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PATCHES-III

USER'S MANUAL

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AIR FORCE ROCKET PROPULSION LABORATORY
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NOTICES

FOREWORD

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This report is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.

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PATCHES-III is a computer program for the analysis of general three-dimensional composite structures and materials. The program constructs solid geometry models and material distribution models using parametric cubic basis functions. Available finite elements range from the 64 node CCC element to the 4 node LLX element for axisymmetric models. The User's Manual is the dictionary or archive source for definitions of all available program options. The program determines the linear elastic response of fully anisotropic composites to thermal loads, mechanical loads and imposed displacements.

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CHAPTER 1

INTRODUCTION

1.1 Overview

PATCHES-III is a computer program for the analysis of general three-dimensional composite structures, laminated composite structures, and axisymmetric composites. It determines the linear elastic response of a general heterogeneous anisotropic solid under thermal loads, mechanical loads, and imposed displacements. The analysis model is based on a 64-node isoparametric solid finite element with variable material properties. This element efficiently models the strain discontinuities at heterogeneous material boundaries, as well as the continuous strains at homogeneous boundaries. The program constructs models for geometry and physical data using piecewise parametric cubic modeling of lines, surfaces, and volumes. This approach eliminates the grid point modeling restriction of most finite element programs by allowing the synthesis of continuous models for both geometry and physical data. It is necessary to input coordinates for at most a few grid points; coordinates for all other grid points are computed internally, as are the parametric coefficients in the mathematical models created for lines, surfaces, and volumes. There are over two dozen bulk data directives available to create the geometry in addition to the basic grid point input. These bulk data directives may cross reference each other and may be input in any order. PATCHES-III will process them in the proper sequence and provide diagnostics if there are unresolvable ambiguities in the data. A similar set of options is available to model temperature data or any physical parameter defined over a line, surface, or volume.

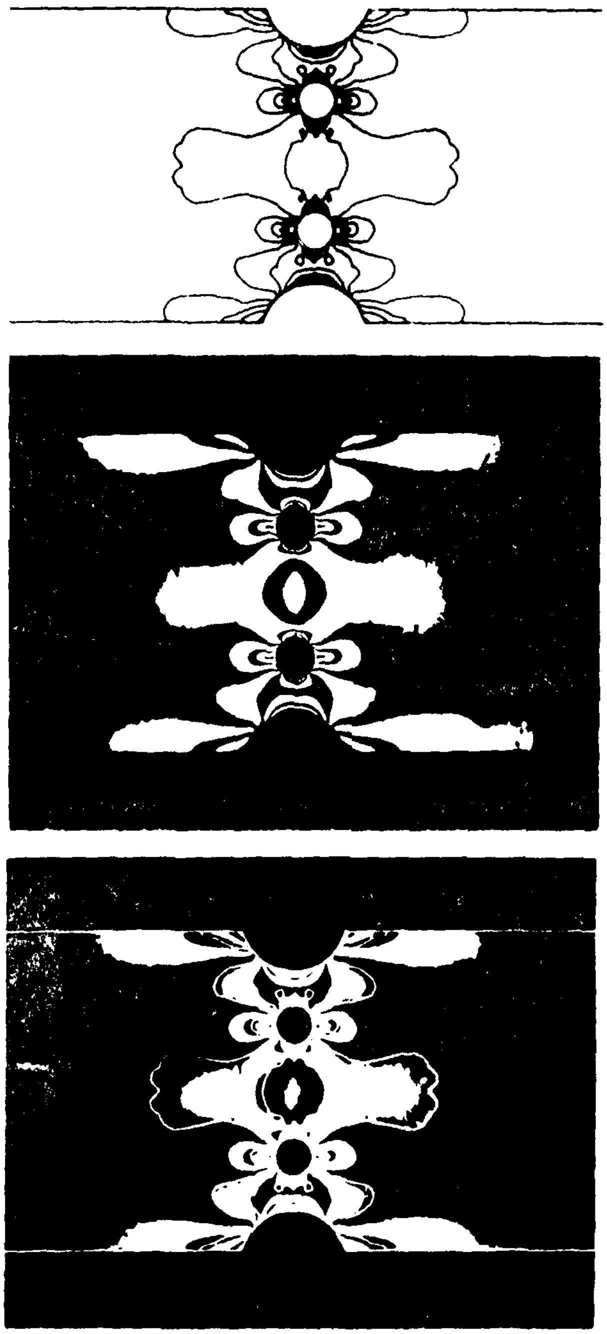
The PATCHES-III modeling system for geometry is the same as that used in the PDA/PATRAN-G interactive graphics system. Models constructed using PATRAN (Phase 1) can be directly input to PATCHES. There are minor syntax differences, but at the data level a patch is a patch is a patch. A translator program is available to convert the Phase-1 neutral file output by PATRAN into LINE, PATCH, and HPAT data for PATCHES. The Case Control and Bulk Data syntax of PATCHES are the same as those for NASTRAN to facilitate use of the program by the many people experienced with data input to NASTRAN. There are major differences in the two finite element modeling systems, but the input syntax is very similar.

The User's Manual is the source book or dictionary for all the Case Control and Bulk Data directives available in the program. A limited amount of background material on how to model with parametric cubics and a few demonstration problems are provided. Those interested in a more comprehensive description of parametric cubic modeling will find References 1, 2, and 3 helpful, and the PDA/PATRAN-G User's Guide has many interesting examples. The documentation for specific application areas such as laminated nozzle components is available as separate User's Guides. The demonstration problems in this manual illustrate the stress precision of the finite element library, which is unusually high. A graphic example of this, Figure 1-1, shows a comparison of a 31-element solution with photoelastic test results. The maximum computed stress concentration factor was equal to the experimental result to three significant digits.

1.2 Parametric Cubic Modeling

Models based on parametric cubic polynomials are developed in detail in Reference 1. This chapter introduces the user to the terminology and a few basic concepts from that development. Finite dimension lines, surfaces, and volumes are continuous *geometry modeling* elements added to the familiar grid point. The mappings $\underset{\sim}{Z}(\xi)$, $Z(\xi_1, \xi_2)$, and $\underset{\sim}{Z}(\xi_1, \xi_2, \xi_3)$ that define these continuous elements are cubic, bicubic, and tricubic, respectively, based on the four Hermite polynomials, $F_i(\xi)$, often called the beam functions. They map the unit interval, unit square, and unit cube, respectively, into any desired shape (see Figure 1-2). These new modeling elements are mathematically related to each other in a very special way that allows a more complicated element to be <u>uniquely</u> constructed from the union of simpler elements and in a variety of constructions. A hyperpatch, for example, can be defined uniquely by 64 points, 16 lines, or 4 patches. This property makes possible the model construction procedures described in Chapter 2 of this manual.

The points, lines, patches, and hyperpatches of the geometry model are given by their components with respect to a global Cartesian frame whose basis vectors are denoted by $\underset{\sim}{e}_1$, $\underset{\sim}{e}_2$, and $\underset{\sim}{e}_3$ (see Figures 1-3 and 1-4). The tangent vectors $\underset{\sim}{Z},_{\xi_i}$ define the vectors $\underset{\sim}{a}_i \equiv \underset{\sim}{Z},_{\xi_i}$, and they are used to construct local curvilinear (parametric) frames. Surface constraints and loads are usually given by their components with respect to a local parametric frame, as Chapter 2 describes in detail. The 8 corner points of a hyperpatch are called grid points in PATCHES-III and are used to define the connectivity of a finite element. The 64 points associated with a uniform parametric mesh (i.e., the 1/3 points) are termed mesh points, and, obviously, 8 of these points are also grid points. Mesh points normally are not used to construct models, but they are the recovery points for all element data in PATCHES-III. The program automatically determines mesh point connectivity from the grid point connectivity.



PLAN VIEW ISOGRAM OF PRINCIPAL STRAIN DIFFERENCES

PHOTOELASTIC TEST RESULTS

OVERLAY OF PHOTOELASTIC RESULTS AND PARAMETRIC CUBIC SOLUTION

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Figure 1-1. Parametric Cubic Finite Element Accuracy

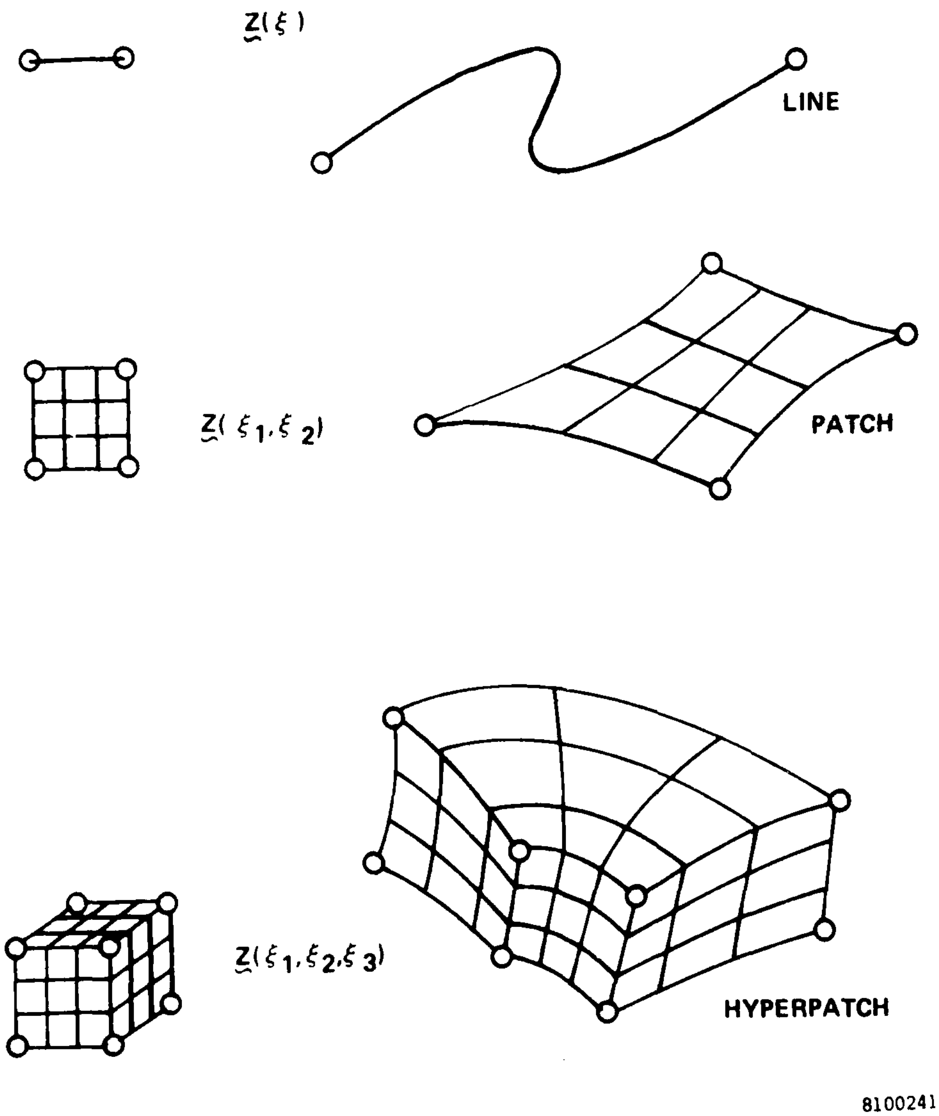
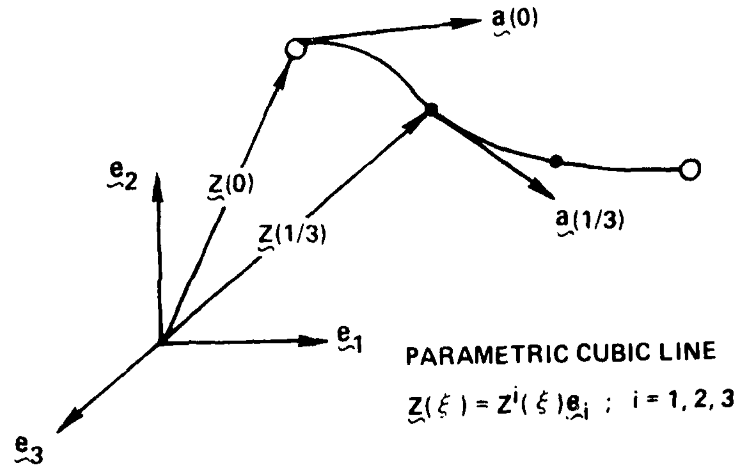


Figure 1-2. Parametric Cubic Mappings for Line, Surface and Volume Models



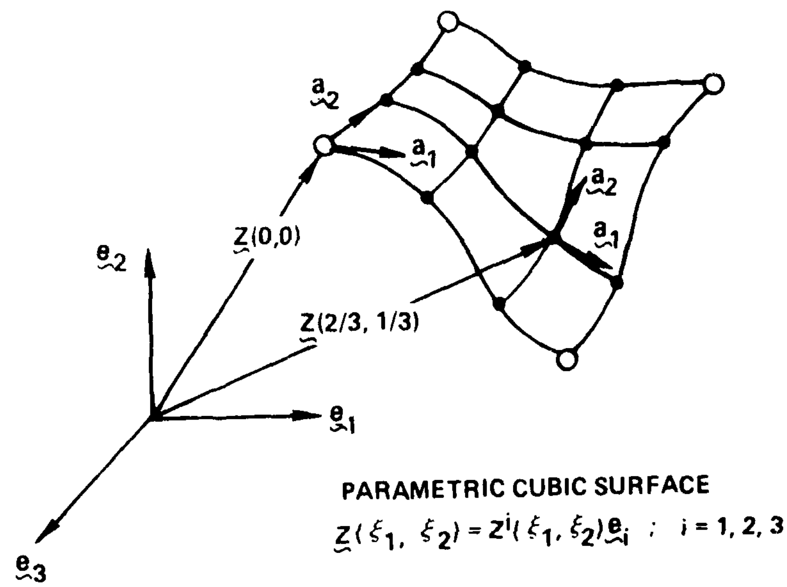


Figure 1-3. PATCHES-III Tangent Vectors for Lines and Surfaces

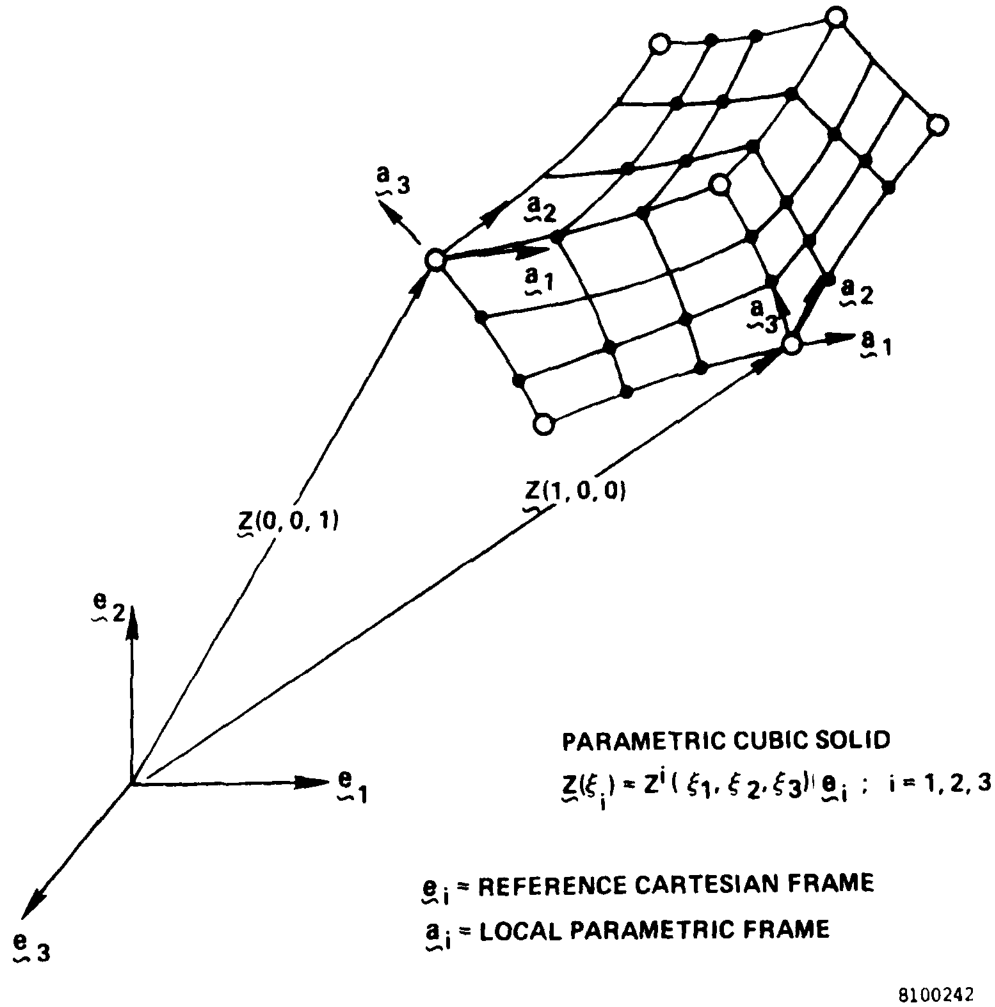


Figure 1-4. PATCHES-III Coordinate Frames for 3D Elements

CHAPTER 2

PATCHES-III CAPABILITIES

2.1 Overview

PATCHES-III will compute for a general solid: 3 components of displacement, 6 components of strain, and 6 components of stress at 64 points in each finite element used to model the body. The basic difference in capability with respect to other *three-dimensional finite* element programs is the construction of parametric cubic models for both geometry and physical data by the program. This allows the finite element model to be created with very little input, and the model itself efficiently predicts the response of heterogeneous structures. These characteristics are essential to the solution of monolithic three-dimensional problems with the resources normally available for a structural analysis. This section describes techniques for creating parametric cubic models and the matrix solution method available in PATCHES-III.

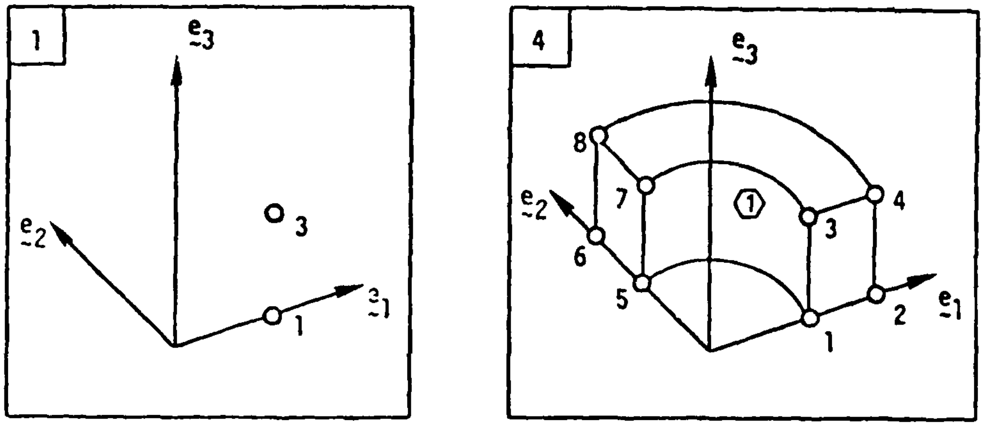
In mathematical terms a parametric cubic model is one in which the interpolation functions are multivariate and piecewise cubic in the parameters, ξ_i. Those interested in a mathematical development are referred to Reference 1. This discussion is for the structural analyst familiar with finite element modeling and interested in using PATCHES-III without becoming expert in parametric cubics. The basic concept is construction: lines from points, surfaces from lines, and hypersurfaces from surfaces. Parametric models: $\underset{\sim}{Z} = (Z^i(\xi))$, $\underset{\sim}{Z} = (Z^i(\xi_1, \xi_2))$, and $\underset{\sim}{Z} = (Z^i(\xi_1, \xi_2, \xi_3))$ are used because they are convenient for numerical work and independent of the shape of the line, surface, or hypersurface. A geometric line requires 12 parameters for definition, a geometric surface patch 48 parameters, and a geometric hypersurface patch (hyperpatch) 192 parameters. These parameters may be uniquely given in 3 different but mathematically equivalent ways: (1) Algebraic, in which the coefficients of ξ^ℓ or $\xi_i^\ell \xi_j^m$ or $\xi_i^\ell \xi_j^m \xi_k^n$ are given; (2) Geometric, in which the derivatives $\underset{\sim}{Z},_{\xi_i}$ or $\underset{\sim}{Z},_{\xi_i \xi_j}$ or $\underset{\sim}{Z},_{\xi_i \xi_j \xi_k}$ are given at the corners; and (3) Point, in which the value of Z is specified at 4, 16, or 64 points and where certain of these points must be interior points. How the user directs PATCHES-III to compute these parameters will be described briefly.

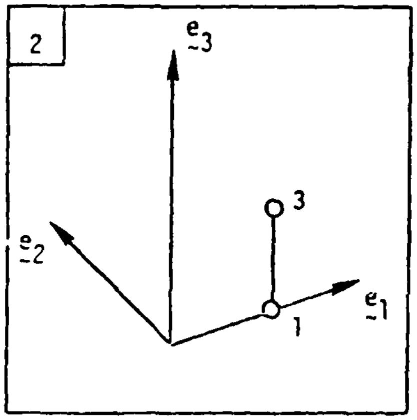
2.2 Geometry Modeling

Construction of the geometry model is accomplished through the translation, rotation, segmentation, interpolation, and scaling of space figures. These figures may be points, lines, surfaces, or hypersurfaces, any of which also may be the result of a previous operation. This latter feature allows the synthesis of complex models from simple input. To avoid order dependent input, PATCHES-III contains a queuing algorithm that determines the processing order required to synthesize the geometry. Diagnostics are provided when bulk data directives produce conflicting data, such as different coordinates at a grid point, or when bulk data directives contain unresolvable ambiguities, such as a reference to coordinates never computed.

Consider the construction of a hyperpatch for one segment of a thick-walled circular cylinder. Two quite different but virtually equal constructions illustrate the procedure for a simple shape. In the first, grid points 1 and 3 are input (Figure 2-1), and a straight line connecting them is created with a LINEPC card. This line is rotated about the $\underset{\sim}{e}_3$ axis through 90 degrees to form one quadrant of a cylindrical surface using a PATCHR directive. In this process, grid points 7 and 5 are automatically created. The surface 1-3-7-5 is expanded a unit amount in the direction of its normal to create a hyperpatch using the HPN directive. The grid points 2, 4, 6, and 8 are automatically created in this process along with all the hyperpatch parameters. The new grid point identification numbers are determined by the element connectivity specified with a CPDE3 directive. The construction of this 192-parameter hyperpatch required five (5) directives of very simple format. Now consider the same construction problem, but this time input grid points 1, 2, 3, and 4 (Figure 2-2). A quadrilateral surface is created with a PATCHQ directive, and this surface is rotated about the $\underset{\sim}{e}_3$ axis through 90 degrees to form a hyperpatch using the HPR directive. The construction this time required six (6) bulk data directives. Although the two figures constructed are nearly equal in volume and shape, the two hyperpatches are quite different parameterizations *of the same figure*. In the case of method one, the surface $Z^{I}(\xi_1,\xi_2,0)$ is 1-3-7-5, but for method two the surface $Z^{II}(\xi_1,\xi_2,0)$ is 1-5-6-2. The order of the ξ_i parameters in a hyperpatch is the parameterization or "sort" of the hyperpatch. Fortunately, a hyperpatch is invariate under reparameterization in PATCHES-III because multivariate interpolation functions, $F_i(\xi_1)F_j(\xi_2)F_k(\xi_3)$, are used. The program allows each finite element to be in any right-handed parameterization; however, all data input or data created for an element must use the same parameterization. This subject will be discussed further in the data modeling section.

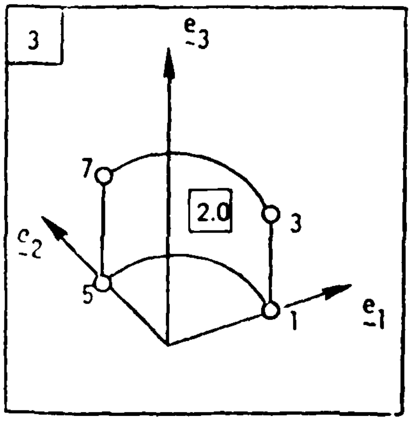
The two constructions just presented for the sample figure are but two of many that could have been made. Experience with parametric cubic modeling indicates the average user quickly develops his own techniques for creating geometry. As a rule of thumb, simple figures (cubes, etc.) should be used for finite elements whenever possible. Elements completely interior to a body, for example, can be parallelepipeds without changing the surface geometry. This reduces the cost of integrating the stiffness matrix for the associated finite elements, sometimes by a factor of five.





BULK DATA DIRECTIVES

GRID, 1, , 1.0
GRID, 3, , 1.0, 1.0
LINEPC, 1, 1, 3
PATCHR, 20, 1, , , , 0.0, 90.0, 3
HPN, 1, 20, 1.0
. . . . . .
CPDE 3, 1, 1, 3, 7, 5, , , , , 2, 4, 8, 6



STEP	BULK DATA OPTION	INPUT
1	GRID	2
2	LINEPC	1
3	PATCHR	1
4	HPN	1

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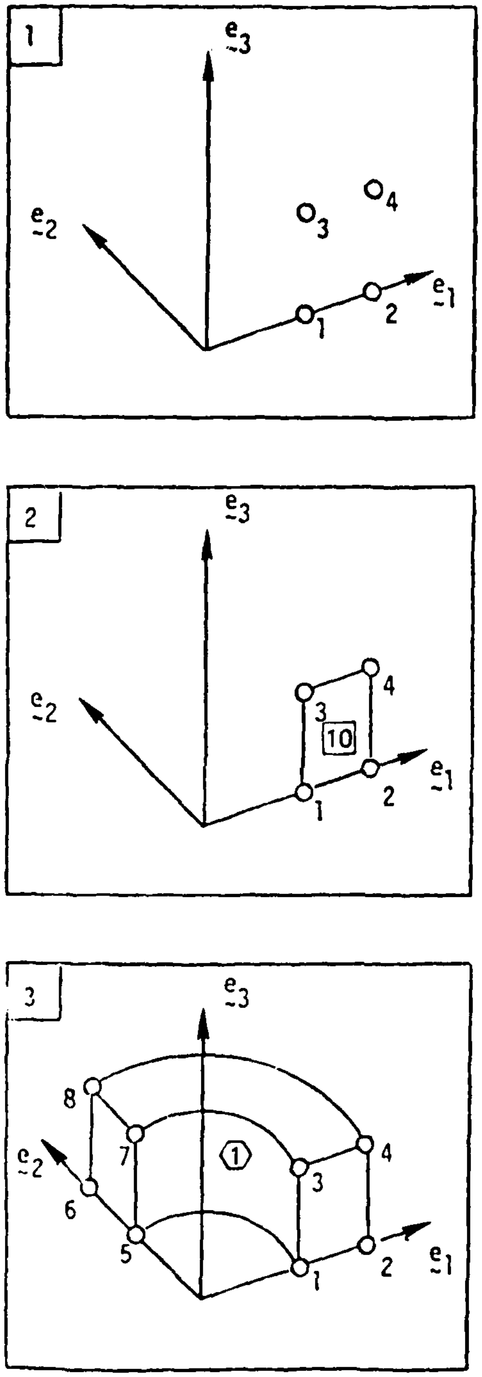
Figure 2-1. Hyperpatch Construction - Method One Example



BULK DATA DIRECTIVES

GRID, 1, , 1.0
GRID, 2, , 2.0
GRID, 3, , 1.0, 1.0
GRID, 4, , 2.0, 1.0
PATCHQ, 10, 1, 2, 4, 3
HPR, 1, 10, , , , 0.0, 90.0, 3
. . . . . .
CPDE 3, 1, 1, 2, 4, 3, , , , , 5, 6, 7, 8

STEP	BULK DATA OPTION	INPUT
1	GRID	4
2	PATCHQ	1
3	HPR	1

Figure 2-2. Hyperpatch Construction - Method Two Example

Before leaving geometric modeling, let us examine the components of a space curve represented in parametric form to help describe the basic concept behind PATCHES geometric models. It may be helpful at first to think of the parametric parameter ξ as representing time or arc length or any parameter that increases monotonically as we progress from one point on the space curve $\underset{\sim}{Z}(t)$ to another, say, from time $t = 0$ to $t = T$. Each coordinate function, $Z^i(t)$, is a well-behaved function on the interval $0 \leqslant t \leqslant T$, as illustrated by the helix, $\underset{\sim}{Z}(t) = (R \cos t, R \sin t, t)$, Figure 2-3. Using a monotonic parameter like t avoids all the tangent vector singularity problems (removable) associated with line equations in traditional analytic geometry. The tangent vector is simply $\underset{\sim}{Z}_{,t} = (-R \sin t, R \cos t, 1)$, and all the geometric properties of the curve, such as curvature and twist, can be computed easily.

The last step is to represent each coordinate function, $Z^i(t)$, with a cubic. First we change to a normalized parameter, $0 \leqslant \xi \leqslant 1$, where $t = T\xi$. Then PATCHES computes PC coefficients such that each cubic interpolates each coordinate function. The algebraic coefficients for line coordinate functions, S_k^i, in the case of a helix are

$$R \cos \xi t \cong S_1^1\xi^3 + S_2^1\xi^2 + S_3^1\xi + S_4^1 \quad (2.1.1)$$

$$R \sin \xi t \cong S_1^2\xi^3 + S_2^2\xi^2 + S_3^2\xi + S_4^2 \quad (2.1.2)$$

$$\xi t = 0 \cdot \xi^3 + 0 \cdot \xi^2 + S_3^3\xi + 0 \quad (2.1.3)$$

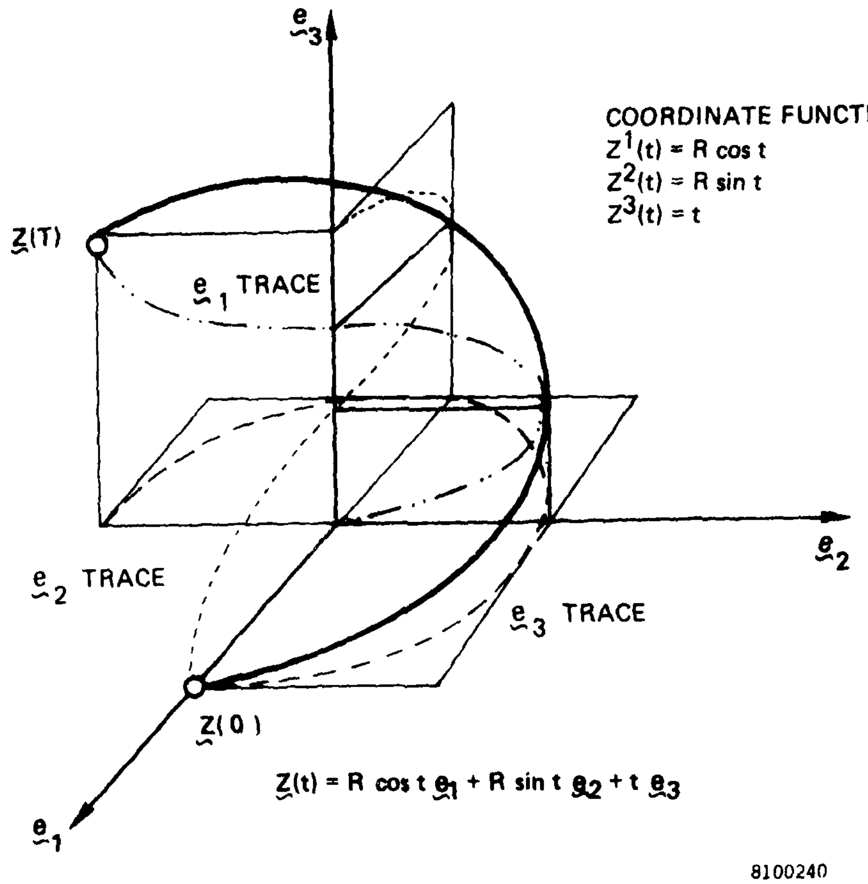


Figure 2-3. Space Curve Defined in Parametric Form

hyperpatch associated with the referenced finite element. This is the connection between data and geometry that makes the parameterization (ordering) of the hyperpatch important. As a user convenience, there is an option that will reorder any data hyperpatch, but note that since the data-geometry relation is implicit, any ordering of the input coefficients is correct. Only the user can determine if the input data distribution is oriented as he/she intended. A DRY run is recommended if there is any doubt about input data distributions. This allows the user to inspect the data models in point format. Another user convenience is the data patch equivalence option. This will allow the same data patch to be used on many different surfaces, and it is particularly useful for constant pressure loads. Note that since the data are modeled in parametric space, a constant pressure data patch is the same for every surface. It merely gives the magnitude of the pressure; the direction of the surface normal is determined from the hyperpatch for the finite element loaded by the pressure. There are options, such as the DPATCH directive, provided especially for direct input data modeling. This particular option could be used for a problem in which the temperature is a quadratic function of radius. In such cases, it is more convenient to model the data directly, rather than to synthesize the model from grid point values. In other cases, it may not even be possible to synthesize the model from grid point values. As a convenience in these situations, options are provided that are divorced from any grid point data sets.

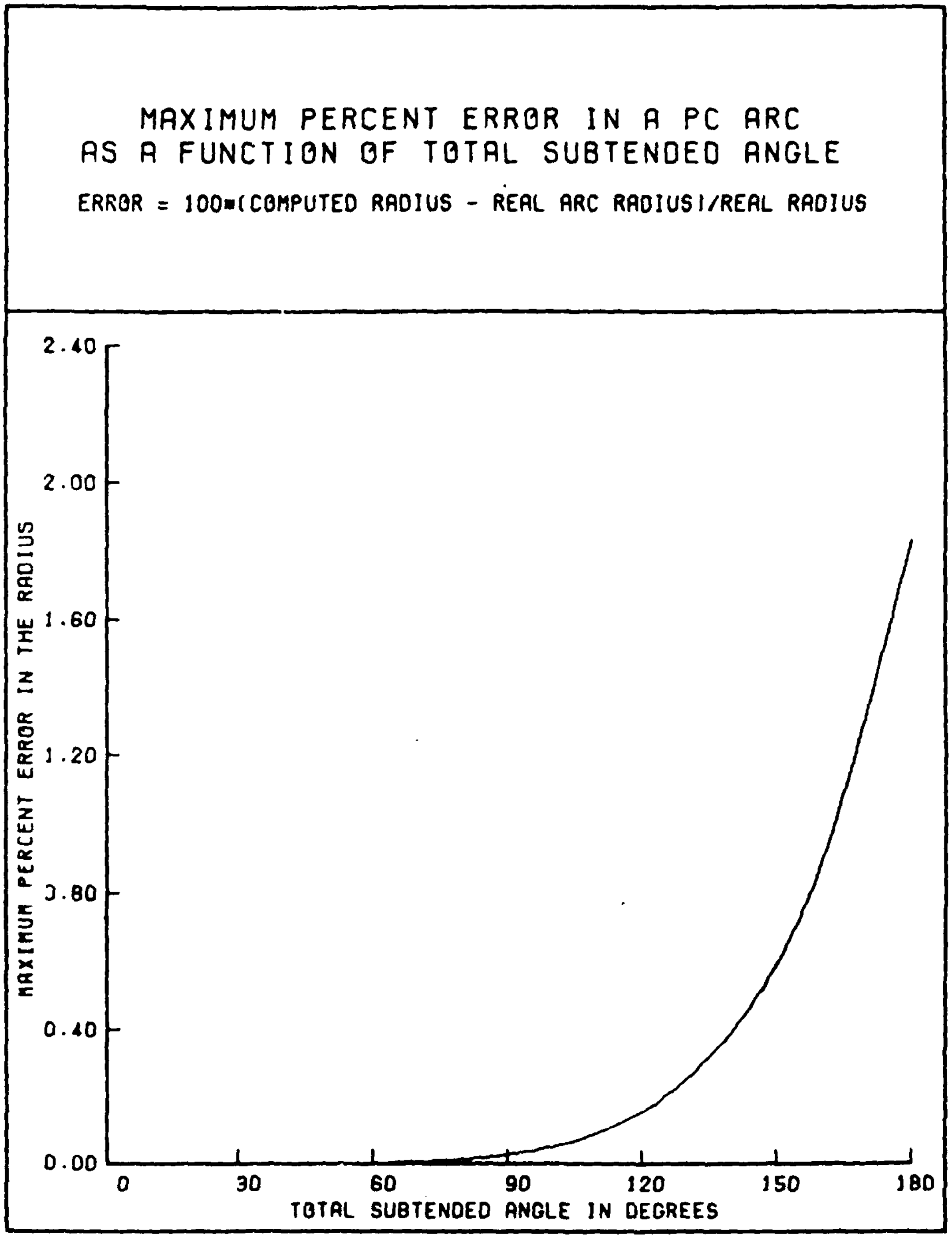


Figure 2-4. LARCPC Maximum Radial Error as a Function of Subtended Angle

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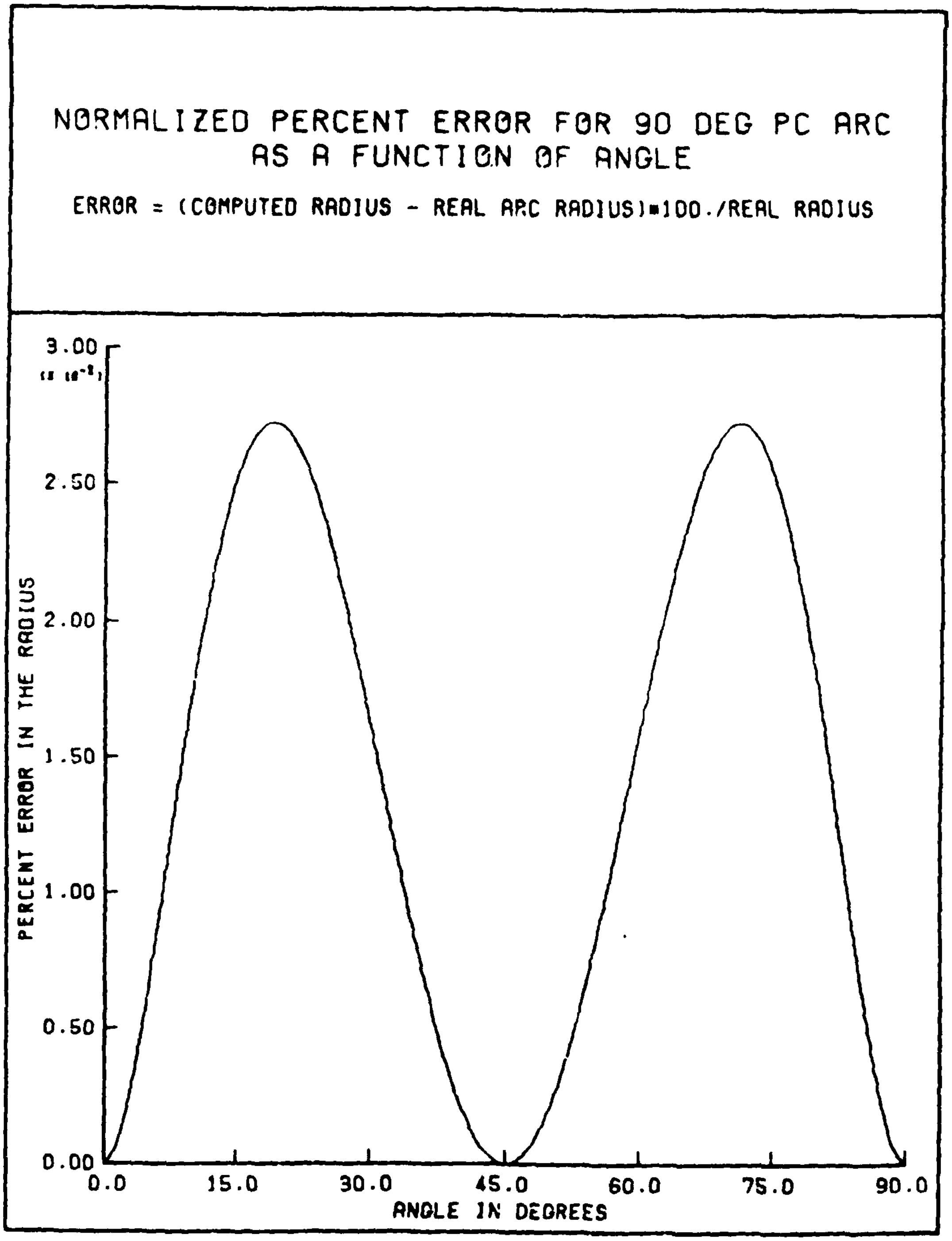


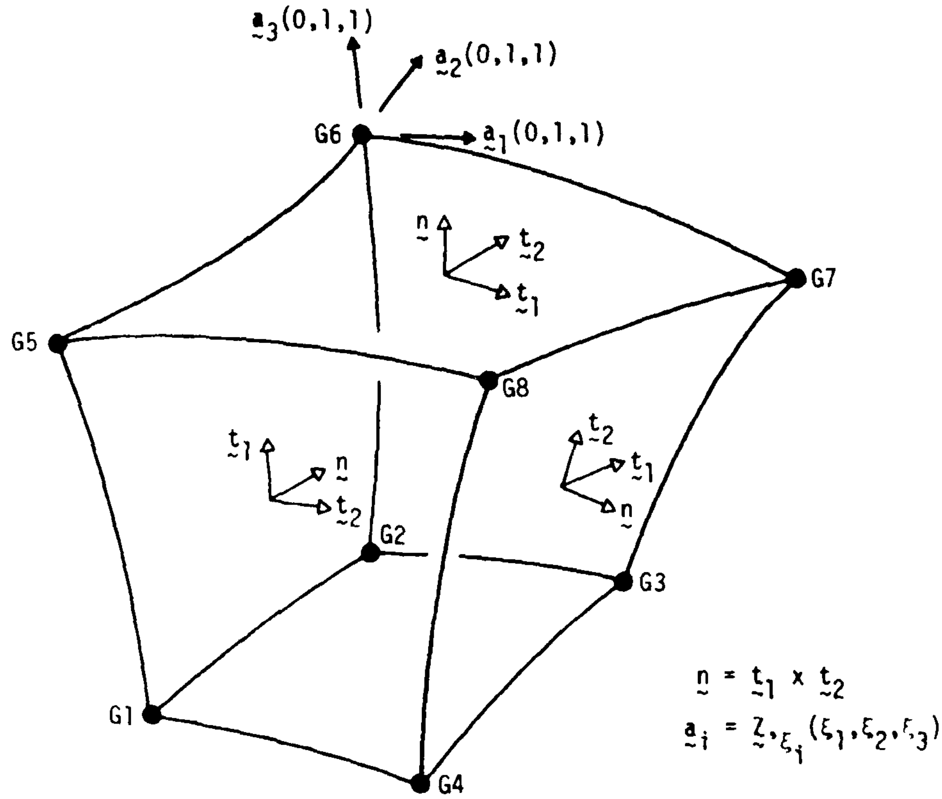
Figure 2-5. LARCPC Radial Error Distribution 8100309

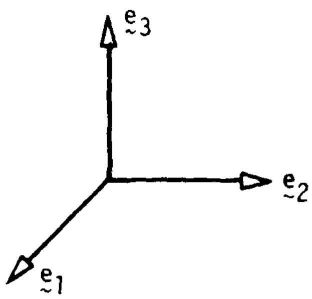
In addition to distributed data, the user can input temporal data using data table functions. The functions are again piecewise parametric cubics in one variable at present. Temperature-dependent material properties are input using data table functions, and in advance development versions of the program properties can be functions of other state variables. Data table functions are nondimensional in the sense that the data assume physical significance only when they are referenced and used by some other directive.

2.4 Constraint Modeling

Most imposed displacement boundary conditions are specified over a surface, not simply at a grid point. As a user convenience, both zero and nonzero constraint options are available that constrain the entire face of an element with a single bulk data directive. Either the reference frame, $\underset{\sim}{e}_i$, or the local surface frame, $\underset{\sim}{a}_1$, $\underset{\sim}{a}_2$, $\underset{\sim}{n}$, (Figure 2-6) may be used. In the case of zero constraints, only the corner grid point numbers, frame identification number, and displacement component numbers are input. In the case of nonzero constraints, up to 3 data patches per surface may be specified that define the magnitude of constrained displacement components over the surface. In both cases, PATCHES-III computes any required frame transformation for all 16 points on the surface.

At the intersection of constrained surfaces, a number of abstruse conditions can occur. The constrained displacement components may be in different frames at the same point; the constraints may be redundant, and when the user makes an error they may be inconsistent. The program allows multiple frames at a point and redundant constraints, and it will provide diagnostics when the user specifies inconsistent constraints. A general vector approach is used that synthesizes a local frame at every constrained point from the linearly independent constraint vectors. The details are described in Reference 4. It is possible using a debug option (PARAM directive) to output the transformation matrix relating vector components in the $\underset{\sim}{e}_i$ frame to components in the local constraint frame.





Faces	Surfaces	t_1	t_2
1,2	$\xi_1 = 0,1$	a_2	a_3
3,4	$\xi_2 = 0,1$	a_3	a_1
5,6	$\xi_3 = 0,1$	a_1	a_2

Figure 2-6. Hyperpatch Surface Coordinate Frames - Six Surfaces

2.5 Constraint Finite Elements

The finite elements used to model laminate force-deformation behavior are a family of linear constraint options developed for Version 9.0 and higher of the PATCHES-III program. The need for low-cost modeling in regions of uniaxial or biaxial strain was noted in earlier versions, and the new elements in Table 2-1 provide this capability. They are based on the linear constraints defined by

$$P_i = T_{i\alpha} P_\alpha \qquad i = 1, 2, 3, 4 \qquad \alpha = 1, 4 \tag{2.5-1}$$

where the coefficients $T_{i\alpha}$ are simply

$$T_{i\alpha} = \begin{bmatrix} 1 \,, & 0 \\ 2/3 \,, & 1/3 \\ 1/3 \,, & 2/3 \\ 0 \,, & 1 \end{bmatrix} \tag{2.5-2}$$

The same coefficients apply to all three parametric coordinates and, in general,

$$P_{ijk} = T_{i\alpha} T_{j\beta} T_{k\gamma} P_{\alpha\beta\gamma} \tag{2.5-3}$$

If constraints are introduced in only two coordinates,

$$P_{ijk} = T_{i\alpha} T_{j\beta} \delta_{k\ell} P_{\alpha\beta\ell} \tag{2.5-4}$$

and for only one constraint

$$P_{ijk} = T_{i\alpha} \delta_{j\ell} \delta_{km} P_{\alpha\ell m} \tag{2.5-5}$$

Table 2-1

PATCHES-III CONSTRAINT FINITE ELEMENT

Displacements*	Nodes	Geometry	Properties
LLL	8	CCC	CCC
LLC	16	CCC	CCC
LCC	32	CCC	CCC

* Any combination of L and C is available. L = linear, C = cubic.

Two key issues affecting the development of the new family of elements are how to efficiently generate their stiffness matrices and how to connect them to each other. After some early confusion, it was determined that all linear constraints can be applied before integration with the same result as when they are applied after integration. This greatly reduces the cost of generating their stiffness matrices. It is simply to demonstrate this equivalence in one dimension where, obviously,

$$\begin{aligned} K^P_{\alpha\beta} &= \int T_{i\alpha} F_i(\xi)\, F_j(\xi)\, T_{j\beta}\, d\xi \\ &= T_{i\alpha} \int F_i(\xi)\, F_j(\xi)\, d\xi\, T_{j\beta} \\ &= T_{i\alpha} K^P_{ij} T_{j\beta} \end{aligned} \tag{2.5-6}$$

But in higher dimensions interpolatory quadrature is used in PATCHES-III, and this equivalence is tedious to prove.

The second issue was resolved by automating the generation of interface constraints between elements ot different dimension. This allows the user of PATCHES-III to specify linear constraints on any element or group of elements by simply placing a mnemonic of the type listed in Table 2-1 on the connectivity card for that element. The program first generates all explicit mesh point constraints and then on a second pass generates all interface or implicit constraints. This requires extensive checking for conflicts, and, in order to reduce their incidence, all three displacement components are constrained alike. At every constrained mesh point, one of the Equations (2.5-3) - (2.5-4) is automatically generated and applied to all affected matrices.

A family of finite elements based on axisymmetric constraints is also available. These elements require hyperpatches of the form

$$Z^1(\xi_1, \xi_2, \xi_3) = r(\xi_1, \xi_2) \sin \xi_3$$
$$Z^2(\xi_1, \xi_2, \xi_3) = r(\xi_1, \xi_2) \cos \xi_3$$
$$Z^3(\xi_1, \xi_2, \xi_3) = Z(\xi_1, \xi_2)$$

which can be generated using the HPR directive. Note the convention here that associates the hoop coordinate θ with the third parametric coordinate ξ_3. A generalized axisymmetric displacement constraint that allows torsion $U^i{}_{,\xi_3} \equiv 0$ results in bicubic displacement functions for U_θ, U_R, and U_Z. The axisymmetric finite elements are designated CCX, etc., as listed in Table 2-2, and they reduce the dimension of an element by a factor of 4. In general, the number of varying strain components remains 6 because of the torsional response mode. This behavior is typical of axisymmetric composites of involute construction.

Table 2-2

PATCHES-III AXISYMMETRIC FINITE ELEMENTS

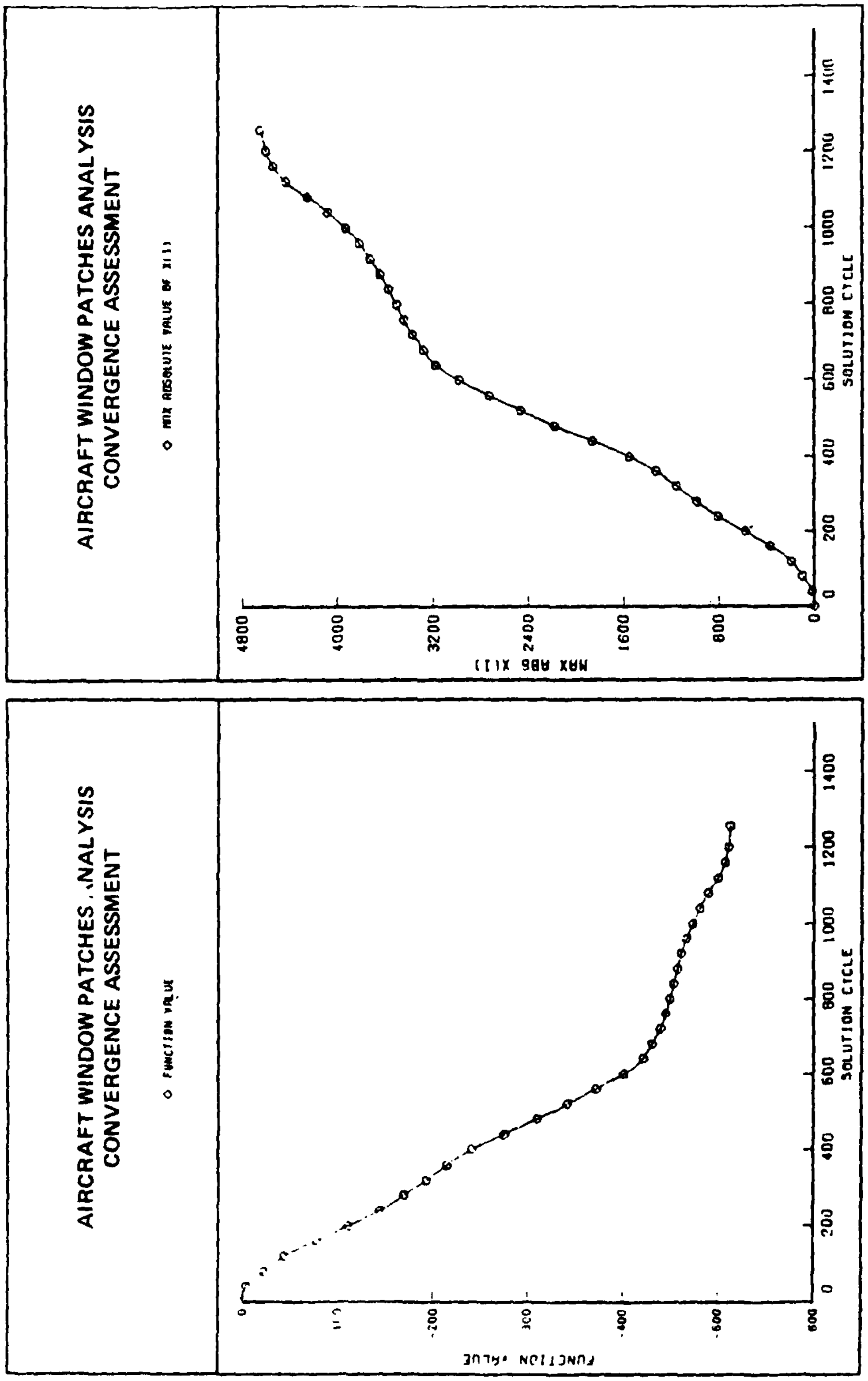
Displacements*	Nodes	Geometry	Properties
LLX	4	CCC	CCC
LCX	8	CCC	CCC
CCX	16	CCC	CCC

* Any combination of L and C in the first two positions is available with X in the third position. *L = linear, C = cubic, X = axisymmetric.*

2.6 Solution Method

PATCHES-III utilizes a scaled conjugate gradient solution procedure which has been shown to be extremely effective for three-dimensional problems. Core requirements increase very slowly with increasing problem size, virtually eliminating the "spill" problem associated with direct decomposition on many computers. This is primarily the result of only a single element stiffness matrix being in core at any one time. Also, since the global stiffness matrix is never constructed, bandwidth minimization considerations are eliminated.

The solution procedure has been formulated around the dot product operation, which permits the program to take full advantage of recent developments in machine architecture. As a result, the cost per iteration is extremely low, and the total cost to convergence is generally substantially lower than for direct decomposition. For most isotropic problems, engineering accuracy, if not convergence, will be obtained in approximately N/4 iterations where N is the number of degrees of freedom, called NFSET. In orthotropic problems, the convergence is slower, depending on the E/G ratio of the material. Most laminate problems converge in N cycles, but laminates with rubber plies mixed with high modulus plies can take 2N cycles. Models requiring more than 2N cycles are very ill conditioned and often indicate a modeling error of some sort. Figure 2-7 shows slow convergence caused by two rubber plies in an aircraft window model that act as shear strain isolators. There is a checkpoint feature provided to allow continued iterations on a subsequent restart run if additional iterations are required. Through default values or specific overrides, the user can control the iteration processes defining convergence, maximum cycles, maximum time, cut-off for rigid body modes, checkpoint, restart, and more. Full strain, stress, and force recovery is always available.



8100312

Figure 2-7. Conjugate Gradient Convergence Behavior for all Ill Condition Problem

CHAPTER 3

A GUIDE TO THE USER MANUAL

3.1 Overview

After reading the introduction and Chapter 2, the user should have a general understanding of the modeling features available in PATCHES-III. This chapter introduces the user to the actual operation of the program and describes its architecture. Those familiar with NASTRAN will recognize the bulk data and case control input formats. The syntax is virtually the same, including order independent bulk data and checkpoint-restart processing which has been simplified to eliminate the checkpoint dictionary. Chapter 4 provides a detailed description of the bulk data directives in the familiar NASTRAN format. Chapter 5 provides the same information for the case control data directives, and Chapter 6 describes the optional executive requests. Chapter 7 shows the input and output for several sample problems which illustrate the basic simplicity of modeling with parametric cubics. Chapter 8 illustrates job control options (tape request, etc.), and Chapter 9 describes diagnostic and user information data output by the program.

3.2 Data Preparation

The sequence of input directives necessary for execution of PATCHES-III is similar to that necessary for execution of NASTRAN. The input file is shown schematically in Figure 3-1 for a single run. It is possible to concatenate files, but this would not normally be done. Detailed information on the preparation of executive, case control, and bulk data may be found in Chapters 4, 5, and 6 of this manual. Information on computer processing of the deck and a schematic of the PATCHES-III load map are presented next.

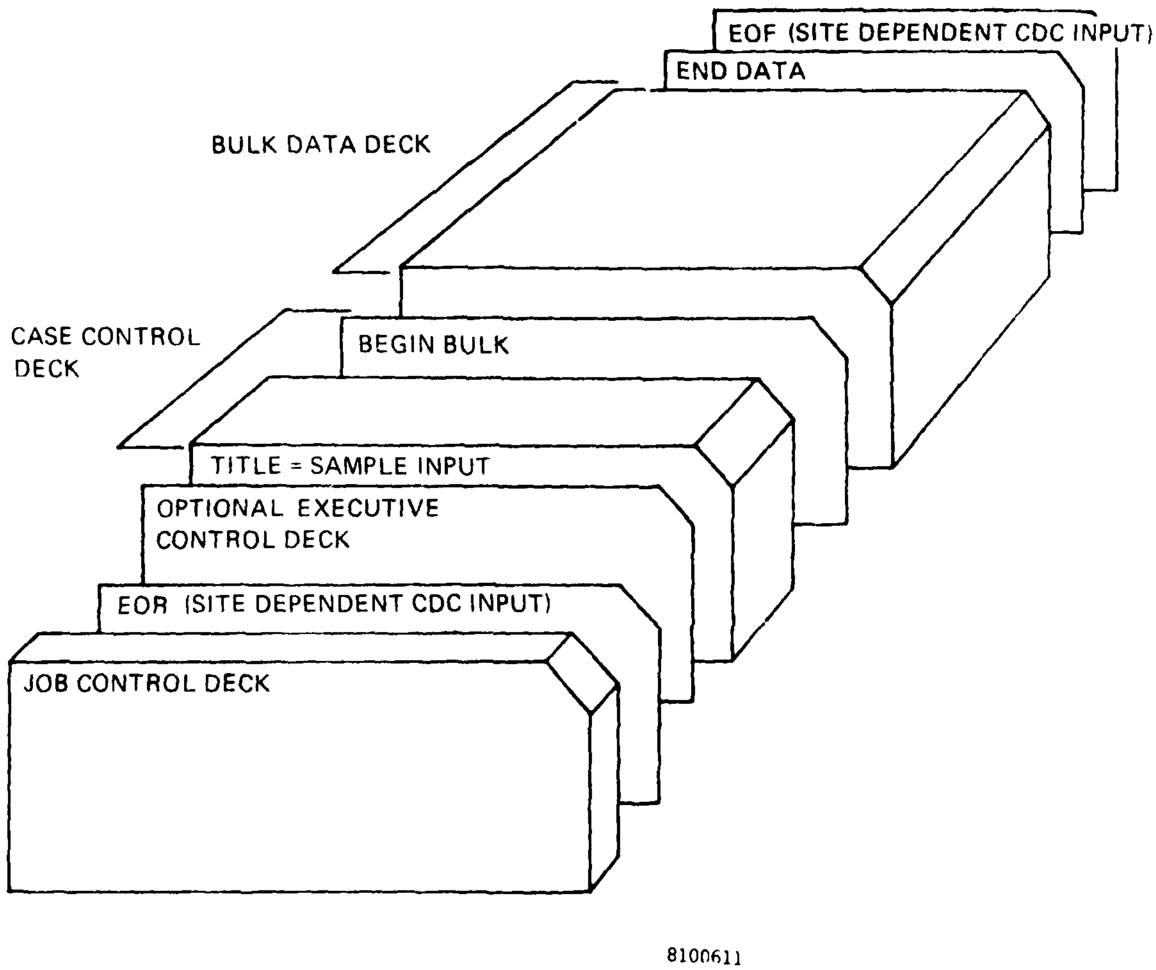


Figure 3-1. PATCHES-III Input File

3.3 Computer Processing

To use PATCHES-III efficiently it is necessary to understand the basic structure of the program and the relative expense of individual modules. This allows the user to plan the dry runs, checkpoints, and restarts that best suit his application. A schematic of the PATCHES-III load map is shown in Figure 3-2 where the core storage each link requires is indicated by the length of the line for that link. The program is loaded on CDC computers using the segmentation loader. The resident link, Link 0, is always in core. It contains the PATCHES-III executive system and the communication data blocks. Each of the other links is executed as needed under the control of the PATCHES-III executive. A brief description of the function of each link is provided in Table 3-1.

At the end of execution, a user information table is printed which shows the CP time, core storage, and random access disk requirements of each link and major subregions within complex links. The various PATCHES-III links do not require a fixed amount of core storage but, rather, an "open core" concept wherein each link determines and assigns the necessary core based upon the problem requirements. This allows PATCHES-III to process very large problems without penalizing those small problems that can be solved with modest storage requirements (approximately 170000_8). To check all input data and the geometry model before execution on large problems, use the Case Control option DRY.

This will terminate the run at the flag labeled DRY in Figure 3-2. Less than 10 percent of the cost of a complete solution is required for a DRY run, and the percentage decreases with increasing problem size.

There are two volumes of data that may be saved on two separate files of a checkpoint tape for later use on a restart run. The first volume contains the element stiffness matrices, and the second contains the current iterate and direction vector from the iterative solution. One or both volumes may be created on a checkpoint run using the case control options CHKPNT, ELEMENT or CHKPNT, CG or CHKPNT, ELEMENT, CG. On a subsequent restart run, any or all of the element matrices can be modified using the option RESTART, ELEMENT, LIST. All restart runs require the complete case control and bulk data decks to be present, even on a CHKPNT, CG run. This is necessary because all data not on the checkpoint tape (geometry data, etc.) must be regenerated. A restart run can create an additional CG checkpoint file, thereby allowing the user to monitor intermediate results in a large analysis.

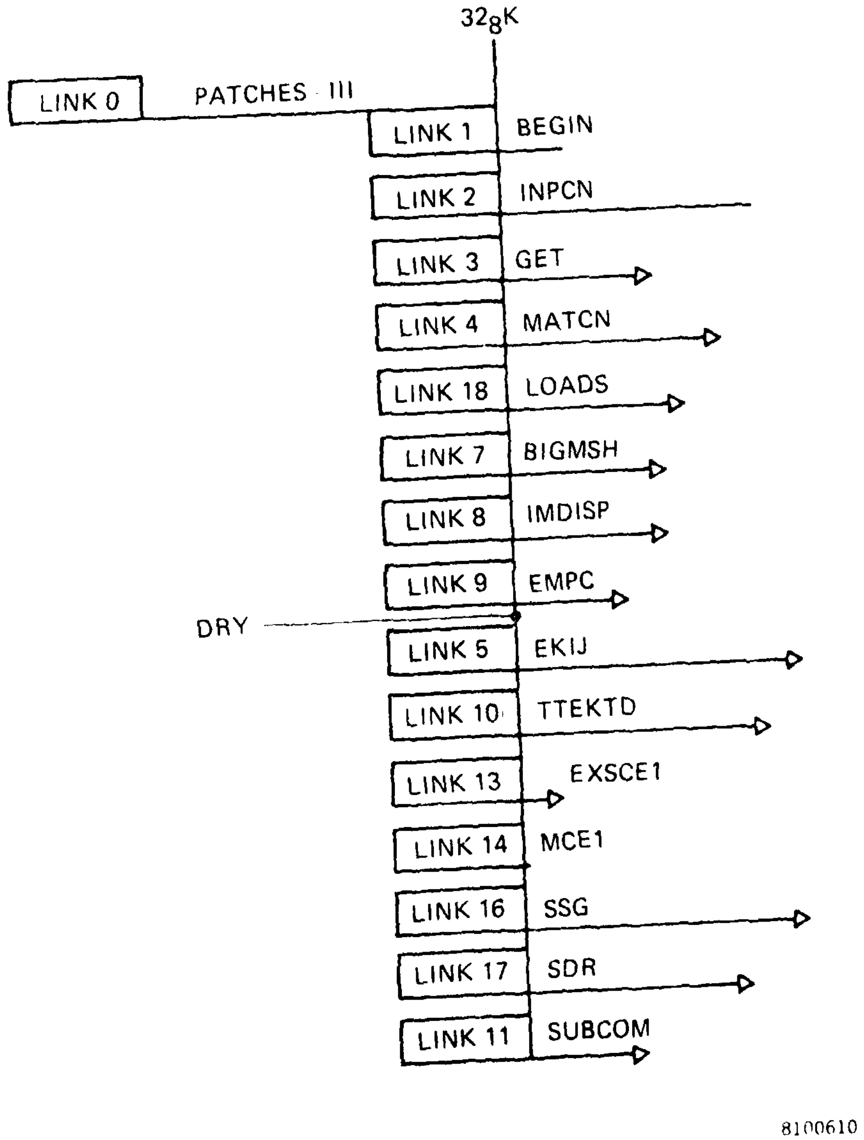


Figure 3-2. PATCHES-III Load Map

Table 3-1

PATCHES-III LINK DESCRIPTIONS

Link	Region Name	Function
0	MAIN	Executive control and common storage
1	BEGIN	Initialize PATCHES-III system
2	INPCN	Input control - construct geometry and data models
3	GET	Initialize integration tables
4	MATCN	Material property card
18	LOADS	Generate element load vectors
7	BIGMSH	Generate element mesh point connectivity
8	IMDISP	Imposed displacement model
9	EMPC	Element mesh point constraints
5	*EKIJ	Generate element stiffness matrices
10	TTEKTD	Transform element matrices to analysis coordinates
13	EXSCE1	Single point constraint eliminator
14	MCE1	Multipoint constraint eliminator
16	*SSG	Static solution generator
17	SDR	Stress recovery
11	SUBCOM	Subcase combinations

* Links that use majority of the CP time

CHAPTER 4

BULK DATA OPTIONS

4.1 Overview

The primary source of input to PATCHES-III is a bulk data file whose syntax is the same as that used by NASTRAN, Reference 2. This data defines the geometry, physical properties, boundary conditions, and loading conditions for the finite element model of the structure. Certain execution parameters, such as grid point tolerances, can also be input with bulk data directives, all of which may be submitted in any order. PATCHES-III preprocesses the bulk data file to determine the order in which directives must be processed to account for data hierarchies. The input data may be in one of two formats: free-form or fixed-form. Fixed-form is identical in format to standard NASTRAN bulk data cards. The preferred format for PATCHES Control Case and Bulk Data Directives is free-form because of the string notation syntax which is convenient for input via a CRT terminal.

4.1.1 Free-Form Input

1. Definition: A directive is assumed to be of free form if a comma exists anywhere on the first physical card (line) of that directive. Continuation cards (lines) are assumed to be of the same format. Column positions and all blanks are ignored by the free-form processor.

2. Syntax: The data input to PATCHES is broken into individual fields. Each field represents a particular type of data. A field may consist of any number of characters and digits and is terminated by a comma. As an example, consider the following directive:

   HPR, 7, 10,,,, 0.0, 90.0, 3

   As in a NASTRAN bulk data card, the first field is the name of the directive, in this case, HPR. The second field identifies by number the item to be created, in this case, HYPERPATCH number 7. The third field, 10, identifies the patch to be used in the construction option. The next three fields are nul for this option, indicated by blanks between the commas. This is similar to DMAP's syntax. The last three fields on this directive define rotation angles and rotation axis. The primary rule to note is that a comma terminates a field; column positions are of no importance.

After the final field in the above example, a comma is not required. If the last nonblank character on a card (line) is a comma, the next card (line) is assumed to be a continuation card (line). Data continues on the next card as if the physical card were in excess of 80 columns. A PATCHES data directive can have up to eight continuation cards, but an individual field cannot cross card boundaries.

3. In-Line Lists: There are circumstances in which a list can occur within a field. Such a field can be input using a slash ,/, in place of the comma to separate items. An example would be

PATCHO, 11, 5/3, 4

As before, a field cannot extend over card boundaries.

4.1.2 Fixed-Form Input

1. Definition: A directive is assumed to be of fixed form if there are no commas on the first physical card (line) of that directive. Continuation cards are assumed to be of the same format.

2. Syntax: The format of the directive is identical to that of a NASTRAN bulk data card. Fields exist totally within 8- or

16-column blocks. Input is similar to free-form input if you imagine a comma between blocks. The following two cards result in identical definitions:

```
LIST, 5, 8, 12, 16 THRU 20, 34, 4, 3, 9, 40
LIST    5  8  12  16THRU20  34  4  3  9  +CONT
+CONT   40
```

where eight columns must occur in each field of the fixed-format cards indicated by underlining.

Restrictions and use of fixed format are otherwise identical to those of free format. The 16-character input field format is specified by appending an asterisk, *, to the mnemonic in field 1 or by placing an asterisk in column 1 of a continuation card.

4.2 Available Options

There are over 70 bulk data directives available to model the structure, its properties, and its environment. These are grouped into six functional categories and are catalogued by mnemonic in Table 4-1 for easy reference. Few of these directives are mandatory on any given run. PATCHES-III analyzes the input bulk data and provides diagnostics if there are errors or omissions. Every attempt is made to analyze the entire bulk data set independent of the number of errors that may be found. On most runs a geometry model will be created and output, even when there are fatal errors. Cross-referencing between bulk data directives is by explicit reference to an identification number. The only exception is the *CPDE3 directive, which implicitly requires* the property card and hyperpatch card to have the same identification number as the finite element. The number of elements is limited to 512, which corresponds to a range of stiffness matrix dimensions from 5,000 to 100,000, depending on the finite element type.

Table 4-1

BULK DATA OPTIONS

1. GEOMETRY*

GRID	LARCPC	PATCH	HPATCH	SCALP
	LINE	PATCHGR	HPHEX	SCALPH
	LINECS	PATCHL	HPL	TMOVE
	LINEGR	PATCHO	HPN	
	LINEPC	PATCHQ	HPR	
		PATCHR	HP2PAT	
		PATCH4L	HP4PAT	
			HP6PAT	

2. ELEMENT AND PROPERTIES

CPDE3	MATAL	MAT1	MATTA
PPDE3	MATC		MATTAT
	MATE		MATTC
	MATOR		MATTE
			MATTO
			MATT1

3. CONSTRAINTS

MPE1	SDC10	SDC1	SPC1
MPE2	SDC20	SDC2	SPC2

4. LOADS

FORCE	FORCEL3	FORCET	TEMP
		PLOAD3	

(Table continued on following page.)

* Mnemonic Suffixes:

A = Algebraic, B = Geometric, CS = Cubic spline, HEX = Hexahedra, L = Line, N = Normal, P = Point, PC = Parametric Cubic, Q = Quadrilateral, R = Rotation.

Table 4-1 (Continued)

BULK DATA OPTIONS

5. DATA MODELING*

DATAG	DLINCS	DPATA	DHPAT	DTCS
	DLINE	DPATCH	DHPHEX	DTPC
	DLINP	DPATEQ	DHPL	
	DLINPC	DPATL	DHPSORT	
		DPATQ	DHP2P	
		DPAT4L	DHP4P	

6. MISCELLANEOUS

PARAM	MTRX-ID
$comment	MTRX-CID

* Mnemonic Suffixes:

A = Algebraic, B = Geometric, CS = Cubic spline, HEX = Hexahedra, L = Line, N = Normal, P = Point, PC = Parametric Cubic, Q = Quadrilateral, R = Rotation.

4.3 Bulk Data Directives

This section details in alphabetical order for each of the bulk data directives their input, format, restrictions and, where necessary, additional information concerning the use of the particular directive. The descriptions are in the nature of dictionary information with illustrated examples for key directives. Table 4-2 shows the format used to document each directive.

Table 4-2

DOCUMENTATION FORMAT FOR BULK DATA

CATEGORY	CONTENT
Input Directive:	Mnemonic for directive.
Description:	Dictionary description of directive.
Format:	Mnemonic for each input field.
Example Syntax:	Typical input data.
Field:	Dictionary description of each input field.
Remarks*:	Restrictions and assumptions.
Commentary*:	Background information for certain directives.
Example Application*:	Typical application is illustrated.

* This item of documentation is not available for all directives.

BULK DATA INPUT

Input Directive:	$ Comment
Description:	A comment which the user may input to annotate the bulk data file in its unsorted form. This card is ignored by the bulk data processor.
Format:	$ Any legitimate characters in columns 2 - 80.
Example Syntax:	$****GRAPHITE PHENOLIC PROPERTIES.
Remarks:	1. Comment cards cannot be used with the current Version 9.5 for the VAX-11/780.

BULK DATA INPUT

Input Directive:	CPDE3
Description:	Connectivity card for a three-dimensional parametric discrete (finite) element.
Format:	CPDE3, EID, G1, G2, G3, G4,,,, EMPC, G5, G6, G7, G8
Example Syntax:	CPDE3, 7, 1, 3, 13, 12,,,, CCL, 2, 4, 14, 5

Field	Contents
EID	Element identification number.
G1, G2,..., G8	Corner grid point identification numbers in the sequence given by Figure 4-1.
EMPC	Mesh point constraint mnemonic for elements reduced to less than cubic in one or more of the parametric directions. The above example, CCL, generates an element with cubic-cubic-linear displacement functions. The default is CCC.

Remarks:

1. The element identification number must be the same as the hyperpatch identification number.
2. See Figures 4-1 and 2-6 for the parameterization and element surface orientation generated by the CPDE3 card.
3. Any element connected to a reduced element will automatically have the same constraints (if any) on their common surface.

BULK DATA INPUT

Input Directive:	CPDE3 (Axisymmetric model)
Description:	Connectivity card for a three-dimensional parametric (finite) discrete element.
Format:	CPDE3, EID, G1, G2, G3, G4,,,, EMPC, G5, G6, G7, G8
Example Syntax:	CPDE3, 7, 1, 3, 13, 12,,,, CCX, 101, 103, 113, 112

Field	Contents
EID	Element identification number.
G1, G2,..., G8	Corner grid point identification numbers in the sequence given by Figure 4-1.
EMPC	Mesh point constraint mnemonic for elements reduced to less than cubic in parametric directions one or two and axisymmetric in the third parametric direction. The above example, CCX, generates an element with cubic-cubic-constant displacement functions. The default is CCC; i.e., not axisymmetric.

Remarks:

1. The axisymmetric constraint is designed by an X and can only be used in the third parametric coordinate direction.

2. All remarks concerning a general CPDE3 element apply.

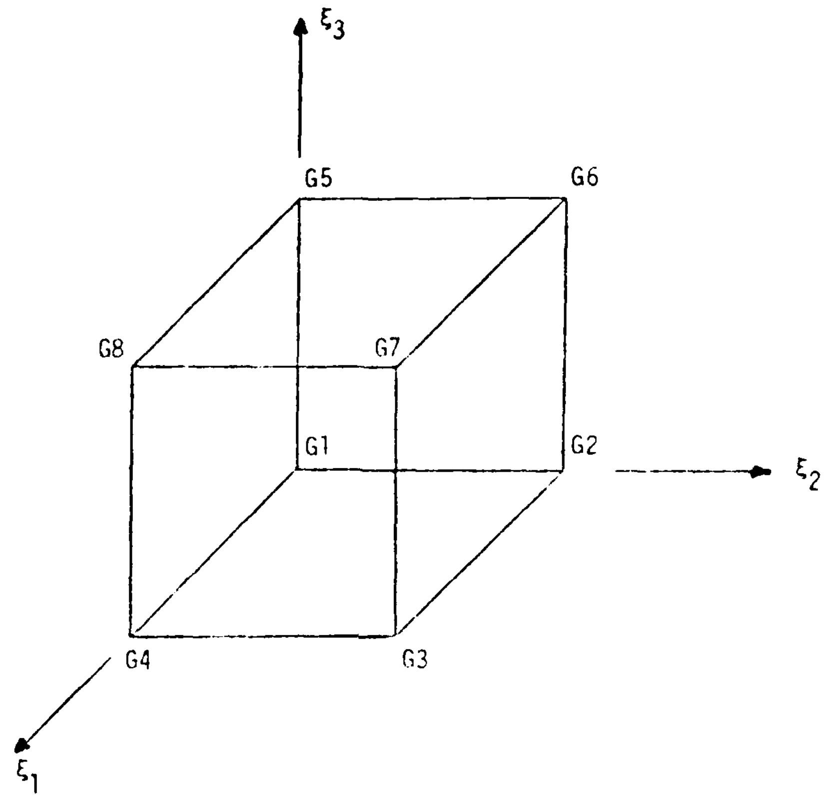
3. If the PPDE3 card for an axisymmetric element references a nonisotropic material, then variable Euler angle data should be used to generate an axisymmetric material for the element.

4. Surface displacement constraints must not be input for mesh points not on face five.

Commentary:

The connectivity bulk data card, CPDE3, causes the hyperpatch for a discrete element to have the parameterization shown in Figure 4-1, independent of how it was constructed. Any reparameterization that may be required takes place automatically and prior to all output. The CPDE3 card, for example, results in the G1-G2-G3-G4 surface being face 5 and the G5-G6-G7-G8 surface being face 6 when the hyperpatch is in geometric format. The parameterization is defined as "3" sort in that face 5 is associated with $\xi_3 = 0$ and face 6 with $\xi_3 = 1$. All geometric hyperpatches in PATCHES-III are in "3" sort. At the present time, data hyperpatches are not effected by the CPDE3 card, and the user must ensure that their parameterizations are consistent with the geometric. Consider, for example, a temperature hyperpatch created by a DHP2P card using temperature patches on the G1-G4-G8-G5 surface and G2-G3-G7-G6 surface for face 5 and face 6, respectively. This data would be in "2" sort, referring to Figure 4-1, and a DHPSORT card would be required to change from "2" sort to "3" sort.

The convention for defining an element surface by giving the corner grid points is also established by the CPDE3 card. This convention, detailed on Figure 4-1, may be thought of as the "left-hand rule," in which the sequence always proceeds from the origin clockwise about an axis in the a_i direction where the surface is associated with ξ_i = constant. This convention must be used when defining constraint surfaces and data patches over an element surface.



<u>Face</u>		
5	G1-G2-G3-G4	$\equiv \underset{\sim}{Z}(\xi_1, \xi_2, 0)$
6	G5-G6-G7-G8	$\equiv \underset{\sim}{Z}(\xi_1, \xi_2, 1)$
3	G1-G4-G8-G5	$\equiv \underset{\sim}{Z}(\xi_1, 0, \xi_3)$
4	G2-G3-G7-G6	$\equiv \underset{\sim}{Z}(\xi_1, 1, \xi_3)$
1	G1-G5-G6-G2	$\equiv \underset{\sim}{Z}(0, \xi_2, \xi_3)$
2	G4-G3-G7-G3	$\equiv \underset{\sim}{Z}(1, \xi_2, \xi_3)$

Figure 4-1. Grid Point Conventions for Element Connectivity and Element Surface

BULK DATA INPUT

Input Directive:	DATAG General spatial data input by grid point
Description:	Scalar input data at a set of grid points.
Format:	DATAG, DSID,, GID1, D1, GID2, D2, GID3, D3, GID4, D4, GID5, D5,..., GIDN, DN
Example Syntax:	DATAG, 11,, 3, -4.0, 4, -3.6, 5, -3.2, 6, -3.0
Field	Contents
DSID	Identification number for the data set defined by this card. Pressure, temperature, and force components are typical data types that form an individual data set. $1 \leq DSID \leq 12$.
GIDK	Identification number of the grid point that locates the input data in space.
DK	Data value at grid point GIDK.

Remarks:

1. The data set identification number must be an integer one through twelve.
2. Data at up to 29 grid points can be input with a single directive. Additional data in the set can be input with additional directives.
3. Data at grid points in a data set, DSID, can also be created with data line directives without the use of DATAG input.

BULK DATA INPUT

Input Directive:	DHPAT Data Hyperpatch.
Description:	Direct input of a one-component data hyperpatch in any PC format.
Format:	DHPAT, ID, FORMAT, MTRX-ID
Example Syntax:	DHPAT, 3, P, 117

Field	Contents
ID	Data hyperpatch identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
MTRX-ID	Matrix identification number containing the coefficients.

Remarks:

1. The default FORMAT is point format where the mathematical definitions are provided in Chapter 5.
2. The 64 hyperpatch coefficients in any format are input in the same sequence that a triply subscripted array is stored in FORTRAN; namely, P111, P211, P311, P411, P121, P221, ... P344, P444.

BULK DATA INPUT

<u>Input</u> <u>Directive</u>: DHPHEX Data hyperpatch generator

<u>Description</u>: One-component data hyperpatch created from the 8 corner values.

<u>Format</u>: DHPHEX, DHPID, DSID, G1, G2, G3, G4,,,,, G5, G6, G7, G8

<u>Example</u> <u>Syntax</u>: DHPHEX, 5, 2, 1, 2, 4, 6,,,,, 11, 3, 7, 5

<u>Field</u>	<u>Contents</u>
DHPID	Data hyperpatch identification number.
DSID	Identification number of the data set that defines data values, DI, at the grid points.
G1-G8	Corner grid points that locate the data hyperpatch in space in the sequence given by Figure 4-1.

<u>Remarks</u>:

1. The data, DI, are interpolated trilinearly.
2. The data in a data set, DSID, are normally input with a DATAG directive.

BULK DATA INPUT

Input Directive:	DHPL Data hyperpatch generator
Description:	One-component data hyperpatch created from data lines.
Format:	DHPL, DHPID, DL1, DL2, DL3, DL4, DL5, DL6,, CROSSF, DL7, DL8, DL9, DL10, DL11, DL12
Example Syntax:	DHPL, 10, 3, 6, 7, 2, 1, 5,, 0, 8, 11, 12, 13, 21, 18

Field	Contents
DHPL	Data hyperpatch identification number.
DL1-DL12	Data line identification numbers in the sequence specified for the HPL directive.
CROSSF	0 = Set cross derivatives to zero. 1 = Interpolate cross derivatives linearly.

Remarks:

1. The data lines are checked for common values at the corner nodes.

2. The data lines must all reference the same data set.

3. The CROSSF parameter controls the local surface warping. A zero indicates a data surface with zero twist at the four corners.

BULK DATA INPUT

Input Directive: DHPSORT Resort a data hyperpatch

Description: Transform a data hyperpatch from the input or construction parameterization to the output parameterization requested.

Format: DHPSORT, DHPID, INSORT, OUTSORT, NCOMP

Example Syntax: DHPSORT, 10, -2

Field	Contents
DHPID	Data hyperpatch ID.
INSORT	Input sort format. INSORT = ±i where i = 1, 2, or 3 relative to the geometric hyperpatch implicitly associated with the data hyperpatch.
OUTSORT	Output sort format. Default = 3.
NCOMP	Number of components in the data hyperpatch. Default = 1.

Remarks:

1. Resorting a data hyperpatch is a user convenience feature. The data for an element may be easier to create in an order different from that used for the geometry.

2. A minus sign reverses the two faces associated with a particular sort. INSORT = -3, for example, reverses faces 5 and 6.

BULK DATA INPUT

Input Directive:	DHP2P Data hyperpatch generator
Description:	One-component data hyperpatch created from two data patches.
Format:	DHP2P, DHPID, DP1, DP2
Example Syntax:	DHP2P, 3, 11, 12

Field	Contents
DHPID	Data hyperpatch identification number.
DP1, DP2	Data patch identification numbers for $\xi_3 = 0$ and $\xi_3 = 1$.

Remarks:

1. The data patches must both reference (directly or indirectly) the same data set.
2. The data are linearly interpolated between the two referenced data patches.
3. The data hyperpatch is in "3" sort by construction. Use DHPSORT if another sort is desired.

BULK DATA INPUT

Input Directive: DHP4P Data hyperpatch generator

Description: Data hyperpatch generated from four patches in one parametric direction.

Format: DHP4P, ID, DP1, DP2, DP3, DP4

Example Syntax: DHP4P, 1, 1, 2, 8, 7

Field	Contents
ID	Data hyperpatch identification number.
DP1, 2, 3, 4	Data patch identification numbers.

Remarks:

1. This construction assumes the input order of the four data patches is associated with $\xi 3 = 0, 1/3, 2/3, 1$ surfaces of the geometry hyperpatch.

BULK DATA INPUT

Input Directive:	DLINCS Data line generator
Description:	Scalar data interpolated over a set of grid points using cubic splines.
Format:	DLINCS, DLID, DSID, G1, G2,..., GN
Example Syntax:	DLINCS, 10, 3, 4, 2, 1, 5, 16
Field	Contents
DLID	Identification number for the one-component data line created by this card.
DSID	Identification number of the data set that defines data values, DI, at grid points in the data line DLID.
G1, G2,..., GN	The list of grid points that locate the data interpolation points in space. The maximum number is 25.

Remarks:

1. The data DI are interpolated using a piecewise cubic spline with the lineal arc-length between grid points serving as abscissa. Data must exist at G1, GN, and at least one other grid point and may exist at all grid points.

2. The data in data set, DSID, are usually input with a DATAG directive.

BULK DATA INPUT

Input Directive:	DLINE Data line generator
Description:	Direct input of a data line in any format.
Format:	DLINE, DLID, DSID, FORMAT, P1, P2, P3, P4,, G1, G2,..., GN
Example Syntax:	DLINE, 5, 1, B, 1., 12., 0., -.5, 103 thru 120

Field	Contents
DLID	Data line identification number.
DSID	Data set identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
P1, P2, P3, P4	Coefficients of the line in the specified format.
G1, G2,...,GN	Grid points at which data will be generated.

Remarks:

1. The default FORMAT is point format, P(0), P(1/3), P(2/3), P(1). The sequence is the same for all formats as described in Chapter 5.

2. The data line extends from G1 to GN with intermediate values determined by the distance between points.

BULK DATA INPUT

Input Directive:	DLINP Data line generator
Description:	Scalar data for a data line in point format between two grid points.
Format:	DLINP, DLID, DSID, G1, G2, D(1/3), D(2/3)
Example Syntax:	DLINP, 10, 5, 3, 6, .4, -.2-1

Field	Contents
DLID	Data line ID.
DSID	Data set ID that defines the data at G1, G2.
G1, G2	Grid points that locate the ends of the data line in space.
D(1/3), D(2/3)	Data values at the one-third points in parametric space. The spatial location of these points is determined by the discrete element whose edge is associated with this data line.

BULK DATA INPUT

Input Directive:	DLINPC Data line generator
Description:	Scalar data interpolated over a set of grid points as piecewise linear.
Format:	DLINPC, DLID, DSID, G1, G2,..., GN
Example:	DLINPC, 7, 4, 14, 3, 1, 5, 6

Field	Contents
DLID	Identification number for the one-component data line created by this card.
DSID	Identification number of the data set that defines data values, DI, at grid points in the data line DLID.
G1, G2,..., GN	The list of grid points that locate the data interpolation points in space. The maximum number is 25.

Remarks:

1. The data, DI, are interpolated as piecewise linear with the lineal arclength between grid-points serving as abscissa. Data must exist at G1 and GN and may exist at all grid points.

BULK DATA INPUT

Input Directive:	DPATA Data patch generator
Description:	Algebraic format data patch on one surface of an element.
Format:	DPATA, DPATID, G1, G2, G3, G4,,,, S11, S21, S31, S41, S12, S22, S32, S42, S13, S23, S33, S43, S14, S24, S34, S44
Example Syntax:	DPATA, 10, 1, 3, 16, 4,,,,,, -1.3, 2.4,,, 1.0, 1.0

Field	Contents
DPATID	Data patch ID.
G1, 2, 3, 4	Corner grid points that locate the data patch in space.
S11,S21,S31,...,S44	Data patch in algebraic format where a blank is equivalent to a zero SIJ. The spatial location of these data points is determined by the discrete element whose surface uses the data patch.

$$F(\xi_1,\xi_2) \equiv (\xi_1^3,\xi_1^2,\xi_1,1) \begin{bmatrix} S11 & S12 & S13 & S14 \\ S21 & S22 & S23 & S24 \\ S31 & S32 & S33 & S34 \\ S41 & S42 & S43 & S44 \end{bmatrix} \begin{Bmatrix} \xi_2^3 \\ \xi_2^2 \\ \xi_2 \\ 1 \end{Bmatrix}$$

BULK DATA INPUT

Input Directive:	DPATCH Data patch
Description:	Direct input of a one-component data patch in any format.
Format:	DPATCH, ID, FORMAT, MTRX-ID, G1, G2, G3, G4
Example Syntax:	DPATCH, 4, B, 22

Field	Contents
ID	Data patch identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
MTRX-ID	Matrix identification number containing the coefficients.
G1, G2, G3, G4	Data patch spatial location given by corner grid points.

Remarks:

1. The default FORMAT is point format.
2. The 16 patch coefficients are input in the sequence P11, P21, P31, P41, P12, P22, ... for all formats as described in Chapter 5.

BULK DATA INPUT

Input Directive:	DPATEQ Data patch generator
Description:	Creates a data patch equal to a reference data patch but located on a different surface.
Format:	DPATEQ, DPATID, REFID, G1, G2, G3, G4
Example Syntax:	DPATEQ, 3, 6, 1, 2, 5, 11

Field	Contents
DPATID	ID of the data patch to be created.
REFID	ID of the reference data patch.
G1, G2, G3, G4	Corner grid points of the surface on which data patch DPATID will be located.

BULK DATA INPUT

Input Directive: DPATL Data patch generator

Description: One-component data patch created from data lines.

Format: DPATL, DPID, G1, G2, G3, G4,,,,, DL1, DL2, DL3, DL4

Example Syntax: DPATL, 14, 5, 6, 10, 12,,,,, 3, 4, 7, 2

Field	Contents
DPID	Data patch identification number.
G1, G2, G3, G4	Corner grid point identification numbers.
DL1, DL2, DL3, DL4	Data line identification numbers.

Remarks:

1. The data lines are checked for common values at the corner nodes.
2. The data lines must all reference the same data set.
3. DATAG input is not mandatory if the data lines are direct input. The grid point values will be determined from the data lines.
4. The grid point and line sequencing is as shown for the PATCHL directive.

BULK DATA INPUT

Input Directive: DPATQ Data patch generator

Description: One-component bilinear data patch created from corner values.

Format: DPATQ, DPID, DSID, G1, G2, G3, G4

Example Syntax: DPATQ, 2, 6, 5, 11, 7, 3

Field	Contents
DPID	Identification number for the one-component data patch created by this card.
DSID	Identification number for the data set that has data values, DI, at the corner grid points.
G1, G2, G3, G4	Corner grid points that locate the data patch in space.

Remarks: 1. See PATCHL directive for grid point sequence illustration.

BULK DATA INPUT

Input Directive:	DPAT4L. Data patch generator
Description:	One-component data patch generated from single line segments of four data lines in one parametric direction.
Format:	DPAT4L, DPID, G1, G2, G3, G4,,,,, DL1/SEG, DL2/SEG, DL3/SEG, DL4/SEG
Example Syntax:	DPATL4, 6, 5, 4, 7, 9,,,,, 5, 19, 21/3, 22/4

Field	Contents
DPID	Data patch identification number.
G1, 2, 3, 4	Corner grid point identification numbers.
DLI/SEG	Data line number for line I, segment number SEG. (Default SEG is 1.)

Remarks:

1. See PATCHL directive for grid point sequence illustration.

BULK DATA INPUT

Input Directive: DTCS Data table function

Description: Defines a scalar function from tabular data using piecewise cubic spline interpolation.

Format: DTSC, ID, Tref, T1, f(T1), T2, f(T2), T3, f(T3)

Example Syntax: 7*,, 100.0, 10.1E6, 200.0, 9.8E6, 250.0, 8.4E6

Field	Contents
ID	Table identification number. If followed by an asterisk the function is normalized such that f* (Tref) = 1.0.
Tref	Reference abscissa, T1 $\leq$ Tref $\leq$ TN. The default value is Tref = T1.
Ti	Abscissa values in increasing order, Ti $>$ Ti-1.
f(Ti)	Value of the function f(T) at T = Ti.

Remarks:

1. The function f(T) is interpolated by a piecewise cubic spline. Off table values are set to

   $f(T) \equiv f(T1)$ for $T < T1$

   $f(T) \equiv f(TN)$ for $T > TN$

2. Attempts to normalize a function with f(Tref) = 0.0 are fatal errors.

BULK DATA INPUT

Input Directive: DTPC Data table function

Description: Defines a scalar function from tabular data using piecewise linear interpolation.

Format: DTPC, ID, Tref, T1, f(T1), T2, f(T2), T3, f(T3),..., TN, f(TN)

Example Syntax: DTPC, 6*, 160, 60., 30.0E6, 300., 26.0E6, 1000., 10.0+6,..., 5000, 1.0+6

Field	Contents
ID	Table identification number. If followed by an asterisk the function is normalized such that f* (Tref) = 1.0.
Tref	Reference abscissa, $T1 \leq Tref \leq TN$. The default value is Tref = T1.
Ti	Abscissa values in increasing order, $Ti \geq Ti-1$.
f(Ti)	Value of the function f(T) at T = Ti.

Remarks:

1. The function f(T) is interpolated as piecewise linear. Off table values are set to

$$f(T) \equiv f(T1) \quad \text{for } T < T1$$

$$f(T) \equiv f(TN) \quad \text{for } T > TN$$

2. Attempts to normalize a function with f(Tref) = 0.0 are fatal errors.

BULK DATA INPUT

Input Directive:	FORCE Static load
Description:	Defines a static load at a grid point by Cartesian vector components.
Format:	FORCE, ID, GID, F1, F2, F3
Example Syntax:	FORCE, 5, 21, 500.,, 600.

Field	Contents
ID	Load set identification number (integer, 1 to 999).
GID	Grid point identification number.
F1, F2, F3	Components of the load vector in the reference Cartesian coordinate directions $\underset{\sim}{e}_1$, $\underset{\sim}{e}_2$, and $\underset{\sim}{e}_3$.

BULK DATA INPUT

Input Directive:	FORCEL3 Line load data
Description:	Defines a line load on one edge of a 3-D element.
Format:	FORCEL3, ID, EID, DL1, DL2, DL3, S1, S2, S3
Example Syntax:	FORCEL3, 6, 10, 2,, 4,, 2.0

Field	Contents
ID	Load set identification number.
EID	Element identification number.
DL1, 2, 3	Data lines for components F1, F2, and F3 where $F = Fia_i$ and the a_i are unit tangent vectors.
S1, 2, 3	Scale factors applied to the data lines DL1, 2, 3. Default values are 1.0.

Remarks:

1. The data lines must reference the same grid points, and these are used to locate the edge of element EID on which the line load acts. A blank field for a data line ID indicates that component of the load is identically zero.

BULK DATA INPUT

Input Directive: FORCET Surface force data

Description: Defines a surface traction on one surface of a 3-D element.

Format: FORCET, ID, EID, DP1, DP2, S1, S2

Example Syntax: FORCET, 6, 10, 11,, -2.3

Field	Contents
ID	Load set identification number.
EID	Element identification number.
DP1, 2	Data patches for components T1 and T2 of the traction $\underset{\sim}{T} = T1\underset{\sim}{t}_1 + T2\underset{\sim}{t}_2$ where $\underset{\sim}{t}_1$, $\underset{\sim}{t}_2$ are unit tangent vectors.
S1, 2	Scale factors applied to the data patches DP1, 2. Default values are 1.0.

Remarks:

1. The data patches must reference the same grid points, and these are used to locate the face of element EID on which the traction acts. A blank field for DP1 (DP2) indicates T1 (T2) is identically zero.

2. The sense of the unit tangent vectors is given in Figure 2-6.

BULK DATA INPUT

Input Directive:	GRID Grid point
Description:	Defines the coordinates of a grid point.
Format:	GRID, GID, CID, Z1, Z2, Z3
Example Syntax:	GRID, 5, 1, 0.0, 2.0, 4.05

Field	Contents
GID	Grid point identification number.
CID	Coordinate type. 1-Cartesian, 2-Polar (default = 1, integer).
Z1, Z2, Z3	Location of the grid point in coordinate system CID.

Remarks:

1. The input sequence for polar coordinates is r, θ, Z.

BULK DATA INPUT

Input Directive:	HPATCH Hyperpatch generator
Description:	Direct input of a hyperpatch in any format.
Format:	HPATCH, ID, FORMAT, M1, M2, M3, TID.
Example Syntax:	HPATCH, 1, P, 101, 102, 103.

Field	Contents
ID	Hyperpatch identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
M1, 2, 3	MTRX identification numbers for Z1, Z2, and Z3.
TID	Transformation identification number to be applied to the hyperpatch, if any.

Remarks:

1. The default FORMAT is point format.
2. The 64 coefficients in any format for each hyperpatch coordinate function are input in the sequence P111, P211, P311, P411, P121, ...
3. The mathematical definition of the different format coefficients is defined in Chapter 5.

BULK DATA INPUT

Input Directive:	HPHEX Hyperpatch for a linear hexahedron
Description:	Generates a hyperpatch from the 8 corner grid points.
Format:	HPHEX, HPATID, G1, G2, G3, G4,,,,, G5, G6, G7, G8
Example Syntax:	HPHEX, 1, 1, 2, 3, 4,,,,, 5, 6, 7, 8

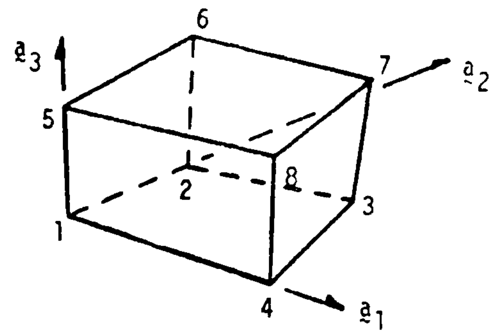
Field	Contents
HPATID	Hyperpatch identification number.
G1	The grid point identification number for the (0, 0, 0) node.
G2	The grid point identification number for the (0, 1, 0) node.
G3	The grid point identification number for the (1, 1, 0) node.
G4	The grid point identification number for the (1, 0, 0) node.
G5	The grid point identification number for the (0, 0, 1) node.
G6	The grid point identification number for the (0, 1, 1) node.
G7	The grid point identification number for the (1, 1, 1) node.
G8	The grid point identification number for the (1, 0, 1) node.

Remarks:

1. The trilinear hexahedron is not required to have flat surfaces.

Commentary:

Generation of a hyperpatch from the eight corner points.



Method:

First generate the lower and upper surface patches B1 and B2 using PATCH1, and then use the technique outlined in the description of HP2PAT to compute B3 and B4 as

$$[B3] = [B4] = [B2] - [B1]$$

BULK DATA INPUT

Input Directive: HPL Gridline definition of a hyperpatch

Description: Generates a hyperpatch from the 12 edge lines.

Format: HPL, HPATID, L1, L2, L3, L4, L5, L6,, CROSSF, L7, L8, L9, L10, L11, L12

Example Syntax: HPL, 1, 4, 12, 8, 9, 2, 11,,, 6, 10, 1, 3, 7, 5

Field	Contents
HPATID	Hyperpatch identification number.
L1 - L12	Line identification numbers, as shown below.
CROSSF	Cross derivatives flag. 0 for 0. cross derivatives, 1 for linearly interpolated cross derivatives.

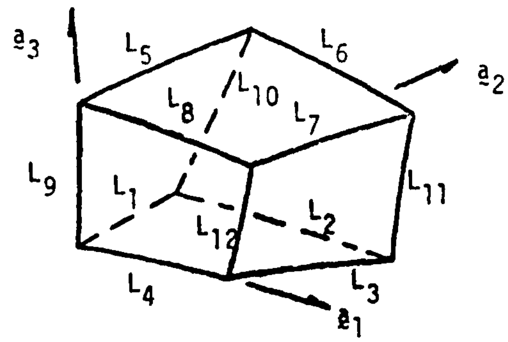
$L1 = \underset{\sim}{Z}(0,\xi_2,0)$	$L7 = \underset{\sim}{Z}(1,\xi_2,1)$
$L2 = \underset{\sim}{Z}(\xi_1,1,0)$	$L8 = \underset{\sim}{Z}(\xi_1,0,1)$
$L3 = \underset{\sim}{Z}(1,\xi_2,0)$	$L9 = \underset{\sim}{Z}(0,0,\xi_3)$
$L4 = \underset{\sim}{Z}(\xi_1,0,0)$	$L10 = \underset{\sim}{Z}(0,1,\xi_3)$
$L5 = \underset{\sim}{Z}(0,\xi_2,1)$	$L11 = \underset{\sim}{Z}(1,1,\xi_3)$
$L6 = \underset{\sim}{Z}(\xi_1,1,1)$	$L12 = \underset{\sim}{Z}(1,0,\xi_3)$

Remarks:

1. The CROSSF parameter controls the local surface warping. A zero indicates a data surface with zero twist at the four corners.

Commentary:

Generation of a hyperpatch from the 12 edge lines.



Method:

Generate surface patch P1 from the lines L1, L2, L3, L4.

Generate surface patch P2 from the lines L5, L6, L7, L8.

Generate surface patch P3 from the lines L4, L12, L8, L9.

Generate surface patch P4 from the lines L2, L11, L6, L10.

Generate surface patch P5 from the lines L9, L5, L10, L1.

Generate surface patch P6 from the lines L12, L7, L11, L3.

Use the procedure described for HP6PAT to compute B1, B2, B3, B4 from six patches after checking all lines for common end points at the corners.

BULK DATA INPUT

Input Directive:	HPN Hyperpatch for thick shells
Description:	Generates a hyperpatch from a patch and a given thickness in the normal direction.
Format:	HPN, HPATID, PATID, THK
Example Syntax:	HPN, 1, 7, 1.675

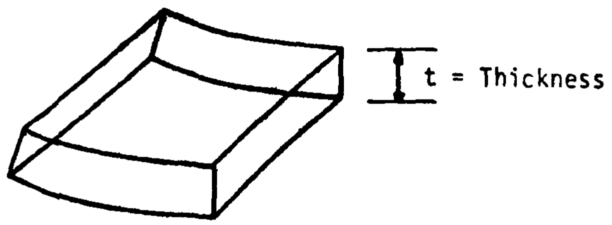
Field	Contents
HPATID	Hyperpatch identification number.
PATID	Base patch identification number.
THK	Thickness of the hyperpatch.

Remarks:

1. When used with degenerate patches, the normals near the degenerate node may have some distortion.

Commentary:

Generation of a hyperpatch from a patch and a given thickness in the normal direction.



Method:

Transform B to point format, [Z].

Compute the unit normals at 16 points on the patch, [N].

If $t > 0$ define

$B1 \equiv [Z]$, $B2 \equiv [Z] + t\,[N]$

If $t < 0$ define

$B1 \equiv [Z] + t\,[N]$, $B2 \equiv [Z]$

Use the procedure described for HP2PAT to compute B3 and B4.

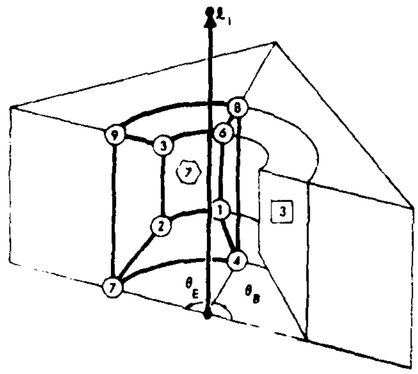
BULK DATA INPUT

Input Directive:	HPR Hyperpatch for a body of revolution segment
Description:	Generates a hyperpatch by rotating a planar patch about a coordinate axis.
Format:	HPR, HPATID, PATID, Z1, Z2, Z3, THETAB, THETAE, IDRA
Example Syntax:	HPR, 7, 3, 0.0, 1.0, -2.5, 15.0, 40.0, 2

Field	Contents
HPATID	Hyperpatch identification number.
PATID	Identification number of the patch to be rotated.
Z1, Z2, Z3	Coordinates for shifting the origin.
THETAB, THETAE	Beginning and ending angles through which the patch will be rotated (real, degrees).
IDRA	Axis of rotation (integer, -3 to 3). +1 = +X, -1 = -X, +2 = +Y, +3 = +Z, etc.

Commentary:

Generation of a hyperpatch by rotating a planar patch about a coordinate axis, $\underset{\sim}{e}_i$.



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Method:

Given the planar patch $\underset{\sim}{Z}(\xi_1,\xi_2)$, rotate the lines $\underset{\sim}{Z}(0,\xi_2)$, $\underset{\sim}{Z}(1/3,\xi_2)$, $\underset{\sim}{Z}(2/3,\xi_2)$, and $\underset{\sim}{Z}(1,\xi_2)$ to form the patches $\beta 1$, $\beta 2$, $\beta 3$, and $\beta 4$ using PATCHR.

Then compute the patch coefficients.

$$[B1] = [\beta 1] \ , \ [B2] = [\beta 4]$$

$$[B3] = -5.5\,[\beta 1] + 9[\beta 2] - 4.5[\beta 3] + [\beta 4]$$

$$[B4] = -[\beta 1] + 4.5[\beta 2] - 9[\beta 3] + 5.5[\beta 4]$$

The parameterization generated is as follows: If a_1^* and a_2^* are the tangent vectors of the original patch and

(1) If $\underset{\sim}{e}_i \times \underset{\sim}{Z}(1/2,1/2) \cdot \underset{\sim}{N}(1/2,1/2) > 0$ then $\underset{\sim}{a}_1^* = \underset{\sim}{a}_3$, $\underset{\sim}{a}_2^* = \underset{\sim}{a}_1$

(2) If $\underset{\sim}{e}_i \times \underset{\sim}{Z}(1/2,1/2) \cdot \underset{\sim}{N}(1/2,1/2) < 0$ then $\underset{\sim}{a}_1^* = \underset{\sim}{a}_3$, $\underset{\sim}{a}_2^* = \underset{\sim}{a}_2$

BULK DATA INPUT

Input Directive:	HP2PAT Hyperpatch for interpolating two surfaces
Description:	Generates a hyperpatch from two surface patches with linear interpolation of the hyperpatch parameters between faces five and six.
Format:	HP2PAT, HPATID, PAT1, PAT2
Example Syntax:	HP2PAT, 1, 11, 12

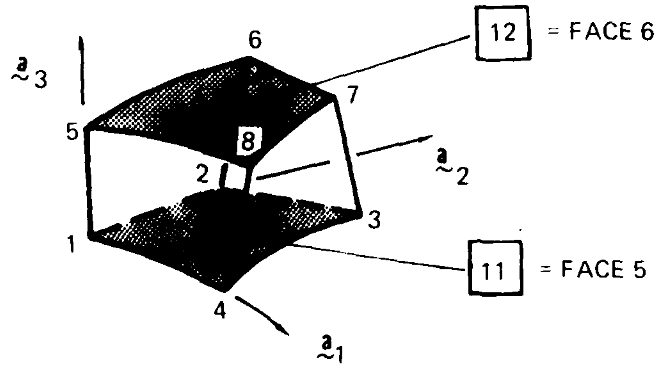
Field	Contents
HPATID	Hyperpatch identification number.
PAT1	Surface patch identification number of the $\xi_3 = 0$ patch.
PAT2	Surface patch identification number of the $\xi_3 = 1$ patch.

Remarks:

1. The hyperpatch is in "3" sort by construction. It cannot be resorted automatically.

Commentary:

Generation of a hyperpatch from two surface patches with linear interpolation of the hyperpatch parameters between the faces.



Method:

$$\text{Patch 1,} \quad [B1] = \begin{bmatrix} Z1 & Z2 & (Z,_{\xi_1})1 & (Z,_{\xi_2})2 \\ Z4 & Z3 & (Z,_{\xi_2})4 & (Z,_{\xi_2})3 \\ (Z,_{\xi_1})1 & (Z,_{\xi_1})2 & (Z,_{\xi_1\xi_2})1 & (Z,_{\xi_1\xi_2})2 \\ (Z,_{\xi_1})4 & (Z,_{\xi_1})3 & (Z,_{\xi_1\xi_2})4 & (Z,_{\xi_1\xi_2})3 \end{bmatrix}$$

$$\text{Patch 2,} \quad [B2] = \begin{bmatrix} Z5 & Z6 & (Z,_{\xi_2})5 & (Z,_{\xi_2})6 \\ Z8 & Z7 & (Z,_{\xi_2})8 & (Z,_{\xi_2})7 \\ (Z,_{\xi_1})5 & (Z,_{\xi_1})6 & (Z,_{\xi_1\xi_2})5 & (Z,_{\xi_1\xi_2})6 \\ (Z,_{\xi_1})8 & (Z,_{\xi_1})7 & (Z,_{\xi_1\xi_2})8 & (Z,_{\xi_1\xi_2})7 \end{bmatrix}$$

To make the hyperpatch linear between faces $\underset{\sim}{Z}(\xi_1, \xi_2, 0)$ and $Z(\xi_1, \xi_2, 1)$ compute

$$[B3] = [B4] = [B2] - [B1]$$

BULK DATA INPUT

Input Directive:	HP4PAT Hyperpatch generator
Description:	Hyperpatch generated from four director patches in parametric direction three.
Format:	HP4PAT, ID, P1, P2, P3, P4, TID
Example Syntax:	HP4PAT, 1, 3, 4, 8, 7

Field	Contents
ID	Hyperpatch identification number.
P1	Patch identification number for $\xi_3 = 0$.
P2	Patch identification number for $\xi_3 = 1/3$.
P3	Patch identification number for $\xi_3 = 2/3$.
P4	Patch identification number for $\xi_3 = 1$.
TID	Transformation identification number, if any, to be applied to the hyperpatch.

BULK DATA INPUT

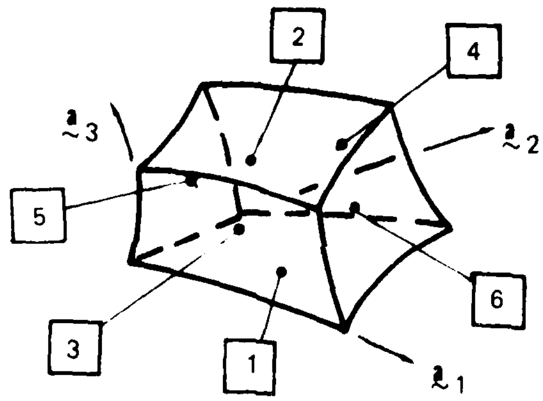
Input Directive:	HP6PAT Hyperpatch for a curvilinear hexahedron
Description:	Generates a hyperpatch from 6 patches which enclose a volume.
Format:	HP6PAT, HPATID, P1, P2, P3, P4, P5, P6, CROSSF
Example Syntax:	HP6PAT, 1, 1, 2, 3, 5, 6, 4, 0

Field	Contents
HPATID	Hyperpatch identification number.
P1	Surface patch identification number of the $\xi_3 = 0$ patch.
P2	Surface patch identification number of the $\xi_3 = 1$ patch.
P3	Surface patch identification number of the $\xi_2 = 0$ patch.
P4	Surface patch identification number of the $\xi_2 = 1$ patch.
P5	Surface patch identification number of the $\xi_1 = 0$ patch.
P6	Surface patch identification number of the $\xi_1 = 1$ patch.
CROSSF	Cross derivatives flag. 0 for 0. cross derivatives and 1 for linearly interpolated cross derivatives.

Remarks: 1. The CROSSF parameter controls the local surface warping. A zero indicates a geometric surface with zero twist at the four corners.

Commentary:

Generation of a hyperpatch from 6 patches which enclose a volume.



Method:

Given the patches P1, P2, P3, P4, P5, and P6, form the hyperpatch coefficients B1, B2, B3, B4 as follows:

[B1] = [P1]

[B2] = [P2]

Coefficients for B3 and B4 are extracted from P3, P4, P5, and P6 after checking all patches for common lines on intersecting edges.

BULK DATA INPUT

Input Directive:	LARCPC A circular arc with N-1 line segments
Description:	Generates a piecewise parametric cubic line from a circular arc with N-1 line segments.
Format:	LARCPC, LID, R, Z1, Z2, Z3, THETAB, THETAE, IDRA, G1, G2, G3,..., GN
Example Syntax:	LARCPC, 21, .5, 0.0, 3.2, .006, 30.0, 60.0, 3, 2, 5 THRU 10, 12

Field	Contents
LID	Line identification number for the generated line (integer, 1 to 180).
R	Radius of the arc.
Z1, Z2, Z3	Coordinates of the center of the circle.
THETAB, THETAE	Beginning and ending angles of the sweep of the arc (real, degrees).
IDRA	Axis of rotation (integer, -3 to 3). +1 = +X, -1 = -X, +2 = +Y, +3 = +Z, etc.
G1, G2,..., GN	G1 is the first grid point on the arc, GN is the last grid point on the arc, and the interior items in the list are the equally spaced interior grid-points.

Remarks:

1. See PATCHGR commentary for an illustration of the construction method.

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BULK DATA INPUT

Input Directive:	LINE Direct input of a parametric cubic line.
Description:	Direct input of a parametric cubic line in any format. The line is subdivided into N-1 line segments with N grid points.
Format:	LINE, LID, FORMAT, M1, M2, M3, TID, G1, G2, G3, G4,..., GN
Example Syntax:	LINE, 7, B, 201, 202, 203,, 21, 24, 25, 30,,, 100

Field	Contents
LID	Line identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
M1, 2, 3	Matrix identification numbers for Z1, Z2, and Z3.
TID	Transformation identification number, if any, to apply to the line.
G1, 2,..., N	Grid point identification numbers for the N grid-points on the line.

Remarks: The default FORMAT is point format. The mathematical definition of the input coefficients for each format is in Chapter 5.

BULK DATA INPUT

Input Directive:	LINECS Parametric spline line
Description:	Generates a piecewise parametric cubic line from the input grid points and spline constraints.
Format:	LINECS, LID, G1, G2, G3,..., GN
Example Syntax:	LINECS, 5, 2, 4 THRU 10 EXCEPT 7

Field	Contents
LID	Line identification number for the generated line (integer, 1 to 180).
G1, G2,..., GN	List of grid points through which the spline is to be passed.

Remarks:	There must be at least three grid points, $N \geqslant 3$, to use this line card. There can be a maximum of 25.

BULK DATA INPUT

Input Directive:	LINEGR A line from a general rotation
Description:	Generation of a piecewise parametric cubic line from the general rotation of a point about an arbitrary axis.
Format:	LINEGR, LID, GP, ZA1, ZA2, ZA3, ZB1, ZB2, ZB3, TID, GAMMA, GAMMO, G1, G2,..., GN
Example Syntax:	LINEGR, 6, 21, 0., 0., 0., 1., 1., -2.5,, 30., 0., 1 THRU 6, 50

Field	Contents
LID	Line identification number.
GP	Grid point to be rotated.
ZA1, 2, 3	Coordinates of the base of the rotation vector (axis).
ZB1, 2, 3	Coordinates of the head of the rotation vector (axis).
TID	Transformation identification number, if any, to be applied to the line.
GAMMA, GAMMO	Subtended angle, initial offset angle. Same as PATCHGR.
G1, 2,..., N	The grid point identification numbers for the N grid points on the line.

Remarks:

1. The default offset angle is zero.
2. See the PATCHGR directive for an illustration of the construction.

BULK DATA INPUT

Input Directive:	LINEPC Generate a straight line with N - 1 line segments
Description:	Generates a piecewise parametric cubic line with N - 1 line segments.
Format:	LINEPC, LID, G1, G2, G3,..., GN
Example Syntax:	LINEPC, 5, 1, 5, 8 THRU 16 EXCEPT 14

Field	Contents
LID	Line identification number for the generated line (integer, 1 to 180).
G1, G2,..., GN	G1 is the starting grid point for the line. GN is the ending grid point for the line.

Remarks:

1. The coordinates of the intermediate grid points are automatically computed and are uniformly spaced.
2. The end points G1 and GN must be input or constructed by another directive.

BULK DATA INPUT

Input Directive:	MATAL Thermal expansion coefficients
Description:	Matrix identification numbers for the three-dimensional thermal expansion coefficients at N points in an element.
Format:	MATAL, MID, FRAME, POINTS, AL1, AL2,...,..., ALN
Example Syntax:	MATAL, 7, 1, 8, 101 THRU 108

Field	Contents
MID	Material identification number.
FRAME	= 1, Thermal expansion coefficients $\vec{\alpha}$ are in an orthonormal Cartesian frame. = 2, Thermal expansion coefficients $\vec{\alpha}$ are in the normalized parametric frame.
POINTS	= 1, Constant properties. = 8, Trilinear variation in properties. = 64, Tricubic variation in properties.
AL1, AL2,..., ALN	Matrix identification numbers for the thermal expansion coefficients $\vec{\alpha}$ at the interpolation points. If N = 64 a single entry is used to identify a matrix containing the 64 identification numbers.

Remarks: 1. The αIJ are input in the sequence $\alpha 11$, $\alpha 22$, $\alpha 33$, $\alpha 12$, $\alpha 13$, $\alpha 23$.

BULK DATA INPUT

Input Directive:	MATC Materials stiffness matrix
Description:	Matrix identification numbers for the three-dimensional stress-strain equations at N points in an element.
Format:	MATC, MID, FRAME, POINTS, C1, C2,..., CN
Example Syntax:	MATC, 7, 2, 8, 6 THRU 12, 16

Field	Contents
MID	Material identification number.
FRAME	= 1, C Matrix is in an orthonormal Cartesian frame. = 2, C Matrix relates contravariant physical components of stress to covariant physical components of strain in the parametric frame. (Useful with orthotropic bodies of revolution.)
POINTS	= 1, Constant material properties (N = 1). = 8, Trilinear variation of material properties (N = 8). = 64, Tricubic variation of material properties (N = 64).
C1, C2,..., CN	Matrix identification numbers for the stress-strain coefficient matrices at the interpolation points. If N = 64 a single entry is used to identify a matrix containing the 64 CID's. A special partitioning format is used to input [C] for user convenience, as shown on MTRX-CID directive.

Remarks: 1. The MTRX-CID directive defines the input sequence.

BULK DATA INPUT

Input Directive:	MATE Materials compliance matrix
Description:	Matrix identification numbers for the three-dimensional strain-stress equations at N points in an element.
Format:	MATE, MID, FRAME, POINTS, C1, C2,..., CN
Example Syntax:	MATE, 7, 2, 8, 6 THRU 12, 16

Field	Contents
MID	Material identification number.
FRAME	= 1, $E = C^{-1}$ Matrix is in an orthonormal Cartesian frame. = 2, $E = C^{-1}$ Matrix relates contravariant physical components of strain to covariant physical components of stress in the parametric frame. (Useful with orthotropic bodies of revolution.)
POINTS	= 1, Constant material properties (N = 1). = 8, Trilinear variation of material properties (N = 8). = 64, Tricubic variation of material properties (N = 64).
C1, C2,..., CN	Matrix identification numbers for the strain-stress coefficient matrices at the interpolation points. If N = 64 a single entry is used to identify a matrix containing the 64 CID's. A special partitioning format is used to input [E] for user convenience, as shown on MTRX-CID directive.

BULK DATA INPUT

Input Directive:	MATOR Orthotropic material definition
Description:	Defines the material properties for a linear, temperature independent, orthotropic material from engineering constants.
Format:	MATOR, MID, FRAME, POINTS, O1, O2,..., ON
Example Syntax:	MATOR, 3, 1, 8, 2, 6 THRU 12

Field	Contents
MID	Material identification number.
FRAME	= 1, Properties are in an orthonormal Cartesian frame. = 2, Properties are in the normalized parametric frame of the element. Assumes parametric frame is quasi-cylindrical or spherical.
POINTS	= 1, Constant material properties (N = 1). = 8, Trilinear variation of material properties (N = 8). = 64, Tricubic variation of material properties (N = 64).
O1, O2,..., ON	Matrix identification number for the orthotropic material engineering constants at the interpolation points. If POINTS is equal to 64 a single entry is used to identify a matrix containing the 64 OID's.

Remarks:

1. The engineering constants are entered in sequence E11, E22, E33, NU12, NU13, NU23, G12, G13, G23 on the MTRX matrix card(s).
2. The Air Force Design Guide convention for Poisson ratios is used; i.e., $E_{ii}\ NU_{ji} = E_{jj}\ NU_{ij}$.

BULK DATA INPUT

Input Directive: MATTA Temperature-dependent properties

Description: Specifies the data table functions that define the temperature dependence of the thermal expansion moduli relative to a reference test temperature.

Format: MATTA, MID, MPID, DT1, DT2, DT3, DT2, DT5, DT6

Example Syntax: MATTA, 3,, 1, 1, 1, 2, 2, 2

Field	Contents
MID	Material identification number. The same MID must appear on a MATAL card if normalized data table functions are used.
MPID	Identification number of the matrix that defines the meshpoints for which these data apply. The default is all meshpoints in the element. This may be delimited by other MATTA cards.
DTI	Data table function, DTCS or DTPC, for component I of the $\vec{\alpha}$ vector. The default for a blank field is the α_{ii} given by the MATAL card if present and zero if none is defined.

Remarks:

1. When the reference temperature for a data table function is not equal to the ambient temperature for the case, then $\alpha(T)$ is computed as

$$\alpha(T) = (f(T)(T-T_{ref})-f(T_A)(T_A-T_{ref})) \ / \ (T-T_A)$$

to ensure zero thermal strain at ambient temperature.

BULK DATA INPUT

Input Directive:	MATTAT Temperature-dependent properties
Description:	Specifies the data table functions that define the temperature dependence of the thermal expansion moduli relative to a reference test temperature using strain data directly.
Format:	MATTAT, MID, MPID, DT1, DT2, DT3, DT4, DT5, DT6
Example Syntax:	5,, 11, 14, 3

Field	Contents
MID	Material identification number. The same MID may appear on a MATTA, but the meshpoints referenced by MPID must be different.
MPID	Identification number of the matrix that defines the meshpoints for which these data apply. The default for a blank field is all meshpoints in the element. This may be delimited by other MATTAT cards.
DTI	Data table function, DTCS or DTPC, for component I of the strain vector $\vec{\varepsilon}$. The default for a blank field is zero.

Remarks:

1. When the reference temperature for a data table function is not equal to the ambient temperature for the case, then $\alpha(T)$ is computed as

$$\alpha(T) = (f(T) - f(T_A)) / (T - T_A)$$

   to ensure zero thermal strain at ambient temperature.

2. Since there is no temperature-independent property card based on thermal strain data, the data table functions cannot be normalized.

BULK DATA INPUT

Input Directive: MATTC Temperature-dependent stiffness properties

Description: Specifies the data table functions that define the temperature dependence of each CIJ component.

Format: MATTC, MID, MPID, DT11, DT12, DT13, DT22, DT23, DT33

Example Syntax: MATTC, 7,, 10, 11, 11, 10, 11, 10

Field	Contents
MID	Material identification number. The same MID must appear on a MATC card when using normalized data table functions.
MPID	Identification number of the matrix that defines the meshpoints for which these data apply. The default for a blank field is all meshpoints in the element. This may be delimited by other MATTC cards.
DTIJ	Identification number of the data table function for component CIJ in the sequence defined on the MTRX-CID card. The default for a blank field is the CIJ given by the MATC card if present and zero if none is defined.

Remarks:

1. Normalized data table functions result in

   CIJ (T) - CIJ f* (T)

   where CIJ is defined by a MATC card. This allows one data table function to model several CIJ (T) when components have similar temperature dependence.

BULK DATA INPUT

Input Directive:	MATTE Temperature-dependent compliance properties
Description:	Specifies the data table functions that define the temperature dependence of each component, EIJ = CIJ inverse.
Format:	MATTE, MID, MPID, DT11, DT12, DT13, DT22, DT23, DT33
Example Syntax:	MATTE, 5, 4, 11, 12, 12, 11, 12, 13

Field	Contents
MID	Material identification number. The same MID must appear on a MATE card when using normalized data table functions.
MPID	Identification number of the matrix that defines the meshpoints for which these data apply. The default for a blank field is all meshpoints in the element. This may be delimited by other MATE cards.
DTIJ	Identification number of the data table function for component DIJ in the sequence defined on the MTRX-CID card. The default for a blank field is the EIJ given by the MATE card if present and zero if none is defined.

Remarks:

1. Normalized data table functions result in

$$EIJ\ (T) = DIJ\ f^*\ (T)$$

where EIJ is defined by a MATE card. This allows one data table function to model several EIJ (T) when components have similar temperature dependence.

BULK DATA INPUT

Input Directive: MATTO Temperature dependent orthotropic properties

Description: Specifies the data table functions that define the temperature dependence of the nine elastic constants for an orthotropic material.

Format: MATTO, MID, MPID, DT1, DT2, DT3,..., DT9

Example Syntax: MATTO, 1,, 1, 2, 3, 4, 5, 5, 6, 7, 3

Field	Contents
MID	Material identification number. The same MID must appear on a MATOR directive when using normalized data table functions.
MPID	Identification number of the matrix that defines the mesh points for which these data apply. The default for a blank field is all mesh points in the element(s) referencing this MID. The list may be delimited by other MATTO directives.
DTI	Identification number of the data table function for E11, E22, E33, NU12, NU13, NU23, G12, G13, G23 in that order. The default for a blank field is the value given that field by the MATOR if present and zero if none is defined.

Remarks: 1. Normalized data table functions result in

$$EII(T) = EII \cdot f^*(T)$$

where EII is defined by a MATOR directive. This feature allows one data table function to model several EII(T) when several modulii have the same temperature dependence.

BULK DATA INPUT

Input Directive:	MAT1 Material property definition
Description:	Defines the material properties for linear, temperature-independent, isotropic, and certain orthotropic materials.
Format:	MAT1, MID, E, G, NU
Example Syntax:	MAT1, 17, 3.+7, 1.9+7

Field	Contents
MID	Material identification number (integer, 1 to 50).
E	Young's Modulus (real, ⩾ 0 or blank).
G	Shear Modulus (real, ⩾ 0 or blank).
NU	Poisson's Ratio (real or blank).

Remarks:

1. If all three elastic constants are input the material is, in general, orthotropic.
2. Any two of the elastic constants can be input to define an isotropic material. The blank field value will be automatically computed.

BULK DATA INPUT

Input Directive: MATT1 Temperature dependent properties

Description: Specifies the data table functions that define the temperature dependence for an isotropic material.

Format: MATT1, MID, MPID, DT1, DT2, DT3

Example Syntax: MATT1, 3,, 1,, 1

Field	Contents
MID	Material identification number. The same MID must appear on a MAT1 card when using normalized data table functions.
MPID	Identification number of the matrix that defines the meshpoints for which these data apply. The default for a blank field is all meshpoints in the element. This may be delimited by other MATT1 cards.
DTI	Identification number of the data table function for E, G, and NU, respectively. The default for a blank field is the moduli given by the MAT1 card when present. If no MAT1 card is present, at least two data table functions must be present.

BULK DATA INPUT

Input Directive:	MPE1 Mesh point equality constraint
Description:	Imposes displacement equality constraints at one or more mesh points in Cartesian coordinates.
Format:	MPE1, SID, COMPS, EID-P, IJK-P, EID-S, IJK-S, PSI-P, THETA-P, PHI-P, PSI-S, THETA-S, PHI-S
Example Syntax:	MPE1, 10, 23, 1, 111, 2, 114, -2.2, 90, 90, -32.2, 90, 90

Field	Contents
SID	Constraint set identification number.
COMPS	Constrained displacement components U1, U2, U3 identified by any combination of the digits 1, 2, and 3.
EID-P	Element identification number associated with the primary or independent mesh points.
IJK-P	Defines the primary mesh points using the mesh point convention described in the Commentary for this directive.
EID-S	Element identification number associated with the secondary or dependent mesh points.
IJK-S	Defines the secondary mesh points using the mesh point convention described in the Commentary for this directive.
PSI, THETA, PHI-P	Euler angles in the 3, 1, 3 sequence that rotate the reference Cartesian coordinate frame to the constraint frame at a primary mesh point.
PSI, THETA, PHI-S	Euler angles in the 3, 1, 3 sequence that rotate the reference Cartesian coordinate frame to the constraint frame at a secondary mesh point.

Input Directive: MPE1 Mesh point equality constraint (Continued)

Remarks:

1. The primary and secondary mesh points can come from the same element.

2. Conflicts between SDC and MPE constraints are not allowed.

3. The number of primary and secondary mesh points must be equal unless there is only one primary.

4. Constraint frame synthesis continues just as with SPC constraints. The same mesh point may have both SPC and MPE constraints if they are linearly independent.

5. Equality constraints can be used for periodic boundary conditions and sliding interfaces.

Commentary:

The constraint of entire surfaces or strings of mesh points with a single MPE directive is provided as a user convenience. To support this option, the following convention for IJK definition of mesh points is adopted.

IJK	ELEMENT SURFACE	MESH POINTS
1	$Z(0, \xi_2, \xi_3)$	111, 121, 131,..., 134, 144
2	$Z(1, \xi_2, \xi_3)$	411, 421, 431,..., 434, 444
3	$Z(\xi_1, 0, \xi_3)$	111, 211, 311,..., 314, 414
4	$Z(\xi_1, 1, \xi_3)$	141, 241, 341,..., 344, 444
5	$Z(\xi_1, \xi_2, 0)$	111, 211, 311,..., 341, 441
6	$Z(\xi_1, \xi_2, 1)$	114, 214, 314,..., 344, 444
11	$Z(1/3, \xi_2, \xi_3)$	211, 221, 231,..., 234, 244
12	$Z(2/3, \xi_2, \xi_3)$	311, 321, 331,..., 334, 344
13	$Z(\xi_1, 1/3, \xi_3)$	121, 221, 321,..., 324, 424
14	$Z(\xi_1, 2/3, \xi_3)$	131, 231, 331,..., 334, 434
15	$Z(\xi_1, \xi_2, 1/3)$	112, 212, 312,..., 342, 442
16	$Z(\xi_1, \xi_2, 2/3)$	113, 213, 313,..., 343, 443
111	$Z(0, 0, 0)$	111
211	$Z(1/3, 0, 0)$	211
.	.	.
.	.	.
.	.	.
444	$Z(1, 1, 1)$	444
1001	List dependent	MTRX-1 Input mesh point list
1002	List dependent	MTRX-2 Input mesh point list
.	.	.
.	.	.
.	.	.
10ID	List dependent	MTRX-ID Input mesh point list

The IJK convention for individual mesh points is identical to the point format input convention. The convention for surfaces is illustrated in Figure 4-2 for the six external surfaces or faces of an element and the six internal parametric surfaces. The use of an MTRX directive to input a list of IJK mesh points is convenient when several elements are similarly constrained.

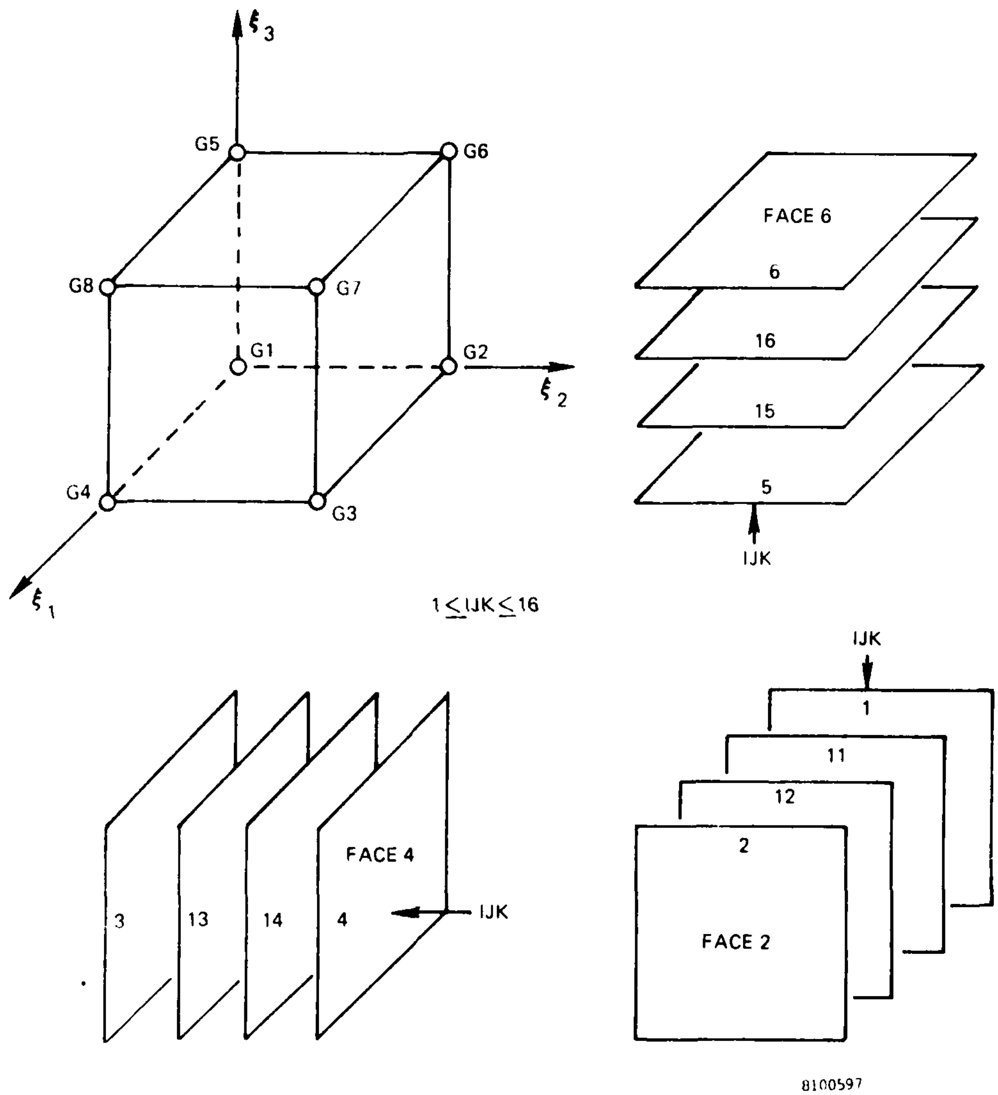


Figure 4-2. IJK Mesh Point Convention for the MPE Directives

BULK DATA INPUT

Input Directive:	MPE2 Mesh point equality constraint
Description:	Imposes displacement equality constraints at one or more mesh points in local surface coordinates.
Format:	MPE2, SID, COMPS, EID-P, IJK-P, EID-S, IJK-S, PSI-P, THETA-P, PHI-P, PSI-S, THETA-S, PHI-S
Example Syntax:	MPE2, 10, 123, 1, 5, 2, 6

Field	Contents
SID	Constraint set identification number.
COMPS	Constrained displacement components U1, U2, U3 identified by any combination of the digits 1, 2, and 3 where $\underset{\sim}{u} = U1\underset{\sim}{t}_1 + U2\underset{\sim}{t}_2 + U3\underset{\sim}{m}$.
EID-P	Element identification number associated with the primary or independent mesh points.
IJK-P	Defines the primary mesh points using the mesh point convention described in the Commentary for the MPE1 directive.
EID-S	Element identification number associated with the secondary or dependent mesh points.
IJK-S	Defines the secondary mesh points using the mesh point convention described in the Commentary for the MPE1 directive.
PSI, THETA, PHI-P	Euler angles in the 3, 1, 3 sequence that rotate the reference Cartesian coordinate frame to the constraint frame at a primary mesh point.
PSI, THETA, PHI-S	Euler angles in the 3, 1, 3 sequence that rotate the reference Cartesian coordinate frame to the constraint frame at a secondary mesh point.

Input Directive: MPE2 Mesh point equality constraint (Continued)

Remarks:

1. The primary and secondary mesh points can come from the same element.

2. Conflicts between SLC and MPE constraints are not allowed.

3. The number of primary and secondary mesh points must be equal unless there is only one primary.

4. Constraint frame synthesis continues just as with SPC constraints. The same mesh point may have both SPC and MPE constraints if they are linearly independent.

5. Equality constraints can be used for periodic boundary conditions and sliding interfaces. The example syntax is from a run using periodic boundary conditions.

BULK DATA INPUT

Input Directive:	MTRX-ID Input of a matrix or table
Description:	Input of a matrix or table of values which is referenced by 1 or more bulk data cards.
Format:	MTRX-ID, V1, V2, V3, V4, V5, V6, V7, V8
Example Syntax:	MTRX-5, 1.0, 2.0, 3.0, 4.0, 1.0, 2.0, 3.0, 4.0 MTRX-6, 2(1T4)

Field	Contents
MTRX-ID	The MTRX identification number. The ID number is a free-form integer within the last 4 positions of the mnemonic field. The dash (or any other character) is optional.
V_i	Input values in floating point format. Up to 64 values may be defined.

Remarks:

1. Multiple values may be indicated by parentheses; e.g., 4(20, 5, 8). Parentheses may not be nested; i.e., 4(2, 3(4), 3, 5).

BULK DATA INPUT

Input Directive: MTRX-CID

Description: Stress-strain coefficient matrix associated with CID.

Format: MTRX-CID, C11, C12, C13, C22, C23, C33, C44, C45, C46, C55, C56, C66

Example Syntax: MTRX-6, 1.0E7, 0.3E7, 0.3E7, 2.0E7, 0.2E7, 1.0E7, 0.0, 0.0, 0.5E7, 0.0, 0.5E7

Field	Contents	
CIJ	C11, C12, C13, C22, C23, C33	(Data items 1-6)
	C44, C45, C46, C55, C56, C66	(Data items 7-12)
	C14, C15, C16, C24, C25, C26, C34, C35, C36	(Data items 13-21)

Remarks:

1. If the material has cubic symmetry, locations 13-21 will be zero and need not be entered.

$$\begin{bmatrix} \sigma 11 \\ \sigma 22 \\ \sigma 33 \\ \sigma 12 \\ \sigma 13 \\ \sigma 23 \end{bmatrix} = \begin{bmatrix} C11 & C12 & C13 & C14 & C15 & C16 \\ C21 & C22 & C23 & C24 & C25 & C26 \\ C31 & C32 & C33 & C34 & C35 & C36 \\ C41 & C42 & C43 & C44 & C45 & C46 \\ C51 & C52 & C53 & C54 & C55 & C56 \\ C61 & C62 & C63 & C64 & C65 & C66 \end{bmatrix} \begin{bmatrix} \varepsilon 11 \\ \varepsilon 22 \\ \varepsilon 33 \\ \varepsilon 12 \\ \varepsilon 13 \\ \varepsilon 23 \end{bmatrix}$$

BULK DATA INPUT

Input Directive:	PARAM Special parameters
Description:	Special program parameter definition card for flags and other constants.
Format:	PARAM, VAR1, VALUE1, VAR2, VALUE2,..., VARN, VALUEN
Example Syntax:	PARAM, ACCG, 6, DEBUG, 1, DISK, 13

Field	Contents
VAR i	Name of the variable to be defined.
VALUE i	Value assigned to VAR i.

Currently the following parameters are recognized:

ACCG	Number of significant digits of accuracy to be used in the test for consistency between generated grid point coordinates. Default value = 5.
ORDERG/ORDERD	Changes the geometric (G) or data (D) line interpolation order to cubic first; i.e., if the same grid point appears on two line cards without input values, the (first) cubic line will be used to interpolate the point rather than the (first) linear line for VALUE = 1. Default value = 0.
DEBUG	Debugging flag to dump certain data during execution. Default value = 0. See Chapter 9.
AXY	The subtended angle in a CCX axisymmetric model.

(Continued on following page.)

Input Directive: PARAM Special parameters (continued)

Field	Contents
ITER	Maximum number of iterations to be executed in the conjugate gradient solution. Default = 110% of NFSET.
NSTP	Maximum number of steepest descent moves before a CG solution is terminated. Default = 5.
ERRORS	Maximum number of errors that the system will permit beyond the DRY point. Default = 0.
FLLINK	Field length override. Value is n, m where n is the link number and m is the octal number of thousand words of core; e.g., 12, 16 requests link 12 to begin with 16K octal words.
CONVRG	CG solution convergence value. Convergence is said to have occurred when the difference term is unchanged to CONVRG significant places. Default = 8.
EKREL	Relative factor in element stiffness generation which defines how small a number in algebraic format must be relative to the largest value in the element before it is set to 0.0. Default = 1.E - 11 on UNIVAC, 1.3 - 9 on CDC.

BULK DATA INPUT

Input Directive:	PATCH Patch generator
Description:	Direct input of a patch in any format.
Format:	PATCH, PID, FORMAT, MTRX-1, MTRX-2, MTRX-3, TID
Example Syntax:	PATCH, 4, S, 101, 102, 103

Field	Contents
PID	Patch identification number.
FORMAT	A or S Algebraic coefficients. B Geometric coefficients. P Point coefficients. G Gaussian coefficients.
MTRX-1, 2, 3	Matrix identification number for Z1, Z2, and Z3.
TID	Transformation identification number, if any, to be applied to the patch.

Remarks:

1. The default FORMAT is point format.
2. The 16 coefficients input in any format for each patch coordinate function are input in the sequence P11, P21, P31, P41, P21, P22,..., P44.

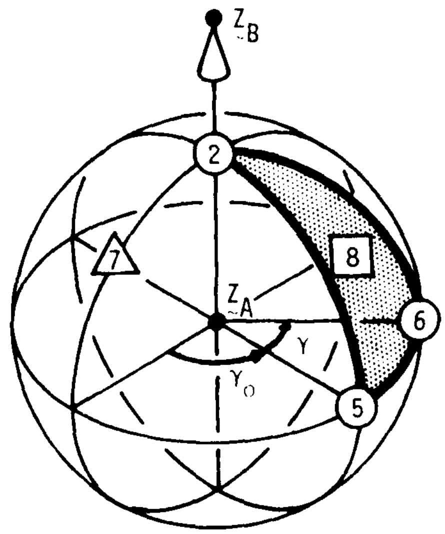
BULK DATA INPUT

Input Directive:	PATCHGR Patch generated by general line rotation
Description:	Generates a bicubic patch for the surface created by rotating a PC line about a general axis of rotation through gamma degrees.
Format:	PATCHGR, ID, LID/SEG, ZA1, ZA2, ZA3, ZB1, ZB2, ZB3, TID, GAMMA, GAMMO
Example Syntax:	PATCHGR, 5, 3, 1.5, 0., -3.0,, 2.5, 0.3,, 25

Field	Contents
ID	The identification number to be given the patch generated from line LID, segment number SEG.
LID, SEG	The line number, LID, and segment number, SEG, that identify the PC line to be rotated. A blank SEG defaults to one.
ZAI, ZBI	Coordinates of two points that define the rotation axis directed from ZA to ZB.
TID	Transformation ID, if any, that defines a geometric transformation to be applied to the PC line before rotation. The line, LID, does not change.
GAMMA, GAMMO	The PC line is rotated through GAMMA degrees starting GAMMO degrees from the initial position of the line. The sense of rotation is determined by the right-hand rule and the directed line (vector) from ZA to ZB.

Commentary:

Generation of a surface patch by rotating a PC line about a general axis of rotation. Four-sided and degenerate three-sided patches are constructed.



Method:

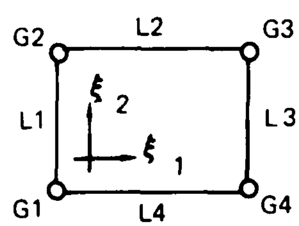
Given the PC line $Z(\xi)$, rotate the points $Z(0)$, $Z(1/3)$, $Z(2/3)$, and $Z(1)$ to form the surface patch using LINEGR. The axis of rotation is the vector from Z_A to Z_B.

BULK DATA INPUT

Input Directive:	PATCHL Define a patch with boundary lines
Description:	Generates a bicubic patch from four grid line segments. The orientation of the segments is checked, as is the presence of referenced grid points.
Format:	PATCHL, ID, G1, G2, G3, G4,,,,, L1, L2, L3, L4
Example Syntax:	PATCHL, 2, 1, 2, 3, 4,,,,, 4, 5, 8, 12

Field	Contents
ID	The identification to be given to the patch.
G1, G2, G3, G4	Grid point identification numbers of the corner points of the patch.
L1, L2, L3, L4	Line identification numbers for the lines that bound the patch.

Remarks: 1. The grid point and line sequencing is shown below.



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BULK DATA INPUT

Input Directive:	PATCHO Outline patch(es)
Description:	Generates patch(es) by moving an outline curve along a base curve with a fixed orientation of the outline curve in the global frame or in the local Frenet frame of the base curve.
Format:	PATCHO, ID1, BLID/SEG, OLID/SEG, TID, FRAME, ID2,..., IDN
Example Syntax:	PATCHO, 5, 6/1, 3,, F, 11 THRU 15

Field	Contents
ID1	Patch identification number for first patch generated.
BLID, SEG	Baseline identification number and segment number, SEG. If the SEG is not specified, the entire line BLID is used.
OLID, SEG	Outline curve identification number and segment number, SEG. If the SEG is not specified, the entire line OLID is used.
TID	Transformation ID, if any, that defines a rotation matrix to reorient the outline curve relative to the base curve. The outline curve is always translated to the first grid point of the baseline independent of TID.
FRAME	E for fixed outline orientation with respect to the Cartesian frame. F for fixed outline orientation with respect to the local Frenet or binormal coordinate frame of the base curve.
ID2, 3,..., N	List of identification numbers to be given the second and subsequent patches generated, if any. This sequence proceeds from the second line segment of OLID to the last and then repeats from the first segment for the next segment of BLID.

Input Directive: PATCHO Outline patch(es) (Continued)

Remarks: 1. The Frenet frame is defined by

$$\underset{\sim}{T} = \underset{\sim}{Z},_{\xi} \quad , \quad \underset{\sim}{N} = \underset{\sim}{Z},_{\xi\xi} \quad , \quad \underset{\sim}{B} = \underset{\sim}{T} \times \underset{\sim}{N}$$

BULK DATA INPUT

Input Directive:	PATCHQ Bilinear patch from four corner points
Description:	Defines a parametric bilinear patch from four previously defined corner grid points.
Format:	PATCHQ, ID, G1, G2, G3, G4
Example Syntax:	PATCHQ, 5, 1, 2, 7, 6

Field	Contents
ID	Patch identification number (integer, 1 to 50).
G1, G2, G3, G4	Grid point identification numbers of the four corner points in the order (0, 0), (0, 1), (1, 1), (1, 0) (integer, 1 to 9999).

BULK DATA INPUT

Input Directive:	PATCHR Patch generation by line rotation
Description:	Generates a bicubic surface of revolution patch or set of patches by the rotation of a line segment or set of line segments through a specified arc about a coordinate axis.
Format:	PATCHR, ID1, LID/SEG, Z1, Z2, Z3, THETAB, THETAE, IDRA, ID2, ID3, ID4,..., IDN
Example Syntax:	PATCHR, 3, 5/2, 0.0, 5.0, -12.2, 30., 60., -3

Field	Contents
ID1	The identification number to be given to the first patch to be generated. This is the patch generated from line LID, segment SEG if SEG is defined and segment 1 if SEG is not defined (integer, 1 to 50).
LID	The identification number of the line to be rotated.
SEG	If specified, the segment within line LID to be rotated. If not specified, all segments of line LID will be rotated.
Z1, Z2, Z3	Coordinates for shifting the origin.
THETAB, THETAE	The beginning and ending angles through which the segment or segments will be rotated (degrees).
IDRA	Axis of rotation (integer, -3 to 3). +1 = +X, -1 = -X, +2 = +Y, +3 = +Z, etc.
ID2, ID3,..., IDN	List of identification numbers to be given to the second, third,..., nth patch to be generated. The list may include any of the list operators such as THRU, EXCEPT, etc.

Remarks:

1. See the PATCHGR commentary for a description of the method.

BULK DATA INPUT

Input Directive:	PATCH4L Patch generator
Description:	Generates a patch from four lines in parametric direction two.
Format:	PATCH4L, PID, L1/SEG, L2/SEG, L3/SEG, L4/SEG, TID
Example Syntax:	PATCH4L, 5, 1/3, 17/6, 9, 12

Field	Contents
PID	Patch identification number.
L1, 2, 3, 4	Line identification number for lines $\underset{\sim}{Z}(\xi_1, 0)$, $\underset{\sim}{Z}(\xi_1, 1/3)$, $\underset{\sim}{Z}(\xi_1, 2/3)$, and $\underset{\sim}{Z}(\xi_1, 1)$.
SEG	The segment number. (Default SEG is 1.)
TID	Transformation identification number, if any, to be applied to the patch.

BULK DATA INPUT

Input Directive:	PLOAD3 Pressure load data
Description:	Defines a normal pressure load on one surface of a 3-D element.
Format:	PLOAD3, ID, EID, DPID, Scalar
Example Syntax:	PLOAD3, 6, 2, 10

Field	Contents
ID	Load set identification number.
EID	Element identification number.
DPID	Data patch identification number.
Scalar	The magnitude of the data in DPID will be scaled by this number. The default value is 1.0.

Remarks:

1. The grid points referenced by the data patch are used to locate the face of element EID on which the pressure acts. A positive pressure is directed in the positive direction of the normal to the surface.

2. Refer to Figure 2-6 for definition of normal vectors on the hyperpatch faces. WARNING: A positive pressure is not in on all faces!

BULK DATA INPUT

Input Directive: PPDE3 Property data for a solid element

Description: Property card for a three-dimensional parametric discrete element.

Format: PPDE3, EID, MID, DCID, PSI, THETA, PHI

Example Syntax: PPDE3, 10, 5,, 30.0, 0.0, 1302

Field	Contents
EID	Element identification number.
MID	Material identification number.
DCID	Direction cosine matrix identification number. If blank or zero, the Euler angle option will be used to relate the material axes to the reference axes $\tilde{e}_i$.
PSI, THETA, PHI	Euler angles in the 3, 1, 3 sequence that rotate the reference axes to the material axes relative to the Z1, Z2, Z3 system. Same sequence of Euler angles as used by H. Goldstein, Classical Mechanics, p. 107, 1959 edition. If an Euler angle varies over the element, its data hyperpatch ID + 1000 is entered in the field normally used for that angle.

Remarks:

1. If material MID is given in the parametric frame (TYPE = 2), any direction cosine or Euler angle data will be ignored.

   In the above example, PHI is defined by data hyperpatch 302.

BULK DATA INPUT

Input Directive:	SCALP Scaling of a bicubic patch
Description:	Scales a bicubic patch or set of patches relative to a specified scaling origin.
Format:	SCALP, S1, S2, S3, Z1(0), Z2(0), Z3(0),,, PATCH1, PATCH2,..., PATCHN
Example Syntax:	SCALP, 1, 2.0, 1.5,, 5.,,,, 4, 15 THRU 40 EXCEPT 22

Field	Contents
S1, S2, S3	Scaling factors in the Z1, Z2, and Z3 directions (default = 1.0).
Z1(0), Z2(0), Z3(0)	Origin of scaling (default = 0).
PATCH1,..., PATCHN	The list of patch identification numbers to be scaled.

Remarks:

1. The origin strongly influences the scaling operation. See SCALPH commentary.

BULK DATA INPUT

Input Directive:	SCALPH Scaling of all hyperpatches
Description:	Scales all hyperpatches relative to a specified scaling origin.
Format:	SCALPH, S1, S2, S3, Z1(0), Z2(0), Z3(0)
Example Syntax:	SCALPH, 1., 2.0, 1.5,, 5.

Field	Contents
S1, S2, S3	Scaling factors in the Z1, Z2, and Z3 directions (default = 1.0).
Z1(0), Z2(0), Z3(0)	Origin of scaling (default = 0).

Remarks:

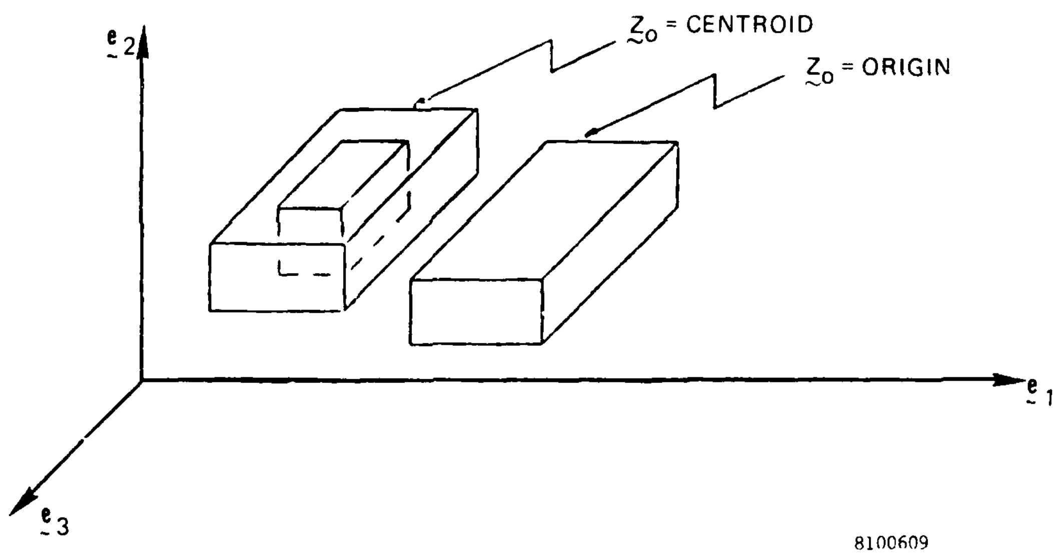
1. The origin strongly influences the scaling operation. See commentary.

Commentary:

The SCALP and SCALPH cards both are based on the transformation

$$\underset{\sim}{ZS} = [S](\underset{\sim}{Z} - \underset{\sim}{ZO}) + \underset{\sim}{ZO}$$

where [S] is a diagonal matrix of coordinate scale factors, $\underset{\sim}{ZO}$ is the scaling origin, and $\underset{\sim}{ZS}$ is the vector of scaled coordinates. Note that $\underset{\sim}{ZS}_{,\xi i} = [S]\underset{\sim}{Z}_{,\xi i}$. The effect of $\underset{\sim}{ZO}$ on scaling is illustrated below for a parallelopiped where [S] is the same for both figures.



8100609

BULK DATA INPUT

Input Directive:	SDC1 Surface displacement constraint
Description:	Imposes a surface displacement constraint on components in the reference Cartesian frame.
Format:	SDC1, ID, EID, DP1, DP2, DP3, S1, S2, S3
Example Syntax:	SDC1, 3, 16, 2,, 1, 3.4

Field	Contents
ID	Constraint set identification number.
EID	Element identification number.
DP1, 2, 3	Data patches for the components UI of the displacement $\underset{\sim}{u} = U1\underset{\sim}{e}_1 + U2\underset{\sim}{e}_2 + U3\underset{\sim}{e}_3$. A blank field indicates the component is unconstrained.
S1, 2, 3	Scale factors applied to the data patches. Default values are 1.0.

Remarks:

1. The data patches must reference the same grid points, and these are used to locate the constrained surface on element EID.

BULK DATA INPUT

Input Directive:	SDC10 Surface displacement constraint -- zero components
Description:	Imposes a surface displacement constraint of zero on components in the reference Cartesian frame.
Format:	SDC10, ID, EID, COMPS, G1, G2, G3, G4
Example Syntax:	SDC10, 10, 15, 23, 11, 12, 16, 24

Field	Contents
ID	Constraint set identification number.
EID	Element identification number.
COMPS	Components UI of the displacement vector $\underset{\sim}{u} = U1\underset{\sim}{e}_1, U2\underset{\sim}{e}_2, U3\underset{\sim}{e}_3$ that are to be constrained to zero.
G1, 2, 3, 4	Corner grid points of element EID that define the constrained surface on that element.

BULK DATA INPUT

Input Directive:	SDC2 Surface displacement constraint
Description:	Imposes a surface displacement constraint on components in the local surface coordinate directions.
Format:	SDC2, ID, EID, DP1, DP2, DP3, S1, S2, S3
Example Syntax:	SDC2, 6, 10, 2

Field	Contents
ID	Constraint set identification number.
EID	Element identification number.
DP1, 2, 3	Data patches for the components UI of the displacement $\underset{\sim}{u} = U1\underset{\sim}{t}_1 + U2\underset{\sim}{t}_2 + U3\underset{\sim}{n}$ in the local surface frame. These are physical components in that $\underset{\sim}{t}_1$, $\underset{\sim}{t}_2$, $\underset{\sim}{n}$ are normalized to unity for constraint purposes. A blank field indicates the component is unconstrained.
S1, 2, 3	Scale factors applied to the data patches. Default values are 1.0.

Remarks:

1. The data patches must reference the same grid points, and these are used to locate the constrained surface on element EID.
2. The local surface coordinate directions for each face are defined in Figure 2-6.

BULK DATA INPUT

Input Directive:	SDC20 Surface displacement constraint -- zero components
Description:	Imposes a surface displacement constraint of zero on components in the local surface coordinate directions.
Format:	SDC20, ID, EID, COMPS, G1, G2, G3, G4
Example Syntax:	SDC20, 5, 6, 31, 8, 9, 1, 3

Field	Contents
ID	Constraint set identification number.
EID	Element identification number.
COMPS	Components UI of the displacement vector $\underset{\sim}{u} = U1\underset{\sim}{t}_1 + U2\underset{\sim}{t}_2 + U3\underset{\sim}{n}$ in the local surface frame. The constrained components are identified by any combination of the digits 1, 2, and 3. These are physical components in that $\underset{\sim}{t}_1$, $\underset{\sim}{t}_2$, n are normalized to unity for constraint purposes.
G1, 2, 3, 4	Corner grid points of element EID that define the constrained surface on that element. The patch for that surface is extracted from the hyperpatch EID and used to compute $\underset{\sim}{t}_1$, $\underset{\sim}{t}_2$, and $\underset{\sim}{n}$ on that surface.

BULK DATA INPUT

Input Directive:	SPC1 Single point constraint
Description:	Imposes a displacement constraint at a grid point for components in an orthonormal frame.
Format:	SPC1, ID, GID, U1, U2, U3, DCFL,,, DCID, PSI, THETA, PHI
Example Syntax:	SPC1, 3, 5,, 0.0,, 1,,,, 30.0

Field	Contents
ID	Constraint set identification number.
GID	Grid point identification number.
UI	Value of constrained displacement component I. A blank field implies that component is unconstrained.
DCFL	Direction cosine flag. If blank or any value other than 1, the components UI are in the reference $\underset{\sim}{e}_i$ frame, and the continuation card can be omitted. A value of 1 indicates the components are in the frame defined by the continuation card.
DCID	Direction cosine matrix identification number. If blank or zero the Euler angles PSI, THETA, and PHI used to define the constraint frame.
PSI, THETA, PHI	Euler angles in the 3, 1, 3 sequence that rotate the reference frame $\underset{\sim}{e}_i$ to the constraint frame. Same sequence of Euler angles as used by H. Goldstein, Classical Mechanics, p. 107, 1959 edition.

BULK DATA INPUT

Input Directive: SPC2 Single point constraint

Description: Imposes a displacement constraint at a meshpoint of an element for components in an orthonormal frame.

Format: SPC2, ID, EID, PIJK, U1, U2, U3, DCFL,, DCID, PSI, THETA, PHI

Example Syntax: SPC2, 10, 6, 223,,, 0.0

Field	Contents
ID	Constraint set identification number.
EID	Element identification number.
PIJK	Meshpoint identification number defined as the subscripts in point format P_{ijk} for one of the UI meshpoints.
UI	Value of constrained displacement component I. A blank field implies that component is unconstrained.
DCFL	Direction cosine flag. If blank or any value other than 1, the components UI are in the $\underset{\sim}{e}_i$ frame, and the continuation card can be omitted. A value of 1 indicates the components are in the frame defined by the continuation card.
DCID	Direction cosine matrix identification number. If blank or zero the Euler angles PSI, THETA, and PHI in the 3, 1, 3 sequence (see SPC1 card) are used to define the constraint frame.

Remarks:

1. If the meshpoint is on (a) surface(s) the point also will be constrained on all connected elements. The location in space of the constrained point is available from the hyperpatch for element EID.

BULK DATA INPUT

Input Directive: TEMP Temperature data

Description: Defines the temperature over the volume of an element.

Format: TEMP, ID, EID, DHP

Example Syntax: TEMP, 10, 3, 6

Field	Contents
ID	Temperature set identification number.
EID	Element identification number.
DHP	Data hyperpatch identification number.

Remarks:

1. The ambient temperature is defined by a case control card for each case. The temperature difference, $\theta = T - T_a$, is used for computing

   thermal loads and strains where the temperature T is defined by a TEMP card. The default value for ambient temperature is zero.

BULK DATA INPUT

Input Directive: TMOVE Rigid body transformation

Description: Defines a transformation that moves objects (lines, patches, hyperpatches) as rigid bodies.

Format: TMOVE, ID, ZO1, ZO2, ZO3, DCID, PSI, THETA, PHI, T1, T2, T3

Example Syntax: TMOVE, 1, 3.0, 0., 3.,, 30., 20., -10., 3.0, 0., 4.0

Field	Contents
ID	Transformation identification number (1 to 100).
ZOI	Defines an origin for rotation of the object.
DCID	Direction cosine matrix identification number. If blank or zero the Euler angles PSI, THETA, and PHI define the rotation matrix.
PSI, THETA, PHI	Euler angles in the 3, 1, 3 rotation sequence. Same sequence of Euler angles as used by Goldstein, Classical Mechanics, p. 107, 1959 edition.
TI	Defines a translation to be applied after the rotation.

Remarks:

1. The complete transformation can be defined as

$$\underset{\sim}{Z}^* = R(\underset{\sim}{Z} - \underset{\sim}{ZO}) + \underset{\sim}{T}$$

CHAPTER 5

CASE CONTROL OPTIONS

5.1 Overview

Case control in PATCHES-III consists of executive data that directs execution, case definition data that selects loads and/or constraints, and output requests that select the data for output. As with bulk data, the format and function of the case control input is by design similar to NASTRAN. A checkpoint-restart editor has been provided for more efficient multiple run applications and to help protect the user in the event of abnormal termination. Unlike NASTRAN, no checkpoint dictionary is required for restart. The case control data is checked for input errors and diagnostics provided. These checks include cross-referencing the bulk data to ensure all referenced load and/or constraint sets are present. The syntax of all case control cards is free form. There are no fixed fields; the data may be placed anywhere on the card. A comma acts as the delimiter between items in a list.

5.2 Available Options

There are over forty (40) case control options available. These options are summarized in Table 5-1 where they are grouped by function into three basic categories. Case control directives may be input in any order within a category, but the categories must be input in the order shown. All output, if there is to be any, must be selected by one or more of the case control options. The fundamental model for the most data output by PATCHES-III is the parametric cubic. This representation is available for lines, surfaces, and volumes. A parametric line representing either geometric data or physical data can be output in geometric or point format, as shown in Table 5-2 for a one-component line. Surface patch formats are also shown in Table 5-2, including the algebraic format. Patch coefficients in the algebraic format do not have a simple expression in terms of coordinate (data) functions or their derivatives. They are simply printed as a matrix of Sij coefficients. Hyperpatches can also be output in geometric format, Table 5-3, or point format. The latter output is the same as that for a patch except that there are four surfaces: $\xi_3 = 0$, $\xi_3 = 1/3$, $\xi_3 = 2/3$, and $\xi_3 = 1$. The location in space of a data model can only be determined by reference to the geometry of the associated finite element. The standard output format for hyperpatches is point format, Table 5-4, and this is the only format used for finite element solution data.

Table 5-1

CASE CONTROL DIRECTIVES

1. EXECUTIVE DATA

TITLE	CHKPNT	AMBIENT
TIME	RESTART	
DRY		

2. CASE DEFINITION

LOAD	SUBCASE	SUBCOM
SDC	SUBTITLE	AXY

3. OUTPUT REQUESTS

OUTPUT	SET	EVERYTHING	ALL	
GRID	LINEB	PATCHA	HPB	VOLUME
FMESH	LINEP	PATCHB	HPP	DETJ
	LORDER	PATCHP		
DATAG	DLINEB	DPATB	DHPB	DTLINEB
ODISP	DLINEP	DPATP	DHPP	DTLINEP
OLOAD				
ELEMENT	EDISP	ESTRAIN	ESTRESS	ELOAD
	EFORCE	MSTRAIN	MSTRESS	
		PSTRAIN	PSTRESS	
MATC	MATA			

Table 5-2

LINE AND PATCH OUTPUT

Line

Geometric - $Z(0),\ Z(1),\ Z,_{\xi}(0),\ Z,_{\xi}(1)$

Point - $Z(0),\ Z(1/3),\ Z(2/3),\ Z(1)$

Gaussian - $Z(.069432),\ Z(.330010),\ Z(.669991),\ Z(.930568)$

Algebraic*- S1, S2, S3, S4

Patch

Geometric -
$$\begin{bmatrix} Z(0,0), & Z(0,1), & Z,_{\xi_2}(0,0), & Z,_{\xi_2}(0,1) \\ Z(1,0), & Z(1,1), & Z,_{\xi_2}(1,0), & Z,_{\xi_2}(1,1) \\ Z,_{\xi_1}(0,0), & Z,_{\xi_1}(0,1), & Z,_{\xi_1\xi_2}(0,0), & Z,_{\xi_1\xi_2}(0,1) \\ Z,_{\xi_1}(1,0), & Z,_{\xi_1}(1,1), & Z,_{\xi_1\xi_2}(1,0), & Z,_{\xi_1\xi_2}(1,1) \end{bmatrix}$$

Point -
$$\begin{bmatrix} Z(0,0), & Z(0,1/3), & Z(0,2/3), & Z(0,1) \\ Z(1/3,0), & Z(1/3,1/3), & Z(1/3,2/3), & Z(1/3,1) \\ Z(2/3,0), & Z(2/3,1/3), & Z(2/3,2/3), & Z(2/3,1) \\ Z(1,0), & Z(1,1/3), & Z(1,2/3) & Z(1,1) \end{bmatrix}$$

Algebraic*-
$$\begin{bmatrix} S11, & S12, & S13, & S14 \\ S21, & S22, & S23, & S24 \\ S31, & S32, & S33, & S34 \\ S41, & S42, & S43, & S44 \end{bmatrix} ; \quad N_{ij} = \begin{bmatrix} -9/2 & 27/2 & -27/2 & 9/2 \\ 9 & -45/2 & 18 & -9/2 \\ -11/2 & 9 & -9/2 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

* The algebraic coefficients are related to the point format coefficients by N_{ij} where $S_i = N_{ij}P_j$ and $S_{ij} = N_{ik}P_{kl}N_{jl}$.

Table 5-3

HYPERPATCH OUTPUT - GEOMETRIC FORMAT

$$B1 = \begin{bmatrix} Z(0,0,0) & Z(0,1,0) & Z_{,\xi_2}(0,0,0) & Z_{,\xi_2}(0,1,0) \\ Z(1,0,0) & Z(1,1,0) & Z_{,\xi_2}(1,0,0) & Z_{,\xi_2}(1,1,0) \\ Z_{,\xi_1}(0,0,0) & Z_{,\xi_1}(0,1,0) & Z_{,\xi_1\xi_2}(0,0,0) & Z_{,\xi_1\xi_2}(0,1,0) \\ Z_{,\xi_1}(1,0,0) & Z_{,\xi_1}(1,1,0) & Z_{,\xi_1\xi_2}(1,0,0) & Z_{,\xi_1\xi_2}(1,1,0) \end{bmatrix}$$

$$B2 = \begin{bmatrix} Z(0,0,1) & Z(0,1,1) & Z_{,\xi_2}(0,0,1) & Z_{,\xi_2}(0,1,1) \\ Z(1,0,1) & Z(1,1,1) & Z_{,\xi_2}(1,0,1) & Z_{,\xi_2}(1,1,1) \\ Z_{,\xi_1}(0,0,1) & Z_{,\xi_1}(0,1,1) & Z_{,\xi_1\xi_2}(0,0,1) & Z_{,\xi_1\xi_2}(0,1,1) \\ Z_{,\xi_1}(1,0,1) & Z_{,\xi_1}(1,1,1) & Z_{,\xi_1\xi_2}(1,0,1) & Z_{,\xi_1\xi_2}(1,1,1) \end{bmatrix}$$

$$B3 = \begin{bmatrix} Z_{,\xi_3}(0,0,0) & Z_{,\xi_3}(0,1,0) & Z_{,\xi_2\xi_3}(0,0,0) & Z_{,\xi_2\xi_3}(0,1,0) \\ Z_{,\xi_3}(1,0,0) & Z_{,\xi_3}(1,1,0) & Z_{,\xi_2\xi_3}(1,0,0) & Z_{,\xi_2\xi_3}(1,1,0) \\ Z_{,\xi_1\xi_3}(0,0,0) & Z_{,\xi_1\xi_3}(0,1,0) & Z_{,\xi_1\xi_2\xi_3}(0,0,0) & Z_{,\xi_1\xi_2\xi_3}(0,1,0) \\ Z_{,\xi_1\xi_3}(1,0,0) & Z_{,\xi_1\xi_3}(1,1,0) & Z_{,\xi_1\xi_2\xi_3}(1,0,0) & Z_{,\xi_1\xi_2\xi_3}(0,1,0) \end{bmatrix}$$

$$B4 = \begin{bmatrix} Z_{,\xi_3}(0,0,1) & Z_{,\xi_3}(0,1,1) & Z_{,\xi_2\xi_3}(0,0,1) & Z_{,\xi_2\xi_3}(0,1,1) \\ Z_{,\xi_3}(1,0,1) & Z_{,\xi_3}(1,1,1) & Z_{,\xi_2\xi_3}(1,0,1) & Z_{,\xi_2\xi_3}(1,1,1) \\ Z_{,\xi_1\xi_3}(0,0,1) & Z_{,\xi_1\xi_3}(0,1,1) & Z_{,\xi_1\xi_2\xi_3}(0,0,1) & Z_{,\xi_1\xi_2\xi_3}(0,1,1) \\ Z_{,\xi_1\xi_3}(1,0,1) & Z_{,\xi_1\xi_3}(1,1,1) & Z_{,\xi_1\xi_2\xi_3}(1,0,1) & Z_{,\xi_1\xi_2\xi_3}(1,1,1) \end{bmatrix}$$

Table 5-4

HYPERPATCH OUTPUT - POINT FORMAT

$$[P1] = \begin{bmatrix} Z(0,0,0), & Z(0,1/3,0), & Z(0,2/3,0), & Z(0,1,0) \\ Z(1/3,0,0), & Z(1/3,1/3,0), & Z(1/3,2/3,0), & Z(1/3,1,0) \\ Z(2/3,0,0), & Z(2/3,1/3,0), & Z(2/3,2/3,0), & Z(2/3,1,0) \\ Z(1,0,0), & Z(1,1/3,0), & Z(1,2/3,0), & Z(1,1,0) \end{bmatrix}$$

$$[P2] = \begin{bmatrix} Z(0,0,1/3), & Z(0,1/3,1/3), & Z(0,2/3,1/3), & Z(0,1,1/3) \\ Z(1/3,0,1/3), & Z(1/3,1/3,1/3), & Z(1/3,2/3,1/3), & Z(1/3,1,1/3) \\ Z(2/3,0,1/3), & Z(2/3,1/3,1/3), & Z(2/3,2/3,1/3), & Z(2/3,1,1/3) \\ Z(1,0,1/3), & Z(1,1/3,1/3), & Z(1,2/3,1/3), & Z(1,1,1/3) \end{bmatrix}$$

$$[P3] = \begin{bmatrix} Z(0,0,2/3), & Z(0,1/3,2/3), & Z(0,2/3,2/3), & Z(0,1,2/3) \\ Z(1/3,0,2/3), & Z(1/3,1/3,2/3), & Z(1/3,2/3,2/3), & Z(1/3,1,2/3) \\ Z(2/3,0,2/3), & Z(2/3,1/3,2/3), & Z(2/3,2/3,2/3), & Z(2/3,1,2/3) \\ Z(1,0,2/3), & Z(1,1/3,2/3), & Z(1,2/3,2/3), & Z(1,1,2/3) \end{bmatrix}$$

$$[P4] = \begin{bmatrix} Z(0,0,1), & Z(0,1/3,1), & Z(0,2/3,1), & Z(0,1,1) \\ Z(1/3,0,1) & Z(1/3,1/3,1), & Z(1/3,2/3,1), & Z(1/3,1,1) \\ Z(2/3,0,1), & Z(2/3,1/3,1), & Z(2/3,2/3,1), & Z(2/3,1,1) \\ Z(1,0,1), & Z(1,1/3,1), & Z(1,2/3,1), & Z(1,1,1) \end{bmatrix}$$

5.3 Case Control Cards

There are three basic categories of case control cards: executive data, case definition, and output requests. The following sections detail each of the options within these categories. In the description of the format for individual directives, items enclosed in parentheses are optional inputs. The item "list" represents a free-form list of integers, separated by commas, and can include the operators ALL, NONE, THRU, and EXCEPT.

5.3.1 Execution Control

The executive data portion of the case control deck is used to control the executive functions CHKPNT and RESTART, the axisymmetric AXY, as well as the global parameters TITLE, DRY, and TIME. It is possible to use RESTART and CHKPNT options on the same run, and in some instances a CHKPNT file is automatically generated. The management of these files is, of course, machine dependent, and the job control language (JCL) directives are described in a later chapter.

5.3.2 Case Definition

The case definition section of the case control deck is used to activate certain sets of data from the bulk data on each subcase and to define the subcase title. The SUBCASE card defines the beginning of the next subcase. Within any subcase at least one of the set identifiers LOAD or SDC must be defined. If any errors are detected in the definition or execution of a subcase, that subcase will be skipped. Up to 15 subcases may be defined, including the zero or implied subcase.

5.3.3 Output Requests

The output requests section of the case control input selects the particular data to be printed. Entry into this region is initiated through the OUTPUT card, which is mandatory if any output requests are to be made. Up to 25 sets can be defined using SET cards. The items in these sets are not limited to any particular type of data so that they can serve a number of purposes. The individual output requests are made through the use of the mnemonics listed in Table 5-5. The majority of these cards are of the form GRID, set where set can be a list of SET identifiers.

CASE CONTROL INPUT

Input Directive: AMBIENT Temperature

Description: Defines a temperature at which there are no thermal strains.

Format: AMBIENT, T

Example Syntax: AMBIENT, 70.0

Remarks:

1. If not specified, the ambient temperature is assumed to be zero.
2. The ambient temperature is used to compute the temperature difference, $\Delta T = T - T_A$, for thermal loads, stresses, and strains.

CASE CONTROL INPUT

Input Directive: AXY Axisymmetric model

Description: Defines a model as axisymmetric and sets the size of CCX elements.

Format: AXY, $\Delta\theta$

Example Syntax: AXY, -15.0

Remarks:

1. The subtended angle in a CCX axisymmetric model may also be input with a PARAM directive in the bulk data.
2. The magnitude and sign of $\Delta\theta$ must agree with the hyperpatch construction for the CCX element shape.

BULK DATA INPUT

Input Directive: CHKPNT Checkpoint request

Description: Defines the restart situations for which a checkpoint volume will be written.

Format: CHKPNT, checkpoint 1, checkpoint 2

Example Syntax: CHKPNT, ELEMENT, CG

Remarks:

1. Checkpoint and restart may not be requested on the same run. The checkpoint request is ignored in this situation.

2. A file or tape labeled INPT (CDC) or 25. (UNIVAC) must be requested in the job control deck.

3. CHKPNT, ELEMENT causes all element stiffness matrices to be saved on tape.

4. CHKPNT, CG causes the last iterate and direction vector to be saved for continued iteration on a subsequent restart run.

5. Whenever a CG solution is terminated prior to convergence (due to a TIME insufficiency, maximum iterations, or maximum steepest descent moves) a CG checkpoint is appended to the restart file. Thus the file or tape must have write permission.

BULK DATA INPUT

Input Directive:	DRY Dry run request
Description:	Automatically halts execution after processing of all modeling data.
Format:	DRY
Example Syntax:	DRY
Remarks:	1. This feature allows all geometry, material, load and boundary condition data to be checked before execution.

CASE CONTROL INPUT

Input Directive: LOAD Defines active load set

Description: Defines for each subcase the load set to be used for analysis.

Format: LOAD, ID

Example Syntax: LOAD, 10

Remarks:

1. The LOAD directive selects the active load set from all those present in the bulk data.

2. Thermal, as well as mechanical, load sets are controlled with this directive.

BULK DATA INPUT

Input Directive: OUTPUT Output selection

Description: Defines the beginning of the output requests region.

Format: OUTPUT

Remarks:

1. This card is required if there are any output requests.

2. All output flags in Table 5-5 can be selectively turned off. The modifier OFF is used, for example, OLOAD = OFF, to prevent output from a flag activated by an EVERYTHING request.

CASE CONTROL INPUT

Input Directive: RESTART Restart from a checkpoint tape

Description: Specifies the checkpoint volume on the restart tape to be used on the restart run. Also identifies elements to be modified.

Format: RESTART, type, (element list)

Example Syntax:

```
RESTART, CG, n file, STP
RESTART, ELEMENT
RESTART, ELEMENT, 6 thru 14, 18
RESTART, CG, 2, S
```

Remarks:

1. The element list identifies those elements that are to be modified or deleted.

2. All case control and bulk data cards are submitted on a restart.

3. In a CG restart request, the parameters n file and STP are optional; n file is the CG restart file number. This can be greater than 1 for multiple restarts and checkpoints. Default = 1. STP is request for the restart to begin with a steepest descent move. Any character in this field will activate the request. The default is no steepest descent move in which case iteration continues from the requested restart file direction.

4. A CG restart request automatically defines an element restart.

CASE CONTROL INPUT

Input Directive:	SDC Surface displacement constraint selection
Description:	Selects the surface displacement constraint set to be applied to the structural model.
Format:	SDC, n
Example Syntax:	SDC, 12

Field	Contents
n	Set identification number found on at least one surface or grid point displacement card within the bulk data deck (integer > 0).

Remarks:

1. The SDC card is supplied at the subcase level.
2. The total load applied will be the sum of external LOAD and SDC loads.
3. At least one LOAD or SDC card must be input for each subcase.
4. Single point constraint sets are also activated by the SDC card.
5. Constraints adequate to prevent rigid body motion must be present.

CASE CONTROL INPUT

Input Directive:	SET Set definition
Description:	Specifies the integer identification numbers of all elements in the set being defined.
Format:	SET ID, List
Example Syntax:	SET 7, 1, 2, 7, 10 THRU 25 EXCEPT 15 THRU 20

Field	Contents
ID	Identification number of the set being defined.
List	A string of integers and/or the list operators ALL, EXCEPT, NONE, THRU that define the elements in the set. The example list defines SET 7 as containing the elements 1, 2, 7, 10, 11, 12, 13, 14, 21, 22, 23, 24, 25. All specifications following the operator EXCEPT turn off items that may have been activated earlier on this card.

CASE CONTROL INPUT

Input Directive:	SUBCASE Subcase delimiter
Description:	Delimits and identifies a subcase.
Format:	SUBCASE, n
Example Syntax:	SUBCASE, 501

Field	Contents
n	Subcase identification number (integer > 0).

CASE CONTROL INPUT

Input Directive: SUBCOM Subcase combination

Description: Defines a linear combination of subcases for output data recovery.

Format: SUBCOM, R_1, R_2,.., R_N,/, S_1,.., S_M

Example Syntax:

```
SUBCOM, 1.1, -3.2,/, 1.5,,, -6.7
SUBCOM, -1.047, 0.163
```

Remarks:

1. R_i is the load factor for subcase number i generated by current execution.
2. S_i is the load factor for subcase number i on the INDATA file, if any.
3. There are no default values.
4. A subcase may be skipped using a double comma.
5. In general, to recover data in all octants of a symmetry-symmetry-symmetry model will require selectively changing the sign of individual displacement components before combination.

CASE CONTROL INPUT

Input Directive:	SUBTITLE Output subtitle
Description:	Defines a subtitle which will appear on the second heading line of each page of PATCHES-III printer output.
Format:	SUBTITLE, any data string
Example Syntax:	SUBTITLE, PATCHES-III SUBTITLE FOR SUBCASE 501.
Remarks:	1. SUBTITLE will title output for the subcase in which it is defined. 2. If no SUBTITLE card is supplied, the SUBTITLE field will be blank.

CASE CONTROL INPUT

Input Directive:	TIME CP time estimate in minutes
Description:	Defines the maximum allowable CP time in minutes.
Format:	TIME, minutes
Example Syntax:	TIME, 12

Field	Contents
Minutes	Integer maximum CP time in minutes.

Remarks:

1. The default value is 1 minute.
2. This time estimate is used by several PATCHES utilities to check the time-to-go before attempting to execute a module.

CASE CONTROL INPUT

Input Directive:	TITLE Output title
Description:	Defines a title which will appear on the first heading line of each page of PATCHES-III printer output.
Format:	TITLE, any bcd data
Example Syntax:	TITLE, SAMPLE TITLE FOR PATCHES-III
Remarks:	1. If no TITLE card is supplied, blanks are assumed. 2. TITLE information is also written onto the restart volume.

Table 5-5

CASE CONTROL OUTPUT REQUESTS AND FLAGS

REQUEST	EFFECT
ALL	All output requests are turned on except those subsequently redefined and except the algebraic and geometric format output. Principal frame output and several diagnostic data are also turned off.
EVERYTHING	All output requests are turned on except those which are redefined subsequently.
GRID, set	Grid points.
DATAG, set	Data grid points.
LINEB, set	Geometric lines in geometric format.
LINEP, set	Geometric lines in point format.
DLINEB, set	Data lines in geometric format.
DLINEP, set	Data lines in point format.
PATCHB, set	Geometric patches in geometric format.
PATCHP, set	Geometric patches in point format.
PATCHA, set	Geometric patches in algebraic format.
DPATB, set	Data patches in geometric format.
DPATP, set	Data patches in point format.
HPB, set	Geometric hyperpatches in geometric format.
HPP, set	Geometric hyperpatches in point format.
DHPB, set	Data hyperpatches in geometric format.
DHPP, set	Data hyperpatches in point format.

(Table continued on following page.)

Table 5-5 (Continued)

CASE CONTROL OUTPUT REQUESTS AND FLAGS

REQUEST	EFFECT
DETJ, set	Determinate of geometric hyperpatch's Jacobians at Gaussian points.
EDISP, set	Element Cartesian displacements in point format.
ELEMENT, set	Element results. Simultaneously activates EDISP, ESTRAIN, ESTRESS, MSTRAIN, MSTRESS, PSTRAIN, PSTRESS. ELEMENT, ALL is assumed unless overridden.
ESTRAIN, set	Element Cartesian strains in point format.
MSTRAIN, set	Material frame strains in point format.
PSTRAIN, set	Principal frame strains in point format.
ESTRESS, set	Element Cartesian stresses in point format.
MSTRESS, set	Material frame stress in point format.
PSTRESS, set	Principal frame stresses in point format.
MATC, set	Element elastic constants in point format.
MATA, set	Element thermal expansion constants in point format.
VOLUME, set	Volume of hyperpatches.
ELOAD, set	Element load vectors in point format prior to transformation to analysis coordinates.
DTLINEB, set	Data table lines in geometric format.
DTLINEP, set	Data table lines in point format.
EFORCE, set	Element node forces in point format.

(Table continued on following page.)

Table 5-5 (Continued)

CASE CONTROL OUTPUT REQUESTS AND FLAGS

FLAG	EFFECT
OLOAD	Output the global load vector.
ODISP	Output the global displacement vector.
EMESH	Output from the matrix assembly module.
LORDER	Output the order in which geometric lines were processed.

CHAPTER 6

EXECUTIVE CONTROL OPTIONS

6.1 Overview

The executive control deck is completely optional and, in fact, is rarely used. The executive control deck provides specialized system level control over the execution of PATCHES-III. This section should be skipped by most users and used by experienced users in special circumstances.

(2 Executive Control Options

Executive control cards are the first input cards in an execution and always start with PATCHES as the first nonblank field followed by the option selections. A sample executive control card is shown below.

PATCHES, NODROP, MAXFL = 90112, BREAKPT

A card which does not begin with the letters PATCHES is assumed to be the first card of the case control deck. The current executive control options are described below.

BREAKPT

specifies that this run is to create random access breakpoint files at the completion of each execution link for a possible restart. The files are stored on the RASTUS random access file RNDM16. This option should not be confused with the case control breakpoint/restart option. An executive control restart is a continuation of execution from the beginning of a specified link using the random access file as the source of all input and results. The BREAKPT request adds an overhead cost of approximately 1 to 4 seconds per link (15 to 60 seconds for a typical execution).

MAXFL = nnn

specifies a maximum field length above which the program will not attempt to expand. The default MAXFL is 131000_{10} or 377670_8. An attempt by the program to exceed this limit to satisfy an open core requirement will result in a fatal diagnostic and termination of execution. The form is MAXFL = nnn where nnn is a positive, base 10 integer.

NORFL

does not permit the field length to vary during execution. The field length upon entry to the program will remain in effect throughout the run.

RASTUSIN

uses the existing random access RASTUS file located on file RNDM16 as the basis for random access operations. Otherwise a new file is generated.

RESTART = n

requests that execution be restarted from the random access RASTUS file RNDM16 from the beginning of link n. The input case control and bulk data decks must not be input, and only the END DATA card should be included. All options and data will be restored to their conditions at the time of the BREAKPT generation. (With one exception: If a case control CG restart was in effect and completed the link 16 BREAKPT then a subsequent RESTART = 16 will proceed from the CG restart file generated on the most recent execution. In other words, multiple runs using the RESTART = 16 and BREAKPT executive control cards following an original RESTART = CG case control request will result in continuous iteration without going through the geometry links, etc.). A less complicated example would be if a run with BREAKPT started execution of link 17 (displacement, strain, stress, force recovery) and terminated for MAX pages, then a RESTART = 17 would restart execution from the beginning of link 17.

SCAFFOLD

(Plot system or generalized postprocessor only.) Does not attempt to read the PPDATA file.

CHAPTER 7

EXAMPLE INPUT/OUTPUT

7.1 Disk Thermal Stresses

A solid disk with free surfaces is heated to a temperature distribution, $T = 100 - 10000r^2$ where r is the radius in inches. This is an axisymmetric problem whose solution is known in closed form. The PATCHES-III model of the disk, Figure 7-1, illustrates a number of important modeling features. First, element number one has a degenerated surface at the center of the disk. The bulk data for the model demonstrate that no special input are required to either create this hyperpatch or identify the element as degenerate.

Note that the parameterization of both hyperpatches is determined from the connectivity data (CPDE3 cards) per Figure 4-1 and not from the HPR card parameterization. Also, since the through the thickness behavior of this problem is well-behaved, half of the degrees of freedom of the model can be eliminated at little cost in accuracy by constraining the element to be linear in the ξ_3 direction (the CCL parameter on the CPDE3 card). Second, these data illustrate the input of symmetry boundary conditions. Note that the centerline is fully restrained in the (1,2) plane as a result of two surface normal constraints (SDC20 cards) on surfaces that intersect along the centerline. To constrain rigid body motion in the $\underset{\sim}{e}_3$ direction, grid point one has component number three constrained via an SPC1 card. The synthesis of constraints at this grid point then involves both surface and grid point data cards. Third, several data modeling features are illustrated by the temperature input. The algebraic format data patch is particularly simple in this case; only two of the sixteen parameters are nonzero for data patch 10 and three for data patch 20. (See lines 3 to 10 of the bulk data.) Note that $r = 0.05\xi_1$ for element one and $r = 0.05(\xi_1 + 1)$ for element two. Since the temperature field is axisymmetric, the data patch equivalence option can be used to create data patches 30 and 40. The data hyperpatches are created using DHP2P cards where the parameterization is consistent with the geometric hyperpatches. Were they not consistent, the DHPSORT card would be used to reparameterize the data hyperpatches. The stress results from PATCHES-III are compared to the closed-form solution (Reference 3) in Table 7-1. The maximum difference is less than one percent (1%) with respect to the peak stress. Note that [illegible] the outer radius is a natural boundary condition which is very closely approximated with only a two-element model. Finally, Table 7-1 shows that subtended angle has little effect on modeling error in this problem. The 90-degree subtended angle model has virtually the same stress accuracy as the

30-degree model. This is somewhat surprising because a circular arc cannot be modeled exactly with a parametric cubic, and the geometry modeling error for the 90-degree case is much higher than the 30-degree case.

Table 7-1

DISK THERMAL STRESS COMPARISONS

	PATCHES-III (PSI)				EXACT SOLUTION (PSI)	
	$\phi = 30^{\circ}$		$\phi = 90^{\circ}$			
10r	σ_r	σ_ϕ	σ_r	σ_ϕ	σ_r	σ_ϕ
0	-24.97	-24.97	-25.14	-25.13	-25.00	-25.00
1/6	-23.93	-22.63	-24.26	-22.97	-24.31	-22.92
1/3	-21.81	-16.29	-22.08	-16.55	-22.22	-16.67
1/2	-18.59	- 5.99	-19.17	- 6.40	-18.75	- 6.25
2/3	-13.57	8.64	-13.72	8.59	-13.89	8.33
5/6	- 7.32	27.39	- 7.91	27.02	- 7.64	27.08
1	.24	50.27	.10	50.58	0.00	50.00

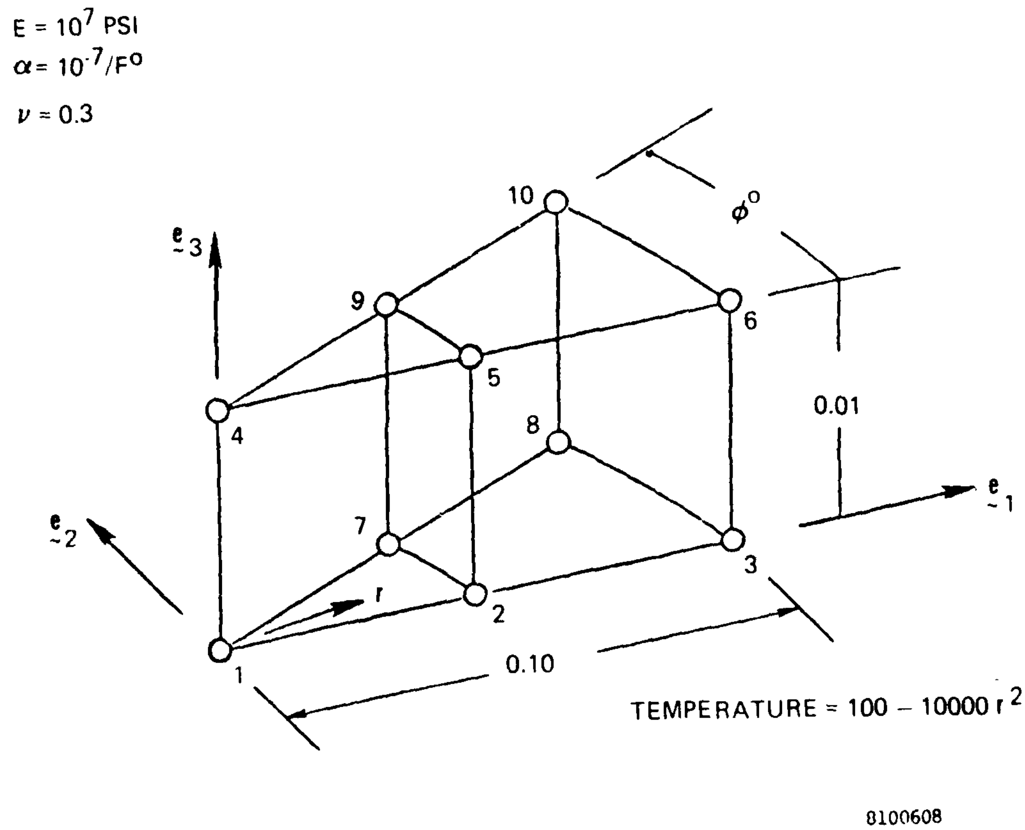


Figure 7-1. Disk Thermal Stress Model

PATCHES CONTROL DIRECTIVES

```
TITLE, DISK THERMAL STRESS PROBLEM
TIME, 5
RESTART, CG
SDC, 10
LOAD, 10
OUTPUT
EVERYTHING
BEGIN BULK
```

PATCHES DATA DIRECTIVES

```
CPDE3,    1,  1,  1,  7,  2,,,, CCL,  4,  4,  9,  5
CPDE3,    2,  2,  7,  8,  3,,,, CCL,  5,  9, 10,  6
DPATA,   10,  1,  1,  7,  2,,,, 13(0), -25.0,  0, 100.0
DPATA,   20,  2,  7,  8,  3,,,, 13(0), -25.0, -50.0, 75.0
DPATEQ, 30, 10,  4,  4,  9,  5
DPATEQ, 40, 20,  5,  9, 10,  6
DHP2P,    1, 10, 30
DHP2P,    2, 20, 40
TEMP,    10,  1,  1
TEMP,    10,  2,  2
GRID,     1,, 0.0,  0., 0.
GRID,     2,, 0.05, 0., 0.
GRID,     3,, 0.10, 0., 0.
GRID,     4,, 0.0,  0., 0.01
GRID,     5,, 0.05, 0., 0.01
GRID,     6,, 0.10, 0., 0.01
PATCHQ, 11,  1,  2,  5,  4
PATCHQ, 12,  2,  3,  6,  5
HPR,      1, 11,,,, 0., 90., 3
HPR,      2, 12,,,, 0., 90., 3
MATAL,    1,  1,  1,  2
MAT1,     1,  1.+7,,  0.3
MTRX-2,  1.0-7, 1.0-7, 1.0-7
PPDE3,    1,  1
PPDE3,    2,  1
SDC20,   10,  2,  3,  7,  8, 10,  9
SDC20,   10,  2,  3,  2,  3,  6,  5
SDC20,   10,  1,  3,  1,  7,  9,  4
SDC20,   10,  1,  3,  1,  2,  5,  4
SPC1,    10,  1,,,  0.0
END DATA
```

7.2 Interlaminar Normal Stresses

One of the few three-dimensional composite laminate problems for which corroborative solutions exist is a four-ply graphite-epoxy plate under uniaxial load. A finite difference solution of the elasticity equations (Reference 4), a stress-function discrete element solution of the elasticity equations (Reference 5), an analytic solution of certain higher order laminated plate theory equations (Reference 6), and the PATCHES-III displacement-function discrete element solution of the elasticity equations all agree well for the interlaminar normal stress. Stresses are computed for the $0^{\circ}/90^{\circ}/90^{\circ}/0^{\circ}$ laminate shown in Figure 7-2 under a uniform imposed displacement in the axial direction. Taking full advantage of symmetry, a simple four-element PATCHES-III model was created from 46 bulk data directives. There are three planes of symmetry all modeled with SDC10 cards. The imposed axial displacement which constrains only the $\underset{\sim}{e}_1$ component on the $Z(1, \xi_2, \xi_3)$ surfaces is modeled with SDC1 directives. Note that blank fields for the $\underset{\sim}{e}_2$, $\underset{\sim}{e}_3$, data patches on the SDC1 directives allow these components to remain unconstrained. The material property modeling required only one materials matrix since all lamina are the same except for orientation. The Euler angle option (PSI = 90°, THETA = PHI = 0°) was used on the PPDE3 property directive for elements 1 and 2 and to obtain the materials matrix for a 90° lamina. Using this feature it would be a trivial data change to model a $45^{\circ}/-45^{\circ}/-45^{\circ}/45^{\circ}$ laminate. The nature of the solution made it possible to use two tri-linear elements leading into the linear-cubic-cubic elements at the free edge.

A view of the deformation of the center cross-section, Figure 7-3, indicates the local nature of the distortion caused by the free edge. The interlaminar normal stress, Figure 7-4, peaks at the free edge and damps out quickly as expected. Comparison with the reference solutions in this figure show excellent agreement. The printed output shows that the displacement at any point in the cross-section is independent of Z^1, as assumed in Reference 4, and that the axial strain, ε_{11}, is constant. Table 7-2 shows the interlaminar normal stress for three models that use the constant strain information to reduce the cost of the analysis.

Table 7-2

INTERLAMINAR NORMAL STRESS COMPARISONS*

ξ/2h**	CCC/CCC (428 D.O.F.)	LLL/LCC (92 D.O.F.)	LLL/LCL (44 D.O.F.)
0	+2.95	+2.89	+2.76
1/3	- .26	- .27	- .31
2/3	- .43	- .44	- .25
1	- .16	- .05	- .03
2	- .02	- .03	- .03
3	+ .01	- .01	- .00
4	- .01	+ .02	+ .02

*Comparisons at midsurface between 90-degree plies.
**Z_2 = b - ξ; distance from free-edge.

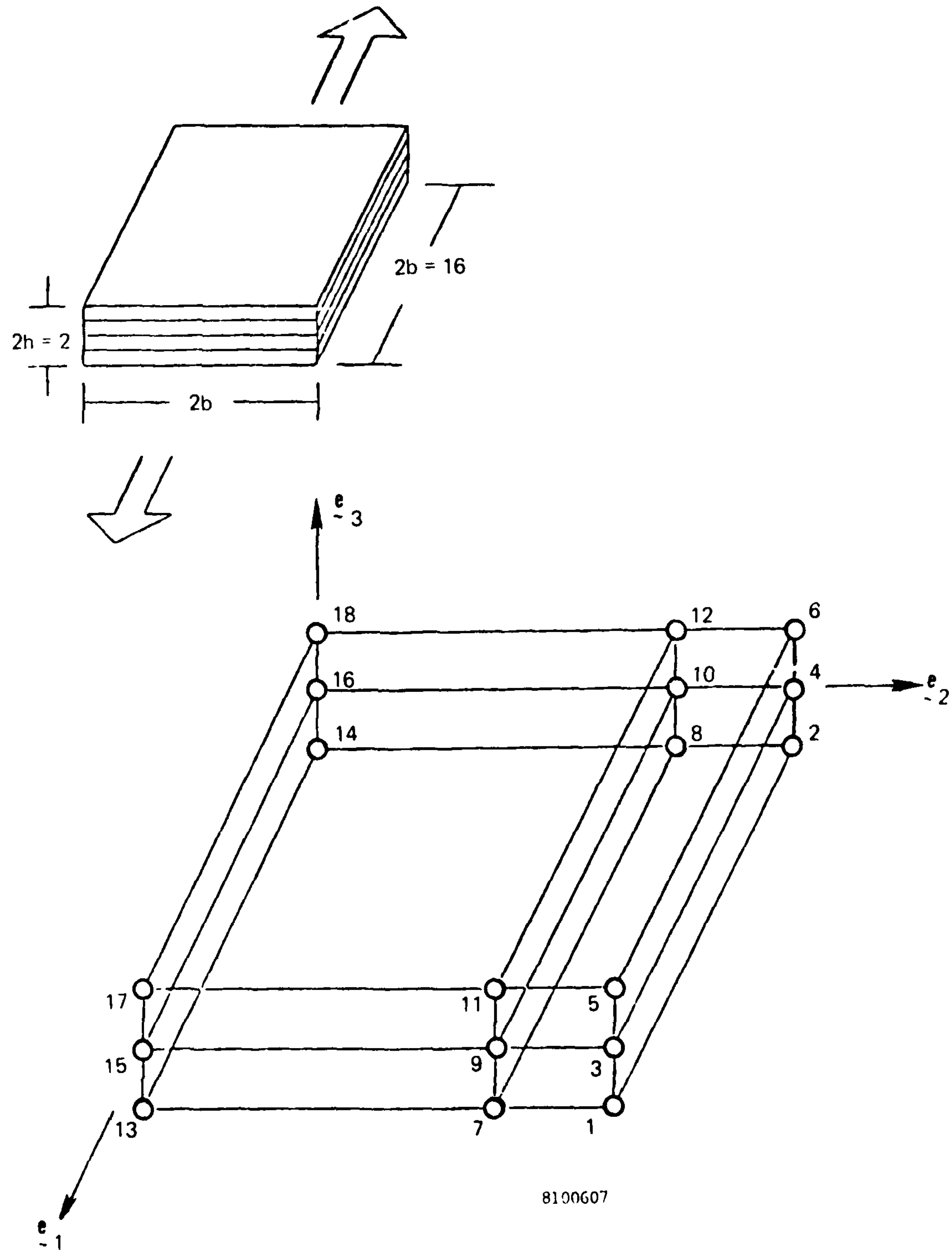


Figure 7-2. Model of a Graphite Epoxy Laminate

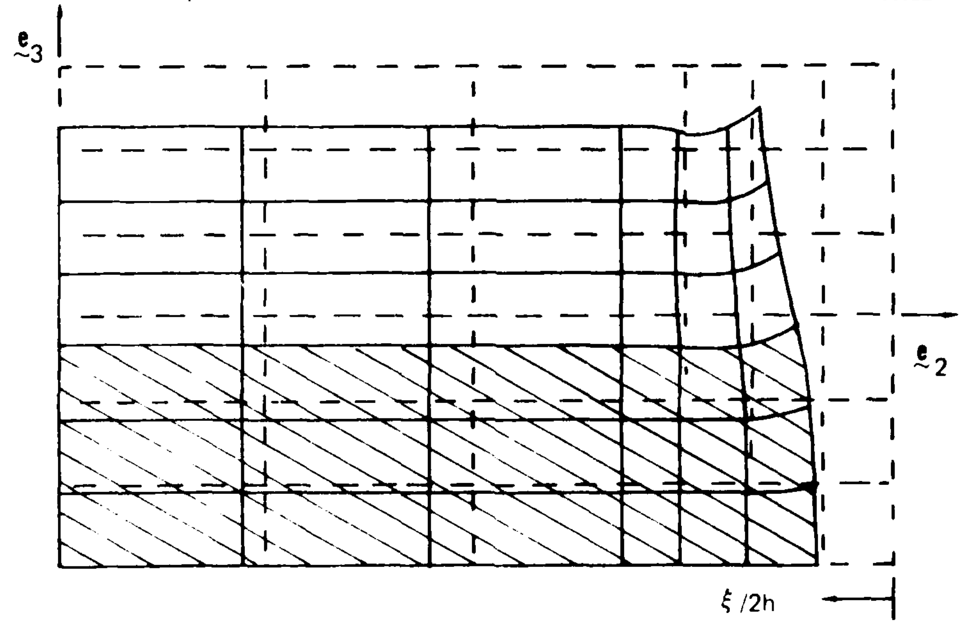


Figure 7-3. Laminate Deformations at the Center Cross-Section

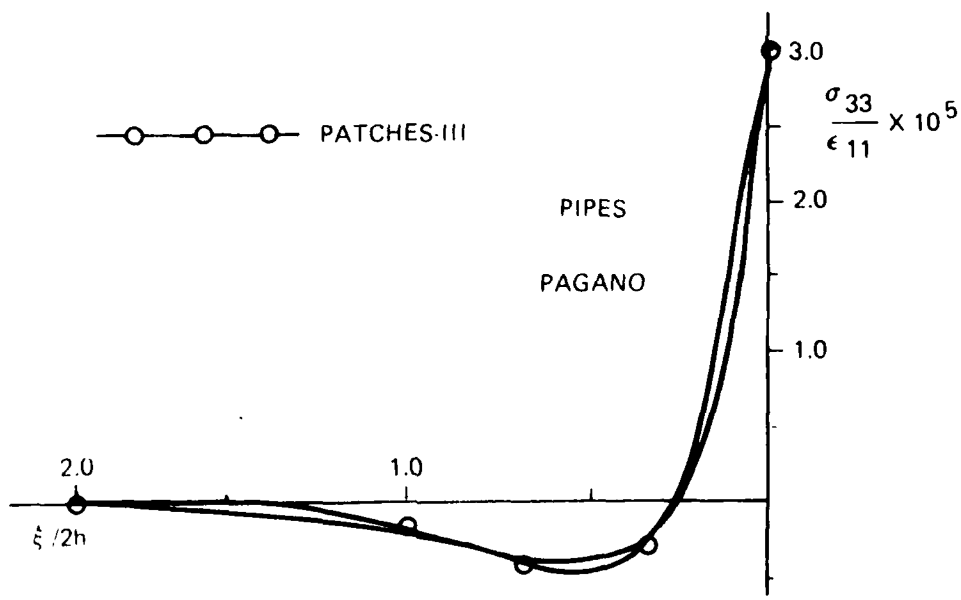


Figure 7-4. Interlaminar Normal Stress Comparison

PATCHES CONTROL DIRECTIVES

```
TITLE, INTERLAMINAR STRESS PROBLEM

TIME, 8

SDC, 10

OUTPUT

EVERYTHING

BEGIN BULK
```

PATCHES DATA DIRECTIVES

```
CPDE3,   1, 14,  8,  7, 13,,,, LLL, 16, 10,  9, 15
CPDE3,   2,  8,  2,  1,  7,,,, LCC, 10,  4,  3,  9
CPDE3,   3, 16, 10,  9, 15,,,, LLL, 18, 12, 11, 17
CPDE3,   4, 10,  4,  3,  9,,,, LCC, 12,  6,  5, 11
DATAG,   1,, 1, 0.01, 3, 0.01, 5, 0.01, 7, 0.01, 9, 0.01, 11, 0.01, 13,
         0.01, 15, 0.01, 17, 0.01
DPATQ,  10,  1, 13, 15,  9,  7
DPATQ,  20,  1,  7,  9,  3,  1
DPATQ,  30,  1, 15, 17, 11,  9
DPATQ,  40,  1,  9, 11,  5,  3
GRID,   15,, 8., 0., 0.
GRID,    9,, 8., 6., 0.
GRID,    3,, 8., 8., 0.
GRID,   16,, 0., 0., 0.
GRID,   10,, 0., 6., 0
GRID,    4,, 0., 8., 0
HPN,     1,  1,  -.5
HPN,     2,  2,  -.5
HPN,     3,  1,   .5
HPN,     4,  2,   .5
PPDE3,   1,  1,, 90.
PPDE3,   2,  1,, 90.
PPDE3,   3,  1
PPDE3,   4,  1
MATC,    1,  1,  1,  1
MTRX-1, 20.2+6, 0.56+6, 0.56+6, 2.21+6, 0.48+6, 2.21+6, 0.85+6, 0.0,
         0.0, 0.85+6, 0.0, 0.85+6
PATCHQ,  1, 16, 10,  9, 15
PATCHQ,  2, 10,  4,  3,  9
SDC10,  10,  1,  1, 14, 16, 10,  8
SDC10,  10,  1,  2, 14, 13, 15, 16
SDC10,  10,  1,  3, 14,  8,  7, 13
SDC10,  10,  2,  1,  8, 10,  4,  2
SDC10,  10,  2,  3,  8,  2,  1,  7
SDC10,  10,  3,  1, 16, 18, 12, 10
SDC10,  10,  3,  2, 16, 15, 17, 18
SDC10,  10,  4,  1, 10, 12,  6,  4
SDC1,   10,  1, 10
SDC1,   10,  2, 20
SDC1,   10,  3, 30
SDC1,   10,  4, 40
END DATA
```

7.3 Thick Cylinder Pressure Stresses

A widely used three-dimensional test case for mechanical loads is a thick-walled cylinder under pressure. An exact solution for this problem, the so-called Lame cylinder, is available in Reference 7. A one-element PATCHES-III model of the cylinder, Figure 7-5, was loaded by an internal pressure of 5 psi and an external pressure of 10 psi. The principal new modeling feature demonstrated by this problem is the pressure load card, PLOAD3. Note that a negative scale factor was used for data patch 30 because the positive normal on this surface is directed away from the outer surface of the cylinder.

The stress results for three different subtended angles are compared in Table 7-3 with the exact solution. Again, as with the disk problem, there is little loss in accuracy even in the 90-degree model. The maximum error is approximately three percent (3%) relative to the peak stress using a single CCL element to model one quadrant.

Table 7-3

CYLINDER PRESSURE STRESS COMPARISONS

r	σ_ϕ (psi)				σ_r (psi)			
	EXACT	$\Delta\phi$=10	$\Delta\phi$=45	$\Delta\phi$=90	EXACT	$\Delta\phi$=10	$\Delta\phi$=45	$\Delta\phi$=90
1	-18333.	-18464.	-18450.	-18516.	-5000.	-5512.	-5503.	-5554.
4/3	-15417.	-15340.	-15319.	-15276.	-7917.	-7757.	-7741.	-7763.
5/3	-14067.	-14114.	-14091.	-14014.	-9267.	-9392.	-9372.	-9388.
2	-13333.	-13172.	-13143.	-12995.	-10000.	-9726.	-9703.	-9676.

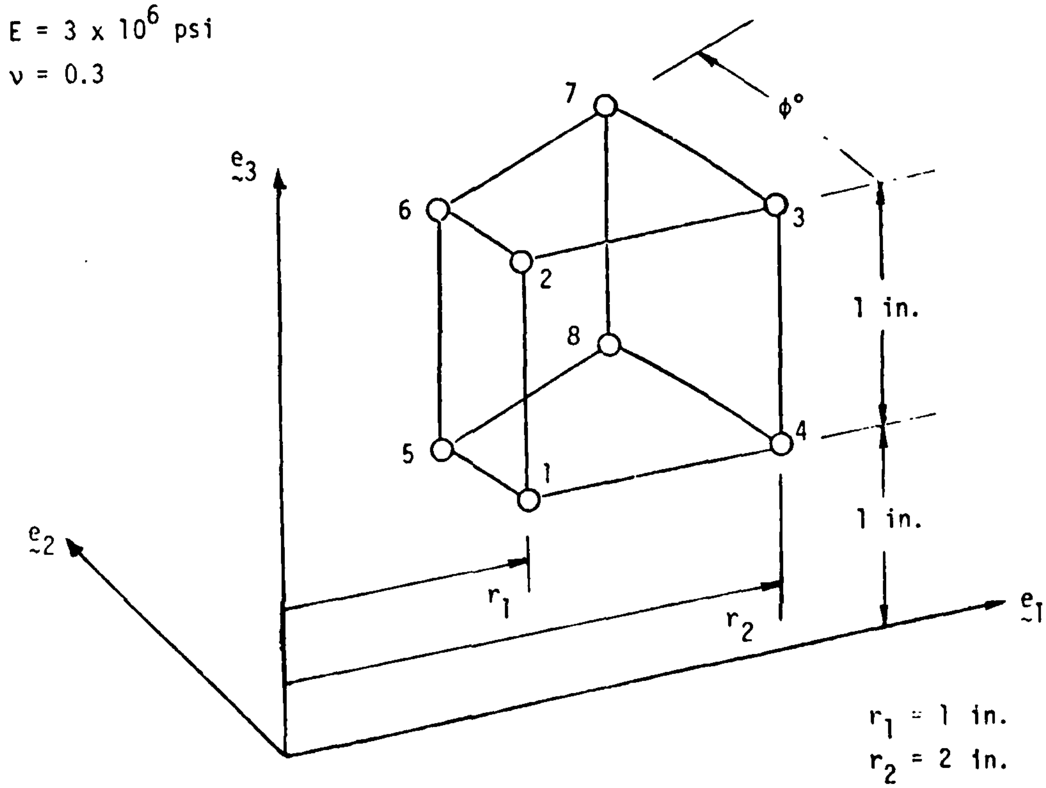


Figure 7-5. Thick Walled Cylinder Model

PATCHES CONTROL DIRECTIVES

```
TITLE, LAME CYLINDER
TIME, 6
CHKPNT, ELEMENT, CG
SDC, 10
LOAD, 10
OUTPUT
EVERYTHING
BEGIN BULK
```

PATCHES DATA DIRECTIVES

```
CPDE3,   1,  1,  5,  8,  4,,,, CCL,  2,  6,  7,  3
GRID,    1,  2,  1.0, 0.0, 1.0
GRID,    2,  2,  1.0, 0.0, 2.0
GRID,    3,  2,  2.0, 0.0, 2.0
GRID,    4,  2,  2.0, 0.0, 1.0
DATAG,   1,, 1, 1000., 2, 1000., 6, 1000., 5, 1000., 4, 1000., 3, 1000.,
         7, 1000., 8, 1000.
DPATQ,  20,  1,  1,  2,  6,  5
DPATQ,  30,  1,  4,  3,  7,  8
HPR,     1,  1,,,,, 10.0, 3
MATC,    1,  1,  1,  1
MTRX-1,  .40385+7, .17308+7, .17308+7, .40358+7, .17308+7, .40385+7,
        1.1538+6, 0., 0., 1.1538+6, 0., 1.1538+6
PLOAD3, 10,  1, 20,  5.0
PLOAD3, 10,  1, 30, -10.0
PATCHQ,  1,  1,  4,  3,  2
PPDE3,   1,  1
SDC20,  10,  1,  3,  5,  8,  7,  6
SDC20,  10,  1,  3,  1,  4,  3,  2
SDC10,  10,  1,  3,  2,  6,  7,  3
SDC10,  10,  1,  3,  1,  5,  8,  4
END DATA
```

7.4 Symmetry-Asymmetry Analysis of a Filamentary Composite

The efficient modeling of structures often requires using any symmetries or asymmetries present. In general, this requires the superposition of several cases to obtain the complete solution. The SUBCOM case control card automates this procedure, and its use is illustrated using the fiber-reinforced structure shown in Figure 7-6. The reinforcing fibers are oriented at -45 degrees in the one-two plane. The $\underset{\sim}{Z}(\xi_1, 0, \xi_3)$ boundary is restrained in the $\underset{\sim}{e}_2$ direction, and a uniform tension is applied to the opposite face $\underset{\sim}{Z}(\xi_1, 1, \xi_3)$. This load can be factored into the sum of a symmetric-symmetric load and an asymmetric-asymmetric load in the material axes, e_i'. A structural symmetry model, Figure 7-6, was first analyzed with symmetry-symmetry boundary conditions and the results stored on a postprocessing data file. Then on a second run, the asymmetry-asymmetry solution was obtained and, using the SUBCOM feature, added to the previous solution to obtain the complete solution. The control cards for this procedure, shown in Section 8.2 of this manual, are very simple. The results from the combined solution agree to six places with a single-element model of the complete cubical structure. The shear stresses, which should be identically zero, are on the order of 1.0×10^{-6} psi in the full cube model and 1.0×10^{-7} psi in the symmetry model. Note that although the u_2 displacement component is zero for the asymmetry case, this will not be true generally and is not part of the asymmetry constraints.

The strain results for the three cases are summarized in Table 7-4.

Table 7-4

SYMMETRY-ASYMMETRY MODEL

Case	E11	E22	E33
Symmetry	3.8024-7	3.8024-7	-2.3708-7
Asymmetry	-7.1429-7	7.1429-7	0.0
Combined	- .3340-6	1.0945-6	-2.3708-7

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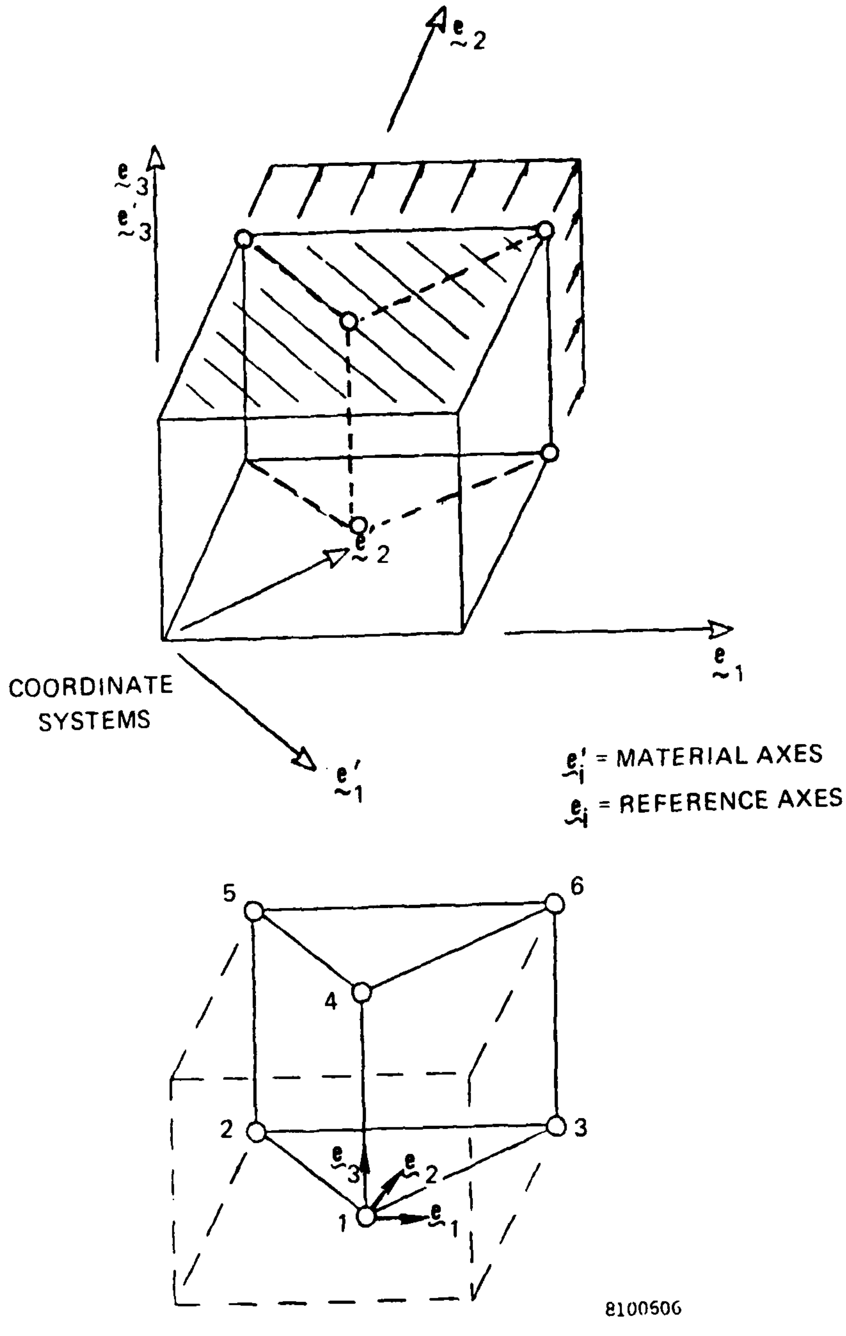

Figure 7-6. Symmetry Modeling of a Filamentary Composite

PATCHES CONTROL DIRECTIVES

```
TITLE, ANGLE PLY LAMINA, SUBCOM TEST CASE

SUBTITLE, SYMMETRY BOUNDARY CONDITIONS

TIME, 2

LOAD, 5

SDC, 10

OUTPUT

ALL

BEGIN BULK
```

PATCHES DATA DIRECTIVES

```
CPDE3,    1,  1,  2,  3,  1,,,,, 4, 5, 6, 4
DATAG,    1,, 2, 1.0, 3, 1.0, 5, 1.0, 6, 1.0
DPATQ,   10,  1,  2,  3,  6,  5
GRID,     1,,  0.0, 0.0
GRID,     2,, -1.0, 1.0
GRID,     3,,  1.0, 1.0
PATCHQ,   1,  1,  2,  3,  1
HPN,      1,  1, 2.0
MATC,     1,  1,  1,  1
MTRX-1   20.35+6, .5888+6, .5888+6, 1.501+6, .4621+6, 1.501+6, 0.7+6,
         0.0, 0.0, 0.7+6, 0.0, 0.7+6
PPDE3,    1,  1,, -45.0
PLOAD3,   5,  1, 10, 1.0
SDC20,   20,  1,  1,  1,  4,  6,  3
SDC20,   20,  1,  1,  1,  4,  5,  2
SDC20,   10,  1,  3,  1,  4,  6,  3
SDC20,   10,  1,  3,  1,  4,  5,  2
END DATA
```

PATCHES CONTROL DIRECTIVES

```
TITLE, ANGLE PLY LAMINA, SUBCOM TEST CASE
SUBTITLE, ASYMMETRY BOUNDARY CONDITIONS
TIME, 2
LOAD, 5
SDC, 20
SUBCASE, 2
SUBTITLE, COMBINED SOLUTION
SUBCOM, 1.0, /, 1.0
OUTPUT
ALL
BEGIN BULK
```

PATCHES DATA DIRECTIVES

```
CPDE3,   1,  1,  2,  3,  1,,,,, 4,  5,  6,  4
DATAG,   1,, 2, 1.0, 3, 1.0, 5, 1.0, 6, 1.0
DPATQ,  10,  1,  2,  3,  6,  5
GRID,    1,,  0.0, 0.0
GRID,    2,, -1.0, 1.0
GRID,    3,,  1.0, 1.0
PATCHQ,  1,  1,  2,  3,  1
HPN,     1,  1,  2.0
MATC,    1,  1,  1,  1
MTRX-1, 20.35+6, .5888+6, .5888+6, 1.501+6, .4621+6, 1.501+6, 0.7+6,
         0.0, 0.0, 0.7+6, 0.0, 0.7+6
PPDE3,   1,  1,, -45.0
PLOAD3,  5,  1, 10, 1.0
SDC20,  20,  1,  1,  1,  4,  6,  3
SDC20,  20,  1,  1,  1,  4,  5,  2
SDC20,  10,  1,  3,  1,  4,  6,  3
SDC20,  10,  1,  3,  1,  4,  5,  2
END DATA
```

CHAPTER 8

JOB CONTROL OPTIONS

8.1 Overview

Only one control card is necessary to execute the basic PATCHES-III system on a CDC computer. At other sites only two cards are required. Versions 9.4 and higher of the program operate under the NOSBE operating system. The program was compiled using the FTN 4.7 compiler. The following section shows the job control directives necessary for each of the basic PATCHES-III executions using NOSBE directives. When executing under NOS the CATALOG directives must be changed to DEFINE directives, and other minor variations may occur, depending on how physical tapes are requested. Other minor variations may also be necessary at individual computer facilities to account for local system differences.

8.2 Example Deck Setups

The following group of deck setups assumes that the user has already input the appropriately formatted job and accounting cards. The

CP time estimate should be at least as large as the case control TIME directive. The maximum field length parameter should accommodate the maximum open core requirement for the problem (try 200000_8 initially). The PATCHES file may require an ID=XXXX entry on the ATTACH card at some sites.

1. Execution of a new model

```
•
•
•
ATTACH, PATCHES, MR=1.
PATCHES, PL=9999999.
EOR Card
Case and bulk data decks
EOF Card
```

2. Execution of a new model and generation of a checkpoint file

```
•
•
•
REQUEST, INPT, *PF.
ATTACH, PATCHES, MR=1.
PATCHES, PL=9999999.
CATALOG, INPT, RP=999.
EOR
Case and bulk data decks
EOF
```

3. Restart from a checkpoint tape

```
•
•
•
ATTACH, INPT, PW=EXTEND, MODIFY.
ATTACH, PATCHES, MR=1.
PATCHES, PL=9999999.
EOR
Case control with RESTART request and bulk data
EOF
```

4. Execution of a new model, saving the PPDATA file

```
●
●
●
REQUEST, PPDATA, *PF.
ATTACH, PATCHES, MR=1
PATCHES, PL=9999999.
CATALOG, PPDATA, RP=999.
EOR
Case and bulk data decks
EOF
```

5. Execution of a SUBCOM utilizing a previous PPDATA file, outputting a new PPDATA file

```
●
●
●
REQUEST, PPDATA, *PF.
ATTACH, INDATA, old PPDATA file.
ATTACH, PATCHES, MR=1.
PATCHES, PL=9999999.
CATALOG, PPDATA, RP=999.
EOR
Case control with SUBCOM and bulk data deck.
EOF
```

6. Save the random access file for later use.

```
●
●
●
REQUEST, RNDM16, *PF.
ATTACH, PATCHES, MR=1.
PATCHES, PL=9999999.
CATALOG, RNDM16, RP=999.
EOR
Executive deck perhaps with BREAKPT option case control
   and bulk data decks
EOF
```

7. Execute a new model and create a plot file

```
•
•
•
REQUEST, TAPE21, *PF.
ATTACH, PATCHES, MR=1.
ATTACH, PATPLOT, MR=1.
PATCHES, PL=9999999.
PATPLOT.
CATALOG, TAPE21, plot file name, RP=999.
EOR
Case and bulk data decks
EOR
Plotting directives
EOF
```

8.3 Program Files

The PATCHES file names in order are as follows:

Default File Name	Contents
INPUT	Input directives
OUTPUT	Output print file
TAPE1	Alternate input file
TAPE2	Bulk data sequence
TAPE3	Case control cards
TAPE4	Line sequence network
TAPE8	Bulk data output, scratch file
TAPE9	Scratch file
TAPE10	Bulk data cards
INPT	Checkpoint/restart file
PPDATA	Postprocessing data file
INDATA	Input of a previous PPDATA file
RNDM16	RASTUS file, random access
TAPE17	SUBCOM request file
TAPE18	Scratch file
TAPE20	User information file

8.4 PATPLOT Postprocessor

PATCHES-III output can be plotted using the PATPLOT postprocessor which operates on the RNDM16 file created during a CDC execution. This file on the VAX-11/780 is labeled RASTUS.DAT. The PATPLOT program is normally used in an interactive mode and prompts the user for information about what data are to be plotted on each frame. The user responds from his terminal to each prompt with a line of free-form input. The syntax is exactly as described in Chapter 4 for free-form bulk data input. The system can also be used in batch mode by putting all the responses in one sequential input record following the CDC job control directive that executes PATPLOT.

1. PATPLOT interactive mode plot file creation

```
•
•
Plotting from run entitled ... DISK THERMAL STRESS PROBLEM.
Input list of elements to plot.
3(1), 3(2)
Input corresponding list of faces.
2(3,4,5)
Input the plot subtitle.
CARTESIAN STRESS S11
Input displacement magnification factor.
0
Input data component:  0 = NONE, 1-3 = DISP, 4-9 = STRAIN,
   10-15 = STRESS, 16-21 = MATERIAL FRAME STRAIN,
   22-27 = MATERIAL FRAME STRESS.
10
Input viewing angles about the X,Y,Z axes, respectively.
45, 0, -45
Input hidden lines flag:  0 = ALL, 1 = HIDDEN, 2 = BOTH.
0
Input number of U/W lines/patch.
1
Input contours flag:  0 = NO, -1 = DELTA, N = N CONTOURS.
-1
10
Input carpet flag:  0 = NO, 1 = YES.
0
Input smoothing flag:  0 = NO, 1 = YES.
1
Working.
Input list of elements to plot.
0
```

The above PATPLOT session will plot one frame showing Cartesian stress contours on faces 3, 4, and 5 of elements 1 and 2. The contours will be in 10 psi intervals, as illustrated in Figure 8-1. The session was ended by inputting a zero in response to the last prompt for the number of elements in the next frame. The same session executed in batch mode on a CDC computer would have the following input.

2. PATPLOT batch mode plot file creation

```
•
•
ATTACH (RNDM16, ID = ...)
REQUEST (TAPE21, *PF)
RFL (100000)
PATPLOT
CATALOG (TAPE21, PLOTID, ID = ...)
*EOR
3(1), 3(2)
2(3,4,5)
CARTESIAN STRESS S11
0
10
45, 0, -45
0
1
-1
10
0
1
0
*EOJ
```

In both the batch mode and interactive mode sessions, a plot file of CALCOMP compatible instructions has been generated for processing on a hardcopy plotter. The interface with a specific hardware device, i.e., CALCOMP, TRILOG, etc., is a site dependent operation. The format of the plot file is industry standard, which makes this a routine operation. There is also a version of PATPLOT available for output directly on a TEKTRONIX 4014, which is interactive in a truly graphic sense. The prompting is exactly the same, and the same RNDM16 file is used by the interactive graphics version of PATPLOT.

An examination of the sample session file shows that each element face plotted must be defined individually. To plot all six faces of an element then requires the element number to be input six times in the element list. This feature places complete control in the user's hands for composing each frame plotted. Any or all faces of any or all elements may be examined for any response mode. This allows regions as small as a single element to be excised and viewed in great detail (Figure 8-2), or the overall deformations of the entire model can be viewed (Figure 8-3) at any magnification.

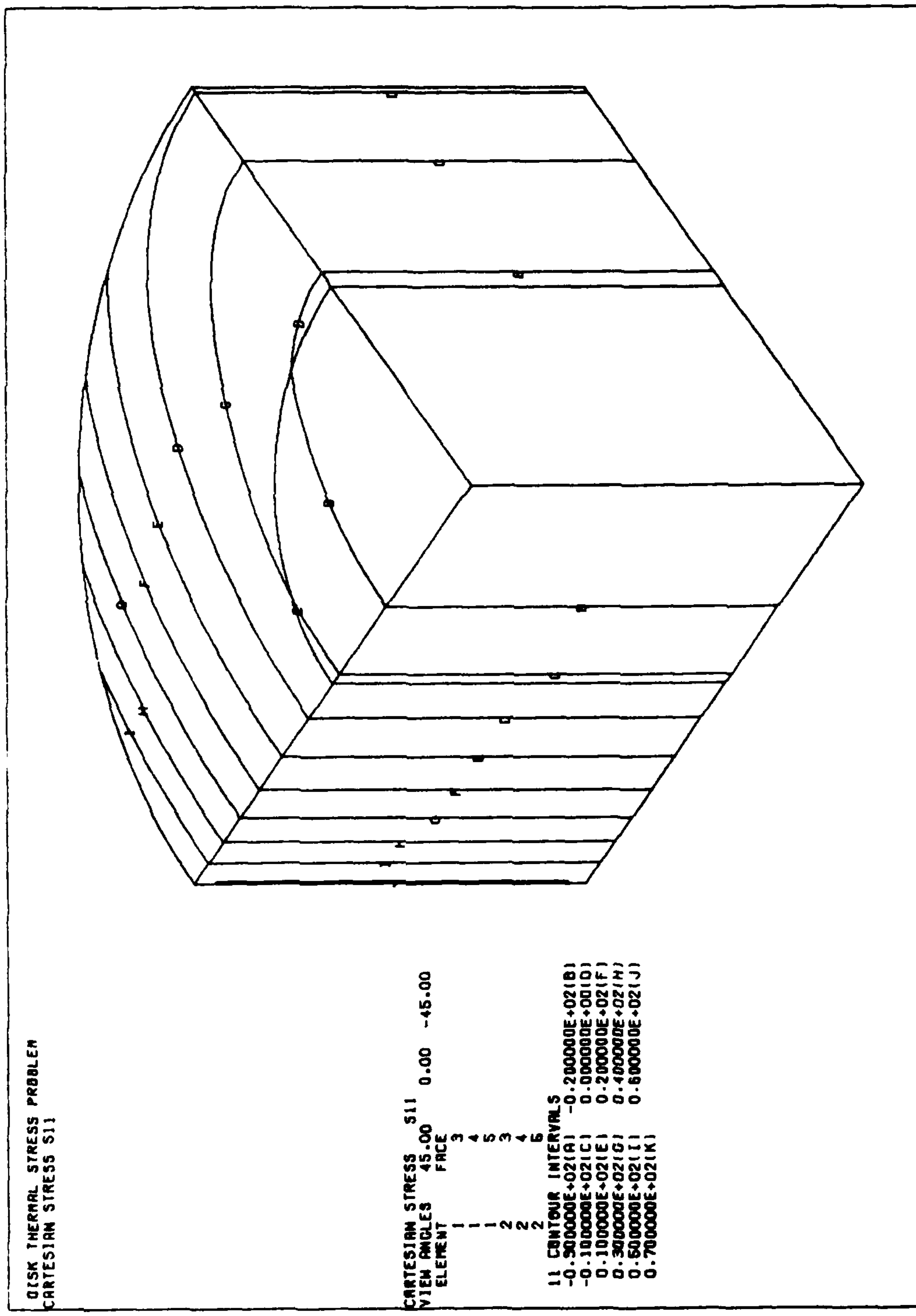

Figure 8-1. Disk Thermal Stress Contour Plot

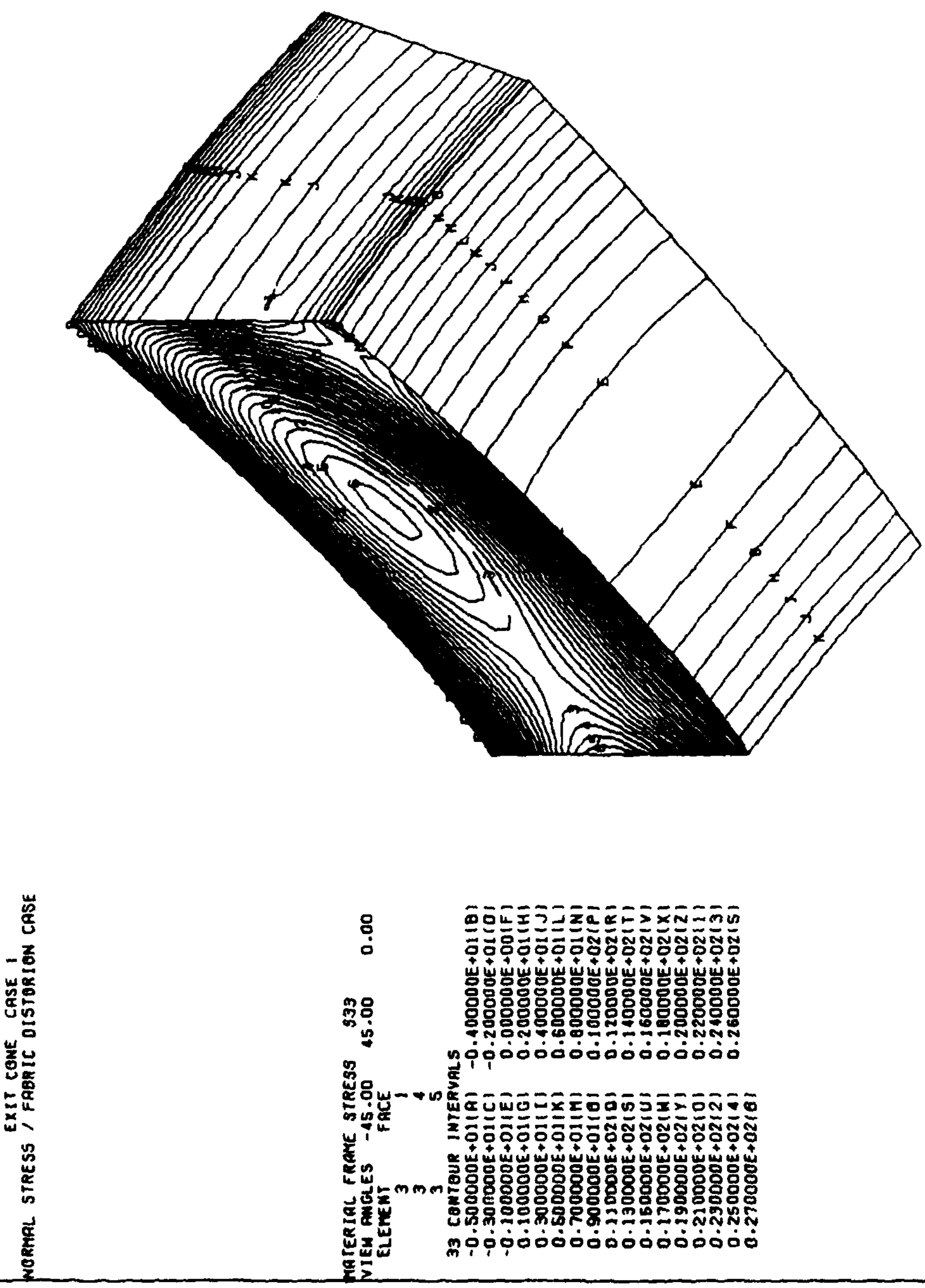

Figure 8-2. Interlaminar Normal Stress Contour Plot

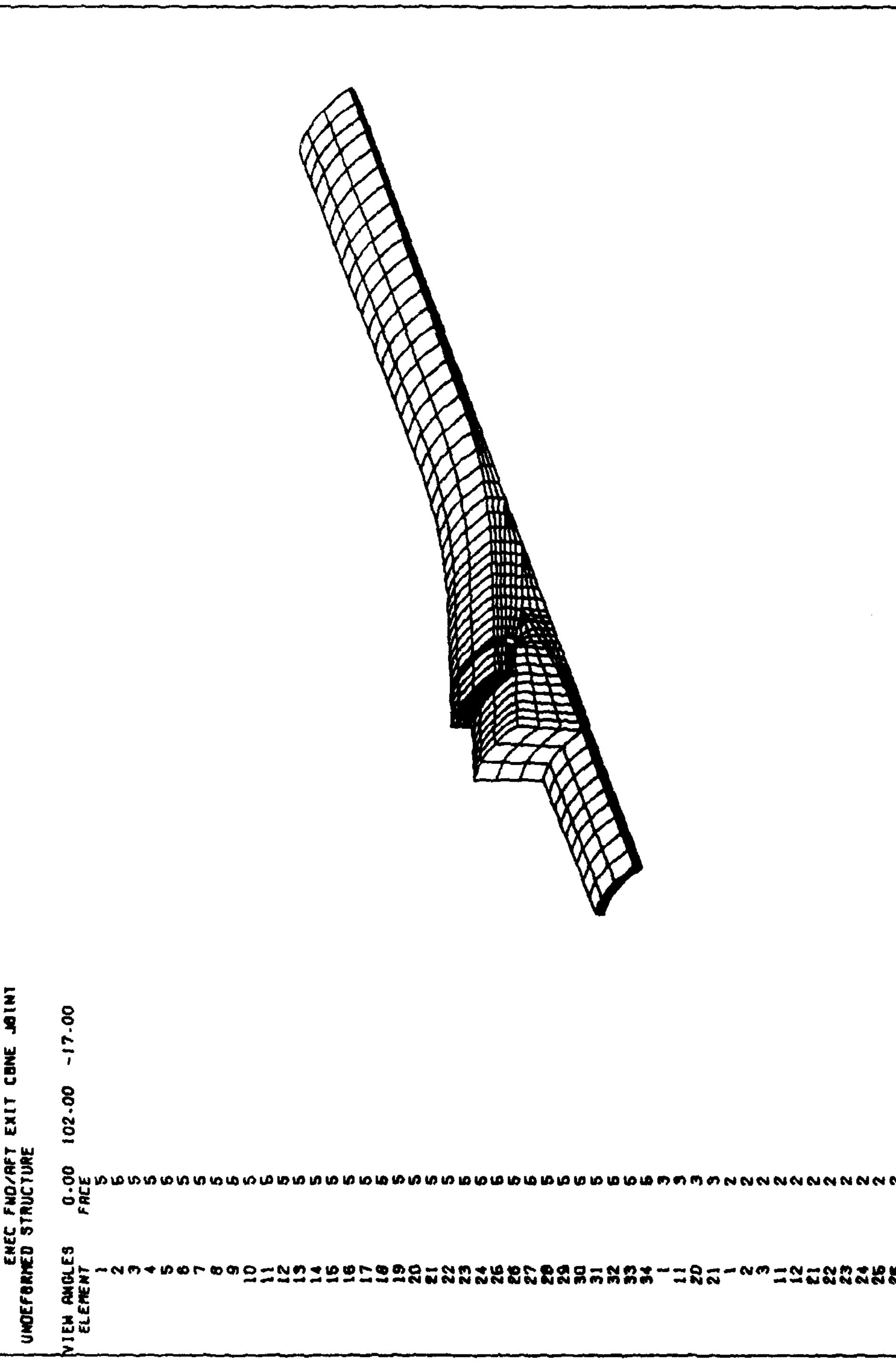

Figure 8-3. Undeformed Structure Plot

CHAPTER 9

DIAGNOSTICS

9.1 Overview

The executive and data processing systems in PATCHES-III have been designed to diagnose as many errors as possible on any execution. All cards are processed and cross referenced, and whenever possible the remaining fields of a card in which errors have been detected are also scanned.

In the case data region, the error message is listed on the line following the erroneous card. Errors detected in the OUTPUT region of case control are not fatal.

In the bulk data region, the card which precipitated the error is listed along with a description of the error condition. A run in which errors were detected will terminate at the DRY location unless the ERRORS PARAM field is overridden.

9.2 Error Messages

The error messages in PATCHES-III are generally self-explanatory, and the number of possible messages is so large as to make even an enumeration of possible error conditions unreasonable. Therefore, this section will identify and explain only the most common or more complicated errors. Letters in small type within an all-caps error message text represent variables.

THE CORNER GRID POINT VALUES RESULTING FROM THE CONSTRUCTION OF HYPERPATCH n CANNOT BE ORIENTED TO MATCH THE PREVIOUSLY DEFINED GRID POINT VALUES.

GRID POINTS INVOLVED	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8
ORIGINAL COORDINATES	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8
	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8
COMPUTED COORDINATES	x_1^n	x_2^n	x_3^n	x_4^n	x_5^n	x_6^n	x_7^n	x_8^n
	y_1^n	y_2^n	y_3^n	y_4^n	y_5^n	y_6^n	y_7^n	y_8^n
	z_1^n	z_2^n	z_3^n	z_4^n	z_5^n	z_6^n	z_7^n	z_8^n

CONNECTIVITY CONSISTENCY CHECK nnnnnnn mmmmmmmm

This message indicates that the 8 corner grid points associated with element n (from the CPDE3 card) as generated using one of the various HPAT directives are not consistent with the prior definitions of the grid point coordinates. Those grid points may have been input with a set of GRID cards, or they could be the result of prior hyperpatch constructions. The tolerance on this test is as defined by the ACGG field on the PARAM directive (default is 5 significant figures). Check the connectivity definition on the CPDE3 directive. Check the construction operations, including the construction of associated patches and lines. Originally undefined grid points (for which consistency is not required) are represented on output as a .999E-99. The "connectivity consistency" check is a check on the degeneracy of the connectivity and geometry definitions and should be identical. A final item to check stems from the fact that an element needs at least one grid point to "hang on to" to get its bearings. An element constructed first, or alone in space, is "consistent" with 8 undefined grid points in its original parameterization.

UNRECOGNIZABLE BULK DATA CARD.

The first field on the card listed before this message does not have a valid mnemonic. Check the spelling of the card. Check that the card prior to this one did not require a continuation character.

VALUE OUT OF RANGE. DATA FIELD NUMBER n.

INPUT = f_n RANGE = R_{min} R_{max}

The card image that follows this message has a value that is not within a range of reasonable values $R_{min} \leq f_n \leq R_{max}$. The position of the offending parameter is n where fields 1 to 10 are on the first card, 11 to 20 on the first continuation card, etc.

ERROR IN A RASTUS REQUEST FROM THE xxxxxx MODULE.

CALLING INDEX SET TO n.

This message is generally preceded and followed by other messages which serve to further identify the problem. However, the xxxxxx parameter is helpful in deciphering the cause of the problem. There are two basic forms for this parameter: FETCHx and STOREx representing a random access fetch or store request for volume x. The request was for page n of that volume. The table below summarizes the various volumes and their contents.

Volume	Contents
A	Auxiliary storage
B	Data patches
C	Material properties
D	Data lines
E	Element matrices
F	Function tables
G	Element connectivity
H	Geometric hyperpatches
I	Input MAT data
J	Jacobians
K	DD tensor for elements
L	Geometric lines
M	Matrices
N	Mesh point numbers for elements
O	Output requests
P	Geometric patches
Q	Load tables by elements
R	R table of imposed displacements for mesh points
S	Rigid body transformation
T	Load vectors by elements
U	Element displacements, strains, stresses
V	Not active
W	Element matrices F set and partitioning

Volume	Contents
X	Original C and alpha matrices
Y	Mesh point vs. F table ID's
Z	Temperature hyperpatches
1	One-component data hyperpatches
2	Element tables and vectors
3	Archive element matrices, E frame
4	Packed element constraints matrices
5	Element mesh point constraint flags
6	U* Master cartesian displacements

For example, a message concerning the FETCHP module with an index of 7 is referring to a problem fetching geometric patch 7. Therefore check that patch 7 was properly generated.

THE RESULTANT GEOMETRY FOR HYPERPATCH n IS NOT GEOMETRICALLY REASONABLE. The construction of hyperpatch n resulted in local regions at which the Jacobians at the Gaussian points were negative. This implies a negative local volume. Check the connectivity and the construction operations. An element such as this can still be plotted, and this can serve as a clue to the problem. As an example of this situation, consider a ruled hyperpatch in which one of the patches is reversed (physically or by connectivity). Then the ξ_3 lines will tend to cross near the center of the element.

9.3 Debugging Data

Additional information can be printed to aid in the debugging of a model through the use of the PARAM DEBUG bulk data card. The user inputs an integer value for the DEBUG parameter, and bits of the resultant word activate the debugging options listed in Table 9-1.

A DEBUG value of 138, for example, would activate three options since 138 = 128 + 8 + 2. Currently only two bits in this table are active.

Table 9-1

DEBUG OPTIONS AVAILABLE

Base Value	Bit Position	Result
1	1	Not active
2	2	Imposed displacement flags and YS vector
4	3	Not active
8	4	Not active
16	5	Not active
32	6	Not active
64	7	Not active
128	8	Imposed displacement transformations (row sort)

The imposed displacement flags printout (bit 2) gives for each mesh point the code numbers representing the degrees of freedom. Only three distinct values exist in this table in PATCHES-III: 50 for constrained to 0., 496 for unconstrained, and 1074 for constrained to a nonzero value. The YS table gives the magnitude of the imposed displacement for each component of each mesh point consistent with USET.

The imposed displacement transformations printout (bit 8) defines for each mesh point having an imposed displacement the 3 X 3 transformation matrix (in row sort) that maps displacement components in the constraint frame to components in the reference $\underset{\sim}{e}_i$ frame.

9.4 User Information File

The final output from any PATCHES-III execution is the User Information File. This file is a chronological listing of the major events during the execution of the program and the resources required. The file has the appearance of a CDC day file and can be used to estimate CPU costs per element on any given computer. For each of the categories of output, the following definitions apply.

PROGRAM REGION	The major region, usually the link name.
SUBREGION	The subregion name or start or end for a program region.
SSTIME	The number of system seconds (or CPU seconds on CDC) up to this point in the job. NOTE: A job will begin with SSTIME greater than 0 if other operations are performed prior to initiating the PATCHES execution.
DELTA	The difference in SSTIME between this and the prior event.
FIELD LENGTH	Octal total field length at this time.
RASTUS REQUESTS	Total number of RASTUS random access requests.
TOTAL WORDS TRANSFERRED	Total number of words transferred (written and read) using RASTUS.
DELTA WORDS TRANSFERRED	The difference in TOTAL WORDS TRANSFERRED between this and the prior event.
SUBINDEX SORTS	The number of RASTUS subindex sorts, an overhead requirement for the adaptive subindex buffer technique.
PERCENT SORTS	The percent of RASTUS REQUESTS requiring SUBINDEX SORTS. Generally under 3%.

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