.06	14910.29
85.0	-89125.44	57954.28	-57992.48	198039.13	41107.65	-54579.84	-34902.36	---	-223432.44	25324.41
90.0	-54890.81	33871.97	-59382.70	172857.94	66169.88	-60121.92	-41638.49	---	35846.14	-22035.46
95.0	-481964.38	808495.63	32022.68	-564191.50	246550.50	-86629.88	-8456.13	---	223792.94	4476.54
100.0	191133.19	32120.41	20808.85	-13572.79	12974.57	12510.36	51409.51	---	71766.19	-4169.37
105.0	56210.35	73014.13	11303.79	-49897.39	-153452.50	84620.00	141207.38	---	34124.68	-14371.46
110.0	157107.06	73777.63	13517.83	30420.26	6924.27	184807.06	324180.50	---	34541.01	-8421.68
115.0	123203.38	60756.18	-8628.77	-3753.18	98450.81	56039.26	-186156.88	---	50151.01	-10198.30
120.0	72155.31	-16942.42	26096.33	-85527.69	61935.59	-4262.55	-116811.44	---	50917.07	-14588.93
125.0	30849.06	-21004.46	23278.25	-83631.31	62059.53	-27827.26	40552.36	---	20514.27	-17491.39
130.0	2141.89	9876.37	5073.38	25533.01	21175.43	-8123.35	-5669.99	---	-4410.66	-29606.40
135.0	2242.21	-3047.31	5569.14	34190.19	18337.61	-4428.91	-2817.41	---	-41723.62	-42299.68
140.0	2273.97	-9536.70	10364.16	32448.52	8191.64	-1620.30	-567.86	---	-62486.91	-43318.28
145.0	-9534.13	-13067.22	18933.00	23303.40	-4346.64	27.79	886.93	---	-45861.91	-27245.51
150.0	-21488.26	-3365.79	18227.15	21133.92	-11828.38	373.08	1876.43	---	22844.40	-2654.75
155.0	-27100.18	13181.14	3114.47	72380.44	-26001.77	3929.86	2620.24	---	27059.45	-665.82
160.0	-34574.75	16094.84	75.71	76495.44	-30481.41	4961.23	3133.62	---	29287.47	731.46
165.0	-34013.80	16916.27	-1945.95	73574.13	-35436.34	5397.42	3340.20	---	30517.90	1711.29
170.0	-23751.43	-70955.06	78437.54	-282697.88	53586.14	-12588.36	4993.33	---	31289.14	1908.91
175.0	32805.65	-177129.69	110062.56	-376787.00	68659.88	-14978.75	6152.11	---	-19876.87	-4740.37
180.0	39366.07	-174374.88	110553.00	-387197.56	70583.81	-15331.14	6615.40	---	-19874.18	-3640.73
185.0	40980.61	-184915.63	111065.75	-385713.50	72637.19	-15013.99	6929.22	---	-20506.83	-2494.84
190.0	22463.36	34291.04	-19406.22	52206.05	-664.37	300.91	-719.20	---	-21528.57	-1297.61
195.0	8957.54	52111.74	-23009.35	68026.94	-3645.16	1325.42	-886.49	---	-22236.98	2.06
200.0	7900.23	151368.13	-109302.94	438788.88	-106996.69	20469.91	-5362.71	---	-21304.69	1470.21

FIGURE 118 Body Link Angle Accelerations for Example 1

REGION LINE SEGMENT MOVEMENT FOR INSTRUMENT PANEL (IN)
(X,Z) W.R.T. VEHICLE FRAME
REGION CONTAINS 2 LINE SEGMENTS

TIME	(MID IP A	) 1	(LOWER IP	) 2	(	) 3	(	) 4	(	) 5	
	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z
0.0	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
5.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
10.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
15.00	44.90	-27.30	43.70	-15.90	46.80	-12.00	0.0	0.0	0.0	0.0	0.0	0.0
20.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
25.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
30.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
35.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
40.00	44.90	-27.30	43.70	-15.90	46.80	-12.80	0.0	0.0	0.0	0.0	0.0	0.0
45.00	44.99	-27.55	43.31	-16.27	46.28	-13.06	0.0	0.0	0.0	0.0	0.0	0.0
50.00	45.07	-27.80	42.93	-16.65	45.75	-13.32	0.0	0.0	0.0	0.0	0.0	0.0
55.00	45.16	-28.05	42.54	-17.02	45.23	-13.59	0.0	0.0	0.0	0.0	0.0	0.0
60.00	45.25	-28.30	42.15	-17.40	44.70	-13.85	0.0	0.0	0.0	0.0	0.0	0.0
65.00	45.34	-28.55	41.76	-17.77	44.18	-14.11	0.0	0.0	0.0	0.0	0.0	0.0
70.00	45.42	-28.80	41.38	-18.15	43.65	-14.37	0.0	0.0	0.0	0.0	0.0	0.0
75.00	45.51	-29.05	40.99	-18.52	43.13	-14.64	0.0	0.0	0.0	0.0	0.0	0.0
80.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
85.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
90.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
95.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
100.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
105.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
110.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
115.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
120.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
125.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
130.00	45.60	-29.30	40.60	-19.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
135.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
140.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
145.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
150.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
155.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
160.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
165.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
170.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
175.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
180.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
185.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
190.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
195.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0
200.00	45.60	-29.30	40.60	-18.90	42.60	-14.90	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 119 Example Region Line Segment Movement from Example 1

CONTACT INTERACTION BETWEEN

ELLIPSE HIP MADE OF HIPMATL

AND

LINE CUSHION LINE 1 WHICH IS AN ELEMENT OF REGION SEAT CUSHION MADE OF SEAT MATERIAL

INITIAL LINE LENGTH = 13.50(IN) EDGE CONSTANT = 0.164

	DEFLECTION		DEFL. RATE		FORCE		CONTACT LOCATION ON LINE		CONTACT LOCATION IN SPACE		CONTACT LOCATION ON BODY SEG.	
TIME (MSEC)	LINE (IN)	ELLIPSE (IN)	LINE (IN/SEC)	ELLIPSE (IN/SEC)	NORMAL (LB)	TANGNTL. (LB)	POSITION (NONDIM.)	RATE (IN/SEC)	X (IN)	Z (IN)	X (IN)	Z (IN)
0.0	0.87	0.00	0.	0.	174.4	0.0	0.311	0.	19.67	-5.69	3.43	2.77
5.00	0.88	0.00	5.	0.	176.2	80.6	0.313	17.	22.31	-5.69	3.43	2.77
10.00	0.95	0.00	21.	0.	198.0	95.5	0.328	59.	24.94	-5.70	3.43	2.77
15.00	1.06	0.00	20.	0.	231.4	120.9	0.351	57.	27.54	-5.72	3.42	2.77
20.00	1.18	0.00	29.	0.	268.6	153.2	0.376	81.	30.13	-5.73	3.42	2.78
25.00	1.33	0.00	34.	0.	318.4	204.1	0.410	98.	32.70	-5.75	3.42	2.77
30.00	1.51	0.00	38.	0.	374.6	272.7	0.449	112.	35.23	-5.77	3.43	2.77
35.00	1.73	0.00	46.	0.	544.8	458.3	0.496	141.	37.72	-5.81	3.43	2.77
40.00	1.95	0.01	45.	0.	802.4	782.1	0.549	145.	40.13	-5.86	3.43	2.76
45.00	2.19	0.01	50.	1.	1071.1	1208.0	0.604	150.	42.38	-5.91	3.45	2.74
50.00	2.42	0.03	44.	6.	1333.8	1747.8	0.659	138.	44.35	-5.94	3.48	2.70
55.00	2.51	0.15	-5.	36.	1415.1	2075.7	0.705	106.	45.92	-5.98	3.54	2.62
60.00	2.49	0.29	-3.	18.	1356.4	2114.3	0.737	73.	47.02	-6.04	3.64	2.48
65.00	2.48	0.33	-3.	-2.	1318.3	2091.5	0.759	47.	47.66	-6.11	3.79	2.22
70.00	2.42	0.27	-22.	-21.	1146.5	1712.6	0.773	29.	47.93	-6.29	3.98	1.85
75.00	2.24	0.14	-50.	-32.	579.2	724.2	0.782	25.	47.91	-6.63	4.18	1.34
80.00	1.83	0.07	-104.	-2.	209.5	196.5	0.793	37.	47.78	-7.13	4.32	0.74
85.00	1.26	0.06	-127.	-3.	133.5	84.2	0.809	51.	47.61	-7.75	4.38	0.15
90.00	0.57	0.04	-151.	-3.	41.3	15.4	0.832	69.	47.45	-8.52	4.37	-0.32
95.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
100.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
105.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
110.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
115.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
120.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
125.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
130.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
135.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
140.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
145.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
150.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
155.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
160.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
165.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
170.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
175.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
180.00	0.0	0.0									0.0	0.0

FIGURE 120 Example (A) Ellipse-Line Contact Interaction from Example 1 (see footnote, section 3.4.3)

CONTACT INTERACTION BETWEEN

ELLIPSE HEAD ASSUMED TO BE RIGID

AND

LINE LW WHICH IS AN ELEMENT OF REGION WINDSHIELD MADE OF WINDSHIELD GLASS

INITIAL LINE LENGTH = 28.13(IN) EDGE CONSTANT = 0.0

TIME (MSEC)	DEFLECTION LINE (IN)	DEFLECTION ELLIPSE (IN)	DEFL. RATE LINE (IN/SEC)	DEFL. RATE ELLIPSE (IN/SEC)	FORCE NORMAL (LB)	FORCE TANGNTL. (LB)	CONTACT LOCATION ON LINE POSITION (NONDIM.)	CONTACT LOCATION ON LINE RATE (IN/SEC)	CONTACT LOCATION IN SPACE X (IN)	CONTACT LOCATION IN SPACE Z (IN)	CONTACT LOCATION ON BODY SEG. X (IN)	CONTACT LOCATION ON BODY SEG. Z (IN)
0.0	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
5.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
10.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
15.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
20.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
25.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
30.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
35.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
40.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
45.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
50.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
55.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
60.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
65.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
70.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
75.00	0.67	0.0	195.	0.	950.5	636.8	0.247	518.	55.80	-38.17	-3.91	-0.33
80.00	1.45	0.0	144.	0.	234.9	157.4	0.338	525.	58.30	-37.46	-3.91	-0.35
85.00	2.11	0.0	114.	0.	369.2	247.4	0.432	528.	60.73	-36.60	-3.93	-0.24
90.00	2.55	0.0	56.	0.	463.2	310.3	0.525	518.	63.09	-35.57	-3.97	0.00
95.00	2.67	0.0	5.	0.	489.6	328.1	0.614	462.	64.98	-34.34	-4.00	0.45
100.00	2.67	0.0	-10.	0.	449.8	301.4	0.685	335.	66.44	-33.29	-3.87	1.50
105.00	2.60	0.0	-12.	0.	130.2	87.2	0.739	286.	67.46	-32.42	-3.55	2.34
110.00	2.55	0.0	-14.	0.	65.8	44.1	0.786	237.	68.32	-31.67	-3.13	2.98
115.00	2.40	0.0	-47.	0.	46.4	31.1	0.822	170.	68.87	-30.99	-2.76	3.40
120.00	2.08	0.0	-77.	0.	4.4	3.0	0.846	97.	69.01	-30.37	-2.48	3.63
125.00	1.67	0.0	-84.	0.	0.0	0.0	0.858	0.	68.83	-29.85	-2.29	3.78
130.00	1.27	0.0	-77.	0.	0.0	0.0	0.863	0.	68.48	-29.43	-2.11	3.90
135.00	0.92	0.0	-64.	0.	0.0	0.0	0.865	0.	68.10	-29.10	-1.93	4.00
140.00	0.63	0.0	-52.	0.	0.0	0.0	0.867	0.	67.74	-28.82	-1.76	4.09
145.00	0.39	0.0	-44.	0.	0.0	0.0	0.868	0.	67.37	-28.61	-1.60	4.17
150.00	0.19	0.0	-36.	0.	0.0	0.0	0.865	0.	66.96	-28.48	-1.42	4.24
155.00	0.03	0.0	-28.	0.	0.0	0.0	0.858	0.	66.47	-28.45	-1.22	4.31
160.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
165.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
170.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
175.00	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
190.00	0.0	0.0									0.0	0.0

FIGURE 121 Example (B) Ellipse-Line Contact Interaction from Example 1 (see footnote, section 3.4.3)

FEMUR AND TIBIA LOADS (LB)
WITH FEMUR SENSOR LOCATED 11.55(IN) FROM HIP

	FEMUR			TIBIA	
TIME	AXIAL AT SENSOR	AXIAL AT KNEE	SHEAR AT KNEE	AXIAL AT KNEE	AXIAL AT FOOT
0.0	8.1	4.6	-34.6	2.5	0.0
5.00	-92.2	-40.3	-66.6	7.3	0.0
10.00	-131.2	-68.8	14.8	-85.1	8.5
15.00	-131.0	-64.8	5.5	-82.3	22.9
20.00	-131.9	-61.1	-2.2	-77.6	39.4
25.00	-137.2	-60.0	-6.6	-72.2	55.2
30.00	-138.2	-52.9	-39.8	-64.0	67.1
35.00	-168.6	-59.5	-56.9	-69.5	84.6
40.00	321.6	420.3	-498.8	470.8	1232.9
45.00	655.0	864.9	-1091.0	1145.5	2704.2
50.00	1027.6	1383.9	-724.0	996.4	2001.4
55.00	1623.2	2162.4	-572.7	903.9	1600.0
60.00	1517.9	2035.3	-1065.1	1130.8	2543.9
65.00	670.8	1048.9	-871.8	718.6	1662.8
70.00	26.2	221.0	-190.2	104.9	-228.6
75.00	106.1	99.0	-151.4	107.4	-60.3
80.00	159.5	71.6	-182.7	133.8	0.0
85.00	212.7	90.4	-255.7	175.7	0.0
90.00	233.2	102.3	-281.3	175.8	0.0
95.00	-73.9	2.4	-236.7	188.8	-19.3
100.00	1237.8	1627.2	-361.1	-624.0	-579.1
105.00	5027.1	5848.4	-770.9	-1599.5	-1462.1
110.00	1262.3	1406.7	-1605.8	1367.9	3261.2
115.00	-577.4	-750.1	-763.1	1028.1	2049.2
120.00	-178.9	-259.7	-332.6	410.7	519.7
125.00	97.7	62.6	-168.7	132.3	-96.6
130.00	-15.7	-26.7	-101.9	105.1	0.0
135.00	-32.4	-31.7	-87.0	92.4	0.0
140.00	-43.9	-34.1	-68.0	73.6	0.0
145.00	-50.0	-34.5	-49.7	54.3	0.0
150.00	-54.7	-35.3	-36.1	39.1	0.0
155.00	-58.7	-36.3	-15.5	16.5	0.0
160.00	-63.6	-38.4	-3.5	2.1	0.0
165.00	-66.9	-40.4	6.0	-10.0	0.0
170.00	-77.9	-43.8	-31.4	23.8	0.0
175.00	-89.1	-48.8	-30.6	18.7	0.0
180.00	-94.0	-51.6	-26.1	9.8	0.0
185.00	-98.7	-54.8	-20.7	-0.3	0.0
190.00	-23.0	-23.9	8.5	-17.8	0.0
195.00	-25.4	-26.5	12.4	-23.7	0.0
200.00	-9.3	-26.4	52.7	-58.6	0.0

FIGURE 122 Femur and Tibia Loads for Example 1

JUN 24, 197702:00:20 MVMA 2-D TUTORIAL EXAMPLE #1 PAGE 125-06
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER NO BELTS MVMA 2-D, VER. 3

UNFILTERED ACCELERATIONS (G'S)

	HEAD			CHEST			HIP		
TIME	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	X	Z	RESULTANT
0.0	-0.199	0.980	1.000	0.485	-0.667	0.825	-0.543	-1.605	1.694
5.00	-2.445	0.877	2.598	-13.023	-3.607	13.513	-7.311	-3.560	8.131
10.00	-2.663	0.351	2.686	-12.607	-5.371	13.703	-6.601	1.691	6.814
15.00	-2.617	0.011	2.617	-12.485	-5.667	13.711	-7.084	1.495	7.240
20.00	-2.750	-0.003	2.750	-12.269	-6.024	13.668	-7.651	1.286	7.758
25.00	-2.813	-0.073	2.814	-12.003	-6.445	13.623	-8.456	0.991	8.514
30.00	-2.748	-0.390	2.776	-11.642	-6.751	13.458	-9.708	-0.115	9.709
35.00	-2.781	-1.103	2.991	-10.557	-8.369	13.471	-12.670	-1.231	12.730
40.00	1.134	-4.373	4.518	18.622	-0.935	18.646	-10.521	1.756	10.667
45.00	-1.060	-5.353	5.457	19.145	0.700	19.158	-21.853	0.728	21.865
50.00	-3.815	-5.419	6.627	22.133	-1.332	22.173	-35.665	-1.752	35.708
55.00	-8.429	-4.341	9.481	10.842	-6.295	12.537	-56.717	3.199	56.808
60.00	-10.226	1.000	10.275	8.828	-0.296	8.833	-54.579	5.142	54.820
65.00	-11.206	12.104	16.495	6.004	0.950	6.079	-45.198	-6.229	45.626
70.00	-11.306	24.231	26.739	2.150	-0.393	2.186	-36.477	-19.870	41.537
75.00	56.073	94.908	110.235	12.636	12.000	17.426	-10.807	-14.942	18.440
80.00	0.875	9.974	10.012	13.738	21.866	25.824	0.685	-12.888	12.907
85.00	9.894	20.242	22.530	14.280	27.413	30.910	4.391	-15.541	16.149
90.00	13.299	35.806	38.196	14.253	27.616	31.077	9.313	-15.512	18.093
95.00	44.284	-4.257	44.488	-33.873	9.229	35.108	5.461	-32.311	32.770
100.00	45.479	33.763	56.642	4.549	13.903	14.628	-5.946	2.218	6.346
105.00	14.325	5.420	15.316	-4.470	28.843	29.187	-59.711	12.448	60.994
110.00	21.388	41.426	46.621	-4.260	16.458	17.001	-5.284	7.818	9.436
115.00	12.403	44.020	45.733	-3.344	6.051	7.623	19.113	-1.738	19.192
120.00	11.993	29.908	32.223	-0.590	3.982	4.026	9.071	-3.636	9.773
125.00	9.871	13.695	16.882	1.392	8.286	8.402	4.707	-4.425	6.461
130.00	8.464	2.364	8.787	3.746	7.309	8.213	2.324	1.906	3.005
135.00	6.523	-0.424	6.537	3.885	7.597	8.532	1.156	3.230	3.430
140.00	6.028	3.664	7.054	3.959	5.553	6.820	0.143	3.904	3.906
145.00	6.681	7.831	10.294	4.691	2.200	5.181	-0.540	3.972	4.009
150.00	6.463	7.646	10.012	4.534	0.244	4.540	-0.951	3.459	3.587
155.00	5.137	3.769	6.372	5.612	0.349	5.622	-1.703	4.906	5.193
160.00	3.390	-0.649	3.451	5.076	-0.164	5.078	-2.191	5.009	5.467
165.00	1.762	-2.546	3.097	4.155	-1.329	4.362	-2.460	4.858	5.445
170.00	0.819	-1.543	1.747	-10.363	-7.022	12.518	0.444	-5.550	5.568
175.00	-0.777	6.008	6.058	-12.334	-10.253	16.039	0.620	-7.161	7.188
180.00	0.111	7.204	7.205	-13.245	-10.712	17.035	0.844	-7.429	7.477
185.00	0.339	4.197	4.210	-13.012	-10.063	16.450	0.952	-7.271	7.333
190.00	1.342	-0.110	1.346	-0.765	1.817	1.972	1.318	2.332	2.679
195.00	1.970	-2.370	3.082	-0.101	2.335	2.338	1.097	2.826	3.032
200.00	2.001	-2.148	2.936	13.684	6.315	15.071	-3.436	12.620	13.079

FIGURE 123 Unfiltered Head, Chest, and Hip Accelerations for Example 1

SEVERITY INDICES FOR UNFILTERED ACCELERATIONS

HEAD
HIC= 491.21, BEG. TIME= 65.00, END TIME= 125.00
3 MSEC AVER= 107.979 AT TIME= 74.00
PEAK= 128.533 AT TIME= 74.00

CHEST
3 MSEC AVER= 133.633 AT TIME= 92.00
PEAK= 145.528 AT TIME= 91.00

	HEAD SEVERITY INDEX			HEAD GMR MODIFIED S.I.			CHEST SEVERITY INDEX			CHEST GMR MODIFIED S.I.		
TIME	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00	0.02	0.00	0.02	0.01	0.01	0.00	1.54	0.10	1.76	0.03	0.00	0.04
10.00	0.09	0.00	0.08	0.01	0.01	0.01	4.44	0.34	5.15	0.08	0.00	0.12
15.00	0.13	0.00	0.14	0.01	0.05	0.01	7.31	0.61	8.59	0.13	0.01	0.19
20.00	0.19	0.00	0.20	0.01	0.18	0.01	10.08	0.96	12.03	0.18	0.01	0.27
25.00	0.26	0.00	0.26	0.02	0.25	0.01	12.70	1.39	15.45	0.22	0.01	0.34
30.00	0.32	0.00	0.33	0.02	0.27	0.02	15.11	1.95	18.84	0.25	0.01	0.41
35.00	0.38	0.01	0.39	0.02	0.28	0.02	17.22	2.72	22.17	0.27	0.01	0.48
40.00	0.40	0.09	0.51	0.02	0.28	0.02	20.98	3.18	26.72	0.47	0.02	0.70
45.00	0.41	0.35	0.78	0.03	0.28	0.02	28.53	3.19	34.30	0.92	0.02	1.16
50.00	0.45	0.71	1.22	0.04	0.28	0.02	38.26	3.19	44.04	1.74	0.03	1.98
55.00	0.96	0.99	2.15	0.04	0.28	0.03	42.69	3.89	49.68	1.94	0.04	2.24
60.00	2.35	1.06	3.69	0.05	0.29	0.04	44.30	4.03	51.57	1.95	0.04	2.25
65.00	4.22	1.79	6.65	0.07	0.30	0.12	45.08	4.04	52.36	1.95	0.05	2.25
70.00	6.35	9.41	17.83	0.09	0.98	1.46	45.29	4.04	52.58	1.95	0.06	2.26
75.00	60.00	232.11	332.96	42.98	202.04	250.77	45.46	4.23	53.03	1.96	0.07	2.29
80.00	73.35	292.79	417.04	44.38	239.40	312.54	48.37	11.00	64.32	2.02	0.55	3.56
85.00	73.90	296.62	422.13	44.39	238.61	312.91	52.13	26.57	86.37	2.11	2.80	7.94
90.00	76.66	318.40	449.03	44.44	243.69	320.41	56.17	47.67	114.70	2.22	6.59	14.69
95.00	147.65	328.43	535.66	92.19	245.32	377.27	689.44	50.99	764.71	467.56	6.70	490.30
100.00	244.74	347.77	666.76	161.54	250.31	493.44	692.16	53.28	770.33	467.57	6.74	490.38
105.00	263.00	356.92	698.96	165.44	251.32	504.84	692.24	62.91	780.20	467.57	7.95	491.63
110.00	269.47	375.89	728.22	165.86	257.68	516.82	692.41	76.10	793.91	467.57	9.37	493.17
115.00	274.68	439.38	802.39	166.13	288.04	556.32	692.54	77.61	795.68	467.57	9.38	493.17
120.00	277.09	486.09	854.60	166.16	304.71	576.74	693.18	77.83	796.71	467.59	9.38	493.20
125.00	279.20	497.65	869.95	166.18	305.82	578.68	693.18	78.37	797.25	467.60	9.38	493.20
130.00	280.60	498.66	872.77	166.19	305.83	578.72	693.27	78.95	798.02	467.60	9.38	493.20
135.00	281.35	498.66	873.54	166.19	305.83	578.72	693.42	79.76	799.09	467.60	9.38	493.21
140.00	281.83	498.69	874.06	166.19	305.84	578.72	693.57	80.36	799.94	467.61	9.38	493.21
145.00	282.32	499.17	875.22	166.20	305.84	578.73	693.76	80.53	800.36	467.61	9.39	493.21
150.00	282.88	500.12	877.00	166.20	305.85	578.74	693.99	80.54	800.62	467.61	9.39	493.21
155.00	283.40	500.53	878.10	166.20	305.85	578.75	694.34	80.54	800.97	467.61	9.40	493.21
160.00	283.61	500.56	878.36	166.20	305.86	578.75	694.67	80.54	801.30	467.61	9.42	493.21
165.00	283.67	500.58	878.45	166.20	305.86	578.75	694.90	80.54	801.55	467.61	9.43	493.21
170.00	283.67	500.63	878.51	166.21	305.86	578.75	695.14	80.62	801.92	467.61	9.43	493.22
175.00	283.68	500.77	878.67	166.21	305.86	578.76	697.37	81.93	806.10	467.64	9.44	493.35
180.00	283.68	501.40	879.31	166.23	305.87	578.76	700.18	83.65	811.44	467.69	9.46	493.57
185.00	283.68	501.82	879.74	166.23	305.87	578.76	703.14	85.26	816.83	467.74	9.47	493.78
190.00	283.70	501.86	879.80	166.24	305.87	578.76	704.44	85.91	819.13	467.76	9.47	493.84
195.00	283.72	501.88	879.86	166.24	305.88	578.76	704.44	85.96	819.18	467.77	9.47	493.84
200.00	283.76	501.93	879.95	166.24	305.88	578.76	704.64	86.05	819.53	467.79	9.48	493.86

FIGURE 124 Severity Indices for Unfiltered Accelerations for Example 1

3.4.4 Input Data for Example 2

The second example data set includes the same 30-mph frontal barrier crash acceleration profile as used for Example 1. Simulation Example 2 is similar to Example 1 in other ways also. It uses the same occupant description data subset and the occupant is positioned within the vehicle in an identical manner. The vehicle interior used is basically the same. The primary difference between Examples 1 and 2 is that while both occupants are restrained by a knee bar, the occupant in Example 2 is additionally restrained by a torso harness. There are a number of other differences in the data sets. None of these should affect the crash dynamics; they have been included to illustrate various program options.

3.4.4.1 Belt Restraint System. The three-belt submodel described in Module 9 is used for this simulation. Since simulation Example 1 was for an occupant unrestrained by belts, the belt system usage switch in field 1 of Card 102 was set to 0. For Example 2, however, Card 102 in Figure 128 is seen to have a 2. in field 1. This indicates usage of the three-belt submodel with both lap and torso restraints. Since it is desired for this simulation to have only the torso harness and the knee bar as restraints, and not a lap belt, the belt system data subset shown in Figure 125 includes some specifications worthy of note.

While any of the seven belt segments of the Advanced Belt-Restraint Submodel may be included or omitted from a belt system design, the Three-Belt Submodel is not as flexible. It must include either both lap belt and torso harness or the lap belt alone. Therefore, in the data subset shown, in order to effectively eliminate the lap belt, a belt material named NO STRENGTH is defined by 704- and 705-Cards and is prescribed a zero stiffness with a 708-Card. This belt material is assigned to the lap belt on Card 702.

The torso belts are each pre-tensioned to 5 lb. This is done by assigning negative values for initial slack on Cards 701 and 702. Belt anchor locations and attachment points on the occupant are prescribed on Cards 501 and 218.

2.75	7.	0.	0.	0.	1.8	-1.96	14.12	-5.07	218
0.	0.	0.	0.	0.	-33.52	17.	-1.2		501
100.	0.	15.13	-.00178	6600.	6600.	10.			701
NO STRENGTH				14.04	-.00172	2.	1.		702
6% WEBBING #1				6% WEBBING #2					703
6% WEBBING #1		0.	0.	0.16	14.36	15.04	0.	0.	704
6% WEBBING #1		5.				SBELT1	IZERO	GBELT1	705
GBELT1	0.	0.							706
GBELT1	.16	0.							706
GBELT1	1.37	.56							706
GBELT1	6.15	.95							706
GBELT1	40.	.95							706
GBELT1	0.	1.							707
GBELT1	1.37	.33							707
GBELT1	2.06	.19							707
GBELT1	6.15	.05							707
GBELT1	40.	.05							707
SBELT1	0.	0.							708
SBELT1	.533	1500.							708
SBELT1	9.91	2000.							708
SBELT1	11.28	5300.							708
SBELT1	14.36	6600.							708
SBELT1	15.04	0.							708
6% WEBBING #2		0.	0.	.155	13.85	14.51	0.	0.	704
6% WEBBING #2		5.				SBELT2	IZERO	GBELT1	705
SBELT2	0.	0.							708
SBELT2	.396	1150.							708
SBELT2	9.56	1650.							708
SBELT2	10.9	5300.							708
SBELT2	13.85	6600.							708
SBELT2	14.51	0.							708
NO STRENGTH		0.	0.	0.	10.	11.	0.	0.	704
NO STRENGTH		5.				SNOSTR	IZERO	GNOSTR	705
GNOSTR	-1.	0.							706
GNOSTR	-1.	1.							707
SNOSTR	-1.	0.							708

FIGURE 125 Belt Restraint System Cards for Example 2

3.4.4.2 Auxiliary Debugging Printout. Module 12 explains the use of 104- and 105-Cards for obtaining "debugging" printout of intermediate results from the Execution Processor. Time-dependent, multi-level switches may be set for sixteen divisions of program variables. Figure 126 illustrates specifications for debugging printout for Example 2 from 0 to 3 ms and from 198 to 200 ms inclusive. Printout beginning at times zero will be for switches 1, 7, 9, 10, 11, and 16 at levels 3, 1, 3, 3, 2, and 2, respectively. At 1.1 ms, switches 7 and 16 are set to 0, and at 3.1 ms all debugging printout is suppressed. At 198 ms, all sixteen switches are set at level 1; debugging printout continues through the end of the simulation (200 ms for Example 2) since the switches are not reset to 0. Field 9 of Card 104 is set to 1. in order to limit debugging printout to each final evaluation for the four-step Runge-Kutta integration. A "packing dictionary," which is often useful in interpreting debugging printout,is requested by defaulting the ninth field of Card 105 to 0. by omission of the card from the data deck.

3.4.4.3 Output Variable Storage. Section 3.4.2.11 has explained the use of Cards 1001 and 1002 for specifying categories of calculated data for which printout is desired. It should be kept in mind that in order for the Output Processor to print out variables in response to specifications on Cards 1001 and 1002, those variables must first be stored in an external file. Specification of categories which are to be stored during execution of the "GO" processor for possible later printout is made separately through use of Cards 107 through 111. For Example 1, these cards were omitted from the data deck and thus, by default, all categories were stored for printout. However, the data deck for Example 2 includes the cards shown in Figure 127. Only variables for categories for which a "0." is specified will be written to the external file for possible printout. Use of Cards 107 through 111 is explained in Module 12.

3.4.4.4 Other "Example 2" Modifications. Additional differences between the data decks for Example 1 and Example 2 include the following. (These can be seen in comparing the appropriate sections of their complete data decks, which are shown in Figures 109 and 128.) First, the vehicle interior for Example 2 does not include the ROOFHEADER,

0.	C004F8021.1	C000F8003.1	00000000198.	555555551.	104

FIGURE 126 Debugging Printout Specifications for Example 2

0.	1.	1.	0.	0.	0.	1.	0.	1.	107
0.	0.	0.	0.	0.	0.	1.	1.	1.	108
1.	1.	0.	0.	0.	0.	0.	0.	1.	109
1.	1.	0.	0.	0.	1.	1.	1.	1.	110
0.	1.	1.	0.	0.	0.	0.	0.	0.	111

FIGURE 127 Specifications for Storage of Output Categories for Example 2

WINDSHIELD, and INSTRUMENT PANEL regions. Second, the 106-Cards are absent from the data deck, and interaction "inhibition" controls on Card 102 are redefined so that all potential ellipse-line interactions are investigated. Third, the THORAX and HIP ellipses have been made rigid since materials were defined for them for Example 1 only because of the possibility of THORAX-INSTRUMENT PANEL and HIP-FLOOR interactions. Finally, printout of the summary of the input data is often not desired; it is suppressed for Example 2 by removing Category 0 from the string on Card 1001. Alternatively, a 1001-Card containing only "-1" in columns one and two could have been used. This requests the default ordering for Categories 1 through 40 and 46 through 50 with omission of printout of the input data summary, Category 0.

3.4.5 Selected Output from Simulation Example 2

Selected pages of printout produced by the complete Example 2 data deck in Figure 128 are shown as Figures 129 through 134. These are: a printer-plot stick figure sequence; example debugging printout; belt system data; body link angle accelerations; head, chest, and hip accelerations; and HIC and Severity Indices.

```
                    MVMA 2-D TUTORIAL EXAMPLE #2                                    100
  KNEE BAR                                                                          400
OCC. COMP. DISPL.                                                                   500
30MPH FRONT BARRIER                                                                 600
 FORCE-LIM. HARNESS                                                                 700
  NO LAP BELT                                                                       800
1.        1.        32.174    0.        0.        200.      1.        5.        10.       101
2.        0.        0.        0.        1.        1.        10.       .000001   5.        102
.2        .05       100000.   15000.    10.       .05       10.       1.        1.        103
0.        C004F8021.1         C000F8003.1         00000000198.        555555551.          104
0.        1.        1.        0.        0.        0.        1.        0.        1.        107
0.        0.        0.        0.        0.        0.        1.        1.        1.        108
1.        1.        0.        0.        0.        0.        0.        0.        1.        109
1.        1.        0.        0.        0.        1.        1.        1.        1.        110
0.        1.        1.        0.        0.        0.        0.        0.        0.        111
0.        44.       0.        0.        0.        0.        0.        0.                  601
23.       1.        1.                                                                  602
0.        -1.7      1.        -1.4      7.        -33.9     12.       2.8
13.5      3.9       18.       -21.2     21.5      -12.4     28.       -9.2
32.       -24.0     33.       -24.0     36.       -9.9      37.       -9.9
42.       -26.9     47.       -31.8     50.       -25.9     54.       -27.2
58.       -32.2     61.       -29.0     76.       -6.9      90.       -1.4
100.      -1.4      120.      0.        300.      0.
2.        1.        1.                                                                  603
0.        0.        300.      0.
2.        1.                                                                            604
0.        0.        300.      0.
GM HYBRID II DUMMY                                                                      200
(PRELIMINARY DATA)                                                                      300
1.1       13.44     3.4       5.        15.8                10.3      3.25      -.88      201
2.75      7.        1.7       4.2       8.2       9.3       5.        5.8       .5        202
.0259     .0951     .0052     .0982     .0932     .0518     .022      .0256     .007      203
.198      1.97      .04       1.53      1.39      2.82      .18       .62                 204
12.8      .58       0.        .52       17.4      1.                  -25.      .35       205
12.8      .58       0.        .52       17.4      1.                  -22.      .35       206
72.       15.       0.        .66       1000.     1.        -8.       -25.5     .35       207
102.5     -7.624    .1944     .66       1000.     1.        -33.999   -34.001   .35       208
84.44     -4.810    .1053     0.        850.      1.        -49.999   -50.001   .5        209
0.        29.8      0.        0.        204.      1.        135.      0.        .5        210
0.        10.       0.        0.        222.      1.        28.       -197.     .5        211
0.        10.       0.        0.        64.       1.        0.        -165.     .5        212
751.      0.        757.      1.98                                                      213
20.       230.      0.        0.                            2.                  .5        214
38.       .58       0.        .52       0.        1.        -1.                 .16       215
38.       .58       0.        .52       0.        1.        2.                  .16       216
751.      0.        757.      1.98                                                      242
HEAD                                    1.        3.                                    219
THORAX                                  2.        1.                                    219
HIP                                     4.        1.                                    219
THIGH                                   5.        1.                                    219
KNEE                                    5.        1.                                    219
SHANK                                   6.        1.                                    219
HEEL                                    6.        2.                                    219
TOE                                     6.        2.                                    219
ELBOW                                   7.        1.                                    219
HAND                                    8.        3.                                    219
HEAD                0.        .5        4.        4.                                    220
THORAX              -.5       -.68      5.52      4.44                                  220
HIP                 -.12      0.        4.5       4.5                                   220
THIGH               -.5       -.1       7.        3.                                    220
```

FIGURE 128 Complete Data Set for Simulation Example 2 (page 1 of 5)

KNEE		7.	-.4	2.25	2.25				220
SHANK		-7.54	0.	3.	2.4				220
HEEL		8.57	0.	1.2	1.2				220
TOE		5.61	-5.16	1.2	1.2				220
ELBOW		5.3	0.	1.5	1.5				220
HAND		5.6	-.4	2.72	1.52				220
CHESTMATL		0.	0.	0.	100.	101.	0.	0.	221
CHESTMATL		5.				CSTAT	IZERO	CGR	222
CGR	-1.	.1							223
CGR	0.	1.							224
CGR	.01	.64							224
CGR	.3	.5							224
CGR	1.35	.45							224
CSTAT	0.	0.							225
CSTAT	.01	1125.							225
CSTAT	.05	1460.							225
CSTAT	.3	1350.							225
CSTAT	.4	1260.							225
CSTAT	1.1	1260.							225
CSTAT	4.25	12600.							225
IZERO	-1.	0.							226
HIPMATL		0.	0.	0.	100.	101.	0.	0.	221
HIPMATL		5.				CSTAT	IZERO	CGR	222
-11.	-8.	-18.	-34.	-50.	0.	0.	0.		217
78.5	97.5	115.5	149.5	19.5	-45.	-41.	3.	89.5	301
0.	0.	0.	0.	0.	0.	0.	0.	0.	302
12.2	0.	-21.4	0.	3.28	0.				303
0.	0.	0.	0.						304
SEAT BACK		SEAT MATERIAL		0.	1.	1.	1.		401
SEAT BACK		1.	1.	1.	0.	0.			402
SEAT MATERIAL		0.	0.	1.6	3.5	4.	0.	0.	403
SEAT MATERIAL		5.				SSEAT	IZERO	GRSEAT	404
GRSEAT	-1.	.1							405
GRSEAT	-1.	.5							406
SSEAT	0.	0.							407
SSEAT	.8	150.							407
SSEAT	1.6	400.							407
SSEAT	3.	2000.							407
SSEAT	3.5	4000.							407
SSEAT	4.	0.							407
BACK LINE		SEAT BACK		5.	0.	-1.	1.		409
BACK LINE		1.							410
BACK LINE		-1.	6.2	-25.8	15.44	-4.96			411
SEAT CUSHION		SEAT MATERIAL		0.	1.	1.	1.		401
SEAT CUSHION		2.	1.	1.	0.	0.			402
CUSHION LINE 1		SEAT CUSHION		5.	.164	1.	1.		409
CUSHION LINE 1		1.							410
CUSHION LINE 1		-1.	15.44	-4.96	28.	-9.92			411
CUSHION LINE 2		SEAT CUSHION		5.	.5	-1.	2.		409
CUSHION LINE 2		1.							410
CUSHION LINE 2		-1.	28.	-9.92	32.24	-10.64			411
FLOOR		FMATL		0.	1.	1.	1.		401
FLOOR		2.	2.	1.	0.	0.			402
SEAT BOTTOM		FLOOR		5.	0.	-1.	1.		409
SEAT BOTTOM		1.							410
SEAT BOTTOM		-1.	31.2	-8.	31.2	-.84			411
FLOORBOARD		FLOOR		5.	0.	-1.	2.		409
FLOORBOARD		1.							410
FLOORBOARD		-1.	31.2	-.84	49.	-.84			411
TOEPAN		FMATL		0.	1.	1.	1.		401

FIGURE 128 Complete Data Set for Simulation Example 2 (page 2 of 5)

TOEPAN	1.	2.	1.	0.	0.			402
TOEBOARD	TOEPAN		5.	0.	1.	1.		409
TOEBOARD	4.							410
TOEBOARD	0.	47.3	1.1	54.7	-5.6			411
TOEBOARD	40.	47.3	1.1	54.7	-5.6			411
TOEBOARD	80.	47.3	1.1	47.9	-5.6			411
TOEBOARD	300.	47.3	1.1	47.9	-5.6			411
KNEE BAR	SHEET METAL		0.	1.	1.	1.		401
KNEE BAR	1.	3.	1.	0.	0.			402
SHEET METAL	0.	0.	.5	8.	9.	10000.	10000.	403
SHEET METAL	5.				SSHEET	IZERO	GRSHEET	404
GRSHEET 0.	0.							405
GRSHEET 0.5	0.							405
GRSHEET 5.5	0.9							405
GRSHEET 0.	1.							406
GRSHEET .5	1.							406
GRSHEET 2.	.7							406
GRSHEET 4.	.2							406
GRSHEET 5.5	.15							406
GRSHEET 8.	.1							406
GRSHEET 9.	.01							406
SSHEET 0.	0.							407
SSHEET 2.	1500.							407
SSHEET 4.	1500.							407
SSHEET 5.5	10000.							407
SSHEET 8.	10000.							407
SSHEET 9.	0.							407
KNEEBAR LINE	KNEE BAR		5.	0.5	1.	1.		409
KNEEBAR LINE	4.							410
KNEEBAR LINE	0.	40.4	-13.2	38.9	-16.4			411
KNEEBAR LINE	60.	40.4	-13.2	38.9	-16.4			411
KNEEBAR LINE	80.	38.9	-13.2	37.4	-16.4			411
KNEEBAR LINE	300.	38.9	-13.2	37.4	-16.4			411
DASH	DASHMATL		0.	1.	1.	1.		401
DASH	1.	2.	1.	0.	0.			402
DASHLINE	DASH		5.	0.	1.	1.		409
DASHLINE	4.							410
DASHLINE	0.	54.7	-5.6	54.2	-20.1			411
DASHLINE	40.	54.7	-5.6	54.2	-20.1			411
DASHLINE	80.	47.9	-5.6	47.4	-20.1			411
DASHLINE	300.	47.9	-5.6	47.4	-20.1			411
DASHMATL	0.	0.	0.	100.	101.	0.	0.	403
DASHMATL	5.				DSTAT	IZERO	DGR	404
DGR 0.	0.							405
DGR .001	.01							405
DGR 10.	.01							405
DGR 0.	1.							406
DGR .001	.91							406
DGR .75	.8							406
DGR 1.5	.5							406
DGR 10.	.3							406
DSTAT 0.	0.							407
DSTAT 0.75	2100.							407
DSTAT 1.5	9000.							407
DSTAT 40.	9000.							407
FMATL	0.	0.	0.	100.	101.	0.	0.	403
FMATL	5.	0.	0.	0.	FSTAT	IZERO	FGR	404
FGR 0.	0.							405
FGR 2.	.7							405
FGR 0.	1.							406

FIGURE 128 Complete Data Set for Simulation Example 2 (page 3 of 5)

FGR	2.	.2							406
FSTAT	0.	0.							407
FSTAT	.25	100.							407
FSTAT	.5	400.							407
FSTAT	.75	1200.							407
FSTAT	1.	2400.							407
FSTAT	1.5	4000.							407
FSTAT	2.	4600.							407
FSTAT	3.	5000.							407
FSTAT	4.	5200.							407
FSTAT	6.	5400.							407
FSTAT	10.	5600.							407
FSTAT	16.	10000.							407
1.	1.	.25	.125	.125					412
1.	2.	.5							412
1.	3.	.5							412
1.	4.	.4							412
2.	2.	.8							412
3.	1.	.4							412
3.	2.	.5							412
3.	4.	.4							412
3.	5.	.67							412
3.	6.	.9							412
2.75	7.	0.	0.	0.	1.8	-1.96	14.12	-5.07	218
0.	0.	0.	0.	0.	-33.52	17.	-1.2		501
100.	0.	15.13	-.00178	6600.	6600.	10.			701
NO STRENGTH				14.04	-.00172	2.	1.		702
6% WEBBING #1				6% WEBBING #2					703
6% WEBBING #1		0.	0.	0.16	14.36	15.04	0.	0.	704
6% WEBBING #1		5.				SBELT1	IZERO	GBELT1	705
GBELT1	0.	0.							706
GBELT1	.16	0.							706
GBELT1	1.37	.56							706
GBELT1	6.15	.95							706
GBELT1	40.	.95							706
GBELT1	0.	1.							707
GBELT1	1.37	.33							707
GBELT1	2.06	.19							707
GBELT1	6.15	.05							707
GBELT1	40.	.05							707
SBELT1	0.	0.							708
SBELT1	.533	1500.							708
SBELT1	9.91	2000.							708
SBELT1	11.28	5300.							708
SBELT1	14.36	6600.							708
SBELT1	15.04	0.							708
6% WEBBING #2		0.	0.	.155	13.85	14.51	0.	0.	704
6% WEBBING #2		5.				SBELT2	IZERO	GBELT1	705
SBELT2	0.	0.							708
SBELT2	.396	1150.							708
SBELT2	9.56	1650.							708
SBELT2	10.9	5300.							708
SBELT2	13.85	6600.							708
SBELT2	14.51	0.							708
NO STRENGTH		0.	0.	0.	10.	11.	0.	0.	704
NO STRENGTH		5.				SNOSTR	IZERO	GNOSTR	705
GNOSTR	-1.	0.							706
GNOSTR	-1.	1.							707
SNOSTR	-1.	0.							708
									1000

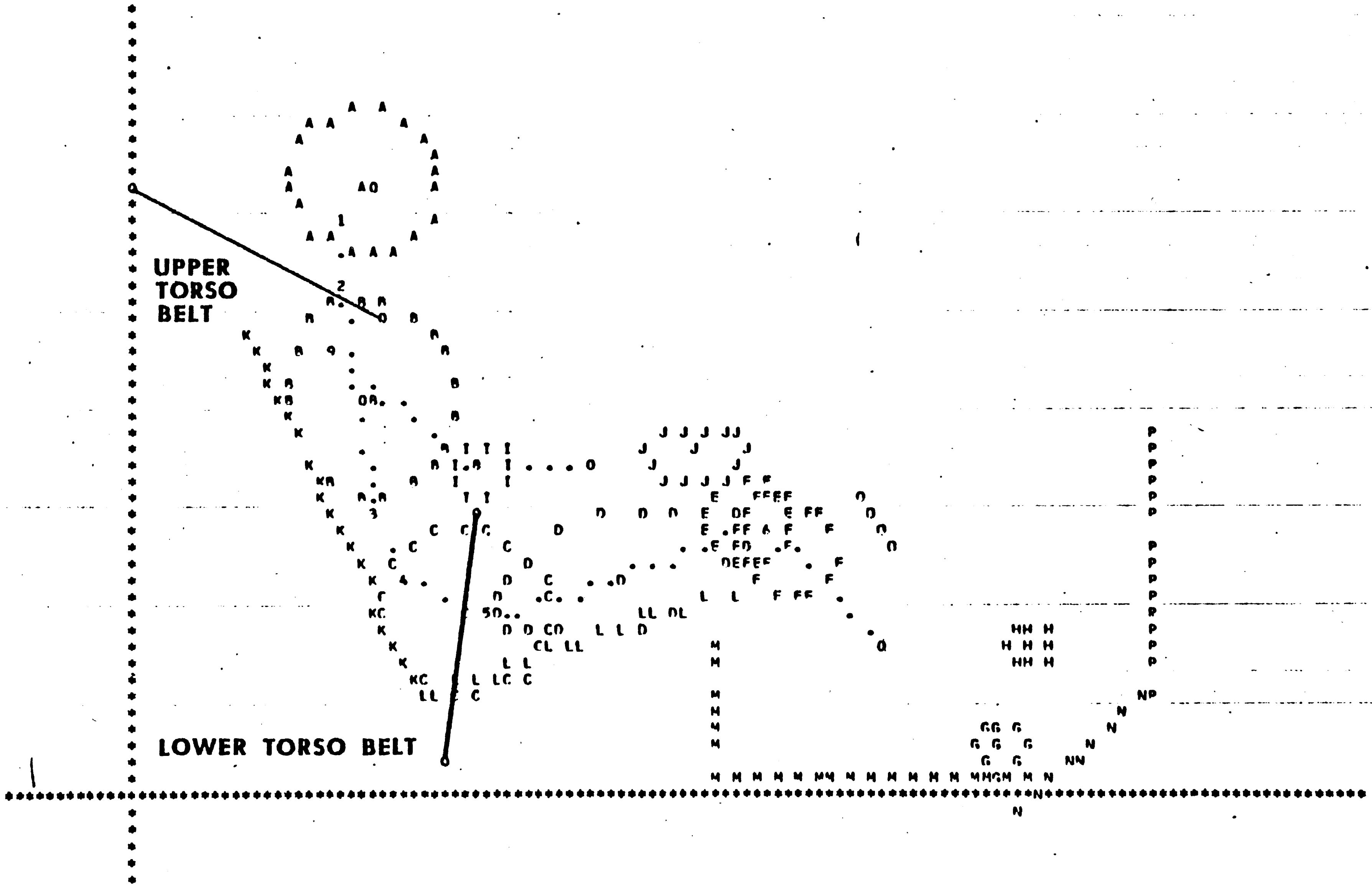
FIGURE 128 Complete Data Set for Simulation Example 2 (page 4 of 5)

```
 1,46-48,10-14,21, 22,37,38,49,50,15,23-26,2-5, 18-20,33-36,30-32,16,          1001
27-29,39,17,40,6-9, 45                                                          1002
0.        0.        0.        11.55     .025                                    1003
40.       500.      560.      0.        .85       201.      5.        5.        1004
0.        0.        -3.       62.       5.        -44.      10.       0.        1500
21.       0.        0.        1.        1.        0.        1.        0.    10. 1501
                                                                                1600
```

FIGURE 128 Complete Data Set for Simulation Example 2 (page 5 of 5)

JUN 24, 197702:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 41-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 0.0 MSEC.

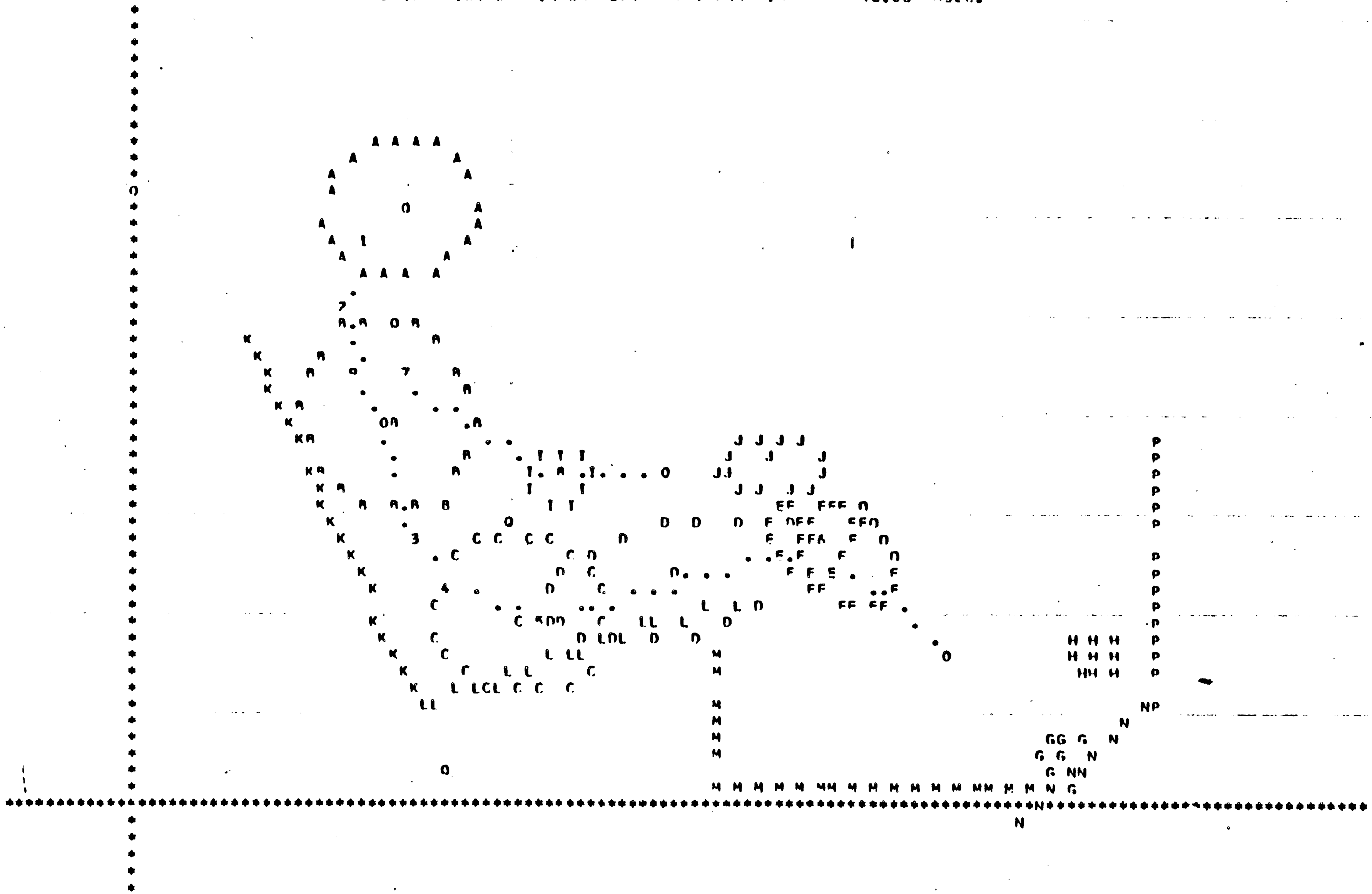


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) . X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129a Printer-Plot Time Sequence for Example 2 (0 ms)

JUN 24, 1977 02:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 45-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 40.00 MSEC.

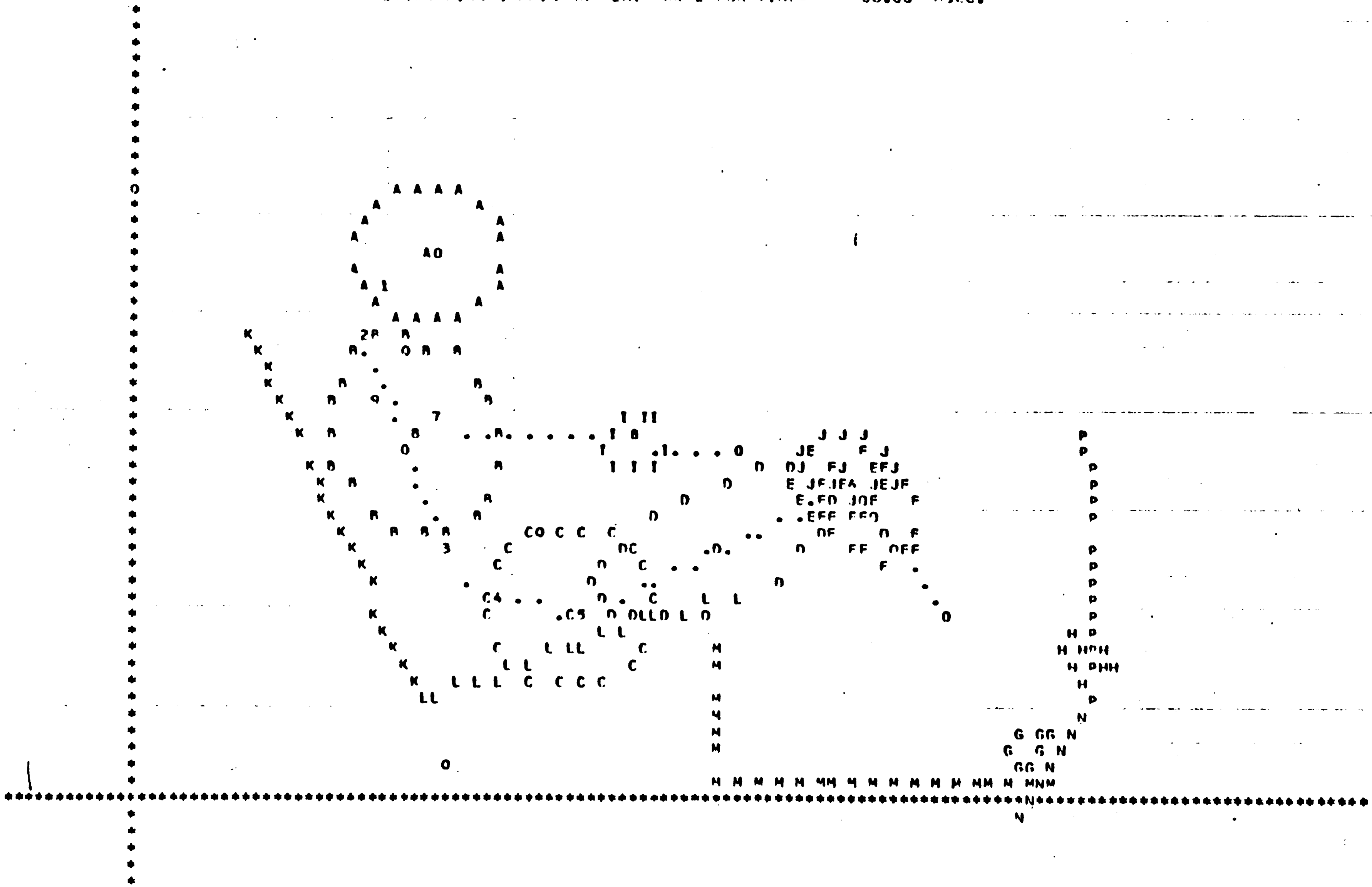


COORDINATE RANGES FOR PLOT ARE X= -6.55 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129b Printer-Plot Time Sequence for Example 2 (40 ms)

JUN 24, 1977021:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 47-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 60.00 MSEC.

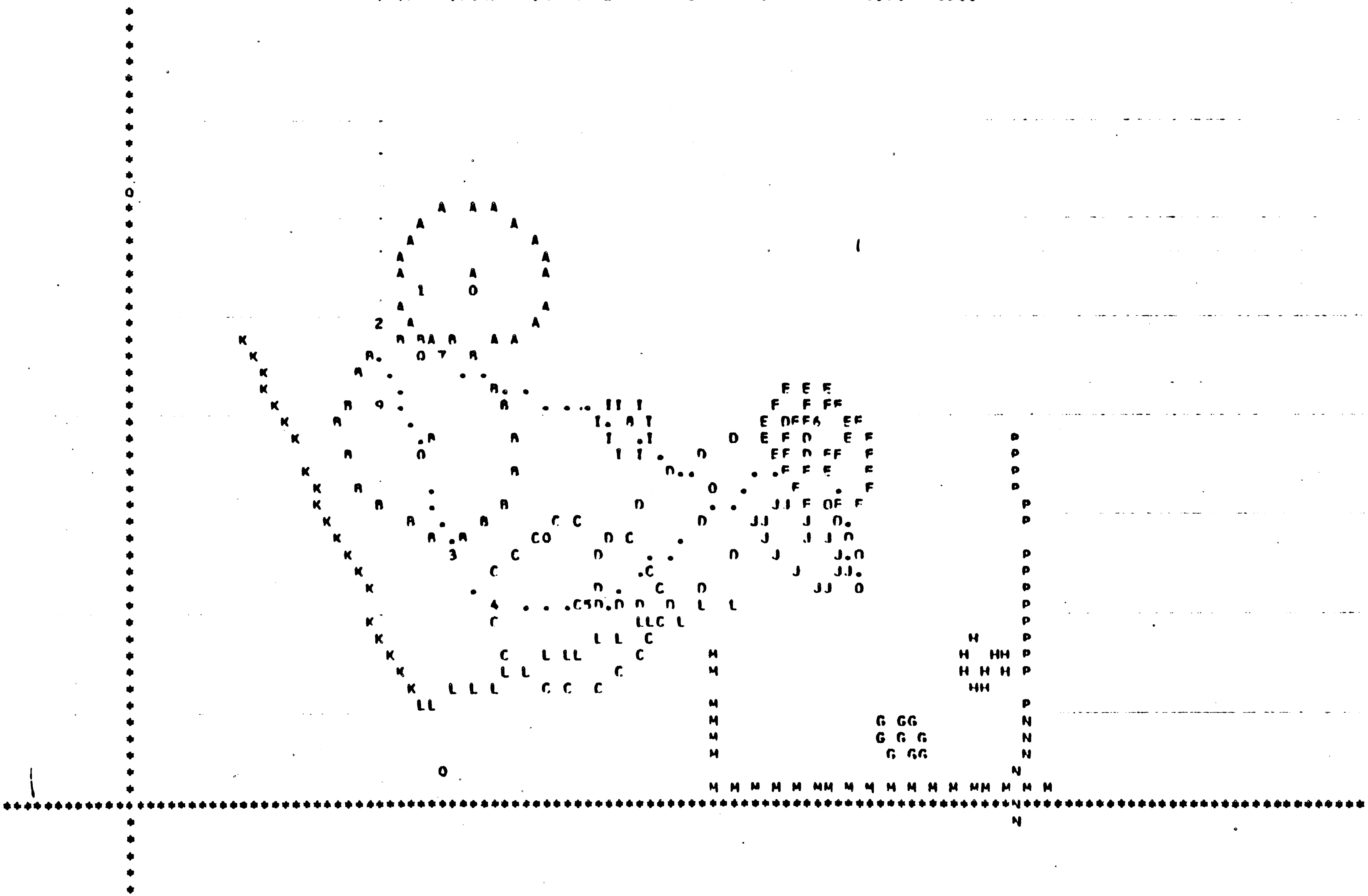


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) . X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129c Printer-Plot Time Sequence for Example 2 (60 ms)

JUN 24, 197702:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 49-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 80.00 MSEC.

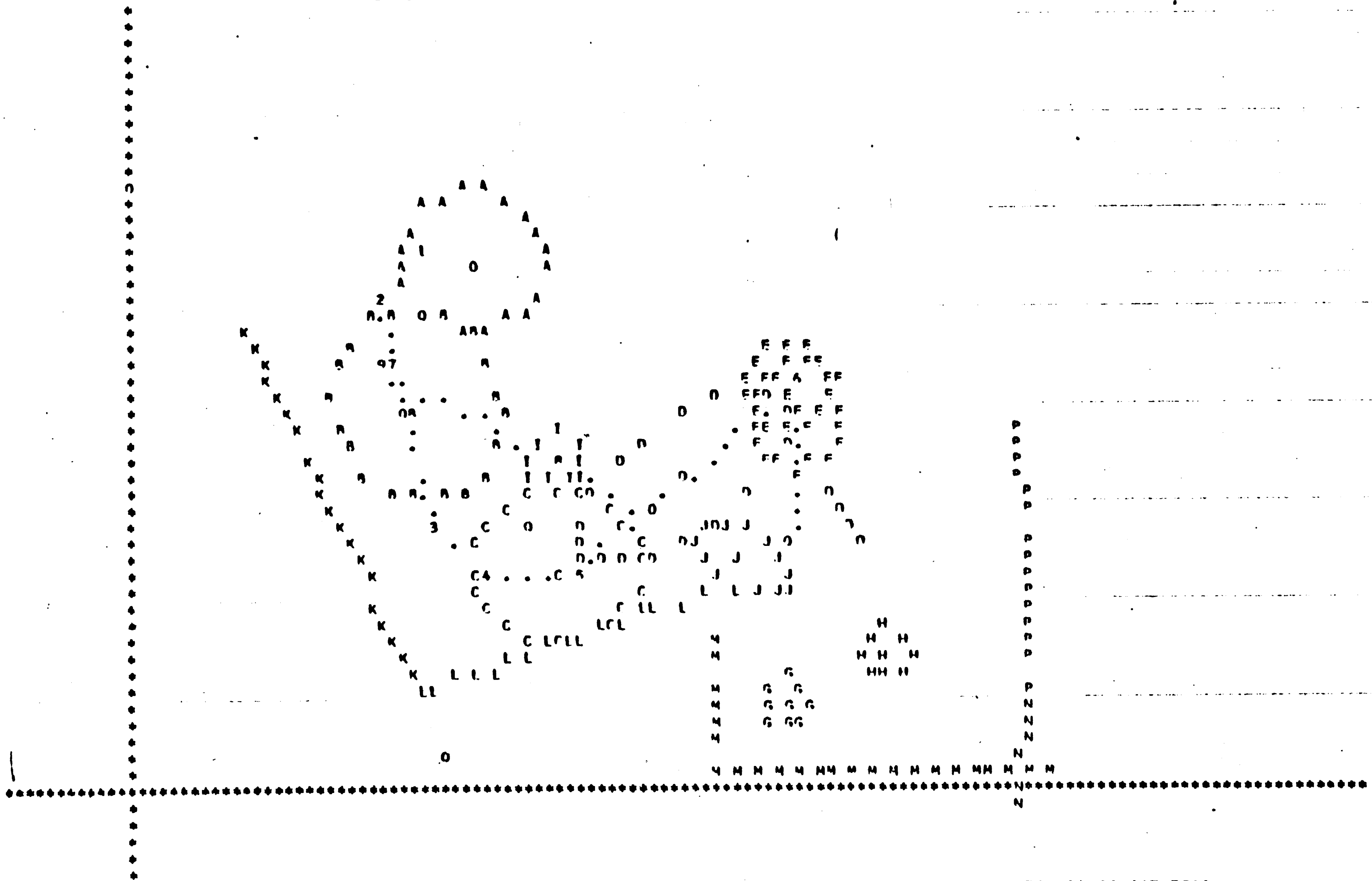


COORDINATE RANGES FOR PLOT ARE X= -6.55 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129d Printer-Plot Time Sequence for Example 2 (80 ms)

JUN 24, 1977 02:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 51-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 100.00 MSEC.

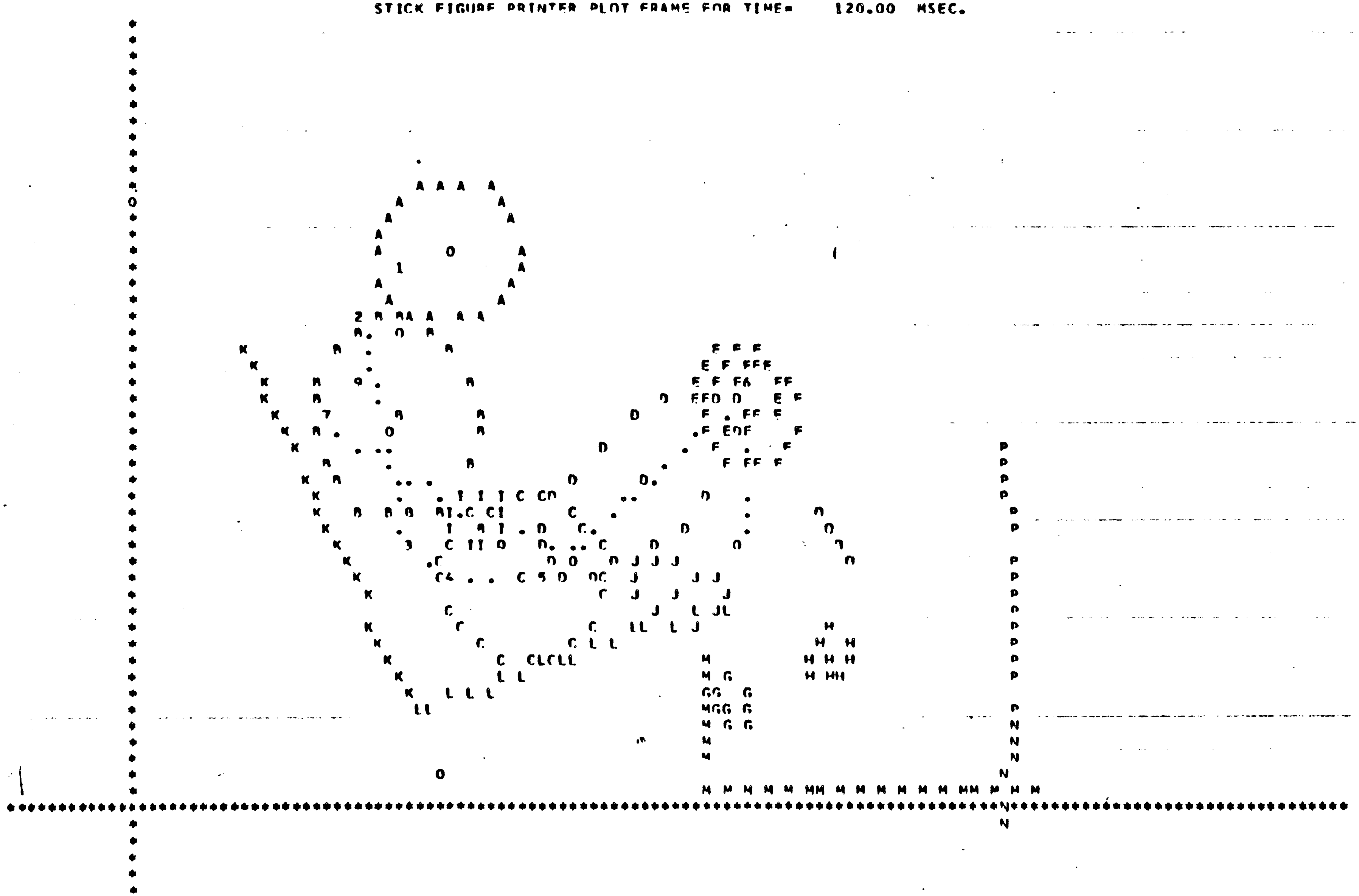


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) . X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129e Printer-Plot Time Sequence for Example 2 (100 ms)

JUN 24, 1977 02:02:15 HVMA 2-D TUTORIAL EXAMPLE #2 PAGE 53-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 120.00 MSEC.

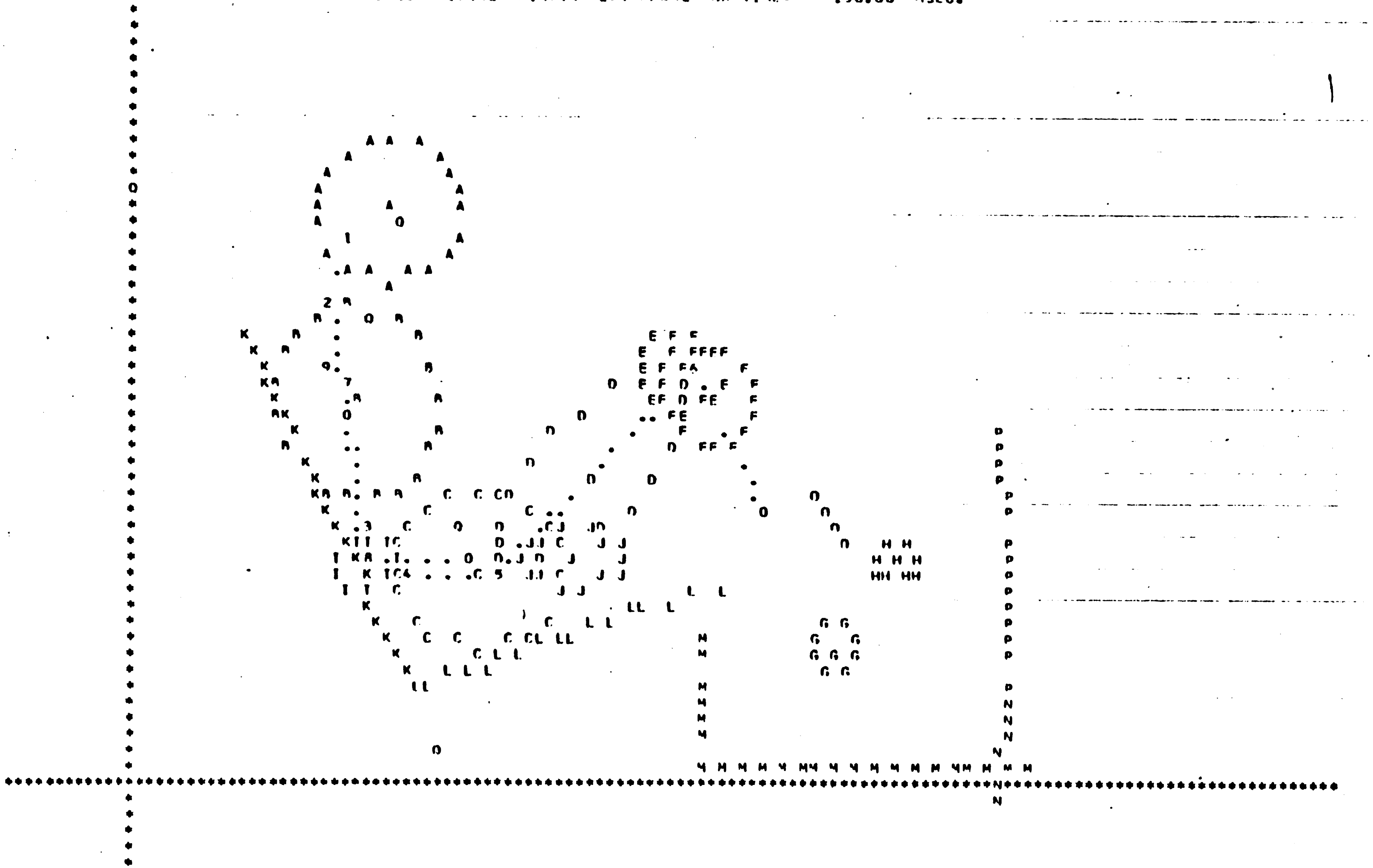


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) . X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129f Printer-Plot Time Sequence for Example 2 (120 ms)

JUN 24, 1977 02:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 56-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 150.00 MSEC.

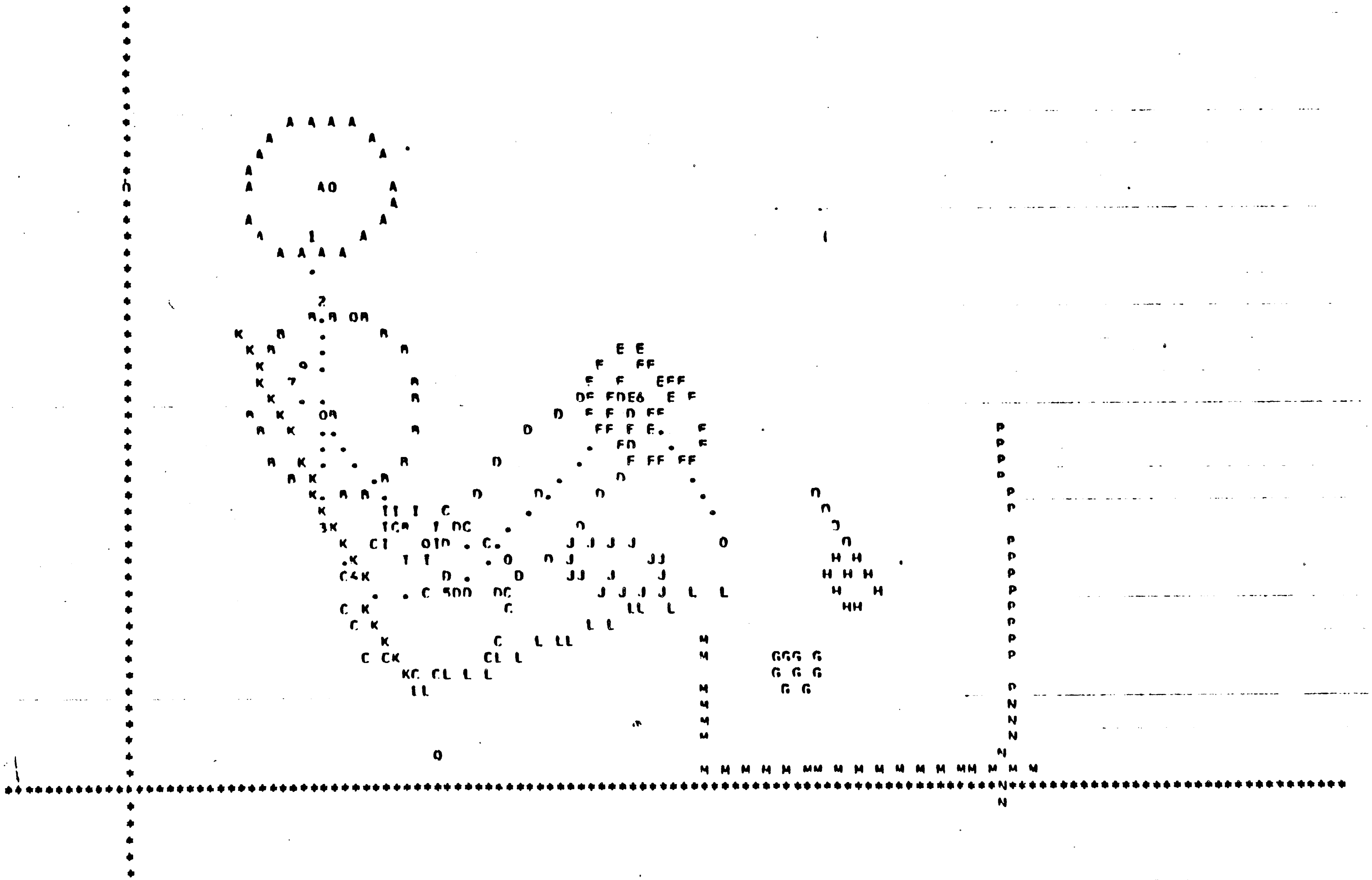


COORDINATE RANGES FOR PLOT ARE X= -6.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) . X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129g Printer-Plot Time Sequence for Example 2 (150 ms)

JUN 24, 1977021021:15 HVMA 2-D TUTORIAL EXAMPLE #2 PAGE 61-45
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR DEC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

STICK FIGURE PRINTER PLOT FRAME FOR TIME= 200.00 MSEC.



COORDINATE RANGES FOR PLOT ARE X= -4.56 (AT LEFT) TO 65.56 (AT RIGHT) AND Z= 5.00 (AT BOTTOM) TO -44.00 (AT TOP)
SCALE FACTOR IS (IN) = 5.547 (IN) , X AND Z POINT RESOLUTION ERRORS EQUAL RESPECTIVELY 0.277 AND 0.462 (IN) IN SCALE.

FIGURE 129h Printer-Plot Time Sequence for Example 2 (200 ms)

```
38        0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.0                100.000000000      101.000000000      0.0
          -7.000000000       0.0                -8.000000000       0.350000024
          1                  1            -9             -9
94    0    0    0    1    1    -3    640      1.000000000        0.0
          0.0                0.0                0.0                0.0                795.950439453      0.0
          54.699996948       0.0                5.600000381        54.199996948       -795.950439453     20.100006104
          -0.500000000       0.0                -14.500005722UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU   53.456649780       187.499984741      0.0                0.0
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
 88   757        0.0        0.0        0.0        0.0
 52   191   393   757   896    0
 53   191   393  3398  -896  1768   558    0    0
 52   379     0   766   906    0
 53   379     0     0  -906    0     0    0    6

BELT DEBUG AT T=   0.100000E-02
 52    -9     0   902   945    0
 53    -9    -1  3570  -945 -1816   646    0    0
    91     902    646     0    -1816    3570    -9    459    0    0.0

EVAL DEBUG AT T =    0.001000
36    1  662  668    5    1    0    0
          0.003051758        0.853636146        0.0                0.0                0.0                0.0
37      0.0010000      0.0        0.0        0.0        0.0        0.0        0.0030518      0.8536361
        0.0            0.0        0.0        0.0        0.0        0.0        0.0            0.0
38        0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.0                10.000000000       11.000000000       0.0
          0.0                0.0                1.000000000        0.350000024
          1                  1            662            662
94    0    0    0    1    1    662    640      1.000000000        0.0
          0.0                0.0                0.0                0.0                795.950439453      0.0
          54.699996948       0.0                5.600000381        54.199996948       -795.950439453     20.100006104
          -0.500000000       0.0                -14.500005722UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU   0.0                0.0                0.0                0.0
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
 88   902        0.0031        0.8536        0.0        0.0
76   2  0.305176E-02  0.853636E+00  0.0        -0.0        0.0        -0.0        0.0
77      0.375844E+02  0.853636E+00  0.100000E+03  0.688999E+00  0.688999E+00UUUUUUUUUUUUUUU  0.0      0.100000E-01   0
 52   -11     0   775   927    0
 53   -11    -1  3441  -927  1790   602    0   165
    91     775    602     0    1780    3441    -11    463    0    0.0

EVAL DEBUG AT T =    0.001000
36    1  -15  618    3    1    0    0
          0.002670705        -0.321057022       7.516055107        2814.258789063     0.0                0.0
37      0.0010000      0.0        0.0        0.0        0.0        0.0100366      0.0026707      -0.3210570
        0.0            0.0        0.0        0.0        0.0        0.0044582      0.0017800      -0.0
38        0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.0                0.0                0.0                0.0
          0.0                0.0                0.160000026        14.359999657       15.039999962       5.009305954
          -13.000000000      0.0                -14.000000000      0.350000024
          1                  1            -15            -15
```

FIGURE 130   Example Debugging Printout from Example 2

CONTACT FORCES FOR UPPER TORSO BELT MADE OF 6% WEBBING #1 VS. UPPER TORSO LINK MADE OF

TIME (MSEC)	DEFLECTION (IN)	DEFLECTION RATE (IN/SEC)	RING EQUIL. TENSION (LB)	UNADJUSTED TENSION (LB)	TENSION ADJUSTMENT (LB)	RESULTANT FORCE (LB)	RESULTANT HEADING (DEGREES)	ABSORBED ENERGY (FT-LBS)
0.0	0.002	-0.0	0.0	5.009	0.0	5.009	-26.485	0.0
5.00	0.027	13.419	0.0	74.643	0.0	74.643	-26.436	0.0
10.00	0.186	38.526	0.0	523.294	0.0	523.294	-26.087	0.0
15.00	0.309	8.115	0.0	869.567	0.0	869.567	-25.743	0.0
20.00	0.340	12.848	0.0	957.781	0.0	957.781	-25.671	0.0
25.00	0.411	15.907	0.0	1157.508	0.0	1157.507	-25.816	0.0
30.00	0.467	11.172	0.0	1315.537	0.0	1315.537	-26.313	0.0
35.00	0.522	12.541	0.0	1469.601	0.0	1469.600	-27.084	0.0
40.00	0.547	2.651	0.0	1500.744	0.0	1500.743	-28.118	0.0
45.00	0.638	40.872	0.0	1505.612	0.0	1505.611	-29.259	0.0
50.00	0.954	81.385	0.0	1522.442	0.0	1522.442	-30.136	0.0
55.00	1.407	99.309	0.0	1546.586	0.0	1546.586	-30.713	0.0
60.00	1.947	116.695	0.0	1575.393	0.0	1575.393	-30.916	0.0
65.00	2.479	97.409	0.0	1603.780	0.0	1603.779	-30.774	0.0
70.00	2.810	40.056	0.0	1621.412	0.0	1621.411	-30.418	0.0
75.00	2.891	-5.706	0.0	1619.998	0.0	1619.997	-29.749	3428.47
80.00	2.847	-10.395	0.0	1518.209	0.0	1518.209	-28.483	0.0
85.00	2.751	-27.963	0.0	1300.570	0.0	1300.570	-27.187	0.0
90.00	2.589	-34.975	0.0	961.904	0.0	961.803	-26.268	0.0
95.00	2.400	-39.016	0.0	613.058	0.0	613.058	-25.720	0.0
100.00	2.192	-45.534	0.0	281.315	0.0	281.315	-25.470	0.0
105.00	1.959	-43.019	0.0	0.0	0.0	0.0	0.0	0.0
110.00	1.763	-36.056	0.0	0.0	0.0	0.0	0.0	0.0
115.00	1.592	-34.579	0.0	0.0	0.0	0.0	0.0	0.0
120.00	1.394	-47.934	0.0	0.0	0.0	0.0	0.0	0.0
125.00	1.148	-50.707	0.0	0.0	0.0	0.0	0.0	0.0
130.00	0.887	-55.345	0.0	0.0	0.0	0.0	0.0	0.0
135.00	0.621	-53.877	0.0	0.0	0.0	0.0	0.0	0.0
140.00	0.352	-55.047	0.0	0.0	0.0	0.0	0.0	0.0
145.00	0.085	-53.925	0.0	0.0	0.0	0.0	0.0	0.0
150.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
155.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
160.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
165.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
170.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
175.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
180.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
185.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
190.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
195.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 131 Belt System Response for Example 2

JUN 24, 197702:02:15 MVMA 2-D TUTORIAL EXAMPLE #2 PAGE 4-12
GM HYBRID II DUMMY (PRELIMINARY DATA) KNEE BAR OCC. COMP. DISPL. 30MPH FRONT BARRIER FORCE-LIM. HARNESS NO LAP BELT

ACCELERATION OF BODY LINK ANGLES (DEG/SEC**2) (RELATIVE TO VEHICLE)

TIME	HEAD	NECK	UPPER TORSO	MID TORSO	LOW TORSO	UPPER LEG	LOWER LEG	SHOULDER	UPPER ARM	LOWER ARM
0.0	-0.08	2472.72	-3369.38	4187.97	4791.00	-3654.55	-532.90	-3369.38	-0.02	0.00
5.0	-36277.99	202123.63	-122974.75	511293.63	-136217.06	9182.16	-9746.21	-122974.75	38936.98	-13613.07
10.0	-69937.50	142145.50	-101421.94	535445.75	-144715.25	5840.46	-9162.04	-5858771.00	18355.12	-1235.52
15.0	-50702.54	24220.45	-13962.38	114147.81	5539.62	-3808.85	46.16	-638069.00	19995.30	-1834.06
20.0	4892.39	-132393.63	76780.38	-271422.94	99105.56	-3818.76	9780.20	-64139.92	23100.53	-2981.26
25.0	11630.43	-102146.25	59878.74	-218069.56	99105.94	-5304.78	10334.03	-105636.75	27683.31	-4512.86
30.0	9467.41	-130537.19	81664.56	-261257.63	93090.50	-5863.14	11960.36	123920.00	-23744.93	9083.46
35.0	-13672.41	-105207.44	86282.39	-251464.06	95182.56	-9044.09	11730.34	50785.32	-15507.76	6861.76
40.0	-14926.60	91887.49	-42421.32	242983.19	-63910.83	19370.45	-42745.56	-127553.38	74262.50	-20218.74
45.0	39498.34	-22120.58	43914.52	-313123.06	73345.88	107922.25	-323136.19	-354468.25	233964.31	-80275.25
50.0	7940.16	-3444.15	-3637.99	-44456.77	2248.92	80246.69	-392992.50	-96550.50	110156.31	-73141.94
55.0	-11989.90	-107785.50	31527.12	-269215.31	23709.77	10740.67	25916.59	647656.88	-325770.00	24846.93
60.0	-18656.94	-153326.25	39202.44	-295571.06	12372.99	58936.93	58442.38	549960.88	-287023.88	-13952.23
65.0	-92188.56	22549.05	-71599.88	190119.06	-76477.06	9564.13	30520.02	-6055.24	19304.21	-178778.50
70.0	-51852.16	55610.06	-91518.38	214786.13	-45751.32	-85118.31	39773.69	-72172.50	-72213.63	-180260.44
75.0	-8930.25	61076.37	-9315.07	-26092.86	-22868.02	-51734.41	-390.03	-417572.00	-46930.01	349000.56
80.0	30610.19	81348.75	-36117.29	205201.13	-44494.70	-25690.53	-1158.93	-78471.75	-32420.76	227261.44
85.0	94420.19	45627.31	14781.25	-13465.64	35007.38	-13489.38	7997.40	-197095.25	92000.56	20065.71
90.0	131209.31	29738.05	32527.42	-131764.44	67698.44	-7998.28	12310.14	-296780.56	19735.95	19071.18
95.0	115031.94	56570.52	-21963.40	117033.13	-34962.05	5434.86	11296.11	-1006787.63	11785.10	9639.82
100.0	56579.57	-7604.69	28282.15	-84393.98	-5462.32	15363.62	15266.59	-2801550.00	17503.61	2179.29
105.0	31652.58	13532.64	21721.50	-103914.63	-5318.95	20489.11	17275.59	2085407.00	18358.71	4898.86
110.0	29835.16	90923.81	-43824.30	123817.69	-23117.95	-5057.83	41320.36	339520.56	3082.96	18634.95
115.0	13922.72	11480.43	-7973.85	95904.75	-38995.58	43982.23	296038.63	105292.50	-68472.13	38260.85
120.0	-13290.49	72839.13	-27225.04	140956.50	-50737.55	-2714.30	-5852.54	35314.27	-124729.00	37192.25
125.0	11307.13	79625.00	-49405.37	208207.81	-62674.27	-4571.51	-8284.20	78377.88	-110690.31	1104.51
130.0	-11356.64	135331.00	-70999.06	270748.13	-77755.88	-4979.86	-9469.11	234228.81	-45340.96	-19871.89
135.0	-9333.99	99292.06	-59928.29	233828.06	-69529.69	-5035.82	-9030.35	522193.00	21784.67	-31598.70
140.0	-17581.50	101894.63	-64621.43	259533.63	-72497.38	-4572.51	-9405.40	464822.63	31980.51	-30794.24
145.0	-17372.78	109560.06	-70235.00	271788.88	-74122.13	-3770.93	-9510.38	-619088.88	41650.56	-27209.38
150.0	-12643.99	111431.88	-73931.94	275165.50	-73583.06	-2843.00	-9575.76	-569465.38	111948.31	-22023.69
155.0	-9210.14	114794.69	-75651.75	269000.81	-70734.44	221.19	-37138.03	-313556.38	209617.69	-44237.49
160.0	-27907.26	161274.44	-82943.31	286656.69	-76994.63	14863.13	-134172.44	-249063.94	217110.56	-65264.53
165.0	-6237.63	85943.50	-60632.59	212280.00	-60989.81	5576.13	-25592.93	-296225.31	22597.65	-18096.84
170.0	-28062.97	166635.56	-82738.56	262192.06	-71798.38	5489.44	-15006.77	-135756.13	-3809.79	-12194.30
175.0	1380.27	70281.00	-52696.13	171726.38	-59704.55	3945.74	-6803.27	238426.13	-33810.54	-6744.58
180.0	-15310.37	104029.94	-61733.41	195275.44	-60390.52	4750.87	-8519.39	204336.63	-53852.91	2578.55
185.0	-11496.09	36996.97	-43320.99	159204.56	-53119.63	3093.68	-9782.53	144288.13	-64538.80	9343.79
190.0	-44145.89	99959.06	-68933.63	259318.50	-63474.78	3247.14	-12222.36	85436.06	-80516.63	14715.38
195.0	-54832.52	77816.75	-69308.75	295854.69	-63156.43	1551.25	-13167.94	127607.25	-75039.69	16257.81
200.0	-67433.13	93982.38	-83737.00	365517.19	-68741.13	832.03	-13527.80	115966.56	-8261.88	-449.33

FIGURE 132 Body Link Angle Accelerations for Example 2

UNFILTERED ACCELERATIONS (G'S)

	HEAD			CHEST			HIP		
TIME	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	X	Z	RESULTANT
0.0	-0.199	0.980	1.000	0.599	-0.625	0.866	-0.518	-1.623	1.704
5.00	2.316	-0.696	2.418	15.631	2.216	15.787	4.520	1.181	4.672
10.00	6.527	-1.005	6.604	24.832	0.574	24.838	3.780	0.245	3.788
15.00	8.050	3.715	8.866	16.691	2.630	16.897	-3.808	-3.398	5.104
20.00	6.491	11.898	13.553	6.086	2.497	6.578	-9.625	-1.047	9.682
25.00	7.532	17.871	19.393	9.752	3.924	10.512	-10.939	-1.655	11.063
30.00	9.025	21.299	23.132	10.614	1.414	10.708	-12.352	-2.116	12.532
35.00	12.569	21.906	25.255	11.696	-1.615	11.807	-13.244	-2.890	13.556
40.00	14.908	21.856	26.456	22.950	2.479	22.984	-11.268	0.107	11.269
45.00	11.017	17.527	20.702	2.205	-0.956	2.404	-23.992	9.367	25.756
50.00	12.242	6.461	13.842	14.756	-4.949	15.564	-23.133	3.678	23.423
55.00	13.947	-0.401	13.953	14.637	-16.963	22.405	-40.477	8.136	41.286
60.00	15.017	-2.633	15.246	17.971	-23.002	29.190	-46.842	10.164	47.932
65.00	23.183	5.699	23.373	38.481	-26.318	46.620	-46.803	-7.787	47.447
70.00	24.224	18.616	30.551	35.913	-30.789	47.304	-47.150	-20.374	51.363
75.00	24.035	26.130	35.502	1.211	-29.776	29.801	-17.057	-19.126	25.627
80.00	21.997	15.624	26.981	19.642	-4.248	20.096	-7.904	-6.788	10.419
85.00	18.947	18.808	26.697	14.027	3.114	14.368	-9.682	-1.165	9.752
90.00	12.544	19.748	23.395	6.995	4.897	8.531	-10.522	2.424	10.797
95.00	7.346	14.498	16.252	11.571	8.349	14.280	-4.068	6.653	7.798
100.00	4.278	8.196	9.236	1.691	2.119	2.711	-2.311	11.312	11.546
105.00	3.151	5.133	6.023	-3.673	2.148	4.255	-0.683	13.022	13.040
110.00	1.475	2.308	2.740	4.767	9.368	10.511	-2.424	3.424	4.195
115.00	0.936	2.418	2.559	5.186	5.273	7.395	4.106	4.389	6.011
120.00	2.572	7.992	8.387	6.513	4.361	7.838	2.321	2.568	3.461
125.00	-0.165	10.471	10.472	7.951	5.942	9.926	2.665	1.035	2.859
130.00	0.804	9.491	9.525	8.399	7.060	10.972	3.330	0.242	3.339
135.00	-0.411	5.343	5.359	7.529	5.466	9.304	3.099	0.242	3.108
140.00	-0.364	2.138	2.228	8.852	6.274	10.849	3.654	0.009	3.654
145.00	-0.919	1.001	1.359	8.307	6.518	10.559	4.242	-0.071	4.243
150.00	-1.982	0.903	2.178	7.383	6.534	9.859	4.752	-0.049	4.752
155.00	-3.196	0.992	3.346	5.825	6.751	8.917	5.324	0.335	5.334
160.00	-2.302	1.092	2.544	4.467	8.053	9.209	6.954	1.624	7.141
165.00	-4.986	1.425	5.089	2.875	4.352	5.216	5.721	0.781	5.774
170.00	-3.765	-0.016	3.765	1.409	5.510	5.688	7.015	0.559	7.038
175.00	-7.416	-1.646	7.597	-1.666	0.412	1.716	7.118	0.023	7.118
180.00	-8.234	-4.779	9.521	-2.749	1.598	3.180	8.533	-0.357	8.541
185.00	-10.948	-5.492	12.248	-2.155	-0.754	2.284	8.496	-1.314	8.597
190.00	-9.628	-4.798	10.757	2.174	2.719	3.481	9.937	-2.202	10.179
195.00	-8.929	-1.540	9.061	7.527	3.451	8.281	9.756	-3.027	10.215
200.00	-6.942	1.556	7.114	13.099	5.634	14.259	9.737	-3.220	10.255

FIGURE 133 Unfiltered Head, Chest, and Hip Accelerations for Example 2

SEVERITY INDICES FOR UNFILTERED ACCELERATIONS

HEAD: HIC= 183.27, BEG. TIME= 20.00, END TIME= 95.00
3 MSEC AVER= 35.055 AT TIME= 75.00
PEAK= 35.502 AT TIME= 75.00

CHEST: 3 MSEC AVER= 47.405 AT TIME= 69.00
PEAK= 47.514 AT TIME= 69.00

	HEAD						CHEST					
	SEVERITY INDEX			GMR MODIFIED S.I.			SEVERITY INDEX			GMR MODIFIED S.I.		
TIME	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT	A-P	S-I	RESULTANT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00	0.02	0.00	0.02	0.00	0.01	0.00	3.36	0.04	3.49	0.10	0.00	0.11
10.00	0.22	0.01	0.23	0.01	0.02	0.01	12.28	0.06	12.46	0.95	0.01	0.96
15.00	1.32	0.02	1.38	0.01	0.02	0.01	28.28	0.07	28.53	3.39	0.01	3.42
20.00	2.39	0.90	3.55	0.02	0.03	0.05	31.25	0.16	31.74	3.50	0.02	3.55
25.00	3.04	5.41	9.40	0.02	0.21	0.35	32.26	0.29	32.99	3.50	0.02	3.56
30.00	4.22	14.07	20.31	0.03	0.86	1.41	34.34	0.38	35.29	3.53	0.02	3.59
35.00	6.38	24.91	34.39	0.06	1.85	3.29	36.43	0.39	37.40	3.55	0.03	3.61
40.00	10.18	36.18	52.44	0.15	2.90	5.92	47.33	0.42	48.43	4.87	0.03	4.96
45.00	13.56	45.64	67.35	0.23	3.59	7.72	53.80	0.48	55.08	5.30	0.03	5.42
50.00	15.52	48.50	73.00	0.25	3.65	7.94	55.80	0.54	57.27	5.36	0.04	5.49
55.00	18.80	49.62	76.54	0.33	3.65	8.02	60.33	3.48	66.01	5.51	0.14	6.23
60.00	22.54	48.65	80.38	0.42	3.65	8.13	65.06	11.21	80.73	5.69	0.72	8.34
65.00	30.62	49.71	88.66	1.10	3.66	8.95	93.32	28.79	134.55	15.11	3.48	34.09
70.00	43.83	51.81	107.12	2.59	3.79	12.10	129.02	55.46	208.92	25.56	9.70	73.95
75.00	57.94	64.93	139.45	4.27	5.46	21.17	140.88	85.02	255.88	27.63	17.05	90.78
80.00	69.98	75.70	165.51	5.45	6.42	27.12	141.76	94.80	266.91	27.70	18.01	91.87
85.00	79.96	81.36	184.92	6.22	6.68	29.97	149.09	94.83	274.23	28.29	18.01	92.47
90.00	84.94	90.14	201.15	6.39	7.32	32.15	150.95	95.01	276.46	28.31	18.02	92.49
95.00	86.52	96.68	210.41	6.40	7.43	32.82	151.17	95.32	277.23	28.31	18.02	92.51
100.00	86.94	98.82	213.30	6.40	7.45	32.96	151.94	95.72	278.61	28.32	18.02	92.52
105.00	87.10	99.47	214.22	6.41	7.65	32.97	151.99	95.77	278.72	28.32	18.02	92.52
110.00	87.13	99.57	214.37	6.41	7.65	32.97	152.19	95.87	279.06	28.32	18.03	92.53
115.00	87.14	99.61	214.43	6.41	7.66	32.97	152.62	96.41	280.20	28.32	18.03	92.53
120.00	87.16	99.93	214.79	6.42	7.66	32.97	152.99	96.49	280.71	28.32	18.04	92.53
125.00	87.17	101.35	216.25	6.42	7.67	32.89	153.69	96.92	281.92	28.33	18.04	92.54
130.00	87.17	103.09	218.01	6.43	7.68	32.90	154.72	97.44	283.86	28.33	18.04	92.56
135.00	87.17	103.89	218.92	6.44	7.59	32.90	155.59	97.91	285.43	28.33	18.04	92.57
140.00	87.18	104.04	218.97	6.44	7.69	32.91	156.45	98.25	286.86	28.34	18.04	92.59
145.00	87.18	104.05	218.99	6.45	7.69	32.91	157.55	98.78	288.76	28.34	18.04	92.61
150.00	87.19	104.05	219.01	6.46	7.70	32.91	158.41	99.32	290.43	28.34	18.05	92.62
155.00	87.25	104.06	219.08	6.46	7.70	32.92	159.00	99.87	291.78	28.35	18.05	92.63
160.00	87.35	104.07	219.19	6.46	7.71	32.92	159.27	100.49	292.81	28.35	18.05	92.63
165.00	87.52	104.09	219.38	6.46	7.71	32.92	159.39	100.97	293.50	28.35	18.05	92.63
170.00	87.74	104.09	219.61	6.46	7.72	32.92	159.45	101.23	293.88	28.35	18.05	92.63
175.00	88.17	104.09	220.06	6.47	7.73	32.92	159.46	101.30	293.96	28.36	18.05	92.64
180.00	89.04	104.19	221.13	6.47	7.73	32.93	159.50	101.31	294.02	28.36	18.06	92.64
185.00	90.49	104.53	223.17	6.48	7.73	32.95	159.56	101.32	294.09	28.37	18.06	92.64
190.00	92.15	104.87	225.44	6.49	7.73	32.98	159.57	101.34	294.13	28.37	18.07	92.65
195.00	93.95	104.94	227.41	6.51	7.74	33.00	160.46	101.41	295.17	28.38	18.07	92.65
200.00	94.80	104.95	228.27	6.51	7.74	33.00	162.23	101.65	297.40	28.40	18.07	92.70

FIGURE 134 Severity Indices for Unfiltered Accelerations for Example 2