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WL/MN-TR-91-53

User Instructions for the 1991 Version of the EPIC Research Code

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JANUARY 1992

FINAL REPORT FOR PERIOD JANUARY - JUNE 1991

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
January 1992

3. REPORT TYPE AND DATES COVERED
Final; From January 1991 to June 1991

4. TITLE AND SUBTITLE
User Instructions for the 1991 Version of the EPIC Research Code

5. FUNDING NUMBERS
C:F08635-89-C-0074
PE: 62602F
PR: 2502
TA: 07
WU: 15

6. AUTHOR(S)
G.R. Johnson and R.A. Stryk

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Alliant Techsystems Inc.
7225 Northland Drive
Brooklyn Park, MN 55428

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Munitions Division
Armament Directorate, Wright Laboratory
Eglin Air Force Base, FL 32542-5434

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
WL/MN-TR-91-53

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

This report provides user instructions for the 1991 version of the EPIC Research code. This code has capabilities for 1D, 2D, and 3D geometries; and is intended to be used primarily for high velocity impact and explosive detonation computations. Example problems, including results and input data, are also provided.

14. SUBJECT TERMS
EPIC Code, Finite Element, Computations, High Velocity Impact, Explosive Detonation

15. NUMBER OF PAGES
142

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
Unlimited

NSN 7540-01-280-5500
N52844C(I)

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std Z39-18
298-102

PREFACE

This report on the EPIC computer code was prepared by Alliant Techsystems Inc., 7225 Northland Drive, Brooklyn Park, MN 55428, for the Armament Directorate, Wright Laboratory, Eglin Air Force Base, FL 32542, under Contract F08635-89-C-0074.

This effort was conducted during the period from January 1991 to June 1991. The authors would like to thank W.H. Cook, WL/MNMW program manager, for many helpful technical discussions. Contributions to this work were also provided by J.A. Schonhardt, Alliant Techsystems Inc.

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INTRODUCTION

This report provides user instructions for the 1991 version of the EPIC Research code. This code has capabilities for 1D, 2D, and 3D geometries; and is intended to be used primarily for high velocity impact and explosive detonation computations.

Some of the earlier versions of the EPIC-2 and EPIC-3 codes are documented in References 1–6. Additional references to various material models and computational algorithms are provided throughout the report.

SECTION II
USER INSTRUCTIONS

This section provides user instructions for the EPIC Research code, which consists of a Preprocessor, Main Routine, and Postprocessor for state and time plots. The formulation is not provided here; however, most of the basic equations are identical to those of the earlier versions (References 1–4). Additional references are included throughout the remainder of this report.

A description of input data for the EPIC code is given in Figures 1 through 24. In Figures 1 through 8, the page numbers of the descriptions in the text are included for each card.

In some instances instructions are given for features which are not yet available. It is anticipated that these features will be available in future versions of EPIC.

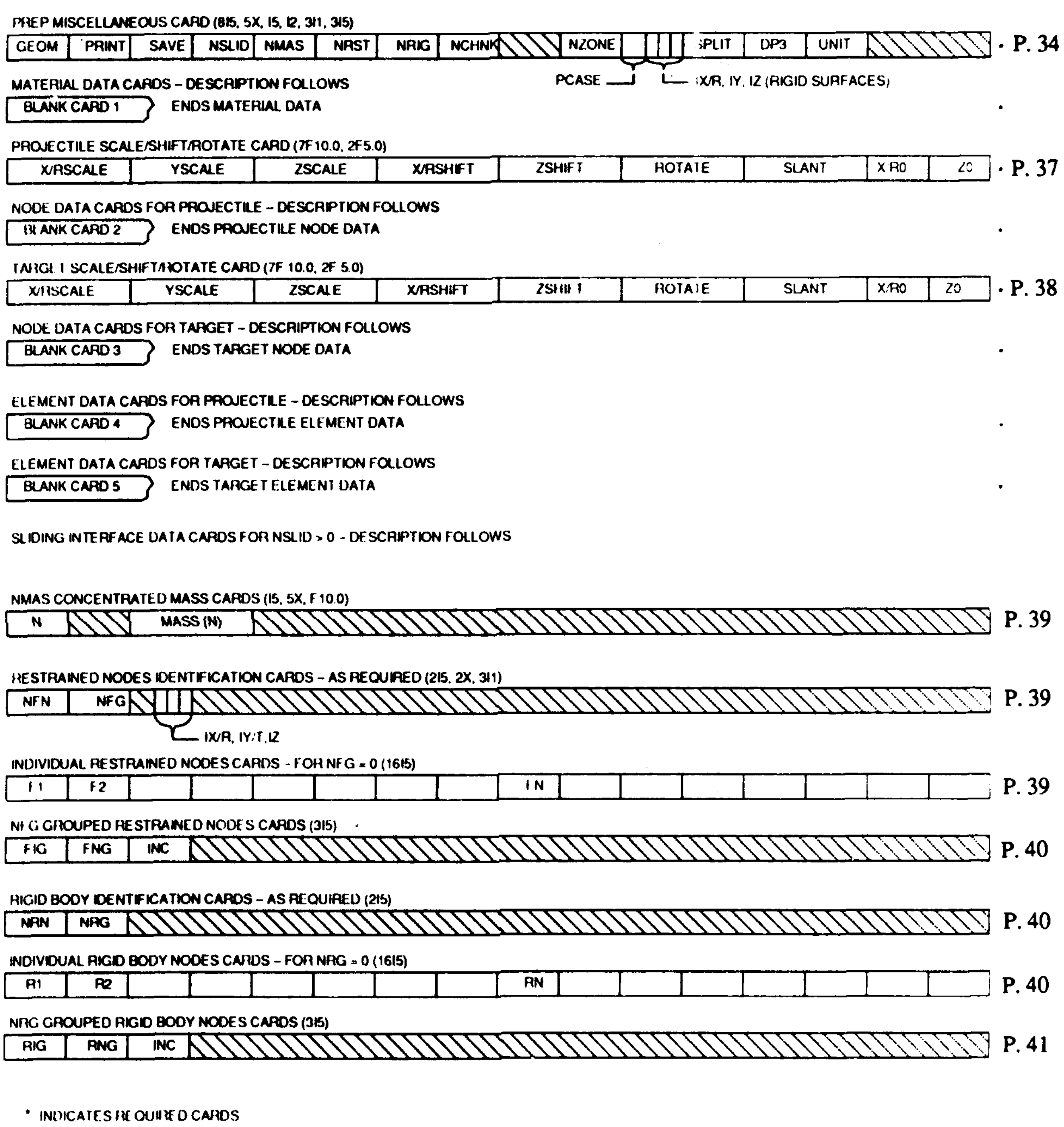

Figure 1. Preprocessor Input Data

PREP (2 OF 2)

NCHNK CHUNK ELEMENT CARDS (2I5)

CE1	CEN	▨

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AUTOMATIC REZONE REGION DEFINITION CARDS FOR NZONE >0 – DESCRIPTION FOLLOWS

DETONATION CARD (4F 10.0)

X/RDET	YDET	ZDET	TBURN	▨

· P. 41

INITIAL VELOCITY CARD (7F 10.0, I5)

PX/RDOT	PY/TDOT	PZDOT	TX/RDOT	TY/TDOT	TZDOT	DT1	NVFLD	▨

· P. 42

NVFLD VELOCITY FIELD DEFINITION CARDS (6F 10.0, 4I5)

X/R1DOT	Y/T1DOT	Z1DOT	X/R2DOT	Y/T2DOT	Z2DOT	N1	N2	NA1	NA2

P. 42

Figure 1. Preprocessor Input Data (Concluded)

MATERIAL CARD FOR SOLIDS FROM LIBRARY (4I5, 2F5.0)

MATL	0	DAM	FAIL	DFRAC	EFAIL	▨	P. 43

DESCRIPTION CARD FOR SOLIDS INPUT DATA (4I5, 5X, F5.0, A50)

MATL	1	DAM	FAIL	▨	EFAIL	MATERIAL DESCRIPTION	P. 44

CARD 2 FOR SOLIDS (6F10.0, I5)

DENSITY	SPH HEAT	TEMP1	TROOM	TMELT	TZERO	MODEL	▨	P. 44

CARD 3 FOR JOHNSON — COOK MODEL (MODEL = 1) (8F10.0)

SHEAR MOD	C1	C2	N	C3	M	C4	SMAX	P. 45

CARD 3 FOR MODIFIED JOHNSON — COOK MODEL (MODEL = 2) (8F10.0)

SHEAR MOD	C1	C2	N	C3	M	C4	SMAX	P. 45

CARD 3 FOR ZERILLI — ARMSTRONG FCC MODEL (MODEL = 3) (6F10.0)

SHEAR MOD	C0	C2	C3	C4	N	▨	P. 46

CARD 3 FOR ZERILLI — ARMSTRONG BCC MODEL (MODEL = 4) (7F10.0)

SHEAR MOD	C0	C1	C3	C4	C5	N	▨	P. 46

CARD 4 FOR SOLIDS (8F10.0)

K1	K2	K3	Γ	PMIN	CL	CQ	CH	P. 46

CARD 5 FOR SOLIDS (8F10.0)

D1	D2	D3	D4	D5	SPALL	EFMIN	X1	P. 47

MATERIAL CARD FOR EXPLOSIVES FROM LIBRARY (2I5)

MATL	0	▨	P. 48

DESCRIPTION CARD FOR EXPLOSIVES INPUT DATA (2I5, 20X, A50)

MATL	2	▨	MATERIAL DESCRIPTION	P. 48

CARD 2 FOR EXPLOSIVES (7F10.0, I5)

DENSITY	ENERGY	DET VEL	CL	CQ	CH	X1	JWL	▨	P. 48

JWL MODEL CONSTANTS CARD FOR JWL = 1 (5F10.0)

C1	C2	C3	C4	C5	▨	P. 48

MATERIAL CARD FOR CRUSHABLE SOLIDS FROM LIBRARY (2I5, 15X, F5.0)

MATL	0	▨	EFAIL	▨	P. 49

DESCRIPTION CARD FOR CRUSHABLE SOLIDS INPUT DATA (2I5, 15X, F5.0, A50)

MATL	3	▨	EFAIL	MATERIAL DESCRIPTION	P. 49

CARD 2 FOR CRUSHABLE SOLIDS (3F10.0)

DENSITY	SPH HEAT	TEMP1	▨	P. 49

CARD 3 FOR CRUSHABLE SOLIDS (8F10.0)

SHEAR MOD	C1	C4	SMAX	CL	CQ	CH	X1	P. 49

CARD 4 FOR CRUSHABLE SOLIDS (8F10.0)

PCRUSH	UCRUSH	K1	K2	K3	KLOCK	ULOCK	PMIN	P. 49

Figure 2. Material Input Data

MATL (2 OF 2)

MATERIAL CARD FOR LIQUIDS FROM LIBRARY (2I5, 15X, F5.0)

MATL	0	▨	EFAIL	▨	P. 50

DESCRIPTION CARD FOR LIQUIDS INPUT DATA (2I5, 15X, F5.0, A50)

MATL	4	▨	EFAIL	MATERIAL DESCRIPTION	P. 50

CARD 2 FOR LIQUIDS (4F10.0)

DENSITY	SPH HEAT	TEMP1	X1	▨	P. 50

CARD 3 FOR LIQUIDS (8F10.0)

K1	K2	K3	Γ	PMIN	CL	CQ	CH	P. 50

Figure 2. Material Input Data (Concluded)

NODE (1 OF 2)

LINE OF NODES DESCRIPTION CARD (2I5, 2X, 3I1, 25X, 2I5, F10.0)

1	NNODE	▨				▨	N1	INC	EXPAND	▨

IX/R, IY/T, IZ

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LINE OF NODES COORDINATE CARD (6F 10.0)

X/R1	Y1	Z1	X/RN	YN	ZN	▨

P. 51

ROD (DISK) NODE DESCRIPTION CARD (10I5, 3F10.0)

2	NOR	NIR	NPLN	RAD	AX	CROS	JOIN	N1	NTOP	ZTOP	ZBOT	EXPAND

P. 52

ROD NODE RADII CARD FOR RAD = 1 (4F 10.0)

ROTOP	RITOP	ROBOT	RIBOT	▨

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ROD NODE TOP RADII CARDS FOR RAD = 2 (8F 10.0)

RT(NIR)					RT(NOR)		

P. 54

ROD NODE BOTTOM RADII CARDS FOR RAD = 2 (8F 10.0)

RB(NIR)					RB(NOR)		

P. 55

ROD NODE TOP SURFACE CARD FOR RAD = 3 AND AX = 3 (2I5, 7F10.0)

TYPE	CLOCK	RTO	ZTO	RT1	ZT1	RTN	ZTN	TT

P. 55

ROD NODE BOTTOM SURFACE CARD FOR RAD = 3 AND AX = 3 (2I5, 7F10.0)

TYPE	CLOCK	RBO	ZBO	RB1	ZB1	RBN	ZBN	TB

P. 56

ROD NODE TOP SURFACE CARD FOR AX = 1 (8F 10.0)

A0	A1	A2	A3	A4	A5	A6	A7

P. 56

ROD NODE BOTTOM SURFACE CARD FOR AX = 1 (8F 10.0)

B0	B1	B2	B3	B4	B5	B6	B7

P. 56

ROD NODE TOP SURFACE CARDS FOR AX = 2 (8F 10.0)

ZT(NIR)				ZT(NOR)			

P. 56

ROD NODE BOTTOM SURFACE CARDS FOR AX = 2 (8F 10.0)

ZB(NIR)				ZB(NOR)			

P. 56

NOTE: IF NIR = 0 BEGIN RADII AND SURFACE CARDS WITH NIR = 1

NOSE NODE DESCRIPTION CARD (7I5, 5X, I5, 5X, 2F 10.0)

3	TYPE	NOR	NIR	RAD	AX	CROS	▨	N1	▨	ZTOP	ZMIN	▨

P. 56

NOSE NODE TOP RADII CARD FOR RAD = 1 (2F 10.0)

ROTOP	RITOP	▨

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NOSE NODE TOP RADII CARDS FOR RAD = 2 (8F 10.0)

RT(NIR)				RT(NOR)			

P. 58

NOTE: IF NIR = 0 BEGIN RADII CARD WITH RT (1)

NOSE NODE ZMIN CARDS FOR AX = 2 (8F 10.0)

ZMIN(NIR)				ZMIN(NOR)			

P. 58

NOTE: IF NIR = 0 BEGIN ZMIN CARDS WITH ZMIN (1)

Figure 3. Node Input Data

NODE (2 OF 2)

FLAT PLATE DESCRIPTION CARD (10I5, 3F 10.0)

4	TYPE	NX/R	NY	NZ	FIX	CROS	JOIN	N1	INC	X/R-EXPAND	Y-EXPAND	Z-EXPAND

P. 58

2D FLAT PLATE CARD FOR TYPE = 1 (2I5, 2F5.0, 4F 10.0)

NREND	NZEND	RPART	ZPART	RMAX	RMIN	ZMAX	ZMIN	▨

P. 61

3D CIRCULAR FLAT PLATE CARD FOR TYPE = 2 (2I5, 2F5.0, F10.0, 10X, 2F 10.0)

NREND	NZEND	RPART	ZPART	RADIUS	▨	ZMAX	ZMIN	▨

P. 62

3D RECTANGULAR FLAT PLATE CARD FOR TYPE = 3 (2I5, 2F5.0, 6F 10.0)

NXEND	NYEND	XPART	YPART	X1	Y1	Z1	XN	YN	ZN

P. 63

3D RECTANGULAR FLAT PLATE CARD FOR TYPE = 4 (2I5, 2F5.0, 6F 10.0)

NXEND	NZEND	XPART	ZPART	X1	Y1	Z1	XN	YN	ZN

P. 64

SPHERE NODE DESCRIPTION CARD (3I5, 5X, I5, 5X, I5, 5X, I5, 5X, 3F 10.0)

5	NOR	NIR	▨	RAD	▨	CROS	▨	N1	▨	R0	RI	ZCG

P. 64

SPHERE NODE RADII CARDS FOR RAD = 2 (8F 10.0)

R(NIR)				R(NOR)			

P. 65

NOTE: IF NIR = 0 BEGIN RADII CARD WITH R (1)

PATRAN NODE CARD (3I5)

888	N1	NN	▨

P. 65

NODE SCALE/SHIFT/ROTATE IDENTIFICATION CARD (I5)

999	▨

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NEW SCALE/SHIFT/ROTATE CARD (7F 10.0, 2F5.0)

X/RSCALE	YSCALE	ZSCALE	XSHIFT	ZSHIFT	ROTATE	SLANT	X/R0	Z0

P. 66

Figure 3. Node Input Data (Concluded)

SERIES OF INDIVIDUAL AND COMPOSITE ELEMENTS CARD (13I5, 5X, F10.0)

1	MATL	NCOM	N1	N2	N3	N4	N5	N6	N7	N8	INC	SHELL	▨	T/A	P. 67

THICKNESS CARD FOR 2D SHELL ELEMENTS – FOR SHELL = 1 AND T/A = 0 (8F 10.0)

T(1)					T(NCOMP+1)			P. 69

AREA CARD FOR 3D BAR ELEMENTS – FOR SHELL = 1 AND T/A = 0 (8F 10.0)

A(1)				A(NCOMP)				P. 69

THICKNESS CARD FOR 3D SHELL ELEMENTS – FOR SHELL = 1 AND T/A = 0 (8F 10.0)

T(1)				T(NCOMP)				P. 70

SERIES OF 3D TETRAHEDRAL ELEMENTS CARD – SYMMETRIC ARRANGEMENT (3I5)

1	MATL	NCOM	▨	P. 70

NODE DESCRIPTION CARD FOR 3-D SYMMETRIC ARRANGEMENT (16I5)

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	INC	P. 70

ROD (DISK) ELEMENT CARD (7I5, 5X, 2I5, 10X, F10.0)

2	MATL	N1	DIAG	NOER	NIER	NLAY	▨	SHELL	PLACE	▨	THICK	▨	P. 70

3D ROD TOP/BOTTOM SHELL THICKNESS CARD – FOR THICK = 0 (8F10.0)

T(NIER)					T(NOER)			P. 72

3D ROD SIDE SHELL THICKNESS CARD – FOR THICK = 0 (8F10.0)

T(1)					T(NLAY)			P. 72

ROD MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 72

NOSE ELEMENT CARD (6I5, 10X, I5, 15X, F10.0)

3	MATL	N1	DIAG	NOER	NIER	▨	SHELL	▨	THICK	▨	P. 72

3D NOSE THICKNESS CARD FOR THICK = 0 (8F10.0)

T(1)		T(2*NOER)		P. 74

NOSE MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 74

FLAT PLATE ELEMENT CARD (10I5, 10X, F10.0)

4	MATL	N1	DIAG	TYPE	NLX/R	NLY	NLZ	SHELL	PLACE	▨	THICK	▨	P. 74

SPHERE ELEMENT CARD (6I5, 10X, I5, 15X, F10.0)

5	MATL	N1	DIAG	NOER	NIER	▨	SHELL	▨	THICK	▨	P. 76

SPHERE MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 77

PATRAN ELEMENT CARD (3I, 55X, F10.0)

888	PL1	PLN	▨	TA	P. 77

Figure 4. Element Input Data

SLIDING INTERFACE CARD FOR 1D GEOMETRY – AS REQUIRED (2I5)

M1	S1	▨	P. 79

SLIDING INTERFACE IDENTIFICATION CARD FOR 2D GEOMETRY – AS REQUIRED (10I5, 3F10.0)

NMG	NMN	NSG	NSN	NSR	TYPE	MBOT	ISR	IT1	IT2	REF VEL	ERODE	FRICTION	P. 79

NMG GROUPED MASTER NODE CARDS (3I5)

M1G	MNG	INC	▨	P. 84

INDIVIDUAL MASTER NODE CARDS – FOR NMN > 0 (16I5)

M1	M2							MN								P. 84

NSG GROUPED SLAVE NODE CARDS (3I5)

S1G	SNG	INC	▨	P. 84

INDIVIDUAL SLAVE NODE CARDS – FOR NSN > 0 (16I5)

S1	S2							SN								P. 84

NSR SLAVE NODE LIMITS CARDS (4F10.0)

RMAX	RMIN	ZMAX	ZMIN	▨	P. 85

SLIDING INTERFACE INDENTIFICATION CARD FOR 3D GEOMETRY – AS REQUIRED (9I5, 5X, 3F10.0)

NMG	SEEK	NSG	NSN	NSR	TYPE	MBOT	ISR	IT	▨	REF VEL	ERODE	FRICTION	P. 85

MASTER DEFINITION CARD FOR RECTANGULAR PLATE GEOMETRY (2I5, 5X, 5I5)

1	M1	▨	DIAG	NML	NMW	IDL	IDW	▨	P. 88

MASTER DEFINITION CARD FOR ROD–NOSE GEOMETRY (7I5)

2	M1	MCODE	DIAG	NOR	NIR	NPL	▨	P. 89

MASTER DEFINITION CARD FOR CIRCULAR PLATE (DISK) GEOMETRY (5I5)

3	M1	MCODE	DIAG	NRING	▨	P. 90

MASTER DEFINITION CARD FOR CYLINDER (ROD) GEOMETRY (7I5)

4	M1	MCODE	DIAG	NOR	NIR	NPL	▨	P. 91

MASTER DEFINITION CARD FOR GENERAL GEOMETRY (8I5)

5	NCOMP	INC	M1	M2	M3	M4	M5	▨	P. 92

MASTER DEFINITION CARD FOR PATRAN GEOMETRY (3I5)

888	PL1	PLN	▨	P. 92

NSG GROUPED SLAVE NODE CARDS (3I5)

S1G	SNG	INC	▨	P. 93

INDIVIDUAL SLAVE NODE CARDS – FOR NSN > 0 (16I5)

S1	S2							SN								P. 94

NSR SLAVE NODE LIMITS CARDS (6F10.0)

XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN	▨	P. 94

Figure 5. Sliding Interface Input Data

RESTART DESCRIPTION CARD (2I5, A70)

3	CASE	MAIN DESCRIPTION

• P. 94

TIME INTEGRATION CARD (I5, 5X, 7F10.0)

CYCLE	▨	TIME	DTMAX	DTMIN	SSF	TMAX	CPMAX	EMAX

• P. 95

MAIN MISCELLANEOUS CARD (2I5, 5X, 3I5, F10.0, 10X, F10.0)

TPLOT	DROP	▨	PRES	PUSH	HRG	VFRACT	▨	PMAX	▨

• P. 96

PLOT CARD FOR TPLOT = 1 (4I5, 6F10.0)

SYS	NPLOT	LPLOT	DPLOT	DT SYS	TSYS	DT NODE	TNODE	DT DYN	T DYN

P. 97

DESIGNATED NODES CARD – FOR NPLOT > 0 (16I5)

N1	N2							NN							

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DESIGNATED ELEMENTS CARD – FOR LPLOT > 0 (16I5)

E1	E2							EN							

P. 98

DYNAMIC PLOT CARD FOR DPLOT = 1 (6I5, 2F10.0)

LINE	SIDEL	NMAT	SIDEM	VAR	SIDEV	VMAX	VMIN	▨

P. 99

MATERIAL DESIGNATION CARD – FOR NMAT >0 (16I5)

M1	M2								MN						

P. 100

COLOR DESIGNATION CARD – FOR NMAT >0 (16I5)

C1	C2								CN						

P. 100

DYNAMIC PLOT LIMITS CARD (6F10.0)

X/RMAX	YMAX	ZMAX	X/RMIN	YMIN	ZMIN	▨

P. 101

DROP CARD FOR DROP = 1 (F10.0, I5, 5X, 4I5, 5X, 3I5, 2X, 3I , I5)

TDROP	NNODE	▨	NELE	NSLID	NRIG	NCHNK	▨	NZONE	NPLOT	LPLOT	▨			NFAIL	▨

IX/R, IY, IZ

P. 101

DESIGNATED ELEMENTS FAILURE CARD – FOR NFAIL > 0 (16I5)

EF1	EF2							EFN							

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Figure 6. Main Routine Input Data

MAIN (2 OF 2)

PRESSURE CARDS FOR PRES = 2 – AS REQUIRED (6I5, F10.0)

ELE1	ELEN	ELEINC	N1	NN	NODINC	PRESSURE	▨

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BLANK CARD ENDS PRESSURE CARDS FOR PRES = 2

TIME – PRESSURE CARDS FOR PRES = 2 – AS REQUIRED (2F10.0)

PTIME	P(T)	▨

P. 103

BLANK CARD ENDS TIME – PRESSURE CARDS FOR PRES = 2

VELOCITY CARDS FOR PUSH = 2 – AS REQUIRED (3I5, 5X, 3F10.0)

N1	NN	INC	▨	X/RDOT	Y/TDOT	ZDOT	▨

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BLANK CARD ENDS VELOCITY CARDS FOR PUSH = 2

TIME – VELOCITY CARDS FOR PUSH = 2 – AS REQUIRED (2F10.0)

VTIME	V(T)	▨

P. 104

BLANK CARD ENDS TIME – VELOCITY CARDS FOR PUSH = 2

DATA OUTPUT CARDS – AS REQUIRED (4F10.0, 8I5)

TIME	ECHECK	NCHECK	RDAMP	SAVE	BURN	YPRNT	NDATA	SLPR	PROJ	PAT	RZONE

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BLANK CARD ENDS MAIN ROUTINE

Figure 6. Main Routine Input Data (Concluded)

POST1 (1 OF 2)

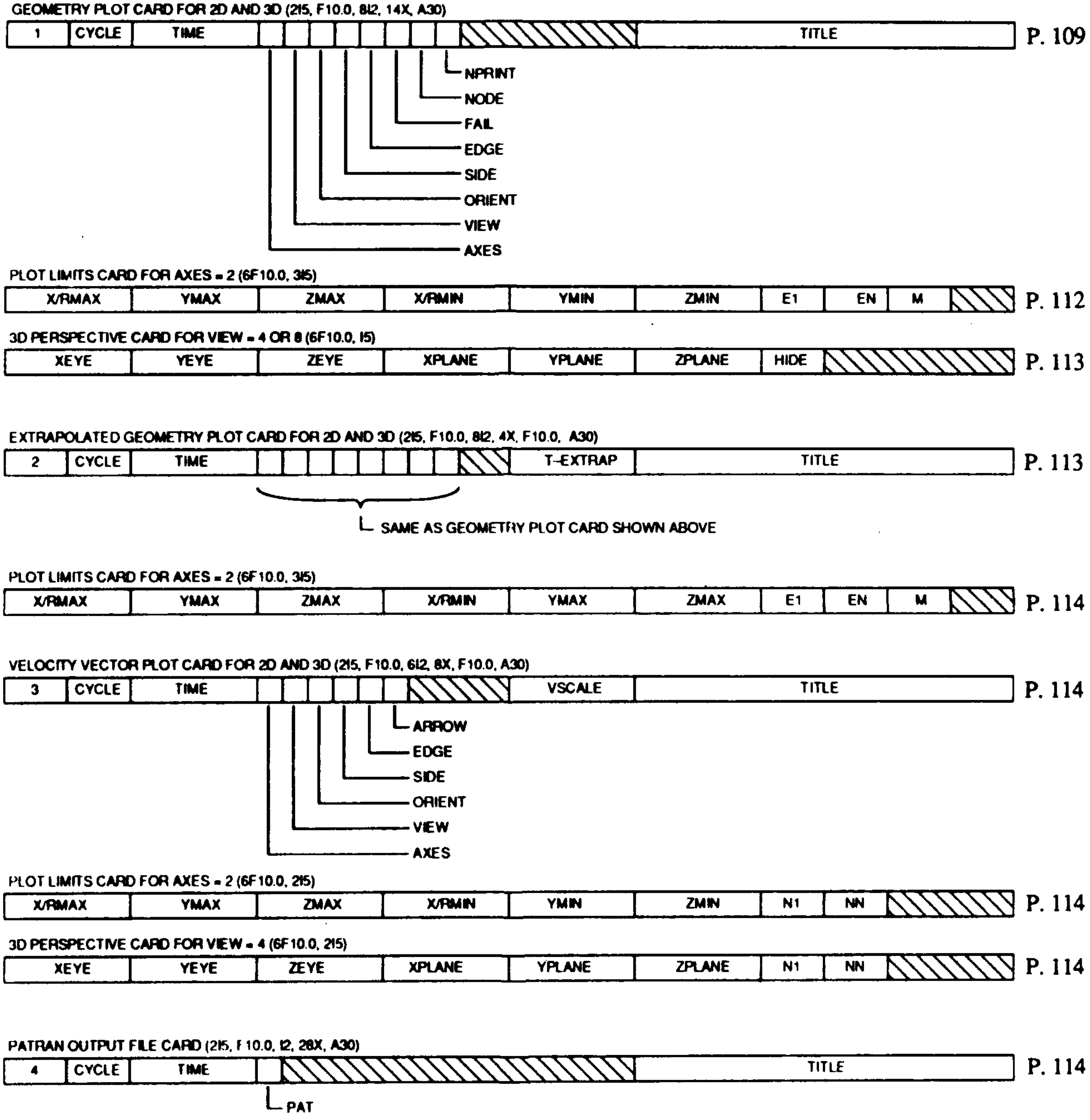

Figure 7. Postprocessor Input Data for State Plots

POST1 (2 OF 2)

CONTOUR PLOT CARD FOR 2D AND 3D (2I5, F10.0, 8I2, 14X, A30)

TYPE	CYCLE	TIME									▨	TITLE

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PRINT
SYMBOL
NLINE
EDGE
SIDE
ORIENT
VIEW
AXES

TYPE	CONTOUR PLOTTED	
11	PRESSURE	
12	VON MISES STRESS	
13	EQUIVALENT STRAIN	
14	DAMAGE / BURN FRACTION	
15	TEMPERATURE	
16	PLASTIC WORK	
17	INTERNAL ENERGY	
18	LOG (10) STRAIN RATE	
19	NET X / R STRESS	NOT AVAILABLE FOR 3D SHELL ELEMENTS
20	NET Y / T STRESS	
21	NET Z STRESS	

PLOT LIMITS CARD FOR AXES = 2 (6F10.0, 3I5)

X/RMAX	YMAX	ZMAX	X/RMIN	YMIN	ZMIN	E1	EN	M	▨

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CONTOUR SPECIFICATION CARDS FOR NLINE > 0 (8F10.0)

C1	C2				CN		

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PLOT CARDS FOR 1D ONLY (2I5, F10.0, I2, 12X, I2, 14X, A30)

TYPE	CYCLE	TIME		▨		▨	TITLE

P. 116

AXES
PRINT

TYPE	VARIABLE VS Z AXIS
11-21	SAME AS CONTOURS
22	Z VELOCITY

PLOT LIMITS CARD FOR AXES = 2 (4F10.0)

VMAX	VMIN	ZMAX	ZMIN	▨

P. 116

BLANK CARD — ENDS POST 1 POSTPROCESSOR

Figure 7. Postprocessor Input Data for State Plots (Concluded)

POST2 (1 OF 1)

SYSTEM/CHUNK PLOT CARDS – AS REQUIRED (3I5, F5.0, 4F10.0, A20)

TYPE	AXES	CODE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE

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INDIVIDUAL NODE PLOT CARDS – AS REQUIRED (3I5, F5.0, 4F10.0 A20)

TYPE	AXES	NODE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE

P. 118

INDIVIDUAL ELEMENT PLOT CARDS – AS REQUIRED (3I5, F5.0, 4F10.0, A20)

TYPE	AXES	ELE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE

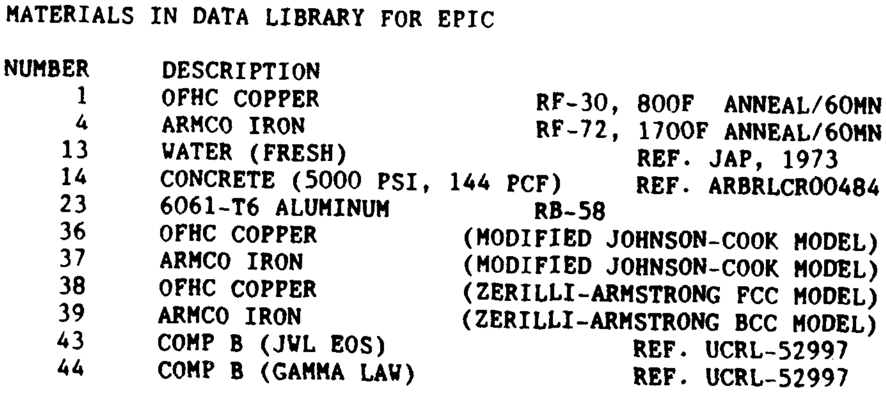
P. 118

BLANK CARD — ENDS POST2 POSTPROCESSOR

TYPE	VARIABLE PLOTTED		
1–4	ENERGIES: TOTAL (1), KINETIC (2), INTERNAL (3), PLASTIC WORK (4)		SYSTEM/CHUNK DATA
5–7	XYZ / RTZ MAXIMUM COORDINATES		
8–10	XYZ / RTZ MINIMUM COORDINATES		
11–13	XYZ / RTZ CENTERS OF GRAVITY	ONLY R, Z FOR 2D	
14–16	XYZ / RTZ LINEAR MOMENTA		
17–20	XYZ / RTZ VELOCITIES (17–19) AND NET VELOCITY (20)		
21–23	XYZ / RTZ ANGULAR MOMENTA	READ DESCRIPTION FOR 2D	
24–26	XYZ / RTZ ANGULAR VELOCITIES		
27	MASS		
40–42	XYZ / RTZ NODE POSITIONS		INDIVIDUAL NODE DATA
43–46	XYZ / RTZ NODE VELOCITIES (43–45) AND NET VELOCITY (46)		
47–49	XYZ / RTZ NODE ACCELERATIONS		
50	NODAL PRESSURE		
60	ELEMENT PRESSURE		INDIVIDUAL ELEMENT DATA
61	ELEMENT PRESSURE (NODAL AVERAGE)		
62	VON MISES STRESS		
63	EQUIVALENT PLASTIC STRAIN		
64	DAMAGE / BURN FRACTION		
65	TEMPERATURE		
66	PLASTIC WORK PER INITIAL VOLUME		
67	INTERNAL ENERGY PER INTIAL VOLUME		
68	LOG (10) STRAIN RATE		
69–71*	XYZ / RTZ NORMAL STRESSES		
72–74*	SHEAR STRESSES: X–Y / R–T (44), X–Z / R–Z (45), Z–Y / Z–T (46)		
75	RATIO: MEAN STRESS / VON MISES STRESS		

* NOT AVAILABLE FOR BAR AND / OR SHELL ELEMENTS

Figure 8. Postprocessor Input Data for Time Plots



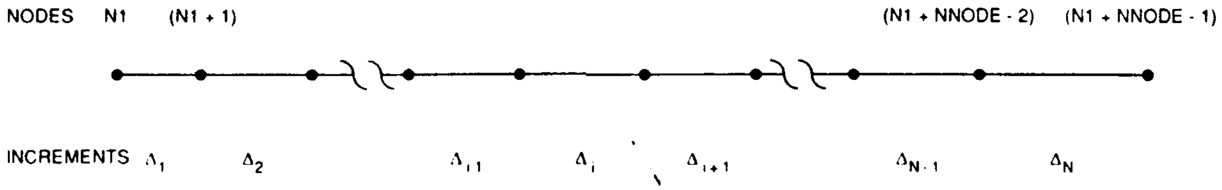
```
MATERIALS IN DATA LIBRARY FOR EPIC

NUMBER     DESCRIPTION
     1     OFHC COPPER                  RF-30, 800F  ANNEAL/60MN
     4     ARMCO IRON                   RF-72, 1700F ANNEAL/60MN
    13     WATER (FRESH)                       REF. JAP, 1973
    14     CONCRETE (5000 PSI, 144 PCF)        REF. ARBRLCR00484
    23     6061-T6 ALUMINUM             RB-58
    36     OFHC COPPER                (MODIFIED JOHNSON-COOK MODEL)
    37     ARMCO IRON                 (MODIFIED JOHNSON-COOK MODEL)
    38     OFHC COPPER                (ZERILLI-ARMSTRONG FCC MODEL)
    39     ARMCO IRON                 (ZERILLI-ARMSTRONG BCC MODEL)
    43     COMP B (JWL EOS)                    REF. UCRL-52997
    44     COMP B (GAMMA LAW)                  REF. UCRL-52997
```

Figure 9. Materials in the EPIC Material Library

NUMBER OF INCREMENTS N	EXPAND																			
	.7		.8		.9		1.0		1.1		1.2		1.3		1.4		1.5	
	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$	$\frac{\Delta_1}{\bar{\Delta}}$	$\frac{\Delta_N}{\bar{\Delta}}$
2	1.176	.824	1.111	.889	1.053	.947	1.0	1.0	.952	1.048	.909	1.091	.870	1.130	.833	1.167	.800	1.200
3	1.370	.671	1.230	.787	1.107	.897	↓	↓	.906	1.097	.824	1.187	.752	1.271	.688	1.349	.632	1.421
4	1.579	.542	1.355	.694	1.163	.848			.862	1.147	.745	1.288	.647	1.420	.563	1.545	.492	1.662
5	1.803	.433	1.487	.609	1.221	.801			.819	1.199	.672	1.393	.553	1.579	.457	1.755	.379	1.919
6	2.040	.343	1.626	.533	1.281	.756			.778	1.252	.604	1.504	.470	1.746	.368	1.977	.289	2.192
7	2.288	.269	1.772	.464	1.342	.713			.738	1.307	.542	1.618	.398	1.922	.293	2.210	.218	2.487
8	2.547	.210	1.923	.403	1.405	.672			.700	1.363	.485	1.737	.335	2.104	.233	2.452	.162	2.775
9	2.814	.162	2.079	.349	1.469	.632			.663	1.421	.433	1.861	.281	2.293	.183	2.702	.120	3.080
10	3.087	.125	2.241	.301	1.535	.595			.627	1.479	.385	1.988	.235	2.488	.143	2.959	.088	3.392
12	3.651	.072	2.577	.221	1.672	.525			.561	1.601	.303	2.253	.161	2.893	.086	3.490	.047	4.031
14	4.229	.041	2.929	.161	1.815	.461			.500	1.728	.237	2.530	.109	3.315	.051	4.036	.024	4.683
16	4.816	.023	3.293	.116	1.964	.404			.445	1.859	.183	2.819	.073	3.749	.030	4.592	.012	5.341
18	5.409	.013	3.666	.083	2.118	.353			.395	1.995	.140	3.117	.048	4.191	.017	5.155	.006	6.004
20	6.003	.005	4.037	.046	2.246	.273			.349	2.102	.089	3.407	.024	4.634	.007	5.719	.002	6.668

NTS/N13-0·7 TKC

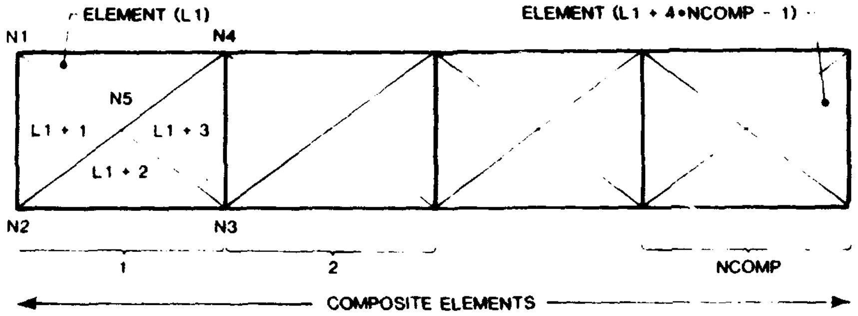


$$\bar{\Delta} = \frac{\text{TOTAL LENGTH}}{\text{NUMBER INCREMENTS}} = \frac{L}{N} \qquad \Delta_{i+1} = \Delta_i \cdot \text{EXPAND}$$

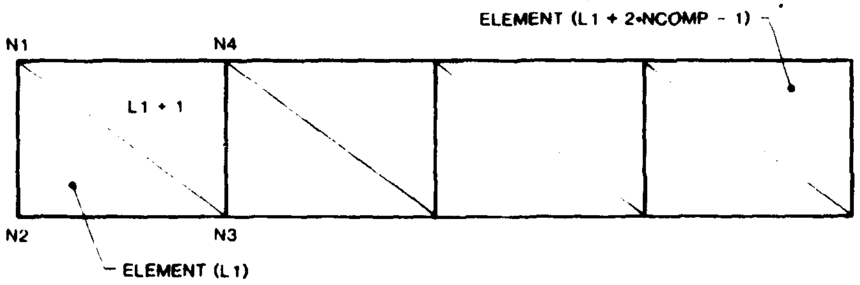
$$\frac{\Delta_1}{\bar{\Delta}} = \frac{N(1 - \text{EXPAND})}{(1 - \text{EXPAND}^N)} \qquad \frac{\Delta_N}{\bar{\Delta}} = \frac{N\left(1 - \frac{1}{\text{EXPAND}}\right)}{\left[1 - \left(\frac{1}{\text{EXPAND}}\right)^N\right]}$$

Figure 10. Nodal Spacing for Various Expansion Factors

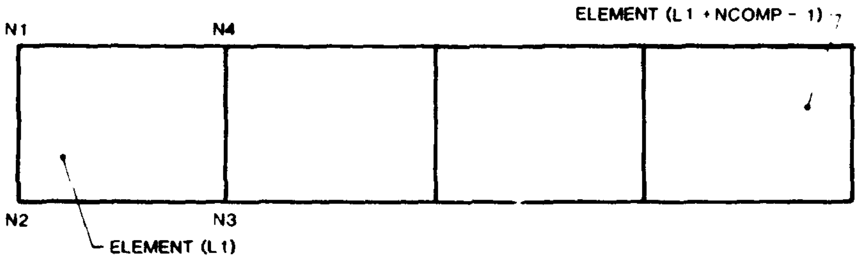
CROSSED TRIANGLES (N5> 0)



STANDARD TRIANGLES (N5=0)



QUAD ELEMENTS (N5=-1)



ONE DIMENSIONAL ELEMENTS (N3=0)

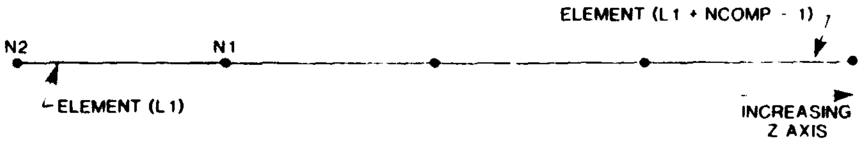
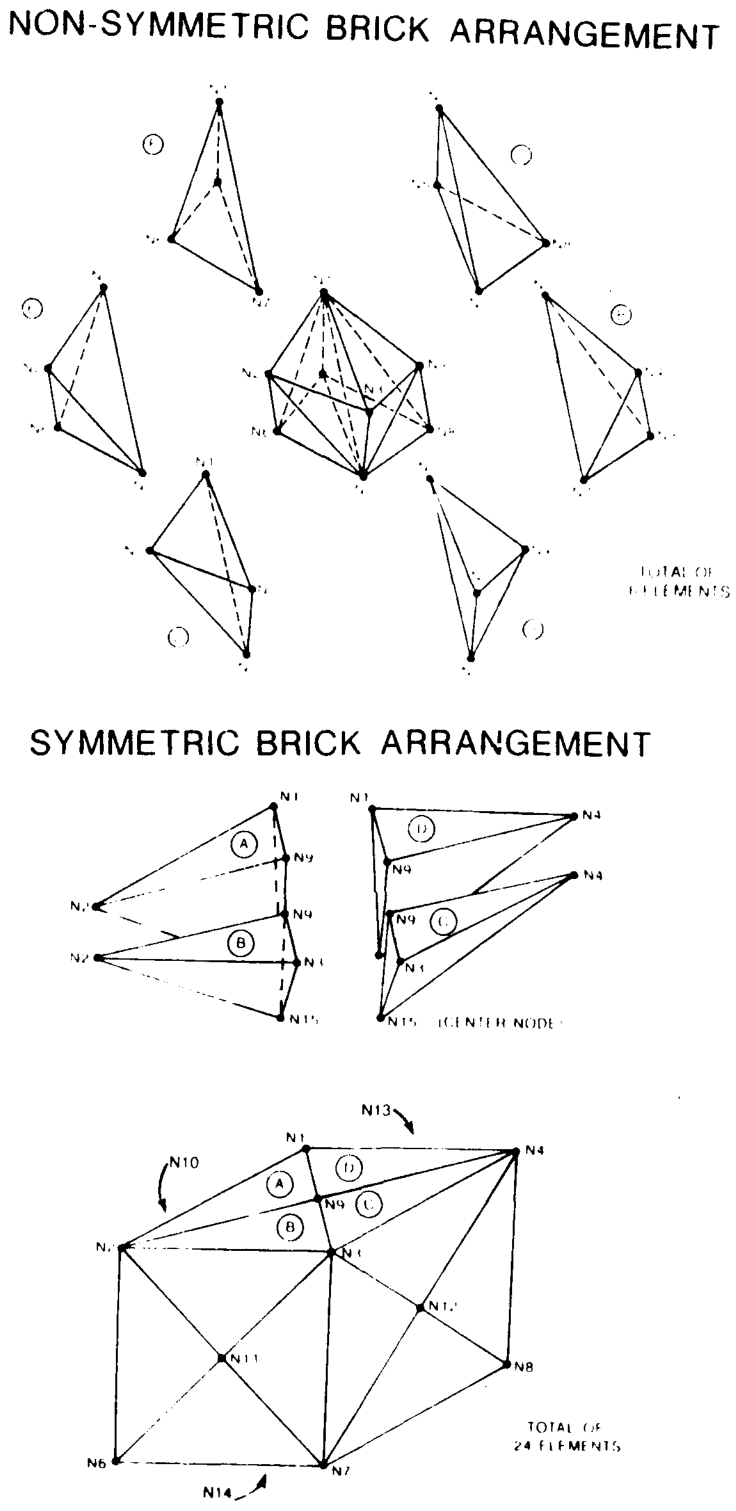


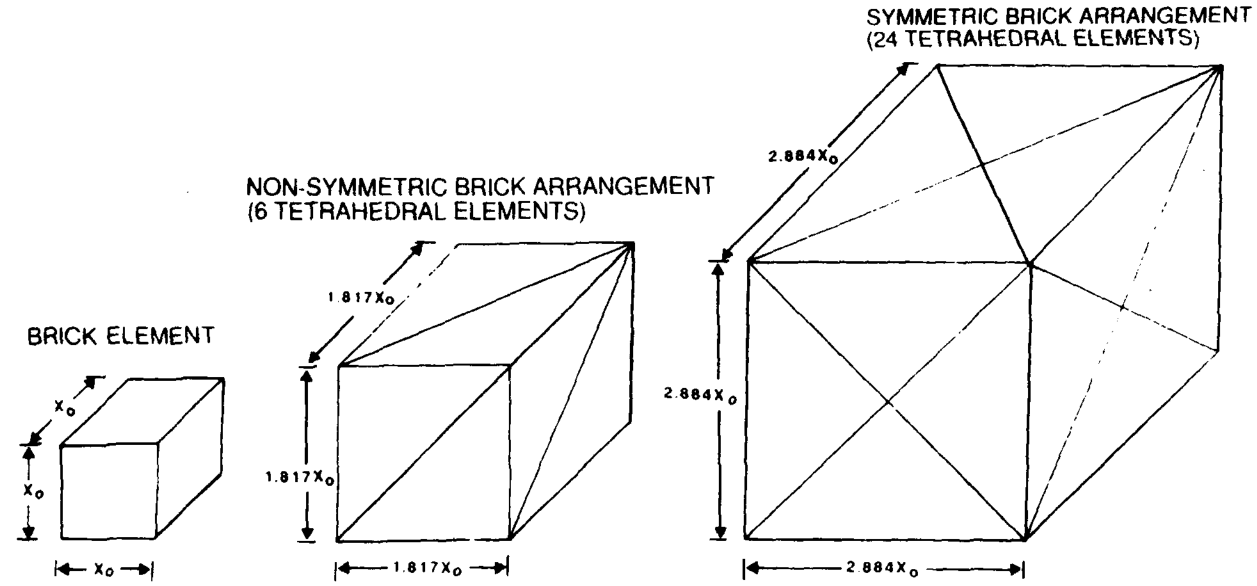
Figure 11. 2D Composite Element Geometry



NON-SYMMETRIC BRICK ARRANGEMENT

SYMMETRIC BRICK ARRANGEMENT

Figure 12. 3D Composite Element Geometry



L_{MAX}	1.732 X_O	L_{MAX}	3.147 X_O	L_{MAX}	2.884 X_O
H_{MIN}	= X_O	H_{MIN}	1.049 X_O	H_{MIN}	1.020 X_O

NOTES

- ALL ELEMENTS HAVE EQUAL VOLUMES ($X_O{}^3$)
- L_{MAX} IS MAXIMUM DISTANCE BETWEEN TWO NODES OF AN ELEMENT
- H_{MIN} IS MINIMUM ALTITUDE OF AN ELEMENT

Figure 13. 3D Element Arrangements

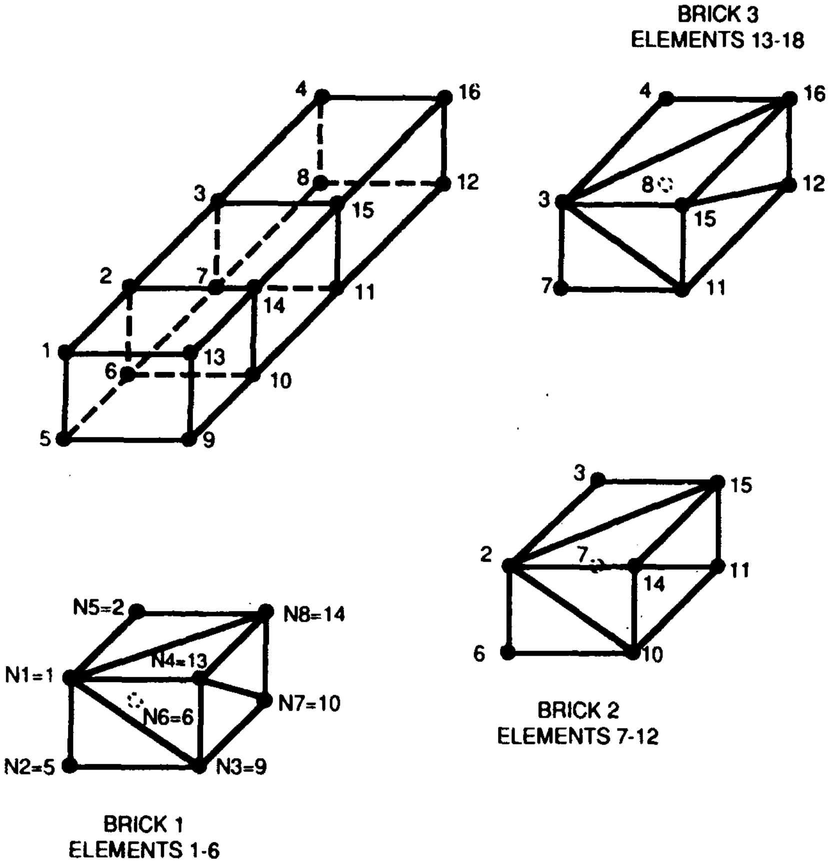
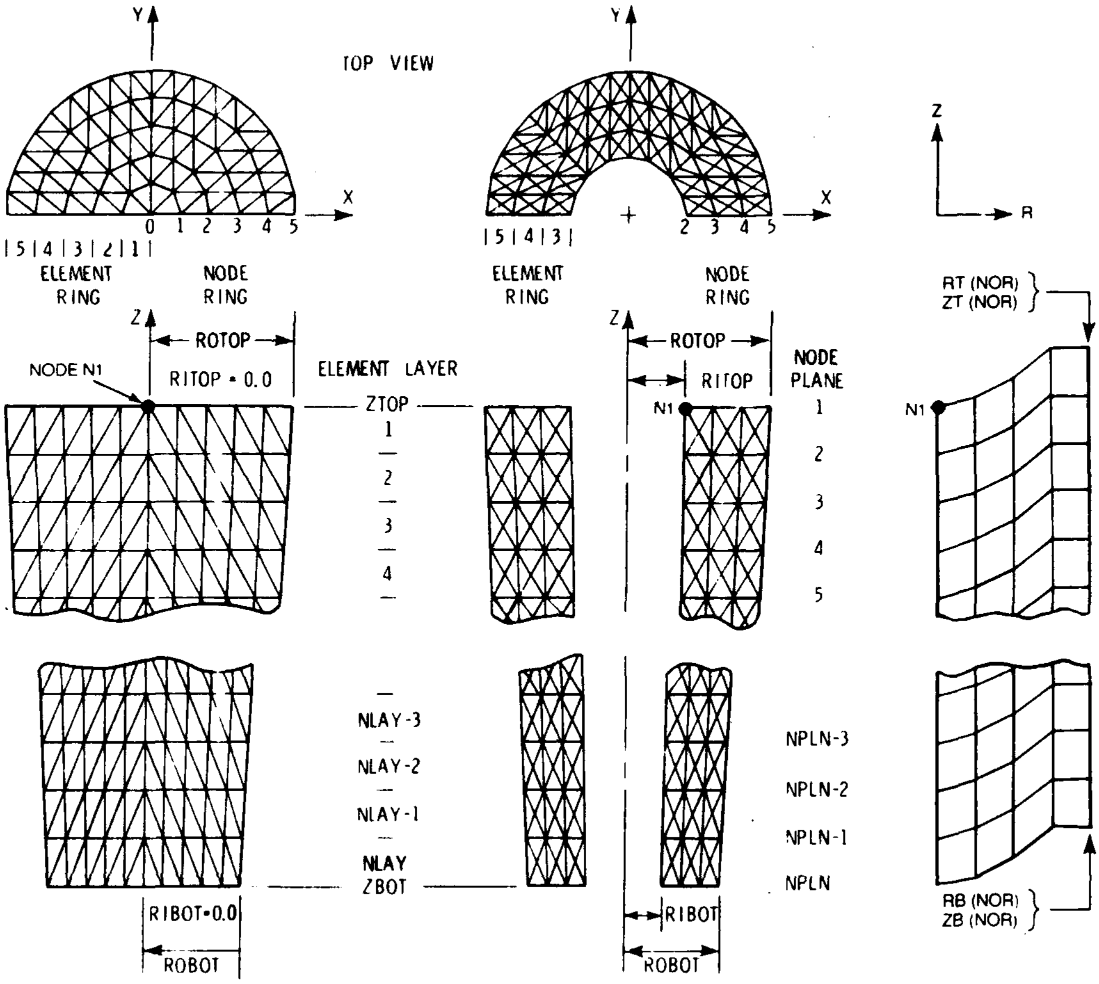


Figure 14. 3D Node/Element Input Data Example

GEOMETRY	NODES								SHELL	DESCRIPTION
	N1	N2	N3	N4	N5	N6	N7	N8		
1D	N1	N2	0	0	0	0	0	0	0	1D ELEMENT
	N1	0	0	0	0	0	0	0	2	NON-REFLECT
2D	N1	N2	0	0	0	0	0	0	1	SHELL/BAR
	N1	N2	N3	0	0	0	0	0	0	1 TRI ELE
	N1	N2	N3	N4	0	0	0	0	0	2 TRI ELE
	N1	N2	N3	N4	N5	0	0	0	0	4 TRI ELE
	N1	N2	N3	N4	-1	0	0	0	0	1 QUAD ELE
	N1	N2	0	0	0	0	0	0	2	NON-REFLECT
3D	N1	N2	0	0	0	0	0	0	1	BAR
	N1	N2	N3	0	0	0	0	0	1	1 TRI SHELL ELE
	N1	N2	N3	N4	0	0	0	0	1	2 TRI SHELL ELE
	N1	N2	N3	N4	N5	0	0	0	1	4 TRI SHELL ELE
	N1	N2	N3	N4	0	0	0	0	0	1 TET ELE
	N1	N2	N3	0	N5	N6	N7	0	0	3 TET ELE
	N1	0	N3	N4	N5	0	N7	N8	0	3 TET ELE
	N1	N2	N3	N4	N5	N6	N7	N8	0	6 TET ELE
	N1	N2	N3	0	0	0	0	0	2	1 NON-REFLECT TRI
	N1	N2	N3	N4	0	0	0	0	2	2 NON-REFLECT TRI
	N1	N2	N3	N4	N5	0	0	0	2	4 NON-REFLECT TRI

Figure 15. Summary of Individual and Composite Element Options



3-D SOLID ROD

NIR = 0, NOR = 5, NIER = 1, NOER = 5
RAD = 1, AX = 0, CROS = 0, DIAG = 1

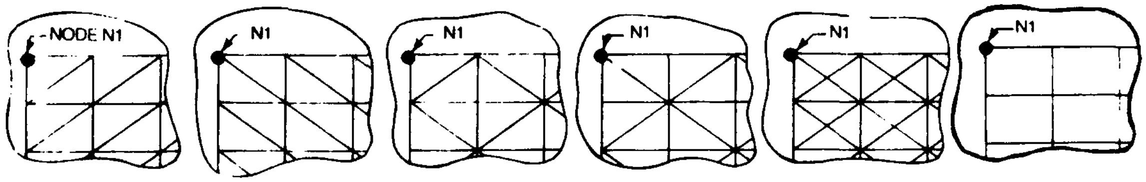
3-D HOLLOW ROD

NIR = 2, NOR = 5, NIER = 3, NOER = 5
RAD = 1, AX = 0, CROS = 1, DIAG = 5

2-D SOLID ROD

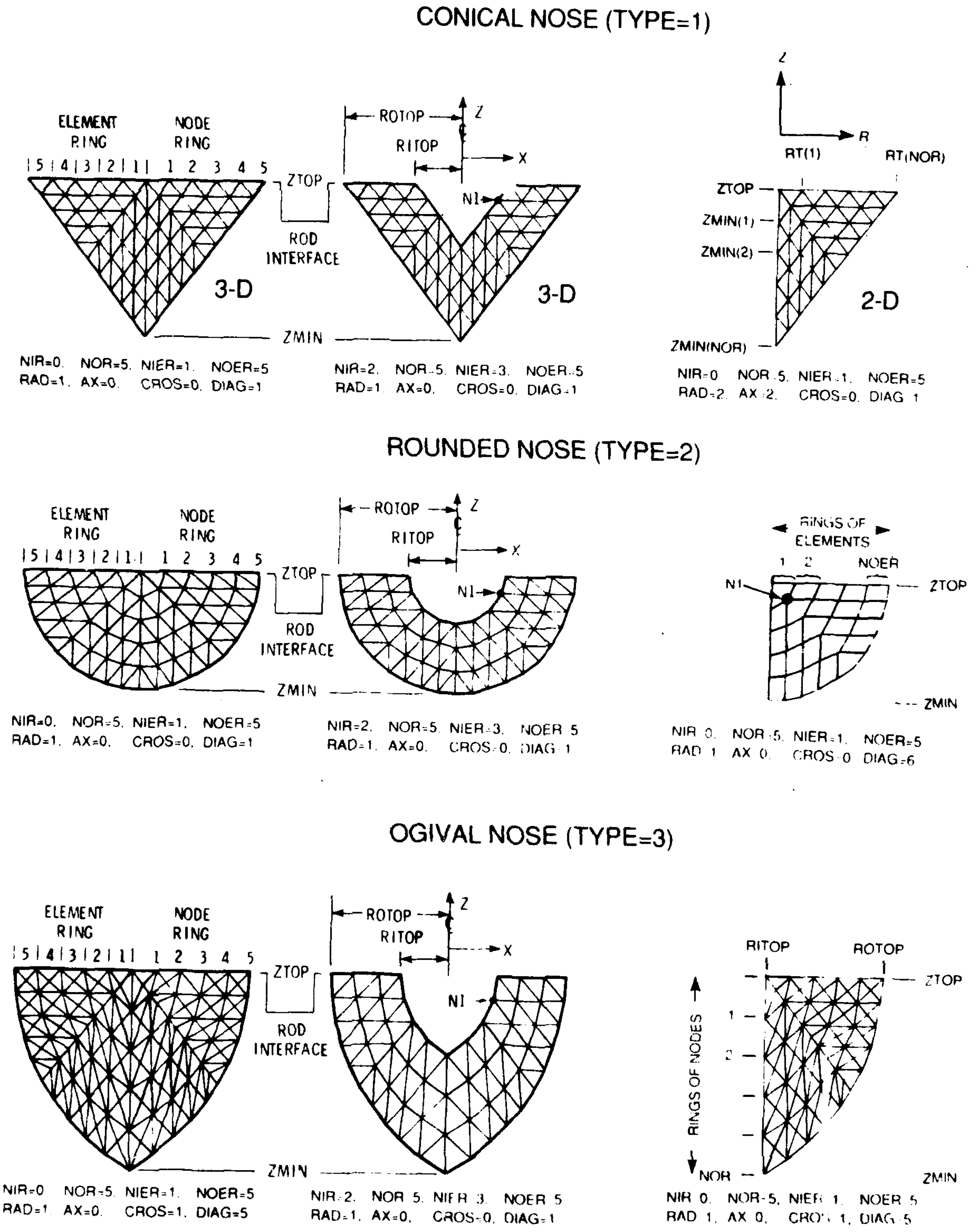
NIR = 0, NOR = 4, NIER = 1, NOER = 4
RAD = 2, AX = 2, CROS = 0, DIAG = 6

NODE AND ELEMENT ARRANGEMENTS FOR 2-D GEOMETRY ONLY



DIAG = 1 CROS = 0
DIAG = 2 CROS = 0
DIAG = 3 CROS = 0
DIAG = 4 CROS = 0
DIAG = 5 CROS = 1
DIAG = 6 CROS = 0

Figure 16. Rod Shape Geometry


CONICAL NOSE (TYPE=1)

ROUNDED NOSE (TYPE=2)

OGIVAL NOSE (TYPE=3)

Figure 17. Nose Shape Geometry

ROD GEOMETRY								
NUMBER OF RINGS	2D GEOMETRY				3D GEOMETRY			
	CROSSED TRIANGLE		STANDARD TRIANGLE		SYMMETRIC		NON SYMMETRIC	
	NODES PER LAYER*	ELEMENTS PER LAYER	NODES PER LAYER	ELEMENTS PER LAYER	NODES PER LAYER*	ELEMENTS PER LAYER	NODES PER LAYER	ELEMENTS PER LAYER
1	3	4	2	2	17	48	6	12
2	5	8	3	4	53	192	15	48
3	7	12	4	6	109	432	28	108
4	9	16	5	8	185	768	45	192
5	11	20	6	10	281	1200	66	300
6	13	24	7	12	397	1728	91	432
7	15	28	8	14	533	2352	120	588
8	17	32	9	16	689	3072	153	768
9	19	36	10	18	865	3888	190	972
10	21	40	11	20	1061	4800	231	1200
N	$2N+1$	$4N$	$N+1$	$2N$	$10N^2+6N+1$	$48N^2$	$2N^2+3N+1$	$12N^2$

* ADDITIONAL NODES PER ADDITIONAL ELEMENT LAYER (INCLUDES SECONDARY NODES)

NOSE GEOMETRY **								
NUMBER OF RINGS	2D GEOMETRY				3D GEOMETRY			
	CROSSED TRIANGLE		STANDARD TRIANGLE		SYMMETRIC		NON SYMMETRIC	
	NODES	ELEMENTS	NODES	ELEMENTS	NODES	ELEMENTS	NODES	ELEMENTS
1	3	4	2	2	17	48	6	12
2	10	16	6	8	89	384	30	96
3	21	36	12	18	221	1296	84	324
4	36	64	20	32	413	3072	180	768
5	55	100	30	50	665	6000	330	1500
6	78	144	42	72	977	10368	546	2592
7	105	196	56	98	1349	16464	840	4116
8	136	256	72	128	1781	24576	1224	6144
9	171	324	90	162	2273	34992	1710	8748
10	210	400	110	200	2825	48000	2310	12000
N	$2N^2+N$	$4N^2$	N^2+N	$2N^2$	$30N^2-18N+5$	$48N^3$	$2N^3+3N^2+N$	$12N^3$

** DOES NOT INCLUDE NODES AT ROD INTERFACE

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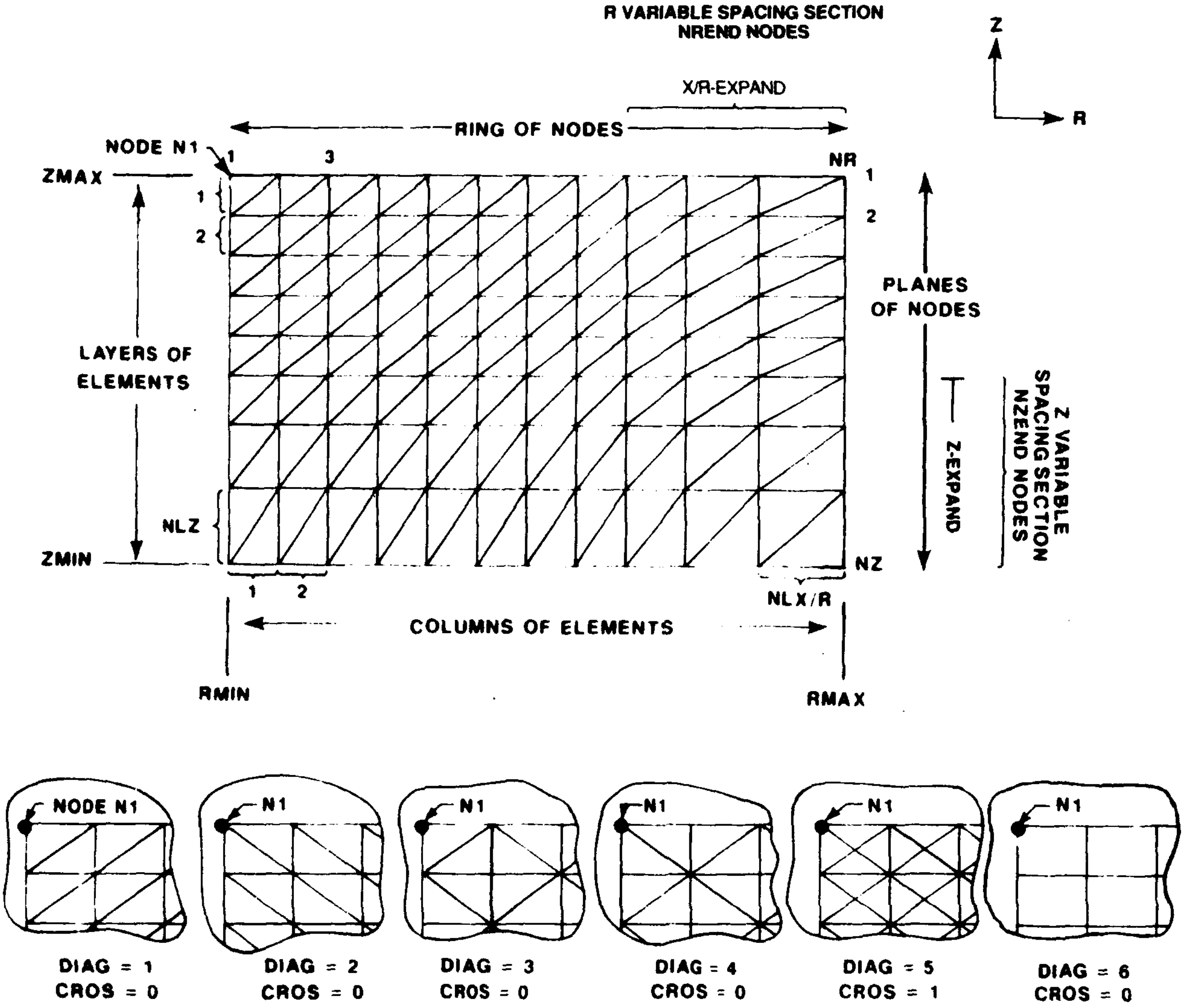
7/10/90

Figure 18. Summary of Nodes and Elements for Rod and Nose Shapes



DIAG = 1
CROS = 0

DIAG = 2
CROS = 0

DIAG = 3
CROS = 0

DIAG = 4
CROS = 0

DIAG = 5
CROS = 1

DIAG = 6
CROS = 0

Figure 19. 2D Flat Plate Geometry

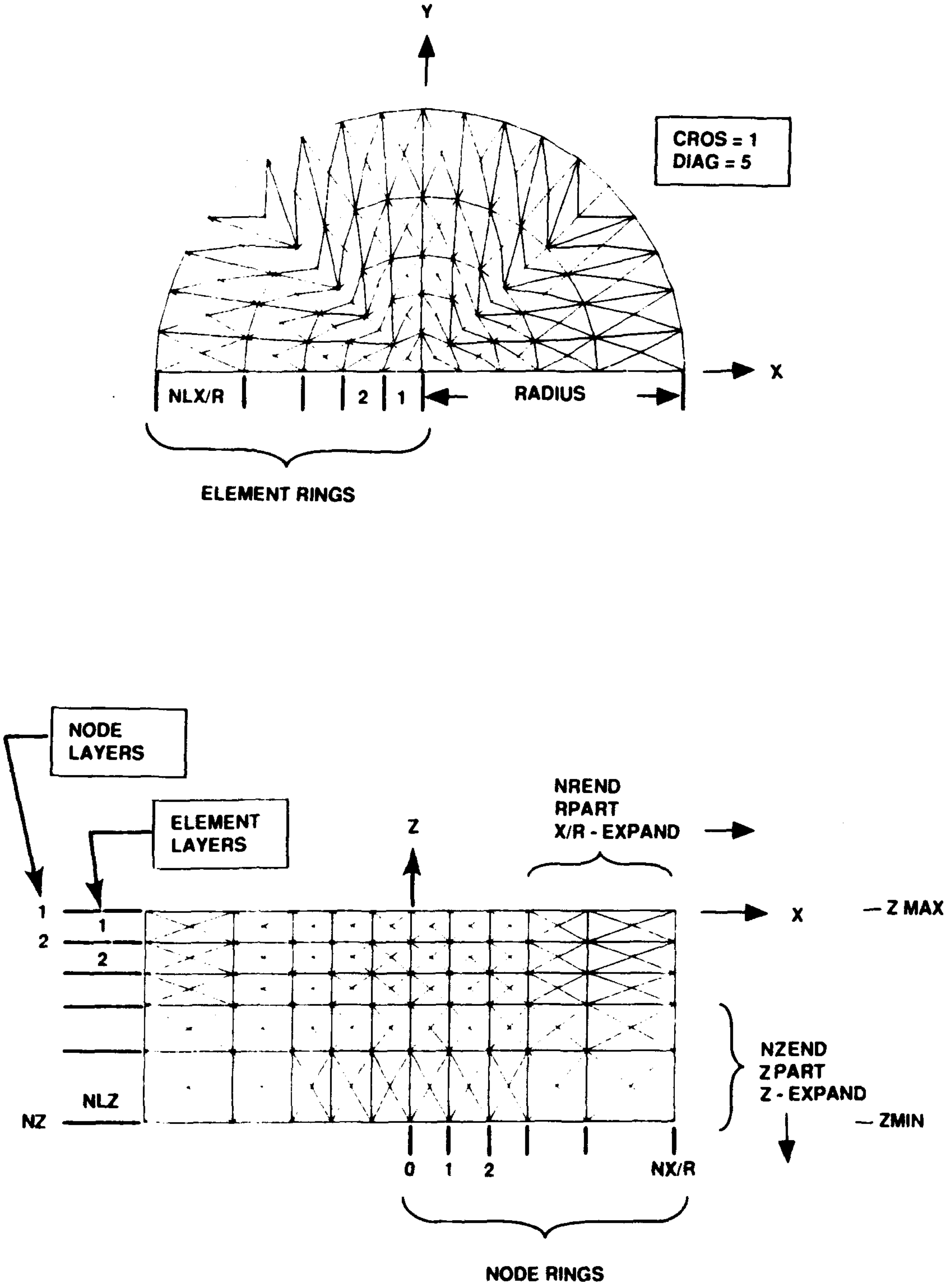
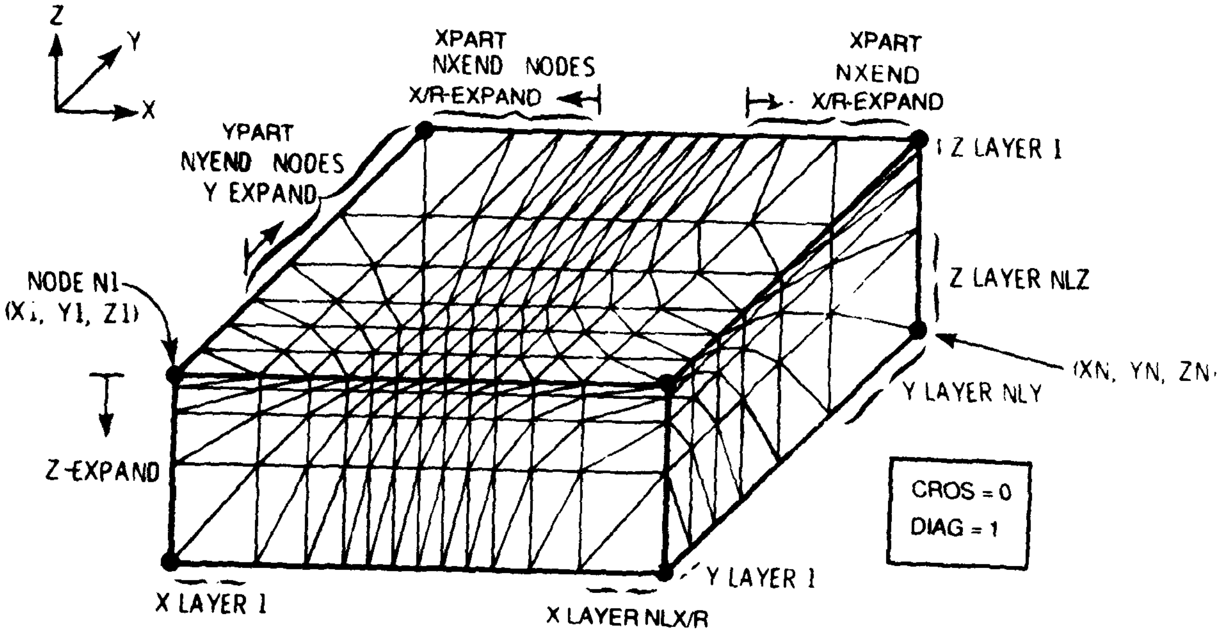


Figure 20. 3D Circular Flat Plate Geometry

TYPE = 3 (HORIZONTAL LAYERS)



TYPE = 4 (VERTICAL LAYERS)

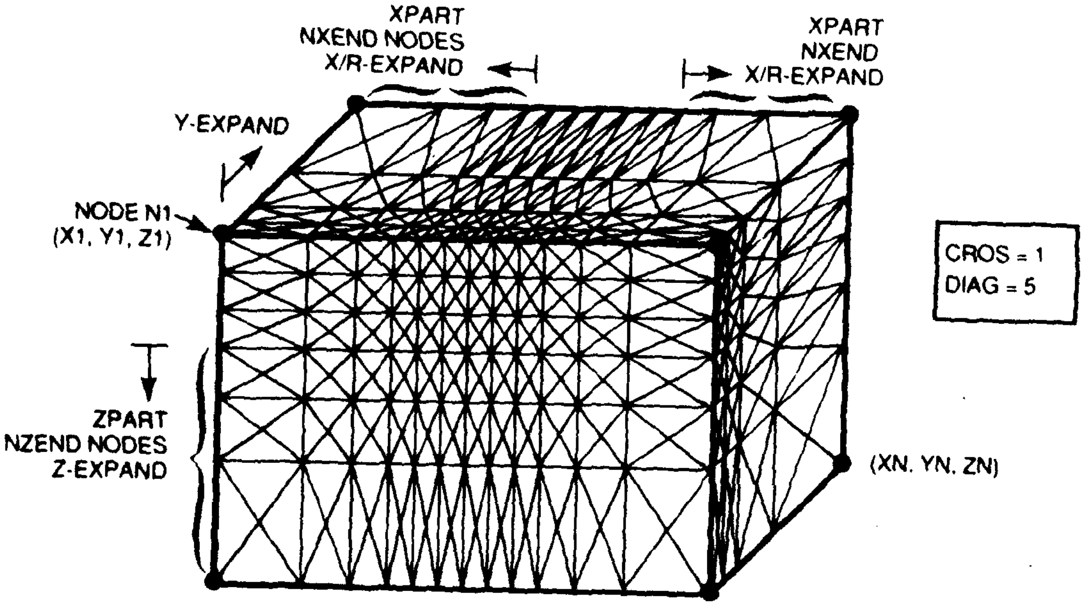
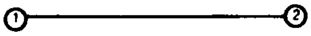
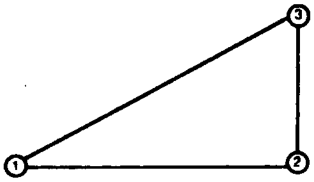
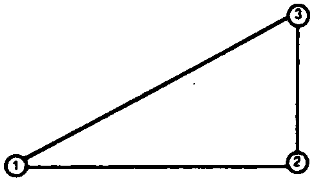
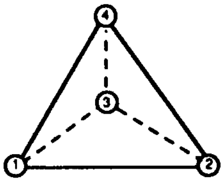
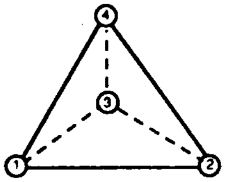
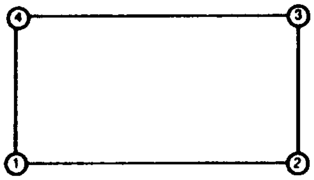
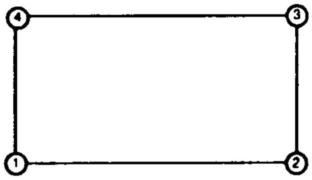
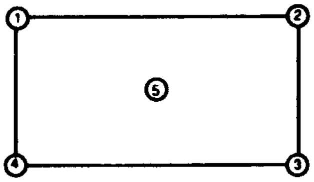
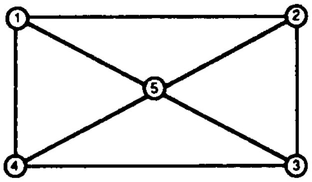
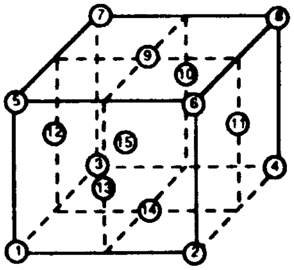
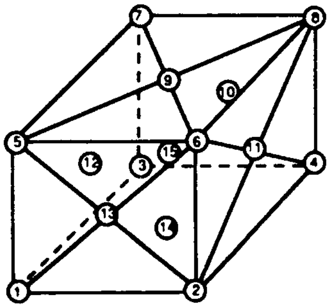


Figure 21. 3D Rectangular Flat Plate Geometry

PATRAN		EPIC	
NAME	GEOMETRY	NAME	GEOMETRY
BAR/2		BAR/SHELL	
TRI/3		TRIANGLE	
TET/4		TETRAHEDRON	
QUAD/4		QUAD	
QUAD/5		CROSSED TRIANGLES (4 TRIANGLES)	
HEX/27 (MODIFIED)		SYMMETRIC BRICK ARRANGEMENT (24 TETRAHEDRA)	

NTS/N23MCII-001.TQ

Figure 22. PATRAN to EPIC Translators for Nodes and Elements

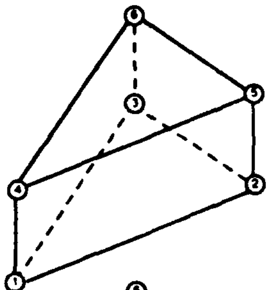
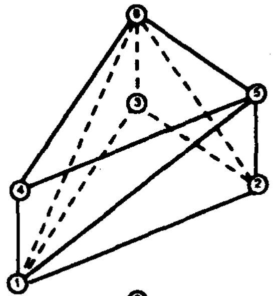
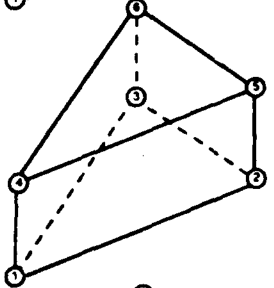
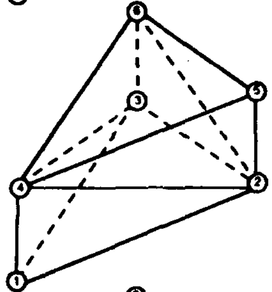
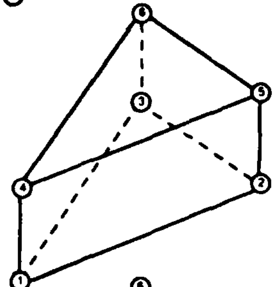
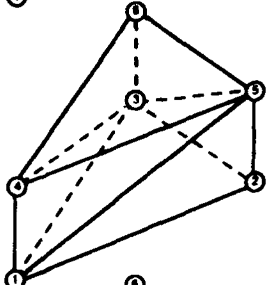
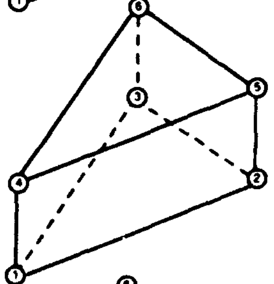
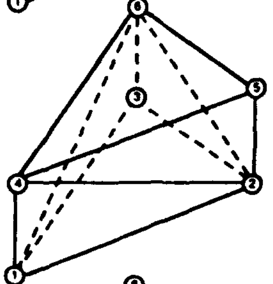
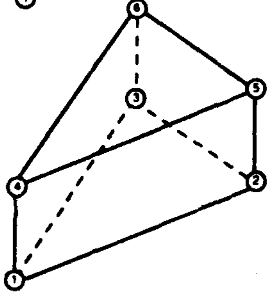
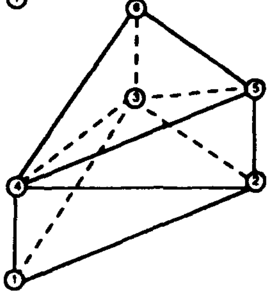
PATRAN		EPIC	
NAME	GEOMETRY	NAME	GEOMETRY
WEDGE/6 (CID = 11)		WEDGE 1 (3 TETRAHEDRA)	
WEDGE/6 (CID = 12)		WEDGE 1 (3 TETRAHEDRA)	
WEDGE/6 (CID = 13)		WEDGE 1 (3 TETRAHEDRA)	
WEDGE/6 (CID = 21)		WEDGE 2 (3 TETRAHEDRA)	
WEDGE/6 (CID = 22)		WEDGE 2 (3 TETRAHEDRA)	

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Figure 22. PATRAN to EPIC Translators for Nodes and Elements (Continued)

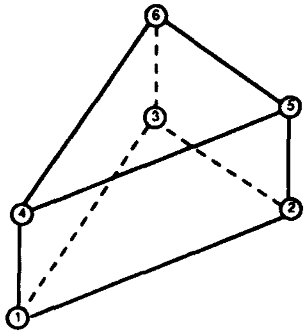
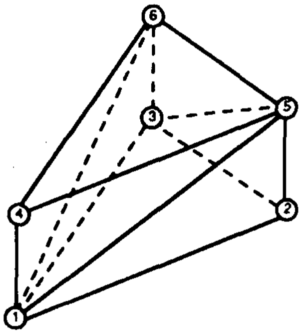
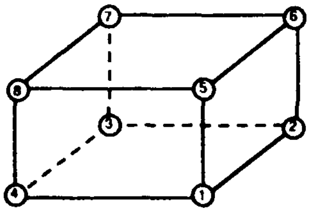
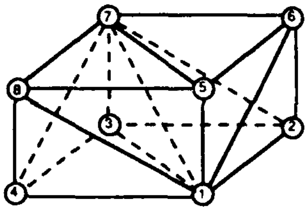
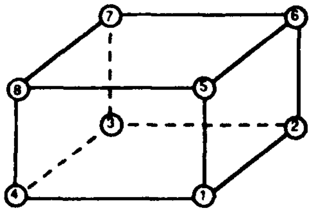
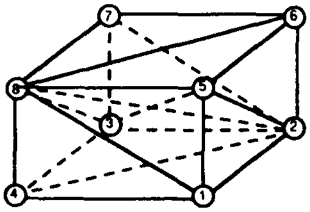
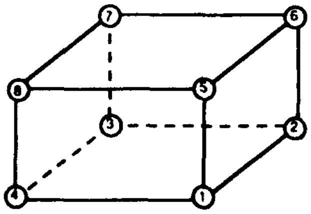
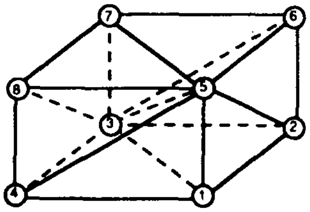
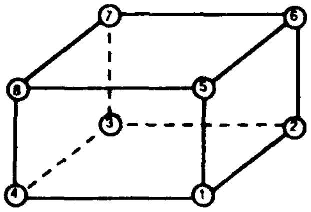
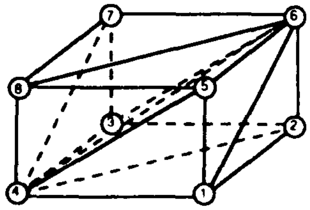
PATRAN		EPIC	
NAME	GEOMETRY	NAME	GEOMETRY
WEDGE/6 (CID=23)		WEDGE 2 (3 TETRAHEDRA)	
HEX/8 (CID=1)		NON-SYMMETRIC BRICK ARRANGEMENT (6 TETRAHEDRA)	
HEX/8 (CID=2)		NON-SYMMETRIC BRICK ARRANGEMENT (6 TETRAHEDRA)	
HEX/8 (CID=3)		NON-SYMMETRIC BRICK ARRANGEMENT (6 TETRAHEDRA)	
HEX/8 (CID=4)		NON-SYMMETRIC BRICK ARRANGEMENT (6 TETRAHEDRA)	

Figure 22. PATRAN to EPIC Translators for Nodes and Elements (Concluded)

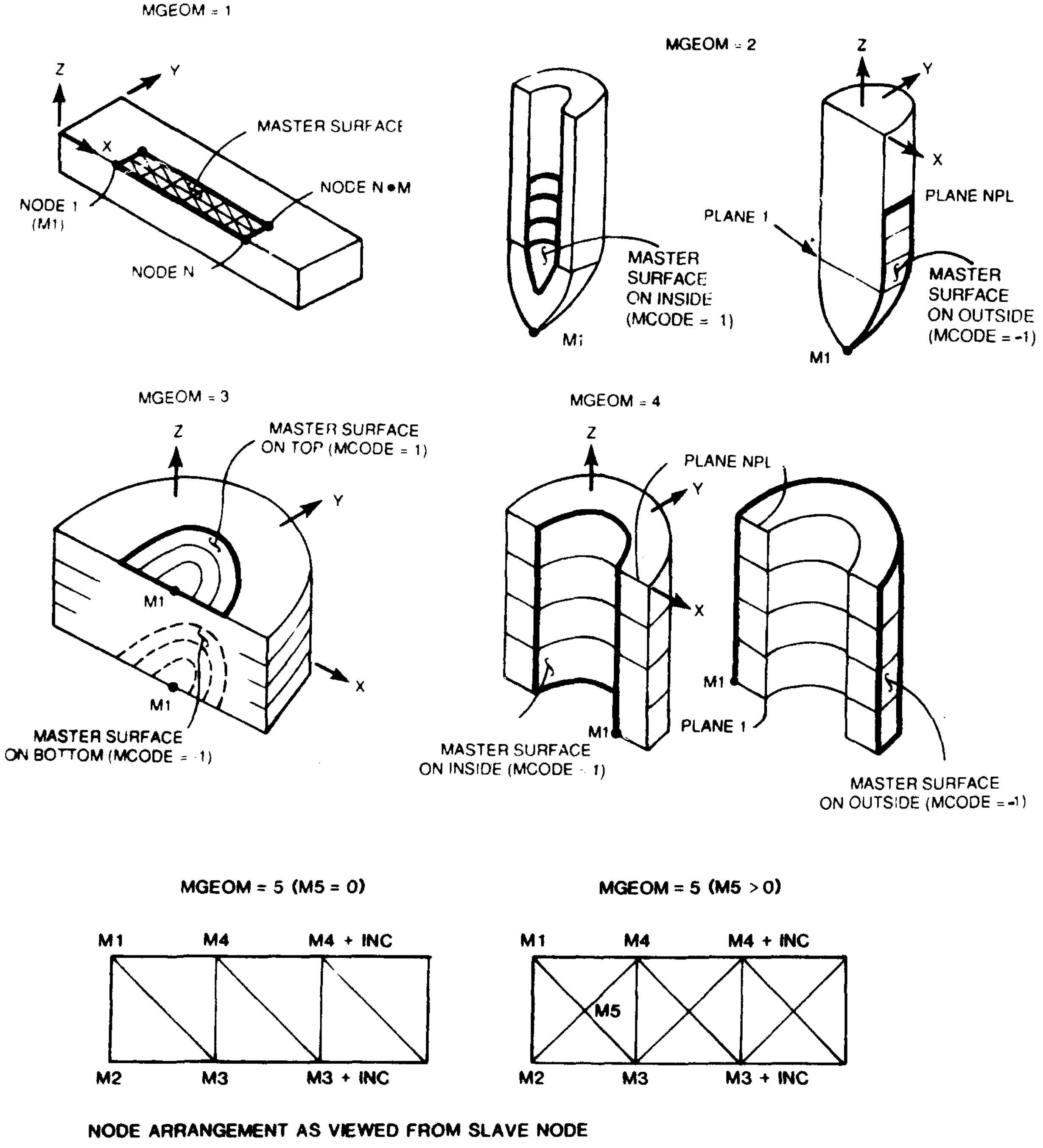


Figure 23. Master Surface Options for 3D Sliding Interfaces

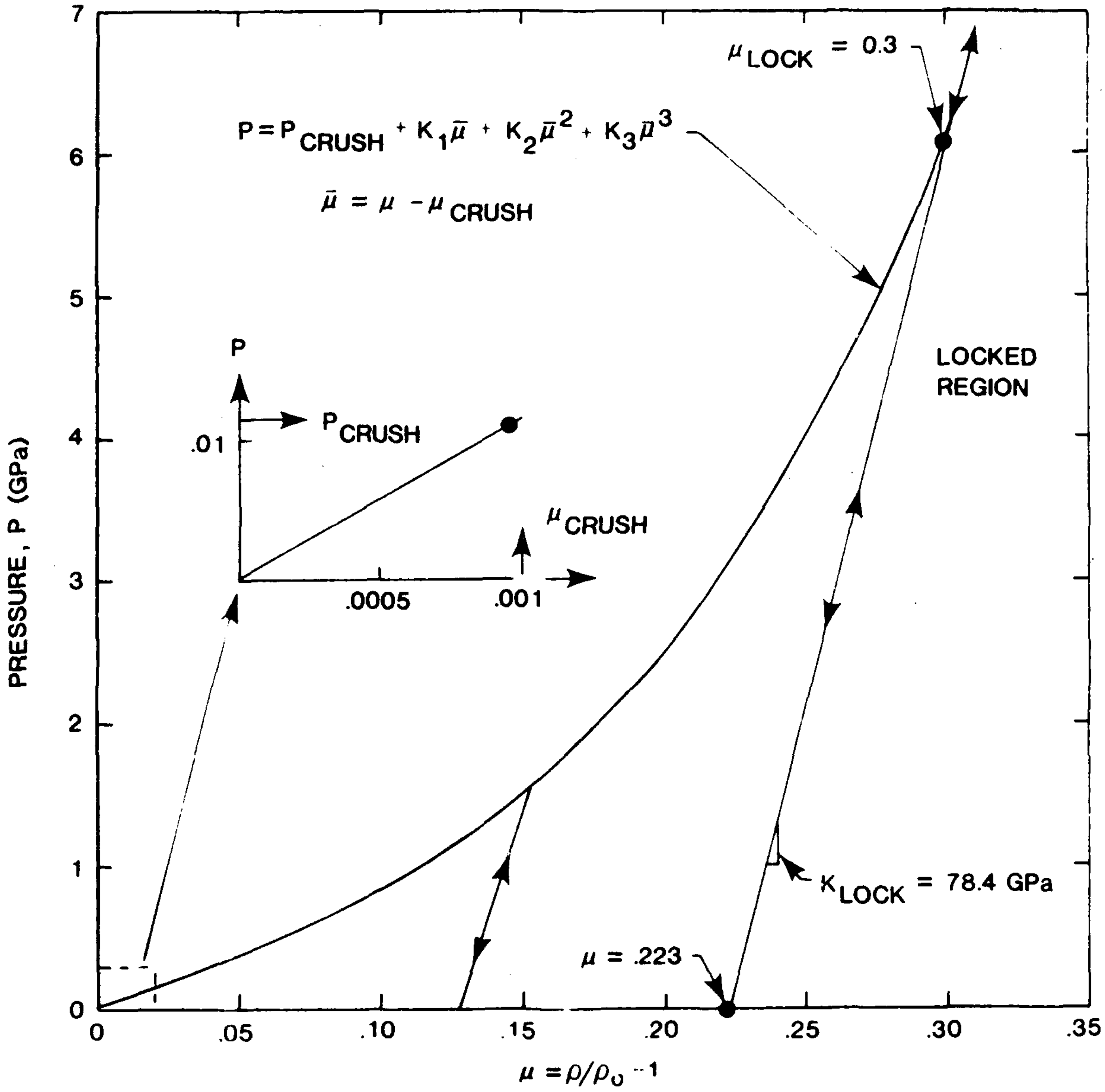


Figure 24. Pressure Model for Crushable Solids (Specific Data Shown are for Concrete)

1. INPUT DATA FOR THE PREPROCESSOR

The function of the Preprocessor is to define the initial geometry and velocity conditions. The descriptions which follow are for the data in Figure 1. Consistent units must be used and the unit of time must be seconds.

It is possible to interject user comments into the data by use of a $ character. If the $ is in the first column of the card, that entire card is ignored as input data. If the $ is beyond the first column in the card, then the $ and all data to the right of the $ are ignored (Reference 7).

A card with a $ in the first column can be used to show the field names and/or to show a title for a group of cards. A card with a blank in the first column and a $ in the second column can be used as a blank card with a comment about which section this blank card ends.

Prep Description Card (2I5, A70) —

TYPE = 1 specifies a Preprocessor run only.
= 2 specifies a Preprocessor and Main Routine Run.

CASE = Case number for run identification. This same case number must be used for all subsequent restart runs

PREP DESCRIPTION = Description provided by user.

Prep Miscellaneous Card (8I5, 5X, I5, I2, 3I1, 3I5) —

GEOM = 1 specifies 1D cartesian geometry.
= 2 specifies 1D cylindrical geometry.
= 3 specifies 1D spherical geometry.
= 4 specifies 2D plane stress geometry. (Reference 8.)
= 5 specifies 2D plane strain geometry.
= 6 specifies 2D axisymmetric geometry (without spin).
= 7 specifies 2D axisymmetric geometry (with spin).
= 8 specifies 3D geometry.

PRINT = 0 will not print individual data for each node, element, and sliding interface.
= 1 will print individual data.
= 2 will restrict printing of 3D node data to nodes with Y = 0 and to 3D element data with one face on the Y = 0 plane.

SAVE = 0 will not write Preprocessor data on restart file.
= 1 will write Preprocessor data on restart file, IRESIN.
= 2 will write Preprocessor data on restart file, IRESOT.
= 3 will write Preprocessor data on restart file (opened on channel IRES03) with the name EiP00.RES, where i = PCASE, which is described later on this card.

NSLID = Number of sliding interfaces.

NMAS = Number of concentrated masses to be input separately.

NRST = Number of groups of nodes to have restraints redefined.

NRIG = Number of systems of nodes which move as rigid system.

NCHNK = Number of groups of elements for which subsystem data are requested. Only the non-eroded (intact) elements are included in these data.

NZONE = Number of regions to be input for automatic rezoning during a Main Routine run. (Not yet available.)

PCASE = Identification number for PATRAN files generated by the Main Routine. Use different number for different EPIC runs so that the different PATRAN files are not assigned the same name. Is also used as identification number for restart files when SAVE = 3.

IX/R = 0 will not provide a rigid frictionless surface on the positive side of a plane described by R = 0 (2D) or X = 0 (3D).

= 1 will provide a rigid frictionless surface on the positive side of a plane described by R = 0 (2D) or X = 0 (3D). If the equations of motion cause a node to have a negative X/R coordinate, the X/R coordinate and velocity are set to zero.

IY = 0 will not provide a rigid frictionless surface on the positive side of a plane described by Y = 0 (3D only).

= 1 will provide a rigid frictionless surface on the positive side of a plane described by Y = 0 (3D only).

IZ = 0 will not provide a rigid frictionless surface on the positive side of a plane described by Z = 0.

= 1 will provide a rigid frictionless surface on the positive side of a plane described by Z = 0 (1D, 2D, 3D).

SPLIT = 0 will perform the sliding interface computations after the updated velocities and displacements are determined from the usual equations of motion. Contact is established as long as the slave node interferes with the master surface before the velocities and displacements are adjusted in the sliding surface routines. This option is the most reliable and should be used for complicated sliding surfaces which include double pass options and intersecting sliding surfaces. It must be used for the eroding interface option. For 3D computations involving relatively low velocity impact problems and rigid body nodes (NRIG > 0), this option can introduce significant errors in the form of excessive deformation and internal energy.

= 1 will perform the sliding surface computations after the updated velocities are determined but before the updated displacements are determined. This should be used if the sliding interfaces are relatively simple and/or contain rigid body nodes. Specifically, it requires that no slave node or master node be a slave node or master node on more than one sliding interface. Also, the double pass option for 2D computations (IT2 > 0) cannot be used. Contact is first established when the slave node interferes with the master surface. Thereafter, a slave node is considered to be in contact until the preadjusted normal velocities between the two surfaces are separating rather than closing. This approach minimizes the distance the slave node is moved to place it on the master surface (for rigid body nodes) and is therefore more accurate for this case. If there are no sliding surfaces, either option can be used (SPLIT = 0 or SPLIT = 1).

DP3 = 0 will not perform any double precision computations.

= 1 will perform double precision computations for 3D volume computations and parts of the 3D sliding interface computations. This sometimes may be required for 32-bit computers, but is not required for 64-bit computers.

UNIT = 0 indicates the constants in the material library have English units (pound/inch/second/degree Fahrenheit).

= 1 indicates the constants in the material library are converted to Standard International (SI) units.

Material Data Cards — Material data can be completely defined by the user or taken from the material data library. Specific instructions are presented later. End material data with a blank card.

Projectile Scale/Shift/Rotate Card (7F10.0, 2F5.0) —

X/RSCALE = Factor by which the R coordinates (2D) or X coordinates (3D) of all projectile nodes are multiplied. Applied after the coordinate shifts (X/RSHIFT, ZSHIFT) and before the rotations (ROTATE/SLANT) described later.

YSCALE = Factor by which the Y coordinates are multiplied for 3D geometry. Leave blank for 1D or 2D geometry.

ZSCALE = Factor by which the Z coordinates are multiplied.

X/RSHIFT = Increment added to the X/R coordinates of all projectile nodes (length). Applied before the scale factors (X/RSCALE, YSCALE, ZSCALE).

ZSHIFT = Increment added to the Z coordinates (length).

ROTATE = Rotation about X/R0 and Z0 in the R–Z plane (2D), or the X–Z plane (3D), of all projectile nodes (degrees). Applied after the coordinate shifts (X/RSHIFT, ZSHIFT) and the scale factors (X/RSCALE, ZSCALE). Clockwise is positive for 2D, and for 3D when looking in a positive Y direction.

SLANT = The angle (degrees) used to redefine the X/R coordinates of all projectile nodes, with the relationship $X/R_{new} = X/R_{old} + (Z - Z0)$ tan (SLANT). This takes vertical lines of nodes and aligns them at an angle, SLANT, with the vertical. Applied after the other SCALE/SHIFT/ROTATE options.

X/R0 = X/R reference coordinate for the ROTATE/SLANT options.

Z0 = Z reference coordinate for the ROTATE/SLANT options.

Node Data Cards for Projectile — These cards are required to define the projectile nodes. If a node is at the interface of the projectile and the target and contains mass from both the projectile and the target, it must be included with the projectile nodes. The node numbers must not exceed the dimension of the node arrays, and they need not be numbered consecutively or in increasing order. Specific instructions for node input data are presented later. End projectile node data with a blank card.

Target Scale/Shift/Rotate Card (7F10.0, 2F5.0) — Same as Projectile Scale/Shift/Rotate Card except it applies to the target nodes. Must be included even if there are no target nodes.

Node Data Cards for Target — Similar to node data cards for projectile. Specific instructions are presented later. End target node data with a blank card. Include blank card even if there are no target nodes.

Element Data Cards for Projectile — These cards are required to define the projectile elements. The element numbers must not exceed the dimension of the element arrays, and they will automatically be numbered consecutively. Specific instructions are presented later. End projectile element data with a blank card.

Element Data Cards for Target — Similar to element data cards for projectile. Specific instructions are presented later. End target element data with a blank card. Include blank card even if there are no target elements.

Sliding Interface Data Cards for NSLID > 0 — These cards are required to define the sliding interfaces. Specific instructions are presented later.

NMAS Concentrated Mass Cards (I5, 5X, F10.0) — There are NMAS (defined in Prep Miscellaneous Card) cards entered for the concentrated masses. These cards are omitted when NMAS = 0. Each card contains data for one mass.

N = Node number to which the concentrated mass is added.

MASS (N) = Concentrated mass added to node N.

Restrained Nodes Identification Cards (2I5, 2X, 3I1) — Each set of restrained nodes contains one Restrained Nodes Identification Card and additional cards to specify the nodes. The program does not impose any constraint on the number of sets and each set can contain as many as the node arrays can handle. If there are no restrained node sets (NRST = 0 in Prep Miscellaneous Card), this group of cards is omitted. If there is more than one set of restrained nodes, all cards for the first set are entered before the Restrained Nodes Identification Card for the next set is entered. This input redefines the restraints on the designated nodes (it does not simply add to existing restraints).

NFN = Number of nodes in set.

NFG = Number of groups of nodes to be read. If NFG = 0, the nodes are read individually.

IX/R, IY/T, IZ = 1 restrains nodes in R, θ, Z directions, respectively, for 2D geometry and the X, Y, Z directions for 3D geometry. Expanded description given for Line of Nodes Description Card in Node Geometry Subsection.

Individual Restrained Nodes Cards for NFG = 0 (16I5) —

F1...FN = Individual nodes to be restrained.

NFG Grouped Restrained Nodes Cards (3I5) —

F1G = First node in the group of nodes to be restrained.

FNG = Last node in the group of nodes to be restrained. Leave blank if there is only one node in the group.

INC = Increment between nodes in the group of restrained nodes. Leave blank if there is only one node in the group.

Rigid Body Identification Cards (2I5) — Each system of rigid body nodes contains one Rigid Body Identification Card and additional cards to specify the nodes. If there are no rigid body systems (NRIG = 0 in Prep Miscellaneous Card), this group of cards is omitted. If there is more than one system of rigid body nodes, all cards for the first system are entered before the Rigid Body Identification Card for the next system is entered. Rigid body nodes must not contain any slave nodes on sliding interfaces or have nodes restrained in the Z direction. (An exception is that a slave node can be designated a rigid body node, if it is the only node in the system.) For 1D cylindrical and spherical geometries (GEOM = 2 or 3) there can be no rigid body nodes. For plane strain or plane stress geometry (GEOM = 4 or 5), if any rigid body node is restrained in the R direction, then all are restrained in the R direction. For axisymmetry geometries (GEOM = 6 or 7), all rigid body nodes are restrained in the R direction. For 3D geometry (GEOM = 8) all rigid body nodes are restrained in the Y direction. If any 3D rigid body nodes are restrained in the X direction, then all are restrained in the X direction. Also, if NRIG > 0 for 3D, then the 3D sliding algorithm uses a less accurate technique.

NRN = Number of rigid body nodes in the system.

NRG = Number of groups of rigid body nodes to be read. If NRG = 0, the nodes are read individually.

Individual Rigid Body Nodes Cards for NRG = 0 (16I5) —

R1...RN = Individual nodes in rigid body system.

NRG Grouped Rigid Body Nodes Cards (3I5) —

R1G = First node in the group of rigid body nodes.

RNG = Last node in the group of rigid body nodes. Leave blank if there is only one node in the group.

INC = Increment between nodes in the group of rigid body nodes. Leave blank if there is only one node in the group.

NCHNK Chunk Element Cards (2I5) — Each subsystem of element chunks for which output is desired requires a Chunk Element Card. If there are no chunk data to be obtained (NCHNK = 0 in Prep Miscellaneous Card), these cards are omitted.

CE1 = First element in the chunk.

CEN = Last element in the chunk. The chunk includes all elements between (and including) CE1 and CEN.

Note: If CE1 and/or CEN exceed the I5 format (≥100,000), set CE1 = –1 and then read CE1 and CEN on the following card in 2I10 format.

Automatic Rezone Region Definition Cards for NZONE > 0 — These cards describe the regions which can be automatically rezoned during a Main Routine run. This applies to 2D geometry only (GEOM = 4, 5, 6, 7). Specific instructions are presented later. (Not yet available.)

Detonation Card (4F10.0) — This card describes the initial explosive detonation conditions. Leave this card blank (but include) if no explosives are used.

X/RDET = X/R coordinate of the explosive detonation (distance).

YDET = Y coordinate of the explosive detonation (3D only).

ZDET = Z coordinate of the explosive detonation.

TBURN = Time (second) at which the detonation begins at X/RDET, YDET, ZDET.

Initial Velocity Card (7F10.0, I5) — This card describes the initial velocity conditions. If there are interface nodes which include mass from both the projectile and the target, the velocities of these nodes are automatically adjusted to conserve momentum.

PX/RDOT = Projectile velocity in the R direction for 2D geometry or the X direction for 3D geometry (distance/second).

PY/TDOT = Projectile velocity in the θ direction for 2D geometry (radians/second) or the Y direction for 3D geometry (distance/second).

PZDOT = Projectile velocity in the Z direction.

TX/RDOT = Target velocity in the X/R direction.

TY/TDOT = Target velocity in the Y/θ direction.

TZDOT = Target velocity in the Z direction. Should be zero when the erosion option is used (ERODE > 0) with axisymmetric geometry (GEOM = 6, 7).

DT1 = Integration time increment for the first cycle. This must be less than the time required to travel across the minimum dimension of each element at the sound speed of the material in that element.

NVFLD = Number of additional velocities fields to be input. The additional velocity fields will supersede those input with this card.

NVFLD Velocity Field Definition Cards (6F10.0, 4I5) — These cards describe the additional NVFLD velocity fields to be input. One card is required for each new velocity field. The velocities vary linearly from node N1 to node N2 and include nodes NA1 to NAN. They supersede previously input velocities.

X/R1DOT = X/R velocity at node N1 (distance/second).

Y/T1DOT = Y/θ velocity at node N1.

Z1DOT = Z velocity at node N1.

X/R2DOT = X/R velocity at node N2.

Y/T2DOT = Y/θ velocity at node N2.

Z2DOT = Z velocity at node N2.

N1 = Node at which velocities are X/R1DOT, Y/T1DOT, and Z1DOT.

N2 = Node at which velocities are X/R2DOT, Y/T2DOT, and Z2DOT.

NA1-NA2 = Range of nodes whose velocities are updated.

a. Material Descriptions

There are four material types available to the user. They are for Solids, Explosives, Crushable Solids, and Liquids. Input data are shown in Figure 2. Data may be input directly or the material library may be used.

Material Card for Solids from Library (4I5, 2F5.0) — Data for some materials are available from the material library in subroutine MATLIB. The specific materials are shown in Figure 9 and listed as output from the Preprocessor. Library materials may only be used after being called by this card. The user should read the comments in subroutine MATLIB to obtain the references from which the data were generated.

MATL = Material identification number. It must be in the range of 1 through 100 and must correspond to a material number in the library.

0 = Code to specify library material.

DAM = 0 will not compute material damage.
= 1 will compute material damage.

FAIL = 0 will not allow fracture of the material when the damage exceeds 1.0, but rather will continue to accumulate the damage.

= 1 will allow the material to fracture partially when the damage exceeds 1.0. Partial fracture causes shear and tensile failure, so only compressive hydrostatic pressure capability remains. Can be used only with DAM = 1.

DFRAC = Factor by which library fracture strain constants (D1, D2, EFMIN—defined later) are multiplied. DFRAC = 1.0 will provide the exact library constants.

EFAIL = Equivalent plastic strain, or volumetric strain, which, if exceeded, will totally fail the element such that it produces no stresses or pressures. If EFAIL ≥ 999, the check for total failure will be omitted.

Description Card for Solids Input Data (4I5, 5X, F5.0, A50) — This card (plus four additional cards) specifies all the material constants for a solid material. Four options are available for the strength model. These cards will supersede any material library data with the same material number, MATL. Only previously undefined variables will be defined.

MATL = Material number specified by user. Will supersede library material data with same material number.

1 = Code to specify Solids input data.

MATERIAL DESCRIPTION = Description provided by user.

Card 2 for Solids (6F10.0, I5) —

DENSITY = Material density (mass/volume).

SPH HEAT = Specific heat (work/mass/degree).

TEMP1 = Initial temperature of the material (degree).

TROOM = Room temperature (degree).

TMELT = Melting temperature of the material (degree).

TZERO = Absolute zero temperature (degree).

MODEL = 1 specifies Johnson-Cook strength model (Reference 9).
= 2 specifies modified Johnson-Cook strength model.
= 3 specifies Zerilli-Armstrong FCC strength model (Reference 10).
= 4 specifies Zerilli-Armstrong BCC strength model (Reference 10).

Card 3 for Johnson-Cook Model (MODEL = 1) (8F10.0) —This card describes strength constants for the Johnson-Cook Model (Reference 9).

SHEAR MOD = Shear modulus of elasticity (force/area).

C1, C2, N, C3, M, C4, SMAX = Constants to describe the material strength, σ, using the Johnson-Cook model.

$$\sigma = [C1 + C2 \cdot \epsilon^{N}] [1 + C3 \cdot \ln \dot{\epsilon}^{*}] [1 - T^{*M}] + C4 \cdot P \qquad (1)$$

Where ϵ is the equivalent plastic strain, $\dot{\epsilon}^{*} = \dot{\epsilon}/\dot{\epsilon}_{o}$ is the dimensionless strain rate for $\dot{\epsilon}_{o} = 1.0\ s^{-1}$, T^{*} is the homologous temperature, and P is the hydrostatic pressure (compression is positive). Valid only for $0 \leq T^{*} \leq 1.0$. N must be a positive number, and the thermal softening fraction, $K_T = [1 - T^{*M}]$, is set to $K_T = 1.0$ when M = 0. If SMAX is input as a positive number, then the maximum strength for σ is limited to SMAX. If left blank (SMAX = 0), the strength (σ) is not limited.

A constant flow stress can be obtained by setting C1 to the flow stress, N = 1.0, and C2 = C3 = C4 = SMAX = M = 0. C1, C2, and SMAX have units of stress (force/area), and the others are dimensionless.

Card 3 for Modified Johnson-Cook Model (MODEL = 2) (8F10.0) — This card describes strength constants for the modified Johnson-Cook model.

C1, C2, N, C3, C4, SMAX = Constants to describe the material strength, σ, using the modified M, Johnson-Cook model.

$$\sigma = [C1 + C2 \cdot \epsilon^{N}] [\dot{\epsilon}^{*C3}] [1 - T^{*M}] + C4 \cdot P \qquad (2)$$

This is similar to the Johnson-Cook model except that the strain rate effect [$\dot{\epsilon}^{*C3}$] is different. This model provides an enhanced strain rate effect at high strain rates.

Card 3 for Zerilli-Armstrong FCC Model (MODEL = 3) (6F10.0) — This card describes strength constants for the Zerilli-Armstrong FCC model (Reference 10). It does not represent the grain size as a variable, but rather includes it in C0.

C0, C2, C3, C4, N = Constants to describe the material strength, σ, using the Zerilli-Armstrong FCC model.

$$\sigma = C0 + C2 \cdot \epsilon^{N} \cdot \exp(-C3 \cdot T + C4 \cdot T \cdot \ln\dot{\epsilon}) \qquad (3)$$

Where ϵ is the equivalent plastic strain, T is the absolute temperature (degree) and $\dot{\epsilon}$ is the equivalent strain rate (s^{-1}). C0 and C2 have units of stress (force/area); and C3 and C4 have the units of $(\text{degree})^{-1}$.

Card 3 for Zerilli-Armstrong BCC Model (MODEL = 4) (7F10.0) — This card describes strength constants for the Zerilli-Armstrong BCC model (Reference 10).

C0, C1, C3, C4, C5, N = Constants to describe the material strength, σ, using the Zerilli-Armstrong BCC model.

$$\sigma = C0 + C1 \cdot \exp(-C3 \cdot T + C4 \cdot T \cdot \ln\dot{\epsilon}) + C5 \cdot \epsilon^{N} \qquad (4)$$

This is similar to the Zerilli-Armstrong FCC model. C0, C1, and C5 have units of stress (force/area).

Card 4 for Solids (8F10.0) —

K1, K2, K3 = Cubic coefficients for the Mie-Gruneisen Equation of State (force/area).

$$P = (K1\mu + K2\mu^2 + K3\mu^3)(1 - \Gamma\mu/2) + \Gamma E_s(1 + \mu) \qquad (5)$$

where $\mu = \rho/\rho_o - 1$ and E_s is internal energy per initial volume.

Γ = Gruneisen coefficient for Mie-Gruneisen equation of state.

PMIN = Maximum hydrostatic tension allowed (force/area).

CL = Linear artificial viscosity coefficient (CL ≈ 0.2).

CQ = Quadratic artificial viscosity coefficient (CQ ≈ 4.0).

CH = Hourglass artificial viscosity coefficient for 2D quad elements or 3D composite brick elements with pressure averaging option (CH ≈ 0.02).

Card 5 for Solids (8F10.0) —

D1...D5 = Constants for the Johnson-Cook fracture model (Reference 11).

$$\epsilon^f = [D1 + D2 \cdot \exp(D3 \cdot \sigma^*)] [1 + D4 \cdot \ln\dot{\epsilon}^*] [1 + D5 \cdot T^*] \qquad (6)$$

Where ϵ^f is the equivalent strain to fracture under constant conditions of the dimensionless strain rate, $\dot{\epsilon}^*$, homologous temperature, T^*, and the pressure-stress ratio, $\sigma^* = \sigma_m/\bar{\sigma}$. The mean normal stress is σ_m and $\bar{\sigma}$ is the von Mises equivalent stress. Expression is valid for $\sigma^* \leq 1.5$. Damage is computed from $D = \Sigma\Delta\epsilon/\epsilon^f$, and fracture is allowed to occur when D = 1.0.

SPALL = Tensile spall stress (negative pressure) at which fracture can occur (force/area).

EFMIN = Minimum fracture strain allowed. For $\sigma^* > 1.5$, ϵ^f varies linearly from ϵ^f at $\sigma^* = 1.5$ to EFMIN at σ_m = SPALL.

X1 = Extra material constant stored in the C10 array.

Material Card for Explosives from Library (2I5) — Similar to the card for the solid materials in the library except that no options are provided for fracture.

Description Card for Explosives Input Data (2I5, 20X, A50) — This card (and one or two additional cards) specifies the material constants for explosives. Only new variables will be defined. See solid material definitions for other variables.

2 = Code to specify explosives input data.

Card 2 for Explosives (7F10.0, I5) —

ENERGY = Initial internal energy in explosive, E_o (energy/volume).

DET VEL = Detonation velocity, D (distance/second).

X1 = Extra material variable stored in array C10.

JWL = 0 will use gamma law equation of state.

= 1 will use JWL equation of state.

For gamma law, the pressure is determined from

$$P = (\gamma - 1)\, E/\overline{V} \tag{7}$$

$$\text{where } \gamma = \sqrt{1 + D^2\rho_o/2E_o} \tag{8}$$

E is the internal energy per initial volume, ρ_o is the initial density, and $\overline{V} = V/V_o$ is the relative volume.

JWL Model Constants Card for JWL = 1 (5F10.0) —

C1...C5 = Constants for the JWL equation of state.

For the JWL model, the pressure is determined from

$$\begin{aligned} P = {} & C1 \cdot (1 - C5/C2\,\overline{V}) \cdot \exp(-C2 \cdot \overline{V}) \\ & + C3 \cdot (1 - C5/C4\,\overline{V}) \cdot \exp(-C4 \cdot \overline{V}) \\ & + C5 \cdot E/\overline{V} \end{aligned} \qquad (9)$$

where E is internal energy per initial volume and $\overline{V} = V/V_0$ is the relative volume. C1 and C3 have the units of pressure (force/area); and C2, C4, and C5 are dimensionless.

Material Card for Crushable Solids from Library (215, 15X, F5.0) — Similar to the cards for other library materials. Total failure is allowed through EFAIL, but fracture due to damage is not allowed.

Description Card for Crushable Solids Input Data (215, 15X, F5.0, A50) —This card (plus three additional cards) specifies the material constants for a crushable solid material (Reference 12). Only new variables will be defined. See previous material definitions for other variables.

3 = Code to specify Crushable Solids input data.

Card 2 for Crushable Solids (3F10.0) — All variables previously defined.

Card 3 for Crushable Solids (8F10.0) — Only new variables will be defined. See previous material definitions for other variables.

C1, C4 = Constants to describe the material strength, σ (force/area).

$$\sigma = C1 + C4 \cdot P \qquad (10)$$

SMAX = Maximum strength allowed (force/area). If left blank (SMAX = 0), strength (σ) is not limited.

X1 = Extra material constant stored in the D1 array.

Card 4 for Crushable Solids (8F10.0) — Only new variables will be defined. See previous material definitions for other variables.

PCRUSH UCRUSH, K1, K2, K3, KLOCK, ULOCK = Constants to describe the pressure, P. The model, and specific data for concrete, are shown in Figure 24. The basic model can also be used for other crushable solid materials. PCRUSH, K1, K2, K3, and KLOCK have units of pressure (force/area). UCRUSH and ULOCK are dimensionless. Both PCRUSH and UCRUSH must be positive (PCRUSH > 0 and UCRUSH > 0), and they should define a reasonable elastic bulk modulus (PCRUSH/UCRUSH).

Material Card for Liquids from Library (2I5, 15X, F5.0) — Similar to the cards for other library materials. Total failure is allowed through EFAIL.

Description Card for Liquids Input Data (2I5, 15X, F5.0, A50) — This card (plus two additional cards) specifies the material constants for liquids. Only new variables will be defined. See previous material definitions for other variables.

4 = Code to specify Liquids input data.

Card 2 for Liquids (4F10.0) —

X1 = Extra material constant stored in array C10.

Card 3 for Liquids (8F10.0) — Same constants as used for solid material.

b. Node Geometry

Node geometry data are required for the projectile nodes and the target nodes. These data can be input as lines of nodes, various rod shapes, nose shapes, flat plates, and/or spheres. PATRAN generated data can also be used. The input data are summarized in Figure 3. One dimensional geometry (GEOM = 1, 2, 3) is taken along the Z axis at X/R = 0 and Y/θ = 0. Two dimensional geometry (GEOM = 4, 5, 6, 7) has the Z coordinate positive upward and the R coordinate positive to the right. Three dimensional geometry (GEOM = 8) has the Z coordinate positive upward and X coordinate positive to the right when looking in the positive Y direction. The node numbers must not exceed the dimension of the node arrays, and they need not be numbered in any special order. They should, however, be generally numbered consecutively so that blocks of nodes can be formed for vectorized computations.

Line of Nodes Description Card (2I5, 2X, 3I1, 25X, 2I5, F10.0) — Two cards are required for each line of nodes to be generated. The nodes may be numbered consecutively or incremented by INC, and the nodes may be uniformly or variably spaced. Refer to Figure 10 for more details.

1 = Identification number for line of nodes geometry.

NNODE = Total number of nodes in the row of nodes.

IX/R = 0 will not restrain nodes in X/R direction.
= 1 will restrain nodes in X/R direction.

IY/T = 0 will not restrain nodes in Y/θ direction.
= 1 will restrain nodes in Y/θ direction.

IZ = 0 will not restrain nodes in Z direction.
= 1 will restrain nodes in Z direction.

N1 = Number of the first node of the line of nodes.

INC = Node number increment between corresponding nodes. Leave blank if a single node is to be generated.

EXPAND = Factor by which the distance between nodes is multiplied going from the first node to the last node. EXPAND = 1.0 gives uniform spacing. See Figure 10 for effects of various expansion factors.

Line of Nodes Coordinate Card (6F10.0) — This card reads the coordinates of the two end nodes in a line of nodes.

X/R1 = X/R coordinate of the first node (distance).

Y1 = Y coordinate (3D only) of the first node.

Z1 = Z coordinate of the first node.

X/RN = X/R coordinate of the last node. Leave blank if a single node is generated.

YN = Y coordinate of the last node.

ZN = Z coordinate of the last node.

Rod (Disk) Node Description Card (10I5, 3F10.0) —Two or more cards are required for each rod shape to be generated. The rod shape geometry descriptions for both 2D and 3D geometries are given in Figures 16 and 18. For 2D geometry the first node is at the upper left corner of the rod shape, and the nodes are numbered across each layer working down. Radial restraints on the centerline nodes are provided when NIR = 0. Either the primary only or both the primary and secondary (crossed triangle) nodes may be generated in the rod geometry.

For 3D geometry the rod is always generated in a vertical position about the Z axis. When viewed from the positive Z direction, the nodes are numbered consecutively counterclockwise, inner to outer and downward. Only one half the rod is generated as shown and normal restraints are provided on the plane of symmetry at Y = 0. Either the symmetric or non-symmetric arrangement of elements can be used.

The nodes on the top and bottom surfaces, for both 2D and 3D, may be generated uniformly, read in individually, or computed by analytic functions. They can also be used to generate nodes for shell elements by setting NPLN = 1 or by setting NOR = NIR. The rotation of the rod for oblique impact is obtained with a Scale/Shift/Rotate Card.

2 = Identification number for rod nodes geometry.

NOR = Outer node ring number.

NIR = Inner node ring number. For a solid rod in 2D axisymmetric geometry (GEOM = 6, 7) or 3D geometry (GEOM = 8) set NIR = 0. This will assign the centerline nodes to the Z axis and will restrain these nodes in the R direction for the 2D geometry. Do not use NIR = 0 for 2D geometry if the inner ring is not on the z axis (R = 0).

NPLN = Number of horizontal planes of nodes (not including the secondary nodes if CROS = 1). If NPLN = 1, do not read node data for bottom of rod.

RAD = 1 gives uniform radial spacing at the top and bottom of the rod.

= 2 requires all radial coordinates at top and bottom of rod to be input individually.

= 3 will read input data for 2D circular or 3D spherical shapes to be generated about a point which is not on the Z axis. Must be used with AX = 3.

AX = 0 requires all top axial coordinates to be ZTOP and all bottom coordinates to be ZBOT.

= 1 requires axial coordinates at the top and bottom of the rod to be generated with an analytic function.

= 2 requires all axial coordinates to be input individually.

= 3 must be used with RAD = 3, as described previously.

CROS = 0 will not generate secondary nodes for either the 2D or 3D geometry.

= 1 will generate secondary nodes for 2D crossed triangle geometry or 3D symmetric brick arrangements.

JOIN = 0 will not eliminate any nodes.

= 1 will eliminate the top row of nodes, such that a rod can be joined to the bottom of a previously input rod.

N1 = Number of the first node in the rod. If the join option is used (JOIN = 1), then N1 should be identical to the innermost (lowest number) node on the bottom of the previously input rod to which the join is being made.

NTOP = 0 will use the input values of AX and RAD to define the top surface of the rod.

\> 0 will override the input values of AX and RAD to define the top surface of the rod. The coordinates of node N1 will be equated to those of node NTOP. Similarly, the coordinates of node N1 + 1 will be equated to those of NTOP + 1, etc., until all nodes on the top surface are equated to existing nodes. The AX and RAD options will be used for the bottom surface of the rod. For this option (NTOP > 0), the Scale/Shift/Rotate, etc., values used for both surfaces (which contain nodes N1 and NTOP) must be identical.

ZTOP = The constant Z coordinate of the top surface for AX = 0, or the top centerline Z coordinate for NIR = 0 and AX = 2 (distance).

ZBOT = The constant Z coordinate of the bottom surface for AX = 0, or the bottom centerline Z coordinate for NIR = 0 and AX = 2.

EXPAND = Factor by which the distance between corresponding nodes in the vertical direction is multiplied going from top to bottom. EXPAND = 1.0 gives uniform spacing in the vertical direction.

Rod Node Radii Card for RAD = 1 (4F10.0) —

ROTOP = Outer radius of the rod top (distance).

RITOP = Inner radius of the rod top.

ROBOT = Outer radius of the rod bottom.

RIBOT = Inner radius of the rod bottom.

Rod Node Top Radii Cards for RAD = 2 (8F10.0) —

RT(NIR)...
RT(NOR) = Radius of each ring of nodes at the top of the rod (distance). One or more cards as required. If NIR = 0, then begin with RT(1), as RT(0) will be set to RT(0) = 0.

Rod Node Bottom Radii Cards for RAD = 2 (8F10.0) —

RB(NIR)... RB(NOR)	= Radius of each ring of nodes at the bottom of the rod. One or more cards as required. If NIR = 0, then begin with RB(1), as RB(0) will be set to RB(0) = 0. Skip this card for special case of NPLN = 1.

Rod Node Top Surface Card for RAD = 3 and AX = 3 (2I5, 7F10.0) — This option allows 2D circular and 3D spherical shapes to be generated about a point which is not on the Z axis. The nodal spacing in the X/R – Z plane is at equal angular intervals.

TYPE	= 1 ends the far end of the shape by specifying the X/R coordinate at the end of the shape.
	= 2 ends the far end by specifying the Z coordinate.
	= 3 ends the far end by specifying an incremental angle from the near end.
CLOCK	= 0 generates the surface in a counterclockwise direction.
	= 1 generates surface in a clockwise direction.
RTO	= The X/R coordinate at the center of the 2D circular or 3D spherical section (distance).
ZTO	= The Z coordinate at the center of the 2D circular or 3D spherical section (distance).
RT1	= The X/R coordinate at the beginning of the circular/spherical section at node N1 (distance).
ZT1	= The Z coordinate of node N1 (distance).
RTN	= The X/R coordinate at the far end of the circular/spherical section (distance). Use only for TYPE = 1.

ZTN = The Z coordinate at the far end of the circular/spherical section (distance). Use only for TYPE = 2.

TT = The included angle in the circular/spherical section (degrees). Must always be positive as direction is specified with CLOCK. Use only for TYPE = 3.

Rod Node Bottom Surface Card for RAD = 3 and AX = 3 (2I5, 7F10.0) — Similar to the previous card for the top surface. Skip this card for the special case of NPLN = 1.

Rod Node Top Surface Card for AX = 1 (8F10.0) —

$A_0, A_1, \ldots A_7$ = Coefficients of the analytical function describing the top surface

$$Z_{top} = A_0 + A_1 r + \ldots + A_6 r^6 + A_7 (1 - \cos\theta) \qquad (11)$$

where θ is the angle from the Z axis.

Rod Node Bottom Surface Card for AX = 1 (8F10.0) —

$B_0, B_1, \ldots B_7$ = Coefficients of the analytical function describing the bottom surface

$$Z_{bot} = B_0 + B_1 r + \ldots + B_6 r^6 + B_7 (1 - \cos\theta) \qquad (12)$$

Skip this card for special case of NPLN = 1.

Rod Node Top Surface Cards for AX = 2 (8F10.0) —

ZT(NIR)... ZT(NOR) = Top Z coordinate of each ring of nodes (distance). One or more cards as required. If NIR = 0, then begin with ZT(1), as ZT(0) will be set to ZT(0) = ZTOP.

Rod Node Bottom Surface Cards for AX = 2 (8F10.0) —

ZB(NIR)... ZB(NOR) = Bottom Z coordinate of each ring of nodes. One or more cards as required. If NIR = 0, then begin with ZB(1), as ZB(0) will be set to ZB(0) = ZBOT. Skip this card for special case of NPLN = 1

Nose Node Description Card (7I5, 5X, I5, 5X, 2F10.0) — One or more cards are required for each nose shape to be generated. The nose shape geometries for both 2D and 3D are given in Figures 17 and 18. The nodes at the rod interface are not generated with the nose generator and must therefore be previously generated with the rod generator. The first node (N1) must be the next consecutive node after the last node (N1 – 1) generated by the rod generator. The nose shapes are always generated pointing downward, and the nodes are generally numbered downward, and inner to outer.

For 2D geometry the nodes on the centerline (R = 0) are restrained in the R direction. For 3D geometry, only one half the nose is generated as shown, and restraints are provided in the Y direction, normal to the plane of symmetry (Y = 0). The number of rings must be identical for the rod and the nose.

3 = Identification number for nose nodes geometry.

TYPE = 1 will generate a conical nose.

= 2 will generate a rounded nose. If the length of the nose is equal to the radius, a hemispherical nose is generated.

= 3 will generate a tangent ogival nose. The length of the ogival nose cannot be less than the radius of the nose at the rod-nose interface.

NOR = Outer node ring number. Must be identical to that of the corresponding rod at the rod-nose interface.

NIR = Inner node ring number. Must be identical to that of the corresponding rod.

RAD = 1 gives uniform radial spacing at the rod-nose interface.

= 2 requires all radial coordinates at the rod-nose interface to be input individually.

AX = 0 gives uniform spacing of the minimum (tip) Z coordinates of each ring. The rod-nose interface is at Z = ZTOP and the tip of the outer ring is at Z = ZMIN.

= 2 requires all minimum (tip) Z coordinates to be input individually.

CROS = 0 will not generate secondary nodes for either the 2D on the 3D geometry.

= 1 will generate secondary nodes for 2D crossed triangle geometry or 3D symmetric brick arrangements.

N1 = The first node in the nose. It must be the next consecutive node after the last node (N1 – 1) generated by the rod generator.

ZTOP = The Z coordinate of the rod-nose interface (distance).

ZMIN = The minimum (tip) Z coordinate of the outer ring for AX = 0.

Nose Node Top Radii Card for RAD = 1 (2F10.0) —

ROTOP = Top outer node radius at rod-nose interface (distance).

RITOP = Top inner node radius at rod-nose interface.

Nose Node Top Radii Cards for RAD = 2 (8F10.0) —

RT (NIR)... RT(NOR) = Top radius of each ring of nodes at the rod-nose interface (distance). If NIR = 0 then begin with RT(1), as RT(0) will be set to RT(0) = 0. One or more cards as required.

Nose Node ZMIN Cards for AX = 2 (8F10.0) —

ZMIN(NIR)... ZMIN(NOR) = Minimum (tip) Z coordinates for each ring of nodes (distance). If NIR = 0 then begin with ZMIN(1), as ZMIN(0) will be set to ZMIN(0) = ZTOP. One or more cards as required.

Flat Plate Description Card (10I5, 3F10.0) —Two cards are required for each flat plate to be generated. There is one option for 2D geometry (TYPE = 1) and three options for 3D geometry (TYPE = 2, 3, 4).

4 = Identification number for flat plate geometry.

TYPE = 1 generates a 2D flat plate as shown in Figure 19.

= 2 generates a 3D circular flat plate as shown in Figure 20. (Not yet available.)

= 3 generates a 3D rectangular flat plate where the nodes are generated in horizontal planes as shown in the upper portion of Figure 21.

= 4 generates a 3D rectangular flat plate where the nodes are generated in vertical planes as shown in the lower portion of Figure 21.

NX/R = Total number of nodes in the the R direction for 2D geometry (TYPE = 1) and the total number of nodes in the X direction for the 3D rectangular flat plate geometries (TYPE = 3, 4). For the 3D circular flat plate geometry (TYPE = 2), NX/R is the number of rings of nodes. Same as NOR for the rod generator.

NY = Total number of nodes in the Y direction for 3D geometry. For TYPE = 3 and 4 only.

NZ = Total number of nodes in the Z direction.

FIX = 0 will not restrain any nodes.

= 1 will restrain some nodes. For 2D geometry (TYPE = 1), will restrain in the radial direction at R = 0, if RMIN = 0.

For 3D geometry (TYPE = 2, 3, 4) will restrain nodes in the Y direction at Y = 0, if Y1 = 0.

CROS = 0 will not generate secondary nodes for either the 2D or the 3D geometry.

= 1 will generate secondary nodes for 2D crossed triangle geometry or 3D symmetric arrangement.

JOIN = 0 will not eliminate any nodes.

= 1 will eliminate the top horizontal row of nodes for 2D geometry (TYPE = 1), the top horizontal plane of nodes for 3D geometry (TYPE = 2, 3), and the first vertical plane of nodes (parallel to X–Z plane) for 3D geometry (TYPE = 4). This allows a plate to be joined to another previously generated plate.

= 2 will eliminate the left vertical row of nodes for 2D geometry (TYPE = 1) and the left vertical plane of nodes (parallel to Y–Z plane) for 3D (horizontal layer) geometry (TYPE = 3), and the left vertical plane of nodes for 3D (vertical layer) geometry (TYPE = 4). This option (JOIN = 2) requires proper description of INC described later.

= 3 will combine the effects of JOIN = 1 and JOIN = 2. It also requires a proper description of INC.

N1 = Number of the first node in the plate as indicated in Figures 19, 20, and 21. When using the JOIN option, N1 should be identical to the corresponding node generated previously.

INC = Node number increment between 2D lines of nodes and 3D planes of nodes. Required only when plates are joined together.

For 2D geometry (with JOIN = 2 or 3) INC is the node number increment between corresponding nodes in the vertical Z direction. This allows the final plate (composed of multiple individual plates) to have the nodes numbered continuously from left to right and top to bottom. Elements can later be input as a single shape.

For 3D geometry (with JOIN = 2 or 3) INC is the node number increment between corresponding nodes in the vertical Z direction (TYPE = 3), and corresponding nodes in the horizontal Y direction (TYPE = 4).

For the 3D plates (TYPE = 3 or 4) with secondary nodes (CROS = 1), INC can be determined from the following:

$$INC = 5 \cdot NXT \cdot NYT - 3\,NXT - 3 \cdot NYT + 2 \qquad (TYPE = 3)$$

$$INC = 5 \cdot NXT \cdot NZT - 3\,NXT - 3 \cdot NZT + 2 \qquad (TYPE = 4)$$

Where NXT, NYT, and NZT are the total number of nodes (for the combined plate) in the X, Y, and Z directions, respectively.

When there are no secondary nodes (CROS = 0) then INC = NXT · NYT for TYPE = 3 and INC = NXT · NZT for TYPE = 4.

X/R-EXPAND = Factor by which the X/R distance between nodes is multiplied in the variable RPART and XPART spacing sections for TYPE = 1, 3, 4. Applied to radial direction for the 3D circular flat plate (TYPE = 2).

Y-EXPAND = Factor by which the Y distance between nodes is multiplied in the Y variable spacing sections for 3D rectangular flat plates (TYPE = 3, 4).

Z-EXPAND = Factor by which the Z distance between nodes is multiplied in the Z variable spacing section, moving downward.

2D Flat Plate Card for TYPE = 1 (2I5, 2F5.0, 4F10.0) —*This card completes the* description of the 2D flat plate (TYPE = 1), as shown in Figure 19. The first node, N1, is at the RMIN, ZMAX corner of the plate and the nodes are numbered across the plate working down. Flat plates have horizontal tops and bottoms, and vertical sides. They may be joined top to bottom (with or without crossed triangles) if the JOIN = 1 option is used, or side to side if the JOIN = 2 option is used and the node number increment, INC, is equal to the total number of nodes (primary and secondary) in the radial direction. A JOIN = 3 option can also be used. Regions with variable nodal spacing may be included at the RMAX end and/or the ZMIN end.

NREND = Number of nodes in the R variable node spacing section. The node at the division between the uniform and the variable spacing sections is included in this number. Set NREND = 0 for uniform spacing in the R direction and set NREND = NX/R for variable spacing only.

NZEND = Number of nodes in the Z variable node spacing section. The node at the division between the uniform and the variable spacing sections is included in this number. Set NZEND = 0 for uniform spacing in the Z direction and set NZEND = NZ for variable spacing only.

RPART = Fractional part of the radial length occupied by the variable spacing. Set RPART = 0 for uniform spacing in the radial direction.

ZPART = Fractional part of the axial length occupied by the variable spacing. Set ZPART = 0 for uniform spacing in the axial direction.

RMAX = Maximum R coordinate of the plate (distance).

RMIN = Minimum R coordinate of the plate.

ZMAX = Maximum Z coordinate of the plate.

ZMIN = Minimum Z coordinate of the plate.

3D Circular Flat Plate Card for TYPE = 2 (2I5, 2F5.0, F10.0, 10X, 2F10.0) — This card completes the description of the 3D circular flat plate (TYPE = 2), shown in Figure 20. The nodal arrangement is identical to that of a solid rod, with first node N1 at the top center of the flat plate. This geometry option allows for radial expansion factors, which are not offered in the rod geometry. (Not yet available.)

NREND = Number of nodes in the radial variable node spacing section. The node at the division between the uniform and variable spacing sections is included in this number. Set NREND = 0 for uniform radial spacing and NREND = NX/R for variable spacing only.

NZEND = Number of nodes in the Z variable node spacing section. The node at the division between the uniform and variable spacing sections is included in this number. Set NZEND = 0 for uniform spacing in the Z direction and NZEND = NZ for variable spacing only.

RPART = Fractional part of RADIUS occupied by the variable spacing. Set RPART = 0 for uniform spacing in the radial direction.

ZPART = Fractional part of the axial length occupied by the variable spacing. Set ZPART = 0 for uniform spacing in the axial direction.

RADIUS = Radius of the circular plate (distance).

ZMAX = Maximum Z coordinate of the plate (distance).

ZMIN = Minimum Z coordinate of the plate.

3D Rectangular Flat Plate Card for TYPE = 3 (2I5, 2F5.0, 6F10.0) — This option generates nodes in horizontal planes for 3D plates. The following descriptions refer to the upper portion of Figure 21.

NXEND = The number of nodes in the X direction in each of the two variable X spacing regions. The node at the division between the uniform and the variable spacing sections is included in this number. The spacing is determined by X/R-EXPAND and the fractional length by XPART. In Figure 21, NXEND = 4. Depending on whether NX is odd or even, NXEND can have a maximum value of either (NX/R +1)/2 or (NX/R)/2, respectively, unless the special option discussed in XPART is used. The remaining middle X region (if any) is uniformly spaced. Set NXEND = 0 for uniform spacing in the X direction.

NYEND = The number of nodes in the Y direction in the variable Y spacing region. The node at the division between the uniform and the variable spacing sections is included in this number. Spacing is determined by Y-EXPAND and the fractional length by YPART. In Figure 21, NYEND = 4. NYEND can have a maximum value of NY. The remaining Y region (if any) is uniformly spaced. Set NYEND = 0 for uniform spacing in the Y direction.

XPART = Fractional part of the total X length of the flat plate occupied by each of the two variable X spacing regions for $0 \leq \text{XPART} \leq 0.5$. If XPART = 0.0, the entire spacing in the X direction is uniform.

A special option for XPART = 1.0 will give variable spacing from X1 to XN.

YPART = Fractional part of the total Y length of the flat plate occupied by the variable Y spacing region.

X1 = The minimum X coordinate of the plate shape (distance).

Y1 = The minimum Y coordinate of the plate shape.

Z1 = The maximum Z coordinate of the plate shape.

XN = The maximum X coordinate of the plate shape.

YN = The maximum Y coordinate of the plate shape.

ZN = The minimum Z coordinate of the plate shape.

3D Rectangular Flat Plate Card for TYPE = 4 (2I5, 2F5.0, 6F10.0) — This option generates nodes in vertical planes. See lower portion of Figure 21 for description. Definition of variables is analogous to those of the TYPE = 3 variables.

Sphere Node Description Card (3I5, 5X, I5, 5X, I5, 5X, I5, 5X, 3F10.0) — One or more cards are required for each sphere shape to be generated. The element arrangements are similar to those used for the rounded nose geometries shown in Figure 17. For 2D geometry the first node, N1, is the central node and the nodes are numbered consecutively in the clockwise direction, starting at the central node and working outwards ring by ring. Either primary only or both primary and secondary (crossed triangle) nodes may be generated in the sphere geometry. Nodes at R = 0 are restrained in the radial R direction.

For 3D geometry, only one half the top and bottom halves are generated, and Y restraints are provided normal to the vertical plane of symmetry at Y = 0. The sphere is generated with the nodes numbered as two rounded circular noses having an interface between. The top nose is generated first; viewed from the positive Z direction, this generation is counterclockwise, upwards and inner to outer. The bottom nose is generated with the interface included with each spherical shell; this generation viewed from the positive Z direction is counterclockwise, downwards and inner to outer.

5 = Identification number for sphere nodes geometry.

NOR = Outer node ring number.

NIR = Inner node ring number.

RAD = 0 gives uniform radial spacing of the nodal rings.

= 2 requires radii of individual rings of nodes to be input individually.

CROS = 0 will not generate secondary nodes for either the 2D or 3D geometry.

= 1 will generate secondary nodes for 2D crossed triangle geometry or the 3D symmetric arrangement.

N1 = Number of the first node in the sphere. It is the center node for solid spheres, and at the inner radius for hollow spheres.

RO = Outer sphere radius for RAD = 0 (distance).

RI = Inner sphere radius for RAD = 0. Set RI = 0 for solid sphere.

ZCG = Z coordinate at the center of the sphere (distance).

Sphere Node Radii Cards for RAD = 2 (8F10.0) —

R(NIR)... R(NOR) = Radius of each ring of nodes in the sphere (distance). If NIR = 0, then begin with R(1), as R(0) will be set to R(0) = 0. One or more cards as required.

PATRAN Node Card (3I5) — This option allows the user to generate nodes with PATRAN, and then to incorporate them into the EPIC Preprocessor. The PATRAN file will be read from EPIC file designation INPAT. The specific designation is defined later. Expanded description provided later for PATRAN Element Card.

At present only node, element, and nodal displacement data packets (IDs 1, 2, 8) are interpreted by the program. All others are discarded. As a consequence, the neutral file need not contain Geometry Model (Phase 1) or GFEG/CFEG table packets. This should reduce the file size substantially.

Translational restraints may be placed on individual nodes with either the GFEG command or the unprompted DISP command. Do not apply rotational restraints as these are not used by EPIC. For nodes with constraints applied by both methods, the restrictions specified in the DISP command will take precedence. The translator will automatically place restraints on those nodes defined in the above manner. No additional input is required.

888 = Code to direct EPIC to read PATRAN file.

N1 = Lowest node number in PATRAN file to be read and translated to EPIC data. Specific node number, N1, must exist in PATRAN file. The EPIC node numbers are identical to the PATRAN node numbers.

If multiple groups of nodes are input from PATRAN, it is recommended that the groups be read in order of increasing node number. This provides for efficient reading of the file.

NN = Highest node number in PATRAN file to be read and translated. Specific node number, NN, must exist in the PATRAN file.

Node Scale/Shift/Rotate Identification Card (I5) — This option allows the user to change the Scale/Shift/Rotate Card data during the course of generating projectile and/or target nodes. It is, therefore, not necessary to use the same Scale/Shift/Rotate card data for all projectile nodes or for all target nodes.

999 = Code to read a new Scale/Shift/Rotate card next.

New Scale/Shift/Rotate Card (7F10.0, 2F5.0) — These input data are identical to those described for the Projectile Scale/Shift/Rotate card. They remain in effect until another Scale/Shift/Rotate card is read.

c. Element Geometry

The element data are required to be consistent with the node data for the projectile and the target. Thus, a series of composite elements, rod elements, nose elements, flat plate elements, and sphere elements may be created. PATRAN generated data can also be used. The input data are summarized in Figure 4. The element data for these shapes are entered individually in the locations identified in Figure 1. There is no limit to the number of shapes that may be used in the projectile or the target.

The element number must not exceed the dimensions of the element arrays, and they will automatically be numbered consecutively.

It is strongly recommended that 2D triangular elements be used in a crossed triangle arrangement and that 3D tetrahedral elements be used in a symmetric arrangement. This provides increased accuracy for many applications (References 13, 14, 15). It is important to note that the 2D crossed triangle or 3D symmetric arrangement allows for larger composite sizes when compared to a simple quad or brick element. Figure 13 shows the sizes of various composite arrangements for equal individual element volumes.

The 2D quad elements cannot be used for axisymmetric geometry with spin (GEOM = 7).

Series of Individual and Composite Elements Card (13I5, 5X, F10.0) — One card is required for each series of individual or composite elements to be generated. A summary of the various elements is provided in Figure 15. See also Figures 11 through 14. A range of 1D, 2D, and 3D elements can be generated. The nonreflective elements can be used to decrease the grid by absorbing wave reflections at the boundaries (Reference 16). The 2D shell element includes membrane stresses only. The 3D bar and shell elements are similar to the 2D shell elements.

1 = Identification number for series of elements.

MATL = Material number for the series of elements.

NCOMP = Number of composite elements to be generated.

N1–N8 = Node numbers which describe the first of the composite elements. See Figure 15 to determine how the various elements are input.

For 1D geometry, node N1 must have a higher Z coordinate than node N2.

For 2D geometry, the shell/bar element will plot the thickness on the left side of a line going from node N1 to N2. Also, for a group of shell elements input with this card, the elements must be attached to one another and form a continuous string of elements.

The triangular elements require the nodes to be input in a counterclockwise manner. A single triangular element (N1, N2, N3) is generated when N4 = 0 and two triangular elements (N1, N2, N3 and N1, N3, N4) will be generated when N4 > 0 and N5 = 0. Four triangular elements are generated when N5 > 0 and one quad element is generated when N5 = –1. Quad elements cannot be used with axisymmetric (plus spin) geometry (GEOM = 7).

For 3D geometry, tetrahedral, bar, shell, and nonreflective elements are available. The tetrahedral elements require nodes N1, N2, N3 to be counterclockwise when viewed from node N4. This option is exercised when N5 = N6 = N7 = N8 = 0. Six individual tetrahedral elements are generated when N1 . . . N8 are positive. Nodes N1, N2, N3, N4, and nodes N5, N6, N7, N8 are counterclockwise when looking from node N1 to N5, as shown in Figure 11. Composite wedge elements, each containing three individual tetrahedral elements, can also be generated. If N2 = N6 = 0, the first three tetrahedral elements (A, B, C) are defined by nodes N1, N3, N4, N5, N7, N8 as shown in Figure 11. Likewise, if N4 = N8 = 0, the first three elements (D, E, F) are defined by nodes N1, N2, N3, N5, N6, N7.

INC = The node number increment added to the node numbers of the previous composite element for the next composite element.

An example of input data for 3D composite brick elements is shown in Figure 14. In the upper left it can be seen that there are four rows of nodes (1 to 4, 5 to 8, 9 to 12, 13 to 16), which are arranged to contain three composite brick elements. If the first element is numbered 1, then the first composite brick contains elements 1 to 6, the second contains 7 to 12, and the third contains 13 to 18. The first composite brick is defined by nodes N1 = 1, N2 = 5, N3 = 9, N4 = 13, N5 = 2, N6 = 6, N7 = 10, and N8 = 14. Note that N1 to N4 and N5 to N8 are counterclockwise when looking from N1 to N5. The six individual elements are generated according to the arrangement and order (A, B, C, D, E, F) shown in the upper portion of Figure 12. The node numbers for each successive brick are simply INC = 1 greater than those of previous brick. For the second brick, for instance, N1 = 1 + 1 = 2, N2 = 5 + 1 = 6, N3 = 9 + 1 = 10, N4 = 13 + 1 = 14, N5 = 2 + 1 = 3, N6 = 6 + 1 = 7, N7 = 10 + 1 = 11, and N8 = 14 + 1 = 15.

SHELL = 0 indicates a solid 1D, 2D, or 3D element.
= 1 indicates a bar or shell element.
= 2 indicates a nonreflective boundary element.

T/A = Thickness (distance) or area (area) for shell or bar elements. If T/A > 0, then all the elements will have identical thicknesses or areas. If T/A = 0, then the thickness or areas will be read individually.

Thickness Cards for 2D Shell Elements (8F10.0) — This card defines the thicknesses of the shell elements at the nodal positions if they are not input in the previous card. Use only for SHELL = 1 and T/A = 0. If there are NCOMP shell elements, there are NCOMP+1 thicknesses to be input. These thicknesses will not be adjusted by the Scale/Shift/Rotate cards.

T(1)... T(NCOMP+1) = Thickness of shell element at the nodal position (distance). T(1) is the normal thickness at the extreme end node at the first element and T(NCOMP+1) is the normal thickness at the extreme end node of the last element.

Area Cards for 3D Bar Elements (8F10.0) — Similar to thickness cards for 2D shell elements except that the area is input as an average bar area. It is not input at the nodal locations. Use only for SHELL = 1 and T/A = 0.

A(1)... A(NCOMP) = Area of 3D bar elements (Area). A(1) is the area of the first element and A(NCOMP) is the area of the last element.

Thickness Card for 3D Shell Elements (8F10.0) — Similar to the thickness card for 2D shell elements, except that the thickness is input as an average shell thickness; it is not input at the nodal locations. If there are multiple shell elements within a composite element, then all have the same thickness. Use only for SHELL = 1 and T/A = 0.

T(1)... T(NCOMP) = Thickness of 3D shell elements (distance). T(1) is the thickness of the first 3D shell element and T(NCOMP) is the thickness of the last 3D shell element.

Series of 3D Tetrahedral Elements Card — Symmetric Arrangement (3I5) — This is the first of two cards required to input a series of 3D tetrahedral elements in a symmetric arrangement. Same descriptions as used previously.

Node Description Card for 3D Symmetric Arrangement (16I5) — This card describes the fifteen nodes for the first composite element. Must be in the proper order as shown in the lower portion of Figure 12.

N1–N15 = Nodes to describe the 24 tetrahedral element in a symmetric arrangement.

INC = Node number increment added to the node numbers of the previous composite element for the next composite element.

Rod (Disk) Element Card (7I5, 5X, 2I5, 10X, F10.0)— One or more cards are required to describe elements for nodes previously generated for the rod shapes shown in Figure 16. For 2D geometry the elements are numbered consecutively across the rod, working down layer by layer. Standard, alternating diagonal, crossed triangle, and/or quad elements may be generated, as shown in Figure 16.

For 3D geometry the elements are numbered consecutively and are generated in layers of composite brick elements beginning with top layer 1 and ending at bottom layer NLAY. The entire first layer of elements is generated before the second layer, etc., and the composite brick elements of each layer are generated in a counterclockwise manner for each ring of elements from the inner to the outer ring. Both the nonsymmetric (6 tets to a brick) and the symmetric arrangements (24 tets to a brick) are available.

2 = Identification number for rod elements geometry.

MATL = Material number of a uniform material rod. MATL = 0 requires that material numbers for each element ring be input individually.

N1 = The number of the lowest numbered rod node. For the solid rod this is the centerline node on the top end of the rod. For the hollow rod, this is the innermost clockwise node on the top end of the rod when viewed from the top.

DIAG = Diagonal option. For 2D geometry DIAG = 1–6 as shown in Figure 16. For 3D geometry, DIAG = 1 or 5. For DIAG = 5, the secondary nodes must have been previously generated by setting CROS = 1.

NOER = Outer element ring number.

NIER = Inner element ring number. The inner element ring number for a solid rod is NIER = 1. Set NIER = –1 for 3D shell elements when PLACE = 3 and a single ring of nodes is generated (NOER = NOR = NIR).

NLAY = The number of layers of elements in the rod. The total number of elements in a rod shape shown in Figure 16 is dependent on the number of layers and the number of elements per layer. The number of elements per layer is dependent on the inner and outer element ring numbers. Specific numbers are given in Figure 18.

SHELL = 0 uses solid elements.

= 1 uses 3D shell elements. N1, DIAG, NOER, and NIER should have same definition as if rod would be filled with solid tetrahedral elements. For 3D geometry only.

= 2 uses 3D nonreflective elements in the outer ring number only. Same definitions as for SHELL = 1. (Note that 2D nonreflective elements must be generated as a series of individual shell elements.)

PLACE = 0 for SHELL = 0.

= 1 for 3D shell elements on the top of the rod.

= 2 for 3D shell elements on the bottom of the rod.

= 3 for 3D shell elements on the outer ring of the rod.

THICK = Shell thickness for all 3D shell elements (SHELL = 1) in the rod shape (distance). For THICK = 0, the thicknesses for specific rows or layers are read individually.

3D Rod Top/Bottom Shell Thickness Card for THICK = 0 (8F10.0) — This card defines 3D shell thickness by rings for SHELL = 1, PLACE = 1 or 2, and THICK = 0 on previous card.

T(NIER)... T(NOER) = Shell thicknesses for top or bottom of rod from inner (NIER) to outer (NOER) ring (distance).

3D Rod Side Shell Thickness Card for THICK = 0 (8F10.0) — This card defines 3D shell thicknesses by layer for SHELL = 1, PLACE = 3, and THICK = 0 on previous card.

T(1)... T(NLAY) = Shell thicknesses for outer ring of rod from top to bottom (distance).

Rod Material Card for MATL = 0 (16I5) — This card is used to specify material numbers for individual rings of elements.

M(NIER)... M(NOER) = Material number for each ring of elements from inner (NIER) to outer (NOER).

Nose Element Card (6I5, 10X, I5, 15X, F10.0) — One or more cards are required to describe elements for nodes previously generated for the nose shapes shown in Figure 17. For 2D geometry the elements are numbered consecutively in the clockwise direction, working outward ring by ring. For 3D geometry the elements are numbered consecutively and are generated in shells of composite brick elements beginning with the innermost shell and ending with the outermost shell. The entire first shell of elements is generated before the second shell, etc., and the composite elements of each shell are generated in a counterclockwise manner for each ring of elements from the top to the bottom of each shell.

3 = Identification number for nose geometry.

MATL = Material number of a uniform material nose. MATL = 0 requires that material numbers for each element ring be input individually.

N1 = The number of the lowest numbered nose node.

DIAG = 1 gives standard arrangement of elements without secondary nodes.

= 5 gives 2D crossed triangle arrangement or 3D symmetric brick arrangement with secondary nodes. Requires CROS = 1 for nodes.

= 6 gives 2D quad elements.

NOER = Outer element ring number.

NIER = Inner element ring number. The inner element ring number for a solid rod is NIER = 1. Set NIER = –1 for 3D shell elements when a single row of nodes is generated (NOER = NOR = NIR).

SHELL = 0 uses solid elements.

= 1 uses 3D shell elements on the outer surface. N1, DIAG, NOER, and NIER should have same definition as if nose would be filled with solid tetrahedral elements. For 3D geometry only.

THICK = Shell thickness for all 3D shell elements (SHELL = 1) in the nose shape (distance). For THICK = 0, the thicknesses for specific segments are read individually.

3D Nose Shell Thickness Card for THICK = 0 (8F10.0) —This card defines 3D shell thicknesses (for SHELL = 1 and T/A = 0) by segments beginning at the rod-nose interface and working down to the tip. There are (2•NOER) segments.

T(1)...
T(2•NOER) = Shell thickness for outer ring of nose from rod-nose interface to tip (distance).

Nose Material Card for MATL = 0 (16I5) —This card is used to specify material number for individual rings of elements.

M(NIER)...
M(NOER) = Material number for each ring of elements from inner (NIER) to outer (NOER).

Flat Plate Element Card (10I5, 10X, F10.0) — One card is required for each flat plate shape to be generated. For 2D geometry, as shown in Figure 19, the elements are numbered consecutively across the plate, working down layer by layer. Standard, alternating diagonal, crossed triangle, or quad elements may be generated.

For 3D geometry, as shown in Figures 20 and 21, the elements are generated in rings (identical to that of the rod shape) for the circular plate (TYPE = 2), and rows of elements for the rectangular flat plates (TYPE = 3 and 4). The rows of elements go in the direction of the increasing X axis. The TYPE = 3 option generates the elements in horizontal layers and the TYPE = 4 option generates the elements in vertical layers.

4 = Identification number for flat plate geometry.

MATL = Material number for the flat plate elements.

N1 = Number of the first node of the flat plate shape.

DIAG = Element arrangement option. DIAG = 1–6 for 2D geometry as shown in Figure 19. DIAG = 1 or 5 for 3D geometry as shown in Figures 20 and 21. DIAG = 5 is for 2D crossed triangles and 3D symmetric brick arrangement, which require secondary nodes (CROS = 1).

TYPE = 1 will generate elements for 2D flat plate shown in Figure 19.

= 2 will generate elements for 3D circular plate as shown in Figure 20.

= 3 will generate elements for 3D rectangular flat plate, in horizontal layers, as shown in Figure 21.

= 4 will generate elements for 3D rectangular flat plate, in vertical layers, as shown in Figure 21.

NLX/R = Number of composite brick elements in the X/R direction for TYPE = 1, 3, 4. In Figure 21, NLX/R = 12. For the 3D circular plate (TYPE = 2), it is the number of rings of elements.

NLY = Number of composite brick elements in the Y direction. For TYPE = 3 and 4 only. Leave blank for TYPE = 1 and 2. In Figure 21, NLY = 6 for TYPE = 3.

NLZ = Number of layers of composite brick elements in the Z direction. In Figure 21, NLZ = 4 for TYPE = 3.

SHELL = 0 for all 2D elements and 3D solid tetrahedral elements.

= 1 for 3D shell elements. Use of other variables (MATL . . . NLZ) should be consistent with node generation.

= 2 for 3D nonreflective boundary elements.

PLACE = 0 for SHELL = 0.

= 1 will place 3D shell elements or nonreflective boundary elements on the positive X face for TYPE = 3 or 4.

= –1 will place 3D shell elements or nonreflective boundary elements on the negative X face for TYPE = 3 or 4.

= 2 will place 3D shell elements or nonreflective boundary elements on the positive Y face for TYPE = 3 or 4.

= –2 will place 3D shell elements or nonreflective boundary elements on the negative Y face for TYPE = 3 or 4.

= 3 will place 3D shell elements or nonreflective boundary elements on the positive Z face for TYPE = 2, 3, or 4.

= –3 will place 3D shell elements or nonreflective boundary elements on the negative Z face for TYPE 2, 3, or 4.

THICK = Shell thickness for 3D shell elements (distance). Use only for SHELL = 1.

Sphere Element Card (6I5, 10X, I5, 15X, F10.0) —One or more cards are required for each sphere shape to be generated. Arrangement is similar to that used for the rounded nose shown in Figure 17. For 2D geometry the elements are numbered consecutively in a clockwise direction, starting at the center and working outwards ring by ring.

For 3D geometry, the bottom half cross section is identical to the rounded nose shown in Figure 17. When viewed from the top, the elements are consecutively numbered counterclockwise, upward and outward for the top half, and then counterclockwise, downward and outward for the bottom half.

5 = Identification number for sphere element shape.

MATL = Material number for a uniform material nose. MATL = 0 requires that material numbers for each ring be input individually.

N1 = The number of the lowest numbered sphere node.

DIAG = 1 gives standard arrangement of elements without secondary nodes.

= 5 gives 2D crossed triangle arrangement or 3D symmetric brick arrangement. Requires CROS = 1 for nodes.

= 6 gives 2D quad elements.

NOER = Outer element ring number.

NIER = Inner element ring number. The inner ring number for a solid sphere is NIER = 1. Set NIER = –1 for 3D shell elements when a single ring of nodes is generated (NOER = NOR = NIR).

SHELL = 0 for all 2D elements and 3D solid tetrahedral elements.

= 1 for 3D shell elements on the outer node ring only.

THICK = Shell thickness for 3D shell elements (distance). Use only for SHELL = 1.

Sphere Material Card for MATL = 0 (16I5) —This card is used to specify material numbers for individual rings of elements.

M(NIER)... M(NOER) = Material number for each ring of elements from inner (NIER) to outer (NOER).

PATRAN Element Card (3I5, 55X, F10.0) —This option allows the user to generate elements with PATRAN, and then to incorporate them into the EPIC Preprocessor. The PATRAN file will be read from EPIC file designation INPAT, which is the same file from which the PATRAN node data were read.

A limited subset of PATRAN element geometries are supported as shown in Figure 22. These include all the linear element topologies (BAR/2, TRI/3, QUAD/4, TET/4, WEDGE/6, and HEX/8) and two higher order geometries to be discussed momentarily. The first four linear topologies can be directly transferred to EPIC element types. The remaining two (WEDGE/6 and HEX/8) require additional information to fully describe their orientations.

The PATRAN WEDGE/6 element closely mimics the EPIC wedge element. What remains undefined is the orientation of the diagonals along the rectangular faces of the wedge. To describe this directional dependence, the user is required to set the configuration flag when meshing the wedge. As three rectangular faces exist, and each of these may have the diagonal in one of two directions, a total of six configurations are possible.

A CID = 11 places the diagonal of the front face from the lower left corner to the upper right corner; the right back face has its diagonal from lower right to upper left; and the left back face from lower right to upper left. A CID = 21 switches only the orientation of the front face (i.e., the diagonal now runs from upper left to lower right). The remaining orientations are constructed by counterclockwise rotations of above two wedges. These are graphically represented in Figure 22.

The HEX/8 geometries may be described as a nonsymmetric brick. Here, too, a method of defining the diagonal locations needs to be determined. Since the brick can be fully described by defining one of the two nodes into which five edges converge, this node will be taken as the origin node of the element.

As mentioned previously, two higher order topologies are supported. The first, QUAD/5, will automatically be broken down by the translator into four TRI/3 elements. The second, HEX/15, will be broken into 24 TET/4 elements. The HEX/15 element is constructed as a HEX/27 element with mid-edge node generation suppressed. This node suppression can be accomplished with the following PATRAN command:

```
CFEG, <HyperPatch ID>, HEX/27, C1/C2/C3
```

where <HyperPatch ID> = a previously GFEG'ed hyperpatch.

The string "C1/C2/C3" instructs the PATRAN element generator to suspend mid-edge node generation for all edges aligned with the specified C direction. This type of higher-order element must be generated with a GFEG/CFEG command, as it is not supported by the automatic MESH command.

888 = Code to direct EPIC to read PATRAN file.

PL1 = Lowest element number in PATRAN file to be read and translated to EPIC data. Specific element number, PL1, must exit in PATRAN file. The EPIC element numbers will generally be different than the corresponding PATRAN element numbers because EPIC automatically numbers the elements in a consecutive manner.

If multiple groups of elements are input from PATRAN, it is recommended that the groups be read in order of increasing PATRAN element number. This provides for efficient reading of the file.

PLN = Highest element number in PATRAN file to be read and translated. Specific element number, PLN, must exist in PATRAN file.

Note: If PL1 and/or PLN exceed the I5 format (≥100,000), set PL1 = –1 then read PL1 and PLN on the following card in 2I10 format.

T/A = 0 for all solid elements.

= 0 will designate 2D shell/bar elements, and 3D shell elements, to be nonreflective elements.

= Thickness for standard 2D shell/bar elements and 3D shell elements.

= Area for 3D bar elements.

d. Sliding Interface Descriptions

Capabilities for sliding interfaces are provided for 1D, 2D, and 3D geometries. Input data are summarized in Figure 5. Included are contact and release, as well as specialized erosion and plugging options. Separate input formats are required for 1D, 2D, and 3D geometries. If there is more than one sliding interface, all data for the first sliding interface are entered before entering data for subsequent interfaces. If there are no sliding interfaces (NSLID = 0 in Prep Miscellaneous Card), this group of cards is omitted.

Sliding Interface Card for 1D Geometry (2I5) — Only one card is required for each 1D interface.

M1 = Interface node at a lower Z coordinate than the other associated interface node, S1.

S1 = Interface node at a higher Z coordinate than the other associated interface node, M1.

Sliding Interface Identification Card for 2D Geometry (10I5, 3F10.0) — Each 2D sliding interface contains one sliding interface identification card and cards (as required) describing the master nodes and slave nodes. The master nodes generally should include the higher density material. It is also desirable for the master surface to have the stronger material, have equal or greater spacing than the slave nodes, and not have a convex surface toward the slave nodes.

The general sliding algorithm is described in Reference 17, except that both the master and slave nodes are moved in a consistent manner. This algorithm was first introduced in 1989 and is an improvement to earlier versions. It has also been incorporated into the 3D sliding algorithm for problems where there are no rigid body systems (NRIG = 0).

NMG = Number of groups of master nodes to be read.

NMN = Number of master nodes to be read individually.

NSG = Number of groups of slave nodes to be read.

NSN = Number of slave nodes to be read individually.

NSR = Number of regions of slave nodes to be read.

TYPE = 1 is the option used for problems with no plugging.

= 3 is the option used for 2D plugging. (Not yet available.) This option has not been used extensively and may not be reliable under all conditions. The plugging algorithm is similar to that developed by Ringers (Reference 18). The user is asked to provide the value of the plastic strain at the maximum adiabatic stress. It is at this maximum stress where the adiabatic shear band is assumed to begin forming. A plugging slide line is similar to a normal slide line except that a crack may start at the master surface and extend into the material. Implementation has been accomplished with an axisymmetric plate in mind. When the crack reaches the back of the plate, the slide line can be separated into two distinct pieces. The algorithm for plugging has three states for the slide line.

The first state is before the crack has started. The entire length of the master side of the slide line is searched every cycle to see if any element with a node on the master line has a strain greater than the critical strain, and a maximum shear plane through the element.

When such an element is found, the side of the element whose direction is closest to the maximum shear plane is taken to be the crack line. The node on the master line is split into two nodes, each node attached to the elements on each side of the crack. The master line is extended to include the crack. The plugging slide line goes to the second state and the new node is given a node number one higher than the highest node number in the current model.

In the second state, all elements containing the node on the bottom of the crack, and whose center lies forward of the bottom node in the direction of the crack, are put on a watch list. The watch list is inspected each cycle to see if any element has a sufficient strain and a shear plane through the element. When an element meets the criteria, the crack is extended as before. When the node at the bottom of the crack is also on the bottom of the plate, the bottom node is also split and the state of the slide line is advanced to the third and final state.

In the third state, no further cracking occurs and the slide line acts much like a normal slide line.

The crack is automatically formed in all slide lines in the simulation covering the area of the crack. This allows the use of eroding slide lines to remove the highly distorted elements formed along the irregular crack line. The front of the projectile can also have highly distorted elements at the outside edge of the contact area. It appears to be necessary to use two opposing eroding slide lines between the projectile and the target, along with the plugging slide line, to get a good simulation. This formulation of the plugging slide line will modify all slide lines as necessary as the crack extends and breaks through.

Specifically, it is recommended that the first slide line be an eroding slide line (TYPE = 1 and ERODE > 0) with the master surface on the target. The second slide line is an eroding slide line with the master surface on the projectile. The third slide line is a plugging slide line (TYPE = 3 and ERODE > 0) with the master surface on the target.

MBOT = Lowest number on the bottom of the target plate when performing perforation computations with the eroding interface option (ERODE > 0) or plugging option (TYPE = 3). All nodes above the bottom surface of the plate must have lower node numbers than MBOT. This criterion is satisfied when using the flat plate generator for nodes and elements.

ISR = 0 will not release restrained slave nodes.

= 1 will release restrained slave nodes on the Z axis (at R = 0) when they interact with the master surface. (Not yet available for 2D geometry.)

IT1 = Number of velocity iterations for the slave nodes on the master surface (References 17 and 19). Errors in the velocity match lead to errors in the deviator and shear stresses, but generally not the pressure. For high velocity impact and explosive detonation, where the pressures are much higher than the deviator and shear stresses, a relatively low value of IT1 = 1 or IT1 = 2 can be used. For lower pressure problems, higher values should be used (IT1 = 2 to IT1 = 5). The velocity iterations and the corresponding searches on the master surface are performed only for those slave nodes found to be in contact during the first iteration. For the eroding interface option (ERODE > 0), use IT1 = 1.

IT2 = Number of velocity iterations of the master nodes on the slave surface. This allows a double pass to be made such that there is no interference or crossover on the sliding surface (References 17 and 19). If IT2 = 0, there is no second pass, and the slave nodes can be input in any order. With this option, it is possible to designate interior nodes (as well as surface nodes) as slave nodes. This procedure allows elements containing slave nodes to fail completely to simulate an eroding process (References 14 and 20). For IT2 > 0, a double pass is performed, and the slave nodes must be input in a specified order. The double pass option (IT2 > 0) can only be used with TYPE = 1.

REF VEL = Reference velocity (distance/second), which when multiplied by the integration time increment, gives a reference distance. Slave nodes are considered to be associated with a particular master surface only when they are within this reference distance. It is recommended that REF VEL be about 1.5 times the initial relative impact velocity or the detonation velocity of explosives contained in the problem.

ERODE = Erosion strain (equivalent or volumetric) for the eroding interface option (TYPE = 1), or equivalent strain for adiabatic shear to begin for the plugging option (TYPE = 3). The erosion option is for penetration/ perforation of thick plates and is activated when TYPE = 1 and ERODE > 0. It applies to triangular elements only (with no pressure averaging) and should only be used when erosion is the primary mode of penetration. The algorithm and example problems are presented in References 14 and 20. Because the total failure of the elements must be achieved by the eroding interface algorithm, it is important that EFAIL (a material property) be much greater than ERODE.

An eroding interface usually consists of two sets of sliding interface data. The first slide line usually designates the top surface of the plate as the master surface and the potentially eroded nodes in the projectile as slave nodes. The second slide line usually designates the outer surface of the projectile as the master surface and the potentially eroded nodes in the plate as slave nodes. This ensures that there is no crossover of material between the projectile and the target. Under some instances, it may only be possible to use the first slide line.

When using the erosion option with axisymmetric geometry (GEOM = 6 and 7), the radial velocities of free nodes (those whose associated elements have all eroded) are adjusted based on the corresponding axial velocity (RDOT = .5|ZDOT|). Therefore, the initial target velocity in the axial direction should be zero, otherwise the radial velocities would be adjusted incorrectly.

The plugging option is described under the TYPE = 3 explanation.

FRICTION = Coefficient of sliding friction in the R-Z plane. Does not act in θ direction for relative spinning velocities (GEOM = 7).

NMG Grouped Master Node Cards (315) —This option allows master nodes to be input in groups. The nodes must be entered in order from the first master node to the last master node along the row of nodes. When moving from the first node to the last node, the slave nodes must be to the left of the master surface.

M1G = First node in the group of master nodes.

MNG = Last node in the group of master nodes.

INC = Increment between the nodes in the group of master nodes.

Individual Master Node Cards for NMN > 0 (16I5) —Master nodes are input individually when NMN > 0. The nodes must be input in the proper order, as described for the proceeding NMG Grouped Master Node Cards. Master nodes can be input with both groups of nodes and individual nodes, if the individual nodes are at the far end of the master surface.

M1...MN = Master nodes in proper order from M1 to MN.

NSG Grouped Slave Node Cards (3I5) — This option allows the slave nodes to be input in groups. The slave nodes must be to the left of the master surface when moving from the first master node to the last master node. If there is no double pass (IT2 = 0), the slave nodes can be input in any order. If the double pass option is used (IT2 > 0), the slave nodes must be input in the opposite direction of the master nodes. The first slave node must be near the last master node and the last slave node must be near the first master node. This means the master surface is to the left of the slave surface when moving from the first slave node to the last slave node.

S1G = First node in the group of slave nodes.

SNG = Last node in the group of slave nodes.

INC = Increment between the nodes in the group of slave nodes.

Individual Slave Node Cards for NSN > 0 (16I5) — Slave nodes are input individually when NSN > 0. Restrictions on order of input are as described for the NSG Grouped Slave Node Cards. Can be used in conjunction with the Grouped Slave nodes.

S1...SN = Slave nodes in proper order from S1 to SN.

NSR Slave Node Limits Cards (4F10.0) — This option allows all nodes within a specified region to be designated as slave nodes. As there is no specific order, this option can be used only with IT2 = 0. Can be used in conjunction with the Grouped and Individual slave nodes.

RMAX = Maximum R coordinate of slave node region (distance).

RMIN = Minimum R coordinate of slave node region.

ZMAX = Maximum Z coordinate of slave node region.

ZMIN = Minimum Z coordinate of slave node region.

Sliding Interface Identification Card for 3D Geometry (9I5, 5X, 3F10.0) — Each 3D sliding interface contains one Sliding Interface Identification Card and cards (as required) describing the master surfaces and slave nodes. The mass and spacing of the slave nodes should not be significantly greater than that of the master nodes in the initial or *deformed geometry* unless a double pass is used. Also, the 3D slave nodes cannot be restrained in the Z direction. The user should be familiar with the node generators before proceeding.

The searching time for 3D interfaces can be significant. Therefore, it is important to minimize the master surface and slave nodes when possible. Future work will be directed at decreasing the CPU time required for 3D sliding interfaces.

NMG = Number of master surface geometries required to completely define the master surface. No special order is required as the 3D master surface is composed of individual triangular planes.

SEEK = A code describing the search routines used to find the appropriate triangular plan on the master surface. The specialized routines (SEEK = ±1, ±2, ±3) can be used whenever the master surface is a single valued function of two coordinates (i.e., any vertical line parallel to a specified axis must not pass through the master surface at more than one point.) For eroding sliding surfaces set SEEK = 4.

= −1 for all slave nodes on the negative X side of the master surface.

= 1 for all slave nodes on the positive X side of the master surface.

= −2 for all slave nodes on the negative Y side of the master surface.

= 2 for all slave nodes on the positive Y side of the master surface.

= −3 for all slave nodes on the negative Z side of the master surface.

= 3 for all slave nodes on the positive Z side of the master surface.

= 4 for the generalized search routine. Every master triangular surface is considered for each slave node. If a slave node is contained in the triangular projection (onto a principal plane) of one or more master surface triangles, and if it is close to the triangular plane $|\delta n| <$ REF VEL $\cdot$ DT, then the master plane closest to the slave node is selected. δn is the normal distance between the slave node and the master plane, REF VEL is the reference velocity given on this card and DT is the integration time increment. If the slave node projection is not within any master triangular projections but is close normally to at least one triangular plane $|\delta n| <$ REF VEL $\cdot$ DT, and if the distance from the slave node projection to the master triangular projections is small, $|\delta\,\text{edge}| <$ REF VEL $\cdot$ DT, then the master triangle with the smaller $|\delta\,\text{edge}|$ is selected. More detail is given in Reference 19. (When the master surface has acute concave angles toward the slave nodes, it is sometimes possible for a slave node to pass through the master surface. This will be corrected in future versions.)

NSG = Number of groups of slave nodes to be read.

NSN = Number of slave nodes to be read individually.

NSR = Number of regions of slave nodes to be read.

TYPE = 1 is the only option available.

MBOT = Lowest numbered node on the bottom surface. Used only for an eroding plate to detect erosion through the bottom of the plate. All nodes above the bottom surface of the plate must have lower nodes numbers than MBOT. This criteria is satisfied when using the 3D rod generator, or the 3D flat plate generator with TYPE = 2 or 3. Other 3D erosion problems can be handled by placing part of the master surface at the entry surface and part at the exit surface.

ISR = 0 will not release restrained slave nodes.

= 1 will release slave nodes from the plane of symmetry (at Y = 0) when they interact with the master surface.

IT = Number of velocity iterations. Errors in the velocity match lead to errors in the deviator and shear stresses, but generally not the pressure. For high velocity impact, where the pressures are much higher than the deviator and shear stresses, a relatively low value of IT = 1 or IT = 2 can be used. For lower pressure problems, higher values should be used, IT = 2 to IT = 5. The velocity iterations are performed only for those slave nodes found to be in contact during the first iteration. For sliding surfaces with many slave nodes in contact and many master nodes, high values of IT can lead to significant increases in CPU time. For the eroding interface option (ERODE > 0), use IT = 1.

REF VEL = Reference velocity (distance/second), which when multiplied by the integration time increment, gives a reference distance. Slave nodes are considered to be associated with a particular master surface only when they are within this reference distance. It is recommended that REF VEL be about 1.5 times the relative impact velocity, or the detonation velocity of explosives contained in the problem.

ERODE = Equivalent plastic strain (or volumetric strain), which if exceeded by any element on the master surface, will cause the element to be completely failed. Subsequently, the master surface will be redefined to go around the failed element. This allows for penetration and perforation of thick plates. If ERODE = 0, then erosion is not used.

For 3D erosion problems, ERODE for all sliding interfaces must be identical. The specific erosion algorithm is described in Reference 16.

Because total failure of the elements must be achieved by the eroding interface algorithm, it is important that EFAIL (a material property) be much greater than ERODE.

Can use single or double pass, as described for the 2D erosion. A double pass may significantly increase the CPU time.

FRICTION = The coefficient of sliding friction.

Master Definition Card for Rectangular Plate Geometry (2I5, 5X, 5I5) — One card is required to describe a master surface on a rectangular flat plate (MGEOM = 1) as shown in Figure 23. This is consistent with the Rectangular Flat Plate Geometry Generator shown in Figure 21.

1 = Identification number for flat plate geometry (MGEOM = 1).

M1 = Node number of the reference node on the master surface as shown in Figure 23.

DIAG = 1 is for the diagonal orientation shown in Figure 23.

= 2 is for the diagonal orientation where the diagonals go in the general direction away from the M1 reference node.

= 5 is for the symmetric element arrangement where there are secondary nodes. This generator only handles the top and bottom surfaces of a plate where IDL or IDW is ± 1. The other surfaces can be handled by the General Geometry option.

NML = Number of nodes per row of master nodes. NML is equal to N in Figure 23. Each row of master nodes must have the same number of nodes.

NMW = Number of rows of master nodes. NMW is equal to M in Figure 23. Note that a properly described master surface will pass the following test. Place a right-handed triad of orthogonal vectors on node M1. Point the first vector (thumb) away from the master surface towards the slave nodes. Point the second vector (index finger) down the row of nodes starting at M1. The third vector (second finger) will then point in the direction of the remaining rows of nodes.

IDL = The node number increment along the rows of master nodes. If M1 = 100, NML = 6, and IDL = 2, then the first row of nodes in the master surface consists of nodes 100, 102, 104, 106, 108, 110. IDL may be negative.

IDW = The node number increment between the first node in each row. If IDW = 20 and M1, NML, and IDL are as described in the preceding description of IDL, then the second row of master nodes consists of nodes 120, 122, 124, 126, 128, 130. IDW may be negative.

Master Definition Card for Rod-Nose Geometry (7I5) — One card is required to describe a master surface on the outer surface of a rod and a nose (MGEOM = 2) as shown in Figure 23. This is consistent with the Rod and Nose Generator shown in Figures 16 and 17. This option can be used for deep penetration problems when the projectile is significantly harder than the target. The master surface contains all external triangular planes on the nose and specified triangles in the rod. The reference master node, M1, is at the tip of the nose as shown in Figure 23.

For this option the slave nodes are generally in the target. It is recommended that ISR = 1 in the Sliding Interface Identification Card, if there are any restrained nodes on the plane of symmetry at Y = 0. Use of this option will release the restraint when the slave node comes in contact with the master surface.

2 = Identification number for rod-nose geometry (MGEOM = 2).

M1 = Node number of the reference master node at the tip of the nose, as shown in Figure 23.

MCODE = 1 will place master surface on the inside of a hollow rod-nose shape.

= −1 (or 0) will place master surface on the outside of the rod-nose shape.

DIAG = 1 is for the nonsymmetric element arrangement as shown in Figures 16 and 17. No secondary nodes.

= 5 is for the symmetric element arrangement as shown in Figures 16 and 17. Includes secondary nodes.

NOR = Outer node ring number of the nose and the rod of the projectile.

NIR = Inner ring number.

NPL = Number of planes of nodes in the rod included in the master surface. The interface of the rod and the nose is considered to be plate number 1. If NPL = 2, then the master surface would include all triangular faces on the nose, plus those between the interface plane of nodes and the plane of nodes directly above the interface plane.

Master Definition Card for Circular Plate (Disk) Geometry (5I5) — One card is required to describe a master surface on a disk (MGEOM = 3). This option can be used if the master surface is on a disk whose nodal arrangement is equivalent to that of the rod generator or the circular flat plate generator as shown in Figures 16 and 20. (A disk is simply a short rod or cylinder.) The reference node, M1, is at the center of the master surface as shown in Figure 23. The rod for this case must be solid (NIR = 0) and cannot be hollow (NIR > 0).

3 = Identification number for disk geometry (MGEOM = 3).

M1 = Node number of the reference master node at the top center of the disk, as shown in Figure 23.

MCODE = 1 indicates the master surface is on the top surface of the disk (the lower node numbers are on the top).

= –1 indicates the master surface is on the bottom of the disk.

DIAG = 1 is for the nonsymmetric element arrangement as shown in Figures 16 and 20. No secondary nodes.

= 5 is for the symmetric element arrangement as shown in Figures 16 and 20. Includes secondary nodes.

NRING = Maximum node ring number included in the master surface. Can be less than the number of rings used to generate the entire disk.

Master Definition Card for Cylinder (Rod) Geometry (7I5) — One card is required to describe a master surface on the outer or inner surface of a cylinder or rod (MGEOM = 4) as shown in Figure 23. This is consistent with the rod and circular plate generators shown in Figures 16 and 20. The reference node, M1, is on the lower end of the cylinder as shown in Figure 23. Higher node numbers are on the lower end.

4 = Identification number for Cylinder (Rod) geometry (MGEOM = 4).

M1 = Node number of the reference master node on the lower end of the cylinder as shown in Figure 23.

MCODE = 1 indicates the master surface is on the inside of the cylinder. For this option, the reference master node, M1, is on the plane of symmetry, on the positive X axis, when the cylinder is in a vertical position about the Z axis.

= −1 indicates the master surface is on the outside of the cylinder. For this option the reference node is on the negative X axis.

DIAG = 1 is for the nonsymmetric element arrangement as shown in Figures 16 and 20. No secondary nodes.

= 5 is for the symmetric element arrangement as shown in Figures 16 and 20. Includes secondary nodes.

NOR = Outer ring number.

NIR = Inner ring number. For a solid rod NIR = 0.

NPL = Number of planes of nodes included in the master surface. First plane is at node M1 and additional planes move upward.

Master Definition Card for General Geometry (8I5) — One card is required to describe a general series of triangular master planes (MGEOM = 5) as shown in Figure 23. This option can be used when it is necessary to describe a general master surface which cannot be defined by the other master surface generators (MGEOM = 1, 2, 3, 4).

5 = Identification number for General Geometry (MGEOM = 5).

NCOMP = Number of composite groups of triangular surfaces to generate. Each composite group contains one (M4 = 0), two (M4 > 0 and M5 = 0), or four (M5 > 0) triangles. In Figure 23 NCOMP = 3 for both cases shown.

INC = Node number increment (positive or negative) between corresponding nodes in each composite group of triangular elements.

M1 = Number of reference master node. Nodes M1, M2, and M3 must be counterclockwise when viewed from the slave node side of the master surface.

M2 = Number of second node.

M3 = Number of third node.

M4 = Number of fourth node. If M4 = 0, only one triangle will be generated for each composite group of triangles. If M4 > 0 and M5 = 0, then M1, M2, M3, and M4 must be counterclockwise, and two triangles (M1, M2, M3, and M1, M3, M4) are generated for each composite group, as shown in Figure 23.

M5 = Number of fifth node. If M5 = 0, only one or two triangles are formed for each composite group of triangles. If M5 > 0, then four triangles are generated for each composite group of triangles, as shown in Figure 23.

Master Definition Card for PATRAN Geometry (3I5) — This option allows the user to generate master surfaces with PATRAN, and then to incorporate them into the EPIC Preprocessor. The PATRAN file will be read from EPIC file designation, INPAT, which is the same file from which the node and element data are read.

A master surface may be defined in PATRAN with TRI/3, or QUAD/5 elements paved over the top of an existing hyperpatch face. The QUAD/5 element will generate four individual triangular surfaces. For the individual TRI/3 elements, the diagonals must be properly aligned. Nodes for both the TRI/3 and QUAD/5 must be in a counterclockwise order when viewed from the slave node position. Master surfaces can be generated as follows:

- Create a duplicate patch along the face of the hyperpatch which requires a sliding surface
- GFEG-CFEG this patch to match the meshing on the corresponding face of the hyperpatch. Keep track of the first and last element IDs on this patch.
- EQUIV the active set to force the duplicate patch to attain the same node numbers as the hyperpatch face.

888 = Code to direct EPIC to read PATRAN file.

PL1 = Lowest element number in PATRAN file to be read and translated to EPIC master surface data. Specific element number, PL1, must exist in PATRAN file.

PLN = Highest element number in PATRAN file to be read and translated. Specific element number, PLN, must exist in PATRAN file.

Note: If PL1 and/or PLN exceed the I5 format (≥100,000), set PL1 = –1 and then read PL1 and PLN on the following card on 2I10 format.

NSG Grouped Slave Node Cards (3I5) — This option allows the slave nodes to be input in groups.

S1G = First node in the group of slave nodes.

SNG = Last node in the group of slave nodes.

INC = Increment between the nodes in a group of slave nodes.

Individual Slave Node Cards for NSN > 0 (16I5) — Slave nodes are input individually when NSN > 0. Can be used in conjunction with the grouped slave nodes.

S1...SN = Slave nodes (in any order).

NSR Slave Node Limits Cards (6F10.0) — This option allows all nodes in a specified region to be designated as slave nodes. Can be used in conjunction with the grouped and individual slave nodes.

XMAX = Maximum X coordinate of slave node region (distance).

XMIN = Minimum X coordinate of slave node region.

YMAX = Maximum Y coordinate of slave node region.

YMIN = Minimum Y coordinate of slave node region.

ZMAX = Maximum Z coordinate of slave node region.

ZMIN = Minimum Z coordinate of slave node region.

2. INPUT DATA FOR THE MAIN ROUTINE

The function of the Main Routine is to perform the computations. It may be used in conjunction with the Preprocessor, or it can read initial conditions from the restart file which has been previously generated from a Preprocessor run or another Main Routine run. The following descriptions are for the data in Figure 6. Consistent units must be used and the unit of the time must be in seconds.

Restart Description Card (2I5, A70) — This card is used only for restart runs. If the Main Routine is run in conjunction with the Preprocessor (TYPE = 2 on Preprocessor Miscellaneous Card), then this card is omitted.

3 = Code to indicate restart run.

CASE = Case number for run. Must be identical to case number from previous run.

MAIN DESCRIPTION = Description of problem provided by the user.

Time Integration Card (I5, 5X, 7F10.0) —

CYCLE = Cycle number at which the run begins. The cycle numbers for which restart files are written are given in the printed output of the previous run (Preprocessor or Main Routine). If CYCLE = 0 the restart is requested on the basis of time.

TIME = Time (second) at which the restart is requested (for CYCLE = 0). Restarts can be requested by CYCLE or TIME.

DTMAX = Maximum integration time increment which will be used for the equations of motion (second).

DTMIN = Minimum integration time increment allowed (second). If exceeded, the results will be written onto the restart file and the run will stop.

SSF = Fraction of the sound speed transmit time used for the integration time increment. Must be less than 1.0. General practice is to use SSF = 0.9. However, 3D eroding interfaces sometimes may require a lower value down to approximately SSF = 0.5.

TMAX = Maximum time the problem is allowed to run (second). This time refers to the dynamic response of the system, not the central processor time (CPMAX) described next. The results at time = TMAX are written onto the restart file, and the run is discontinued.

CPMAX = Central processor time at which the results will be written onto the restart file and the run will stop. The time units for this input can be seconds, minutes, or hours. It should coincide with the units the specific computer uses to measure central processor time.

EMAX = Upper limit for total kinetic energy. This is used for numerical instability checks. The run will stop if the kinetic energy exceeds

EMAX. If left blank, EMAX will automatically be set to 1.5 times the initial total energy.

Main Miscellaneous Card (2I5, 5X, 3I5, F10.0, 10X, F10.0) —

TPLOT = 0 will not read input and write time plot data to a file.

= 1 will read input and write specified time plot on a file for eventual postprocessing.

DROP = 0 will not allow problem size to be reduced.

= 1 will allow the problem size to be reduced at a specified time.

PRES = 0 gives no applied pressures read or applied.

= 1 will use pressure data which was input in a previous run. (Not yet available.)

= 2 will read applied pressures to be used in subsequent computations. (Not yet available.)

PUSH = 0 gives no applied nodal velocities read or applied.

= 1 will use applied nodal velocity data which was input in a previous run. (Not yet available.)

= 2 will read applied nodal velocity data to be used in subsequent computations. (Not yet available.)

HRG = 0 will not compute hourglass viscosity.

= 1 will use hourglass artificial viscosity for 3D nonsymmetric brick element arrangements, when computing average pressures (VFRACT > 0) for solid materials (MTYPE = 1). This is generally not required. (Not yet available for 2D geometry.)

VFRACT = Fraction of initial volume of a composite 2D quad composed of two triangles or a composite 3D brick composed of six tetrahedral elements, at which an individual element pressure is computed. Applied to DIAG = 1–4 for 2D geometry and DIAG = 1 for 3D geometry. Applies only to solid materials (MTYPE = 1).

A single average pressure is computed for the two (2D) or six (3D) elements in the composite element until one or more achieve a relative volume less than VFRACT. This average pressure technique reduces the number of incompressibility constraints and provides significant increased accuracy for these element arrangements (References 13 and 15).

When the relative volume of a specific element falls below VFRACT, then an individual pressure is computed for that element, and the remaining elements (if any) use an average pressure.

PMAX = Maximum pressure allowed in any element (force/area). Pressure will not be limited if PMAX = 0. (Not yet available.)

Plot Card for TPLOT = 1 (4I5, 6F10.0) — This card specifies system, chunk, node, and element time history data to be written onto a file for eventual postprocessing.

SYS = 0 will not write the system and chunk data on the time plot file.

= 1 will write all the system and chunk data on the time plot file.

NPLOT = Number of nodes for which data will be written on the time plot file. The individual nodes are specified on the Designated Nodes Card.

LPLOT = Number of elements for which data will be written on the time plot file. The individual elements are specified on the Designated Elements Card.

DPLOT = 0 will not provide dynamic plots.

= 1 will provide dynamic plots as run progresses. (Not yet available.)

DT SYS = Time increment at which the system data are written on the time plot file (second). These quantities do not vary as rapidly as do the individual node and element data so a larger time increment can be used. These quantities also require more CPU time to compute, so a larger DT SYS reduces CPU time.

TSYS = Time at which the first system data are written on the time plot file (second). If left blank, the time at the beginning of the Main Routine run will be used. For a restart run, if TSYS < TIME, then these time plots will also be restarted from previous run.

DT NODE = Time increment at which the individual node and element data are written on the time plot file (second). These quantities vary more rapidly than the system data so a smaller time increment should be used.

TNODE = Time at which the first individual node and element data are written on the time plot file (second). For a restart run, if TNODE < TIME, then these time plots will also be restarted from previous run.

DT DYN = Time increment at which the dynamic plots are generated (second).

T DYN = Time at which the dynamic plots begin (second).

Designated Nodes Card for NPLOT > 0 (16I5) — This card is used only if there are node data to be written on the plot file (NPLOT > 0 on the plot card).

N1...NN = Individual node numbers for which data will be written on the plot file. May be input in any order. Program will sort and put in ascending order. Must also be input for subsequent restart runs if data are desired.

Designated Elements Card for LPLOT > 0 (16I5) — This card is used only if there are element data to be written on the plot file (LPLOT > 0 on the plot card).

E1...EN = Individual element numbers for which data will be written on the plot file. May be input in any order. Program will sort and put in ascending order. Must also be input for subsequent restart runs if data are desired.

Note: If any elements, E1...EN, exceed the I5 format (≥100,000), set E1 = –1 and then read E1...EN on the following card(s) in 8I10 format.

Dynamic Plot Card for DPLOT = 1 (6I5, 2F10.0)— This card provides information for the specific type of dynamic plots requested.

LINE = 0 will not plot the lines (sides) around the individual elements.

\> 0 will plot the lines (sides) around the individual elements. The color of the lines is coded to the specific value of LINE.

SIDEL = 0 will plot the element lines (sides) on the actual coordinates.

= 1 will plot the lines on the negated R coordinate only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 will plot the lines on both the actual and negated R coordinates. For 2D geometry only.

NMAT = Number of materials to be defined to plot as specific colors. NMAT = 0 will not plot colors for specific materials.

SIDEM = 0 will plot the material colors on the actual coordinates.

= 1 will plot the material colors on the negated R coordinates only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 will plot the material colors on both the actual and negated R coordinates. For 2D geometry only.

VAR = Code to specify element variable to be plotted as color contour or fringe plots. VAR = 0 will not plot element variables.

VAR	**Variable Plotted**
11	Pressure
12	Von Mises Stress
13	Equivalent Plastic Strain
14	Damage/Burn Fraction
15	Temperature
16	Plastic Work
17	Internal Energy
18	Log (10) Strain Rate
19	Net X/R Stress
20	Net Y/T Stress
21	Net Z Stress

SIDEV = 0 will plot the variable colors on the actual coordinates.

= 1 will plot the variable colors on the negated R coordinates only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 will plot the variable colors on both the actual and negated R coordinates. For 2D geometry only.

VMAX = Maximum value of the variable to be plotted.

VMIN = Minimum value of the variable to be plotted.

Material Designation Card for NMAT > 0 (16I5) — This card defines the NMAT materials to be plotted. Required only for NMAT > 0.

M1...MN = Material numbers to be plotted as specific colors.

Color Designation Card for NMAT > 0 (16I5) — This card defines the specific color codes for the materials request. Required only for NMAT > 0.

C1...CN = Color codes for materials M1...MN.

Dynamic Plot Limits Card (6F10.0) — This card defines the geometric region of the problem to be included in the Dynamic Plots.

X/RMAX... ZMIN = Coordinate limits for dynamic plots. Set YMAX = YMIN = 0 for all 2D plots, and for 3D plots at Y = 0.

Drop Card for DROP = 1 (F10.0, I5, 5X, 4I5, 5X, 3I5, 2X, 3I1, I5) — This card is used only if changes are made which reduce the size of the problem. The portions of the problem which remain are those which were input first. Common uses are to drop the explosive gases after a liner has been accelerated, or to drop the target after a projectile has perforated the target.

TDROP = Time at which the drop (problem size reduction) occurs (second).

NNODE = Total number of nodes which remain in the revised problem.

NELE = Total number of elements which remain in the revised problem.

Note: If NELE exceeds the I5 format (≥100,000), set NELE = –1 and then read NELE on the following card in I10 format.

NSLID = Number of sliding interfaces which remain in the revised problem.

NRIG = Number of rigid systems of nodes which remain in the revised problem.

NCHNK = Number of subsystems of chunks of elements which remain in the revised problem.

NZONE = Number of regions for automatic rezoning which remain in the revised problem.

NPLOT = Number of nodes, for which time-history data are written, which remain in the revised problem. Because these are sorted at input, only the lowest numbered nodes remain.

LPLOT = Number of elements, for which time-history data are written, which remain in the revised problem. Because these are sorted at input, only the lowest numbered nodes remain.

IX/R, IY, IZ = Rigid surface designations which will be in effect. See description in Prep Miscellaneous Card. Must redefine even if no changes are to be made.

NFAIL = Number of elements which will be designated to fail totally. This type of failure sets all stresses in the element to zero. It essentially makes the element disappear except that mass is retained at the nodes.

Designated Element Failure Card for NFAIL > 0 (16I5) — This card is used only if there are elements to be totally failed (NFAIL > 0).

EF1...EFN = Elements to be totally failed in the revised problem.

Note: If any elements, EF1...EFN, exceed the I5 format (≥100,000), set EF1 = −1 and then read EF1...EFN on the following card(s) in 8I10 format.

Pressure Cards for PRES = 2 (6I5, F10.0) — These cards describe the applied pressures and the elements to which they are applied. If other pressures were used previously, they are all deleted, and the only applied pressures which act are those that are input in the current run. End with a blank card as shown in Figure 6. (Not yet available.)

ELE1 = The first element in a series of elements, to which pressure is applied.

ELEN = The last element in a series of elements.

Note: If ELE1 and/or ELEN exceed the I5 format (≥100,000), set ELE1 = −1 and then read ELE1 and ELEN on the following card in 2I10 format.

ELE INC = The element number increment between ELE1 and ELEN. If ELE1 = 100, ELEN = 120 and ELE INC = 5, then pressures are applied to elements 100, 105, 110, 115, and 120.

N1 = A specified node number of element ELE1 which is used to determine where the pressure is applied.

For 1D geometry, N1 is the node to which the pressure is applied.

For 2D geometry (shell/bar, triangles, quads) the pressure is applied normal to the line between nodes N1 and N2 in the general direction of node N3. For shell/bar elements, reference node N3 would be counterclockwise going from N1 to N2.

For 3D geometry, with tetrahedral elements, the pressure is applied to the triangular face opposite of node N1. For 3D shell elements the pressure is applied normal to the triangular face where N1, N2, and N3 are in a counterclockwise arrangement.

NN = The node corresponding to node N1, which is on element ELEN.

NODE INC = The node number increment between N1 and NN. For 3D tetrahedral elements described under ELE INC (100, 105, 110, 115, 120), if N1 = 200, NN = 208, and NODE INC = 2, then the pressures are applied to the triangular faces opposite nodes 200, 202, 204, 206, 208, of elements 100, 105, 110, 115, 120.

PRESSURE = The pressures which are applied to the faces of the elements described on this card (force/area).

Time-Pressure Cards for PRES = 2 (2F10.0) —These cards allow the applied pressures to be varied as a function of time. A minimum of two cards must be used, which span the time from the beginning of the run to TMAX. End with a blank card as shown in Figure 6.

PTIME = The time corresponding to P(T). Cards must be input in order of increasing time (second).

P(T) = The factor by which all pressures are multiplied at the corresponding time. Intermediate values are linearly interpolated between values at specified times.

Velocity Cards for PUSH = 2 (3I5, 5X, 3F10.0) — These cards describe the applied velocities and the nodes to which they are applied. If other applied velocities were used previously, they are all deleted, and the only applied velocities which act are those that are input in the current run. This option will generally require EMAX to be defined in the Time Integration Card. End with a blank card as shown in Figure 6. (Not yet available.)

N1 = The first node, in a series of nodes, to which the velocity is applied.

NN = The last node in a series of nodes.

INC = The node number increment between N1 and NN.

X/RDOT = X/R velocity imposed on nodes N1 . . . NN (distance/time).

Y/TDOT = Y/θ velocity imposed on nodes N1 . . . NN.

ZDOT = Z velocity imposed on nodes N1 . . . NN.

Time-Velocity Cards for PUSH = 2 (2F10.0) — These cards allow the applied velocities to be varied as a function of time. A minimum of two cards must be used, which span the time from the beginning of the run to TMAX. End with a blank card as shown in Figure 6.

VTIME = The time corresponding to V(T). Cards must be input in order of increasing time (second).

V(T) = The factor by which all applied velocities are multiplied at the corresponding time. Intermediate values are linear interpolated between values at specified times.

Data Output Cards (4F10.0, 8I5) — These cards are used to specify various forms of output data at selected times, and the last card must be for a time greater than TMAX even though output will not be provided for that specific time. Recall that output is automatically provided at TMAX, and a data output card need not be provided for this time. End run with a blank card.

TIME = Time at which output data will be provided (second).

ECHECK = Code which governs the printed output. The following options are provided:

1. If ECHECK ≥ 999., the individual node data and element data will not be printed. Only system data such as cg positions, momenta, energies, and average velocities are provided for the projectile, target, and total system.
2. If ECHECK is less than 999., the system data and individual element data will be printed for all elements (except explosives) which have an equivalent plastic strain equal to or greater than ECHECK. For example, if ECHECK = 0.5, all elements with equivalent plastic strains equal to or greater than 0.5 will have data printed.

NCHECK = Net nodal velocity used to govern printed output for nodes. If ECHECK is less than 999., and the net nodal velocity is greater than NCHECK, then the nodal data will be printed.

RDAMP = Radial damping constant, C_D in Equation (38) of Reference 1 for use in axisymmetric geometry with spin only (GEOM = 7). If this option is to be used, Reference 1 should be consulted. This damping acts until the time specified in the following Data Output Card.

SAVE = 0 will not write results unless run is stopped.

= −1 will not write results even if run is stopped.

= 1 will write results on same restart file (IRESIN) for possible restart runs or state plots. Previous and current run are on same restart file.

= 2 will write results on a different restart file (IRESOT) for possible restart runs or state plots. Previous and current run are on different restart files.

= 3 will write results to a file named EiPj.RES, opened on channel IRES03 and closed immediately after writing. In the file name, i = PCASE on the Prep Miscellaneous card and j is an index count for each set (PATRAN and/or restart) of output files requested.

BURN = 0 will print all explosive element data if ECHECK < 999.

= 1 will print only those explosive elements which have been fully detonated if ECHECK < 999.

= 2 will not print any explosive element data.

YPRNT = 0 will not restrict 3D output.

= 1 will restrict printing of 3D node data to nodes with Y = 0 and to element data to elements with one face on the Y = 0 plane. ECHECK and NCHECK limitations also apply.

NDATA = Interval of cycles at which cycle data will be printed. If NDATA = 2, cycle data will be printed for every other cycle (2, 4, 6, etc.). If left blank, cycle data will be printed for every cycle.

SLPR = 0 will not print current sliding interface data.

= 1 will print current data (master and slave) for eroding sliding interfaces only.

= 2 will print current data for all sliding interfaces in problem.

PROJ = 0 will print requested data for both the projectile and the target.

= 1 will print requested data for the projectile only.

= 2 will print requested data for the target only.

PAT = 0 will not write PATRAN data.

= 1 will write PATRAN neutral model data to file "EiPj.MDL."

= –1 is similar to PAT = 1, except that for 3D geometry only data on the plane of symmetry (Y = 0.0) are written. This greatly reduces the size of 3D files.

= 2 will write PATRAN model file and nodal results to file "EiPj.NOD."

= –2 is similar to PAT = 2 as described previously.

= 3 will write PATRAN model file and element results to file "EiPj.ELE."

= –3 is similar to PAT = 3 as described previously.

= 4 will write all three files.

= –4 is similar to PAT = 4 as described previously.

Where i = PATRAN case identifier (PCASE) on Prep Miscellaneous Card, and j = index count for each set (PATRAN and/or restart) of output files requested.

The model file contains the geometry information (nodal coordinates, element ID, etc.) to describe the model. Additional PATRAN Name cards are included for convenience and are described below. These may be accessed in PATRAN with the NAME command.

PROJN = List of all projectile nodes.

PROJE = List of all projectile elements.

TARGN = List of all target nodes.

TARGE = List of all target elements.

MSTi = List of master nodes on sliding interface i (i = 1, NSLID).

SLVi = List of slave nodes on sliding interface (i = 1, NSLID).

The nodal results file contains results information and may be used to plot contours on the nodal properties listed below. Contours may be generated with the PATRAN command RUN, CONTOUR, COL, i.

Property	**PATRAN Column No.**
X/R Velocity	1
Y/θ Velocity	2
Z Velocity	3
Net Velocity	4

The element results file contains results information and may be used to plot contours on the following element properties. Contours may be generated as above.

Property	**PATRAN Column No.**
Pressure	1
Von Mises Stress	2
Equivalent Strain	3
Damage/Burn Fraction	4
Temperature	5
Log (10) Strain Rate	6

RZONE = 0 will not perform an automatic rezone.

= 1 will perform automatic rezone of the regions specified previously.

3. INPUT DATA FOR THE POSTPROCESSOR

The function of the Postprocessor is to provide plots of the results in the form of state plots and time plots. The state plots show results for the entire system at a specified time, and the time plots show results for a specified variable as a function of time.

a. State Plots

Input data for state plots are summarized in Figure 7. Included is the capability to plot geometries, velocity vectors, contours of several variables, various jet characteristics, and behind target debris. Plots can be requested in the order of increasing time and cycle numbers and by either time or cycle number. By using the time option, it is possible to request plots without having access to the output from the Main Routine. The times at which data are requested must simply coincide with those specified on the Data Output Cards of the Main Routine. End state plot data with a blank card.

Geometry Plot Card for 2D and 3D (2I5, F10.0, 8I2, 14X, A30) —

1 = Code to specify geometry plot.

CYCLE = Cycle number of the plot which is desired. The cycle numbers of the data written on the restart file are given in the printed output of the Preprocessor and the Main Routine. If CYCLE = 0, the plots are requested on the basis of time.

TIME = Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE.

AXES = 0 will use the axes (X/R, Y, Z) from the previous plot. This option allows deformed geometry to be plotted together with contours or velocity vectors, for instance.

= 1 will automatically compute the (X/R, Y, Z) axes to include all nodes. The vertical axis is specified to be 10 units, and the horizontal axis is as required, using the same scale as the vertical axis.

= 2 will read the coordinate limits of the plot.

VIEW = 0 for 1D or 2D geometry (GEOM = 1–7).

= 1 provides 2D plot of X–Z axes. For 3D geometry only (GEOM = 8).

= 2 provides 2D plot of Y–Z axes. For 3D geometry only.

= 3 provides 2D plot of X–Y axes. For 3D geometry only.

= 4 provides 3D perspective plot. For 3D geometry only.

= 5 provides 2D cutting plane plot with cutting plane parallel to the X–Z plane. For 3D geometry only.

= 6 provides 2D cutting plane plot with cutting plane parallel to the Y–Z plane. For 3D geometry only.

= 7 provides 2D cutting plane plot with cutting plane parallel to the X–Y plane. For 3D geometry only.

= 8 provides a 2D cutting plot using an arbitrarily positioned cutting plane. For 3D geometry only.

ORIENT = 0 will specify the Z axis as the vertical axis and the R axis as the horizontal axis. For 1D or 2D geometry only (GEOM = 1–7).

= 1 will specify the R axis as the vertical axis and the Z axis as the horizontal axis. For 1D or 2D geometry only (GEOM = 1–7).

SIDE = 0 will plot the grid on the actual coordinates.

= 1 will plot the grid on the negated R coordinates only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 will plot the grid on both the actual and negated R coordinates. For 2D geometry only.

= 3 will not plot the grid.

EDGE = 0 plots no outline around the edges.

= 1 plots an outline on the negated R coordinate only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 plots an outline on both the actual and negated R coordinates. For 2D geometry only.

= 3 plots an outline on the actual coordinates only.

= –1 is same as EDGE = 1 except outlines are also included between different materials.

= –2 is same as EDGE = 2 except outlines are also included between different materials.

= –3 is same as EDGE = 3 except outlines are also included between different materials.

FAIL = 0 will not plot element information.

= 1 will plot star in center of fractured (partially failed) element.

= 2 will plot element number in the center of the element. The element number type size is identical to that of the title line.

= 3 will plot both options (star and element number).

= 4 will plot a triangle in the center of all 3D shell elements and a circle in the center of all 3D bar elements.

= 5 will plot triangles at the three nodes of all 3D shell elements and circles at the two nodes of all 3D bar elements.

NODE = 0 will not plot individual node points.

= 1 will plot node points on negated R coordinates only. For 2D geometry only (GEOM = 4, 5, 6, 7).

= 2 will plot node points on both the actual and negated R coordinates. For 2D geometry only.

= 3 will plot node points on actual coordinates only.

= –1 is same as NODE =1 except projectile nodes are drawn as a plus sign and target nodes are drawn as a diamond.

= –2 is same as NODE = 2 except nodes are drawn as symbols instead of points.

= –3 is same as NODE = 3 except nodes are drawn as symbols instead of points.

NPRINT = 0 will not print node numbers.

= 1 will print node numbers on the plot. Node numbers are only printed where nodes are plotted by the previous NODE option. To print node numbers on a grid with SIDE = 0, it is necessary to set NODE = 3. The node numbers are the same size type as the title line, and the node position is the lower left corner of the first digit in the node number.

TITLE = Title printed on the plot.

Plot Limits Card for Axes = 2 (6F10.0, 3I5) — This card specifies the portion of the problem which is plotted. Regions beyond those specified are not plotted. The vertical axis is scaled to 10 units and the horizontal axes is as required. The scale factor used will be a multiple of 1, 2, 3, 5, or 8 per axis unit.

X/RMAX = Maximum X/R coordinate included in the plot (distance). When VIEW = 6, X/RMAX is the position of the cutting plane.

YMAX = Maximum Y coordinate included in the plot. When VIEW = 5, YMAX is the position of the cutting plane.

ZMAX = Maximum Z coordinate included in the plot. When VIEW = 7, ZMAX is the position of the cutting plane.

X/RMIN = Minimum X coordinate included in the plot.

YMIN = Minimum Y coordinate included in the plot.

ZMIN = Minimum Z coordinate included in the plot.

E1–EN = Range of elements to be plotted. If E1 = EN = 0, all elements will be included.

Note: If E1 and/or EN exceed the I5 format (≥100,000), set E1 = –1 and then read E1 and EN on the following card in 2I10 format.

M = Specific material number of elements to be plotted. If M = 0, all materials will be plotted.

3D Perspective Card for VIEW = 4 or 8 (6F10.0, I5) — This card is included only for the 3D perspective plots (VIEW = 4) and the arbitrary oriented cutting plate plot (VIEW = 8).

XEYE, YEYE ZEYE = Coordinates of the observer (distance).

XPLANE YPLANE ZPLANE = Coordinates included in the plate on which the results are plotted for VIEW = 4. The plane is normal to a line from XEYE, YEYE, ZEYE to XPLANE, YPLANE, ZPLANE. For VIEW = 8, this plane is the cutting plane.

HIDE = 0 will plot all free surfaces (no hidden lines) for VIEW = 4.

= 1 will plot only lines which have both ends visible to the observer for VIEW = 4. This option can require significant CPU time for large problems.

= 2 will produce two plots, one each with HIDE = 0 and HIDE = 1.

Extrapolated Geometry Plot Card for 2D and 3D (2I5, F10.0, 8I2, 4X, F10.0, A30) —This option allows the user to obtain extrapolated geometry plots at times much greater than were computed. Similar options as for Geometry Plot Card (TYPE = 1). Only previously undefined variables are defined.

2 = Code to specify Extrapolated Geometry Plot.

T-EXTRAP = Extrapolated time for which the geometry is desired (second). Nodal positions are based on straight line extrapolation using positions and velocities from the specified cycle (or time).

Plot Limits Card for AXES = 2 (6F10.0, 3I5) — All variables previously defined.

Velocity Vector Plot Card for 2D and 3D (2I5, F10.0, 6I2, 8X, F10.0, A30) — Only previously undefined variables are defined. See Geometry Plot Card description for others.

3 = Code to specify velocity vector plot.

ARROW = 0 will not place arrowheads on the velocity vectors.

= 1 will place arrowheads on the velocity vectors.

VSCALE = Velocity which will give a velocity vector which has a length of 1.0 using the scale of the plot (distance/second). If left blank, VSCALE will automatically be determined to give the longest vector a length of two percent of the length of the vertical axis.

Plot Limits Card for AXES = 2 (6F10.0, 2I5) — Only previously undefined variables are defined.

N1–NN = Range of nodes to have velocity vectors plotted. If N = NN = 0 all nodes will have vectors plotted.

3D Perspective Card for VIEW = 4 (6F10.0, 2I5) — All variables previously defined.

PATRAN Output File Card (2I5, F10.0, I2, 28X, A30) — This card reads data from the EPIC restart file and translates into PATRAN format. See expanded discussion for

Data Output Card in Main Routine. There is an added option (PAT = 5) available only from the Postprocessor.

4 = Code to specify PATRAN file output.

PAT = 1 will write PATRAN neutral file model data to file "EiPj.MDL."

= –1 is similar to PAT = 1, except that for 3D geometry, only data on the plane of symmetry (Y = 0.0) are written. This greatly reduces the size of 3D files.

= 2 will write PATRAN neutral file model data and nodal results to file "EiPj.NOD."

= –2 is similar to PAT = 2 as described previously.

= 3 will write PATRAN neutral file model data and element results to file "EiPj.ELE."

= –3 is similar to PAT = 3 as described previously.

= 4 will write all three files.

= –4 is similar to PAT = 4 as described previously.

= 5 will generate PATRAN neutral file model data for 3D problems, which includes surface elements only. This greatly reduces the size of the PATRAN file.

Contour Plot Card for 2D and 3D (2I5, F10.0, 8I2, 14X,A30) — This card requests contour plots of element variables. Contours are determined by first computing the variable quantities at the nodes (i.e., the nodal pressure is the average of the pressures of all elements which contain the node). Then the contours are drawn through the nodal quantities. Only previously undefined variables are defined. See Geometry and Velocity Vector Plot Cards for others.

TYPE = Code to specify which variable is requested. Must be in the range of 11–21. See Figure 7 for description of variables.

NLINE = Number of contours to be plotted. If NLINE = 0, six contours will be plotted at values 5, 20, 40, 60, 80, and 95 percent of the range between the minimum and maximum variable quantity limits.

SYMBOL = Increment at which symbols are placed on contour lines. SYMBOL = 1 will place symbols at the forward end of each contour line within an element, and SYMBOL = 5 will place symbols at the forward end of every fifth element, etc. SYMBOL = 0 will place only one symbol on the contour line.

PRINT = 0 will not print the nodal quantities of the specified variable on the output of the Postprocessor.

= 1 will print the nodal quantities of the specified variable on the output of the Postprocessor.

Plot Limits Card for AXES = 2 (6F10.0, 3I5) — This card is the same as described for the geometry plots.

Contour Specification Cards for NLINE > 0 (8F10.0) — Used only for NLINE > 0 on Contour Plot Card.

C1 ... CN = Magnitude of contours to be plotted.

Plot Cards for 1D Only (2I5, F10.0, I2, 12X, I2,14X, A30) — For one-dimensional geometry, variables are plotted as a function of the Z axis. The plot axes are divided into 10 units each. Plot types must be in the range of 11–22 as shown in Figure 7. All input variables have been previously defined.

Plot Limits Card for AXES = 2 (4F10.0) —

VMAX = Maximum value of the dependent variable included in the 1D plot.

VMIN = Minimum value of the dependent variable included in the 1D plot.

ZMAX = Maximum Z coordinate included in the plot (distance).

ZMIN = Minimum Z coordinate included in the plot.

b. Time Plots

Input data for time plots are summarized in Figure 8. System/Chunk Plot Cards should be input first, followed by Individual Node and Individual Element Plot Cards. The variables are plotted as a function of time. The plot axes are divided into 10 units each. End with a blank card.

System/Chunk Plot Cards (3I5, F5.0, 4F10.0, A20) — These cards request plots of the system variables or chunk variables. Each plot contains data for the projectile, the target, the total system (projectile plus target), or a specified chunk. The system data include eroded (totally failed) elements, but the chuck data do not include the eroded elements. These data must have been previously written on the plot file by setting SYS = 1 on the Plot Card in the Main Routine.

TYPE = Code describing the type of plot. See Figure 8 for description of type. Must be in range of 1 to 27.

AXES = 0 will automatically select coordinates to include maximum and minimum values of variable for total duration of time.

= 1 will read the coordinate limits of the plot.

= −1, −2, −3, etc., will overplot, using the axes from the previous plot. If multiple plots are included on the same axes, the use of AXES = −1, −2, −3, etc., will move the title location for each plot. This will eliminate overwriting.

CODE = 0 will plot system data for the projectile, the target, and the total system.

= −1 will plot system data for the projectile only.

= −2 will plot system data for the target only.

= –3 will plot system data for the total system only.

> 0 will plot data for chunk number CODE.

SCALE = Factor by which the dependent variables are multiplied before plotting. Negative values are allowed. A blank default gives SCALE = 1.0.

TMAX = Maximum time included on horizontal axis if AXES = 1 (second).

TMIN = Minimum time included on horizontal axis if AXES = 1.

VMAX = Maximum variable included in vertical axis if AXES = 1.

VMIN = Minimum variable included on vertical axis if AXES = 1.

TITLE = Title written on the plot.

Individual Node Plot Cards (3I5, F5.0, 4F10.0, A20) — These cards request plots of nodal variables. These data must have been previously written on the plot file by specifying the requested nodes on the Designated Nodes Card in the Main Routine. Only previously undefined variables are defined.

TYPE = Code describing the type of plot. See Figure 8 for a description of types. Must be in the range of 40 to 50. Note that acceleration data (TYPE = 47–49) may be incorrect for sliding surface and rigid body nodes.

NODE = Specific node for which plot data are requested.

Individual Element Plot Cards (3I5, F5.0, 4F10.0, A20) — These cards request plots of element variables. These data must have been previously written on the plot file by specifying the requested elements on the designated Elements Cards in the Main Routine. Only previously undefined variables are defined.

TYPE = Code describing the type of plot. See Figure 8 for a description of types. Must be in the range of 60–75.

ELE = Specific element for which plot data are requested.

Note: If ELE exceeds the I5 format (≥100,000), set ELE = –1 and then read ELE on the following card in I10 format.

4. INTERACTIVE BATCH OPTION

This option allows the user to see how a run is progressing, and to terminate the run with a restart file written, if desired. At the end of each cycle, EPIC checks to see if a file exists on channel IBIN. If no file exists, the next cycle is started. If a file exists, the first line is read and, if a command is recognized, the command is actuated. The file is deleted after reading. Commands must start in column 1 and be given exactly as shown. The five commands (CYCLE, STOP, SAVE, SAVE1, SAVE2) are as follows:

CYCLE = Print the current cycle line on channel IBOUT.

STOP = Stop EPIC by printing and saving as requested on current Data Output Card.

SAVE = Write to the restart file IRESIN and print the current cycle line on channel IBOUT.

SAVE1 = Same as SAVE.

SAVE2 = Write to the restart file IRESOT and print the current cycle line on channel IBOUT.

5. PROGRAM STRUCTURE AND FILE DESIGNATION

The subroutines are contained in five groups, designated EPIC, SUBS, POST1, POST2, and a machine-dependent group named after the machine. There are machine-dependent subroutines for VAX and CRAY. There is also a generic set of subroutines in group DUMMY. For the Preprocessor and Main Routine, the subroutines in EPIC, SUBS, and CRAY or VAX are required. For the State Plots Postprocessor, the subroutines in POST1, SUBS, and CRAY or VAX are required. For the Time Plots Postprocessor, the subroutines in POST2 are required.

The file designations are as follows:

IN = 5 Input file (file names for CRAY are epic.in for EPIC, post1.in for POST1, and post2.in for POST2).

IOUT = 6 Output file (file names for CRAY are epic.out for EPIC, post1.out for POST1, and post2.out for POST2).

IPLTIN = 7 Restartable plot file for time plots, which is read by the Main Routine, and the time plot postprocessor, POST2 (file name for CRAY is epic.tpi).

IPLOT = 8 Plot file for time plots written by the Main Routine (file name for CRAY is epic.tpo).

IRESIN = 9 Restart file read by the Main Routine. Can also write to this file with SAVE = 1 option (file name for CRAY is epic.res).

IRESOT = 10 Restart file generated by the Main Routine with SAVE = 2 option (file name for CRAY is epic.rst).

IRES03 = 12 Restart file generated by Main Routine with SAVE = 3 option.

INDATA = 15 Input file with comments removed.

IBIN = 16 Interactive batch input read by the Main Routine (file name for CRAY is epic.bin).

IBOUT = 17 Interactive batch output (file name for CRAY is epic.cyc).

MPATOT = 19 PATRAN Model file output.

NPATOT = 20 PATRAN Node file output.

LPATOT = 21 PATRAN Element file output.

INPAT = 30 PATRAN file used by the EPIC Preprocessor (file name for CRAY is epic.pin).

6. INSTRUCTIONS FOR CHANGING PROGRAM DIMENSIONS

The dimensions of the Preprocessor and Main Routine can be changed by redimensioning the arrays in common blocks NODE, ELEMNT, and MISC2. An explanation of the variable names is given in BLOCK DATA INITAL.

7. COMPUTER MACHINE DEPENDENCIES

Several places in the EPIC code require modification when used on various computers. Most of the places are in a single file. Three versions of this file are included with the distribution tape. File VAX.FOR contains code which works with VAX/VMS computers with FORTRAN 77. File CRAY.FOR is for CRAY computers. File DUMMY.FOR contains code which has the best chance of working on all computers. Each file contains different versions of the same subroutines. Subroutine CPCLCK should return the amount of time used by the central processor on this problem. The DUMMY version always returns a zero to avoid a machine dependent clock call. Subroutine DATTIM should return the current date and time in a format suitable for PATRAN data files. The DUMMY version always returns 01-JAN-91 00:00:00. The remaining subroutines have names starting with a Q and open various files. The subroutines QBIN and QBOUT open the input and output files used in the interactive batch option. The VAX version does not use file names because it is preferred to use job control cards to set up the file names. The CRAY version uses a file name because predefined file names are preferred. The remaining Q subroutines have similar differences which should be obvious from comments in the code.

The subroutines QRESIN and QRESOT have a special requirement. These subroutines open the restart input and output files. These files are unformatted and therefore machine dependent. Some machines like the CRAY do not allow a maximum record length to be specified, while other machines like the VAX require the specification of a maximum record length. When the maximum record size can be specified, the best efficiency is usually obtained by specifying the largest record that the system can handle. This situation is handled by modifying the file ENVIRO.FOR. The value of MXRSZ should be 0 (zero) when the maximum record size is not specified, and equal to the maximum record size when the size is specified. The value of NUPV should be the number of record size units per variable. The VAX uses units of words for the record size.

Each VAX single precision variable uses one word so for the VAX, NUPV = 1. On the Apollo, the units of record length are bytes. A single precision variable is 4 bytes long so on the Apollo, NUPV = 4. The variables MXRSZ and NUPV are used by subroutine SAVE to divide large amounts of data into pieces that the machine can handle.

8. EXAMPLE PROBLEMS

This subsection contains input data and computed results for the following example problems:

- Example 1 – 1D Wave Propagation
- Example 2 – 2D Cylinder Impact onto a Rigid Surface
- Example 3 – 2D Normal Impact and Perforation
- Example 4 – 3D Oblique Impact and Perforation

Selected computed results and input data for the examples are shown in Figures 25–32.

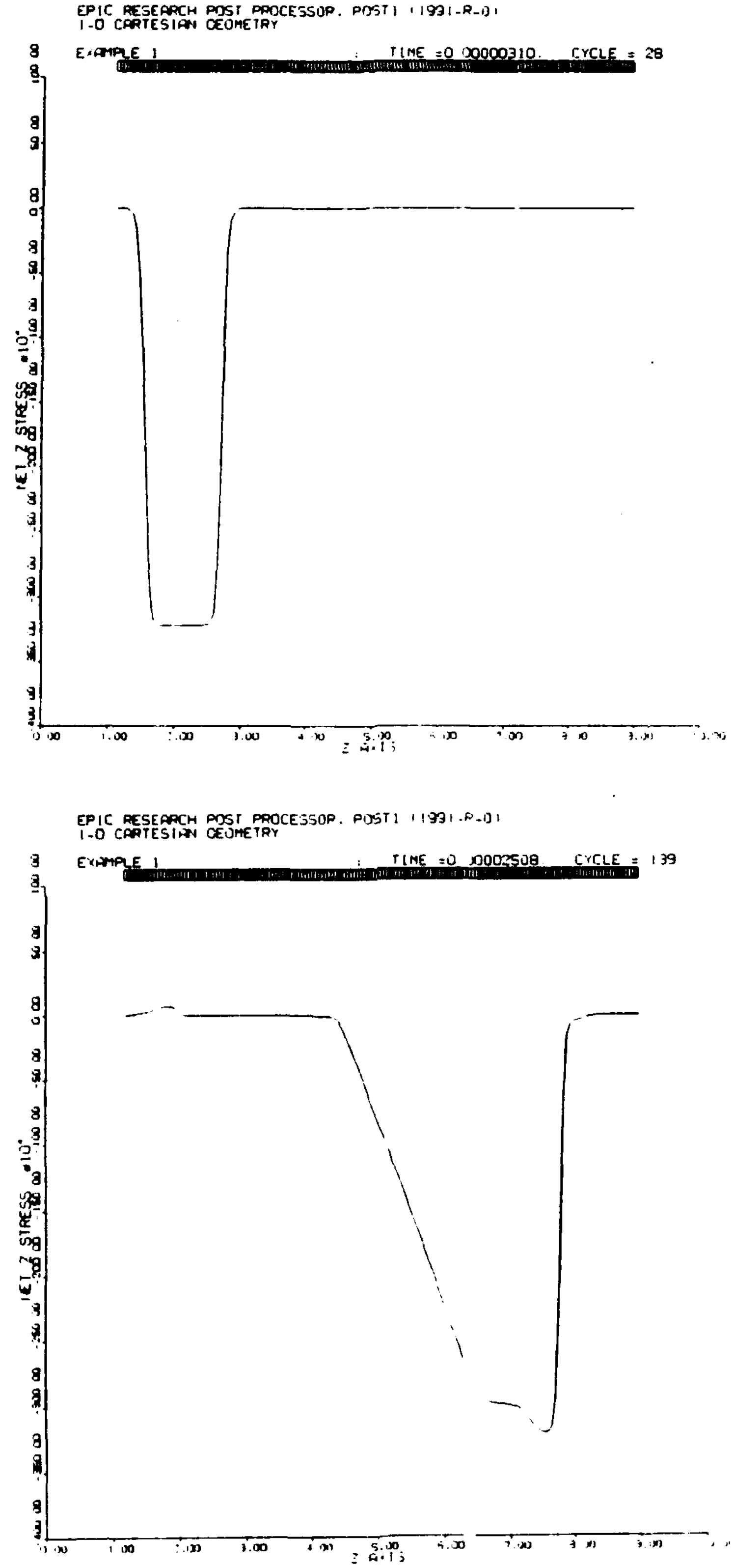


Figure 25. Example 1

```
$TYPE CASE....DESCRIPTION.OF.PROBLEM........................................
    2    1 EXAMPLE 1 - 1D WAVE PROPAGATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK///// NZONpcXYZ SPLT  DP3 UNIT
    1    0    1    1    0    0    0    0         001000    0    0    0
$MATL    0  DAM FAIL DFCT EFAL library materials
    1    0    1    0  1.0 999. $LIBRARY COPPER
    4    0    1    0  1.0 999. $LIBRARY ARMCO IRON
     $ BLANK FOR END OF MATERIALS
$ PROJECTILE NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0
$ LINE OF NODES
$   1NNODE//RTZ/////////////////////////    N1  INC    EXPAND
    1   21  000                              1    1       1.0
$     X/R1        Y1        Z1      X/RN        YN        ZN
       0.0       0.0       1.0       0.0       0.0       2.0
     $ BLANK FOR END OF PROJECTILE NODES
$ TARGET NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0
$ LINE OF NODES
$   1NNODE//RTZ/////////////////////////    N1  INC    EXPAND
    1  141  000                             51    1       1.0
$     X/R1        Y1        Z1      X/RN        YN        ZN
       0.0       0.0       2.0       0.0       0.0       9.0
     $ BLANK FOR END OF TARGET NODES
$ PROJECTILE ELEMENTS
$   1 MATLNCOMP   N1   N2   N3   N4   N5   N6   N7   N8  INC SHEL/////       T/A
    1    1   20   21   20                                   -1    0
     $ BLANK FOR END OF PROJECTILE ELEMENTS
$ TARGET ELEMENTS
$   1 MATLNCOMP   N1   N2   N3   N4   N5   N6   N7   N8  INC SHEL/////       T/A
    1    4  140  191  190                                   -1    0
     $ BLANK FOR END OF TARGET ELEMENTS
$ SLIDE LINE 1
$  M1   S1
  21    51
$   X/RDET      YDET      ZDET     TBURN
       0.0       0.0       0.0       0.0
$  PX/RDOT   PY/TDOT     PZDOT   TX/RDOT   TY/TDOT     TZDOT       DT1 VFLD
       0.0       0.0   40000.0       0.0       0.0       0.0 .00000005    0
$CYCL/////      TIME     DTMAX     DTMIN       SSF      TMAX     CPMAX      EMAX
    0     0.000000       1.0.000000001       0.9  0.000025       1.0
$TPLT DROP///// PRES PUSH  HRG    VFRACT//////////      PMAX
    0    0
$     TIME    ECHECK    NCHECK     RDAMP SAVE BURN YPRT NDAT SLPR PROJ  PAT RZNE
  0.000003    1001.0       0.0       0.0    1    0    0    1
  0.000015    1001.0       0.0       0.0    1    0    0    1
  1.000025    1001.0       0.0       0.0    1    0    0    1
```

Figure 26. Input Data for Example 1

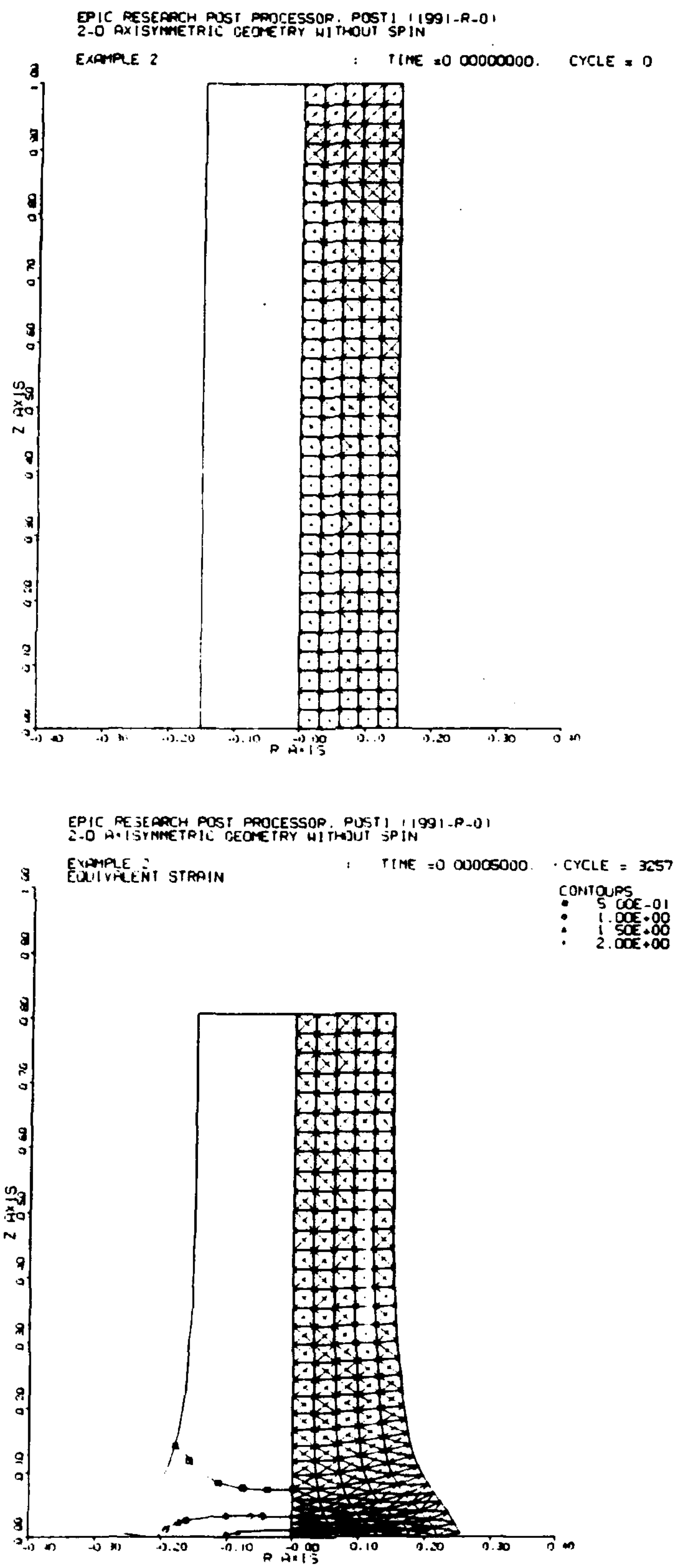


Figure 27. Example 2

```
$TYPE CASE....DESCRIPTION.OF.PROBLEM............................................
    2    2 EXAMPLE 2 - 2D CYLINDER IMPACT ONTO A RIGID SURFACE
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK///// NZONpcXYZ SPLT  DP3 UNIT
    6    0    1    0    0    0    0    0         002001    0    0    0
$MATL    0  DAM FAIL DFCT EFAL library materials
   39    0    1    0  1.0 999. $ LIBRARY ARMCO IRON
     $ BLANK FOR END OF MATERIALS
$ PROJECTILE NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0
$ ROD NODES
$   2  NOR  NIR NPLN  RAD   AX CROS JOIN   N1 NTOP      ZTOP      ZBOT    EXPAND
    2    5    0   34    1    0    1    0    1    0       1.0       0.0       1.0
$    ROTOP     RITOP     ROBOT     RIBOT (for RAD=1)
       .15       0.0       .15       0.0
     $ BLANK FOR END OF PROJECTILE NODES
$ TARGET NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0
     $ BLANK FOR END OF TARGET NODES
$ PROJECTILE ELEMENTS
$ ROD ELEMENTS
$   2 MATL   N1 DIAG NOER NIER NLAY///// SHEL PLAC//////////     THICK
    2   39    1    5    5    1   33         0    0
     $ BLANK FOR END OF PROJECTILE ELEMENTS
$ TARGET ELEMENTS
     $ BLANK FOR END OF TARGET ELEMENTS
$   X/RDET      YDET      ZDET     TBURN
       0.0       0.0       0.0       0.0
$  PX/RDOT   PY/TDOT     PZDOT   TX/RDOT   TY/TDOT     TZDOT       DT1 VFLD
       0.0       0.0   -8000.0       0.0       0.0       0.0 .00000005    0
$CYCL/////      TIME     DTMAX     DTMIN       SSF      TMAX     CPMAX      EMAX
    0       0.000000       1.0.000000001       0.9  0.000050       1.0
$TPLT DROP///// PRES PUSH  HRG    VFRACT//////////      PMAX
    1
$ SYS NPLT LPLT DPLT     DTSYS      TSYS    DTNODE     TNODE     DTDYN      TDYN
    1    1    1    0  0.000001  0.000000 0.0000001  0.000000
$  N1   N2   N3   N4   N5   N6   N7   N8   N9  N10  N11  N12  N13  N14  N15  N16
    1
$  L1   L2   L3   L4   L5   L6   L7   L8   L9  L10  L11  L12  L13  L14  L15  L16
  660
$     TIME    ECHECK    NCHECK     RDAMP SAVE BURN YPRT NDAT SLPR PROJ  PAT RZNE
  0.000025    1001.0       0.0       0.0    1    0    0   50
  1.000050    1001.0       0.0       0.0    1    0    0   50
```

Figure 28. Input Data for Example 2

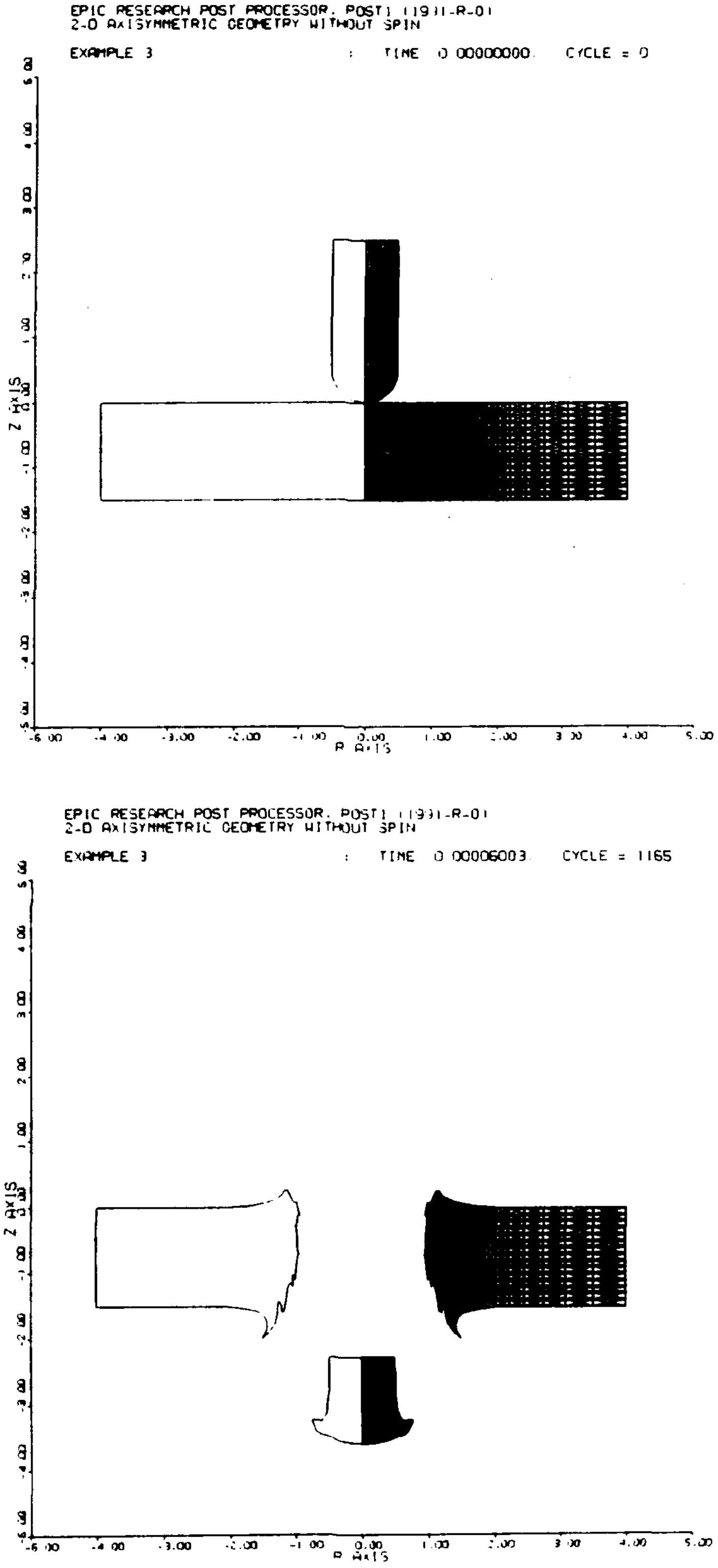


Figure 29. Example 3

```
$TYPE CASE....DESCRIPTION.OF.PROBLEM...........................................
    2    3 EXAMPLE 3 - 2D NORMAL IMPACT AND PERFORATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK///// NZONpcXYZ SPLT  DP3 UNIT
    6    0    1    2    0    0    0    1         003  0    0    0    0
$MATL    0  DAM FAIL DFCT EFAL
    1    0    1    1  1.0 999. $ COPPER FROM LIBRARY
   23    0    1    1  1.0 999. $ 6061-T6 ALUM FROM LIBRARY
     $ BLANK FOR END OF MATERIALS
$ PROJECTILE NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       0.0       1.0
$ ROD NODES
$   2  NOR  NIR NPLN  RAD   AX CROS JOIN   N1 NTOP      ZTOP      ZBOT    EXPAND
    2    5    0   17    1    0    1    0    1    0       2.5       0.5       1.0
$    ROTOP     RITOP     ROBOT     RIBOT
       0.5       0.0       0.5       0.0
$ NOSE NODES
$   3 TYPE  NOR  NIR  RAD   AX CROS/////   N1/////      ZTOP      ZMIN
    3    2    5    0    1    0    1       183          0.5    0.0001
$    ROTOP     RITOP
       0.5       0.0
     $ BLANK FOR END OF PROJECTILE NODES
$ TARGET NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       0.0       1.0
$ FLAT PLATE NODES
$   4 TYPE NX/R   NY   NZ  FIX CROS JOIN   N1  INC    X/REXP      YEXP      ZEXP
    4    1   26    0   16    1    1    0  250    0       1.2       1.0       1.0
$NRND NZND RPRT ZPRT      RMAX      RMIN      ZMAX      ZMIN
   11   16 .625  1.0       4.0       0.0       0.0      -1.5
     $ BLANK FOR END OF TARGET NODES
$ PROJECTILE ELEMENTS
$ ROD ELEMENTS
$   2 MATL   N1 DIAG NOER NIER NLAY///// SHEL PLAC//////////     THICK
    2    1    1    5    5    1   16
$ NOSE ELEMENTS
$   3 MATL   N1 DIAG NOER NIER////////// SHEL///////////////     THICK
    3    1  183    5    5    1
     $ BLANK FOR END OF PROJECTILE ELEMENTS
$ TARGET ELEMENTS
$ FLAT PLATE ELEMENTS
$   4 MATL   N1 DIAG TYPE LX/R  NLY  NLZ SHEL PLAC//////////     THICK
    4   23  250    5    1   25    0   15
     $ BLANK FOR END OF TARGET ELEMENTS
$ SLIDE LINE 1 (TARGET MASTER, PROJECTILE SLAVE, ERODING)
$ NMG  NMN  NSG  NSN  NSR TYPE MBOT  ISR  IT1  IT2   REF VEL     ERODE  FRICTION
    1    0    1    0    0    1 1015    0    1    0  100000.       1.5       0.0
$ M1G  MNG  INC
  250  265    1
$ S1G  SNG  INC
    1  237    1
$ SLIDE LINE 2 (PROJECTILE MASTER, TARGET SLAVE, ERODING)
$ NMG  NMN  NSG  NSN  NSR TYPE MBOT  ISR  IT1  IT2   REF VEL     ERODE  FRICTION
    3    0    0    0    1    1    0    0    1    0  100000.       1.5       0.0
$ M1G  MNG  INC
```

Figure 30. Input Data for Example 3

```
    1    5    1
    6  182   11
  228  237    1
$      RMAX      RMIN      ZMAX      ZMIN (SLAVE BOX)
        1.2       0.0       0.0      -1.6
$ CHUNK CARDS
$ CE1  CEN
    1  420
$   X/RDET      YDET      ZDET     TBURN
       0.0       0.0       0.0       0.0
$  PX/RDOT   PY/TDOT     PZDOT   TX/RDOT   TY/TDOT     TZDOT       DT1 VFLD
       0.0       0.0   -80000.       0.0       0.0       0.0 .00000005    0
$CYCL/////      TIME     DTMAX     DTMIN       SSF      TMAX     CPMAX      EMAX
    0   0.000000       1.0.000000005       0.9  0.000060       1.0       0.0
$TPLT DROP///// PRES PUSH  HRG    VFRACT//////////      PMAX
    0    0    0    0    0    0      0. 0
$      TIME    ECHECK    NCHECK     RDAMP SAVE BURN YPRT NDAT SLPR PROJ  PAT RZON
  0.000020     1001.       0.0       0.0    1    0    0   50
  0.000040     1001.       0.0       0.0    1    0    0   50
  1.000000     1001.       0.0       0.0    1    0    0   50
```

Figure 30. Input Data for Example 3 (Concluded)

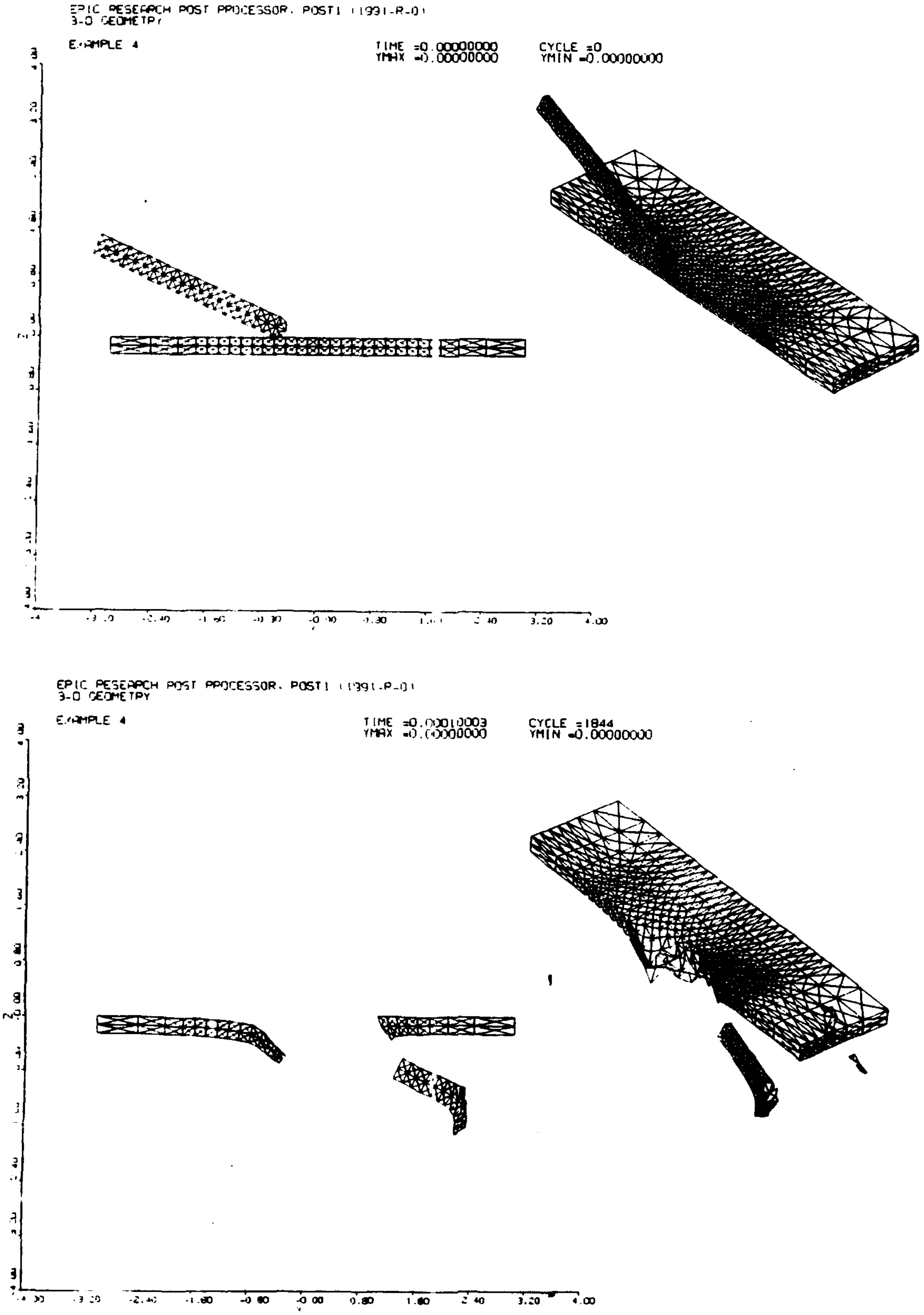


Figure 31. Example 4

```
$TYPE CASE....DESCRIPTION.OF.PROBLEM............................................
    2    4 EXAMPLE 4 - 3D OBLIQUE IMPACT AND PERFORATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK///// NZONpcXYZ SPLT  DP3 UNIT
    8    0    1    2    0    0    0    1         004000    0    1    0
$MATL    0  DAM FAIL DFCT EFAL library materials
    1    0    1    0  1.0 999. $LIBRARY COPPER
    4    0    1    0  1.0 999. $LIBRARY ARMCO IRON
     $ BLANK FOR END OF MATERIALS
$ PROJECTILE NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0       0.0       0.4      -65.       0.0 0.0-.125
$ ROD NODES
$    2  NOR  NIR NPLN  RAD   AX CROS JOIN   N1 NTOP      ZTOP      ZBOT    EXPAND
    2    1    0   20    1    0    1    0    1    0      3.00      0.15       1.0
$     ROTOP     RITOP     ROBOT     RIBOT (for RAD=1)
     0.158       0.0     0.158       0.0
$ NOSE NODES
$    3 TYPE  NOR  NIR  RAD   AX CROS/////   N1/////      ZTOP      ZMIN
    3    2    1    0    1    0    1       332           0.15       0.0
$     ROTOP     RITOP (for RAD=1)
     0.158       0.0
     $ BLANK FOR END OF PROJECTILE NODES
$ TARGET NODES
$ X/RSCALE    YSCALE    ZSCALE  X/RSHIFT    ZSHIFT    ROTATE     SLANT X/RO   ZO
       1.0       1.0       1.0       0.0       0.0       0.0       0.0  0.0  0.0
$ FLAT PLATE NODES
$    4 TYPE NX/R   NY   NZ  FIX CROS JOIN   N1  INC    X/REXP      YEXP      ZEXP
    4    3   29    8    3    1    1    0  501    0       1.5       1.5       1.0
$NXND NYND XPRT YPRT        X1        Y1        Z1        XN        YN        ZN
    5    4 .233 .600      -3.0       0.0       0.0       3.0       1.5     -0.25
     $ BLANK FOR END OF TARGET NODES
$ PROJECTILE ELEMENTS
$ ROD ELEMENTS
$    2 MATL   N1 DIAG NOER NIER NLAY///// SHEL PLAC//////////     THICK
    2    1    1    5    1    1   19
$ NOSE ELEMENTS
$    3 MATL   N1 DIAG NOER NIER////////// SHEL///////////////     THICK
    3    1  332    5    1    1
     $ BLANK FOR END OF PROJECTILE ELEMENTS
$ TARGET ELEMENTS
$ FLAT PLATE ELEMENTS
$    4 MATL   N1 DIAG TYPE LX/R  NLY  NLZ SHEL PLAC//////////     THICK
    4    4  501    5    3   28    7    2
     $ BLANK FOR END OF TARGET ELEMENTS
$ SLIDE LINE 1 (TARGET MASTER, PROJECTILE SLAVE, ERODING)
$ NMG SEEK  NSG  NSN  NSR TYPE MBOT  ISR   IT/////   REF VEL     ERODE  FRICTION
    1    4    1    0    0    1 2603    0    1            75000.       1.5       0.0
$   1   M1      DIAG  NML  NMW  IDL  IDV
    1  506         5   17    4    1   57
$ S1G  SNG  INC
    1  348    1
$ SLIDE LINE 2 (PROJECTILE MASTER, TARGET SLAVE, ERODING)
$ NMG SEEK  NSG  NSN  NSR TYPE MBOT  ISR   IT/////   REF VEL     ERODE  FRICTION
    1    4    0    0    1    1    0    0    1            75000.       1.5       0.0
$    2   M1 CODE DIAG  NOR  NIR  NPL
```

Figure 32. Input Data for Example 4

```
    2  348   -1    5    1    0   20
$     XMAX      XMIN      YMAX      YMIN      ZMAX      ZMIN (SLAVE BOX)
       1.0      -1.0       0.2       0.0       0.0      -0.3
$ CHUNK CARDS
$ CE1  CEN
    1  960
$   X/RDET      YDET      ZDET     TBURN
       0.0       0.0       0.0       0.0
$  PX/RDOT   PY/TDOT     PZDOT   TX/RDOT   TY/TDOT     TZDOT       DT1 VFLD
    46029.       0.0   -21464.       0.0       0.0       0.0 0.0000001    0
$CYCL/////      TIME     DTMAX     DTMIN       SSF      TMAX     CPMAX      EMAX
    0            0.0       1.0.000000001       0.7   .000100       20.
$TPLT DROP///// PRES PUSH  HRG    VFRACT//////////      PMAX
    1
$ SYS NPLT LPLT DPLT     DTSYS      TSYS    DTNODE     TNODE     DTDYN      TDYN
    1    0    0    0  0.000002  0.000000
$     TIME    ECHECK    NCHECK     RDAMP SAVE BURN YPRT NDAT SLPR PROJ  PAT RZNE
   .000050      999.    75000.       0.0    1    0    1   10
  1.000100      999.    75000.       0.0    1    0    1   10
```

Figure 32. Input Data for Example 4 (Concluded)

SECTION III

DISTRIBUTION GUIDELINES

This EPIC Research code is distributed by WL/MNMW, Eglin Air Force Base, Florida 32542. In order to receive a copy of the software associated with this code, the following guidelines must be met:

1) The requester must demonstrate a requirement for the code. The types of calculations to be done and the facilities to be used should be identified.

2) The requester must sign an appropriate form which states that there will be no secondary distribution of the code.

3) All software obtained is to be used on a computer system with limited access, such that as a minimum, passwords and read permission are required to access the code.

4) Any problems or bugs found in the codes are to be reported to WL/MNMW.

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6) Publications referencing work done by this software, or its derivatives, must reference WL/MNMW as the major code sponsor and Alliant Techsystems as its major developer. The reference should identify the version of the code used and identify any enhancements made to the original software.

SECTION IV
CONCLUSIONS AND RECOMMENDATIONS

User instructions have been provided for the 1991 version of the EPIC Research code. This code can be used for a wide range of problems including high velocity impact and explosive-metal interaction.

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