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User Instructions for the Final Version of the EPIC Research Code

G.R. Johnson
R.A. Stryk
E.H. Peterson
T.J. Holmquist
J.A. Schonhardt
C.R. Burns

Alliant Techsystems Inc.
600 Second Street, N.E.
Hopkins, MN 55343

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This technical report has been reviewed and is approved for publication .

FOR THE COMMANDER

AARON D. BRINSON
Technical Director,
Munitions Division

William H. Cook
Program Manager

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G.R. Johnson
E.H. Peterson
J.A. Schonhardt
R.A. Stryk
T.J. Holmquist
C.R. Burns

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This report provides user instructions for the final version of the EPIC research code. It provides a background on the development of the EPIC codes, and also provides some key references. It includes a summary of new features in the final version of EPIC so the users of previous versions can decide if this version has new capabilities that will be helpful to them. Finally, the majority of the report provides user instructions and examples of how to use this explicit finite element transient analysis structural code.

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PREFACE

This report on the EPIC Research computer code was prepared by Alliant Techsystems Inc., 600 Second Street N.E., Hopkins, MN 55343, for the Armament Directorate, Wright Laboratory, Eglin Air Force Base, FL 32542, under Contract F08630-92-C-0006.

This effort was conducted during the period from October 1993 to September 1994. The authors would like to thank W.H. Cook, WL/MNMW program manager, for many helpful technical discussions. In addition, D.J. Grove of the Dayton Research Institute and A.M. Rajendran of the Army Research Laboratory provided assistance for the incorporation of the Bodner-Partom constitutive model and the RDG fracture model. Also, P.J. Maudlin of the Los Alamos National Laboratory provided the MTS constitutive model.

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INTRODUCTION

This report provides user instructions for the final version of the EPIC research code.

Section II provides a background of the development of the EPIC codes and also provides some of the key references. Section III summarizes the new features in the final version of EPIC so the users of previous versions can decide if this version has new capabilities that will be helpful to them.

Section IV provides user instructions and it represents the majority of this report.

SECTION II
BACKGROUND

Some of the earlier versions of EPIC-2 and EPIC-3 are documented in References 1–6. Additional references to various material models and computational algorithms are provided throughout the report. The 1991, 1992 and 1994 versions of the EPIC Research code are documented in References 7, 8 and 9.

This final version of the EPIC Research code is essentially identical to the 1995 version. Also, this DTIC report is essentially identical to an Alliant Techsystems report, "User Instructions for the 1995 Version of the EPIC Research Code."

SECTION III
NEW FEATURES IN FINAL VERSION

This section summarizes the new features that are available in the final version of the EPIC Research code. These features have been added to the 1994 version.

Materials

The following material-related features have been added.

- The Rajendran, Dietenberger, Grove (RDG) model for strength and fracture of metals.
- A Bodner-Partom model option for strength of solid materials.
- An MTS model option for strength of solid materials.
- Several new library materials.

Elements

Two new elements have been added.

- 2D shell elements with bending.
- 3D brick elements (8-node elements with constant stress).

Sliding Interfaces

The primary emphasis continues to be options to allow the sliding interfaces to be input in a more straightforward manner. The following sliding interface features have been added.

- A completely automatic sliding interface option for 2D problems involving impact. Requires minimal sliding input data from user. Not yet available for explosive detonation problems.

- A completely automatic sliding interface option for 3D impact problems, that is similar to the 2D option. Searching CPU time for this option can often be excessive, however, and this option may not be practical for most 3D problems.

- A 3D boundary option for symmetry planes that contain the Z axis.

Miscellaneous

The following miscellaneous features have been added.

- A heat conduction option for 1D Cartesian elements, 2D triangular elements, and 3D tetrahedral elements.

- Expanded capabilities for providing velocity boundary conditions on the nodes.

SECTION IV
USER INSTRUCTIONS

This section provides user instructions for the EPIC Research code, which consists of a Preprocessor, Main Routine, Postprocessor for state and time plots, and a 2D Rezoner. The formulation is not provided here; however, most of the basic equations are identical to those of the earlier versions (References 1, 2, 3 and 4). Additional references are included throughout the remainder of this report.

A description of input data for the EPIC Research code is given in Figures 1 through 31. In Figures 1 through 11, the page numbers of the descriptions in the text are included for each card.

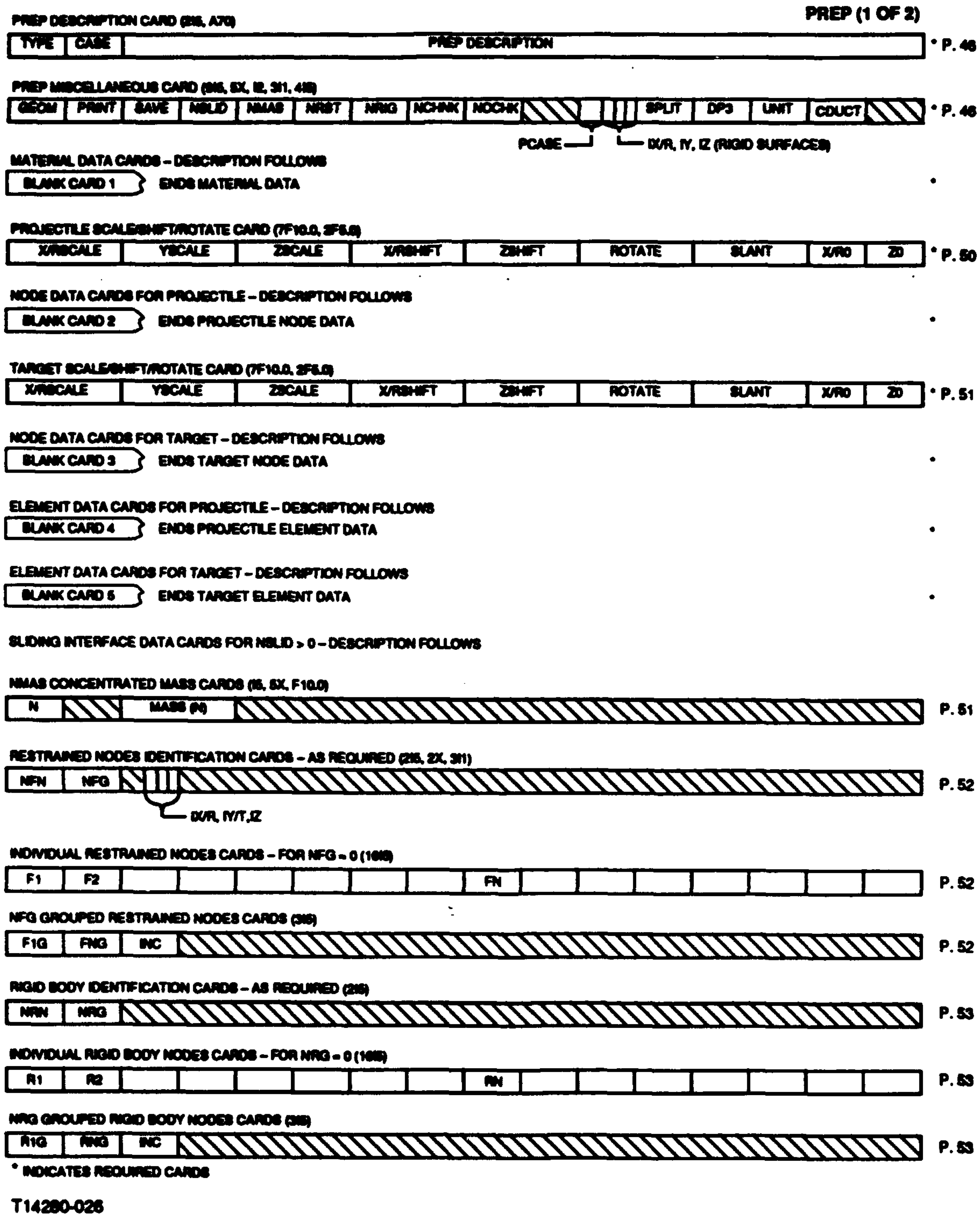

Figure 1. Preprocessor Input Data

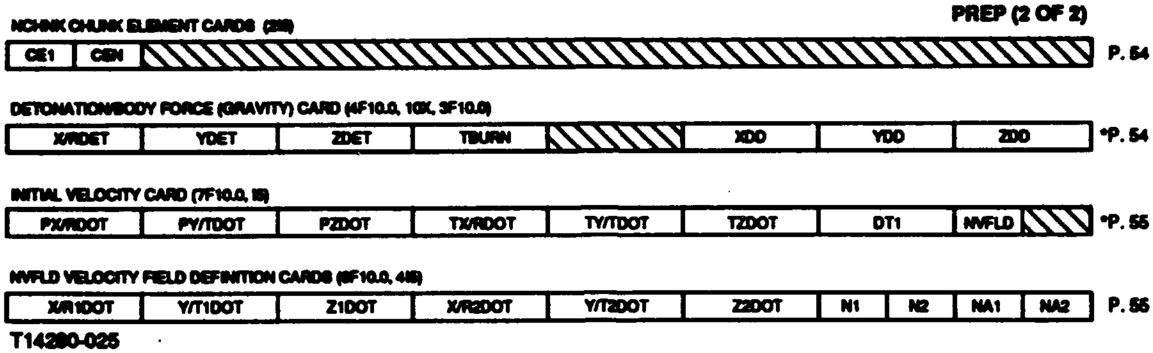

Figure 1. Preprocessor Input Data (Concluded)

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

MATL	0	DAM	FAIL	DFRAC	EFAIL		P. 56

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

MATL	1	DAM	FAIL		EFAIL	MATERIAL DESCRIPTION	P. 57

CARD 2 FOR SOLIDS (6F10.0, 3I5)

DENSITY	SPH HEAT	TEMP1	TROOM	TMELT	TZERO	MODEL	EOS	FRACT		P. 58

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

SHEAR MOD	C1	C2	N	C3	M	C4	SMAX	P. 59

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

SHEAR MOD	C1	C2	N	C3	M	C4	SMAX	P. 59

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

SHEAR MOD	C0	C2	C3	C4	N		P. 60

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

SHEAR MOD	C0	C1	C3	C4	C5	N		P. 60

CARD 3A FOR BODNER-PARTOM MODEL (MODEL = 5) (8F10.0)

SHEAR MOD	Z0	Z1	N0	N1	M0	M1	ALPHA	P. 60

CARD 3B FOR BODNER-PARTOM MODEL (MODEL = 5) (F10.0)

D0		P. 61

CARD 3A FOR MTS MODEL (MODEL = 6) (8F10.0)

SIGA	SIGI	SIGS	SIG0	HF0	HF1	HF2	SIGS0	P. 61

CARD 3B FOR MTS MODEL (MODEL = 6) (8F10.0)

EDOTS0	BURG	CAPA	BOLTZ	SM0	SM1	SM2	EDOT0	P. 63

CARD 3C FOR MTS MODEL (MODEL = 6) (8F10.0)

G0	PINV	QINV	EDOTI	G0I	PINVI	QINVI	EDOTS	P. 64

CARD 3D FOR MTS MODEL (MODEL = 6) (3F10.0)

G0S	PINVS	QINVS		P. 64

CARD 3 FOR USER STRENGTH MODEL (MODEL = 10) (8F10.0)

SHEAR MOD	C0	C1	C2	C3	C4	C5	C6	P. 64

CARD 4 FOR MIE-GRUNEISEN EOS (EOS = 1 OR 0) (8F10.0)

K1	K2	K3	Γ	PMIN	CL	CQ	CH	P. 65

CARD 4 FOR USER EOS MODEL (EOS = 10) (8F10.0)

C11	C12	C13	C14	C15	CL	CQ	CH	P. 66

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Figure 2. Material Input Data

CARD 5 FOR JOHNSON-COOK FRACTURE MODEL (FRACT = 1 OR 0) (8F10.0)

D1	D2	D3	D4	D5	SPALL	EFMIN	SOFT	P. 66

CARD 5 FOR USER FRACTURE MODEL (FRACT = 10) (8F10.0)

C21	C22	C23	C24	C25	C26	C27	SOFT	P. 66

CARD 6 FOR SOLIDS (2F10.0)

CONDUCT	ALPHA	—	P. 67

MATERIAL CARD FOR EXPLOSIVES FROM LIBRARY (2I5)

MATL	0	—	P. 67

DESCRIPTION CARD FOR EXPLOSIVES INPUT DATA (2I5, 20X, A80)

MATL	2	—	MATERIAL DESCRIPTION	P. 67

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

DENSITY	ENERGY	DET VEL	CL	CQ	CH	X1	JWL	—	P. 67

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

C1	C2	C3	C4	C5	—	P. 68

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

MATL	0	DAM	FAIL	DFRAC	EFAIL	—	P. 69

DESCRIPTION CARD FOR CRUSHABLE/CONCRETE SOLIDS INPUT DATA (6I5, F5.0, A80)

MATL	3	DAM	FAIL	MODEL	EFAIL	MATERIAL DESCRIPTION	P. 69

CARD 2 FOR MODEL = 1 OR 0 (6F10.0)

DENSITY	SPH HEAT	TEMP1	EPF	UPF	X1	—	P. 70

CARD 3 FOR MODEL = 1 OR 0 (8F10.0)

SHEAR MOD	C1	C4	SMAX	CL	CQ	CH	C3	P. 71

CARD 4 FOR MODEL = 1 OR 0 (8F10.0)

PCRUSH	UCRUSH	K1	K2	K3	KLOCK	ULOCK	PMIN	P. 72

CARD 5 FOR CRUSHABLE/CONCRETE SOLIDS (2F10.0)

CONDUCT	ALPHA	—	P. 72

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Figure 2. Material Input Data (Continued)

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

MATL	0		EFAIL		P. 72

DESCRIPTION CARD FOR LIQUIDS INPUT DATA (2I5, 15X, F5.0, A80)

MATL	4		EFAIL	MATERIAL DESCRIPTION	P. 72

CARD 2 FOR LIQUIDS (6F10.0)

DENSITY	SPH HEAT	TEMP1	VISCOSITY	CONDUCT	ALPHA		P. 73

CARD 3 FOR LIQUIDS (8F10.0)

K1	K2	K3	Γ	PMIN	CL	CQ	CH	P. 73

MATERIAL CARD FOR RDG MODEL SOLIDS FROM LIBRARY (3I5, 10X, F5.0)

MATL	0	DAM		EFAIL		P. 74

DESCRIPTION CARD FOR RDG MODEL SOLIDS INPUT DATA (3I5, 10X, F5.0, A80)

MATL	11	DAM		EFAIL	MATERIAL DESCRIPTION	P. 74

CARD 2 FOR RDG MODEL (6F10.0, I5)

DENSITY	SPH HEAT	TEMP1	TROOM	TMELT	TZERO	MODEL		P. 75

CARD 3A FOR JOHNSON-COOK STRENGTH MODEL (MODEL = 1) (8F10.0)

SHEAR MOD	C1	C2	N	C3	M	C4	SMAX	P. 75

CARD 3B FOR JOHNSON-COOK STRENGTH MODEL (MODEL = 1) (F10.0)

D0		P. 75

CARD 3A FOR BODNER-PARTOM STRENGTH MODEL (MODEL = 8) (8F10.0)

SHEAR MOD	Z0	Z1	N0	N1	M0	M1	ALPHA	P. 76

CARD 3B FOR BODNER-PARTOM STRENGTH MODEL (MODEL = 8) (2F10.0)

D0	C7		P. 76

CARD 4 FOR RDG EOS MODEL (8F10.0)

K1	K2	K3	Γ	PMIN	CL	CQ	CH	P. 76

CARD 5 FOR RDG MODEL (8F10.0)

FS	SIGMAM	SS	FE	EPSLNM	SE	FCRITS	FCRITC	P. 77

CARD 6 FOR RDG MODEL (3F10.0)

YFBETA	YFN	CONDUCT		P. 78

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Figure 2. Material Input Data (Continued)

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

MATL	10	DAM	FAIL		EFAIL	MATERIAL DESCRIPTION	P. 79

CARD 2 FOR USER MODEL INPUT DATA (8F10.0)

DENSITY	SPH HEAT	TEMP1	TROOM	SHEAR MOD	CL	CQ	CH	P. 79

CARD 3 FOR USER MODEL INPUT DATA (8F10.0)

C0	C1	C2	C3	C4	C5	C6	C7	P. 80

CARD 4 FOR USER MODEL INPUT DATA (8F10.0)

C9	C10	C11	C12	C13	C14	C15	C16	P. 80

CARD 5 FOR USER MODEL INPUT DATA (8F10.0)

C17	C18	C19	C20	C21	C22	C23	C24	P. 80

CARD 6 FOR USER MODEL INPUT DATA (8F10.0)

C25	C26	C27	C28	C29	C30	CONDUCT	ALPHA	P. 80

T14280-027a

Figure 2. Material Input Data (Concluded)

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

1	NNODE	IX/R, IY/T, IZ		N1	INC	EXPAND	

P. 81

LINE OF NODES COORDINATE CARD (6F 10.0)

X/R1	Y1	Z1	X/RN	YN	ZN	

P. 82

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

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

P. 82

FULL ROD POSITION CARD FOR RAD >10 (2F10.0)

XCG	YCG	

P. 85

ROD NODE RADII CARD FOR RAD = 1 OR 11 (4F10.0)

ROTOP	RITOP	ROBOT	RIBOT	

P. 85

ROD NODE TOP RADII CARDS FOR RAD = 2 OR 12 (8F10.0)

RT(NIR)					RT(NOR)		

P. 86

ROD NODE BOTTOM RADII CARDS FOR RAD = 2 OR 12 (8F10.0)

RB(NIR)					RB(NOR)		

P. 86

ROD NODE TOP SURFACE CARD FOR RAD = 3 OR 13 AND AX = 3 (2I5, 7F10.0)

TYPE	CLOCK	RTO	ZTO	RT1	ZT1	RTN	ZTN	TT

P. 86

ROD NODE BOTTOM SURFACE CARD FOR RAD = 3 OR 13 AND AX = 3 (2I5, 7F10.0)

TYPE	CLOCK	RBO	ZBO	RB1	ZB1	RBN	ZBN	TB

P. 87

ROD NODE TOP SURFACE CARD FOR AX = 1 (8F10.0)

A0	A1	A2	A3	A4	A5	A6	A7

P. 88

ROD NODE BOTTOM SURFACE CARD FOR AX = 1 (8F10.0)

B0	B1	B2	B3	B4	B5	B6	B7

P. 88

ROD NODE TOP SURFACE CARDS FOR AX = 2 (8F10.0)

ZT(NIR)				ZT(NOR)			

P. 88

ROD NODE BOTTOM SURFACE CARDS FOR AX = 2 (8F10.0)

ZB(NIR)				ZB(NOR)			

P. 88

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

NOSE NODE DESCRIPTION CARD (7I5, 5X, I5, 5X, 2F10.0)

3	TYPE	NOR	NIR	RAD	AX	CROS		N1		ZTOP	ZMIN	

P. 88

FULL NOSE POSITION CARD FOR RAD >10 (2F10.0)

XCG	YCG	

P. 90

NOSE NODE TOP RADII CARD FOR RAD = 1 OR 11 (2F10.0)

ROTOP	RITOP	

P. 90

NOSE NODE TOP RADII CARDS FOR RAD = 2 OR 12 (8F10.0)

RT(NIR)				RT(NOR)			

P. 90

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

NOSE NODE ZMIN CARDS FOR AX = 2 (8F10.0)

ZMIN(NIR)				ZMIN(NOR)			

P. 91

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

Figure 3. Node Input Data

FLAT PLATE DESCRIPTION CARD (10I5, 3F10.0)

4	TYPE	NX/R	NY	NZ	FIX	CROS	JOIN	N1	INC	X/R-EXPAND	Y-EXPAND	Z-EXPAND	P. 91

2D FLAT PLATE CARD FOR TYPE = 1 (2I5, 2F5.0, 4F10.0)

NREND	NZEND	RPART	ZPART	RMAX	RMIN	ZMAX	ZMIN		P. 94

3D CIRCULAR FLAT PLATE CARD FOR TYPE = 2 (2I5, 2F5.0, I5, 5X, 3F10.0)

NREND	NZEND	RPART	ZPART	FULL		RADIUS	ZMAX	ZMIN		P. 94

FULL CIRCULAR PLATE CARD FOR FULL = 1 (2F10.0)

XCG	YCG		P. 95

3D RECTANGULAR FLAT PLATE CARD FOR TYPE = 3 (2I5, 2F5.0, 6F10.0)

NXEND	NYEND	XPART	YPART	X1	Y1	Z1	XN	YN	ZN	P. 96

3D RECTANGULAR FLAT PLATE CARD FOR TYPE = 4 (2I5, 2F5.0, 6F10.0)

NXEND	NZEND	XPART	ZPART	X1	Y1	Z1	XN	YN	ZN	P. 97

SPHERE NODE DESCRIPTION CARD (3I5, 5X, I5, 5X, I5, 5X, I5, 5X, 3F10.0)

5	NOR	NIR		RAD		CROS		N1		R0	R I	ZCG	P. 98

FULL SPHERE POSITION CARD FOR RAD ≥10 (2F10.0)

XCG	YCG		P. 99

SPHERE NODE RADII CARDS FOR RAD = 2 OR 12 (8F10.0)

R(NIR)				R(NOR)				P. 99

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

PATRAN NODE CARD (3I5)

888	N1	NN		P. 99

NODE SCALE/SHIFT/ROTATE IDENTIFICATION CARD (I5)

999		P. 100

NEW SCALE/SHIFT/ROTATE CARD (7F10.0, 2F5.0)

X/RSCALE	YSCALE	ZSCALE	X/RSHIFT	ZSHIFT	ROTATE	SLANT	X/R0	Z0	P. 100

T14280-029

Figure 3. Node Input Data (Concluded)

SERIES OF INDIVIDUAL AND COMPOSITE ELEMENTS CARD (14I5, F10.0)

1	MATL	NCOMP	N1	N2	N3	N4	N5	N6	N7	N8	INC	SHELL	BRICK	T/A	P. 102

THICKNESS CARD FOR 2D SHELL ELEMENTS – FOR SHELL = 1, 3, 5 AND T/A = 0 (8F10.0)

T(1)					T(NCOMP+1)			P. 105

AREA CARD FOR 3D BAR ELEMENTS – FOR SHELL = 1 AND T/A = 0 (8F10.0)

A(1)					A(NCOMP)			P. 105

THICKNESS CARD FOR 3D SHELL ELEMENTS – FOR SHELL = 1 AND T/A = 0 (8F10.0)

T(1)					T(NCOMP)			P. 105

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

1	MATL	NCOMP		P. 106

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. 106

ROD (DISK) ELEMENT CARD (11I5, 1X, 4I1, 2F10.0)

2	MATL	N1	DIAG	NOER	NIER	NLAY	FULL	SHELL	PLACE	AZONE		THICK	RELAX	P. 106

S1, S2, S3, S4

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

T(NIER)					T(NOER)			P. 109

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

T(1)					T(NLAY)			P. 109

ROD MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 109

NOSE ELEMENT CARD (6I5, 5X, 2I5, 15X, F10.0)

3	MATL	N1	DIAG	NOER	NIER		FULL	SHELL		THICK		P. 109

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

T(1)					T(2-NOER)			P. 110

NOSE MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 111

FLAT PLATE ELEMENT CARD (11I5, 1X, 4I1, 2F10.0)

4	MATL	N1	DIAG	TYPE	NLX/R	NLY	NLZ	SHELL	PLACE	AZONE		THICK	RELAX	P. 111

S1, S2, S3, S4

SPHERE ELEMENT CARD (6I5, 5X, 2I5, 15X, F10.0)

5	MATL	N1	DIAG	NOER	NIER		FULL	SHELL		THICK		P. 114

SPHERE MATERIAL CARD FOR MATL = 0 (16I5)

M(NIER)								M(NOER)								P. 115

PATRAN ELEMENT CARD (4I5, 50X, F10.0)

888	PL1	PLN	SHELL		T/A	P. 115

CHUNK DEFINITION CARD (3I5)

999	START	STOP		P. 117

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Figure 4. Element Input Data

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

M1	S1		P. 118

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. 118

NMG GROUPED MASTER NODE CARDS (3I5)

M1G	MNG	INC		P. 122

MASTER DEFINITION CARD FOR 2D REGION (2I5, 4F10.0, 10X, I5)

6	RSYM	RMAX	RMIN	ZMAX	ZMIN		6		P. 122

MASTER DEFINITION CARD FOR 2D PROJECTILE ONLY (2I5, 4F10.0, 10X, I5)

7	RSYM	RMAX	RMIN	ZMAX	ZMIN		7		P. 123

MASTER DEFINITION CARD FOR 2D TARGET ONLY (2I5, 4F10.0, 10X, I5)

8	RSYM	RMAX	RMIN	ZMAX	ZMIN		8		P. 123

MASTER DEFINITION CARD FOR 2D NODE/ELEMENT/MATERIAL (2I5,5I10, I5)

9	RSYM	MAX NODE	MIN NODE	MAX ELE	MIN ELE	MATL	9		P. 124

MASTER DEFINITION CARD FOR 2D CHUNKS (3I5, 45X, I5)

10	RSYM	CHUNK		10		P. 124

MASTER DEFINITION CARD FOR 2D AUTOMATIC SLIDING (I5, 5X, 4F10.0, 10X, I5)

99		RMAX	RMIN	ZMAX	ZMIN		99		P. 125

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

M1	M2							MN								P. 125

NSG GROUPED/CHUNK 2D SLAVE NODE CARDS (3I5, 5X, 2I5)

S1G	SNG	INC		CHUNK	SURF		P.126

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

S1	S2							SN								P. 127

NSR SLAVE NODE LIMITS CARDS (4F10.0, I5)

RMAX	RMIN	ZMAX	ZMIN	SURF		P. 127

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Figure 5. Sliding Interface Input Data

SLIDE (2 OF 2)

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

NMG	SEEK	NSG	NSN	NSR	TYPE	MSOT	ISR	IT		REF VEL	ERODE	FRICTION	P. 127

ALTERNATE IDENTIFICATION CARD FOR PLANE OF SYMMETRY (25X, I5, 20X, 2F10.0)

	TYPE		THETA	DEL-THETA		P. 131

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

1	M1		DIAG	NML	NMW	IDL	IDW		P. 132

MASTER DEFINITION CARD FOR ROD-NOSE GEOMETRY (8I5)

2	M1	MCODE	DIAG	NOR	NIR	NPL	FULL		P. 133

MASTER DEFINITION CARD FOR CIRCULAR PLATE (DISK) GEOMETRY (5I5, 10X, I5)

3	M1	MCODE	DIAG	NRING		FULL		P. 134

MASTER DEFINITION CARD FOR CYLINDER (ROD) GEOMETRY (8I5)

4	M1	MCODE	DIAG	NOR	NIR	NPL	FULL		P. 135

MASTER DEFINITION CARD FOR GENERAL GEOMETRY (8I5)

5	NCOMP	INC	M1	M2	M3	M4	M5		P. 136

MASTER DEFINITION CARD FOR 3D REGION (2I5, 6F10.0)

6	YSYM	XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN		P. 137

MASTER DEFINITION CARD FOR 3D PROJECTILE ONLY (2I5, 6F10.0)

7	YSYM	XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN		P. 1[illegible]

MASTER DEFINITION CARD FOR 3D TARGET ONLY (2I5, 6F10.0)

8	YSYM	XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN		P. 138

MASTER DEFINITION CARD FOR 3D NODE/ELEMENT/MATERIAL (2I5, 5I10)

9	YSYM	MAX NODE	MIN NODE	MAX ELE	MIN ELE	MATL		P. 139

MASTER DEFINITION CARD FOR 3D CHUNKS (3I5)

10	YSYM	CHUNK		P. 139

MASTER DEFINITION CARD FOR 3D AUTOMATIC SLIDING (I5, 5X, 6F10.0)

99		XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN		P. 140

MASTER DEFINITION CARD FOR PATRAN GEOMETRY (3I5)

999	PL1	PLN		P. 141

NSG GROUPED/CHUNK 3D SLAVE NODE CARDS (3I5, 5X, 2I5)

S1G	SNG	INC		CHUNK	SURF		P. 141

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

S1	S2							SN								P. 142

NSR SLAVE NODE LIMITS CARDS (6F10.0, I5)

XMAX	XMIN	YMAX	YMIN	ZMAX	ZMIN	SURF		P. 142

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Figure 5. Sliding Interface Input Data (Concluded)

RESTART DESCRIPTION CARD (2I5, A70)

TYPE	CASE	MAIN DESCRIPTION

*P. 143

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

CYCLE		TIME	DTMAX	DTMIN	SSF	TMAX	CPMAX	EMAX

*P. 144

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

TPLOT	DROP		PRES	PUSH	HRG	VFRACT	

*P. 145

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

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

P. 146

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

N1	N2							NN							

P. 148

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

E1	E2							EN							

P. 148

DROP CARD FOR DROP = 1 (F10.0, I5, 5X, 4I5, 10X, 2I5, 2X, 3I1, I5)

TDROP	NNODE		NELE	NSLID	NRIG	NCHNK		NPLOT	LPLOT		IX/R, IY, IZ	NFAIL	

P. 148

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

EF1	EF2							EFN							

P. 149

PRESSURE CARDS FOR PRES ≥ 1 – AS REQUIRED (6I5, F10.0)

N1	N2	N3	N4	NSURF	NODINC	PRESSURE	

P. 150

BLANK CARD — ENDS PRESSURE CARDS FOR PRES ≥ 1

TIME – PRESSURE CARDS FOR PRES ≥ 1 – AS REQUIRED (2F10.0)

PTIME	P(T)	

P. 151

BLANK CARD — ENDS TIME – PRESSURE CARDS FOR PRES ≥ 1

VELOCITY CARDS FOR PUSH ≥ 1 – AS REQUIRED (4I5, 3F10.0)

N1	NN	INC	TYPE	X/RDOT	Y/TDOT	ZDOT	

P. 151

BLANK CARD — ENDS VELOCITY CARDS FOR PUSH ≥ 1

TIME – VELOCITY CARDS FOR PUSH ≥ 1 – AS REQUIRED (5F10.0)

VTIME	V(T)	VX/R(T)	VY/T(T)	VZ(T)	

P. 152

BLANK CARD — ENDS TIME – VELOCITY CARDS FOR PUSH ≥ 1

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

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

*P. 153

BLANK CARD — ENDS MAIN ROUTINE

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Figure 6. Main Routine Input Data

STATE PLOTS HEADER CARD (3I5, 35X, A30)

CASE	DVICE	COLOR		TITLE	* P. 157

PATRAN FILE READ CARD (2I5, 40X, A30)

TYPE	GEOM		TITLE	P. 158

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

1	CYCLE	TIME	AXES	VIEW	ORIENT	SIDE	EDGE	FAIL	NODE	PRINT		TITLE	P. 158

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

X/RMAX	YMAX	ZMAX	X/RMIN	YMIN	ZMIN	E1	EN	M		P. 162

3D PERSPECTIVE CARD FOR VIEW = 4 OR 8 (6F10.0, I5)

XEYE	YEYE	ZEYE	XPLANE	YPLANE	ZPLANE	HIDE		P. 162

GEOMETRY COLOR CARD — FOR COLOR = 1 (4I5)

PLINE	TLINE	NMAT	SIDEM		P. 163

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

M1	M2							MN								P. 163

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

C1	C2							CN								P. 164

EXTRAPOLATED GEOMETRY PLOT CARD FOR 2D AND 3D (2I5, F10.0, 8I2, 4X, F10.0, A30)

2	CYCLE	TIME										T-EXTRAP	TITLE	P. 164

(Fields 4–11: SAME AS GEOMETRY PLOT CARD SHOWN ABOVE)

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

X/RMAX	YMAX	ZMAX	X/RMIN	YMIN	ZMIN	E1	EN	M		P. 167

VELOCITY VECTOR PLOT CARD FOR 2D AND 3D (2I5, F10.0, 6I2, 8X, F10.0, A30)

3	CYCLE	TIME	AXES	VIEW	ORIENT	SIDE	EDGE	ARROW		VSCALE	TITLE	P. 168

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

X/RMAX	YMAX	ZMAX	X/RMIN	YMIN	ZMIN	N1	NN		P. 171

3D PERSPECTIVE CARD FOR VIEW = 4 (6F10.0, 2I5)

XEYE	YEYE	ZEYE	XPLANE	YPLANE	ZPLANE	N1	NN		P. 171

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Figure 7. Postprocessor Input Data for State Plots

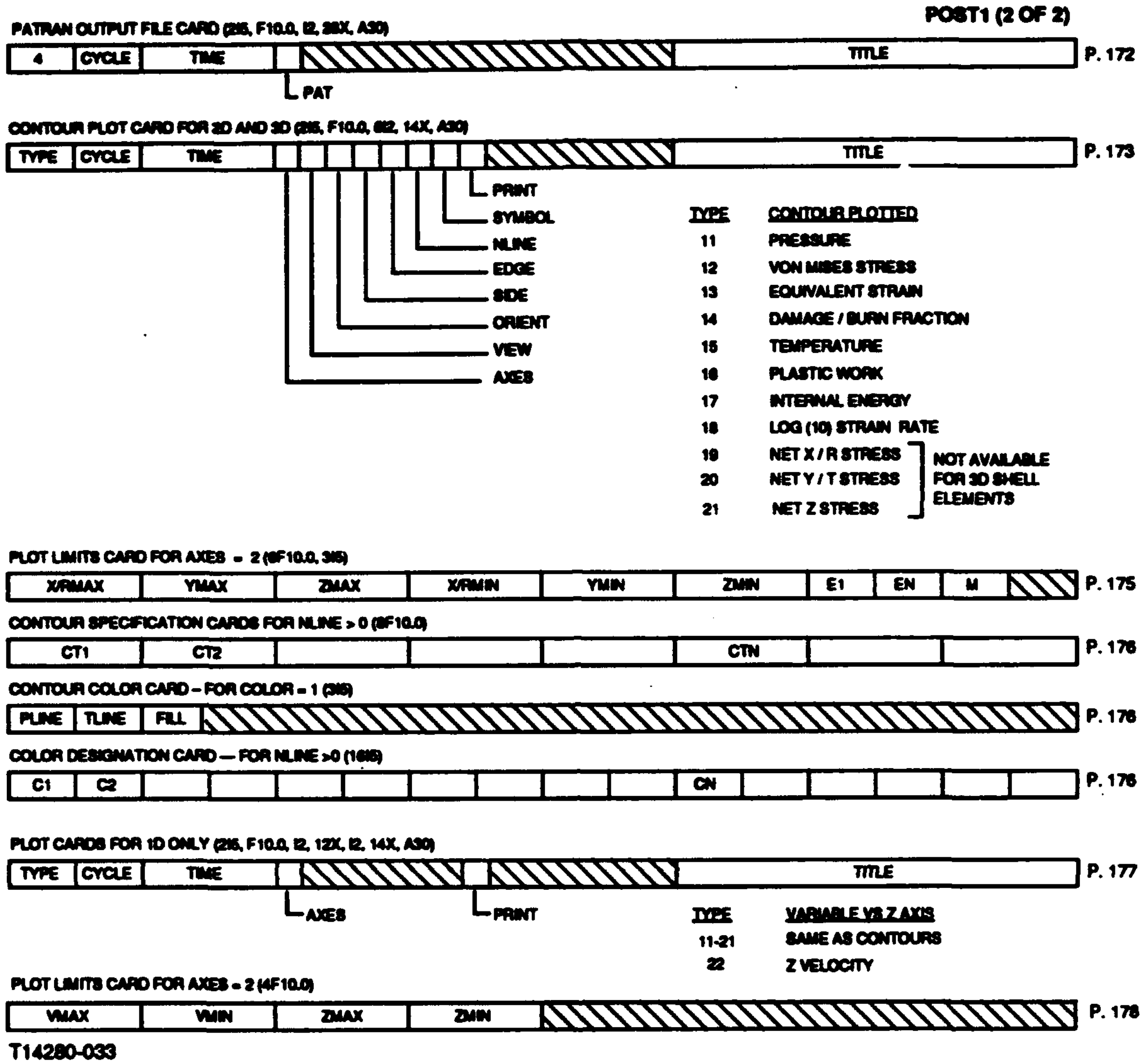

Figure 7. Postprocessor Input Data for State Plots (Concluded)

TIME PLOTS HEADER CARD (2I5, 10X, F10.0, 30X, A20)

CASE	DVICE		T-FILTER		TITLE	* P. 178

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

TYPE	AXES	CODE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE	P. 179

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

TYPE	AXES	NODE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE	P. 180

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

TYPE	AXES	ELE	SCALE	TMAX	TMIN	VMAX	VMIN	TITLE	P. 181

INDIVIDUAL ELEMENT CROSS PLOT CARDS – AS REQUIRED (1X, 2I2, 2I5, F5.0, 4F10.0, A20)

	TV	TH	AXES	ELE	SCALE	TH-MAX	TH-MIN	TV-MAX	TV-MIN	TITLE	P. 182

PATRAN FILE GENERATION CARDS – AS REQUIRED (I5, 5X, I5, 45X, A20)

NTYPE		MISC		TITLE	P. 183

FILE MANIPULATION CARDS – AS REQUIRED (I5, 5X, I5)

TYPE		NODE		P. 183

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		
28–30	XYZ / RTZ ACCELERATIONS		
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		
51–53	XYZ / RTZ FORCES		
54	NODAL TEMPERATURE FOR HEAT CONDUCTION ONLY		
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 INITIAL VOLUME		
68	LOG (10) STRAIN RATE		
69–71 **	XYZ / RTZ NORMAL STRESSES		
72–74 **	SHEAR STRESSES: X-Y / R-T (72), X-Z / R-Z (73), Z-Y / Z-T (74)		
75	RATIO: MEAN STRESS/VON MISES STRESS		
76	VOLUMETRIC STRAIN		
111	READ BINARY FILE AND WRITE ASCII FILE		FILE MANIPULATION
222	READ ASCII FILE AND WRITE BINARY FILE		
333	READ XYZ/RTZ VELOCITIES AND WRITE INPUT FILE		

** NOT AVAILABLE FOR BAR AND/OR SHELL ELEMENTS

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Figure 8. Postprocessor Input Data for Time Plots

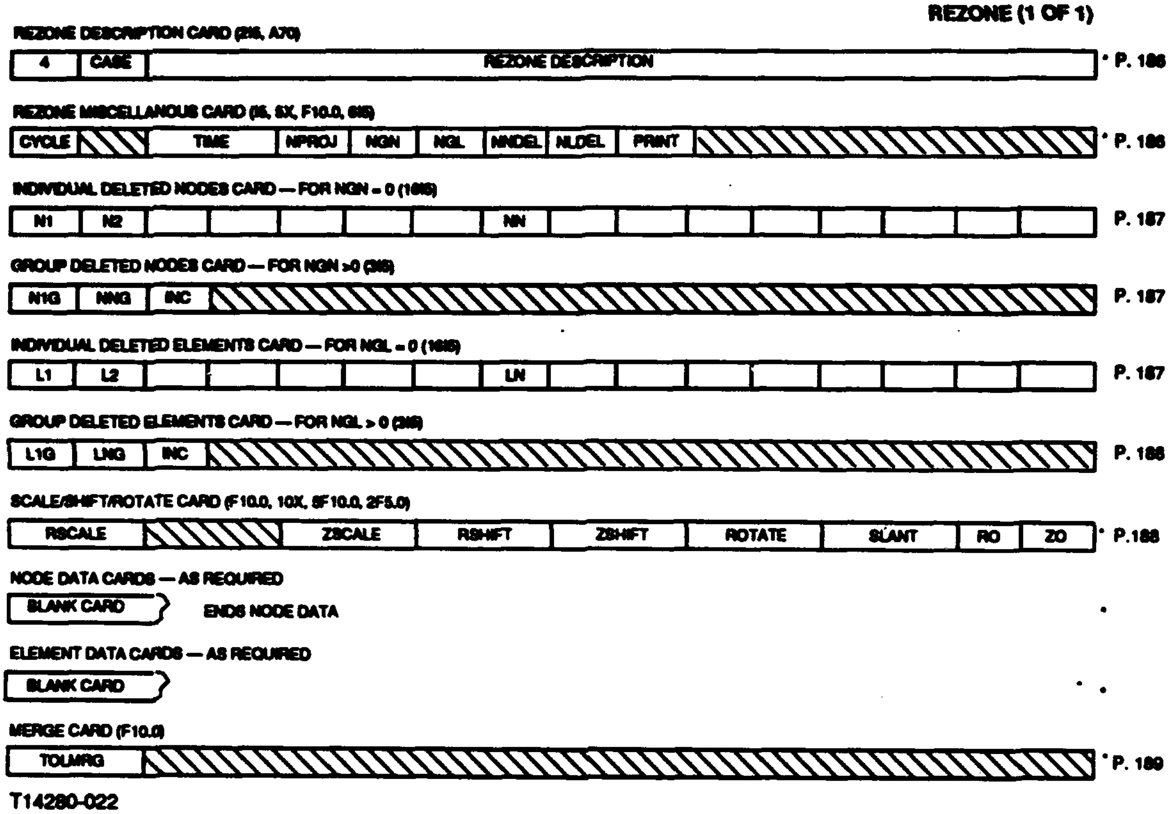

Figure 9. 2D Rezone Input Data

FOUR-SIDED SHAPE NODE CARD (5I5, 25X, F10.0)

8	N1	NC	NL	IRFIX		RELAX		P. 189

CORNER NODE DEFINITION CARDS — 4 REQUIRED (2I5, 2F10.0)

NOLD	NGEN	RCNR	ZCNR		P. 190

SIDE OPTIONS CARD (4I5)

IS1	IS2	IS3	IS4		P. 191

SIDE NODE COORDINATE CARDS — AS REQUIRED (8F10.0)

R1	R2			RN				P. 192
Z1	Z2			ZN				

OLD SIDE NODES CARD(S) — AS REQUIRED (16I5)

NO1	NO2					NON										P.192

GENERATED SIDE NODES CARDS(S) — AS REQUIRED (16I5)

NG1	NG2					NGN										P. 192

THREE-SIDED SHAPE NODE CARD (3I5, 5X, I5, 25X, F10.0)

9	N1	NRING		IRFIX		RELAX		P. 192

CORNER NODE DEFINITION CARDS — REQUIRED (2I5, 2F10.0)

NOLD	NGEN	RCNR	ZCNR		P. 193

SIDE OPTIONS CARD (3I5)

IS1	IS2	IS3		P. 193

SIDE NODE COORDINATE CARDS — AS REQUIRED (SEE ABOVE)

OLD SIDE NODE COORDINATE CARDS — AS REQUIRED (SEE ABOVE)

GENERATED SIDE COORDINATE NODES CARDS — AS REQUIRED (SEE ABOVE)

REGRID LINE OF NODES CARD (4I5, 2X, 3I1, I5)

10	N1	NN	INC		IR	IT	IZ	IS1		P. 195

IR, IT, IZ

CORNER CODE DEFINITION CARDS (SEE ABOVE)

SIDE NODE COORDINATE CARDS — AS REQUIRED (SEE ABOVE)

OLD SIDE NODES CARDS — AS REQUIRED (SEE ABOVE)

GENERATED SIDE NODES CARDS — AS REQUIRED (SEE ABOVE)

T14280-021

Figure 10. Additional Node Input Data for Rezoning

FOUR-SIDED SHAPE ELEMENT DESCRIPTION CARD (5I5)

8	MATL	N1	NCOL	NLAY		P. 197

THREE-SIDED SHAPE ELEMENT DESCRIPTION CARD (4I5)

9	MATL	N1	NCOL		P. 198

TRANSITION ELEMENT DESCRIPTION CARD (16I5)

10	MATL	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	P. 198

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Figure 11. Additional Element Input Data for Rezoning

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)	(MODIFIED HULL MODEL)
23	6061-T6 ALUMINUM	RB-58
33	OFHC COPPER	(BODNER-PARTOM MODEL)
34	ARMCO IRON	(BODNER-PARTOM MODEL)
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
89	OFHC COPPER	(MTS MODEL)
92	OFHC COPPER	(RDG MODEL WITH BP STRENGTH)
93	OFHC COPPER	(RDG MODEL WITH JC STRENGTH)
94	ARMCO IRON	(RDG MODEL WITH BP STRENGTH)
95	ARMCO IRON	(RDG MODEL WITH JC STRENGTH)

Figure 12. Materials in the EPIC Research 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	.686	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	2.776
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	.063	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

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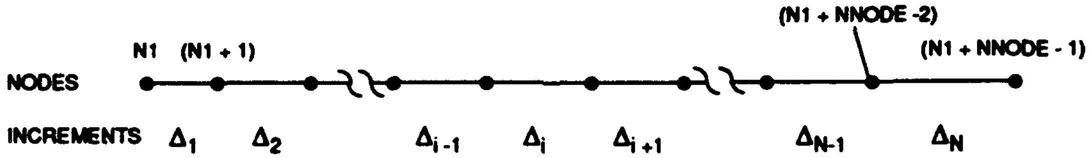

$$\bar{\Delta} = \frac{\text{TOTAL LENGTH}}{\text{NUMBER INCREMENTS}} = \frac{L}{N} \qquad \Delta_{i+1} = \Delta_i \cdot \text{EXPAND}$$

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

T14280-01

Figure 13. Nodal Spacing for Various Expansion Factors

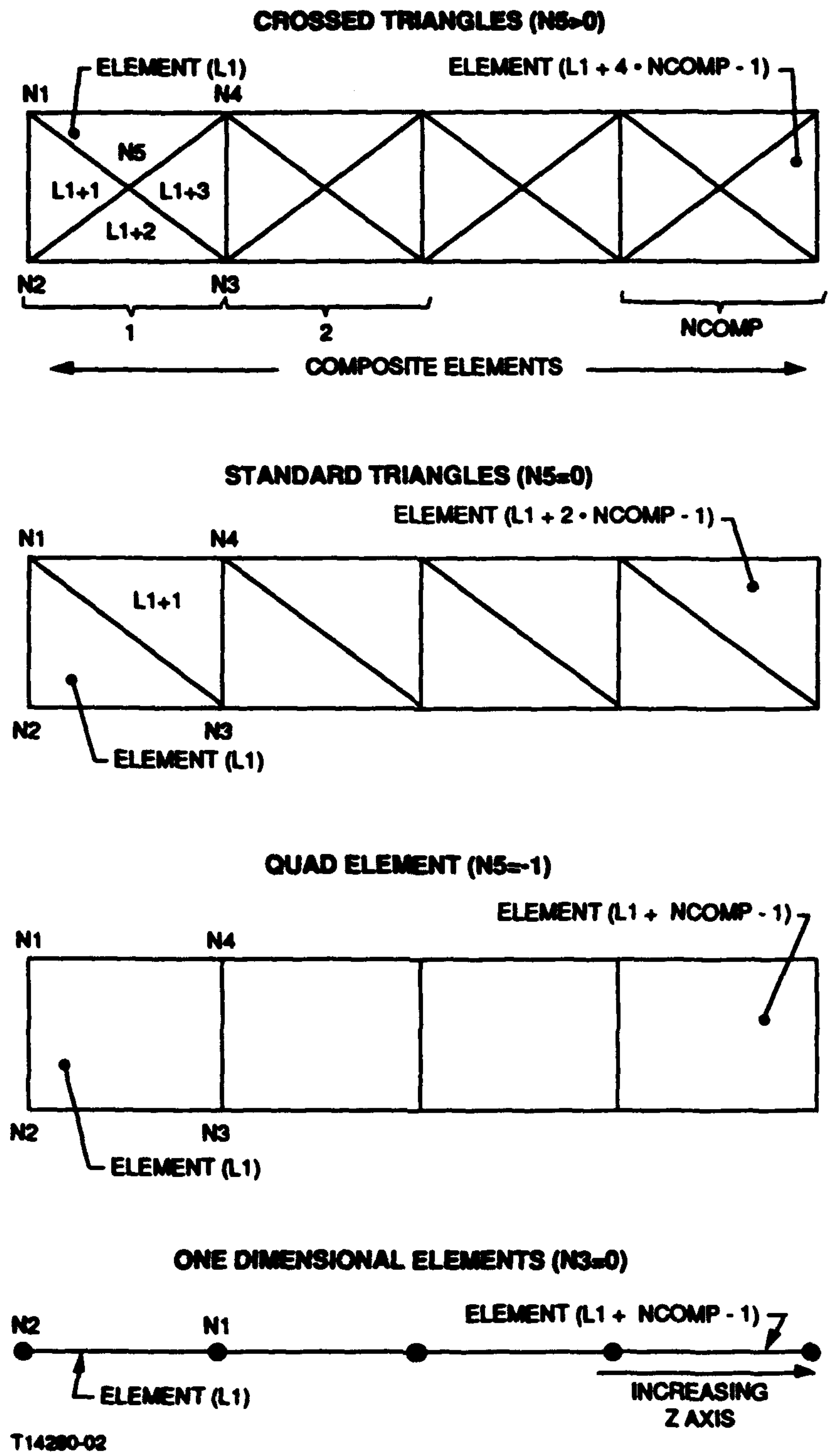

Figure 14. 2D Composite Element Geometry

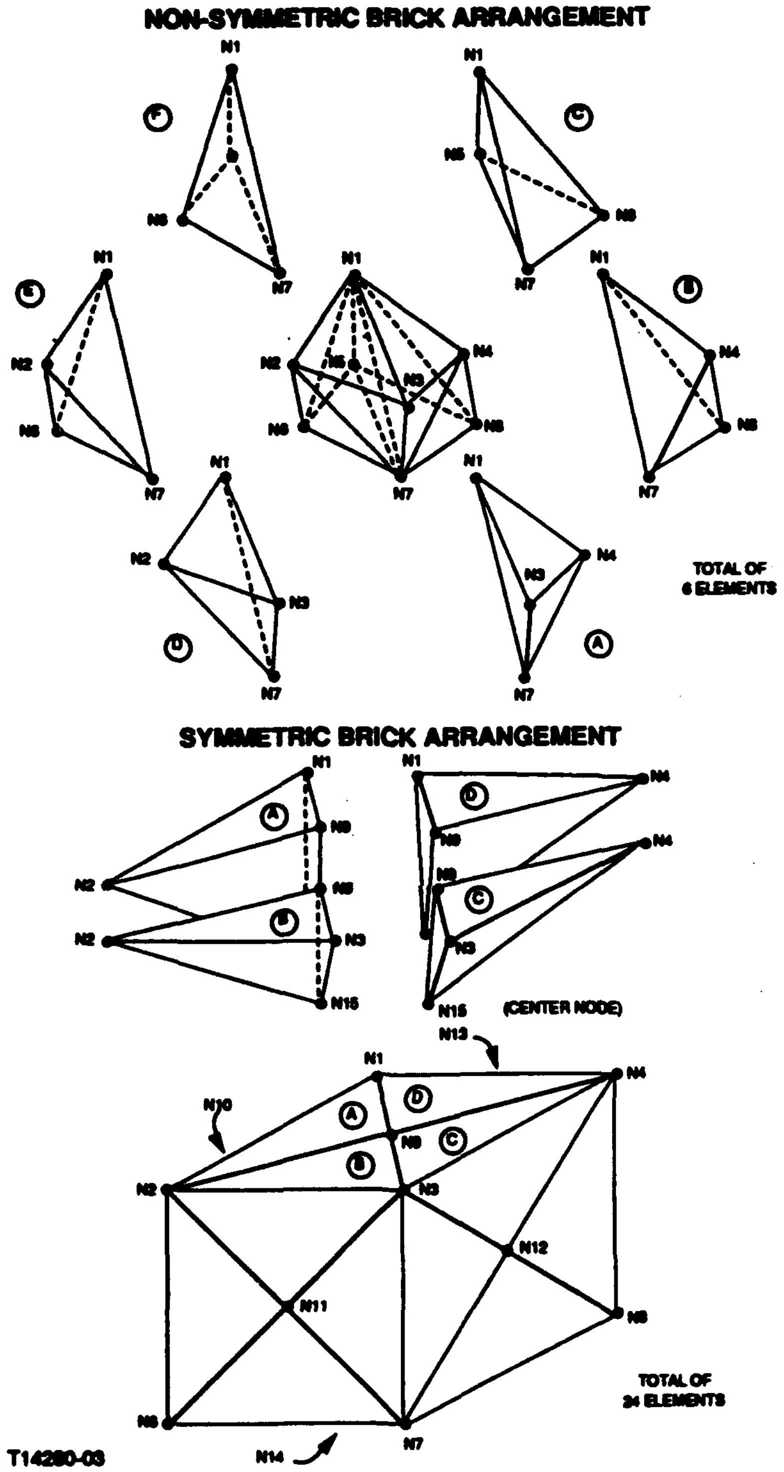

Figure 15. 3D Composite Element Geometry

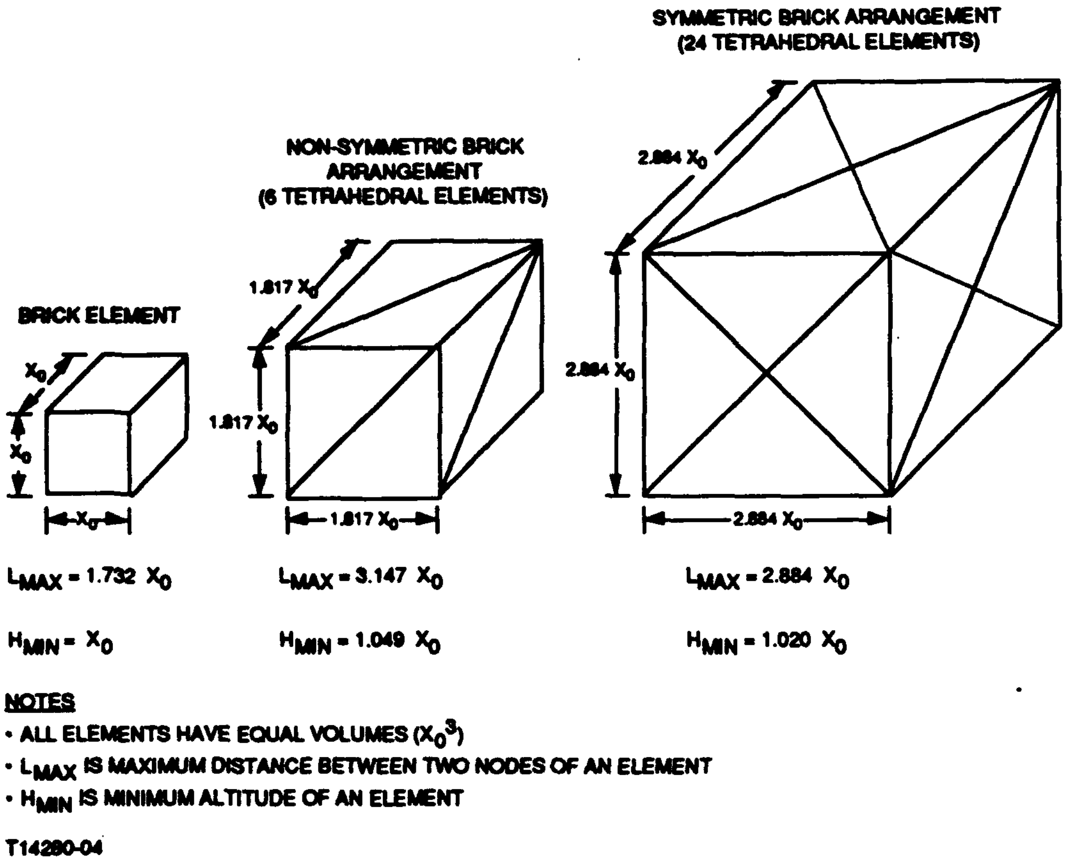

Figure 16. 3D Element Arrangements

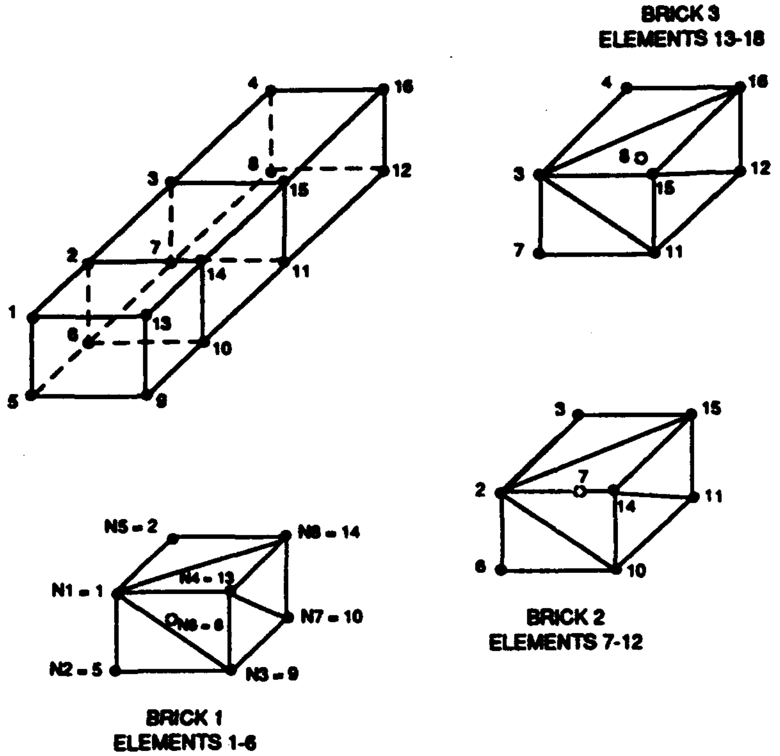

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Figure 17. 3D Node/Element Input Data Example

GEOMETRY	NODES								SHELL	BRICK	DESCRIPTION
	N1	N2	N3	N4	N5	N6	N7	N8			
1D	N1	N2	0	0	0	0	0	0	0	0	1D ELEMENT
	N1	0	0	0	0	0	0	0	2	0	NON-REFLECT
2D	N1	N2	0	0	0	0	0	0	1	0	SHELL/BAR (MEMBRANE)
	N1	N2	0	0	0	0	0	0	3	0	SHELL/BAR (BENDING)
	N1	N2	0	0	0	0	0	0	5	0	SHELL/BAR (BENDING)
	N1	N2	N3	0	0	0	0	0	0	0	1 TRI ELE
	N1	N2	N3	N4	0	0	0	0	0	0	2 TRI ELE
	N1	N2	N3	N4	N5	0	0	0	0	0	4 TRI ELE
	N1	N2	N3	N4	–1	0	0	0	0	0	1 QUAD ELE
	N1	N2	0	0	0	0	0	0	2	0	NON-REFLECT
3D	N1	N2	0	0	0	0	0	0	1	0	BAR
	N1	N2	N3	0	0	0	0	0	1	0	1 TRI SHELL ELE
	N1	N2	N3	N4	0	0	0	0	1	0	2 TRI SHELL ELE
	N1	N2	N3	N4	N5	0	0	0	1	0	4 TRI SHELL ELE
	N1	N2	N3	N4	0	0	0	0	0	0	1 TET ELE
	N1	N2	N3	0	N5	N6	N7	0	0	0	3 TET ELE
	N1	0	N3	N4	N5	0	N7	N8	0	0	3 TET ELE
	N1	N2	N3	N4	N5	N6	N7	N8	0	0	6 TET ELE
	N1	N2	N3	N4	N5	N6	N7	N8	0	1	1 BRICK ELE
	N1	N2	N3	0	0	0	0	0	2	0	1 NON-REFLECT TR
	N1	N2	N3	N4	0	0	0	0	2	0	2 NON-REFLECT TR
	N1	N2	N3	N4	N5	0	0	0	2	0	4 NON-REFLECT TR

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Figure 18. Summary of Individual and Composite Element Options

Dimension	Element/Node Type	Geometry (GEOM)							
		1	2	3	4	5	6	7	8
		1D Cartesian	1D Cylindrical	1D Spherical	2D Plane Stress	2D Plane Strain	2D Axisymmetric	2D Axisymmetric with Spin	3D
1D	1D Element	All*	All	All					
	Non-Reflective	Not 2	Not 2	Not 2					
2D	Shell/Bar (Membrane)					1	1	1	
	Shell/Bar (Bending)					1			
	Triangular				1	All*	All*	All*	
	Quad				1	All	All		
	Non-Reflective				1	Not 2	Not 2	Not 2	
3D	Bar								1
	Shell (Membrane)								1
	Tetrahedral								All*
	Brick								All
	Non-Reflective								Not 2

Notes:
- * indicates heat conduction available for all materials except explosives (MTYPE = 2)
- All indicates all material types are available
- 1 indicates only solid material type is available (MTYPE = 1)
- Not 2 indicates all materials are available except explosives (MTYPE = 2)

Figure 19. Allowable Combinations of Geometries, Elements, and Materials

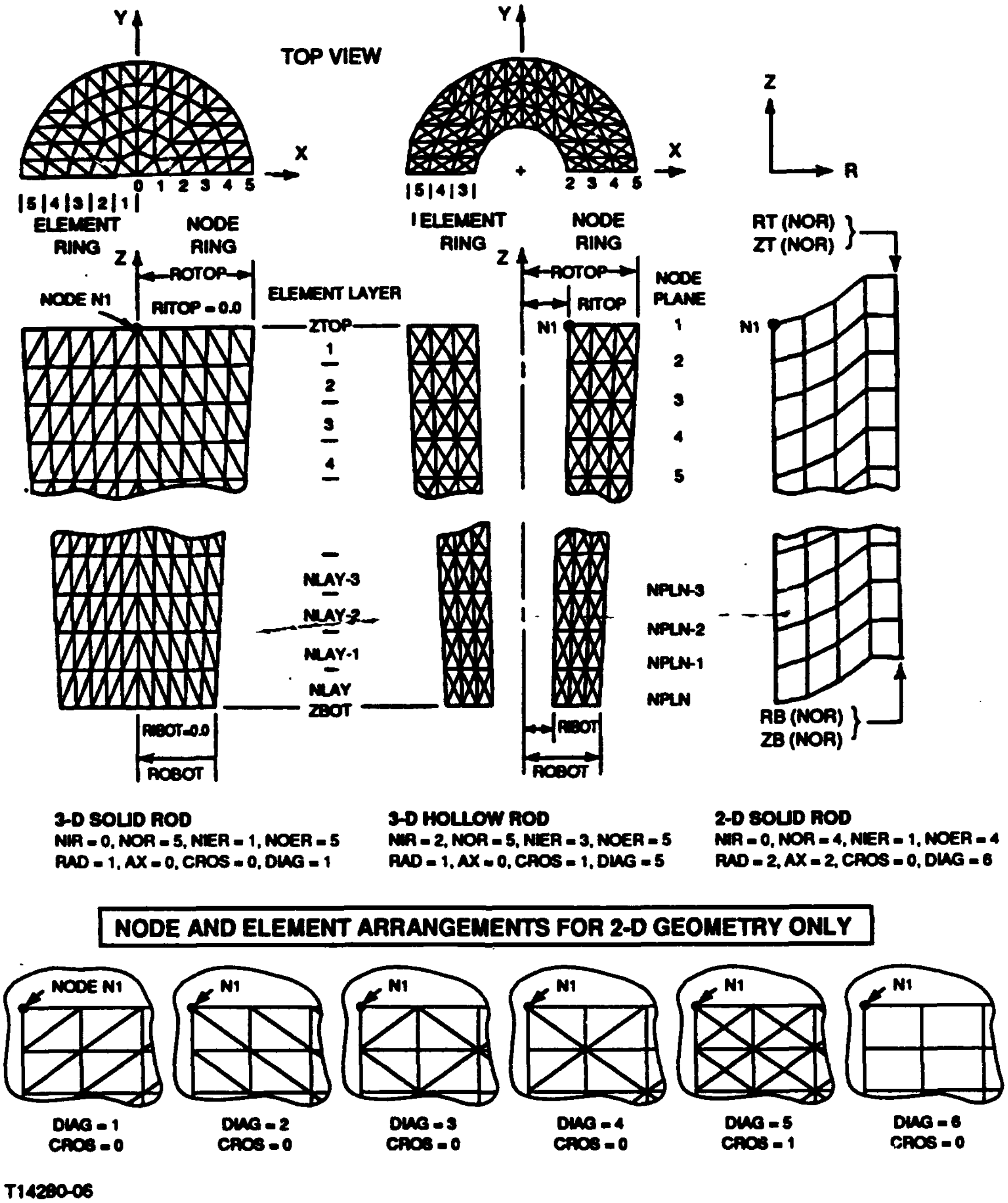


Figure 20. Rod Shape Geometry

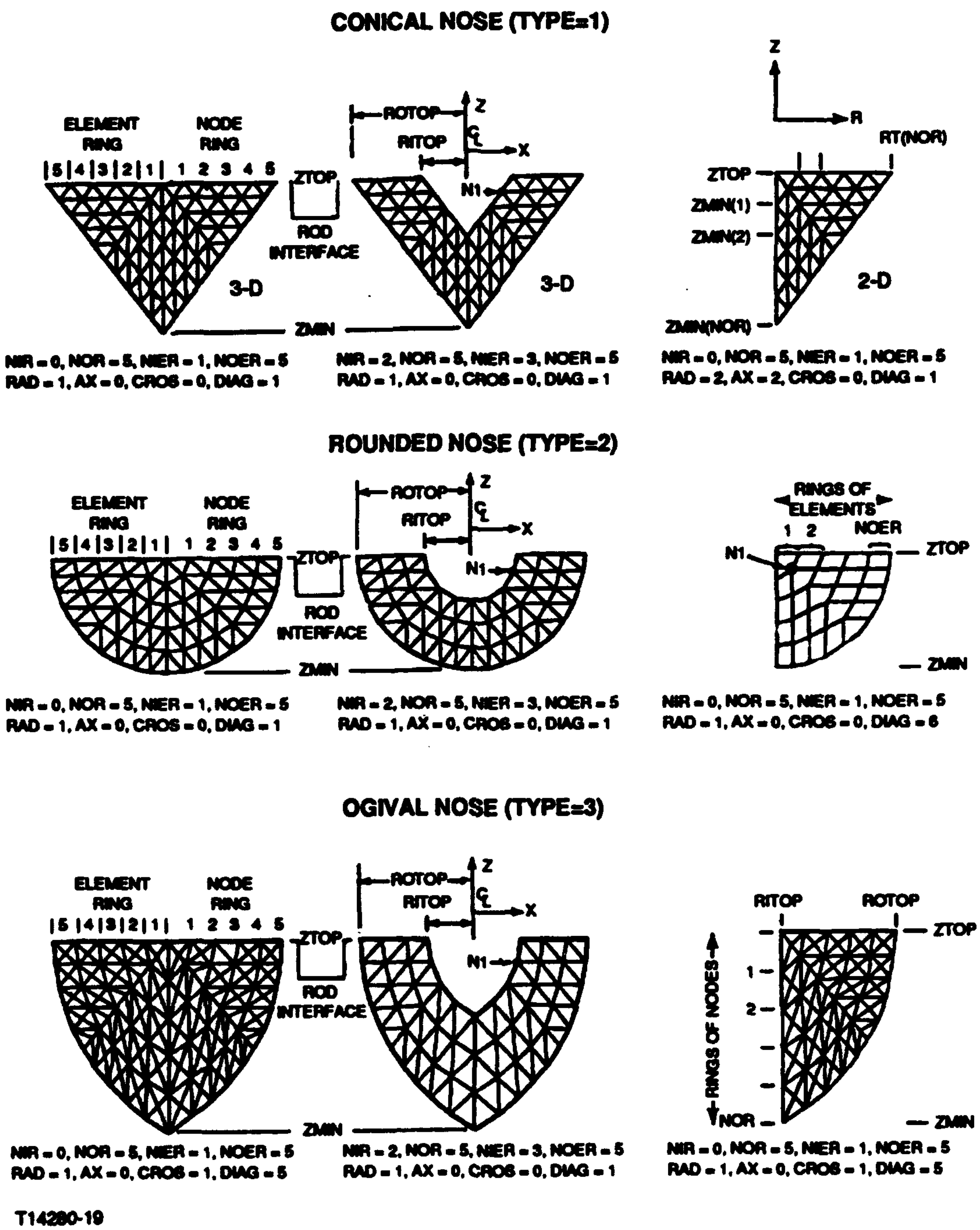


Figure 21. Nose Shape Geometry

Rod Geometry								
	2D Geometry				3D Geometry			
	Crossed Triangle		Standard Triangle		Symmetric		Non Symmetric	
Number of Rings	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**								
	2D Geometry				3D Geometry			
	Crossed Triangle		Standard Triangle		Symmetric		Non Symmetric	
Number of Rings	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.

Figure 22. Summary of Nodes and Elements for Rod and Nose Shapes

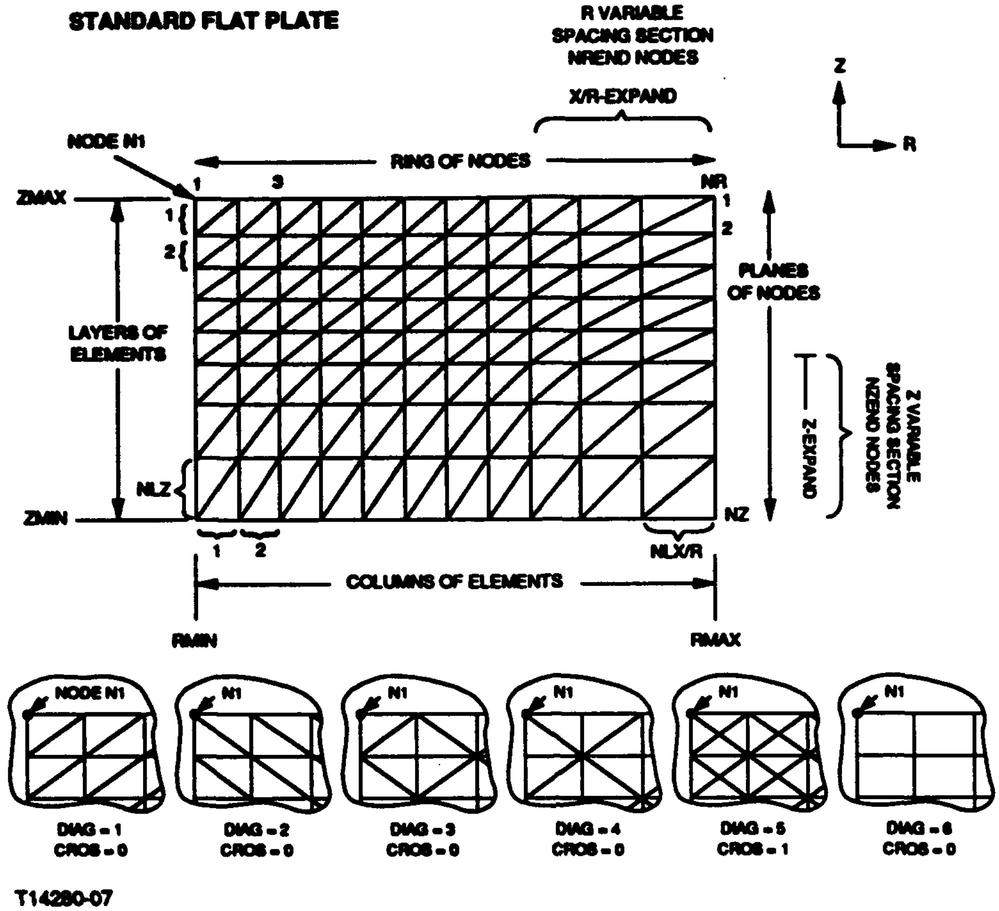


Figure 23. 2D Flat Plate Geometry

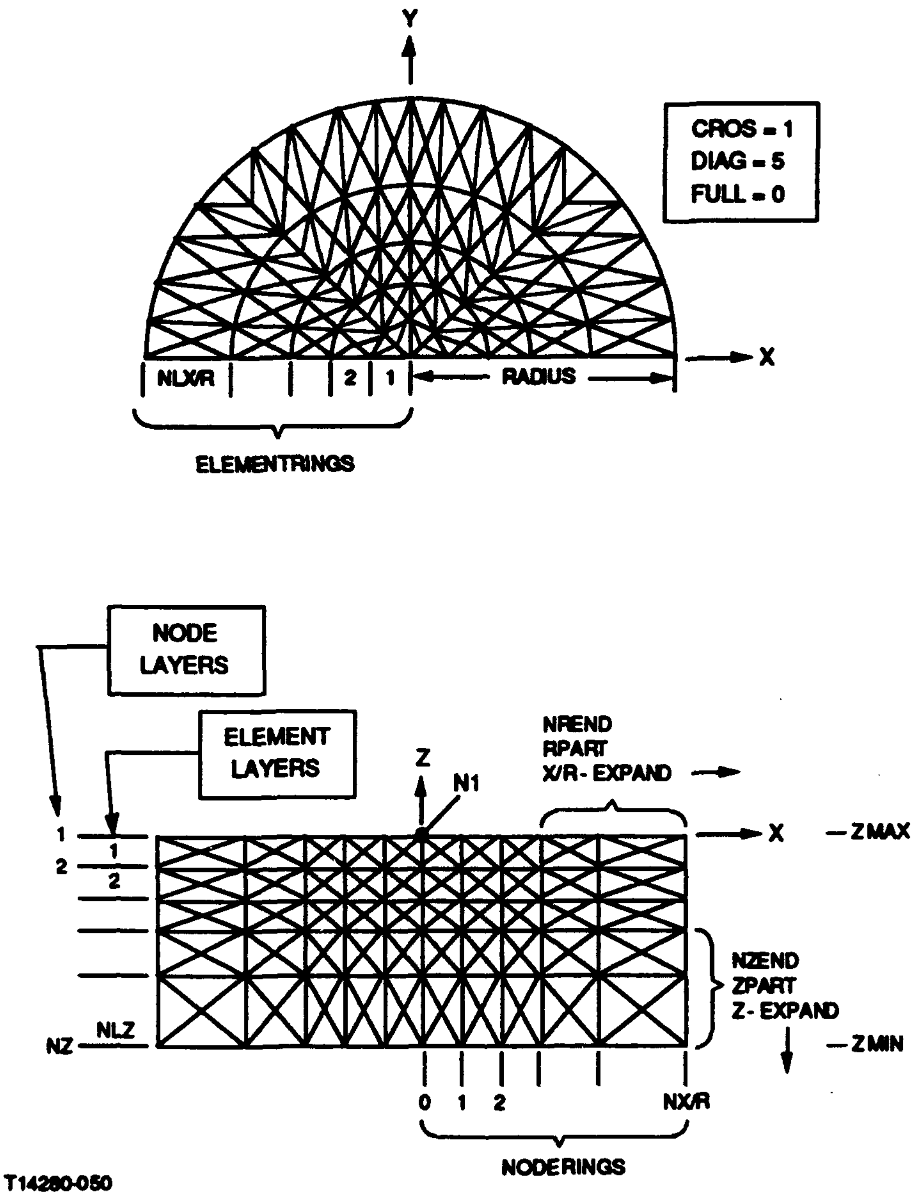
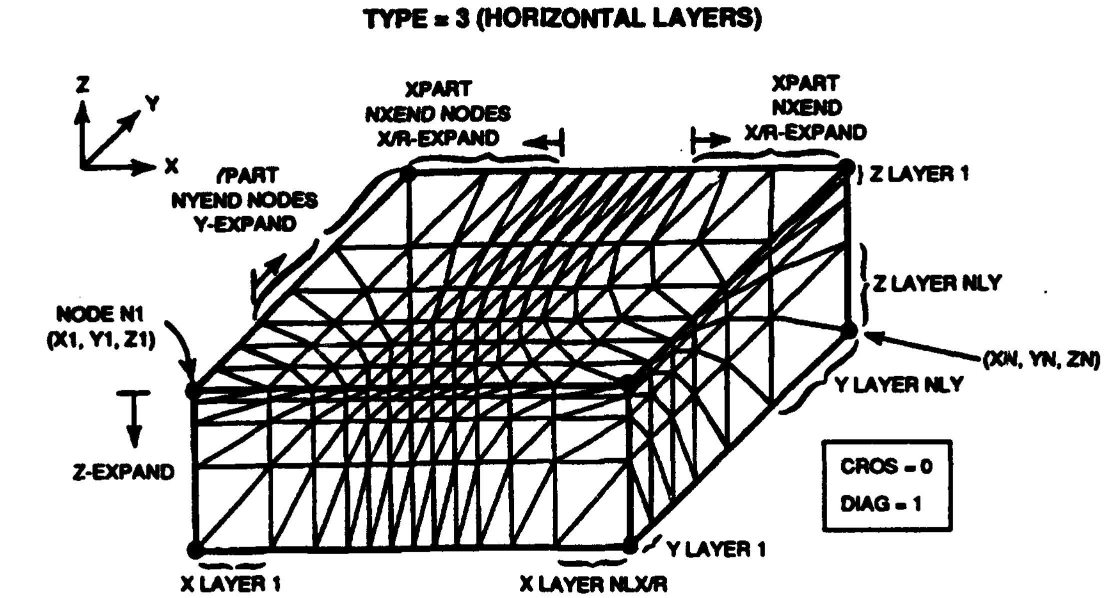


Figure 24. 3D Circular Flat Plate Geometry



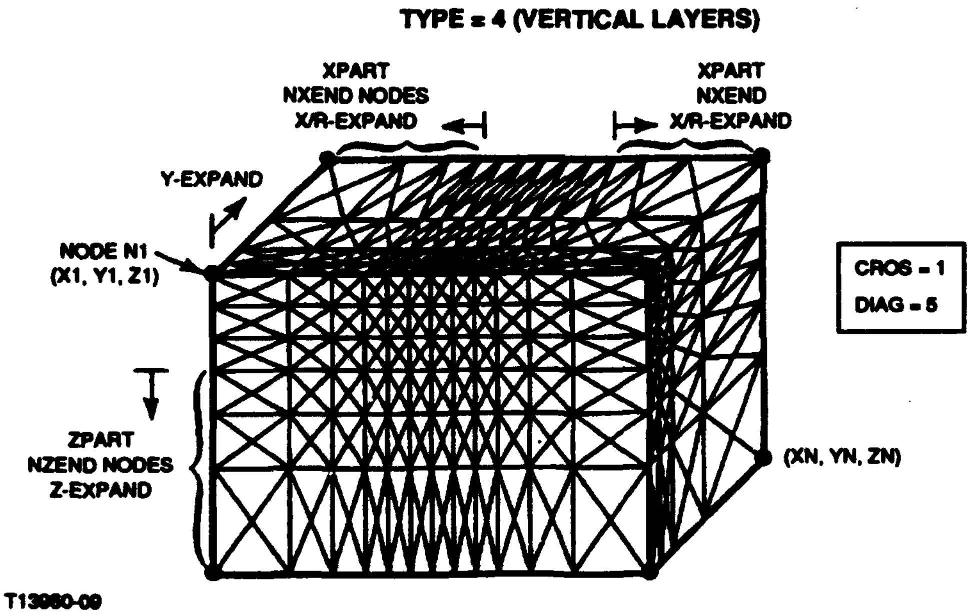
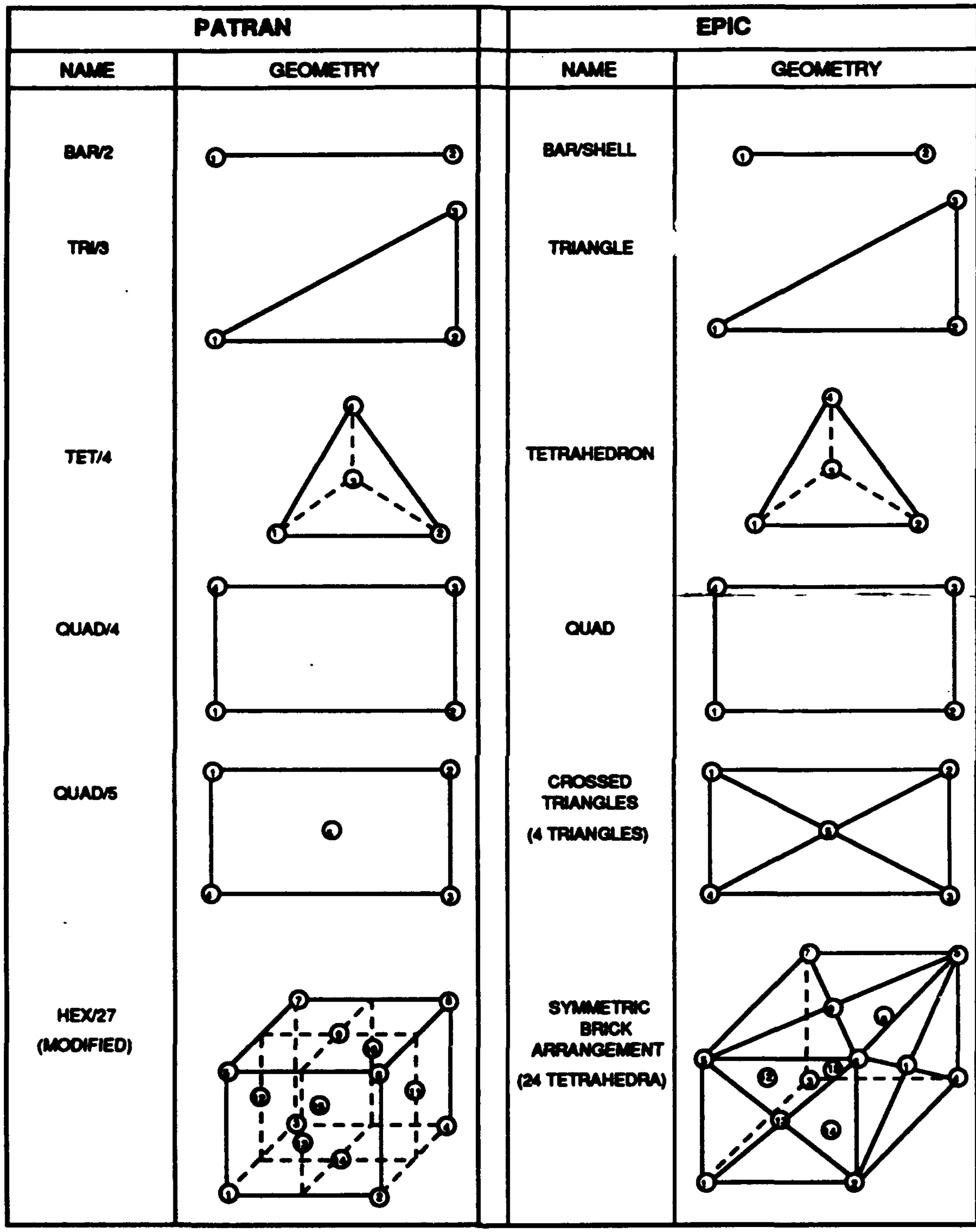
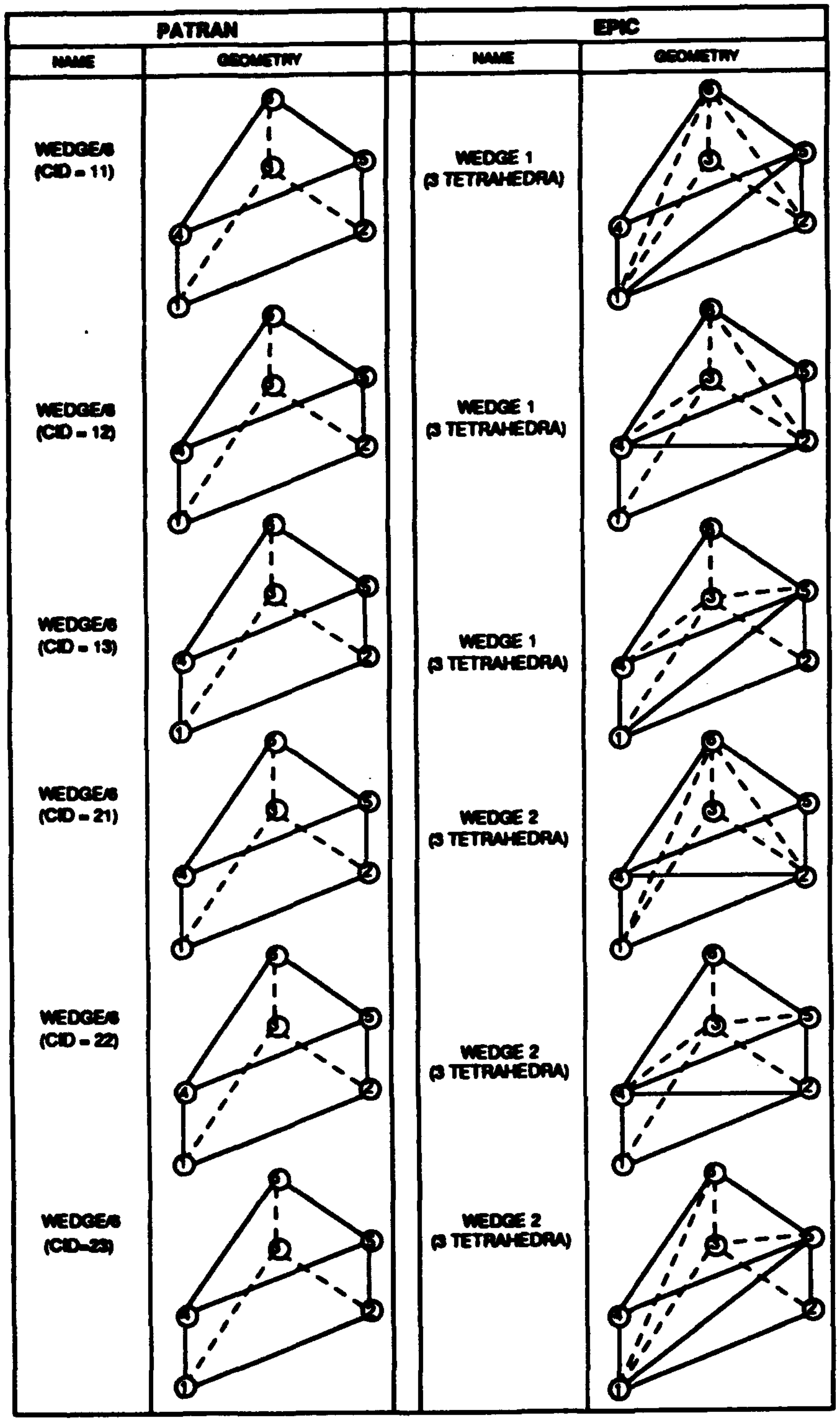


Figure 25. 3D Rectangular Flat Plate Geometry



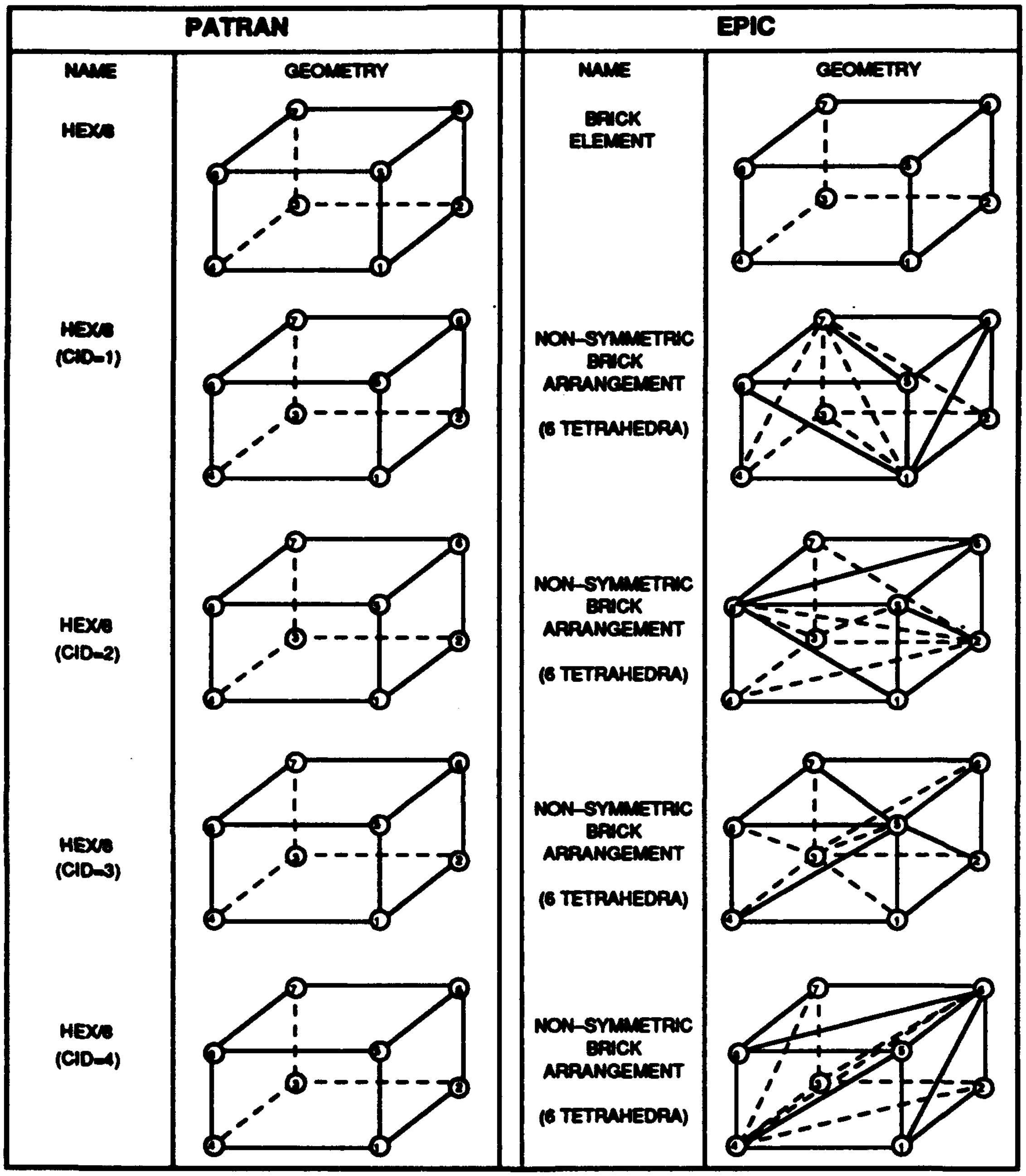
T14280-040

Figure 26. PATRAN to EPIC Translators for Nodes and Elements



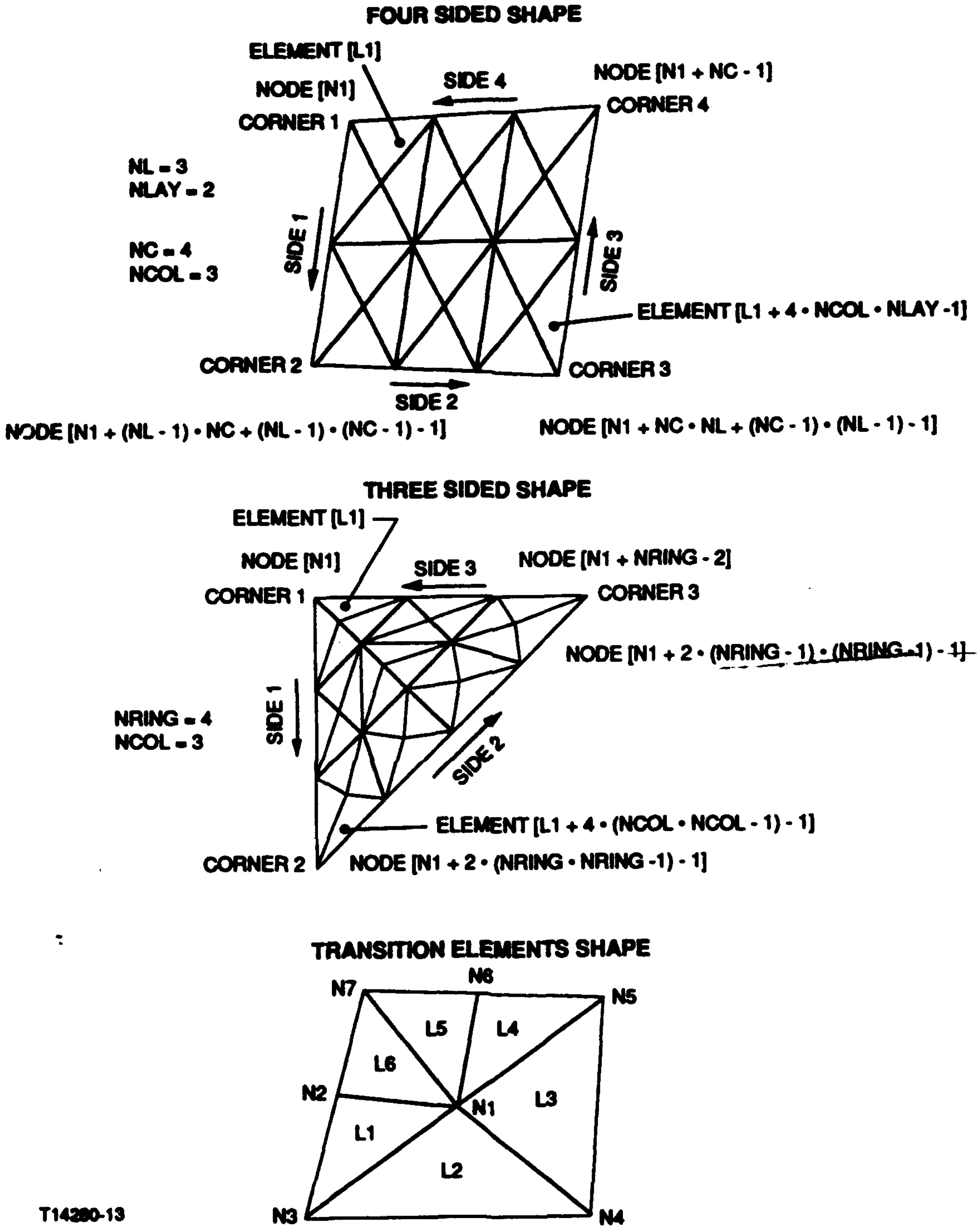
T14280-041

Figure 26. PATRAN to EPIC Translators for Nodes and Elements (Continued)



T14280-042

Figure 26. PATRAN to EPIC Translators for Nodes and Elements (Concluded)



T14280-13

Figure 27. Additional Shapes for Rezoning

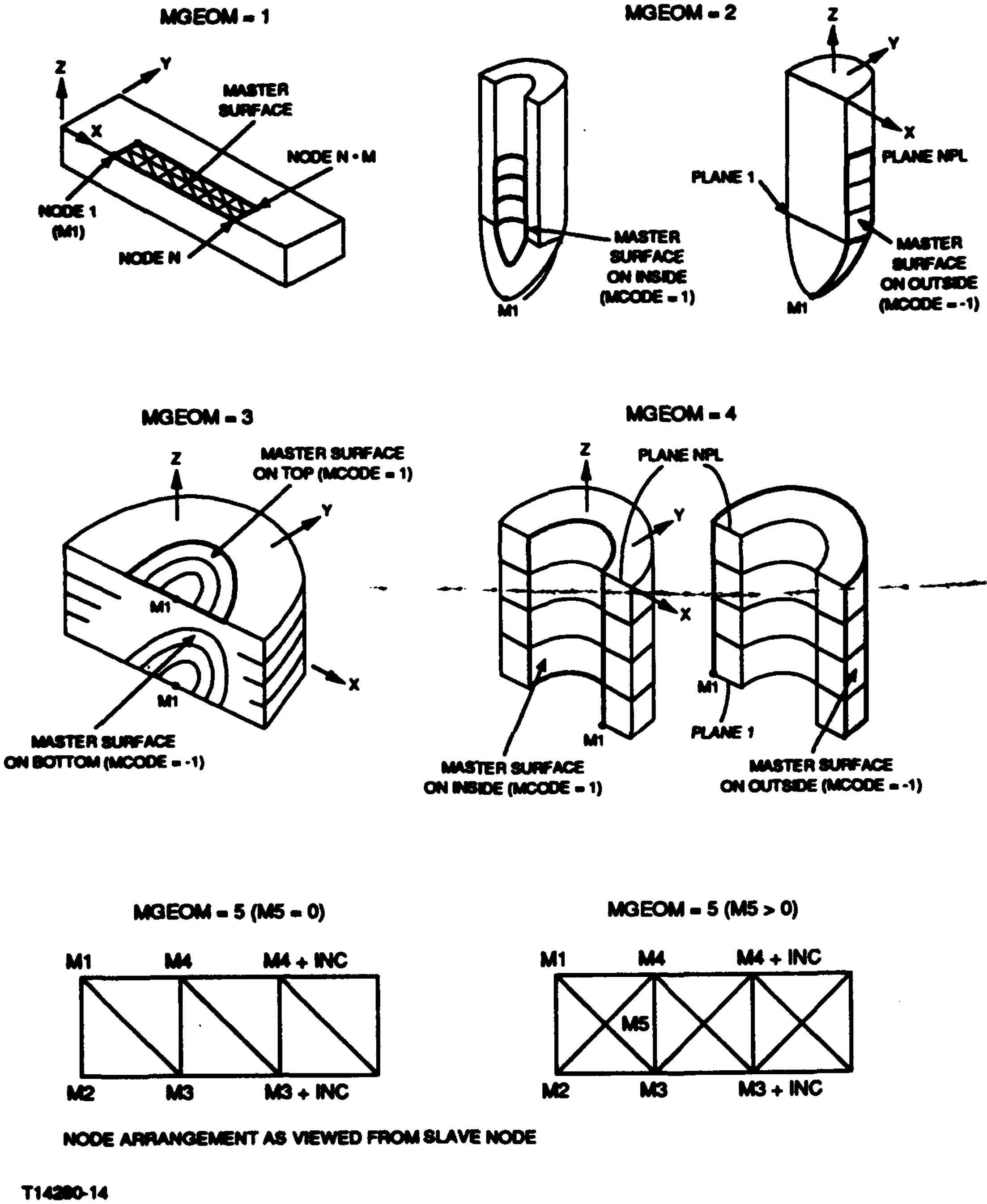


Figure 28. Master Surface Options for 3D Sliding Interfaces

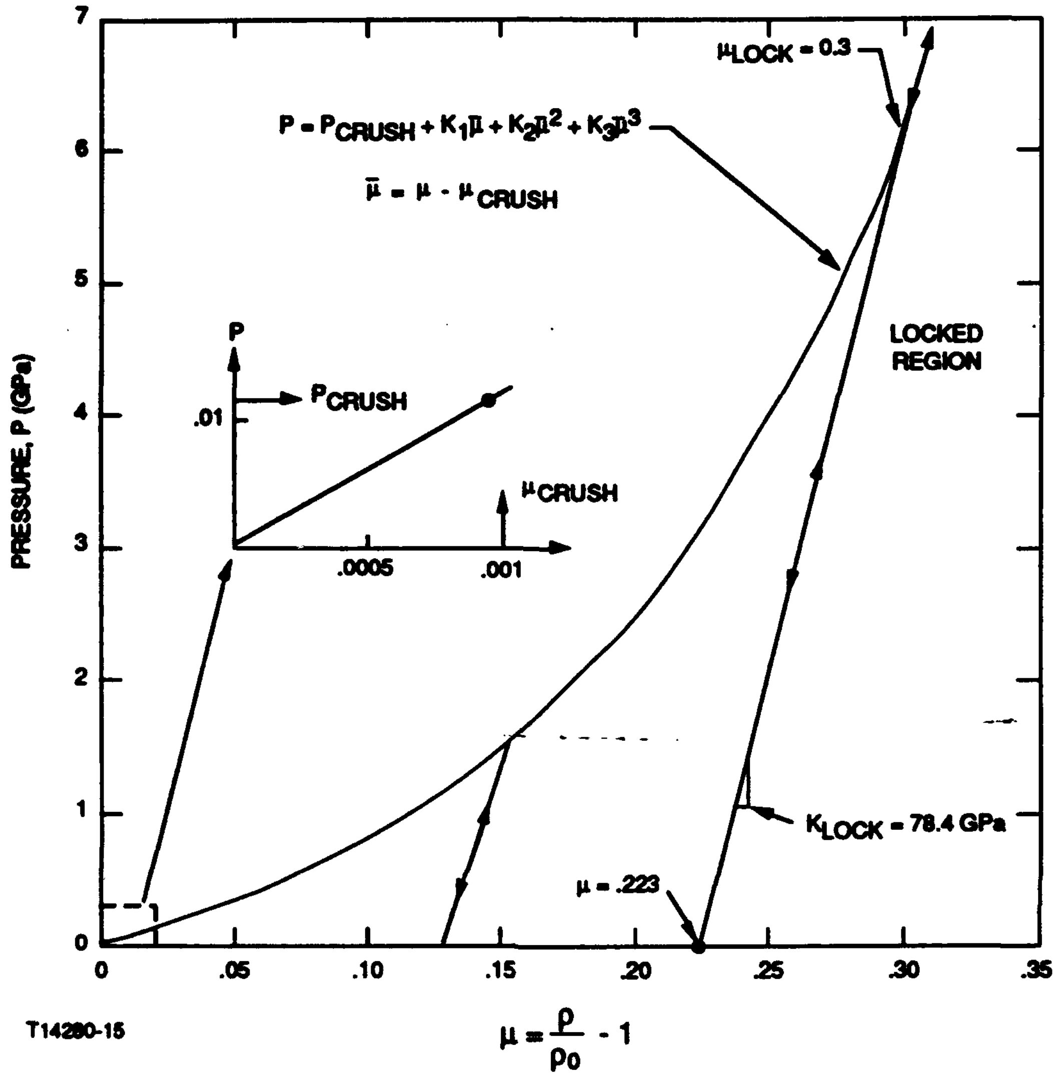


Figure 29. Pressure Model for Crushable/Concrete Solids (Specific Data Shown are for Concrete)

DEVICE NAME	CALCOMP	PLOT10 DR40XX	PLOT10 DR41XX	PLOT10 DR42XX	IRIS GL	RSCORS POPTK4	RSCORS POPT05	RSCORS POPX11	DISSPLA	DISSPLA DEVICE	DESCRIPTION
CALCOMP	X									0	
TEK4014		X				X			X	1	TEKTRONIX TERMINAL
TEK4105			X				X		X	2	TEKTRONIX TERMINAL
TEK4107			X				X		X	3	TEKTRONIX TERMINAL
TEK4109			X				X		X	4	TEKTRONIX TERMINAL
TEK4207				X					X	5	TEKTRONIX TERMINAL
TEK4209				X					X	6	TEKTRONIX TERMINAL
LN03TK									X	7	DEC LASER PRINTER (FILE: DISSPLA.LAS)
DISPOP									X	8	DISSPLA META FILE (BIN) (FILE: DISSPLA.DSPB)
CGMB									X	9	CGM META FILE (BINARY) (FILE: DISSPLA.CGMB)
CGMC									X	10	CGM META FILE (ASCII) (FILE: DISSPLA.CGMC)
CGMT									X	11	CGM META FILE (TEXT) FILE: DISSPLA.CGMT)
TEK4236									X	12	TEKTRONIX TERMINAL
SGI					X						SILICON GRAPHICS GL
X-TERM								X	X	13	X-WINDOWS INTERFACE (FILE: RSCORS.PLT)

Figure 30. Graphics Device Map

COLOR NAME	CALCOMP	DISSPLA	PLOT10 DR40XX	PLOT10 DR41XX	PLOT10 DR42XX	IRIS GL	RSCORS POPTK4	RSCORS POPT05	RSCORS POPX11*
Background	X	0	0	0	0	0	X	0	0
White	X	1	1	1	1	1	X	1	7
Red	X	2	2	2	2	2	X	2	1
Green	X	3	3	3	3	3	X	3	2
Blue	X	4	4	4	4	4	X	4	4
Cyan	X	5	5	5	5	5	X	5	6
Magenta	X	6	6	6	6	6	X	6	5
Yellow	X	7	7	7	7	7	X	7	3
Red-Yellow	X	8	8	8	8	8	X	X	X
Green-Yellow	X	9	9	9	9	9	X	X	X
Green-Cyan	X	10	10	10	10	10	X	X	X
Blue-Cyan	X	11	11	11	11	11	X	X	X
Blue-Magenta	X	12	12	12	12	12	X	X	X
Red-Magenta	X	13	13	13	13	13	X	X	X
Dark-Grey	X	14	14	14	14	14	X	X	X
Light-Grey	X	15	15	15	15	15	X	X	X
Foreground	X	16	16	16	16	16	X	8	8

X = Color not available.
* = Color table defined in POPX11.

T14260-037

Figure 31. Graphics Color Map

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 10).

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 (9I5, 5X, I2, 3I1, 4I5) —

GEOM	= 1 specifies 1D cartesian geometry.
	= 2 specifies 1D cylindrical geometry.
	= 3 specifies 1D spherical geometry.
	= 4 specifies 2D plane stress geometry (Reference 11).
	= 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. Chunks can also be defined automatically during the input of the elements. NCHNK does not include the automatically generated chunks.

NOCHK = 0 will check that the master sliding interfaces and nonreflective soaker elements are attached to solid elements. This should be used when setting up new grids.

= 1 will bypass this check to save CPU time. It can be used when using a previously checked established grid.

PCASE = Identification number for PATRAN files generated by the Main Routine. Use a 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 computations involving rigid body nodes (on the master surface), this option can introduce 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 option should only be used if the sliding interfaces are relatively simple and/or contain rigid body nodes on a master surface. 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, and the segmented master surface for 2D computations (TYPE < 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.

= 2 indicates the constants in the material library are converted to Centimeter-Gram-Second (CGS) units. Temperature is degree Kelvin.

CDUCT	=	0 will not include heat conduction.
	=	1 will include heat conduction. Does not apply to explosive materials, and is currently limited to 1D Cartesian elements, 2D triangular elements, and 3D tetrahedral elements as shown in Figure 19.

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.

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

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

Restrained Nodes Identification Cards—As Required (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.

Note: If any nodes, F1...FN, exceed the I5 format (≥100,000), set F1 = −1 and then read all nodes F1...FN on the following cards in 8I10 format.

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.

Note: If F1G and/or FNG exceed the I5 format (≥100,000), set F1G = −1 and then read F1G and FNG on the following card in 2I10 format.

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—As Required (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. 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.

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.

Note: If any nodes, R1...RN, exceed the I5 format (≥100,000), set R1 = −1 and then read all nodes R1...RN on the following cards in 8I10 format.

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.

Note: If R1G and/or RNG exceed the I5 format (≥100,000), set R1G = −1 and then read R1G and RNG on the following card in 2I10 format.

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. Recall that chunks may also be automatically generated during the input of the elements. The chunks generated by the NCHNK Chunk Element cards will be numbered after those automatically generated during the input of the elements. Furthermore, the chunks generated by the NCHNK Chunk Element Cards cannot be used to define the sliding interfaces.

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.

Detonation/Body Force (Gravity) Card (4F10.0, 10X, 3F10.0) — This card describes the initial explosive detonation conditions. It also allows body forces (gravity) to be defined. Leave this card blank (but include) if no explosives or body forces 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.

XDD = Body force acceleration in X direction (distance/second^2). Positive XDD provides positive force (F = Mass · XDD) in X direction. The body forces are added to the stress-generated forces.

YDD = Body force acceleration in Y direction (3D only).

ZDD = Body force acceleration in Z direction.

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. If left blank (DT1 = 0.0), DT1 will be determined automatically.
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 NA2. 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.

Note: If N1, N2, NA1, and/or NA2 exceed the I5 format (≥100,000), set N1 = –1 and then read N1, N2, NA1, and NA2 on the following card in 4I10 format.

a. Material Descriptions

There are several material types available to the user. They are for Solids, Explosives, Crushable/Concrete Solids and Liquids. Input data are shown in Figure 2. Data may be input directly or the material library may be used. When a library material is used, the program listing includes card images that could be used as material data input for the material. These card images can be used as a template for slightly modifying a material. The card images are limited to four digits of accuracy. Figure 19 shows the material types that can be used with the various elements.

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 12 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 five additional cards) specifies all the material constants for a solid material. Options are available for the strength model, the Equation of State model and the fracture model. These cards will supersede any material library data with the same material number, MATL. Note that the final version of EPIC requires one more card than the 1994 version. This is required to allow for input of heat conduction constants.

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

1 = Code to specify Solids input data.

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.

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.**
MATERIAL DESCRIPTION	=	**Description provided by user.**

Card 2 for Solids (6F10.0, 3I5) —

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 (or 0) specifies Johnson-Cook strength model (Reference 12).**
	=	**2 specifies modified Johnson-Cook strength model (Reference 13).**
	=	**3 specifies Zerilli-Armstrong FCC strength model (Reference 14).**
	=	**4 specifies Zerilli-Armstrong BCC strength model (Reference 14).**
	=	**5 specifies Bodner-Partom strength model (References 15, 16, and 17).**
	=	**6 specifies MTS strength model (References 18 and 19).**
	=	**10 specifies User strength model.**
EOS	=	**1 (or 0) specifies Mie-Gruneisen Equation of State.**
	=	**10 specifies User Equation of State model**

FRACT = 1 (or 0) specifies Johnson-Cook Fracture model (Reference 20).

= 10 specifies User fracture model

Card 3 for Johnson-Cook Model (MODEL = 1 or 0) (8F10.0) — This card describes strength constants for the Johnson-Cook Model (Reference 12).

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.

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

Where ϵ is the equivalent plastic strain, $\dot{\epsilon}^* = \dot{\epsilon}/\dot{\epsilon}_0$ is the dimensionless strain rate for $\dot{\epsilon}_0 = 1.0\ s^{-1}$, 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 (Reference 13).

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

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

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

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 14). It does not represent the grain size as a variable, but rather includes it in C0.

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

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

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

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 14).

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

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

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

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

Card 3A for Bodner-Partom Model (Model = 5) (8F10.0) — This card and the following one describes the Bodner-Partom model (References 15, 16, and 17).

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

Z0, Z1, N0, N1, M0, M1, ALPHA = Constants to define the material strength, σ, using the Bodner-Partom model.

$$\sigma = Z\left[-\left(\frac{2N}{N+1}\right)\cdot \ln\left(\frac{\sqrt{3}\,\dot{\varepsilon}_p}{2\,D0}\right)\right]^{-\left(\frac{1}{2N}\right)}$$

$$Z = \begin{cases} Z1-(Z1-Z0)\,e^{-M0\,W_p} & ,\ M1,\ ALPHA = 0 \\ Z1-(Z1-Z0)\,e^{-M0\,W_p}\ e^{-\frac{(M0+M1-M)}{ALPHA}} & ,\ M1,\ ALPHA > 0 \end{cases}$$

$$M = M0 + M1\cdot e^{-(ALPHA\cdot W_p)}$$

$$N = \begin{cases} N0 & ,\ N1 \le TZERO \\ N0 + \frac{(N1-TZERO)}{(T-TZERO)} & ,\ N1 > TZERO \end{cases}$$

Where $\dot{\varepsilon}_p$ is the equivalent plastic strain rate (s^{-1}), W_p is the plastic work per unit volume (force/area), and T is the absolute temperature (degree). The computed value of N is limited to $N \ge 0.4$ for stability.

Z0 and Z1 have units of stress (force/area), N1 has units of temperature (degree), M0, M1, and ALPHA have units of $stress^{-1}$ (area/force), and the others are dimensionless.

Restrictions on input are $Z0 > 0$, $Z1 > Z0$, $N0 > 0$ when $N1 \le TZERO$, $M0 > 0$, $M1 \ge 0$, $ALPHA \ge 0$, and $D0 > 0$.

Card 3B for Bodner-Partom Model (MODEL = 5) (F10.0) —

D0 = Constant to define the material strength, σ, using the Bodner-Partom model. D0 is the maximum allowable plastic strain rate, and has units of s^{-1}. It will be set to a default value of $D0 = 10^8 s^{-1}$, if left blank.

Cards 3A, 3B, 3C, 3D for MTS Model (Model = 6) [3(8F10.0), 3F10.0] — These cards describe the strength constants needed for the MTS model (Reference 18). Questions regarding this model should be directed to P.J. Maudlin of the Los Alamos National Laboratory, who supplied this model for EPIC. The MTS model is expressed here in a rather general form (Reference 19); forms for most other materials can be obtained through simplification of the following equations. The flow stress σ is given by

$$\sigma = \frac{G}{G_o}\left(\hat{\sigma}_a + s_{th}\,\hat{\sigma} + s_{th,\,i}\,\hat{\sigma}_i + s_{th,\,s}\,\hat{\sigma}_s\right)$$

which contains the constants:

SIGA = $\hat{\sigma}_a$ = dislocation interactions with long-range barriers (force/area).

SIGI = $\hat{\sigma}_i$ = dislocation interactions with interstitial atoms (force/area).

SIGS = $\hat{\sigma}_s$ = dislocation interactions with solute atoms (force/area).

where the appropriate units are indicated in parenthesis.

The first product in the equation for σ contains a micro-structure evolution variable, i.e., $\hat{\sigma}$, called the mechanical threshold stress, that is multiplied by a constant-structure deformation variable s_{th}; s_{th} is a function of absolute temperature T and plastic strain-rate $\dot{\varepsilon}^p$. The evolution equation for $\hat{\sigma}$ is a differential hardening law representing dislocation-dislocation interaction:

$$\frac{\partial\hat{\sigma}}{\partial\varepsilon^p} = \Theta_0\left[1 - \frac{\hat{\sigma}}{\hat{\sigma}_s}\right]$$

which has as a constant:

SIG0 = $\hat{\sigma}$ = initial value of $\hat{\sigma}$ at zero plastic strain(force/area).

In the equation for $\partial\hat{\sigma}/\partial\varepsilon p$, Θ_0 represents hardening due to dislocation generation and the stress ratio represents softening due to dislocation recovery. The threshold stress at zero strain-hardening $\hat{\sigma}_s$ is called the saturation threshold stress. Relationships for Θ_o, $\hat{\sigma}_s$ are:

$$\Theta_o = a_o + a_1 \ln\left(\dot{\varepsilon}^p\right) + a_2\sqrt{\dot{\varepsilon}^p}$$

which contains the constants:

HF0 = a_0 = dislocation generation material constant (force/area).

HF1 = a_1 = dislocation generation material constant (force/area).

HF2 = a_2 = dislocation generation material constant (force/area).

and

$$\hat{\sigma}_s = \hat{\sigma}_{so}\left(\frac{\dot{\varepsilon}^p}{\dot{\varepsilon}_{so}}\right)^{kT/Gb^3A}$$

which contains the constants:

SIGS0 = $\hat{\sigma}_{so}$ = saturation threshold stress at 0 K (force/area).

EDOTS0 = $\dot{\varepsilon}_{so}$ = reference strain-rate(second^{-1}).

BURG = b = magnitude of Burgers vector (inter-atomic slip distance) (distance).

CAPA = A = material constant.

BOLTZ = k = Boltzmann's constant (energy/degree).

The shear modulus G appearing in these equations is assumed to be a function of temperature and is given by the correlation

$$G = b_o - b_1/\left(e^{b_2/T} - 1\right)$$

which contains the constants:

SM0 = b_0 = shear modulus at zero degrees Kelvin (force/area).

SM1 = b_1 = shear modulus constant (force/area).

SM2 = b_2 = shear modulus constant (degree).

For thermal-activation controlled deformation s_{th} is evaluated via an Arrhenius rate equation:

$$s_{th} = \left[1 - \left(\frac{kT\ln(\dot{\varepsilon}_o/\dot{\varepsilon}^p)}{Gb^3g_o}\right)^{\frac{1}{q}}\right]^{\frac{1}{p}}$$

which contains the additional constants:

EDOT0 = $\dot{\varepsilon}_o$ = reference strain-rate (second^{-1}).

G0 = g_0 = normalized activation energy for a dislocation/dislocation interaction.

PINV = $1/p$ = material constant.

QINV = $1/q$ = material constant.

Expressions for $s_{th,i}$ and $s_{th,s}$ are identical to the equation for s_{th} in form but use the constants:

EDOTI = $\dot{\varepsilon}_{o,i}$ = reference strain-rate (second^{-1}).

G0I = $g_{0,i}$ = normalized activation energy for a dislocation/interstitial interaction.

PINVI = $1/p_i$ = material constant.

QINVI = $1/q_i$ = material constant.

and

EDOTS = $\dot{\varepsilon}_{o,s}$ = reference strain-rate (second^{-1}).

G0S = $g_{0,s}$ = normalized activation energy for a dislocation/solute interaction.

PINVS = $1/p_s$ = material constant.

QINVS = $1/q_s$ = material constant.

Card 3 for User Strength Model (MODEL = 10) (8F10.0) — This card describes strength constants for a user-supplied strength model. The user must incorporate the model into subroutine USTRNG.

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

C0...C6 = Constants to describe the user model. Constants correspond to internal variables C0(M)...C6(M)

Card 4 for Mie-Gruneisen EOS (EOS = 1 or 0) (8F10.0) —

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

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

where $\mu = \rho/\rho_0 - 1$ and E_s is internal energy per initial volume.

Γ = Gruneisen coefficient for Mie-Gruneisen equation of state. If the heat conduction option is being used (CDUCT = 1 on the Prep Miscellaneous Card), and if the thermal expansion coefficient is positive (ALPHA > 0 on following Card 6 for Solids), then the Gruneisen coefficient will be set to $\Gamma > 0$. This is done because both effects (ALPHA > 0 and $\Gamma > 0$) tend to provide for thermal expansion.

It is also possible to input $\Gamma > 0$ and ALPHA = 0. Here the expansion will occur in the Mie-Gruneisen equation of state. It can be shown that an approximate relationship between Γ and ALPHA is as follows:

$$\Gamma = K1 \cdot \alpha / \rho C$$

where K1 is the bulk modulus, α = ALPHA is the volumetric coefficient of thermal expansion, ρ = DENSITY is the density, and C = SPH HEAT is the specific heat.

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, 3D brick elements, or 3D composite brick elements with pressure averaging option (CH ≈ 0.02).

Card 4 for User EOS Model (EOS = 10) (8F10.0) — This card describes strength constants for a user-supplied Equation of State model. The user must incorporate the model into subroutine UEOS.

C11...C15 = Constants to describe the user model. Constants correspond to internal variables C11(M)...C15(M).

CL, CQ, CH = Additional constants to describe the user model. Constants correspond to internal variables Q1(M), Q2(M), C8(M) so that they may be used as artificial/hourglass viscosity coefficients if desired. If hourglass viscosity is required, then CH must be used for hourglass viscosity coefficient.

Card 5 for Johnson-Cook Fracture Model (FRACT = 1 or 0) (8F10.0) —

D1...D5 = Constants for the Johnson-Cook fracture model (Reference 20).

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

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.

SOFT = Coefficient to allow the material to soften gradually, rather than fracture instantaneously at D = 1.0. Material begins to soften when D = (1.0 – SOFT) and then linearly softens to no strength at D = 1.0.

Card 5 for User Fracture Model (FRACT = 10) (8F10.0) — This card describes fracture constants for a user-supplied fracture model. The user must incorporate the model into subroutine UDAMAG.

C21...C27 = Constants to describe user model. Constants correspond to internal variables C21(M)...C27(M).

SOFT = Softening coefficient as described previously with Johnson-Cook fracture model.

Card 6 for Solids (2F10.0) —

CONDUCT = Thermal conductivity (power/distance/degree).

ALPHA = Volumetric coefficient of thermal expansion (degree $^{-1}$).

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.

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.

Description Card for Explosives Input Data (2I5, 20X, A50) — This card (and one or two additional cards) specifies the material constants for explosives.

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

2 = Code to specify explosives input data.

MATERIAL DESCRIPTION = Description provided by user.

Card 2 for Explosives (7F10.0, I5) —

DENSITY = Material density (mass/volume).

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

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

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, 3D brick elements, or 3D composite brick elements with pressure averaging option (CH = 0.02).

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

$$P = (\gamma - 1)E/\bar{V}$$

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

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

$$P = C1 \cdot (1 - C5/C2\,\bar{V}) \cdot \exp(-C2 \cdot \bar{V}) + C3 \cdot (1 - C5/C4\,\bar{V}) \cdot \exp(-C4 \cdot \bar{V}) + C5 \cdot E/\bar{V}$$

where E is internal energy per initial volume and $\bar{V} = V/V_o$ 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/Concrete Solids From Library (4I5, 2F5.0) — Identical to Material Card for Solids from Library. DFRAC applies to damage variables EPF and UPF.

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 (EPF, UPF– 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 Crushable/Concrete Solids Input Data (5I5, F5.0, A50) — This card (plus four additional cards) specifies the material constants for a crushable/concrete solid material. The model is similar to the Osborn model used in the Hull code (Reference 21). Note that the final version of EPIC requires one more card than the 1994 version. This is required to allow for input of heat conduction constants.

MATL	= Material number specified by user. Will supersede library material data with same material number.
3	= Code to specify Crushable/Concrete Solids input data.

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.

MODEL = 1 (or 0) will use Osborn model (Reference 21).

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.

MATERIAL DESCRIPTION = Description provided by user.

Card 2 for MODEL = 1 or 0 (6F10.0) — The following constants are used for material fracture. If fracture is included (DAM = FAIL = 1), then the presence of erosion and/or low values of PMIN can provide excessive fracture in the material.

DENSITY = Material density (mass/volume).

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

TEMP1 = Initial temperature of the material (degree).

EPF = Equivalent plastic strain at which all cohesive strength is lost.

UPF = Compressive, volumetric plastic strain (after crushing at P = 0) at which all cohesive strength is lost.

Note: Damage ($0 \leq D \leq 1$) is computed from $D = \Sigma(\Delta \varepsilon p/\varepsilon_p^f + \Delta \mu p/\mu_p^f)$ where

$\Delta\varepsilon_p$ = Increment of equivalent plastic strain

$\Delta\mu_p$ = Increment of compressive, volumetric plastic strain

ε_p^f = EFP

μ_p^f = UFP

The damage is also set to D = 1.0 if the hydrostatic tension exceeds PMIN. Therefore, use PMIN > 0. The cohesive portion of the strength (C1) is degraded with the damage, as described on the next card.

X1 = Extra material constant stored in the D5 array.

Card 3 for Model = 1 or 0 (8F10.0) —

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

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

$$\sigma = [C1\,(1 - D) + C4 \cdot P]\,[1 + C3 \cdot \ln\dot{\varepsilon}^*]$$

Only the cohesive portion of the strength (C1) is degraded by the damage. Note that the damage degradation occurs only with DAM = 1 and FAIL = 1. If DAM = 1 and FAIL = 0, the damage will be accumulated but will not degrade the strength.

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

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).

C3 = Constant to describe the material strength, σ. See equation above.

Card 4 for MODEL = 1 or 0 (8F10.0) —

PCRUSH UCRUSH, K1, K2, K3, KLOCK, ULOCK	=	Constants to describe the pressure, P, for the Osborn model. The model, and specific data for concrete, are shown in Figure 29. 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).
PMIN	=	Maximum hydrostatic tension allowed (force/area).

Card 5 for Crushable/Concrete Solids (2F10.0) — Same constants as used for Solids Materials.

CONDUCT	=	Thermal conductivity (power/distance/degree).
ALPHA	=	Volumetric coefficient of thermal expansion (degree $^{-1}$).

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

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.
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 Liquids Input Data (2I5, 15X, F5.0, A50) — This card (plus two additional cards) specifies the material constants for liquids.

MATL	=	Material number specified by user. Will supersede library material data with same material number.
4	=	Code to specify Liquids input data.

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.

MATERIAL DESCRIPTION = Description provided by user.

Card 2 for Liquids (6F10.0) —

DENSITY = Material density (mass/volume).

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

TEMP1 = Initial temperature of the material (degree).

VISCOSITY = Viscosity coefficient for liquids (force-second/area).

CONDUCT = Thermal conductivity (power/distance/degree).

ALPHA = Volumetric coefficient of thermal expansion ($degree^{-1}$).

Card 3 for Liquids (8F10.0) — Same constants as used for Solids Materials.

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

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

where $\mu = \rho/\rho_0 - 1$ 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).

Material Card for RDG Model Solids From Library (3I5, 10X, F5.0) — **Similar to material card for solids from library. Questions regarding this model, should be directed to A.M. Rajendran of the Army Research Laboratory, who is the primary developer of this model.**

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 permit nucleation and growth of voids.**

= **1 will permit nucleation and growth of voids.**

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 RDG Model Solids Input Data (3I5, 10X, F5.0, A50) — This card (plus six additional cards) specifies all the material constants to describe ductile failure in solids using the RDG model (References 22, 23, and 24). Two options are available for the strength model. The following instructions for the RDG model are from Reference 24.

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

11 = **Code to specify RDG model input data.**

DAM = **0 will not permit nucleation and growth of voids.**

= **1 will permit nucleation and growth of voids.**

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.**

MATERIAL DESCRIPTION = **Description provided by user.**

Card 2 for RDG Model (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.

= 5 Specifies Bodner-Partom viscoplastic strength model.

Card 3A for Johnson-Cook Strength Model (MODEL = 1) (8F10.0) — This card describes the strength of the intact material, using the Johnson-Cook model (Reference 12). Model is identical to that described previously for solids, except that the plastic strain rate is used here instead of the total strain rate.

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.

Card 3B for Johnson-Cook Strength Model (MODEL = 1) (F10.0) —

D0 = Maximum allowable plastic strain rate, with units of s^{-1}. It will be set to a default value of $D0 = 10^8\ s^{-1}$, if left blank.

Card 3A for Bodner-Partom Strength Model (MODEL = 5) (8F10.0) — This card and the following one describes the strength of the intact material, using the Bodner-Partom model (References 15, 16, and 17). Model is identical to that described previously for solids, except that an additional thermal softening factor is available. Note that, for the RDG model, the material strength is represented by Y instead of σ.

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

Z0, Z1, N0, N1, M0, M1, ALPHA = Constants to describe the strength of the matrix (intact) material, Y_m, using the Bodner-Partom viscoplastic model.

$$Y_m = Z\left[-\left(\frac{2N}{N+1}\right)\cdot \ln\left(\frac{\sqrt{3}\,\dot{\varepsilon}^p_m}{2\,D0}\right)\right]^{-\left(\frac{1}{2N}\right)}[1-(T^*)^{C7}]$$

$$Z = \begin{cases} Z1-(Z1-Z0)e^{-M0\,W^p_m} & , M1, ALPHA = 0 \\ Z1-(Z1-Z0)e^{-M0\,W^p_m}\, e^{-\frac{(M0+M1-M)}{ALPHA}} & , M1, ALPHA > 0 \end{cases}$$

$$M = M0 + M1e^{-(ALPHA \cdot W^p_m)}$$

$$N = \begin{cases} N0 & , N1 \le TZERO \\ N0 + \frac{(N1-TZERO)}{(T-TZERO)} & , N1 > TZERO \end{cases}$$

Card 3B for Bodner-Partom Strength Model (MODEL = 5) (2F10.0) —

D0, C7 = Constants to describe the strength of the matrix (intact) material, Y_m using the Bodner-Partom viscoplastic model.

Card 4 for RDG EOS Model (8F10.0) — This is identical to the Mie-Gruneisen EOS used for Solid Materials.

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

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

where $\mu = \rho/\rho_0 - 1$ and E_s is internal energy per initial volume.

Γ = Gruneisen coefficient for Mie-Gruneisen equation of state. If the heat conduction option is being used (CDUCT = 1 on the Prep Miscellaneous Card) with an RDG material, the volumetric expansion must occur through Γ, because a volumetric expansion coefficient cannot be used. An approximate relationship is as follows:

$\Gamma = K1 \cdot \alpha / \rho C$

where K1 is the bulk modulus, α is the volumetric coefficient of thermal expansion, ρ = DENSITY is the density, and C = SPH HEAT is the specific heat.

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, 3D brick elements, or 3D composite brick elements with pressure averaging option (CH ≈ 0.02).

Card 5 for RDG model (8F10.0) — This card describes the constants used to model nucleation, coalescence, and collapse of voids.

FS, SIGMAM, SS = Constants for void nucleation due to stress.

FE, EPSLNM, SE = Constants for void nucleation due to strain.

The void volume fraction nucleation rate is expressed as,

$$\dot{f}_n = F_\sigma (\dot{Y}_m + \dot{P}_m) + F_\varepsilon \dot{D}^p_m$$

$$F_\sigma = \frac{FS}{SS\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{Y_m + P_m - SIGMAM}{SS}\right)^2}$$

$$F_\varepsilon = \frac{FE}{SE\sqrt{2}} e^{-\frac{1}{2}\left(\frac{D^p_m - EPSLNM}{SE}\right)^2}$$

Where Y_m, P_m, and D^p_m are effective stress, pressure, and equivalent plastic strain in the matrix (intact) material. SIGMAM and EPSLNM are the mean equivalent stress and strain, respectively, around which the nucleation stress and strain are distributed in a Gaussian manner.

SS and SE are the standard deviations of these distributions, and FS and FE define the maximum allowable void volume fractions due to stress and strain nucleation, respectively. SIGMAM and SS have units of stress (force/area), and the others are dimensionless.

For stress-driven void nucleation, FS and SIGMAM must both be greater than zero. If left blank, SS will be set to the default value of 1/4SIGMAM. For strain-driven void nucleation, FE and EPSLNM must both be greater than zero. If left a blank, SE will be set to the default value of 1/4EPSLNM. If appropriate, void nucleation maybe simultaneously driven by stress and strain.

FCRITS = Critical void volume fraction for spall (coalescence of voids). $0 < \text{FCRITS} \leq 0.99$. If left blank, FCRITS will be set equal to 0.99.

FCRITC = Critical void volume fraction for instantaneous void collapse. $0 \leq \text{FCRITC} < 1$.

Card 6 for RDG Model (4F10.0) — This card describes the strength of the aggregate (void-containing) material, and the heat conduction constants (described previously for Solids Materials).

YFBETA, YFN = Constants to describe the strength of the aggregate (void-containing) material, Y_a, using a pressure-dependent yield function.

$$Y_a = \sqrt{\frac{3Y_m^2\,\delta(\rho) - 9P^2(1-\rho^2)}{(2+\rho^2)}}$$

$$\delta(\rho) = \frac{g(\rho) - g(0)}{g(1) - g(0)}$$

$$\delta(\rho) = \left[1 - \left(\frac{\text{YFN}}{|\text{YFN}|}\right)\left(\frac{1-\rho}{K}\right)\right]^{\text{YFN}}$$

$$\delta'(1) = \text{YFBETA}$$

Where ρ is relative density, Y_m is the strength of the matrix material, P is the pressure in the aggregate material, and K is a model parameter that is uniquely determined from YFBETA and YFN. YFBETA and YFN are dimensionless.

CONDUCT = Thermal conductivity (power/distance/degree). Note that for the RDG model there is no volumetric coefficient of thermal expansion. Instead, the volumetric expansion must be included through the Gruneisen coefficient, Γ, in the equation of state.

Description Card for User Model Input Data (4I5, 5X, F5.0, A50) — This card (plus five additional cards) specifies constants for a user model that includes strength and pressure and fracture (optional). The user must incorporate these models into subroutine USTRES. It is recommended that the constants in the first two cards be used in the same manner as they are for solid materials. Also, for the final version of EPIC, the last two constants (formerly C31 and C32) have been changed to the heat conduction constants (CONDUCT and ALPHA), as described previously for Solids Materials.

MATL	=	Material number specified by user. Will supersede library material data with same material number.
10	=	Code to specify user model.
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.
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.
MATERIAL DESCRIPTION	=	Description provided by user.

Card 2 for User Input Model (8F10.0) — Same as used in Solid Materials.

DENSITY	=	Material density (mass/volume).

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

TEMP1 = Initial temperature of the material (degree).

TROOM = Room temperature (degree).

SHEAR MOD = Shear modulus of elasticity (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, 3D brick elements, or 3D composite brick elements with pressure averaging option (CH = 0.02).

Card 3 for User Input Model (8F10.0) —

C0...C7 = Constants to describe user model. Constants correspond to internal variables C0(M)...C7(M).

Card 4 for User Input Model (8F10.0) —

C9...C16 = Constants to describe the user model. Constants correspond to internal variables C9(M)...C16(M).

Card 5 for User Input Model (8F10.0) —

C17...C24 = Constants to describe the user model. Constants correspond to internal variables C17(M)...C24(M).

Card 6 for User Input Model (8F10.0) —

C25...C30 = Constants to describe the user model. Constants correspond to internal variables C25(M)...C30(M).

CONDUCT = Thermal conductivity (power/distance/degree).

ALPHA = Volumetric coefficient of thermal expansion (degree $^{-1}$)

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 13 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.
	Note: If N1 exceeds the I5 format (≥100,000), set N1 = −1 and then read N1 on the following card in I10 format.

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 13 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 20 and 22. 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. When a half-rod is generated, normal restraints are provided on the plane of symmetry at Y = 0. A full rod can also be generated. The full rod is a more recent addition and is specified with the RAD options. This indirect input option is necessary to maintain input compatibility with earlier versions. 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).

Note: For both 2D and 3D geometry, the number of rings of nodes is NOR – NIR + 1. For 2D geometry, the specific values of NOR and NIR are not important; it is only the difference (NOR – NIR) which affects the number of rings. For 3D geometry, however, the specific ring numbers (NOR, NIR) determine the number of nodes (and elements) around the circumference of the rod. For the hollow rod in Figure 20, NOR = 5 specifies 21 nodes around the outer circumference, and NIR = 2 specifies 9 nodes around the inner circumference.

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 (for a half-rod).

= 11 gives uniform radial spacing at the top and bottom of the rod (for a full rod).

= 2 requires all radial coordinates at top and bottom of rod to be input individually (for a half-rod).

= 12 requires all radial coordinates at top and bottom of rod to be input individually (for a full rod).

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

= 13 will read input data for 3D spherical shapes (for a full rod) 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 or 13 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.

Note: If N1 and/or NTOP exceed the I5 format (≥100,000), set N1 = –1 and then read N1 and NTOP on the following card in 2I10 format.

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.

Full Rod Position Card for RAD >10 (2F10.0) — This card is required to locate the X and Y position of a full rod when it is in a vertical position, parallel to the Z axis.

XCG = Center of full rod in the X direction (distance). Corresponds to vertical position, before SCALE/SHIFT/ROTATE options.

YCG = Center of full rod in the Y direction (distance).

Rod Node Radii Card for RAD = 1 or 11 (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 or 12 (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 or 12 (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 or 13 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 or 13 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.

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.

RBO = The X/R coordinate at the center of the 2D circular or 3D spherical section (distance).

ZBO = The Z coordinate at the center of the 2D circular or 3D spherical section (distance).

RB1 = The X/R coordinate at the beginning of the circular/spherical section at node N1 (distance).

ZB1 = The Z coordinate of node N1 (distance).

RBN = The X/R coordinate at the far end of the circular/spherical section (distance). Use only for TYPE = 1.

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

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

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

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

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

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

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 21 and 22. 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, when a half-nose is generated, restraints are provided in the Y direction, normal to the plane of symmetry (Y = 0). A full nose can also be generated in 3D geometry. The full nose is a more recent addition and is specified with the RAD options. This indirect input option is necessary to maintain input compatibility with earlier versions. 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 (for a half-nose).

= 11 gives uniform radial spacing at the rod-nose interface (for a full nose).

= 2 requires all radial coordinates at the rod-nose interface to be input individually (for a half-nose).

= 12 requires all radial coordinates at the rod-nose interface to be input individually (for a full nose).

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.

Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.

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

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

Full Nose Position Card for RAD >10 (2F10.0) — This card is required to locate the X and Y position of a full nose when it is in a vertical position, parallel to the Z axis. Similar to the Full Rod Position Card.

XCG = Center of full rod in the X direction (distance). Corresponds to vertical position, before SCALE/SHIFT/ROTATE options.

YCG = Center of full rod in the Y direction (distance).

Nose Node Top Radii Card for RAD = 1 or 11 (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 or 12 (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 23.

= 2 generates a 3D circular flat plate as shown in Figure 24.

= 3 generates a 3D rectangular flat plate where the nodes are generated in horizontal planes as shown in the upper portion of Figure 25.

= 4 generates a 3D rectangular flat plate where the nodes are generated in vertical planes as shown in the lower portion of Figure 25.

NX/R = Total number of nodes in 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. Will not restrain nodes for full circular plate (TYPE = 2 and FULL = 1).
CROS	=	0 will not generate secondary nodes for either the 2D or the 3D geometry. Must use CROS = 0 with JOIN = 4.
	=	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 23, 24, and 25. When using the JOIN option, N1 should be identical to the corresponding node generated previously. Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.

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:

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

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 23. 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. When JOIN = 4, only NX/R -1 nodes are available for variable spacing.
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. Must use NZEND = 0 for JOIN = 4.
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, I5, 5X, 3F10.0) — This card completes the description of the 3D circular flat plate (TYPE = 2), shown in Figure 24. 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. Both a full and half-plate are 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.
FULL	= 0 gives a half-plate, as shown in Figure 24, with a plane of symmetry.
	= 1 gives a full plate without a plane of symmetry.
RADIUS	= Radius of the circular plate (distance).
ZMAX	= Maximum Z coordinate of the plate (distance).
ZMIN	= Minimum Z coordinate of the plate.

Full Circular Plate Card for FULL = 1 (2F10.0) — This card is required to locate the X and Y positions of a full plate when it is in a vertical position, parallel to the Z axis.

XCG	= Center of a full plate in the X direction (distance). Corresponds to vertical position, before SCALE/SHIFT/ROTATE options.
YCG	= Center of full plate in the Y direction (distance).

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 25.

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 25, 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 25, 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 ≤ XPART ≤ 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 25 for description.

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 25, 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.

NZEND = The number of nodes in the Z direction in the variable Z spacing region. The node at the division between the uniform and the variable spacing sections is included in this number. Spacing is determined by Z-EXPAND and the fractional length by ZPART. In Figure 25, NZEND = 4. NZEND can have a maximum value of NZ. The remaining Z region (if any) is uniformly spaced. Set NYEND = 0 for uniform spacing in the Z direction.

XPART = Fractional part of the total X length of the flat plate occupied by each of the two variable X spacing regions for $0 \leq XPART \leq 0.5$. 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.

ZPART = Fractional part of the total Z length of the flat plate occupied by the variable Z 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.

Sphere Node Description Card (3I5, 5X, I5, 5X, I5, 5X, I5, 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 21. 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, when a half-sphere is generated, 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. A full sphere is also available. The full sphere is a more recent addition and is specified with the RAD options. This indirect input option is necessary to maintain input compatibility with earlier versions.

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 (for a half sphere).

= 10 gives uniform radial spacing of the nodal rings (for a full sphere).

= 2 requires radii of individual rings of nodes to be input individually (for a half sphere).

= 12 requires radii of individual rings of nodes to be input individually (for a full sphere).

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. Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.
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).

Full Sphere Position Card for RAD ≥10 (2F10.0) — This card is required to locate the X and Y positions of a full sphere.

XCG	= CG of full sphere in X direction (distance). Applied before SCALE/SHIFT/ROTATE options.
YCG	= CG of full sphere in Y direction.

Sphere Node Radii Cards for RAD = 2 or 12 (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.

Note: If N1 and/or NN exceed the I5 format (≥100,000), set N1 = −1 and then read N1 and NN on the following card in 2I10 format.

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 redefine the Scale/Shift/Rotate and remain in effect until another Scale/Shift/Rotate card is read.

X/RSCALE = Redefined scale factor by which the R coordinates (2D) or X coordinates (3D) of 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 = Redefined rotation about X/R0 and Z0 in the R-Z plane (2D), or the X-Z plane (3D), of 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 nodes, with the relationship

$$X/R_{new} = X/R_{old} + (Z - Z0) \tan(\text{SLANT}).$$

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.

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. In addition, chunks can be specified with the element cards. 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. Figure 19 shows the element types that can be used with the various geometries and material types.

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 25, 26, 27). 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 16 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) and the nonreflective boundary elements cannot be used with Explosive materials. Bar and shell elements, and plane stress geometry can use only solid materials (MTYPE = 1). The non-reflective elements cannot use explosive materials (MTYPE = 2).

The 2D shell elements with bending are based on the algorithms of Belytschko, Lin and Tsay (Reference 28), and the 3D brick elements are based on the algorithm of Flanagan and Belytschko (Reference 29).

Series of Individual and Composite Elements Card (14I5, 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 18. See also Figures 14 through 17. 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 30). There are two types of 2D shell elements. The first includes membrane stresses only, and is based on an incompressible assumption. The other 2D shell element includes bending and is also based on an incompressible assumption. The 3D bar and shell elements are similar to the 2D shell elements with membrane stresses only.

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 18 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, brick, 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 and BRICK = 0. A single 8-node (constant stress) brick element is generated when N1 ... N8 are positive and BRICK = 1. For both cases, nodes N1, N2, N3, N4, and nodes N5, N6, N7, N8 are counterclockwise when looking from node N1 to N5, as shown in Figure 15. 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 15. Likewise, if N4 = N8 = 0, the first three elements (D, E, F) are defined by nodes N1, N2, N3, N5, N6, N7.

Note: If any nodes, N1–N8, exceed the I5 format (≥100,000), set N1 = –1 and then read N1–N8 on the following card in 8I10 format.

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 17. 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 15. 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 with axial or membrane stresses only.

= 2 indicates a nonreflective boundary element.

= 3 indicates shell elements with bending, that have three integration points through the thickness. (Not yet available for GEOM ≥ 6).

= 5 indicates shell elements with bending, that have five integration points through the thickness. (Not yet available for GEOM ≥ 6).

Note: The volume and mass for shell elements are computed differently for SHELL = 1 than they are for SHELL = 3 or 5. SHELL = 1 assumes the thickness of the shell is on the left side of a line going from N1 to N2.

SHELL = 3 or 5 assumes the shell is centered about the line from N1 to N2.

BRICK = 0 for all elements except 3D brick elements.

= 1 indicates a 3D brick element defined by nodes N1 ... N8.

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—for SHELL = 1, 3, 5 and T/A = 0 (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, 3, 5 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—for SHELL = 1 and T/A = 0 (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—for SHELL = 1 and T/A = 0 (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.

1	=	Identification number for series of elements.
MATL	=	Material number for the series of elements.
NCOMP	=	Number of composite elements to be generated.

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 15.

N1–N15	=	Nodes to describe the 24 tetrahedral element in a symmetric arrangement. Note: If any nodes, N1–N15, exceed the I5 format (≥100,000), set N1 = –1 and then read N1–N15 on the following two cards in 8I10/7I10 format.
INC	=	Node number increment added to the node numbers of the previous composite element for the next composite element.

Rod (Disk) Element Card (11I5, 1X, 4I1, 2F10.0) — One or more cards are required to describe elements for nodes previously generated for the rod shapes shown in Figure 20. 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 20. For 2D geometry, the region specified by this card can be automatically rezoned during the course of the run.

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. An 8-node brick element is also 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.

Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.

DIAG = Diagonal option. For 2D geometry DIAG = 1–6 as shown in Figure 20. For 3D geometry, DIAG = 1 for nonsymmetric tetrahedral elements, DIAG = 5 for symmetric tetrahedral elements, and DIAG = 6 for 8-node brick elements. 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).

Note: For 3D geometry, the values of NOER and NIER must be consistent with (but not equal to) the nodal ring numbers, because they specify how many nodes and elements go around the circumference of the rod. This is demonstrated in the hollow rod example in Figure 20.

NLAY = The number of layers of elements in the rod. The total number of elements in a rod shape shown in Figure 20 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 22.

FULL = 0 will generate elements for a half-rod, in 3D geometry, with a plane of symmetry at Y = 0.

= 1 will generate elements for a full rod, in 3D geometry, without a plane of symmetry.

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. (Not yet available for FULL = 1.)

= 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. (Not yet available for FULL = 1.)

= 2 for 3D shell elements on the bottom of the rod. (Not yet available for FULL = 1.)

= 3 for 3D shell elements on the outer ring of the rod. (Not yet available for FULL = 1.)

AZONE = 0 will not allow automatic rezoning.

= 1 will automatically rezone 2D region when requested by RZONE = 1 on the Data Output Card.

S1 = 0 will move nodes along SIDE 1 when rezoning. See Figure 27 for definition of sides.

= 1 will not move nodes along SIDE 1 when rezoning. Primary use of this option is when the side is internal to the grid (i.e., not on an outer boundary).

S2, S3, S4 = Node movement codes for SIDE 2, SIDE 3, and SIDE 4, as shown in Figure 27. Same options as for S1.

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.

RELAX = A dimensionless relaxation distance for rezoning, defined as a fraction of a characteristic grid distance. The characteristic distance is the square root of the area of the smallest element in the rezone region, before rezoning. All nodes must move less than this for the rezoning iterations to discontinue. Recommend using RELAX = 0.001 to 0.050.

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, 5X, 2I5, 15X, F10.0) — One or more cards are required to describe elements for nodes previously generated for the nose shapes shown in Figure 21. 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.

Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.

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 or 3D brick 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).

FULL = 0 will generate elements for a half-nose, in 3D geometry, with a plane of symmetry at Y = 0.

= 1 will generate elements for a full nose, in 3D geometry, without a plane of symmetry.

SHELL = 0 uses solid elements. (Not yet available for FULL = 1.)

= 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).
	=	-1 will not generate the elements in that ring. For 3D with DIAG = 1 only.

Flat Plate Element Card (11I5, 1X, 4I1, 2F10.0) — One card is required for each flat plate shape to be generated. For 2D geometry, as shown in Figure 23, 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 2D geometry, the region specified by this card can be automatically rezoned during the course of the run.

For 3D geometry, as shown in Figures 24 and 25, the elements are generated in rings (identical to that of the rod shape) for the circular plate (TYPE = 2 and 12), 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.
		Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.
DIAG	=	Element arrangement option. DIAG = 1–6 for 2D geometry as shown in Figure 23. DIAG = 1 and 5 for 3D geometry is shown in Figures 24 and 25. DIAG = 6 for 3D geometry gives 8-node brick elements. 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 23.

= 2 will generate elements for 3D circular half-plate as shown in Figure 24, with a plane of symmetry Y= 0.

= 12 will generate elements for a full 3D circular plate, without a plane of symmetry.

= 3 will generate elements for 3D rectangular flat plate, in horizontal layers, as shown in Figure 25.

= 4 will generate elements for 3D rectangular flat plate, in vertical layers, as shown in Figure 25.

NLX/R = Number of composite brick elements in the X/R direction for TYPE = 1, 3, 4. In Figure 25, 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 25, NLY = 6 for TYPE = 3.

NLZ = Number of layers of composite brick elements in the Z direction. In Figure 25, NLZ = 4 for TYPE = 3.

SHELL = 0 for all 2D elements and 3D solid tetrahedral and brick 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, 12, 3, or 4. (Not yet available for TYPE = =12.)
	= −3 will place 3D shell elements or nonreflective boundary elements on the negative Z face for TYPE 2, 12, 3, or 4. (Not yet available for TYPE = =12.)
	= 4 will place 3D shell elements or nonreflective boundary elements on the outer ring of a circular plate for TYPE = 2 or 12. (Not yet available for TYPE = 12.)
AZONE	= 0 will not allow automatic rezoning.
	= 1 will automatically rezone 2D region when requested by RZONE = 1 on the Data Output Card.
S1	= 0 will move nodes along SIDE 1 when rezoning. See Figure 27 for definition of sides.
	= 1 will not move nodes along SIDE 1 when rezoning. Primary use of this option is when the side is internal to the grid (i.e., not on an outer boundary).
S2, S3, S4	= Node movement codes for SIDE 2, SIDE 3, and SIDE 4, as shown in Figure 27. Same options as for S1.
THICK	= Shell thickness for 3D shell elements (distance). Use only for SHELL = 1.
RELAX	= A dimensionless relaxation distance for rezoning, defined as a fraction of a characteristic grid distance. The characteristic distance is the square root of the area of the smallest element in the rezone region, before

rezoning. All nodes must move less than this for the rezoning iterations to discontinue. Recommend using RELAX = 0.001 to 0.050.

Sphere Element Card (6I5, 5X, 2I5, 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 21. 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 21. 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.

Note: If N1 exceeds the I5 format (≥100,000), set N1 = –1 and then read N1 on the following card in I10 format.

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 or 3D brick 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).

FULL = 0 will generate elements for a half-sphere, in 3D geometry, with a plane of symmetry at Y = 0.

= 1 will generate elements for a full sphere, in 3D geometry, without a plane of symmetry.

SHELL	= 0 for all 2D elements and 3D solid tetrahedral elements.
	= 1 for 3D shell elements on the outer node ring only. (Not yet available for FULL = 1.)
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 (4I5, 50X, 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 26. 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 26.

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 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.

SHELL = 0 for all elements except shell elements with bending.

= 3 indicates shell elements with bending, that have three integration points through the thickness. (Not yet available).

= 5 indicates shell elements with bending, that have five integration points through the thickness. (Not yet available).

T/A = 0 for all solid (triangle, quad, tetrahedral, brick) 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.

Chunk Definition Card (3I5) — This card allows the user to describe chunks of elements without having to determine the specific element numbers. Furthermore, it is possible to specify master surfaces and slave nodes by chunk number such that it is not necessary to identify specific node numbers when defining sliding interfaces. The chunks will be numbered consecutively.

999 = Code to identify Chunk Definition Card.

START = 0 will not start a new chunk.

= 1 will start a new chunk with the element cards.

STOP = 0 will not end the existing chunk.

= 1 will end the existing chunk.

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 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—As Required (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.

Note: If M1 and/or S1 exceed the I5 format (≥100,000), set M1 = –1 and then read M1 and S1 on the following card in 2I10 format.

Sliding Interface Identification Card for 2D Geometry—As Required (10I5, 3F10.0) — Each 2D sliding interface generally 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. Also note that the CPU time will be increased if excessive master surfaces and slave nodes are defined. For EPIC-CTH linked computations, a master surface must define the interface of EPIC and CTH. This sliding interface must contain no slave nodes (NSG = NSN = NSR = 0.)

The general sliding algorithm is described in Reference 31, 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.

Also note that an automatic sliding option is now available for impact problems, but not explosive detonation problems. This option requires minimal user input.

NMG = Number of groups of master nodes to be read. Includes the Grouped Master Node Cards, as well as Master Definition Cards for 2D Region, 2D Projectile, 2D Target, 2D Node/Element/Material, and 2D Chunks.

NMN = Number of master nodes to be read individually.

NSG = Number of groups or chunks 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 for sliding interfaces without erosion, or with erosion that maintains the eroded mass at the nodes. TYPE = 1 uses a master surface that is a single continuous line. TYPE = –1 is a more recent option that allows the master surface to be composed of multiple segments.

= ±2 is for sliding interfaces with erosion, where the eroded mass is not maintained at the nodes. This is the option that should be used when EPIC Lagrangian material is eroded and donated to the CTH Eulerian grid for EPIC-CTH linked computations. Can also be used for standard erosion problems without the link. TYPE = 2 is for a single continuous master surface and TYPE = –2 is for a segmented master surface. Eroded mass is not reported in system/chunk output data.

= 30 is for an interface where no sliding or separation is allowed. This interface becomes activated after the first cycle of integration is performed so the problem must be set up to insure that no relative motion occurs (at the interface) during the first cycle. (Not yet available).

MBOT = Lowest number on the bottom of the target plate when performing perforation computations with the eroding interface option. 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. Perforation can also be achieved by using a negative TYPE, and by defining the bottom surface of the target as a master surface.

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

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 with TYPE < 0.)

IT1 = Number of velocity iterations for the slave nodes on the master surface (References 32 and 33). 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.

For the automatic sliding option, use IT1 = 5 to IT1 = 10 for all cases, including erosion.

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 32 and 33). 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. 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. If left blank (REF VEL = 0), the code will automatically compute REF VEL. If it is observed that slave nodes pass through the master surface, then the reference velocity should be increased slightly.

ERODE = Erosion strain (equivalent or volumetric) for the eroding interface options. The TYPE = ±1 erosion option is for penetration/perforation of thick plates and is activated when ERODE > 0. Recommended values are ERODE = 1.5 to 2.5. 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 26 and 33. 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) and TYPE = ±1, 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 primary application of ERODE for TYPE = ±2, is for linked EPIC-CTH computations where the Lagrangian EPIC grid is highly strained and then donates material to the Eulerian CTH grid. Here, recommended values are ERODE = 0.5 to 1.0. Standard erosion computations can also be performed with TYPE = ±2, but here the eroded mass is not maintained, and the result is that mass, momentum and energy will not be conserved.

FRICTION = Coefficient of sliding friction in the R-Z plane. Does not act in θ direction for relative spinning velocities (GEOM = 7). Use FRICTION = 0 for linked EPIC-CTH runs, because all interface conditions are defined with the LINK input.

NMG Grouped Master Node Cards (3I5) — This option allows master nodes to be input in groups. For positive TYPE (TYPE = 1, 2, 3, 4), 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. This limits the master surface to a single continuous line.

For negative TYPE (TYPE = –1 or –2) the master surface can be segmented, and is not restricted to a single continuous line.

M1G = First node in the group of master nodes. For positive TYPE (1 or 2) M1G should not be identical to MNG from the previous card, as a continuous line is assumed. For negative TYPE (–1 or –2), M1G should be identical to MNG from the previous card, if the surface is continuous.

MNG = Last node in the group of master nodes.

Note: If M1G and/or MNG exceed the I5 format (≥100,000), set M1G = –1 and then read M1G and MNG on the following card in 2I10 format.

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

Master Definition Card for 2D Region (2I5, 4F10.0, 10X, I5) — This card allows the master surfaces to be determined automatically. All surface line segment (element faces) are defined as the master surface within a specified region. Must be used with negative TYPE (–1 or –2). Although this option simplifies input, it can increase CPU time if the master surface includes regions where there is no interaction with slave nodes.

6 = Identification number for 2D Region. Must be input in two places (columns 5 and 65) to provide compatibility with previous versions.

RSYM = 0 will not include master segments on the Z axis at R = 0.

= 1 will include master segments on the Z axis at R = 0

RMAX = Maximum R coordinate of master surface region (distance).

RMIN = Minimum R coordinate of master surface region.

ZMAX = Maximum Z coordinate of master surface region.

ZMIN = Minimum Z coordinate of master surface region.

Note: If RMAX = RMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 2D Projectile Only (2I5, 4F10.0, 10X, I5) — This card allows the master surface on the projectile to be determined automatically.

7 = Identification number for 2D Projectile.

RSYM = 0 will not include master segments on the Z axis at R = 0.

= 1 will include master segments on the Z axis at R = 0

RMAX = Maximum R coordinate of master surface region (distance).

RMIN = Minimum R coordinate of master surface region.

ZMAX = Maximum Z coordinate of master surface region.

ZMIN = Minimum Z coordinate of master surface region.

Note: If RMAX = RMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 2D Target Only (2I5, 4F10.0, 10X, I5) — This card allows the master surface on the target to be determined automatically.

8 = Identification number for 2D Target.

RSYM = 0 will not include master segments on the Z axis at R = 0.

= 1 will include master segments on the Z axis at R = 0

RMAX	=	Maximum R coordinate of master surface region (distance).
RMIN	=	Minimum R coordinate of master surface region.
ZMAX	=	Maximum Z coordinate of master surface region.
ZMIN	=	Minimum Z coordinate of master surface region.

Note: If RMAX = RMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 2D Node/Element/Material (2I5, 5I10, I5) — This card allows the master surface to be defined for a range of node numbers, or a range of element numbers, or a material number. Only one of the three options can be used on a card.

9	=	Identification number for 2D Node/Element/Material. Must be input in two places (columns 5 and 65) to provide compatibility with previous versions.
RSYM	=	0 will not include master segments on the Z axis at R = 0.
	=	1 will include master segments on the Z axis at R = 0
MAX NODE	=	Maximum node number for master surface governed by nodes. Leave blank (MAX NODE = 0) if governed by elements or material.
MIN NODE	=	Minimum node number for master surface governed by nodes.
MAX ELE	=	Maximum element number for master surface governed by elements. Leave blank (MAX ELE = 0) if governed by nodes or material.
MIN ELE	=	Minimum element number for master surface governed by elements.
MATL	=	Material number for master surface governed by material. Leave blank (MATL = 0) if governed by nodes or elements.

Master Definition Card for 2D Chunks (3I5, 45X, I5) — This card allows the master surface to be defined for a chunk, as specified in the element input data with the Chunk

Definition Cards. Chunks that will be described with the NCHNK Chunk Element Cards cannot be used to define master surfaces, because these have not yet been defined.

10	=	Identification number for 2D chunks. Must be input in two places (columns 4/5 and 64/65) to provide compatibility with previous versions.
RSYM	=	0 will not include master segments on the Z axis at R = 0.
	=	1 will include master segments on the Z axis at R = 0
CHUNK	=	Chunk number for which master surface is determined.

Master Definition Card for 2D Automatic Sliding (I5, 5X, 4F10.0, 10X, I5)—This card allows the user to define all surfaces as sliding interfaces. Master surfaces and slave nodes are defined automatically. This is currently available only for impact problems and not for explosive detonation problems. Can be limited to a region (to save CPU time) or can include entire problem. If this option is used there can be no other sliding interfaces in the problem. Also, it is not necessary to define slave nodes separately. This option can require more CPU time for some problems. In the previous card, must use NMG = 1 and NMN = NSG = NSR = MBOT = 1T2 = 0. TYPE = ±1 or ±2 will automatically be set to negative TYPE (−1 or −2) for this option. Finally, exterior shell/bar elements will not act as master surfaces, but their nodes will act as slave nodes.

99	=	Identification number for 2D global sliding. Must be input in two places (columns 4/5 and 64/65).
RMAX	=	Maximum R coordinate of master surface region (distance).
RMIN	=	Minimum R coordinate of master surface region.
ZMAX	=	Maximum Z coordinate of master surface region.
ZMIN	=	Minimum Z coordinate of master surface region.
		Note: If RMAX = RMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Individual Master Node Cards for NMN > 0 (16I5) — Master nodes are input individually when NMN > 0. For positive TYPE (1 or 2) 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.

For negative TYPE (–1 or –2), the continuity of the line can be broken by inserting a node number of 0. The 0 node numbers must be included in NMN.

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

Note: If any node, M1...MN, exceeds the I5 format (≥100,000), set M1 = –1 and then read all nodes M1...MN on the following cards in 8I10 format.

NSG Grouped/Chunk 2D Slave Node Cards (3I5, 5X, 2I5) — This option allows the slave nodes to be input in groups or chunks. 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. Leave blank (S1G>0) if slave nodes are defined by chunks.

SNG = Last node in the group of slave nodes.

Note: If S1G and/or SNG exceed the I5 format (≥100,000), set S1G = –1 and then read S1G and SNG on the following card in 2I10 format.

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

CHUNK = Chunk number used to define slave nodes. The chunk must be specified in the element input data with the Chunk Definition Cards. Chunks that will be described with the NCHNK Chunk Element Cards cannot be used to define slave nodes, because these have not yet been defined. Leave blank (CHUNK = 0) if slave nodes are defined as groups.

SURF = 0 will define all nodes in the chunk as slave nodes (including interior nodes).

= 1 will define only the exterior surface nodes in the chunk as slave nodes. Also includes free standard nodes, whose elements in the chunk have eroded.

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.

Note: If any node, S1...SN, exceeds the I5 format (≥100,000), set S1 = −1 and then read all nodes S1...SN on the following cards in 8I10 format.

NSR Slave Node Limits Cards (4F10.0, I5) — 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.

SURF = 0 will define all nodes in the region as slave nodes (including interior nodes).

= 1 will define only the external surface nodes in the region as slave nodes. Also includes free standard nodes (whose elements in the region have eroded).

Sliding Interface Identification Card for 3D Geometry—As Required (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. For EPIC-CTH linked computations, a master surface must define the interface of EPIC and CTH. This sliding interface must contain no slave nodes (NSG = NSN = NSR = 0).

If brick elements are to act as master surfaces, the quadrilateral face should be defined as two triangular faces. There has been limited checkout of sliding with brick elements, and the user should be aware that unforeseen problems could develop.

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 plane 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 or 5.

= –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 · 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 · DT, and if the distance from the slave node projection to the master triangular projections is small, $|\delta \text{ edge}| <$ REF VEL · DT, then the master triangle with the smaller $|\delta \text{ edge}|$ is selected. More detail is given in Reference 32.

= 5 is for a new search routine that eventually may be faster for parallel processor computers. (Not yet available.)

= 6 is for a new search algorithm that is more accurate for complicated sliding interfaces. It has not been thoroughly checked, however, and the user should be aware that unforeseen problems could occur.

NSG = Number of groups or chunks 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 for sliding interfaces without erosion, or with erosion that maintains the eroded mass at the nodes.

= 2 is for sliding interfaces with erosion, where the eroded mass is not maintained at the nodes. This is the option that should be used when EPIC Lagrangian material is eroded and donated to the CTH Eulerian grid for EPIC-CTH linked computations. Can also be used for standard erosion problems without the link. Eroded mass is not reported in system/chunk output data.

= 30 is for an interface where no sliding or separation is allowed. This interface becomes activated after the first cycle of integration is performed so the problem must be set up to insure that no relative motion occurs (at the interface) during the first cycle. (Not yet 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 plate 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.

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

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.

For the automatic sliding option, use IT = 5 to IT = 10 for all cases, including erosion.

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. If left blank (REF VEL =

0), the code will automatically compute REF VEL. If it is observed that slave nodes pass through the master surface, then the reference velocity should be increased slightly.

ERODE = Equivalent plastic strain (or volumetric strain), which if exceeded by any element on the master surface, will cause the element to be eroded. 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 26. The sliding erosion algorithm is for tetrahedral elements only, and cannot be used with brick elements.

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.

For TYPE = 1 the eroded mass is retained, and recommended values are ERODE = 1.5 to 2.5. The primary application of ERODE for TYPE = 2 is for linked EPIC-CTH computations, where the Lagrangian EPIC grid is highly strained and then donates material to the Eulerian CTH grid. Here, recommended values are ERODE = 0.5 to 1.0. Standard erosion computations can also be performed with TYPE = 2, but here the eroded mass is not maintained, and the result is that mass, momentum and energy are not conserved.

FRICTION = The coefficient of sliding friction. Use FRICTION = 0 for linked EPIC-CTH runs, because all interface conditions are defined with the LINK input.

Alternate Identification Card for Plane of Symmetry (25X, I5, 20X, 2F10.0) — This card is used in place of the previous sliding interface identification card for 3D geometry, for the special case of alternate planes of symmetry that contain the Z axis. For this special case, this is the only card required. It is not necessary to define master surfaces and slave nodes. This special sliding interface will identify all nodes on the specified plane of

symmetry. These nodes will be allowed to slide along the plane of symmetry, but they will not be allowed to move off of that plane of symmetry.

TYPE = 20 specifies the special case for an alternate plane of symmetry.

THETA = Angle (degrees) from the X axis to the Y axis, when viewed from the positive Z axis. The plane of symmetry is defined by the Z axis and the specified angle THETA.

DEL-THETA = The tolerance angle (degrees) that is applied to the angle, THETA, for selecting the nodes that are included on the plane of symmetry.

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 28. This is consistent with the Rectangular Flat Plate Geometry Generator shown in Figure 25.

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

M1 = Node number of the reference node on the master surface as shown in Figure 28.

Note: If M1 exceeds the I5 format (≥100,000), set M1 = –1 and then read M1 on the following card in I10 format.

DIAG = 1 is for the diagonal orientation shown in Figure 28.

= 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 28. 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 28. 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 (8I5) — 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 28. This is consistent with the Rod and Nose Generator shown in Figures 20 and 21. 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 28.

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 28.

Note: If M1 exceeds the I5 format (≥100,000), set M1 = −1 and then read M1 on the following card in I10 format.

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 20 and 21. No secondary nodes.
	=	5 is for the symmetric element arrangement as shown in Figures 20 and 21. 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 plane 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.
FULL	=	0 is for a half rod and nose with a plane of symmetry at Y = 0.
	=	1 is for a full rod and nose without a plane of symmetry.

Master Definition Card for Circular Plate (Disk) Geometry (5I5, 10X, I5) — 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 20 and 24. (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 28. 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 28.
		Note: If M1 exceeds the I5 format (≥100,000), set M1 = −1 and then read M1 on the following card in I10 format.

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 20 and 24. No secondary nodes.

= 5 is for the symmetric element arrangement as shown in Figures 20 and 24. 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.

FULL = 0 is for half disk with a plane of symmetry at Y = 0.

= 1 is for a full disk without a plane of symmetry.

Master Definition Card for Cylinder (Rod) Geometry (8I5) — 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 28. This is consistent with the rod and circular plate generators shown in Figures 20 and 24. The reference node, M1, is on the lower end of the cylinder as shown in Figure 28. 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 28.

Note: If M1 exceeds the I5 format (≥100,000), set M1 = –1 and then read M1 on the following card in I10 format.

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 20 and 24. No secondary nodes.

= 5 is for the symmetric element arrangement as shown in Figures 20 and 24. 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.

FULL = 0 is for a half rod with a plane of symmetry at Y = 0.

= 1 is for a full rod without a plane of symmetry.

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 28. 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.

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 28, 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 28.

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 28.

Note: If M1, M2, M3, M4, and/or M5 exceed the I5 format (≥100,000), set M1 = –1 and then read M1, M2, M3, M4, and M5 on the following card in 5I10 format.

Master Definition Card for 3D Region (2I5, 6F10.0) — This card allows the master surfaces to be determined automatically. All surface segments (element faces) are defined as the master surface within a specified region. Although this option simplifies input, it can increase CPU time if the master surface includes regions where there is no interaction with slave nodes.

6 = Identification number for 3D Region.

YSYM = 0 will not include master segments on the X-Z plane at Y =0.

= 1 will include master segments on the X-Z plane at Y = 0.

XMAX = Maximum X coordinate of master surface region (distance).

XMIN = Minimum X coordinate of master surface region.

YMAX = Maximum Y coordinate of master surface region.

YMIN = Minimum Y coordinate of master surface region.

ZMAX = Maximum Z coordinate of master surface region.

ZMIN = Minimum Z coordinate of master surface region.

Note: If XMAX = XMIN = YMAX = YMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 3D Projectile Only (2I5, 6F10.0) — This card allows the master surface on the projectile to be determined automatically. See previous card for definition of input variables.

7	=	Identification number for 3D Projectile.
YSYM	=	0 will not include master segments on the X-Z plane at Y =0.
	=	1 will include master segments on the X-Z plane at Y = 0.
XMAX	=	Maximum X coordinate of master surface region (distance).
XMIN	=	Minimum X coordinate of master surface region.
YMAX	=	Maximum Y coordinate of master surface region.
YMIN	=	Minimum Y coordinate of master surface region.
ZMAX	=	Maximum Z coordinate of master surface region.
ZMIN	=	Minimum Z coordinate of master surface region.

Note: If XMAX = XMIN = YMAX = YMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 3D Target Only (2I5, 6F10.0) — This card allows the master surface on the target to be determined automatically. See two previous cards for definition of input variables.

8	=	Identification number for 3D Target.
YSYM	=	0 will not include master segments on the X-Z plane at Y =0.
	=	1 will include master segments on the X-Z plane at Y = 0.
XMAX	=	Maximum X coordinate of master surface region (distance).

XMIN = Minimum X coordinate of master surface region.

YMAX = Maximum Y coordinate of master surface region.

YMIN = Minimum Y coordinate of master surface region.

ZMAX = Maximum Z coordinate of master surface region.

ZMIN = Minimum Z coordinate of master surface region.

Note: If XMAX = XMIN = YMAX = YMIN = ZMAX = ZMIN = 0, then the entire problem will be included.

Master Definition Card for 3D Node/Element/Material (2I5, 5I10) — This card allows the master surface to be defined for a range of node numbers, or a range of element numbers, or a material number. Only one of the three options can be used on a card.

9 = Identification number for 3D Node/Element/Material.

YSYM = 0 will not include master segments on the X-Z plane at Y =0.

= 1 will include master segments on the X-Z plane at Y = 0.

MAX NODE = Maximum node number for master surface governed by nodes. Leave blank (MAX NODE = 0) if governed by elements or material.

MIN NODE = Minimum node number for master surface governed by nodes.

MAX ELE = Maximum element number for master surface governed by elements. Leave blank (MAX ELE = 0) if governed by nodes or material.

MIN ELE = Minimum element number for master surface governed by elements.

MATL = Material number for master surface governed by material. Leave blank (MATL = 0) if governed by nodes or elements.

Master Definition Card for 3D Chunks (3I5) — This card allows the master surface to be defined for a chunk, as specified in the element input data with the Chunk Definition

Cards. Chunks that will be described with the NCHNK Chunk Element Cards cannot be used to define master surfaces, because these have not yet been defined.

10	=	Identification number for 2D chunks.
YSYM	=	0 will not include master segments on the X-Z plane at Y =0.
	=	1 will include master segments on the X-Z plane at Y = 0.
CHUNK	=	Chunk number for which master surface is determined.

Master Definition Card for 3D Automatic Sliding (I5, 5X, 6F10.0)—This card allows the user to define all surfaces as sliding interfaces. Master surfaces and slave nodes are defined automatically. This is currently available only for impact problems and not for explosive detonation problems. Can be limited to a region (to save CPU time) or can include entire problem. If this option is used there can be no other sliding interfaces in the problem. Also, it is not necessary to define slave nodes separately. This option can require considerably more CPU time for some problems. In the previous card, must use NMG = 1, SEEK $\geq$ 4 and NSG = NSR = MBOT = 0. Finally, exterior bar and shell elements will not act as master surfaces, but their nodes will act as slave nodes.

99	=	Identification number for 3D global sliding.
XMAX	=	Maximum X coordinate of master surface region (distance).
XMIN	=	Minimum X coordinate of master surface region.
YMAX	=	Maximum Y coordinate of master surface region.
YMIN	=	Minimum Y coordinate of master surface region.
ZMAX	=	Maximum Z coordinate of master surface region.
ZMIN	=	Minimum Z coordinate of master surface region.

Note: If XMAX = XMIN = YMAX = YMIN = ZMAX = ZMIN = 0 then the entire problem will be included. Otherwise, region of sliding can be limited by specifying XMAX...ZMIN.

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 in 2I10 format.

NSG Grouped/Chunk 3D Slave Node Cards (3I5, 5X, 2I5) — This option allows the slave nodes to be input in groups or chunks.

S1G = First node in the group of slave nodes. Leave blank (S1G = 0) if slave nodes are defined as chunks.

SNG = Last node in the group of slave nodes.

Note: If S1G and/or SNG exceed the I5 format (≥100,000), set S1G = −1 and then read S1G and SNG on the following card in 2I10 format.

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

CHUNK = Chunk number used to define slave nodes. The chunk must be specified in the element input data with the Chunk Definition Cards. Chunks that will be described with the NCHNK Chunk Element Cards cannot be used to define slave nodes, because these have not yet been defined. Leave blank (CHUNK = 0) if slave nodes are defined as groups.

SURF = 0 will define all nodes in the chunk as slave nodes (including interior nodes).

= 1 will define only the exterior surface nodes in the chunk as slave nodes. Also includes free standard nodes, whose elements in the chunk have eroded.

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

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

Note: If any node, S1...SN, exceeds the I5 format (≥100,000), set S1 = −1 and then read all nodes S1...SN on the following cards in 8I10 format.

NSR Slave Node Limits Cards (6F10.0, I5) — This option allows all nodes in a specified region to be designated as slave nodes. Can be used in conjunction with the grouped, chunk, 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.

SURF = 0 will define all nodes in the region as slave nodes (including interior nodes).

= 1 will define only the external surface nodes in this region as slave nodes. Also includes free standard nodes (whose elements have eroded).

e. PATRAN Preprocessor

This subsection is included to note that PATRAN can be used to generate nodes, elements and 3D sliding interfaces. This capability was developed using PATRAN 2.5. After the PATRAN file has been generated, it is read by the EPIC preprocessor. Specific details are provided in the preceding three subsections for node, element and sliding interface input.

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 that 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.

TYPE = 3 indicates standard restart run.

= 5 indicates an EPIC-CTH linked 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, eroding interfaces sometimes may require a lower value. If there appears to be excessive erosion, then try a lower value of SSF = 0.7.
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. If left blank (CPMAX = 0), there will be no check for a CPU limit.
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. If energy is added to the system (through velocity or pressure boundary conditions), then it is necessary to specify EMAX.

Main Miscellaneous Card (2I5, 5X, 3I5, 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 read applied pressures to be used for computations in this run. PRES is the number of groups of surfaces for which different pressures are applied.

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

≥ 1 will read applied nodal velocity data to be used for computations in this run. PUSH is the number of groups of nodes for which different velocities are applied.

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.

Note: Hourglass viscosity is always included for 2D quad elements and 3D brick elements.

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 26 and 27).

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.

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 state dynamic plots as run progresses. This requires additional plot definition input (on file INP1 = 1) in the same format as used for the State Plots. Not available for RSCORS graphics.

= –1 will provide state dynamic plots (same as DPLOT = 1), and will also create RGB screen dumps of an EPIC DGL graphic.

This feature is implemented by forking a child process from within EPIC to run the SGI utility "scrsave" with the appropriate dimensions to save the window in question. The RGB file is written to the current directory with filename "ExxWyyCzzzzz.RGB", where xx corresponds to the problem case number, yy to the window ID, and zzzzz to the cycle number for that graph. It is assumed that "/usr/sbin/scrsave" is on your

PATH. If this is not the case, you will need to modify your ".login" file accordingly.

RGB writes are available in both the Dynamic version of EPIC and the post processors. In Dynamic EPIC, a negative DTPLOT will cause RGB files to be written at DTDYN intervals over the entire length of the simulation. In the post-processors, a new menu function "Write RGB file . . ." has been added.

= 2 will provide time-history dynamic plots as run progresses. This requires additional plot definition input (on file INP2 = 2) in the same format as used for the Time Plots. (Not yet available.)

= 3 will provide both state and time-history dynamic plots. (Not yet available.)

The dynamic plots are generated at intervals of DT DYN. The definition of the dynamic state plots is provided by input data shown in Figure 7 and described later. The dynamic state plot input data are read from a separate input file, IN1.

The definition of the dynamic time-history plots is provided by input data shown in Figure 8 and described later. The dynamic time-history plot input data are read from a separate input file, IN2.

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.

Note: If any nodes, N1...NN, exceed the I5 format (≥100,000), set N1 = –1 and then read all nodes N1...NN on the following cards in 8F10.0 format.

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 all elements E1...EN on the following cards in 8I10 format.

Drop Card for DROP = 1 (F10.0, I5, 5X, 4I5, 10X, 2I5, 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 NNODE, NNAB, and/or NELE exceed the I5 format (≥100,000), set NNODE = −1 and then read NNODE, NNAB, and NELE on the following card in 3I10 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.

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 elements 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 all elements EF1...EFN on the following cards in 8I10 format.

Pressure Cards for PRES ≥ 1—As Required (6I5, F10.0) — These cards describe the applied pressures and the surfaces to which they are applied. There are PRES groups of these cards, where PRES is the number of groups of surfaces that have different applied pressures. These Pressure Cards, and the following Time-Pressure Cards, should be read for surfaces with the same pressures, before the next set of Pressure Cards and Time-Pressure Cards are input for the next set of pressures. If other pressures were used in a previous MAIN routine run, they are all deleted, and the only applied pressures which act are those that are input in the current restart 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.

N1, N2, N3, N4 = Nodes that describe the surfaces to which the pressures are applied.

If 1D geometry (GEOM = 1, 2, 3), the pressure is applied to node N1, in the direction of node N2.

If 2D geometry (GEOM = 4, 5, 6, 7), the pressure is applied to the side of an element described by nodes N1 and N2. The pressure acts from left to right when viewing node N2 from node N1.

If 3D geometry (GEOM = 8), the pressure is applied to the side of a tetrahedral element, or the face of a triangular shell element, described by nodes N1, N2, and N3. The pressure is applied to the side/face for which nodes N1, N2, and N3 are counterclockwise. For brick elements, use nodes N1, N2, N3, and N4 in a counterclockwise direction.

Note: If N1, N2, N3, or N4 exceed the I5 format (≥100,000), set N1 = –1 and then read N1, N2, N3, and N4 on the following card in 4I10 format.

NSURF = The number of surfaces, described by nodes N1, N2, N3, and N4, together with NODINC, to which the pressures are applied.

NODINC = The nodal increment between subsequent surfaces, to which the pressures are applied. If N1 = 100, N2 = 101, NSURF = 3 and NODINC = 5, then the pressures will be applied to three element sides (100–101, 105–106, 110–111).

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

Time-Pressure Cards for PRES ≥ 1—As Required (2F10.0) — These cards allow the applied pressures to be varied as a function of time. A minimum of two cards should be used, which span the time from the beginning of the run to TMAX. If no cards are given, then P(T) = 1.0 for all times. 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. Any time before the first PTIME will use the first P(T), and any time after the last PTIME will use the last P(T).

Velocity Cards for PUSH ≥ 1—As Required (4I5, 3F10.0) — These cards describe the applied velocities and the nodes to which they are applied. There are PUSH groups of these cards, where PUSH is the number of groups of nodes that have different applied velocities. These velocity cards, and the following Time-Velocity cards, should be read for nodes with the same velocities, before the next set of Velocity Cards and Time-Velocity Cards are input for the next set of velocities. If other applied velocities were used in a previous main routine run, they are all deleted, and the only applied velocities which act are those that are input in the current restart 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.

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

NN = The last node in a series of nodes.

Note: If N1 and/or NN exceed the I5 format (≥100,000), set N1 = –1 and then read N1 and NN on the following card in 2I10 format.

INC = The node number increment between N1 and NN.

TYPE = 0 will read V(T) on the following Time-Velocity Cards, and will then set VX/R(T) = VY/T(T) = VZ(T) = V(T).

= 1 will not read V(T) on the following Time-Velocity Cards, but will read the individual velocity component factors [VX/R(T), VY/T(T) and VZ(T)].

= 2 will read and impose only the X/R velocities on the specified nodes. The Y/T velocities and Z velocities will not be affected.

= 3 will read and impose only the Y/T velocities.

= 4 will read and impose only the Z velocities.

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 ≥ 1—As Required (5F10.0) — These cards allow the applied velocities to be varied as a function of time. A minimum of two cards should be used, which span the time from the beginning of the run to TMAX. If no cards are given, then V(T) = 1.0 for all times. End with a blank card as shown in Figure 6.

VTIME = The time corresponding to V(T), VX/R(T), VY/T(T) and VZ(T). Cards must be input in order of increasing time (second).

V(T) = The factor by which all applied velocities (X/RDOT, Y/TDOT, ZDOT) are multiplied at the corresponding time, for TYPE = 0. Intermediate values are linear interpolated between values at specified times. Any time before the first VTIME will use the first V(T), and any time after the last VTIME will use the last V(T).

VX/R(T) = The factor by which the X/R applied velocity (X/RDOT) is multiplied at the corresponding time for TYPE = 1 and 2.

VY/T(T) = The factor by which the Y/T applied velocity (Y/TDOT) is multiplied for TYPE = 1 and 3.

VZ(T) = The factor by which the Z applied velocity (ZDOT) is multiplied for TYPE = 1 and 4.

Data Output Cards—As Required (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, moments, 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 2 for use in axisymmetric geometry with spin only (GEOM = 7). If this option is to be used, Reference 2 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 nodes) 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.

= 5 will write generate and write a PATRAN neutral file model data for 3D problems, which includes surface elements only. This greatly reduces the size of the PATRAN file. Data written to file "EiPj.MDL."

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 (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.

It is also possible to generate dynamic state plots and dynamic time-history plots during the Main Routine computations. This is initiated by setting DPLOT = 1, 2, or 3 in the Plot Card for TPLOT = 1, in the Main Routine. This option was primarily developed for Silicon Graphics Computers, but it may also be used for some other computers and graphics packages.

a. State Plots

Input data for state plots are summarized in Figure 7. Included is the capability to plot geometries, velocity vectors and contours of several variables. 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. (Neither the time nor the cycle are required for dynamic plots, or plots generated after a PATRAN file has been read instead of a restart file.) End state plot data with a blank card.

State Plots Header Card (3I5, 35X, A30) — This card is required to define the case number, the graphics device, the color option, and the title on the plots. This card was not required for the 1991 version of EPIC, and must be added to 1991 input files if they are to be run on later versions of EPIC.

CASE = The same case number used in the Preprocessor and Main Routine runs. This is required to ensure user is postprocessing from correct restart file.

DVICE = Device number to identify the device on which the plots will be generated. Required only for DISSPLA graphics. Figure 30 shows various graphics devices which are available.

COLOR = 0 will not request input data for color graphics.

= 1 will request input data for color graphics. Figure 31 shows that colors are currently available for DISSPLA, RSCORS, PLOT10 (TK41XX and TK42XX) and IRIS GL plot packages. Colors are available only for Geometry plots, and Contour plots for 2D and 3D sections. Color contours are not yet available for 3D perspective plots.

TITLE = Title printed on plot. This same title will appear in subsequent plots when the TITLE input on the subsequent plots is left blank.

PATRAN File Read Card (2I5, 40X, A30) — This card allows the user to read data from a PATRAN file instead of the standard restart file. This allows the user to perform the computations and the postprocessing on different computers. When this option is used, it should be read immediately after the State Plots Header Card. Because the PATRAN files contain data for only a single time (or cycle), only data from that time (or cycle) can be plotted for a given State Plots run. Subsequent cards should leave CYCLE and TIME inputs blank (CYCLE = TIME = 0), because these are not included in the PATRAN files. Only data included in the PATRAN files can be plotted with the EPIC State Plots Postprocessor.

TYPE = 101 reads a PATRAN Model file.

= 102 reads a PATRAN Model file and a Nodal Results file.

= 103 reads a PATRAN Model file and an Element Results file.

= 104 reads all three files (Model, Nodal Results, and Element Results).

GEOM = The geometry number as specified on the Prep Miscellaneous Card. Must be in range of GEOM = 1 to 8.

TITLE = Title printed on the plot. If left blank, the TITLE input on the State Plots Header Card will be used.

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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

TIME = Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

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. (Not available for brick elements.)
	= 6 provides 2D cutting plane plot with cutting plane parallel to the Y–Z plane. For 3D geometry only. (Not available for brick elements.)
	= 7 provides 2D cutting plane plot with cutting plane parallel to the X–Y plane. For 3D geometry only. (Not available for brick elements.)
	= 8 provides a 2D cutting plot using an arbitrarily positioned cutting plane. For 3D geometry only. (Not available for brick elements.)
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.

= 10, 11, 12 is similar to SIDE = 0, 1, 2 except only the projectile is plotted. When the EDGE option is used, only the projectile is outlined.

= 20, 21, 22 is similar to SIDE 0, 1, 2 except only the target is plotted. When the EDGE option is used, only the target is outlined.

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 (D = 1.0) 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.

= 6 will plot master surface numbers on 3D perspective plot.

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.

PRINT = 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. If left blank, the TITLE input on the State Plots Header Card will be used.

Plot Limits Cards 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.

Note: When both E1-EN and M restrictions are used then an element must pass both tests to 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

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.

Geometry Color Card for COLOR = 1 (4I5) —

PLINE = The color number for all grid and outline lines in the Projectile. The colors associated with the color numbers are shown in Figure 31.

TLINE = The color number for all grid and outline lines in the Target.

NMAT = The number of materials for which a color fill in the element will be designated. Leave blank (NMAT = 0) if no material color fills are requested.

SIDEM = 0 will plot the material color-filled elements on the actual coordinates.

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

= 2 will plot the material color-filled elements on both the actual and negated R coordinates. For 2D geometry only.

Material Designation Card for NMAT > 0 (16I5) —

M1...MN = NMAT material numbers for which color numbers (colors) will be assigned.

Color Designation Card for NMAT > 0 (16I5) —

C1...CN = NMAT color numbers assigned to material numbers M1...MN. The colors associated with the color numbers are shown in Figure 31.

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). (Not applicable or available for Dynamic Plots.)

2 = Code to specify Extrapolated 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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

TIME = Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

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. (Not available for brick elements.)

= 6 provides 2D cutting plane plot with cutting plane parallel to the Y–Z plane. For 3D geometry only. (Not available for brick elements.)

= 7 provides 2D cutting plane plot with cutting plane parallel to the X–Y plane. For 3D geometry only. (Not available for brick elements.)

= 8 provides a 2D cutting plot using an arbitrarily positioned cutting plane. For 3D geometry only. (Not available for brick elements.)

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.

= 10, 11, 12 is similar to SIDE = 0, 1, 2 except only the projectile is plotted. When the EDGE option is used, only the projectile is outlined.

= 20, 21, 22 is similar to SIDE 0, 1, 2 except only the target is plotted. When the EDGE option is used, only the target is outlined.

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 (D = 1.0) 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.

= 6 will plot master surface numbers on 3D perspective plot.

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.

PRINT = 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.

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).

TITLE = Title printed on the plot. If left blank, the TITLE input on the State Plots Header Card will be used.

Plot Limits Card for AXES = 2 (6F10.0, 3I5) —

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. Note: When both E1-EN and M restrictions are used then an element must pass both tests to be plotted.

Velocity Vector Plot Card for 2D and 3D (2I5, F10.0, 6I2, 8X, F10.0, A30) —

3	=	Code to specify velocity vector 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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)
TIME	=	Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)
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.

= 10, 11, 12 is similar to SIDE = 0, 1, 2 except only the projectile is plotted.

= 20, 21, 22 is similar to SIDE 0, 1, 2 except only the target is plotted.

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.

= 10, 11, 12 is similar to SIDE = 0, 1, 2 except only the projectile is plotted.

= 20, 21, 22 is similar to SIDE = 0, 1, 2 except only the target is plotted.

= 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.

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.

TITLE = Title printed on the plot. If left blank, the TITLE input on the State Plots Header Card will be used.

Plot Limits Card for AXES = 2 (6F10.0, 2I5) —

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.

N1–NN = Range of nodes to have velocity vectors plotted. If N1 = NN = 0 all nodes will have vectors plotted.

Note: If N1 and/or NN exceed the I5 format (≥100,000), set N1 = –1 and then read N1 and NN on the following card in 2I10 format.

3D Perspective Card for VIEW = 4 (6F10.0, 2I5) —

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

N1–NN = Range of nodes to have velocity vectors plotted. If N1 = NN = 0 all nodes will have vectors plotted.

Note: If N1 and/or NN exceed the '5 format (≥100,000), set N1 = –1 and then read N1 and NN on the following card in 2I10 format.

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. (Not applicable or available for Dynamic Plots.)

4	=	Code to specify PATRAN file output.
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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)
TIME	=	Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)
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 and write a PATRAN neutral file model data for 3D problems, which includes surface elements only. This greatly reduces the size of the PATRAN file. Data written to file "EiPj.MDL."

TITLE = Title printed on the plot. If left blank, the TITLE input on the State Plots Header Card will be used.

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. 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.

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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

TIME = Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

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 contours on the actual coordinates.

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

= 2 will plot contours on both the actual and negated R coordinates. For 2D geometry only (GEOM = 4, 5, 6, 7).

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.

= 10, 11, 12 is similar to SIDE = 0, 1, 2 except only the projectile is plotted.

= 20, 21, 22 is similar to SIDE = 0, 1, 2 except only the target is plotted.

	=	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.
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.

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.

Note: When both E1-EN and M restrictions are used then an element must pass both tests to be plotted.

Contour Specification Cards for NLINE > 0 (8F10.0) — Used only for NLINE > 0 on Contour Plot Card.

CT1...CTN = Magnitude of contours to be plotted.

Contour Color Card for COLOR = 1 (3I5) —

PLINE = The color number associated with grid and outline lines in the Projectile.

TLINE = The color number associated with grid and outline lines in the Target.

FILL = 0 will plot contour lines at the value specified.

= 1 will fill the elements with the appropriate colors. The color fills can be thought of as wide contour lines. The color for a specified line will extend half way to the adjacent color contour lines.

Color Designation Card for NLINE > 0 (16I5) — This card is required only if the contour lines are specified in the Contour Specification Card. It is not required if the contours are automatically scaled (NLINE = 0).

C1...CN = Color numbers associated with contours CT1...CTN. The colors associated with the color numbers are shown in Figure 31.

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.

TYPE = Code to specify which variable is requested. Must be in the range of 11–22. See Figure 7 for description of variables.

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. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

TIME = Time of the plot which is desired (second). Plots can be requested by either TIME or CYCLE. (Leave blank for Dynamic Plots or plots generated from PATRAN file.)

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.

PRINT = 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. If left blank, the TITLE input on the State Plots Header Card will be used.

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. Options are also available to write ASCII files from binary files, and to then write new binary files from ASCII files. End with a blank card.

Time Plots Header Card (2I5, 10X, F10.0, 30X, A20) — This card is required to define the case number, the graphics device, and the title on the plots. This card was not required for the 1991 version of EPIC, and must now be added to 1991 input files if they are to be run on later versions of EPIC.

CASE = The same case number used in the Preprocessor and Main Routine runs. This is required to ensure user is postprocessing from correct time-history file.

DVICE = Device number to identify the device on which the plots will be generated. Required only for DISSPLA graphics. Figure 30 shows various graphics devices which are available for various plot packages.

T-FILTER = Time increment used to differentiate the velocities to obtain accelerations for the chunk, system and node data. If left blank (T-FILTER = 0), then the time increment will be equal to that used to write the chunk and system velocities in the file. For individual node data, with T-FILTER = 0, the instantaneous acceleration (force/mass) is plotted.

TITLE = Title printed on plot. This same title will appear on subsequent plots when the TITLE input on the subsequent plots is left blank.

System/Chunk Plot Cards—As Required (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 chunk 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 30.

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. If left blank, the TITLE input on the Time Plots Header Card will be used.

Individual Node Plot Cards-As Required (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.

TYPE = Code describing the type of plot. See Figure 8 for a description of types. Must be in the range of 40 to 53. Note that acceleration data (TYPE = 47–49) may be incorrect for sliding surface and rigid body nodes.

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.

NODE = Specific node for which plot data are requested.

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

TMAX = Maximum time included on horizontal axis if AXES = 1 (second).

SCALE = Factor by which the dependent variables are multiplied before plotting. Negative values are allowed. A blank default gives SCALE = 1.0.

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. If left blank, the TITLE input on the Time Plots Header Card will be used.

Individual Element Plot Cards–As Required (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.

TYPE	=	Code describing the type of plot. See Figure 8 for a description of types. Must be in the range of 60–76.
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.
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.
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. If left blank, the TITLE input on the Time Plots Header Card will be used.

Individual Element Cross-Plot Cards—As Required (1X, 2I2, 2I5, F5.0, 4F10.0, A20) — This card allows the user to plot one element variable versus another element variable instead of time. An example would be Von Mises Stress (TYPE = 62) versus Equivalent Plastic Strain (TYPE = 63). Applies only to TYPE = 60 to 76.

TV = TYPE to be shown on the vertical axis.

TH = TYPE to be shown on the horizontal axis.

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.

ELE = Specific element for which plot data are requested.

SCALE = Factor by which the vertical axis (TV) variables are multiplied before plotting. It is not possible to factor the horizontal axis (TH) variables.

TH MAX = Maximum variable included on the horizontal axis if AXES = 1.

TH MIN = Minimum variable included on the horizontal axis if AXES = 1.

TV MAX = Maximum variable included on the vertical axis if AXES = 1.

TV MIN = Minimum variable included on the vertical axis if AXES = 1.

TITLE = Title written on the plot. If left blank, the TITLE input on the Time Plots Header Card will be used.

PATRAN File Generation Cards–As Required (I5, 5X, I5, 45X, A20) — This card will write the time-history data onto an ASCII file which later can be read and plotted with the X-Y Plotting option in PATRAN. Can be used for TYPE = 1 to 76 as shown in Figure 8.

NTYPE = –TYPE will write a time-history file which can be read by the X-Y Plotting option in PATRAN. For example, NTYPE = –1 will write time history data for TYPE = 1 (Total Energy versus Time).

MISC = CODE for System/Chuck data. (Cannot use CODE = 0 as this produces data for three plots.)

= NODE for Individual Node data.

= ELE for Individual Element data.

TITLE = Title printed on plot. This same title will appear on subsequent plots when the TITLE input on the subsequent plots is left blank.

File Manipulation Cards—As Required (I5, 5X, I5) — This card allows for reading and writing ASCII/binary files, such that the computations and postprocessing can be performed on different computers. It also allows node velocity data to be reformatted to be used as input data for applied nodal velocities.

TYPE = 111 will read the entire binary time-history file, and then write an ASCII time-history file.

= 222 will read an ASCII time-history file (generated in a previous run by setting TYPE = 111), and then write a binary file.

= 333 will read XYZ/RTZ velocities for a specified node, and then reformat the data such that it can be used as input data for applied nodal velocities in a Main Restart run. For each node requested, input data will be generated for Velocity Cards with PUSH ≥1 and Time-Velocity Cards with PUSH ≥ 1. The required Blank Cards are also included.

NODE = 0 for TYPE = 111 and TYPE = 222.

= The node number for which the XYZ/RTZ velocity data will be reformatted as input data for applied nodal velocities, when TYPE = 333.

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

c. PATRAN Postprocessor

This subsection is included to note that PATRAN can be used for postprocessing of both state plots and time plots. This capability was developed using PATRAN 2.5. PATRAN files for state plots can be generated directly during the Main Routine run by requesting them on the Data Output Cards. They can also be generated from the EPIC restart files by requesting them in the EPIC State Plots Postprocessor, with the PATRAN Output File Card.

PATRAN files for time plots can be generated from the EPIC time file by requesting them in the EPIC Time Plots Postprocessor, with the PATRAN File Generation Cards.

d. IRIS Explorer Postprocessor

This subsection is included to note that the IRIS Explorer Postprocessor can be used for postprocessing of state plots. This postprocessor is available for SGI computers only. It is an interactive postprocessor that reads an EPIC restart file and can then postprocess the results.

4. INPUT DATA FOR THE REZONER

There are two primary reasons for rezoning. One is to improve accuracy and the other is to decrease computing time through use of a larger integration time increment. When triangular elements become very distorted (long and slender) they may not be able to properly represent gradients along the longer dimension of the element, and this can lead to artificial stiffness. Similarly, during high distortion the minimum altitude of the element can become very small and this decreases the integration time increment, which is bounded by the sound speed transit time across the element. Rezoning allows the user to replace distorted elements with compact elements; decreasing the larger dimension gives greater accuracy, and increasing the shorter dimension gives a larger integration time increment.

There are two separate functions performed in rezoning. The first is to delete the distorted grid and to replace it with a better grid (more compact elements). The second function is to transfer the physical properties (node and element variables) from the old grid to the new grid. This second function is performed automatically without user intervention.

The primary functions performed during rezoning are as follows:

- The EPIC code reads the restart file which must have been previously generated by the Preprocessor or Main Routine.
- The element variables from the restart file are transferred to nodal quantities. For example, the nodal pressure is the average of the element pressures for all elements attached to a specified node.
- Portions of the old grid (from the restart file) are deleted and the new grid is generated. The node and element variables from the old grid are saved in temporary arrays.
- Each new node searches through the old grid to find the appropriate old element which contains the position of the new node.
- The velocities and accelerations for the new node are linearly interpolated from the old nodal velocities and accelerations of the three old nodes which define the old element which contains the new node.
- The center position of each new element searches through the old grid to find the appropriate old element which contains the center position of the new element.
- The variables for the new element are linearly interpolated from the old nodal quantities of the old element variables.
- The new grid, with node and element variables interpolated from the old grid, is written on a restart file. This new restart file is then available to be read by the EPIC code for further computations.

It should be noted that there is no absolute conservation of mass, momentum, or energy. If, however, the outline of the new grid closely coincides with the outline of the old grid, then these system parameters should be closely matched (within a few percent). Significant discrepancies in the outlines of the old and new grids can lead to significant discrepancies in the mass, momentum, and energy. The user should compare the summaries of the system data output for the grid before and after rezoning, to ascertain the accuracy of rezoning.

The input data necessary to perform the rezoning are shown in Figures 9 through 11. Use is restricted to 2D geometry only (GEOM = 4–7), and only triangular elements can be rezoned.

Before continuing, note the following definitions:

- A "deleted node" is a node from the original grid (before rezoning) which has been deleted. There are some instances when the coordinates of a deleted node are used.
- An "old node" is a node from the original grid (before rezoning) which has not been deleted and remains a part of the grid after rezoning occurs.
- A "new node" is a node which is introduced into the rezoned grid.
- A "previously generated new node" is a node which was previously generated during the current rezoning activity. There are some instances when a "new node" may make use of the coordinates of a "previously generated new node," when two adjacent shapes are being generated.

Rezone Description Card (2I5, A70) —

4 = Code to indicate rezoning run.

CASE = Case number for run. Must be identical to previous run which generated the restart file to be rezoned with this run.

REZONE DESCRIPTION = Description of problem provided by the user.

Rezone Miscellaneous Card (I5, 5X, F10.0, 6I5) —

CYCLE = Cycle number at which the rezone occurs. The cycle numbers for which restart files are written are given in the printed output of the previous run. If CYCLE = 0, the rezone is requested on the basis of time.

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

NPROJ = 0 will allow rezoning of projectile only.

= 1 will allow rezoning of target only.

Note: It is not possible to rezone nodes and/or elements in both the projectile and the target in a single rezone run. If it is necessary to do this, then two subsequent rezone runs must be made.

NGN = Number of groups of nodes to be deleted. If NGN = 0, then deleted nodes are read individually.

NGL = Number of groups of elements to be deleted. If NGL = 0, then deleted elements are read individually.

NNDEL = Number of nodes to be deleted.

NLDEL = Number of elements to be deleted. Only elements with the same material number can be deleted.

PRINT = 0 will provide minimal printing.

= 1 will print new nodes and elements.

= 2 will provide extensive printing for program checkout.

Individual Deleted Nodes Card for NGN = 0 (16I5) — The deleted nodes are input individually when NGN = 0.

N1...NN = Nodes to be deleted.

Group Deleted N les Card for NGN > 0 (3I5) — Use one card for each group of nodes to be deleted.

N1G = First node in group.

NNG = Last node in group. May be left blank if group has only one node.

INC = Increment between nodes. May be left blank if increment is 1.

Individual Deleted Elements Card for NGL = 0 (16I5) — The deleted elements are input individually when NGL = 0.

L1...LN = Elements to be deleted.

Group Deleted Elements Card for NGL > 0 (3I5) — Use one card for each group of elements to be deleted.

L1G = First element in group.

LNG = Last element in group. May be left blank if group has only one element.

INC = Increment between elements. May be left blank if increment is 1.

Scale/Shift/Rotate Card (F10.0, 10X, 5F10.0, 2F5.0) — Applies only to the new nodes.

RSCALE = Redefined scale factor by which the R coordinates of nodes are multiplied. Applied after the coordinate shifts (RSHIFT, ZSHIFT) and before the rotations (ROTATE/SLANT) described later.

ZSCALE = Factor by which the Z coordinates are multiplied.

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

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

ROTATE = Redefined rotation about R0 and Z0 in the R-Z plane of nodes (degrees). Applied after the coordinate shifts (RSHIFT, ZSHIFT) and the scale factors (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 R coordinates of nodes, with the relationship

$$R_{new} = R_{old} + (Z - Z0) \tan(SLANT).$$

This takes vertical lines of nodes and aligns them at an angle, SLANT, with the vertical. Applied after the other SCALE/SHIFT/ROTATE options.

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

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

Node Data Cards — These cards are required to define the new nodes for the rezoned grid. Specific instructions for the node input data are provided later. End node data with a blank card.

Element Data Cards — These cards are required to define the new elements for the rezoned grid. Specific instructions for the element input data are provided later. End element data with a blank card.

Merge Card (F10.0) — The node merging function provides a way of combining adjacent shapes to cover a complex region. Each shape can be generated using the node numbering required by the node generator. Adjacent shapes may require different node numbers for the same node location. This requirement can be met by generating a node for each node number needed. After the node and element generators have been used, then the multiple nodes (at a single location) are reduced to single nodes by the node merging function.

TOLMRG = Greater than zero to merge nodes which are close together. All nodes in a box (TOLMRG on each side) are combined to become the same node. The node number entered first (in the node input cards) will be used for the combined node. Only the newly entered nodes are merged. TOLMRG = 0 gives no node merging.

a. Node Geometry

The new node data will generally be input with the three new grid generators shown in Figure 27. The standard grid generators used in the Preprocessor can also be used for rezoning, but the three new generators can take advantage of the availability of the old grid. The new generators can use the coordinates of deleted nodes for the position of a new node. The generators can also find the edge of the deleted grid between two deleted nodes and use this line for the side of a new shape. When this edge option is used, only the approximate position of the deleted end nodes need to be given. With these features it is possible to lay out a new grid using only a geometry state plot. A description of the new node input data is given in Figure 10.

Four-Sided Shape Node Card (5I5, 25X, F10.0) — The four-sided shape is shown in Figure 27. Six cards are required for each four-sided shape generated. Additional cards are needed for certain options. The corner nodes are defined in a counterclockwise direction with the first corner node being N1. The sides are defined in a counterclockwise direction.

The first side starts at the first corner node and ends at the second corner node. The fourth side starts at the fourth corner node and ends at the first corner node. The nodes are numbered in layers. The first layer starts at the first corner node and goes across to the fourth corner node. The following layers go into the interior of the shape with the last layer going from the second to the third corner nodes. This shape can be made continuous with adjacent shapes by aligning border nodes and using the merge option. The RELAX option (described later) provides a method of more evenly spacing the interior primary nodes of this shape. The node placement algorithm gives good results for a rectangular shape but questionable placement for distorted shapes, especially those with curved sides. When questionable node placement occurs, the RELAX option can improve the placement. The border nodes are not moved. The interior primary nodes are moved to be at the average position of the other four connected primary nodes. The secondary nodes are generated later.

8	=	Identification number for four-sided node shape geometry.
N1	=	Number of the first node of the four-sided shape. This should be selected so the generated new nodes do not have the same node numbers as remaining old nodes.
NC	=	Number of nodes along the second and fourth side. Does not include the secondary (crossed triangle) nodes.
NL	=	Number of nodes along the first and third side. Does not include the secondary (crossed triangle) nodes.
IRFIX	=	Radial restraint option. If IRFIX = 1, all nodes on the axis of symmetry are restrained radially. Leave blank for no restraint.
RELAX	=	A dimensionless relaxation distance for rezoning, defined as a fraction of a characteristic grid distance. The characteristic distance is the square root of the area of the smallest element in the rezone region, before rezoning. All nodes must move less than this for the rezoning iterations to discontinue. Recommend using RELAX = 0.001 to 0.050.

Corner Node Definition Cards—4 Required (2I5, 2F10.0) — Four cards are required, one for each corner node. The first corner node is N1. The other three corner nodes are defined in counterclockwise order.

NOLD	=	The old/deleted node to use for coordinates. Leave blank if this option is not used.
NGEN	=	The previously generated new node to use for coordinates. The duplication of node definitions can be removed by the merge step. Leave blank if this option is not used.
RCNR	=	R coordinate of corner node.
ZCNR	=	Z coordinate of corner node.
		Note: The R and Z coordinates are ignored when either the NOLD or NGEN option is used.

Side Options Card (4I5) — There are five options (0, 1, 2, 3, 4) for each of the four sides (IS1, IS2, IS3, IS4).

IS1 IS2 IS3 IS4	= 0	Will equally space the side nodes on a straight line between the corner nodes.
	= 1	Will equally space the side nodes on the edge of the deleted region. If the corner nodes are not already defined as old/deleted nodes on the edge, then the corner node (whose coordinates were input as RCNR and ZCNR) is moved to the closest old/deleted edge node.
	= 2	Will position the side nodes at coordinates given on the following Side Node Coordinate Cards.
	= 3	Will place the side nodes at the coordinates of the old/deleted nodes given on the following Old Side Nodes Cards.
	= 4	Will place the side nodes at the same coordinates as the previously generated new nodes given on the following Generated Side Nodes Cards.
		Note: For side options 2, 3, and 4, an additional card (or cards) is required to define side coordinates and/or side node numbers. The side 1 option should be input first (if needed), followed by sides 2, 3, and 4.

Side Node Coordinate Cards—As Required (8F10.0) — These cards must be input in counterclockwise order.

R1...RN = R coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Z1...ZN = Z coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Old Side Nodes Cards—As Required (16I5) — These cards must be input in a counterclockwise order.

NO1...NON = Node numbers of old/deleted nodes where side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

Generated Side Nodes Cards—As Required (16I5) — These cards must be input in counterclockwise order.

NG1...NGN = Node numbers of previously generated new nodes where the side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

Three-Sided Shape Node Cards (3I5, 5X, I5, 25X, F10.0) — The three sided shape is shown in Figure 27. Five cards are required for each three sided shape generated. Additional cards are needed for certain options. The corner nodes are defined in a counterclockwise direction with the first corner node being N1. The sides are defined in a counterclockwise direction. The first side starts at the first corner node and ends at the second corner node. The third side starts at the third corner node and ends at the first corner node. The shape is meant to be approximately triangular. The first and third sides have the same number of nodes, NRING. The second side has more nodes, 2 * (NRING –1) –1. The total number of nodes is 2 * (NRING * NRING –1). The shape is composed of two regions. The first region starts at the first corner and extends to the last node before the second and third corners. The remaining region, a strip along the second side, is a strip of crossed triangles. The node numbering is also done in two regions. The first region is numbered as described for the four sided shape. The crossed triangle strip along the second side is numbered in a direction generally from corner three towards corner two. The secondary nodes are numbered first and the outside primary nodes are numbered last. The highest numbered node is corner two.

9 = Identification number for three sided shape geometry.

N1 = Number of the first node of the three sided shape.

NRING = Number of nodes on two shorter sides of shape (Sides 1 and 3). Must be 3 or larger.

IRFIX = Radial restraint option. If IRFIX = 1, all nodes on the axis of symmetry are restrained radially. Leave blank for no restraint.

RELAX = A dimensionless relaxation distance for rezoning, defined as a fraction of a characteristic grid distance. The characteristic distance is the square root of the area of the smallest element in the rezone region, before rezoning. All nodes must move less than this for the rezoning iterations to discontinue. Recommend using RELAX = 0.001 to 0.050.

Corner Node Definition Cards (2I5, 2F10.0) — Three cards are required, one for each corner node. The first corner node is N1. The other two nodes are defined in counterclockwise order.

NOLD = The old/deleted node to use for coordinates. Leave blank if you do not want this option.

NGEN = The previously generated new node to use for coordinates. The duplication of node definitions can be removed by the merge step. Leave blank if you do not want this option.

RCNR = R coordinate of corner node.

ZCNR = Z coordinate of corner node.

Note: The R and Z coordinates are not needed when either the NOLD or NGEN option is used.

Side Option Card (3I5) — The choice of five options (0, 1, 2, 3, 4) for each of the three sides (IS1, IS2, IS3) is given.

IS1 = 0 Will equally space the side nodes on a straight line between the corner nodes.
IS2
IS3

= 1 Will equally space the side nodes on the edge of the deleted region. If the corner nodes are not already defined as old/deleted nodes on the edge, then the corner node (whose coordinates were input as RCNR and ZCNR) is moved to the closest old/deleted edge node.

= 2 Will position the side nodes at coordinates given on the following Side Node Coordinate Cards.

= 3 Will place the side nodes at the coordinates of the old/deleted nodes given on the following Old Side Nodes Cards.

= 4 Will place the side nodes at the same coordinates as the previously generated new nodes given on the following Generated Side Nodes Cards.

Note: For side options 2, 3, and 4, an additional card (or cards) is required to define side coordinates and/or side node numbers. The side 1 option should be input first (if needed), followed by sides 2, 3, and 4.

Side Node Coordinate Cards—As Required (8F10.0) — These cards must be input in counterclockwise order.

R1...RN = R coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Z1...ZN = Z coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Old Side Nodes Cards--As Required (16I5) — These cards must be input in a counterclockwise order.

NO1...NON = Node numbers of old/deleted nodes where side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

Generated Side Nodes Cards—As Required (16I5) — **These cards must be input in counterclockwise order.**

NG1...NGN	=	Node numbers of previously generated new nodes where the side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

Regrid Line of Nodes Card (4I5, 2X, 3I1, I5) — Two cards are required if a single node is to be generated and three or more cards are required for more than one node. The nodes may be numbered consecutively or incremented by INC. New nodes can be generated using the coordinates of old/deleted nodes.

10	=	Identification number for regrid line of nodes geometry.
N1	=	Number of the first node.
NN	=	Number of the last node of the line. Leave blank if a single node is to be generated.
INC	=	Node number increment between corresponding nodes. Leave blank for consecutive numbering or if a single node is to be generated.
IR	=	Radial restraint. If IR = 1, all nodes will be restrained in the radial direction. Leave blank for no restraint.
IT	=	Theta restraint. If IT = 1, all nodes will be restrained in the θ direction. Leave blank for no restraint.
IZ	=	Axial restraint. If IZ = 1, all nodes will be restrained in the axial direction. Leave blank for no restraint.
IS1		Used only when more than two nodes are generated.
	= 0	Will equally space the side nodes on a straight line between the corner nodes.
	= 1	Will equally space the side nodes on the edge of the deleted region. If the corner nodes are not already defined as old/deleted nodes on the

edge, then the corner node (whose coordinates were input as RCNR and ZCNR) is moved to the closest old/deleted edge node.

= 2 Will position the side nodes at coordinates given on the following Side Node Coordinate Cards.

= 3 Will place the side nodes at the coordinates of the old/deleted nodes given on the following Old Side Nodes Cards.

= 4 Will place the side nodes at the same coordinates as the previously generated new nodes given on the following Generated Side Nodes Cards.

Note: For side options 2, 3, and 4, an additional card (or cards) is required to define side coordinates and/or side node numbers. The side 1 option should be input first (if needed), followed by sides 2, 3, and 4.

Corner Node Definition Cards (2I5, 2F10.0) — One corner card required for single node generation and two corner cards required for two or more nodes generated.

NOLD = The old/deleted node to use for coordinates. Leave blank if you do not want this option.

NGEN = The previously generated new node to use for coordinates. The duplication of node definitions can be removed by the merge step. Leave blank if you do not want this option.

RCNR = R coordinate of corner node.

ZCNR = Z coordinate of corner node.

Note: The R and Z coordinates are not needed when either the NOLD or NGEN option is used.

Side Node Coordinate Cards—As Required (8F10.0) — Required only when generating three or more nodes and IS1 = 2.

R1...RN = R coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Z1...ZN = Z coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Old Side Nodes Cards—As Required (16I5) — Required only when generating three or more nodes and IS1 = 3.

NO1...NON = Node numbers of old/deleted nodes where side nodes are to be placed. One or more cards as necessary.

Generated Side Nodes Cards—As Required (16I5) — Required only when generating three or more nodes and IS1 = 4.

NG1...NGN = Node numbers of previously generated new nodes where the side nodes are to be placed. One or more cards as necessary.

b. Element Geometry

The new element data will generally be input with the new grid generators in Figure 27. The standard grid generators used in the Preprocessor can also be used for rezoning. The element data must be input in a manner consistent with the previously input node data. A description of the new element input data is given in Figure 11.

Four Sided Shape Element Description Card (5I5) — One card is required for each four-sided shape, as shown in Figure 27. The elements are numbered consecutively, beginning with the layer along side 4 (from corner 1 to corner 4), and ending with the layer along side 2 (from corner 2 to corner 3). The number of elements generated is 4*NCOL*NLAY.

8 = Identification number for four-sided shape geometry.

MATL = Material number for the elements. Must be identical to the deleted material.

N1 = Number of first node in four-sided shape.

NCOL = Number of columns of composite elements (four crossed triangles) along sides 2 and 4.

NLAY = Number of layers of composite elements (four crossed triangles) along sides 1 and 3.

Three Sided Shape Element Description Card (4I5) — One card is required for each three sided shape, as shown in Figure 27. The element numbering follows the pattern of node numbering. The first region is numbered first and the strip along the second side is numbered from the third corner towards the second corner. The number of elements generated is 4 * (NRCOL * NRCOL –1).

9 = Identification number for three sided shape geometry.

MATL = Material number for the elements. Must be identical to the deleted material.

N1 = Number of first node in three sided shape.

NCOL = Number of composite elements (four crossed triangles) along sides one and three.

Transition Elements Description Card (16I5) — One card is required for each group of transition elements, as shown in Figure 27. The group has a central node and from 3 to 13 elements around the central node.

10 = Identification number for transition geometry.

MATL = Material number for the elements. Must be identical to the deleted material.

N1 = Number of the central node.

N2...N14 = Numbers of the perimeter nodes. At least three nodes must be given. The order of the nodes must be counterclockwise. Newly generated nodes and old (undeleted) nodes may be used.

5. 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 six commands (CYCLE, STOP, SAVE, SAVE1, SAVE2, SAVE3) 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.
SAVE3	= 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.

6. INSTALLATION, STRUCTURE, AND COMPUTER/GRAPHICS DEPENDENCIES

A series of makefiles and scripts have been created to aid in the installation of EPIC Research. These files are shipped with the distribution tape and carry file extension which designates the computer upon which they run: *.sgi, *.cry, *.vax, *.dum. Creation of all executables are automated within these procedures. Scripts to run the example problems are also included. Please note that each file will require modifications before execution to locate and define system resources. A more detailed installation description is located within file "INSTALL.DOC". Please refer to this document for a complete description of the setup procedure.

The subroutines for the EPIC Research code are contained in several files. This is done to allow for the following options:

- **Different Types of Runs**
  - Preprocessor and/or Main Routine with Dynamic Plots
  - Preprocessor and/or Main Routine without Dynamic Plots
  - Main Routine for EPIC-CTH Link (without Dynamic Plots)
  - Postprocessor State Plots
  - Postprocessor Time Plots
  - IRIS Explorer Postprocessor State Plots
- **Different Computers**
  - VAX
  - CRAY
  - SGI
  - Other
- **Different Graphics**
  - CALCOMP
  - DISSPLA
  - PLOT10
  - IRIS GL
  - DGL (where available for non-SGI computers)
  - RSCORS (not available for dynamic plots)
  - Other.

The following shows which files of subroutines are required for the different types of runs:

- **Preprocessor and/or Main Routine with Dynamic Plots**
  - epic1.f and epic2.f and epic3.f and epic4.f and epic5.f
  - subs.f
  - p1dynm.f
  - p1stubs.f
  - vax.f or cray.f or sgi.f or dummy.f
  - calcmp.f or displa.f or plot10.f or irisgl.f or pdummy.f
- **Preprocessor and/or Main Routine without Dynamic Plots**
  - epic1.f and epic2.f and epic3.f and epic4.f and epic5.f

- subs.f
- plstubs.f
- vax.f or cray.f or sgi.f or dummy.f

- **Main Routine for EPIC-CTH Link (without Dynamic Plots)**
  - lepcth.f
  - epic1.f and epic2.f and epic3.f and epic4.f and epic5.f
  - subs.f
  - plsubs.f
  - vax.f or cray.f or sgi.f or dummy.f

- **Postprocessor State Plots**
  - post1.f
  - subs.f
  - plstat.f
  - plsubs.f
  - vax.f or cray.f or sgi.f or dummy.f
  - calcmp.f or displa.f or plot10.f or irisgl.f or rscors.f or pdummy.f

- **Postprocessor Time Plots**
  - post2.f
  - subs.f
  - vax.f or cray.f or sgi.f or dummy.f
  - calcmp.f or displa.f or plot10.f or irisgl.f or rscors.f or pdummy.f

- **IRIS Explorer Postprocessor State Plots**
  - Read EPIC.*
  - sgi.f
  - subs.f

The EPIC Research code is written in FORTRAN 77 and is generally compatible with most computers. There are, however, some specific computer dependencies. The vax.f, cray.f, and sgi.f files are for VAX, CRAY, and SGI computers, respectively. The dummy.f file 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-95 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 subroutine ENVIRO, found in the system-specific files. 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. The variables MXRSZ and NUPV are used by subroutine SAVE to divide large amounts of data into pieces that the machine can handle.

There are also some graphics dependencies. The postprocessors for State Plots (POST1) and Time Plots (POST2) provide graphics capabilities using one of six available plotting packages: CALCOMP, PLOT10, DISSPLA, RSCORS, IRIS GL, and DGL. The latter four interfaces are implemented by mimicking the CALCOMP subroutine calls with PLOT10/DISSPLA/RSCORS/IRIS GL/DGL routines. Though this method does not take advantage of certain PLOT10/DISSPLA/RSCORS/IRIS GL/DGL features, it leaves POST1 and POST2 essentially unchanged. Equally important, it provides a consistent approach for incorporating new graphics libraries.

The addition of the PLOT10/DISSPLA/RSCORS/IRIS GL/DGL interfaces introduces certain system dependencies into the code. Principal among them is the nomination of available devices (terminals, printers, plotters, etc.) for output. Choosing a device is accomplished within subroutine PLOTS. Each plot package requires a slightly different device nomination syntax and compile/link sequence.

One non-portable subroutine, ISBTCH, is also included with the interfaces. ISBTCH is a logical function which returns TRUE if the current process is executing in batch mode.

Its purpose is to prevent a device selection which is incompatible with the run-time environment (i.e., nominating a terminal device in batch mode). Currently, only vax.f has a functioning ISBTCH routine. All other versions return FALSE, regardless of the state of the process. The function should be modified only if this increased functionality is warranted.

The DISSPLA graphics library will allow run-time nomination of devices. Figure 30 lists the "default" device map currently available. Subroutine PLOTS may need to be modified to be consistent with the devices available at the user's facility. Contact your system administrator for a complete list of DISSPLA supported devices at a specific facility.

Unlike DISSPLA, the PLOT10 graphics library will allow only compile-time nomination of devices. That is, a single device is linked to each program. This requires a different executable for each device. It can be seen from Figure 30, for instance, that each family of Tektronix terminals (TEK40XX, TEK41XX, TEK42XX) requires a different link module (labeled as DR40XX, DR41XX, DR42XX). No modifications to PLOTS are required.

Tektronix terminals allow graphics objects to be treated and stored as a single entity–a segment. In the PLOT10 interface, each graph produced is saved in segment number N, where N runs from one to the number of plots produced. When the program exits, these segments remain in the terminal's buffer and can be moved, copied, rotated, scaled, and printed as needed.

The CALCOMP package supports a single device–a CALCOMP plotter. Hence, no modifications to PLOTS are required.

As with the CALCOMP interface, only one device is supported in the IRIS GL package. The GL interface was written and tested on a 310/VGX workstation running IRIS 4.0. Compatibility across other SGI architectures and operating systems has not been established.

The IRIS GL interface supports multiple windows for both static and dynamic plots. A separate window is created for each plot contained in the post-processing data file. Windows may be resized, iconified, moved, and closed as needed. Limited zooming is available by pressing the X and Z keys. Each keystroke produces a 5 percent reduction/enlargement, respectively, of the displayed image. Panning is accomplished by pressing the left, right, up, and down arrow keys. Each keystroke here produces a fractional shift of the axis in the direction indicated. All windows events are processed immediately after an image is displayed and, for dynamic plots, at the end of every cycle.

Status information for any IRIS GL graph can be obtained by right-mousing on the window. This produces a submenu of window options. Translation and scaling resets can be accomplished by selecting the appropriate menu choice. Graph axis, scale, translation, labels, and header information can be displayed by selecting the "Get info . . ." option.

The Distributed Graphics Library (DGL) has also been incorporated. This protocol allows users to connect to a remote machine to do simulations, yet display the results on their local SGI workstation.

To establish a distributed connection, the DGL protocol must be followed. The connection rules are described on page 19-3 of the Graphics Library Programmers Guide. Prior to running EPIC/POST, the user must set either DGLSERVER or REMOTEHOST/REMOTEUSER environment variables. This is accomplished with the following commands:

```
setenv DGLSERVER IPName
        or
setenv REMOTEHOST IPName
setenv REMOTEUSER UserName
```

Where IPName is the fully qualified IP server name (e.g., um5.eglin.af.mil) of your LOCAL machine. If your user name is different on the two systems, you will be required to set environment variable REMOTEUSER to your local user name. Otherwise, your current user name is used for the connection. A local connection is established if no environment variables are defined.

To remove the necessity of choosing a particular device during program execution, the RSCORS interface is implemented in the post-processing mode. As a result, both POST1 and POST2 write plot information to an intermediate plot file, "RSCORS.PLT." This file can then be displayed on a particular device using one of the available post option processing (POP) programs supplied with the RSCORS graphics library. The interface was written and tested under RSCORS version 3.05.

Delaying device nomination introduces certain limitations into the RSCORS interface as much of the post processing is removed from POST1 and POST2. First among these is the choice of a color table. The X-Windows interface (POPX11) builds the color table based on system defaults, regardless of the color table defined in POST1. The Tektronix drivers (POPTK4, POPT05, POPT15), conversely, allow up to eight user-defined colors. Hence, the current implementation is limited to the first eight colors of Figure 31. Additional colors may be added by modifying the POP processors as needed and increasing variable MAXCLR within include file "RSCRS."

One final limitation exists as a result of POP processing. Certain display devices permit hardware fills of polygons, while others rely on software to complete the operation. The RSCORS graphics library requires that this choice be made during program execution. The RSCORS interface defaults to software fills for the greatest compatibility among different devices. To increase clarity and drawing speed for terminals capable of hardware fills, the user may wish to modify the call in subroutine PLOTS from POLYCS(0) to POLYCS(-1).

The PDUMMY.FOR subroutines allow the Postprocessors to run without graphics capability. This can be used to generate ASCII files which are portable between different computers. See descriptions for the PATRAN Output File Card in the State Plots Postprocessor, as well as the PATRAN File Generation Cards and the File Manipulation Cards in the Time Plots Postprocessor.

A partial hierarchy chart of subroutines is shown in Figure 32.

7. FILE DESIGNATIONS

There are many files required for the various options in the EPIC Research code. The specific file designations are as follows. These designations will be changed when running linked EPIC-CTH computations

INP1	= 1 Input file for dynamic state plots and POST1 (file name for CRAY is post1.in).
INP2	= 2 Input file for dynamic time-history plots and POST2 (file name for CRAY is post2.in).
NSURF	= 3 Temporary storage for Main Routine.
ITPASC	= 3 Text file (Input and Output) for Time Plot Postprocessor.
IN	= 4 Input file (file name for CRAY is epic.in).
IOUT	= 6 Output file (file names for CRAY are epic.out for EPIC, post1.out for POST1, and post2.out for POST2).
ITPLIN	= 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).
ITPLOT	= 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 the Main Routine with SAVE = 3 option.

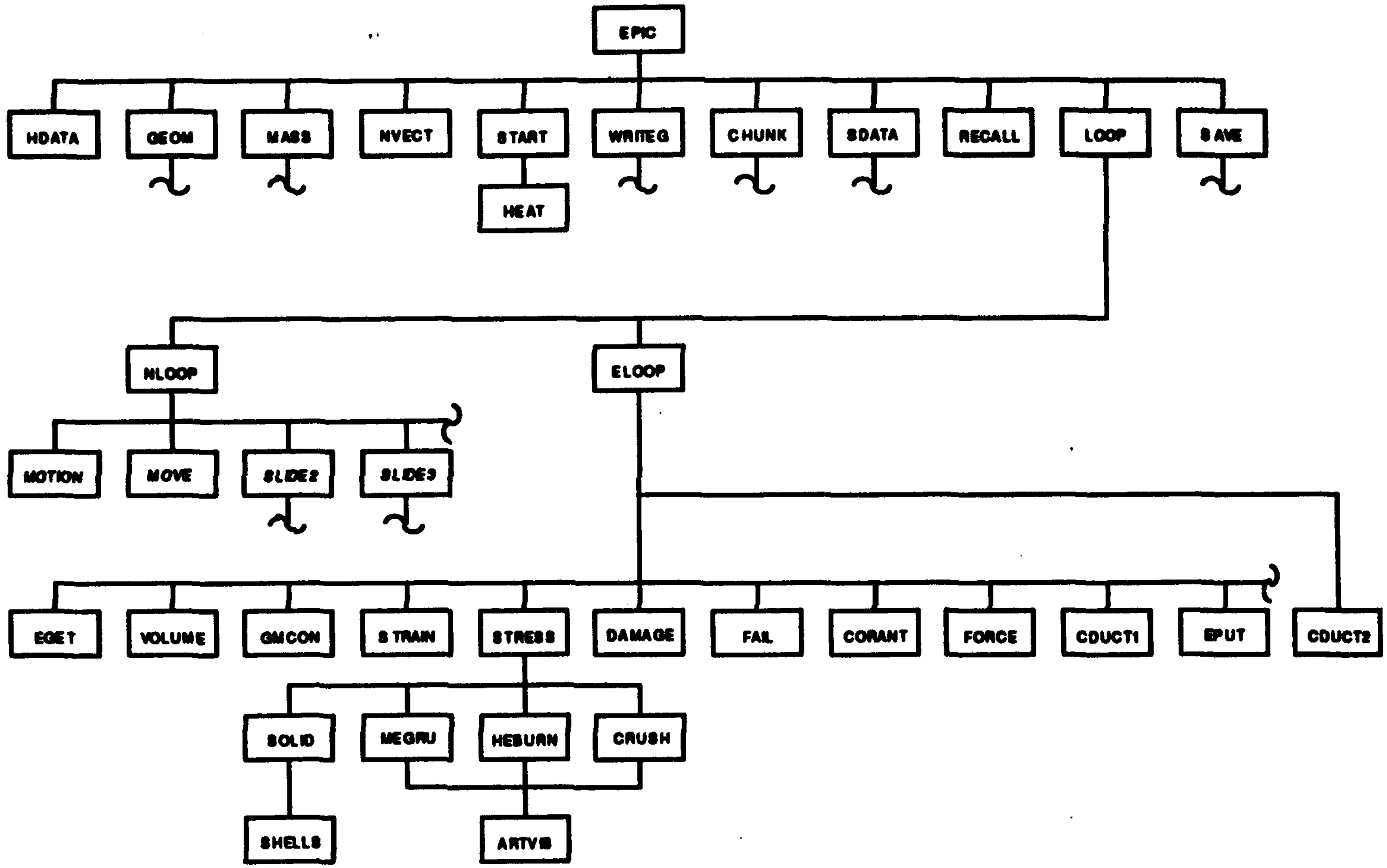


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Figure 32. Partial Hierarchy Chart for EPIC Research Subroutines

INDAP1	=	13 Input file from INP1 with comments removed.
INDAP2	=	14 Input file from INP2 with comments removed.
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 input and output.
NPATOT	=	20 PATRAN Node file input and output.
LPATOT	=	21 PATRAN Element file input and output.
INPAT	=	30 PATRAN file used by the EPIC Preprocessor (file name for CRAY is epic.pin).
(Constant)	=	32 CALCOMP picture file out.

8. 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, ELEMNQ, MISC2 and SLID5C. An explanation of the variable names is given in BLOCK DATA INITAL. Some additional comments are as follows:

- The element block size (MXLB) and the node block size (MXNB) can significantly affect the CPU time. The users should determine the optimum block sizes for their specific computers. Generally, a larger block size (MXLB = MXNB ≥ 1024) is desirable for Cray and other large vectorizing computers. For work stations, however, a smaller block size (MXLB = MSNB = 128) may be more optimum because it will keep the primary computations in cache memory for faster execution.

- If no RDG materials are used, the eleven arrays in ELEMNQ may be set to the minimum size MXLQ = 1.

- If RDG materials are used, the eleven arrays in ELEMNQ may be set to the maximum number of elements MXLQ = MXL. MXLQ can be made smaller but must be at least as large as the largest element number of elements using an RDG material.

- If sliding for parallel computers (SEEK = 5 on the Sliding Interface Identification Card) is not used then the parameters in file SLID5C may be set to 1.

- When sliding for parallel computers is used then uncomment the full usage line in file SLID5C and comment out the "not used" line.

9. EXAMPLE PROBLEMS

Some recent applications, using the EPIC code, are provided in References 34–37. This subsection contains input data and computed results for the following example problems.

- Example 1 — 1D Bar Impact
- Example 2 — Cylinder Impact
- Example 3 — 2D Perforation with Erosion
- Example 4 — 3D Perforation with Erosion

It should be noted that the input data for the 3D example uses DP3 = 0, which does not provide double precision for the volume computations and some of the sliding interface computations. For 32-bit computers, it may be necessary to use DP3 = 1 for some problems. For 64-bit computers, however, double precision is not necessary and DP3 = 0 should be used.

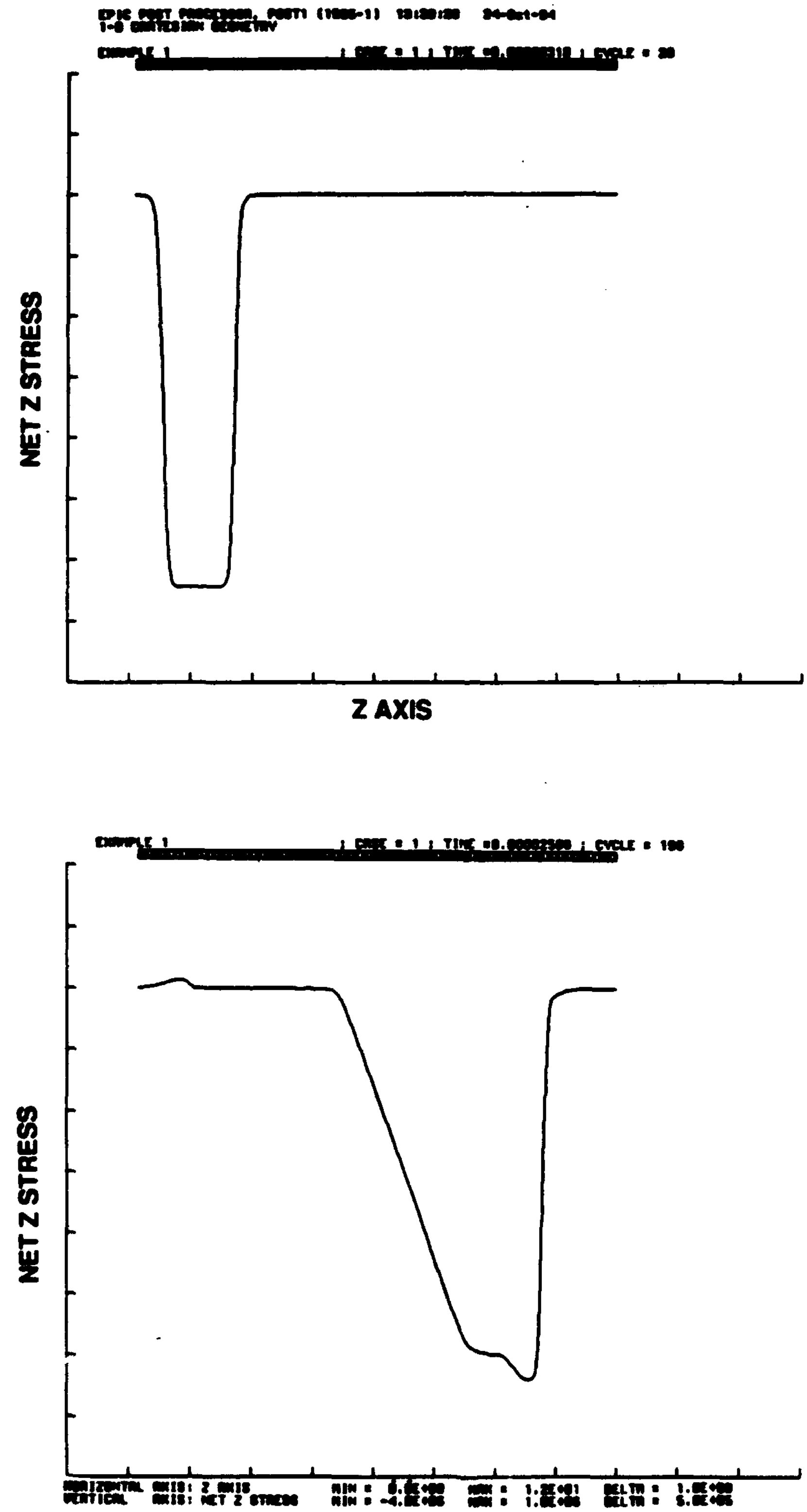

Figure 33. Example 1: 1D Bar Impact

```
$ RESEARCH EPIC EXAMPLE 1 - 1D WAVE PROPAGATION
$
$TYPE CASE....DESCRIPTION.OF.PROBLEM.........................................
    2     1 EXAMPLE 1 - 1D WAVE PROPAGATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK NOCK SCATpcRTZ SPLT  DP3 UNIT/////  PER
    1    0    1    1    0    0    0    0        001000    0    0    0
$MATL    0  DAM FAIL DFRC EFAL solids from library
    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/R0    Z0
       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/R0    Z0
       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       Y"ET       ZDET      TBURN                  XGRAV      YGRAV      ZGRAV
         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
$TPLT DROP///// PRES PUSH  HRG      VFRACT
    1
$ SYS NPLT LPLT DPLT      DTSYS       TSYS     DTNODE      TNODE      DTDYN      TDYN
    1    0    1    1   0.000001        0.0   0.000001        0.00.00000025       0.0
$  L1    L2    L3    L4    L5    L6    L7    L8    L9   L10   L11   L12   L13   L14   L15   L16
   50
$       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 34. Input Data for Example 1

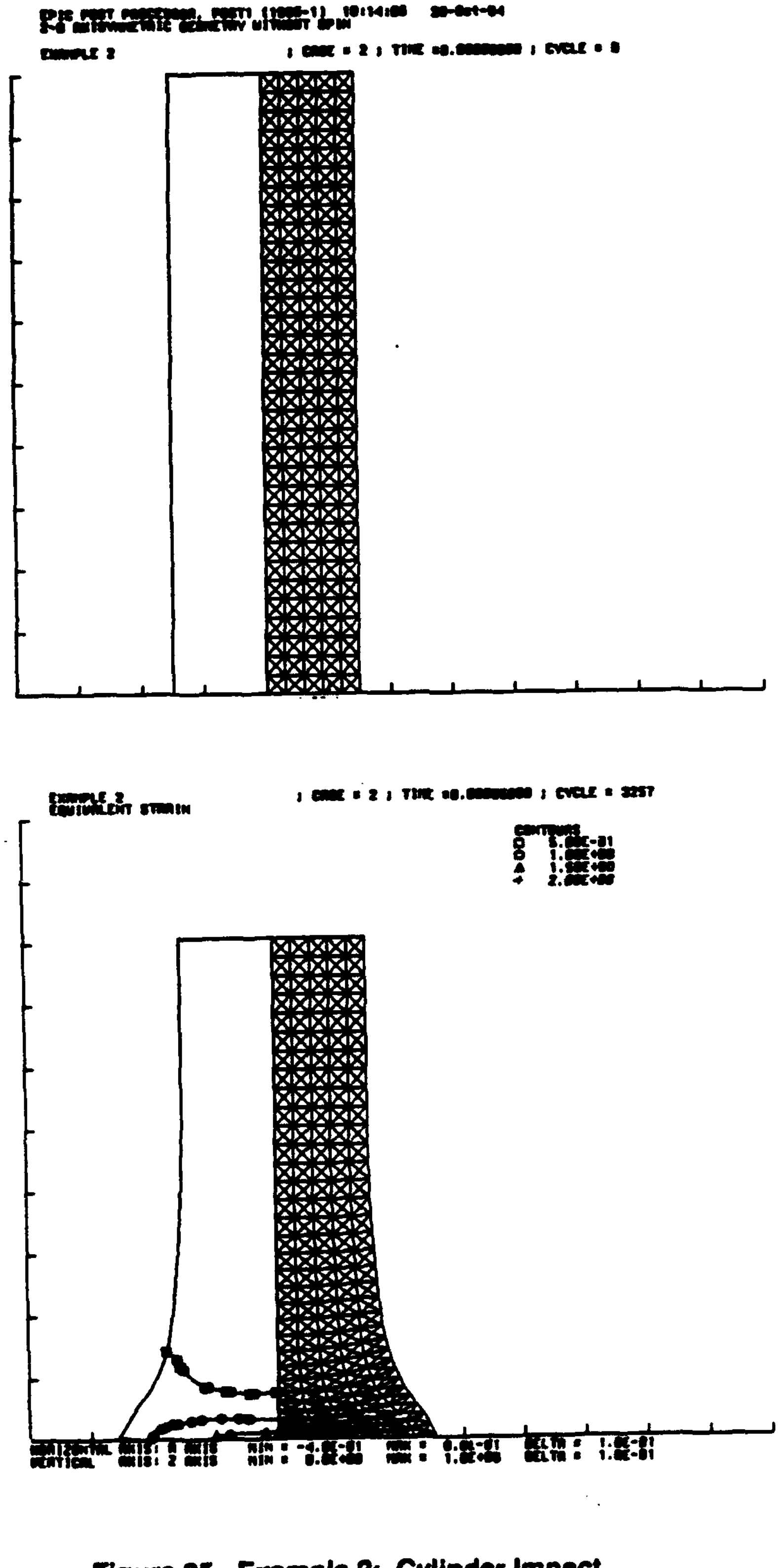

Figure 35. Example 2: Cylinder Impact

```
$ RESEARCH EPIC EXAMPLE 2 - CYLINDER IMPACT
$
$TYPE CASE....DESCRIPTION.OF.PROBLEM.........................................
    2     2 EXAMPLE 2 - 2D CYLINDER IMPACT ONTO A RIGID SURFACE
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK NOCK SCATpcRTZ SPLT  DP3 UNIT/////  PER
    6    0    1    0    0    0    0    0    0    02001    0    0    0
$MATL    0  DAM FAIL DFRC EFAL solids from library
   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/R0    Z0
       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/R0    Z0
       1.0        1.0        1.0
     $ BLANK FOR END OF TARGET NODES
$ PROJECTILE ELEMENTS
$ ROD ELEMENTS
$    2 MATL   N1 DIAG NOER NIER NLAY FULL SHEL PLAC  RZN 1234       THICK      RELAX
     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                 XGRAV      YGRAV      ZGRAV
       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
$TPLT DROP  ADD PRES PUSH  HRG      VFRACT
    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 36. Input Data for Example 2

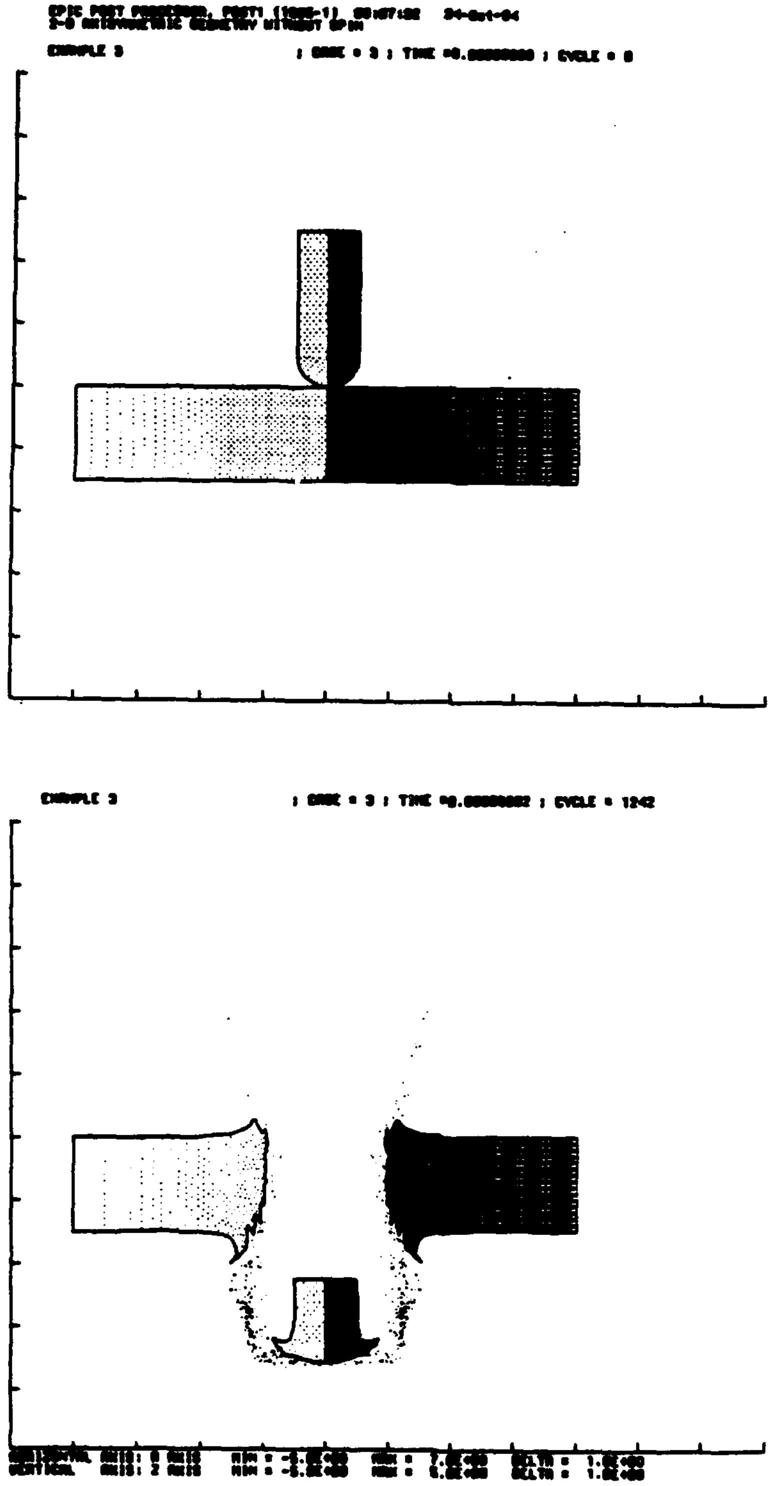

Figure 37. Example 3: 2D Perforation with Erosion

```
$ RESEARCH EPIC EXAMPLE 3 - PROJECTILE NORMAL IMPACT AND TARGET PERFORATION
$
$TYPE CASE....DESCRIPTION.OF.PROBLEM.......................................
   2     3 EXAMPLE 3 - 2D NORMAL IMPACT AND PERFORATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK NOCK SCATpcRTZ SPLT  DP3 UNIT/////  PER
   6    0    1    2    0    0    0    1    0       03  0    0    0    0
$MATL    0  DAM FAIL DFRC EFAL solids from library
   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/R0   Z0
      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/R0   Z0
      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 FULL SHEL PLAC  RZN 1234       THICK      RELAX
    2    1    1    5    5    1   16
$ NOSE ELEMENTS
$   3 MATL   N1 DIAG NOER NIER      FULL 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  RZN 1234       THICK      RELAX
    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
```

Figure 38. Input Data for Example 3

```
$ 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
    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                 XGRAV     YGRAV     ZGRAV
       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
$TPLT DROP///// PRES PUSH  HRG    VFRACT
    1    0    0    0    0    0        0.0
$ 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 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 38. Input Data for Example 3 (Concluded)

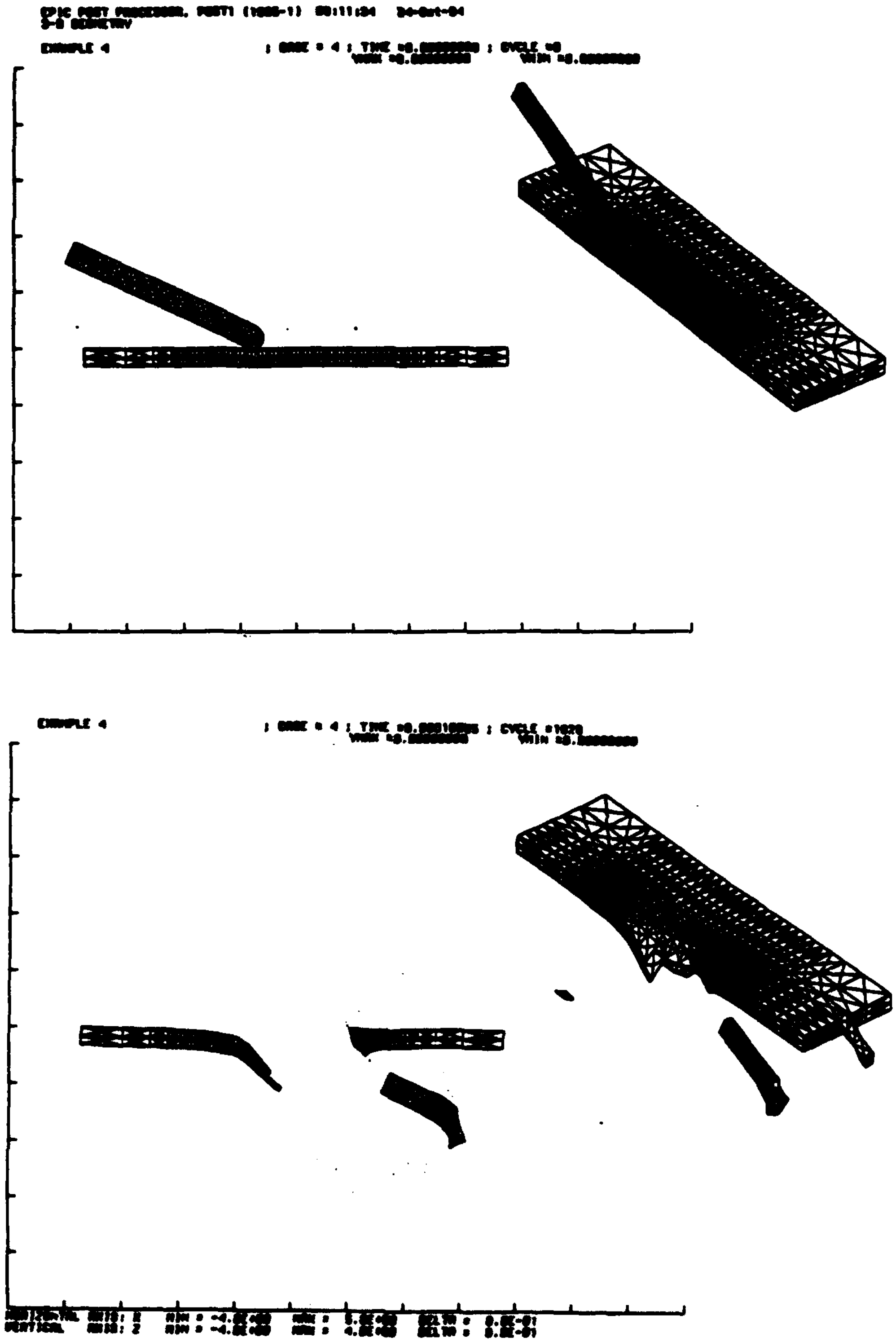

Figure 39. Example 4: 3D Perforation with Erosion

```
$ RESEARCH EPIC EXAMPLE 4 - 3D PROJECTILE OBLIQUE IMPACT AND PERFORATION
$
$TYPE CASE....DESCRIPTION.OF.PROBLEM.......................................
    2    4 EXAMPLE 4 - 3D OBLIQUE IMPACT AND PERFORATION
$GEOM PRNT SAVE NSLD NMAS NRST NRIG NCHK NOCK SCATpcRTZ SPLT  DP3 UNIT/////  PER
    8    0    1    2    0    0    0    1    0     04000    0    1    0
$MATL    0  DAM FAIL DFRC EFAL solids from library
    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/R0   Z0
      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/R0   Z0
      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 FULL SHEL PLAC  RZN 1234       THICK       RELAX
    2    1    1    5    1    1   19
$ NOSE ELEMENTS
$    3 MATL   N1 DIAG NOER NIER      FULL 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  RZN 1234       THICK       RELAX
    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  IDW
    1  506          5   17    4    1   57
$ S1G  SNG  INC
    1  348    1
```

Figure 40. Input Data for Example 4

```
$ 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
    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                XGRAV     YGRAV     ZGRAV
        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
$TPLT DROP///// PRES PUSH  HRG     VFRACT
    1
$ SYS NPLT LPLT DPLT     DTSYS      TSYS    DTNODE     TNODE    DTDYN      TDYN
    1    0    0    0  0.000001  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 40. Input Data for Example 4 (Concluded)

REFERENCES

1. G.R. Johnson, *EPIC-3, A Computer Program for Elastic-Plastic Impact Calculations in 3 Dimensions*, Honeywell Inc., Hopkins, Minnesota, Contract Report BRL-CR-343, July 1977.

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4. G.R. Johnson, *EPIC-2 User Manual AFATL 1983 Version*, Honeywell Inc., Edina, Minnesota, Contract Report AFATL-TR-86-54 (Technical Note), 1986.

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