AFFDL-TR-72-42
VOLUME II

MAGIC III: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

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Approved for public release; distribution unlimited.

FOREWORD

This report was prepared by Textron's Bell Aerospace Company (BAC), Buffalo, New York under USAF Contract No. F-33615-71-C-1390. This contract is an extension of previous work initiated under Project No. 1467, "Structural Analysis Methods", Task No. 146702, "Thermal Elastic Analysis Methods". The program was administered by the Air Force Flight Dynamics Laboratory (AFFDL) under the cognizance of Mr. G.E. Maddux, AFFDL Program Manager. The program was carried out by the Structural Systems Department, Bell Aerospace Company during the period 15 March 1971 to 15 March 1972 under the direction of Mr. Stephen Jordan, BAC Program Manager.

This report, "MAGIC III: An Automated General Purpose System for Structural Analysis" is published in three volumes, "Volume I: Engineer's Manual", "Volume II: User's Manual", and "Volume III: Programmer's Manual". The manuscript for Volume II was released by the authors in July 1972 for publication as an AFFDL Technical Report.

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This technical report has been reviewed and is approved.

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ABSTRACT

An automated general purpose system for analysis is presented. This system, identified by the acronym, ''MAGIC III'' for Matrix Analysis via Generative and Interpretive Computations, is an extension of the structural analysis capability available in the initial MAGIC System. MAGIC III provides a powerful framework for implementation of the finite element analysis technology and provides diversified capability for displacement, stress, vibration, and stability analyses.

Additional elements have been added to the MAGIC element library in this phase of MAGIC development. These are the solid elements; rectangular prism, tetrahedron, triangular prism, symmetric triangular prism, and triangular ring (asymmetrical loading). Also included are the symmetric shear web element and a revised quadrilateral thin shell element. The finite elements listed include matrices for stiffness, mass, prestrain load, thermal load, distributed mechanical load, pressure and stress.

The MAGIC III System for structural analysis is presented as an in integral part of the overall design cycle. Considerations in this regard include, among other things, preprinted input data forms, automated data generation, data confirmation features, restart options, automated output data reduction and readable output displays.

Documentation of the MAGIC III System is presented in three parts; namely, Volume I: Engineer's Manual, Volume II: User's Manual and Volume III: Programmer's Manual. The subject document Volume II (User's Manual) is an extension of the primary technical document and contains instructions for the preparation of input data and for interpretation of output data.

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SECTION I

INTRODUCTION

A. General Considerations

The MAGIC III System for structural analysis is an extension of the MAGIC I and MAGIC II Systems reported in References 1 to 6. All capabilities available in the original systems have been retained and improved upon. Extension of the MAGIC System has been in the following areas:

(a) Incorporation of four (4) solid finite element representations
  (1) Rectangular Prism
  (2) Tetrahedron
  (3) Triangular Prism
  (4) Symmetric Triangular Prism

(b) Incorporation of a triangular cross-section ring finite element which accommodates asymmetric loading.

(c) Incorporation of a symmetric quadrilateral shear web finite element.

(d) Incorporation of a quadrilateral thin shell finite element which reflects high aspect ratio usage.

(e) The addition of miscellaneous arithmetic modules to the System to support the existing computational procedures.

(f) Incorporation of an additional out-of-core variable bandwidth equation solver based on the modified square-root Cholesky method.

(g) The addition to the System of a module designated as ANALIC (Analysis In Core) which can be used to perform a complete linearly elastic stress analysis, selected portions of a linear elastic analysis, or as a general purpose equation solver.

B. Applicable MAGIC Documentation

The work reported herein is a discussion (from the User's point of view) of the extensions listed in Section A. This volume, User's Manual (Volume II) is an extension of the MAGIC II User's Manual (Reference 5) and as such is to be used in conjunction with that manual to effectively utilize the MAGIC III System. It is emphasized that all information contained in Reference 5 is directly applicable to MAGIC III without exception and the subject volume can be thought of as a supplement to Reference 5.

In order to avoid any confusion and to save the reader from frequent consultation of the Reference Section at the end of this document, the manuals applicable to the usage and understanding of the MAGIC III System are listed as follows:

Theoretical Documents

(a) Mallett, R.H. and Jordan, S., "MAGIC: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual", AFFDL-TR-68-56, Volume I, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, January 1969.

(b) Jordan, S., "MAGIC II: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual (Addendum)", AFFDL-TR-71-1, Volume I, Air Force Dynamics Laboratory, Wright-Patterson AFB, Ohio, May 1971.

(c) Batt, J.R., and Jordan, S., "MAGIC III: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual", AFFDL-TR-72-42, Volume I, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, April 1972.

User Documents

(a) Jordan, S., and Gallo, A.M., "MAGIC II: An Automated General Purpose System for Structural Analysis, Volume II. User's Manual", AFFDL-TR-71-1, Volume II, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, May 1971.

(b) Jordan, S., and Batt, J.R., "MAGIC III: An Automated General Purpose System for Structural Analysis, Volume II. User's Manual", AFFDL-TR-72-42, Volume II, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, April 1972.

Programming Document

(a) Gallo, A.M., "MAGIC III: An Automated General Purpose System for Structural Analysis, Volume III. Programmer's Manual", AFFDL-TR-72-42, Volume III, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, April 1972.

C. Summary of Manual Contents

Section II presents additions to the abstraction instruction library of the MAGIC System, descriptions of new agendums for the ANALIC module, and detailed abstraction instructions required for the analysis of structures using the asymmetric triangular ring. Additional preprinted input data sheets have been designed and are explained. Newly implemented finite elements and instructions for their use are discussed in detail.

Section III is devoted to interpretation of the input to and output from the MAGIC III System. Preprinted input data forms are presented for specific example problems which utilize each of the MAGIC III finite element representations. Output from these problems is also displayed and discussed in detail.

Appendix A is included which delineates corrections and updates to the MAGIC II User's Manual (Reference 5). Appendix B is a compilation of all preprinted input data forms required to perform an analysis using MAGIC III.

SECTION II

INPUT TO THE MAGIC III SYSTEM

A. Introduction

The MAGIC III System presents two input data interfaces to the Structural Analyst. The first encountered is referred to as the System Input Data interface. The System data instructs the program as to what operations should be performed during any execution. These operations may be viewed as the interpretive portion of the MAGIC System. For example, the matrix abstraction instructions which are required to perform a structural analysis are System Input Data. All abstraction instructions available to the System prior to MAGIC III are delineated in detail in Reference 5. Instructions added during the MAGIC III development are discussed in detail in the next section.

The second input data interface with the User concerns the Structural Input Data. For example, grid point coordinates and boundary condition information are viewed as Structural Input Data. This problem oriented data accounts for nearly all the effort expended in conducting structural analyses.

As with the matrix abstraction instructions, the bulk of Structural Input Data parameters have been fully documented in Reference 5. Additional preprinted input data forms and specific finite element data for newly implemented elements evolved during the MAGIC III development are included and explained in this Section.

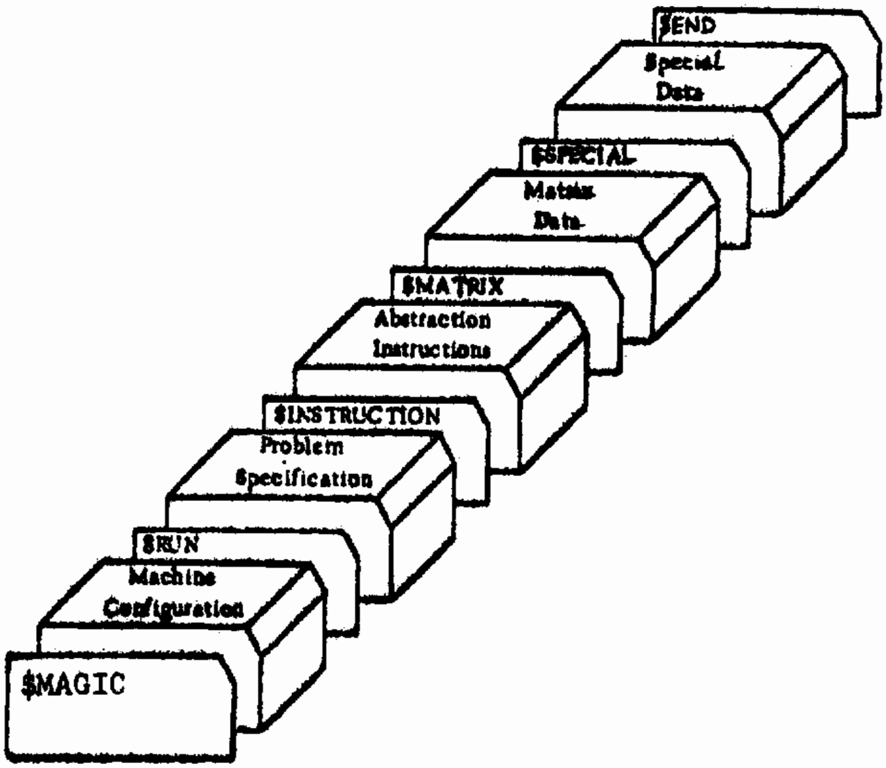
B. System Input Data

1. General Description

The input data for a general MAGIC execution consists of control and specification data, the abstraction instruction sequence, and problem data. Control, machine configuration and problem specification data constitute the control and specification data. Matrix and special (non-matrix) data constitute the problem data. These data must be sequenced as follows:

(1) Machine Configuration Data
(2) Problem Specification Data
(3) Abstraction Instruction Sequence Data
(4) Matrix Data
(5) Special Data

where each section is preceded by a control card which indicates the beginning of and the options chosen for that section. The last section is followed by a control card indicating the end of all input to a MAGIC case. A sketch of a typical MAGIC deck set up is shown below.



All MAGIC III data-deck set-ups have the form typified in the sketch. It is noted that all abstraction instruction data is placed behind the $INSTRUCTION card. All input matrix data is placed behind the $MATRIX card and all special data is placed behind the $SPECIAL card. All structural input data such as gridpoint coordinates, element descriptions, temperature and pressure data are classified as special data and as such appear behind the $SPECIAL card in a data-deck set up.

These data and their relationship to a MAGIC execution are discussed in detail in Reference 5, the companion manual to this document. Of interest here is the additional abstraction instruction capability (Item 3 above) which has been added to MAGIC III.

2. Additional Arithmetic Abstraction Instructions Added to MAGIC III

The basic form for arithmetic statements is:

$$c = \pm a \quad .\mathrm{Op}. \quad \pm b$$

where $\underline{a}$ and $\underline{b}$ are known matrix names, $\underline{c}$ is the name of the matrix to be computed, Op is the operation to be performed in computing $\underline{c}$ from $\underline{a}$ and $\underline{b}$ and the positive signs of $\underline{a}$ and $\underline{b}$ may be omitted.

Variations of this basic form are required for certain operations. These variations are described with the corresponding operational definitions when they occur in the following arithmetic statements.

a. Solution of Equations by Cholesky Triangularization

Statements are of the form:

T,x = A,β.CHTRIA.

Ax = β is the system of equations considered
Output matrix T = Triangularized matrix
Output matrix x = Solution vector
Input matrix A must be symmetric.

b. Computation of Triangularized Matrix

Statements are of the form:

T = A.TRIA.

Input matrix A must be symmetric
Output matrix T = Triangularized form of matrix A

c. Computation of Linear Equation Solution when Triangularized Matrix is Known (Back Substitution)

Statements are of the form:

x = T.CHOL.β

Input matrix T is in triangularized matrix form
Input matrix β is the known set of constants
Output matrix x = solution of back substitution system

This instruction is especially useful for linear equation solution of Ax = β when the matrix A has already been triangularized into T. Note also that T matrix must have been generated from a symmetric matrix A.

d. REPEAT

(1) General

The operation REPEAT has been added to the matrix abstraction capability of the system. The new operation provides a looping capability analogous to the FORTRAN "DO" statement where a certain sequence of instructions is to be repeated a specified number of times.

The sequence of instructions to be repeated is expanded into the range of the REPEAT loop during preprocessing, and unique matrix names attained by appending subscripts which are automatically incremented each time the sequence is repeated. Manipulation of subscripted matrices in the instruction sequence prior and subsequent to the REPEAT loop is entirely general and provision is made for the card input of such matrices. In the absence of a REPEAT statement in the sequence of instructions, use of subscripts on matrix names is optional.

Potential applications include synthesis of fully-stressed structural designs, analysis of structural nonlinearity due to large deflections, creep, short-time plasticity and combinations thereof, 3-dimensional matrix algebra and solutions of systems of nonlinear equations. REPEAT provides for a more expedient mode of abstraction instruction input in such applications.

(2) Abstraction Instruction

"Repeat" statements are of the form

```
REPEAT (n,m)
```

where the arguments are

n - the number of abstraction instructions in the sequence immediately following the REPEAT statement which are to be repeated

m - the number of times the sequence of n instructions is to be repeated

The instruction can be literally interpreted as "repeat the following series of n instructions m times".

The sequence of instructions is expanded into the range of the REPEAT loop during preprocessing. Matrix names which are initially subscripted automatically have their subscripts incremented by one each time the sequence is repeated; unsubscripted matrix names remain the same.

(3) Subscripted Matrix Names*

Subscripted matrix names are specified in an abstraction instruction as one to six alphameric characters, the first of which must be alphabetic (as previously). The subscript of the matrix name, if any, must be a decimal integer between 1 and 9999 enclosed in slashes. If a matrix name is not subscripted, integer one is assumed. Negative or zero subscripts are not allowed.

The matrix name has the form:

NAMEA/k/ or NAMEA

where k is a one to four digit decimal integer.

Subscripted matrix names are specified in card input matrix data by the entry of the matrix name in card columns 67 through 72 (as previously) and the subscript in card columns 73 through 76 (right justified). A modified version of the card input matrix data standard form is shown in Figure II-1, page 20.

(4) Restrictions

Restrictions on the use of the REPEAT loop are as follows:

> A statement number may not appear on a statement which lies in the range of a REPEAT loop. This implies there can be no transfer into or within the range of the loop.

---

* The matrix name is stored in memory as one character per word. The seventh word of the matrix name contains a positive or negative integer. The absolute value of this integer is the subscript of the matrix name. The sign of this integer is the sign of the matrix name.

Nesting of REPEAT loops is not permitted.

The total number of statements generated by the REPEAT loop is restricted by the amount of working storage (NWORK) available for the instruction analyzing module and the allocation module. (Typically with NWORK = 10000, approximately 100 instructions are permitted.)

Matrix names on the left side of an equals sign must be subscripted.

(5) Error Messages

Additional control error messages which pertain to the REPEAT module and which emanate from the instruction processor module are listed below.

INST10	STATEMENT NUMBER SPECIFIED WITHIN RANGE OF LOOP. STATEMENT NUMBER IGNORED
INST11	SYNTAX ERROR IN -REPEAT- INSTRUCTION
INST12	MATRIX NAME LEFT OF EQUALS SIGN NOT SUBSCRIPTED WITHIN RANGE OF LOOP
INST13	INVALID NESTED LOOPS
INST14	SYNTAX ERROR IN SUBSCRIPTED MATRIX NAME
INST15	INSUFFICIENT CORE STORAGE FOR PROCESSING LOOP
INST16	RANGE OF REPEAT LOOP IS UNSATISFIED
INST**	THIS INSTRUCTION NOT AVAILABLE

Other control error messages which include matrix names as additional descriptive information have been modified to accommodate subscripted matrix names.

(6) Application

As an example of the use of REPEAT consider a nonlinear matrix equation of the form

$$A_0 + A_1 x + A_2 x^2 = 0$$

which may be processed iteratively to approximate x as follows:

$$x_{i+1} = - A_1^{-1} (A_0 + A_2 x_i^2)$$

The appropriate abstraction instruction sequence using REPEAT is as follows.

```
1    7
$INSTRUCTION
     A1INV   = -A1    .INVERS.
     X  /1/  =  A1INV .MULT.   A0
     PRINT(,,,)X/1/
     REPEAT (6, 7)
     XR /1/  =  X  /1/.RENAME.
     X2 /1/  =  XR /1/.EMULT.  X  /1/
     AX2/1/  =  A2    .MULT.   X2 /1/
     AAX/1/  =  A0    .ADD.    AX2/1/
     X  /2/  =  A1INV .MULT.   AAX/1/
     PRINT(,,,)X/2/
```

where matrices A0, A1, and A2 are either card input or are available on an input matrix data set.

The effective expanded instruction sequence which would result is as follows.

```
$INSTRUCTION
     A1INV   = -A1    .INVERS.
     X  /1/  =  A1INV .MULT.   A0
     PRINT(,,,)X/1/
     XR /1/  =  X  /1/.RENAME.
     X2 /1/  =  XR /1/.EMULT.  X  /1/
     AX2/1/  =  A2    .MULT.   X2 /1/
     AAX/1/  =  A0    .ADD.    AX2/1/
     X  /2/  =  A1INV .MULT.   AAX/1/
     PRINT(,,,)X/2/
     XR /2/  =  X  /2/.RENAME.
     X2 /2/  =  XR /2/.EMULT.  X  /2/
     AX2/2/  =  A2    .MULT.   X2 /2/
     AAX/2/  =  A0    .ADD.    AX2/2/
     X  /3/  =  A1INV .MULT.   AAX/2/
     PRINT(,,,)X/3/
             .
             .
             .
             .
     XR /7/  =  X  /7/.RENAME.
     X2 /7/  =  XR /7/.EMULT.  X  /7/
     AX2/7/  =  A2    .MULT.   X2 /7/
     AAX/7/  =  A0    .ADD.    AX2/7/
     X  /8/  =  A1INV .MULT.   AAX/7/
     PRINT(,,,)X/8/
```

e. EIGEN2

Large Order Eigensolution statements are of the form:

$c_1, c_2, c_3, c_4, c_5 = a.\text{EIGEN2}.\ b(d,e,f,g,h,i)$

where d eigenvalues and the corresponding eigenvectors are extracted from the matrix a, the real parts of the eigenvalues and eigenvectors are named matrix c_1 and matrix c_2 respectively, the imaginary parts are named matrix c_4 and c_5 respectively and the residual error is named matrix c_3. The following auxiliary definitions apply with matrix a of order (n x n)

c_1 - is the matrix of real eigenvalues (d x 1)

c_2 - is the matrix of real eigenvectors (n x d)

c_3 - is the matrix (currently null) of residuals (n x 1)

c_4 - is the matrix of imaginary eigenvalues (d x 1)

c_5 - is the matrix of imaginary eigenvectors (n x d)

a - is the name of the input eigenmatrix (n x n)

b - is the name of an input starting vector (n x 1); this represents an approximation of the dominant eigenvector. If b is blank a unit vector is assumed.

d - is the number of eigenvalues requested (an unsigned integer, preferably ≤ 5).

e - is the number of calculation vectors (an unsigned integer > 3 and $\geq d$ but as small as possible).

f - is the maximum number of iterations (an unsigned integer < 40).

g - is the starting vector recalculation exponent (a signed integer, nominally -2).

h - is the eigenvalue-eigenvector accuracy criterion (an unsigned floating point number with or without exponent, e.g., 1.0E-4)

i - is the eigenvalue uniqueness criterion (an unsigned floating point number with or without exponent, e.g., 1.0E-8).

f. MATRIX PARTITIONING (DJOIN)

(1) General

The base capability for matrix abstraction has been extended by the incorporation of the matrix operation DJOIN (opposite of ADJOIN). This provides for column partitioning of a matrix into two user-named sub-matrices, a capability hitherto effected by post multiplication of the subject matrix by two card extractor matrices.

(2) Abstraction Instruction

Matrix Dejoin statements are of the form:

$$c_1,\ c_2 = a.\mathrm{DJOIN}.(j,o)$$

where the matrix $\underline{a}$ is column partitioned immediately before its jth column and the resulting dejoined matrices are named $\underline{c}_1$ and $\underline{c}_2$ (i.e., $\left[\underline{c}_1 \vdots \underline{c}_2\right] = a$). Matrices $\underline{c}_1$ and $\underline{c}_2$ are of order $(m \times \underline{j-1})$ and $(m \times \underline{n-j+1})$ respectively with matrix $\underline{a}$ of order $(m \times n)$. Note that $1 \leq j \leq n$.

The "0" argument in the statement indicates column dejoining of matrix $\underline{a}$. Row dejoining may be effected by initially transposing matrix $\underline{a}$. Provisions have been made to accept a "1" in place of the "0" to indicate row dejoin; currently the module will branch to a nonexistent subroutine.

(3) Error Messages

MATRIX COLUMN DIMENSIONS IS TOO SMALL IN .DJOIN.

This error results when the column number, j, is greater than the matrix column dimension, n.

(4) Application

Two example applications are given below.

(1) X, Y = Z.DJOIN. (40,0)

If Z is order 300 x 100 then
X will be of order 300 x 39 and
Y will be of order 300 x 61

(2) G, P = H.DJOIN. (1,0)

G will be a null column with
the row dimensions of H, and
P will be a copy of H.

g. Matrix REPLAC

Matrix Replace statements are of the form:

a = ± b.REPLAC.c

where the input matrix b may be of order n x m
the input matrix c may be of order n x m
the output matrix a may be of order n x m

Wherever the elements of matrix b are equal to the corresponding elements of matrix c or wherever elements of matrix c are equal to 0.0, the output matrix a contains a direct mapping of matrix b. However, when the elements of b are not equal to the corresponding elements of matrix c, (excluding c = 0.0), the output elements of the resulting matrix a are equal to those elements of matrix c. This instruction is useful whenever it is desired to form a new matrix a, such that its corresponding elements will be the same as those of matrix b except where modified by elements of matrix c which are not equal to 0.0.

h. STRUCTURE CUTTER (STRCUT)

(1) General

The matrix abstraction capability of the MAGIC III System includes the "Structure Cutter" module which generates a solution of "n" linear simultaneous equations in "m" unknowns by Jordanian elimination (where $n \leq m$). This module takes advantage of sparsity of the coefficient matrix and utilizes a more effective mode of pivot selection.

The user may optionally control the pivotal acceptance levels used by the module and a list of the column numbers of the unreduced (non-pivotal) columns of the coefficient matrix is now included in the unconditional printed output for a successful execution. If execution is terminated for reason of unacceptable pivots the row numbers of the remaining (dependent) equations in which acceptable pivots cannot be found are listed.

The revised module also includes a restart capability which may be deployed should execution be terminated during the pivot selection phase for abnormal reasons; e.g., system malfunction. The four scratch data sets used during execution must be saved if a restart is to be made. Detailed information relating to this module is contained in Reference 7.

(2) Abstraction Instruction

"Structure-Cutter" statements are of the form:

$$c_1, c_2 = \pm a.STRCUT. \pm b, (d,e,f,g,h)$$

where the solution, Y, of the system of "n" linear simultaneous equations in "m" unknowns, $\pm AY \pm B = 0$, where $n \leq m$, is formed by Jordanian elimination and the two parts of the solution are named matrix $\underline{c}_1$ and matrix $\underline{c}_2$. The following auxiliary definitions apply:

a - is the transpose of the coefficient matrix, A.

b - is the transpose of the matrix of constants, B.

c_1 - is the homogeneous solution.

c_2 - is the particular solution.

d - is an unsigned floating point number, with or without exponent, bounding matrix element values of matrices $\underline{c}_1$ and $\underline{c}_2$ which are trivial and to be suppressed. That is the matrix element c_{ij} is suppressed if $|c_{ij}| \leq d$. If d is blank, zero valued elements are suppressed.

e - is either of the two literal constants. STOP or CONT. When e is STOP, execution is terminated if the available pivot elements do not satisfy the accuracy requirement. When e is CONT, termination of execution for reason of unacceptable pivot elements is delayed until the STRCUT instruction has been completely executed, including printing. If e is blank, the STOP option applies.

f - is the name of the matrix of weighting factors. If f is blank, a unit matrix of weighting factors automatically applies.

g - is the first pivotal acceptance level. If g is blank, 10^{-3} is used.

h - is the second pivotal acceptance level. If h is blank, 10^{-5} is used.

Matrices $\underline{c}_1$ and $\underline{c}_2$ are normal output data for this process. For the case m = n, $\underline{c}_1$ does not theoretically exist. In this case, a null matrix of order (n x 1) is generated as $\underline{c}_1$.

This subroutine unconditionally prints both a list of pivot element values with the corresponding column numbers of matrix A and a list of the column numbers of the unreduced (non-pivotal) columns of matrix A as special output data.

If execution is terminated for reason of unacceptable pivot elements the best remaining pivot is printed together with the row number of matrix A from which it emanates. Row numbers for all remaining rows which contain unacceptable pivots are also listed.

(3) Error Message

Error messages emanating from the Structure Cutter are listed below in alphabetical order on the first word.

```
CANNOT LOCATE MATRIX FOR STRUCTURE CUTTER.

ERROR IN STRUCTURE CUTTER INPUT - IMAX = **** AND JMAX = ****

ERROR IN STRUCTURE CUTTER INPUT - NULL COLUMNS
MATRIX ****** NULL COLUMN = **** (ETC.)

ERROR IN STRUCTURE CUTTER INPUT - NULL ROWS
NULL ROW = **** (ETC.)

INSUFFICIENT STORAGE FOR STRUCTURE CUTTER

INSUFFICIENT TAPES FOR STRUCTURE CUTTER

MATRIX IS SINGULAR.  BEST UNACCEPTABLE PIVOT = ±0.XXXXXXE-XX
EQUATION ****

FOLLOWING EQUATIONS CONTAIN UNACCEPTABLE PIVOTS
         **** (ETC.)
```

3. Matrix Data

Card Input matrix data are specified on the Standard Form shown on the following page. (Figure II-1)

A matrix header card having an H in card column 1, and containing the matrix name and its row and column dimensions, is required for each matrix.

It is noted that columns 73 thru 76 are set aside for subscript information. A blank in these locations indicates that the subscript associated with the matrix in question is equal to the integer one (1). Note that this subscripting option is extremely useful when used in conjunction with the REPEAT abstraction instruction discussed previously.

It is also noted that this revised form is identical to the original form provided for card input matrix data (Pg. 27, Reference 5), with the exception of Columns 73 thru 76. The heading PROG. NO. associated with these columns now reads SUBSCRIPT.

The last card after all $MATRIX data must contain an E in card column 1 with the rest of the card blank.

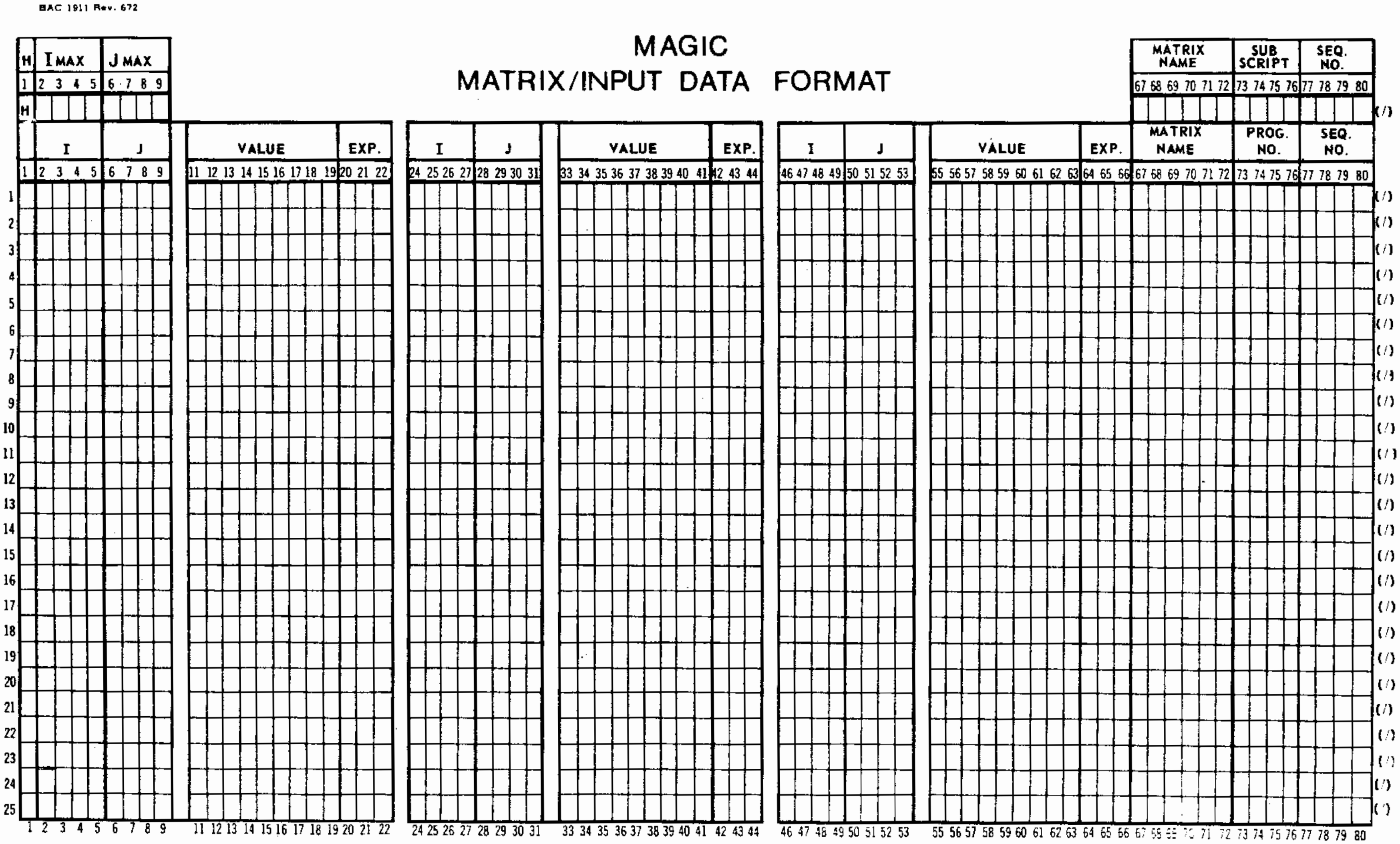
Each matrix may contain up to 6000 randomly ordered elements. Machine sortability requires that the sequence number (first three digits) for each matrix is unique and identical in both header and element cards.

4. USER04

a. Introduction

The fourth user coded module of the program is the structural generator of the MAGIC System.

This .USER04. instruction plays the most important role in MAGIC and it is explained in detail on Pages 28 thru 35 of Reference 5, the companion document to this volume.



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MAGIC
MATRIX/INPUT DATA FORMAT

H	I MAX	J MAX	MATRIX NAME	SUB SCRIPT	SEQ. NO.	
1	2 3 4 5	6 7 8 9	67 68 69 70 71 72	73 74 75 76	77 78 79 80	
H						(/)

		I	J	VALUE	EXP.	I	J	VALUE	EXP.	I	J	VALUE	EXP.	MATRIX NAME	PROG. NO.	SEQ. NO.	
	1	2 3 4 5	6 7 8 9	11 12 13 14 15 16 17 18 19	20 21 22	24 25 26 27	28 29 30 31	33 34 35 36 37 38 39 40 41	42 43 44	46 47 48 49	50 51 52 53	55 56 57 58 59 60 61 62 63	64 65 66	67 68 69 70 71 72	73 74 75 76	77 78 79 80	
1																	(/)
2																	(/)
3																	(/)
4																	(/)
5																	(/)
6																	(/)
7																	(/)
8																	(/)
9																	(/)
10																	(/)
11																	(/)
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22																	(/)
23																	(/)
24																	(/)
25																	(/)
	1	2 3 4 5	6 7 8 9	11 12 13 14 15 16 17 18 19	20 21 22	24 25 26 27	28 29 30 31	33 34 35 36 37 38 39 40 41	42 43 44	46 47 48 49	50 51 52 53	55 56 57 58 59 60 61 62 63	64 65 66	67 68 69 70 71 72	73 74 75 76	77 78 79 80	

Figure II-1 MAGIC Matrix/Input Data Format

The Structural Generative System may have as many as fifteen actual output matrices and require as many as four actual input matrices. The basic form of the .USER04. instruction may be represented as follows:

```
OMP1, OMP2, OMP3, OMP4, OMP5, OMP6, OMP7, OMP8,
OMP9, OMP10, OMP11, OMP12, OMP13, OMP14, OMP15 =
IMP1, IMP2, IMP3, IMP4, .USER04. ;
```

where OMP is read as output matrix position and IMP as input matrix position. All matrix positions, whether input or output, must be present. They may contain matrix names or be blank, but there must be nineteen matrix positions represented by the appropriate number of commas. Blank matrix positions are discussed in the next section. The output matrix positions, if nonblank, will contain the following matrices upon exit from the Structural Generative System:

OMP1 - copy of input structure data deck
OMP2 - revised material library
OMP3 - interpreted input (structure input data as stored after being read and interpreted)
OMP4 - external system grid point loads and load scalar matrix
OMP5 - transformation matrix for application of boundary conditions
OMP6 - transformation matrix for assembly of element matrices
OMP7 - element stiffness matrices stored as one matrix
OMP8 - element generated load matrices stored as one matrix
OMP9 - element stress matrices stored as one matrix
OMP10 - element thermal stress matrices stored as one matrix
OMP11 - element incremental stiffness matrices stored as one matrix

OMP12 - element mass matrices stored as one matrix
OMP13 - structural system constants stored as one matrix
OMP14 - element matrices in compressed format stored as one matrix
OMP15 - prescribed displacement matrix

The input matrix positions, if nonblank must contain the following matrices:

IMP1 - structure data deck (this would be a previously generated matrix saved in OMP1)
IMP2 - interpreted input (this would be a previously generated matrix saved in OMP3 used for restart)
IMP3 - existing material library (this would be a previously generated matrix saved in OMP2)
IMP4 - displacement or stress matrix to be used for stability analyses (the stress matrix must have been generated by the structural abstraction instruction .STRESS.)

In the explanation of the .ANALIC. module and in the explanation of the agendum to use the triangular ring for asymmetric loading, the preceding general discussion of the form of the .USER04. instruction will prove valuable.

b. .ANALIC. (Analysis in Core)

(1) Introduction

.ANALIC. is a MAGIC III abstraction instruction which can be used in conjunction with the .USER04. abstraction instruction to perform a complete statics analysis using in-core routines exclusively. This module may also be used to perform selected portions of a static analysis or as a general purpose equation solver. The ANALIC module is capable of solving problems of approximately 200 reduced degrees of freedom with 18,000 words of working storage. For problems of this size, ANALIC is significantly faster than the STATICS agendum. This abstraction also features 'dynamic' storage which allows the maximum size problem to fit in core, a choice of four different equation solvers and engineering printout of output matrices.

ANALIC reduces the amount of time required for solution of the statics problem mainly by reducing the overhead involved in many MAGIC abstraction instructions. In the STATICS agendum, each abstraction instruction must be analyzed, devices must be allocated for all input and output matrices, and finally the abstractions must be executed. The execution of these instructions consists of reading input matrices from intermediate devices, computing and then writing output matrices on other intermediate devices. These output matrices will, in general, become input matrices for subsequent abstractions and hence the above process is repeated. ANALIC eliminates the amount of I/O time required above by creating and operating on intermediate matrices in core. The need to write and then re-read information in successive abstraction instructions is eliminated.

The flexibility that is lost by having one abstraction instruction instead of several is made up in part by the suppression feature of the ANALIC instruction. This suppression feature is similar to the corresponding feature in the .USER04. instruction. If an output matrix is not desired, simply leave the name blank and code only the comma to denote the position of this missing matrix. Certain input matrices and scalars may also be left blank to indicate they are not present. For example, it is possible to use ANALIC to (1) generate only element stresses, or (2) calculate element forces and reactions for a prescribed displacement problem, or (3) compute stresses for a substructure analysis.

ANALIC is also flexible in allowing the user to solve the largest possible problem based on the particular elements he is using and the amount of working storage, NWORK, available to the MAGIC III System. The User indicates the maximum number of grid points, NNOM, and the maximum number of rows in the stress matrix, NRSELM, for any element used in the analysis. The values of NNOM and NRSELM for all the elements in MAGIC III can be found in a table below. Storage is allocated dynamically based on NNOM, NRSELM and other input parameters found in the SC matrix. ANALIC determines the amount of storage required and if there is insufficient storage available, it tries to reduce the number of load conditions to make the problem fit. If the problem still does not fit with one load condition, ANALIC returns control to MAGIC III indicating insufficient storage to solve the problem.

The User has the option of selecting from four different equation solvers in ANALIC. The reader is referred to Section III of Reference 9 for a detailed theoretical discussion of each equation solver. All four of these methods are designed and coded to operate on symmetric matrices. The first technique generates displacements by computing the inverse of the symmetric stiffness matrix and then multiplying by the loads. The method of bordering is used to calculate the symmetric inverse. Cholesky triangularization is the third method presently available in ANALIC. This method is probably the most effective method of solving system of equations. The fourth method available is the Gauss Wavefront method of Reference 10. This method was designed specifically for problems arising in linearly elastic stress analyses.

Engineering printout of many intermediate results as well as final output matrices is provided by the ANALIC module. The assembled/reduced stiffness matrix and element applied load column are printed with reference to the original grid points and degrees of freedom. The total load column is also printed as well as the inverse of the stiffness matrix if it is generated. The displacements and reactions are printed corresponding to the system grid points and degrees of freedom. Element stresses and forces are printed with appropriate labels indicating the stress point and degree of freedom or the grid point.

(2) .ANALIC. With .USER04.

A complete linearly elastic stress analysis which generates displacements, stresses, forces, and reactions can be obtained by using a .USER04. instruction followed by an .ANALIC. instruction in the $INSTRUCTION section of a MAGIC data deck. It is noted that two instructions provide essentially the same output as a standard STATICS agendum. (Note Page 41 and 42, Reference 5 for a comparison.)

An example of the use of the .ANALIC. instruction in conjunction with the .USER04. instruction follows:

```
CC     CC         CC
1      7          16
$MAGIC
$INSTRUCTION      SOURCE
        ,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC,EM,=,,,.USER04.
        DISPL,STR,FORCE,REACT=TR,SC,EM,XLD,,,,,.ANALIC.(KALC,NNOM,
        NRSELM)
```

where for the .USER04. instruction

MLIB - updated material library

XLD - external load columns with element applied load scalar as first row

TR - transformation matrix from unordered to ordered system

KEL - element stiffness matrices generation control
FTEL - element applied load columns generation control
SEL - element stress matrices generation control
STEL - element thermal stress columns generation control
SC - system constants
EM - all generated element matrices stored as columns

and for the .ANALIC. instruction

DISPL - system displacements
STR - element stresses
FORCE - element forces
REACT - system reactions
KALC - equation solver calculation control (See Table I)
NNOM - maximum number of nodes in any element employed in the analysis (See Table II)
NRSELM - maximum number of rows in the stress matrix of any element employed in the analysis (See Table II)

The three scalar values associated with the .ANALIC. module are KALC, NNOM and NRSELM. These scalars may be entered or suppressed. If the scalar is suppressed, the default values defined below will apply. Commas must be entered in any case to show the position of suppressed scalars. Note that scalars 2 and 3 are used in dynamic storage allocation. Selecting values which correspond to the specific problem are better than taking the default values, since larger problems may be run than with the default values.

SCALAR 1 (KALC) - This scalar indicates the method of solving for displacements based on the following Table (Table I).

KALC	METHOD
1	SYMMETRIC INVERSE
2	GAUSS ELIMINATION
3	CHOLESKY TRIANGULARIZATION
4	GAUSS WAVEFRONT
Anything Else (Default)	CHOLESKY TRIANGULARIZATION

Table I - KALC Scalar Control for .ANALIC.

SCALAR 2 (NNOM) - This scalar indicates the maximum number of grid points used for any element in the analysis. The default value is 8. Table II displays the number of grid points associated with each element in MAGIC III.

SCALAR 3 (NRSELM) - This scalar is the maximum number of rows in the stress matrix for any element used in the analysis. The default value is 40. Table II can be used to choose the largest value of NRSELM for any element used in the analysis.

ELEMENT	IDENT. NUMBER	NNOM	NRSELM
Frame	11	3	12
Incremental Frame	13	3	12
Triangular Thin Shell	20	6	32
Quadrilateral Thin Shell	21	8	40
Quadrilateral Shear Panel	25	4	1
Triangular Plate	27	3	8
Quadrilateral Plate	28	4	12
Symmetric Shear Web	29	2	1
Toroidal Ring (Shell Cap)	30	2	15
High Aspect Ratio Quadrilateral Thin Shell	38	8	40
Triangular Cross-Section Ring	40	3	4
Trapezoidal Ring (Core)	41	4	20
Tetrahedron	50	4	6
Triangular Prism (Symmetric Triangular Prism)	51	6	6
Rectangular Prism	52	8	6

Table II - Element Classification for .ANALIC.

(3) .ANALIC. As An Equation Solver

In addition to using the .ANALIC. instruction with the .USER04. instruction, .ANALIC. can be utilized as an equation solver as follows:

The equation solvers in .ANALIC. are available to use on any system of equations with symmetric coefficient matrices.

$$\underset{(N\text{x}N)}{[A]} \quad \underset{(N\text{x}M)}{[X]} \quad = \quad \underset{(N\text{x}M)}{[B]}$$

The form of the abstraction instruction used in this context is:

```
X,,, = ,,,,,A,B,,.ANALIC.(KALC,N,M)
```

where

<u>OUTPUT MATRIX 1(X)</u> - is the solution vector of order (NxM)

<u>INPUT MATRIX 6(A)</u> - is the matrix of coefficients of order (NxN) in full form. Note that matrix A is symmetric.

<u>INPUT MATRIX 7(B)</u> - is the right hand side vector of order (NxM)

<u>SCALAR 1 (KALC)</u> - This scalar indicates the method of solution based on the following Table:

KALC	METHOD
1	SYMMETRIC INVERSE
2	GAUSS ELIMINATION
3	CHOLESKY TRIANGULARIZATION
4	GAUSS WAVEFRONT
Anything Else (Default)	CHOLESKY TRIANGULARIZATION

SCALAR 2 (N) - is the order of the system of equations.

SCALAR 3 (M) - is the number of right hand columns.

All matrices and scalars must be entered with the exception of Scalar 1 (KALC).

(4) Miscellaneous Uses of .ANALIC.

The .ANALIC. module offers considerable flexibility to a User and its generality is examined in detail in this section.

The most general format of an .ANALIC. instruction is as follows:

```
DISPL,STRESS,FORCE,REACT = TR,SC,EM,XLD,PD,SUBK,
                           SUBF,SUBL,GDIS.ANALIC.
                           (KALC,NNOM,NRSELM)
```

(a) Output Matrices

.ANALIC. will generate any combination of the four output matrices DISPL, STRESS, FORCE, REACT based on the following conventions. To generate the output matrix, enter a name in the appropriate position in the instruction. To suppress the matrix generation, do not enter a name; code only the comma which indicates the position of the matrix which is not generated; i.e., if only stresses are desired, and TR, SC, EM, and XLD are the appropriate matrices output by a prior .USER04. instruction, write:

```
,STRESS,, = TR,SC,EM,XLD,,,,,.ANALIC.(3,,)
```

The format of the output matrices generated by .ANALIC. are as shown on the following pages.

Output Matrix One (DISPL)

Contents - Displacements in unordered form

Number of Rows - Number of degrees of freedom in total system

Number of Columns - Number of load conditions

Column Records - NDIR*NDEG displacements for each system grid point

Output Matrix Two (STRESS)

Contents - Element stress matrices

Number of Rows - Sum of number of rows in each element stress matrix

Number of Columns - Number of load conditions

Column Records - Element stress matrix repeated for each element

Output Matrix Three (FORCE)

Contents - Element force matrices

Number of Rows - Sum of number of degrees of freedom in each element force matrix repeated for each element

Number of Columns - Number of load conditions

Column Records - Element force matrix repeated for each element

Output Matrix Four (REACTIONS)

Contents - Reactions

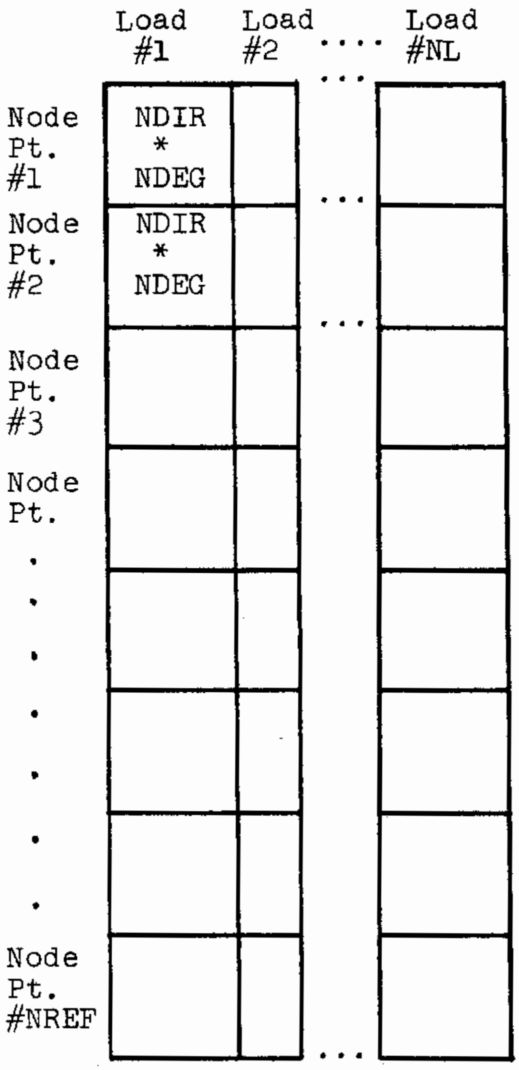
Number of Rows - Number of degrees of freedom in total system

Number of Columns - Number of load conditions

Column Records - NDIR*NDEG reactions for each system grid point

FORMAT OF OUTPUT MATRIX 1 (DISPL)

Displacements from .ANALIC. module (Unordered format)



Matrix is of the order
(NSYS x NL)

where

NSYS = NREF*NDIR*NDEG

NL - number of load conditions

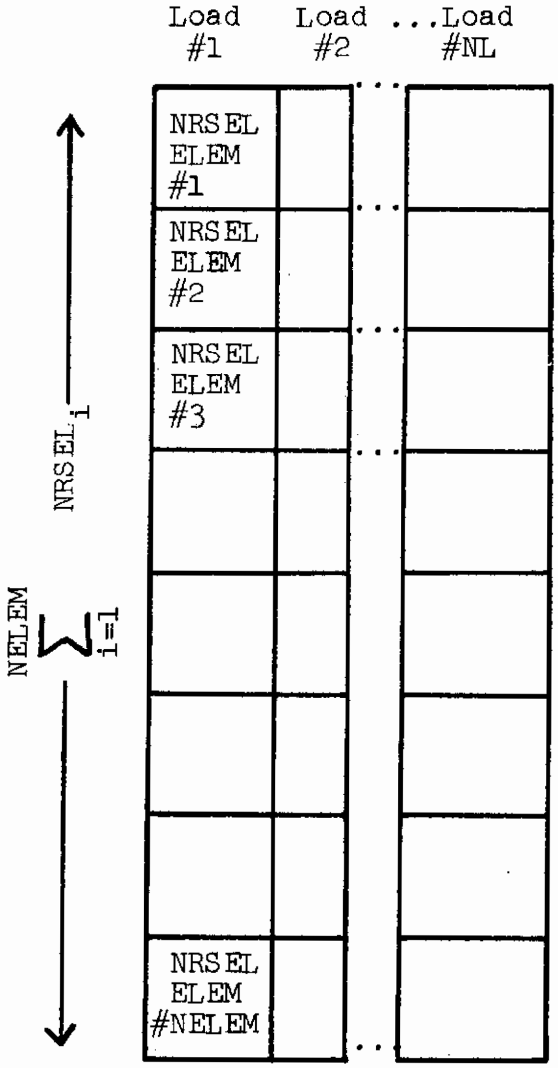
Column records are of the form

LOAD,ZERO,NSYS,(W(I),I=1,NSYS)

NREF = number of reference node points

FORMAT OF OUTPUT MATRIX 2 (STRESS)

Element Stress matrix from .ANALIC.



Matrix is of the order

(NTRSEL x NL)

where

$$NTRSEL = \sum_{i=1}^{NELEM} NRSEL_i$$

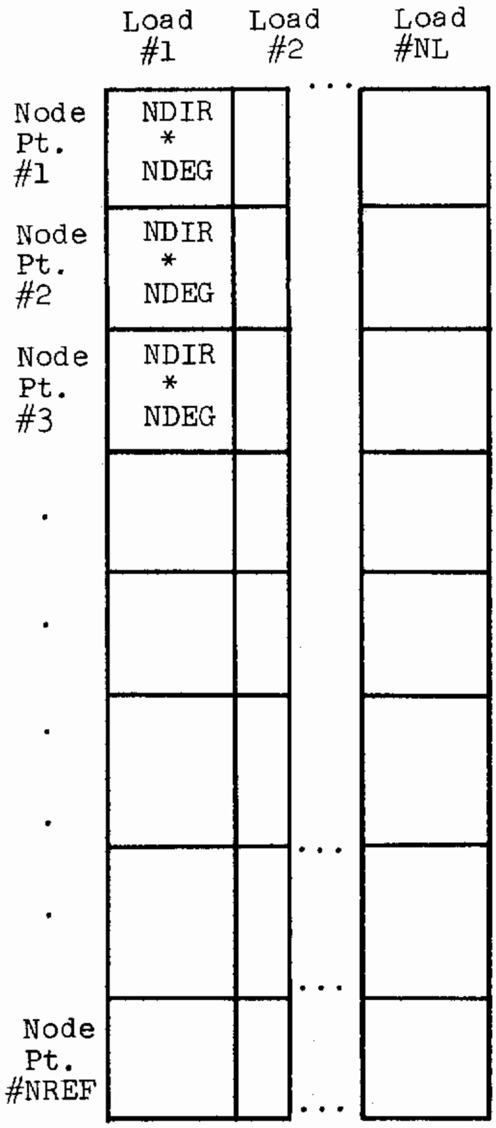
NL = number of load conditions

Column records are of the form

LOAD,ZERO,NTRSEL,(W(I),I=1,NTRSEL)

FORMAT OF OUTPUT MATRIX 4 (REACT)

REACTIONS from .ANALIC. (Unordered format)



Matrix is of the order
(NSYS x NL)
where

NSYS = NREF *NDIR*NDEG

NL - number of load conditions

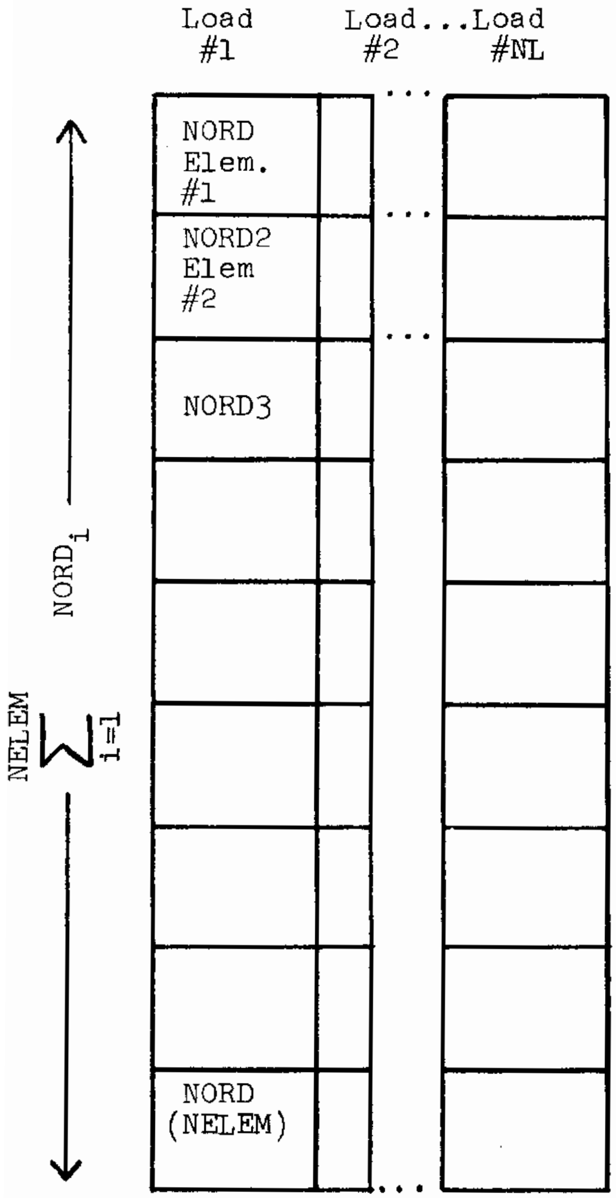
Column records are of the form

LOAD,ZERO,NSYS,(W(I),I=1,NSYS)

NREF = number of reference node points

FORMAT OF OUTPUT MATRIX 3 (FORCE)

Element Forces from .ANALIC.



Matrix is of the order (NTELEM x NL)

where

$$NTELEM = \sum_{i=1}^{NELEM} NORD_i$$

NL = number of load conditions

Column records are of the form

LOAD,ZERO,NTELEM(W(I),I=1,NTELEM)

(b) Input Matrices

There are nine possible input matrices for the .ANALIC. instruction. The first three matrices reflect the element generation information obtained from a .USERO4. instruction and are required for a complete statics analysis (Section III.C.2). If .ANALIC. is used as an equation solver only, they are not input (Section III.C.3).

Input Matrix 1 (TR) - Is a transformation matrix which orders the system into the 0-1-2 order used by the .ANALIC. instruction. This matrix is usually obtained from output matrix position six of the .USERO4. instruction.

Input Matrix 2 (SC) - Is a vector of system constants generated as output matrix 13 of the .USERO4. instruction.

Input Matrix 3 (EM) - Is a matrix containing the element matrices generated by the .USERO4. instruction. This matrix is output matrix 14 of the .USERO4. instruction.

Input Matrix 4 (XLD) (Optional) - Is a matrix containing the external loading columns generated by the .USERO4. instruction as output matrix 4. This matrix is unordered with load scalar as first row.

Input Matrix 5 (PD) (Optional) - Is a matrix containing prescribed displacements generated as output matrix 15 of a .USERO4. instruction. This matrix is unordered.

Input Matrix 6 (SUBK) (Optional) - Is a matrix which contains a stiffenss matrix in one of the following forms:

(a) If input matrix 8 is not present, SUBK is a stiffness matrix of order MxM, $M \leq N$ where N is the order of the reduced stiffness matrix generated in the .ANALIC. module. This matrix must be ordered the same way that the stiffness matrix in .ANALIC. is ordered. This matrix is added to the stiffness matrix assembled inside .ANALIC..

(b) If input matrix 8 is present, SUBK is a stiffness matrix of order $M \leq N$ where N is the maximum order of the reduced stiffness generated in the .ANALIC. module. This matrix does not have to be ordered the same way that the reduced stiffness matrix is. Input matrix 8 is the transformation matrix which will map the degrees of freedom into the assembled system degrees of freedom. SUBK can then be added to the stiffness matrix generated in .ANALIC..

Input Matrix 7 (SUBF) (Optional) - Is a matrix which contains applied loads in one of the following forms:

(a) If input matrix 8 is not present, SUBF is an applied load matrix of order (Mxl) $M \leq N$ where N is the order of the assembled/reduced applied load column. This matrix must be ordered the same way as the assembled/reduced applied load column in .ANALIC..

(b) If input matrix 8 is present, SUBF is an applied load column of order $M \leq N$ where N is the order of the applied load column used in .ANALIC.. This matrix may be unordered as long as input matrix 8 is present to order this matrix the same way as the assembled applied load column in .ANALIC.. SUBF can then be added correctly to the applied load column inside .ANALIC..

Input Matrix 8 (SUBL) (Optional) - Is a matrix which maps input matrices six and/or seven into the assembled system used inside .ANALIC.. This matrix is of order Mxl where M is the order of input matrices seven and eight.

Input Matrix 9 (GDIS) (Optional) - Is a matrix which is reserved for future system use. It has no meaning presently for .ANALIC.. See Reference 8, Programmer's Manual for the procedure required to add a new equation solver to the .ANALIC. module.

KALC, NNOM and NRSELM were explained in detail in Section III.C.2.

c. Additional Abstraction Instructions Available in MAGIC III to Perform Structural Analyses

(1) Introduction

In the MAGIC II System for Structural Analysis, the procedure for performance of the following types of analyses was described in detail on Pages 39 thru 92 of Reference 5, the companion volume to the subject document.

1. Statics
2. Statics With Condensation
3. Statics With Prescribed Displacements
4. Stability
5. Dynamics (Modes and Frequencies)
6. Dynamics With Condensation

In the subject document, the procedure to perform a linearly elastic stress analysis using the triangular ring which accommodates asymmetric load will be discussed and explained in detail. In addition, additional Agendums for conventional linear elastic static analysis, statics analysis with condensation, static analysis with prescribed displacements, elastic instability analysis, dynamic analysis (with and without condensation) and free-free dynamic analysis (with and without condensation) are listed.

The analyses listed above may be performed in two different ways. In the first the User can elect to place the proper set of abstraction instructions in front of his structural input data deck for any given analyses. The second option, utilizes the Agendum Level abstraction capability which has been incorporated into the MAGIC II and MAGIC III Systems. Using this option, the abstraction instructions for the type of analyses desired are automatically generated by the System when the User specifies the corresponding option on the $INSTRUCTION Card. This Agendum level capability will be discussed in detail after the presentation and explanation of the newly available abstraction instructions.

(2) Statics Instruction Sequence Using Triangular Ring With Asymmetric Loading (STATICS ASYM)

Figure II-2 presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis using the triangular cross-section ring which accommodates asymmetric loading. This finite element and instruction for its proper use will be explained in detail in the following section. In addition, a sample problem showing the type of input required and the output obtained for this element is presented in Section III.

Before explaining Figure II-2, two key abstraction instructions used in this Agendum are defined.

.HDECO. - Extracts the harmonic dependent element stiffenss matrix and updates the harmonic loop control matrix

Instructions are of the form:

```
HLC,HM1 = CF,EM,SC.HDECO.
```

There are two output matrices and three input matrices for this instruction.

Output matrix HLC - is the harmonic loop control matrix

Output matrix HM1 - is the harmonic dependent element stiffness matrix

Input matrix CF - is the input harmonic loop matrix to be updated by this instruction. This matrix is used to form the output matrix HLC

Input matrix EM - is generated by the .USER04. instruction and contains all the element stiffness matrices for all desired harmonics

Input matrix SC - is generated by the .USER04. instruction and is a matrix of system constants which contains such items as the total number of elements and the harmonic number

<u>.HSUM.</u> - Computes the sums of harmonic stress, the sum of harmonic displacements and the sum of reactions.

Instructions are of the form:

SUMS,SUMD,SUMR = SC,INPS,INPD,INPR.HSUM.

There are three output matrices and four input matrices for this instruction.

Output matrix SUMS - is the harmonic sum stress matrix

Output matrix SUMD - is the harmonic sum displacement matrix

Output matrix SUMR - is the harmonic sum reaction matrix

```
      $STATICSASYM
C     ASSYMMETRIC CROSS SECTION RING ELEMENT AGENDUM
C---- GENERATE MASTER STIFFNESS MATRIX
      ,MAT,,,TR,,KEL,FTEL,SEL,STEL,,,SC,EM, = ,,, .USER04.
C---- NEXT THREE INSTRUCTIONS GENERATE HARMONIC LOOP CONTROL CF MATRIX
      CA,CB = SC .DEJOIN. (4,1)
      CC,CD = CA .DEJOIN. (3,1)
      CE, HLC /1/ = CD  .DEJOIN. (1,0)
      TR1,TR12 = TR .DEJOIN. (SC(5,1),1)
      REPEAT ( 13,8)
      HLC /2/, EM1 /2/  = HLC /1/, EM, SC  .HDECO.
      SA1 /1/  = EM1 /2/  .ASSEM. SC, (10)
      LA1 /1/  = EM1 /2/  .ASSEM. SC, (4)
      RE1 /1/, RE2 /1/ = SA1 /1/ .DEJOIN. (SC(5,1),1)
      LE1 /1/, LE2 /1/ = RE2 /1/ .DEJOIN. (SC(5,1),0)
      B1 /1/, X1 /1/ = LE2 /1/  .CHTRIA. LA1 /1/
      XX1 /1/  = TR12 .TMULT. X1 /1/
      X01 /1/  = TR .MULT. XX1 /1/
      ST1 /1/  = EM1 /2/, X01 /1/ .STRESS. (4,)
      ATT1 /1/ = SA1 /1/ .MULT. X01 /1/
      LB1 /1/  = EM1 /2/ .ASSEM. SC, (40)
      ACT1 /1/  = ATT1 /1/  .SUBT. LB1 /1/
      IF ( HLC /2/ .NULL. ) GO TO 200
  200 IF ( HLC /2/ .NULL. ) GO TO 2000
      IF ( HLC /3/ .NULL. ) GO TO 3000
 2000 SUM1, SUMD1, SUMR1 = SC, ST1 /1/, XX1 /1/, ACT1 /1/ .HSUM.
      IF ( HLC /2/ .NULL.) GO TO 1000
 3000 ST12  = ST1 /1/  .ADJOIN. ST1 /2/
      X012  = XX1 /1/  .ADJOIN. XX1 /2/
      ACT12 = ACT1 /1/  .ADJOIN. ACT1 /2/
      IF ( HLC /3/ .NULL. ) GO TO 1020
      ST313 = ST12 .ADJOIN. ST1 /3/
      X0313 = X012 .ADJOIN. XX1 / 3/
      ACT313 = ACT12  .ADJOIN. ACT1 /3/
      IF ( HLC /4/ .NULL. ) GO TO 1030
      ST414 = ST313 .ADJOIN. ST1 /4/
      X0414 = X0313 .ADJOIN. XX1 /4/
      ACT414 = ACT313 .ADJOIN. ACT1 /4/
      IF ( HLC /5/ .NULL. ) GO TO 1040
      ST515  =  ST414  .ADJOIN. ST1 /5/
      X0515  =  X0414  .ADJOIN. XX1 /5/
      ACT515 = ACT414 .ADJOIN. ACT1 /5/
      IF ( HLC /6/ .NULL. )  GO TO 1050
      ST616 = ST515 .ADJOIN. ST1 /6/
      X0616 = X0515 .ADJOIN. XX1 /6/
      ACT616 = ACT515 .ADJOIN. ACT1 /6/
      IF ( HLC /7/ .NULL. )  GO TO 1060
      ST717  = ST616  .ADJOIN. ST1 /7/
      X0717  = X0616  .ADJOIN. XX1 /7/
      ACT717 = ACT616 .ADJOIN. ACT1 /7/
      IF ( HLC /8/ .NULL. )  GO TO 1070
```

Figure II-2 STATICS Agendum for Triangular Ring with Asymmetric Loading

```
     ST818   = ST717   .ADJOIN. ST1 /8/                                          00100510
     X0818   = X0717   .ADJOIN. XX1 /8/                                          00100520
     ACT818 = ACT717 .ADJOIN. ACT1 /8/                                           00100530
     IF ( HLC /9/ .NULL. )   GO TO 1080                                          00100540
1020 SUMS12, SUMD12, SUMR12 = SC, ST12 , X012 , ACT12    .HSUM.                  00100550
     IF ( HLC /3/ .NULL. ) GO TO 1000                                            00100560
1030 SUMS13, SUMD13, SUMR31 = SC, ST313, X0313, ACT313  .HSUM.                   00100570
     IF ( HLC /4/ .NULL. ) GO TO 1000                                            00100580
1040 SUMS14, SUMD14, SUMR41 = SC, ST414, X0414, ACT414  .HSUM.                   00100590
     IF ( HLC /5/ .NULL. ) GO TO 1000                                            00100600


1050 SUMS15, SUMD15, SUMR51 = SC, ST515, X0515, ACT515  .HSUM.                   00100610
     IF ( HLC /6/ .NULL. ) GO TO 1000                                            00100620
1060 SUMS16, SUMD16, SUMR61 = SC, ST616, X0616, ACT616  .HSUM.                   00100630
     IF ( HLC /7/ .NULL. ) GO TO 1000                                            00100640
1070 SUMS17, SUMD17, SUMR71 = SC, ST717, X0717, ACT717  .HSUM.                   00100650
     IF ( HLC /8/ .NULL. ) GO TO 1000                                            00100660
1080 SUMS18, SUMD18, SUMR81 = SC, ST818, X0818, ACT818  .HSUM.                   00100670
1000 CAA = CA .RENAME.                                                           00100680
```

Figure II-2 (Concluded)

Input matrix SC - is a matrix of system constants generated by the .USER04. instruction.

Input matrix INPS - is the input stress matrix to be summed. This matrix contains element stresses for each element and for each harmonic.

Input matrix INPD - is the input displacement matrix to be summed. This matrix contains displacements for each harmonic.

Input matrix INPR - is the input reaction matrix to be summed. This matrix contains reactions for each harmonic.

Table III is provided to give explicit definition to the STATICS Agendum for the Triangular Ring with Asymmetric Load illustrated in Figure II-2. Engineering definition for each abstraction instruction which is executed by the System is set forth in detail.

TABLE III

STATICS INSTRUCTION SEQUENCE - TRIANGULAR RING (ASSYMETRIC LOADING)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
1	,MAT,,,TR,,KEL,FTEL,SEL,STEL,,,SC,EM=,,,.USERO4. Generates harmonic numbers, harmonic coefficients, and element matrices for each harmonic number. The controls KEL, FTEL, SEL, STEL must be present to cause these matrices to be generated in EM. MAT is an optional material library maintained by the user. TR and SC matrices are transformation and system control matrices respectively. Statement numbers ②, ③, and ④ generate the harmonic loop control CF for
5	CA,CB = SC.DEJOIN. (4,1)
6	CC,CD = CA.DEJOIN. (3,1)
7	CE,HLC/1/ = CD.DEJOIN. (1,0) These statements are needed to generate the harmonic loop control matrix HLC/1/ which has the dimension of 1 x 1. The control number in this matrix should be greater than zero and less than 12.
8	TR1,TR12 = TR.DEJOIN.(SC(5,1),1) $\left[\begin{array}{c} TR1 \\ \hline TR12 \end{array}\right] = [TR]$ Forms matrix TR12 which when transposed will regenerate the reduced displacement into the non-reduced displacement.
9	Repeat (13, 8) Generate the following 13 statements 8 times. The index of each matrix will be increased by one for each REPEAT.
10	HLC/2/,EM1/2/=HLC/1/,EM,SC.HDECO. Updates the harmonic loop control matrix HLC/1/ by decreasing its control value by one. If the control value is equal to zero, then a null matrix will be output as HLC, otherwise a matrix HLC with the dimension of 1 x 1 will be output. Extract the element stiffness matrix EM1 from the total set stiffness EM. The extraction is dependent on the harmonic loop control value.

TABLE III (Continued)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
11	SA1/1/ = EM1/2/.ASSEM.SC,(10) Generates the assembled stiffness matrix SA1/1/ in form of 0-1 ordered system for harmonic number one. SC contains system constants which are required by the .ASSEM. modules
12	LA1/1/ = EM1/2/.ASSEM.SC,(4) Generates the assembled element applied load column in the 0-1 ordered system from the harmonic one element stiffness matrix EM1. SC contains system constraints which are required by the .ASSEM. modules.
13	RE1/1/,RE2/1/ = SA1/1/.DEJOIN. (SC(5,1),1) $\begin{bmatrix} RE1 \\ RE2 \end{bmatrix} = \begin{bmatrix} SA1 \end{bmatrix}$ The NMDB rows of SA1 which correspond to the 1's are forwarded in the RE2 matrix.
14	LE1/1/,LE2/1/ = RE2/1/.DEJOIN. (SC(5,1),0) $\begin{bmatrix} LE1/1/, & LE2/1/ \end{bmatrix} = \begin{bmatrix} RE2/1/ \end{bmatrix}$ The (NMDB x NMDB) reduced harmonic one element stiffness matrix LE2 is forwarded.
15	BI/1/,X1/1/ = LE2/1/.CHTRIA.LA1/1/ Solves for the harmonic one displacements in the reduced system X1 by using Cholesky method to solve the system of simultaneous equation.
16	XX1/1/ = TR12.TMULT.X1/1/ $XX1/1/ = \begin{bmatrix} TR12 \end{bmatrix}^T \begin{bmatrix} X1/1/ \end{bmatrix}$ Forms unordered system of displacements.
17	X01/1/ = TR.MULT.XX1/1/ $\begin{bmatrix} X01/1/ \end{bmatrix} = \begin{bmatrix} TR \end{bmatrix} \begin{bmatrix} XX1/1/ \end{bmatrix}$ Forms 0-1 ordered displacement columns in X01,
18	ST1/1/ = EM1/2/,X01/1/.STRESS. (4.) Calculates net element stresses for each element.
19	ATT1/1/ = SA1/1/.MULT.X01/1/ $ATT1/1/ = \begin{bmatrix} SA1/1/ \end{bmatrix} \begin{bmatrix} X01/1/ \end{bmatrix}$ To form system displacement vector ATT1 by multiplying the 0-1 ordered displacement vector with the 0-1 ordered stiffness matrix SA1.

TABLE III (Continued)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
20	LB1/1/ = EM1/2/.ASSEM.SC,(40) Generates the system applied load vector LB1/1/ from the element stiffness matrix EM1 and the system matrix SC.
21	ACT1/1/ = ATT1/1/.SUBT.LB1/1/ ACT1/1/ = [ATT1/1/] - [LB1/1/] Generates the reaction vector ACT1 by substracting the system applied load vector from the system displacement.
22	If (HLC/2/.NULL.) go to 200. Test the harmonic control matrix HLC/2/ for number of harmonic loops.
23	200 If (HLC/2/.NULL.) go to 2000 If the harmonic number is equal to one, then go to statement 25.
24	If (HLC/3/.NULL.) go to 3000 If the harmonic number is greater than one, then go to statement 25.
25	2000 SUM1,SUMD1,SUMR1 = SC,ST1/1/,XO1/1/,ACT1/1/.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to one.
26	If (HLC/2/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
27	3000 ST12 = ST1/1/.ADJOIN.ST1/2/ Adjoin the element stress ST1/1/ matrix for harmonic one with the element stress ST1/1/ matrix for harmonic two.
28	XO12 = XX1/1/.ADJOIN.XX1/2/ Adjoin the system displacement XX1/1/ for harmonic one with the system displacement XX1/1/ matrix for harmonic two.
29	ACT12 = ACT1/1/.ADJOIN.ACT1/2/ Adjoin the system reaction ACT1/1/ matrix with the system reaction ACT1/1/ matrix for harmonic two.

TABLE III (Continued)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
30	If (HLC/3/.NULL.) go to 1020. Test the harmonic control value in the harmonic control matrix HLC/3/ for the element stress matrices, the system displacement matrices and the system reaction to be adjoined.
31-34	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three and test the harmonic value in harmonic control matrix HLC/4/.
35-38	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four and test the harmonic value in harmonic control matrix HLC/5/.
39-42	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five and test the harmonic value in harmonic control matrix HLC/6/.
43-46	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six and test the harmonic value in harmonic control matrix HLC/7/.
47-50	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six, seven and test the harmonic value in harmonic control matrix HLC/8/.
51-54	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six, seven, eight and test the harmonic value in harmonic control matrix HLC/9/.
55	1020 SUMS12,SUMD12,SUMR12=SC,ST12,XO12,ACT12.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to two.

TABLE III (Continued)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
56	If (HLC/3/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
57	1030 SUMS13,SUMD13,SUMR31=SC,ST313,X0313,ACT313.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to three.
58	If (HLC/4/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
59	1040 SUMS14,SUMD14,SUMR41=SC,ST414,X0414,ACT414.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to four.
60	If (HLC/5/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
61	1050 SUMS15,SUMD15,SUMR51=SC,ST515,X0515,ACT515.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to five.
62	If (HLC/6/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
63	1060 SUMS16,SUMD16,SUMR61=SC,ST616,X0616,ACT616.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to six.
64	If (HLC/7/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
65	1070 SUMS17,SUMD17,SUMR71=SC,ST717,X0717,ACT717.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to seven.

TABLE III (Concluded)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
66	If (HLC/8/.NULL.) go to 1000 Branch to statement 1000 to terminate the analysis.
67	1080 SUMS18,SUMD18,SUMR81=SC,ST818,X0818,ACT818.HSUM. Compute the sum of element stress, the sum of displacements and the sum reactions, and output the sum of element stresses, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to eight.
68	CAA = CA.RENAME. This instruction terminates the analysis.

(3) Alternate Statics Instruction Sequence Using Triangular Ring with Asymmetric Loading

Figure II-3 presents an alternate set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis using the triangular cross-section ring which accommodates asymmetric loading. It is noted that the suggested set of instructions presented in Figure II-2 made frequent use of the REPEAT option available to MAGIC III. (Note Statement 9) This REPEAT option was explained in detail on pp. 9 thru 12 of this report.

The instructions presented in Figure II-3 do not make use of the REPEAT option. Consequently, sets of instructions are written separately for each harmonic considered in the analysis. It is noted from Figure II-3 that thirteen statements are required for each harmonic which is considered. (Statements 28 thru 41 for Harmonic Number 2 for instance.) With this in mind, it is suggested that the standard set of instructions from Figure II-2 be utilized for most problems. However, the User has the option (if he prefers) of using the instructions as outlined in Figure II-3 which are given explicit engineering definition in Table IV.

```
C     ASSYMMETRIC CROSS SECTION RING ELEMENT
C---- GENERATE MASTER STIFFNESS MATRIX
      ,MAT,,,TR,,KEL,FTEL,SEL,STEL,,,SC,EM, = ,,, .USER04.
C---- NEXT THREE INSTRUCTIONS GENERATE HARMONIC LOOP CONTROL CF MATRIX
      CA,CB = SC .DEJOIN. (4,1)
      CC,CD = CA .DEJOIN. (3,1)
      CE,CF = CD .DEJOIN. (1,0)
C---- EXTRACT STIFFNESS MATRIX FROM MASTER STIFFNESS MATRIX
C---- DECREASED LOOP CONTROL MATRIX BY ONE
      HLC, EM1 = CF, EM, SC .HDECO.
C---- ASSEMBLE STIFF MATRIX FOR HARMONIC ONE
      SA1 = EM1  .ASSEM. SC, (10)
C---- GENERATE SYSTEM APPLIED LOAD FOR HARMONIC ONE
      LA1 = EM1 .ASSEM. SC, (4)
      RE1,RE2 = SA1 .DEJOIN. (SC(5,1),1)
      LE1,LE2 = RE2 .DEJOIN. (SC(5,1),0)
      B1, X1 = LE2 .CHTRIA. LA1
      TR1,TR12 = TR .DEJOIN. (SC(5,1),1)
      XX1 = TR12 .TMULT. X1
      XO1 = TR .MULT. XX1
      ST1 = EM1, XO1 .STRESS. (4,)
      ATT1 = SA1 .MULT. XO1
      LB1 = EM1 .ASSEM. SC , (40)
      ACT1 = ATT1 .SUBT. LB1
C---- TEST HARMONIC LOOP CONTROL MATRIX
      IF ( HLC .NULL.) GO TO 100
C---- IF MORE THAN ONE HARMONIC FOLLOWING THIS PATH
      HLC1, EM2  = HLC , EM, SC .HDECO.
      SA2 = EM2 .ASSEM. SC, (10)
      LA2 = EM2 .ASSEM. SC, (4)
      RE3,RE4 = SA2 .DEJOIN. (SC(5,1),1)
      LE3,LE4 = RE4 .DEJOIN. (SC(5,1),0)
      B2, X2 = LE4 .CHTRIA. LA2
      XX2 = TR12 .TMULT. X2
      XO2 = TR .MULT. XX2
      ST2 = EM2,XO2 .STRESS. (4,)
      ATT2 = SA2 .MULT. XO2
      LB2 = EM2 .ASSEM. SC , (40)
      ACT2 = ATT2 .SUBT. LB2
C---- TEST HARMONIC LOOP CONTROL MATRIX
      IF ( HLC1 .NULL. ) GO TO 200
C---- IF MORE THAN 3 HARMONIC FOLLOWING THIS PATH
      HLC2, EM3  = HLC1, EM, SC .HDECO.
      SA3 = EM3 .ASSEM. SC, (10)
      LA3 = EM3 .ASSEM. SC, (4)
      RE5,RE6 = SA3 .DEJOIN. (SC(5,1),1)
      LE5,LE6 = RE6 .DEJOIN. (SC(5,1),0)
      B3, X3 = LE6 .CHTRIA. LA3
      XX3 = TR12 .TMULT. X3
      XO3 = TR .MULT. XX3
      ST3 = EM3,XO3 .STRESS. (4,)
      ATT3 = SA3 .MULT. XO3
      LB3 = EM3 .ASSEM. SC , (40)
      ACT3 = ATT3 .SUBT. LB3
      IF ( HLC2 .NULL. )  GO TO 200
      HLC3, EM4  = HLC2, EM, SC .HDECO.
      SA4 = EM4 .ASSEM. SC, (10)
      LA4 = EM4 .ASSEM. SC, (4)
      RE7,RE8 = SA4 .DEJOIN. (SC(5,1),1)
      LE7,LE8 = RE8 .DEJOIN. (SC(5,1),0)
```

Figure II-3 Alternate STATICS Agendum for Triangular Ring

```
B4, X4 = LE8 .CHTRIA. LA4
XX4 = TR12 .TMULT. X4
XO4 = TR .MULT. XX4
ST4 = EM4,XO4 .STRESS. (4,)
ATT4 = SA4 .MULT. XO4
LB4 = EM4 .ASSEM. SC , (40)
ACT4 = ATT4 .SUBT. LB4
IF ( HLC3 .NULL. )  GO TO 200
HLC4, EM5  = HLC3, EM, SC .HDECO.
SA5 = EM5 .ASSEM. SC, (10)
LA5 = EM5 .ASSEM. SC, (4)
RE9,RE10= SA5 .DEJOIN. (SC(5,1),1)
LE9,LE10= RE8 .DEJOIN. (SC(5,1),0)
B5, X5 = LE10.CHTRIA. LA5
XX5 = TR12 .TMULT. X5
XO5 = TR .MULT. XX5
ST5 = EM5,XO5 .STRESS. (4,)
ATT5 = SA5 .MULT. XO5
LB5 = EM5 .ASSEM. SC , (40)
ACT5 = ATT5 .SUBT. LB5
IF ( HLC4 .NULL. )  GO TO 200
HLC5, EM6 = HLC4, EM, SC .HDECO.
SA6 = EM6 .ASSEM. SC,(10)
LA6 = EM6 .ASSEM. SC, (4)
RE11,RE12 = SA6 .DEJOIN. (SC(5,1),1)
LE11,LE12 = RE12 . DEJOIN. (SC(5,1),0)
B6, X6 =  LE12 .CHTRIA. LA6
XX6 = TR12 .TMULT. X6
XO6 = TR .MULT. XX6
ST6 = EM6, XO6 .STRESS. (4,)
ATT6  = SA6 .MULT. XO6
LB6 = EM6 .ASSEM. SC, (40)
ACT6  = ATT6 .SUBT. LB6
IF ( HLC5 .NULL. ) GO TO 200
HLC6, EM7 = HLC5, EM, SC .HDECO.
SA7 = EM7 .ASSEM. SC,(10)
LA7 = EM7 .ASSEM. SC, (4)
RE13,RE14 = SA7 .DEJOIN. (SC(5,1),1)
LE13,LE14 = RE14 . DEJOIN. (SC(5,1),0)
B7, X7 =  LE14 .CHTRIA. LA7
XX7 = TR12 .TMULT. X7
XO7 = TR .MULT. XX7
ST7 = EM7, XO7 .STRESS. (4,)
ATT7  = SA7 .MULT. XO7
LB7 = EM7 .ASSEM. SC, (40)
ACT7  = ATT7 .SUBT. LB7
IF ( HLC6 .NULL. ) GO TO 200
HLC7, EM8 = HLC6, EM, SC .HDECO.
SA8 = EM8 .ASSEM. SC,(10)
LA8 = EM8 .ASSEM. SC, (4)
RE15,RE16 = SA8 .DEJOIN. (SC(5,1),1)
LE15,LE16 = RE16 . DEJOIN. (SC(5,1),0)
B8, X8 =  LE16 .CHTRIA. LA8
XX8 = TR12 .TMULT. X8
XO8 = TR .MULT. XX8
ST8 = EM8, XO8 .STRESS. (4,)
ATT8  = SA8 .MULT. XO8
LB8 = EM8 .ASSEM. SC, (40)
ACT8  = ATT8 .SUBT. LB8
IF ( HLC7 .NULL. ) GO TO 200
```

Figure II-3 (Continued)

```
 200  ST12 = ST1 .ADJOIN. ST2
     XO12 = XX1 .ADJOIN. XX2
     ACT12 = ACT1 .ADJOIN. ACT2
     IF ( HLC1 .NULL. )GO TO 1020
     ST313 = ST12 .ADJOIN. ST3
     XO313 = XO12 .ADJOIN. XX3
     ACT313 = ACT12 .ADJOIN. ACT3
     IF ( HLC2 .NULL. )GO TO 1030
     ST414 = ST313.ADJOIN. ST4
     XO414 = XO313.ADJOIN. XX4
     ACT414 = ACT313 .ADJOIN. ACT4
     IF ( HLC3 .NULL. )GO TO 1040
     ST515 = ST414.ADJOIN. ST5
     XO515 = XO414.ADJOIN. XX5
     ACT515 = ACT414 .ADJOIN. ACT5
     IF ( HLC4 .NULL. )GO TO 1050
     ST616   = ST515 .ADJOIN. ST6
     XO616 = XO515 .ADJOIN. XX6
     ACT616 = ACT515 .ADJOIN. ACT6
     IF ( HLC5 .NULL. ) GO TO 1060
     ST717   = ST616 .ADJOIN. ST7
     XO717 = XO616 .ADJOIN. XX7
     ACT717 = ACT616 .ADJOIN. ACT7
     IF ( HLC6 .NULL. ) GO TO 1070
     ST818   = ST717 .ADJOIN. ST8
     XO818 = XO717 .ADJOIN. XX8
     ACT818 = ACT717 .ADJOIN. ACT8
     IF ( HLC7 .NULL. ) GO TO 1080
1020 SUMS12, SUMD12, SUMR12 = SC, ST12 , XO12 , ACT12   .HSUM.
     IF ( HLC1 .NULL. ) GO TO 1000
1030 SUMS13, SUMD13, SUMR31 = SC, ST313, XO313, ACT313  .HSUM.
     IF ( HLC2 .NULL. ) GO TO 1000
1040 SUMS14, SUMD14, SUMR41 = SC, ST414, XO414, ACT414  .HSUM.
     IF ( HLC3 .NULL. ) GO TO 1000
1050 SUMS15, SUMD15, SUMR51 = SC, ST515, XO515, ACT515  .HSUM.
     IF ( HLC4 .NULL. ) GO TO 1000
1060 SUMS16, SUMD16, SUMR61 = SC, ST616, XO616, ACT616  .HSUM.
     IF ( HLC5 .NULL. ) GO TO 1000
1070 SUMS76, SUMD17, SUMR71 = SC, ST717, XO717, ACT717  .HSUM.
     IF ( HLC6 .NULL. ) GO TO 1000
1080 SUMS86, SUMD18, SUMR81 = SC, ST818, XO818, ACT818  .HSUM.
     IF ( HLC7 .NULL. ) GO TO 1000
 100 SUM1,SUMD1,SUMR1 = SC, ST1, XX1, ACT1  .HSUM.
1000 CAA = CA .RENAME.
```

Figure II-3 (Concluded)

TABLE IV
ALTERNATE STATICS INSTRUCTION SEQUENCE
TRIANGULAR RING - ASYMMETRIC LOADING

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
3	,MAT,,,TR,,KEL,FTEL,SEL,STEL,,,SC,EM ....[illegible]. Generates harmonic numbers, harmonic coefficients, and element matrices for each harmonic number. The controls KEL, FTEL, SEL, STEL must be present to cause these matrices to be generated in EM. MAT is an optional material library maintained by the user. TR and SC matrices are transformation and system control matrices respectively. Statement numbers ②, ③, and ④ generate the harmonic loop control CF for
5	CA,CB=SC.DEJOIN. (4,1)
6	CC,CD=CA.DEJOIN. (3,1)
7	CE,CF=CD.DEJOIN. (1,0) These statement numbers generate the harmonic loop control CF which has the dimension of 1 x 1. The control number in this matrix should be greater than zero and less than seven.
10	HLC,EM1=CF,EM,SC.HDECO Updates the harmonic loop control matrix CF by decreasing its control value by one. If the control value is equal to zero, then a null matrix will be output as HLC; othersiwe a matrix HLC with the dimension of 1 x 1 will be output. Extract the element stiffness matrix EM1 from the total set stiffness EM. The extraction is dependent on the harmonic loop control value.
12	SA1=EM1.ASSEM.SC, (10) Generate the assembled stiffness matrix SA1 in form of 0-1 ordered system for harmonic number one. SC contains system constraints which are required by the .ASSEM. modules.
14	LA1= EM1.ASSEM.SC, (4) Generates the assembled element applied load column in the 0-1 ordered system from the harmonic one element stiffness matrix EM1. SC contains system constants which are required by the .ASSEM. modules.

TABLE IV - (CONTINUED)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
15	RE1,RE2=SA1.DEJOIN. (SC(5,1),1) $\begin{bmatrix} RE1 \\ RE2 \end{bmatrix} = [SA1]$ The NMDB rows of SA1 which correspond to the 1's are forwarded in the RE2 matrix.
16	LE1,LE2=RE2.DEJOIN. (SC(5,1),0) $[LE1, LE2] = [RE2]$ The (NMDB x NMDB)reduced harmonic one element stiffness matrix LE2 is formed.
17	BL,X1=LE2.CHTRIA.LA1 Solves for the harmonic one displacements in the reduced system X1 by using Cholesky method to solve the system of simultaneous equations.
18	TR1,TR12=TR.DEJOIN. (SC(5,1),1) $\begin{bmatrix} TR1 \\ TR12 \end{bmatrix} = [TR]$ Forms matrix TR12 which when transposed will regenerate the reduced displacement X1 into the non-reduced displacement XX1.
19	XX1 = TR12.TMULT.X1 $XX1 = [TR12]^T [XX]$ Forms unordered system of displacements.
20	XO1 = TR.MULT.XX1 $[XO1] = [TR] [XX1]$ Forms 0-1 ordered displacement columns in XO1.
21	ST1 = EM1, XO1.STRESS. (4,) Calculates net element stresses for each element
22	ATT1 = SA1.MULT.XO1 $ATT1 = [SAI] [XO1]$ Forms system displacement vector ATT1 by multiplying the 0-1 ordered displacement vector with the 0-1 ordered stiffness matrix SA1.

TABLE IV - (CONTINUED)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
23	LB1 = EM1.ASSEM.SC,(40) Generates the system applied load vector LB1 from the element stiffness matrix EM1 and the system matrix SC.
24	ACT1 = ATT1.SUBT.LB1 ACT1 = [ATT1] - [LB1] Generates the reaction vector ACT1 by subtracting the system applied load vector from the system displacement.
26	If (HLC.NULL.) go to 100. Test the harmonic control matrix HLC for number of harmonic loops.
28-41	Statements 28 thru 41 are used for computation of the second harmonic, when the harmonic control value is dependent on the harmonic control matrix HLC. The explanations for the Statements 28 thru 41 are the same as Statements 10 thru 26.
43-55	Statements 43 thru 55 are used for computation of the third harmonic dependent on the harmonic control matrix HLC1. The explanations for the Statements 43 thru 55 are the same as Statements 10 thru 26.
56-68	Statements 56 thru 68 are used for computation of the fourth harmonic dependent on the harmonic control matrix HLC2. The explanations for the Statements 56 thru 68 are the same as Statements 10 thru 26.
69-81	Statements 69 thru 81 are used for computation of the harmonic 5 when the harmonic control value in the harmonic control matrix HLC3 is greater than zero. The explanations for Statements 69 thru 81 are the same as Statements 10 thru 26.
82-94	Statements 82 thru 94 are used for computation of harmonic 6 when the harmonic control value in the harmonic control matrix HLC4 is greater than zero. The explanations for the Statements 82 thru 94 are the same as the Statements 10 thru 26.
95-107	Statements 95 thru 107 are used for computation of harmonic 7 when the harmonic control value in the harmonic control matrix HLC5 is greater than zero. The explanations for Statements 95 thru 107 are the same as for Statements 10 thru 26.

TABLE IV (CONTINUED)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
108-120	Statements 108 thru 120 are used for computation of harmonic 8 when the harmonic control value in the harmonic control matrix HLC6 is greater than zero. The explanations for Statements 108 thru 120 are the same as for Statements 10 thru 26.
121	200 ST12 = ST1.ADJOIN.ST2 Adjoin the element stress ST1 matrix for harmonic one with the element stress ST2 matrix in harmonic two.
122	XO12 = XX1.ADJOIN.XX2 Adjoin the system displacement XX1 for harmonic one with the system displacement XX2 matrix for harmonic two.
123	ACT12 = ACT1.ADJOIN.ACT2 Adjoin the system reaction ACT1 matrix with the system reaction ACT2 matrix for harmonic two.
124	If (HLC1.NULL.) to go 1020. Test the harmonic control value in the harmonic control matrix HLC1 for the element stress matrix, the system displacement matrices and the system reaction matrix to be adjointed.
125-128	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three and test the harmonic value in harmonic control matrix HLC2.
129-132	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for one, two, three, four and test the harmonic value in harmonic control matrix HLC3.
133-136	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five and test the harmonic value in harmonic control Matrix HLC4.
137-140	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six and test the harmonic value in harmonic control matrix HLC5.

TABLE IV -(CONTINUED)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
141-144	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six, seven and test the harmonic value in harmonic control matrix HLC6.
145-148	Adjoin the element stress matrices, system displacement matrices, system reaction matrices for harmonic one, two, three, four, five, six, seven, eight and test the harmonic value in harmonic control matrix HLC7.
149	1020 SUMS12,SUMD12,SUMR12=SC,ST12,X12,ACT12.HSUM. Compute the sum of element stress, the sum of displacements and the sum of reactions and output the sum of element stress, the sum of displacements and sum of reactions. This statement is used when the harmonic number is equal to two.
150	If (HLC1.NULL.) go to 1000 Branch to statement 164 to terminate the analysis.
151-152	These statements are used when the harmonic number is equal to three. For explanation of these statements, see Statements 149 and 150.
153-154	These statements are used when the harmonic number is equal to four. For explanation of these statements, see Statements 149 and 150.
155-156	These statements are used when the harmonic number is equal to five. For explanation of these statements, see statements 149 and 150.
157-158	These statements are used when the harmonic number is equal to six. For explanation of these statements, see statements 149 and 150.
159-160	These statements are used when the harmonic number is equal to seven. For explanation of these statements, see statements 149 and 150.
161-162	These statements are used when the harmonic number is equal to eight. For explanation of these statements, see statements 149 and 150.

TABLE IV - (CONCLUDED)

STATEMENT NUMBER	INSTRUCTION AND EXPLANATION
163	100 SUM1,SUMD1,SUMR1=SC,ST1,X01,ACT1.HSUM. This statement is used when harmonic number is equal to one. For explanation of this statement see statement 149.
164	1000 CAA = CA.RENAME. Terminates the analysis.

(4) Statics Instruction Sequence Using Cholesky Triangularization (STATICS)

Figure II-4 presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis. This set of instructions differs from those reported on pp. 40 thru 52 of Reference 5 in the following respect.

The set of simultaneous linear equations which arise in the analysis are solved by Cholesky triangularization. The use of these instructions are explained in detail on page 8 of this report.

Statement 47 of Figure II-4 has the following form:

```
TRIA,XX = STIFF,TLOADR.CHTRIA.
```

where in Reference 5, the equation solution had the following form:

```
XX = STIFF.SEQEL.TLOADR
```

Note Statement 47 of Figure II-C (Page 41) of Reference 5.

It is again emphasized that the User is not restricted to this particular set of instructions. The flexibility of the System allows the use of additional or alternate instructions to accommodate special needs and requirements of the User. All instructions available from MAGIC II (Reference 5) are available in MAGIC III.

```
$STATICS
C
C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS
C
C      *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C
C      STATICS INSTRUCTION SEQUENCE
C
C      *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C
C      GENERATE ELEMENT MATRICES
C
      ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.
C
C
C      FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C      DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC
      DIFF = I1 .SMULT. SC(9,1)
C
C      ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      KELA = EM .ASSEM. SC,(10)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
C
C      REDUCE STIFFNESS MATRIX AND PRINT
C
      KO,KNO = KELA .DEJOIN.( SC(5,1),1)
      KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)
      PRINT(FORCE,DISP,,) STIFF
C
C      FORM REDUCED TOTAL LOAD COLUMN
C
C      MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C      TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO = TR.MULT.LOADS
C      FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
      TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
C
C      SOLVE FOR DISPLACEMENTS
C
      TRIA,XX = STIFF,TLOADR .CHTRIA.
      TRO,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XX
      XO = TR.MULT.X
C
C      CALCULATE REACTIONS AND INVERSE CHECK
C
      REACTS = KELA.MULT.XO
      REACTP= REACTS.SUBT.TLOAD
      IF (DIFF.NULL.) GO TO 10
C
C      PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,
C        REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT
```

Figure II-4 STATICS Instruction Sequence Using Cholesky Triangularization

```
C
C         ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP
      IF (I3.NULL.) GO TO 600
C
C         ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X
      GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP
C
C         GENERATE STRESSES  AND FORCES
C
 600  STRESP=EM,XO .STRESS.(4,)
      FORCEP=EM,XO .FORCE.(4,)
```

FIGURE II-4 - (CONCLUDED)

(5) Statics Instruction Sequence With Condensation Using Cholesky Triangularization (STATICSC)

Figure II-5 presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with condensation. The condensation (reduction) technique is that of Guyan (Reference 11). With the use of this option, the User is provided the flexibility to perform a static analysis utilizing a rational condensation procedure. The only basic difference in abstraction instructions between using the statics with condensation option and the standard statics option is the additional instructions required to form the condensed stiffness matrix, i.e.,

$$\left[K\right]_R = \left[K_{11} - K_{12} \quad K_{22}^{-1} \quad K_{21}\right]$$

This set of instructions differs from those reported on pp. 53 thru 55 of Reference 5 in the following respects.

In the Agendum presented in this document, the reduced stiffness matrix, $\left[K\right]_R$ and the deflections, D1 are found using Cholesky Triangularization. Sequence Numbers 213 thru 217 of the present agendum are as follows:

```
K22I,KR1 = K22,K12T.CHTRIA.
KR2 = K12.MULT.-KR1
KR = K11.ADD.KR2
```

And upon solving for displacements, D1, we have:

```
TRIA,D1 = KR,P1.CHTRIA.
```

It is noted that in Reference 5, the reduced stiffness matrix, $\left[K\right]_R$, and the displacements D1 were obtained as follows. (Note Sequence Numbers 393 thru 398, p. 54, Reference 5.)

```
K22I = -K22 .INVERS.
KR1 = K22I.MULT.K12T
KR2 = K12.MULT.KR1
KR = K11.ADD.KR2
D1 = KR.SEQEL.P1
```

The suggested set of instructions presented herein avoids the use of inversion to form the reduced stiffness matrix. Additionally, the instruction using .SEQEL. has been replaced with .CHTRIA.

```
$STATICSC                                                               00001630
C                                                                       00001640
C-----STATICS AGENDUM, WITH CONDENSATION                                00001650
C                                                                       00001660
C        *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *00001670
C                                                                       00001680
C        STATICS INSTRUCTION SEQUENCE                                   00001690
C                                                                       00001700
C        *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *00001710
C                                                                       00001720
C        GENERATE ELEMENT MATRICES                                      00001730
C                                                                       00001740
      ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,     ,.USER04.    00001750
C                                                                       00001760
C        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                    00001770




C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED               00001780
      I1 = SC.IDENTC.                                                   00001790
      I3 = I1.NULL.SC                                                   00001800
      DIFF = I1 .SMULT. SC(9,1)                                         00001810
C                                                                       00001820
C        ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS            00001830
C                                                                       00001840
      KELA = EM .ASSEM. SC,(10)                                         00001850
      FTELA = EM .ASSEM .SC,(40)                                        00001860
C                                                                       00001870
C        REDUCE STIFFNESS MATRIX AND PRINT                              00001880
C                                                                       00001890
      KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                00001900
      KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                               00001910
      PRINT(FORCE,DISP,,) STIFF                                         00001920
C                                                                       00001930
C        FORM REDUCED TOTAL LOAD COLUMN                                 00001940
C                                                                       00001950
      LSCALE,LOADS = XLD .DEJOIN.(1,1)                                  00001960
C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR                  00001970
      FTELS = FTELA.MULT.LSCALE                                         00001980
C-----TRANSFORM EXTERNAL LOADS TO ORDERED SYSTEM, FORM TOTAL LOADS      00001990
      LOADO = TR .MULT. LOADS                                           00002000
      TLOAD = FTELS .ADD. LOADO                                         00002010
C-----CONDENSE ASSEMBLED STIFFNESS MATRIX                               00002020
      TOP,BOT = STIFF .DEJOIN. (SC(6,1),1)                              00002030
      K11,K12 = TOP .DEJOIN. (SC(6,1),0)                                00002040
      K12T,K22 = BOT .DEJOIN. (SC(6,1),0)                               00002050
                                                                        00002060
```

Figure II-5 - Statics With Condensation - Cholesky Triangularization

```
      P0,P12 = TLOAD .DEJOIN. (SC(5,1),1)
C-----CONDENSE EXTERNAL LOAD COLUMNS
      P1,P2  = P12 .DEJOIN. (SC(6,1),1)
C
C-----FORM (K11 - K12*K22(INVS)*K12T)
C
      K22I,KR1 = K22,K12T .CHTRIA.
      KR2 = K12 .MULT. -KR1
      KR =  K11 .ADD. KR2
C-----SOLVE FOR DISPLACEMENTS D1
      TRIA,D1 = KR,P1 .CHTRIA.
C-----SOLVE FOR DISPLACEMENTS D2
      D2 =  KR1 .MULT. D1
C-----FORM TOTAL DISPLACEMET VECTOR
      D1T = D1 .TRANSP.
      D2T = D2 .TRANSP.
      D12 = D1T .ADJOIN. D2T
      XX  = D12 .TRANSP.
C-----EXPAND DISPLACEMENTS TO TOTAL SYSTEM DEGREES OF
C-----FREEDOM AND REARRANGE TO 0-1-2 SYSTEM
      TR0,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XX
      X0 = TR.MULT.X
C
C         CALCULATE REACTIONS AND INVERSE CHECK
C
      REACTS = KELA.MULT.X0
      REACTP= REACTS.SUBT.TLOAD
      IF (DIFF.NULL.) GO TO 10
C




C         PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,
C           REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT
C
C         ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP
      IF (I3.NULL.) GO TO 600
C
C         ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X
      GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP
C
C         GENERATE STRESSES  AND FORCES
C
 600  STRESP = EM,X0 .STRESS. (4,)
      FORCEP = EM,X0 .FORCE. (4,)
```

Figure II-5 (Concluded)

(6) Statics Instruction Sequence With Prescribed Displacements Using Cholesky Triangularization (STATICS2)

Figure II-6 presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with prescribed displacements. With the use of this option, applied loading may be prescribed in terms of non-zero displacement values. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero.

This set of instructions differs from those reported on pp. 56 thru 68 of Reference 5 in the following respect. The set of simultaneous linear equations which arise in the analysis are solved by Cholesky triangularization. Statement 127 of Figure II-6 has the following form:

```
TRIA,X1 = K11,K4.CHTRIA.
```

where in Reference 5, the equation solution had the following form:

```
X1 = K11.SEQEL.K4
```

Note Statement 127 of Figure II-e (Page 58) of Reference 5.

```
$STATICS2
C
C-----STATICS AGENDUM WITH PRESCRIBED DISPLACEMENTS
C
C        STATICS INSTRUCTION SEQUENCE
C
C        GENERATE ELEMENT MATRICES
      ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,PD=,,     ,.USER04.
C
C        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC
      DIFF = I1 .SMULT. SC(9,1)
C
C        ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      KELA = EM .ASSEM. SC,(10)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
C
C        REDUCE STIFFNESS MATRIX AND PRINT
C
      KO,KNO = KELA .DEJOIN.( SC(5,1),1)
      KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)
      PRINT(FORCE,DISP,,) STIFF
C
C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C        TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO  = TR.MULT.LOADS
C        FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
      TL,TLOADR = TLOAD.DEJOIN.(SC(5,1),1)
C
C        SOLVE FOR DISPLACEMENTS
C        PRESCRIBED DISPLACEMENTS ARE PRESENT
C
```

```
C
      K1,K2 = STIFF.DEJOIN.(SC(6,1),1)
      K11,K12 = K1.DEJOIN.(SC(6,1),0)
      PDO = TR.MULT.PD
      PR,D2      = PDO  .DEJOIN.( SC(8,1),1)
      K3 = K12.MULT.D2
      P1,P2 = TLOADR.DEJOIN.(SC(6,1),1)
      K4 = P1.SUBT.K3
      TRIA,X1 = K11,K4 .CHTRIA.
      X1T = X1.TRANSP.
      X2T = D2.TRANSP.
      X12T = X1T.ADJOIN.X2T
      XOT = X1T.NULL.KCO
      XT = XOT.ADJOIN.X12T
      XO = XT.TRANSP.
      X = TR.TMULT.XO
C         CALCULATE AND PRINT REACTIONS
C
```

Figure II-6 Statics With Prescribed Displacements - Cholesky Triangularization

```
      REACTT = KELA.MULT.XO
      REACT = REACTT.SUBT.TLOAD
C
C        ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
C        PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
C        PRINT ASSEMBLED DISPLACEMENT COLUMN
C
      IF (DIFF.NULL.) GO TO 10
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,   )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACT
      IF (I3.NULL.) GO TO 60
C
C        ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,   )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC,)X
      GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACT
C
C        GENERATE STRESSES  AND FORCES
C
 60   STRESS = EM,XO .STRESS. (4,)
      FORCE = EM,XO .FORCE. (4,)
```

Figure II-6 - (Concluded)

(7) Stability Analysis Instruction Sequence (STABILITY)

Figure II-7 presents the suggested set of abstraction instructions for use in performing elastic instability analyses.

The structural stability analysis is a two-phase process, the first step of which is a linear elastic stress analysis for which the initial stress state is zero. The second phase of the analysis procedure, begins with the formation of element incremental stiffness matrices which are derived from the mid-plane stress resultants determined in the linear stress analysis. After assembly of element incremental stiffness matrices, a linear eigenvalue solution is obtained for the critical buckling load. Using this approach, the assumption is made that all mid-plane forces remain in a fixed ratio to one another at all levels of applied load, from the onset of loading to the achievement of instability. A detailed derivation of the algebraic expressions used for the Stability Analyses is given in Section III of Reference 4.

It is to be noted that in the MAGIC III System, incremental stiffness matrices are provided for the following finite element representations:

a. Quadrilateral Plate (Ident. No. 28)
b. Triangular Plate (Ident. No. 27)
c. Incremental Frame (Ident. No. 13)

The derivations of these elements are presented in detail in Reference 4.

The stability analysis instruction sequence of Reference 5 is presented for comparison purposes in Figure II-8. It is included in this document without change. Detailed matrix operations concerning the use of these operations are presented on pp. 69-80 of Reference 5.

The suggested form of solving the elastic instability analysis, shown in Figure II-7, uses the Cholesky triangularization method. Differences in instructions between Figures II-7 and II-8 are as follows:

Statement No. 346 of Figure II-7 has the form:

FLEX,XR = STIFF,TLOADR.CHTRIA.

where

FLEX = The Triangularized Stiffness Matrix
XR = The Reduced Displacement Solution Vector
STIFF = The Reduced Stiffness Matrix
TLOADR = The Reduced Total Applied Load Vector

(Note p. 8 , Section II.B.2 of this report.)

Once the triangularized stiffness matrix, FLEX, has been determined, and after the assembly of the element incremental stiffness matrices, INCR, Statement 386 is utilized as follows:

EIG = FLEX.CHOL.INCR

where EIG = The solution of the back substitution system.

Statement Number 386 of Figure II-7 is equivalent to:

EIG = FLEX.MULT.INCR which is Statement Number 239 of Figure II-8.

The use of the instructions as outlined in Figure II-7 avoids the inversion of the stiffness matrix which for large order systems may prove inefficient and computationally prohibitive.

```
$STABILITY
C
C-----STABILITY AGENDUM ANALYSIS
C
C         STABILITY ANALYSIS INSTRUCTION SEQUENCE
C
C         GENERATE ELEMENT MATRICES
C
      ,MLIB,INTP,XLD ,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,=,,      ,.USER04.
C
C         FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C         DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC
      DIFF = I1 .SMULT. SC(9,1)
C
C         ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      STIFF= EM .ASSEM. SC,(1)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
      PRINT(FORCE,DISP,,) STIFF
C
C         MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C         TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO = TR.MULT.LOADS
C         FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
C         FORM REDUCED TOTAL LOAD COLUMN
      TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
C
C         PRINT FLEXIBILITY  MATRIX
C
      FLEX,XR = STIFF,TLOADR .CHTRIA.
      PRINT (DISP,FORCE,,) FLEX
C
C         SOLVE FOR DISPLACEMENTS
C
      TRO,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XR
      XO = TR.MULT.X
      IF (DIFF.NULL.) GO TO 10
```

Figure II-7 - Stability Instruction Sequence -
Cholesky Triangularization

```
C
C        PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
C
C        ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,   ) X
      IF (I3.NULL.) GO TO 60
C
C        ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )FTELA
      GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,    )LOADS
      GPRINT(2,,,U.O.W.O.THETAY.O.W*.O.W**,SC,   ) X
C
C        GENERATE STRESSES
C
 60   STRESS = EM,XO .STRESS. (4,)
C
C        GENERATE ELEMENT INCREMENTAL STIFFNESS MATRIX
C
      ,,,,,,,,,,NEL,,   ,EL,=, INTP,      ,STRESS.USER04.
C
C        ASSEMBLE AND REDUCE INCREMENTAL MATRIX
C
      INCR = EL .ASSEM. SC,(3)
      PRINT(,,,) INCR
C
C        CREATE INPUT EIGENVALUE MATRIX
C
      EIG = FLEX .CHOL. INCR
      PRINT (,,,) EIG
C
C        CALCULATE AND PRINT E-VALUES,E-VECTORS,FREQUENCIES
C
      EVALUE,EVECTR,, = EIG, .EIGEN1. SC
      GPRINT(3,,,,SC,TR12) EVECTR,EVALUE
```

Figure II-7 - Concluded

```
$STABILITYA
C
C-----STABILITY AGENDUM ANALYSIS
C
C         STABILITY ANALYSIS INSTRUCTION SEQUENCE
C
C         GENERATE ELEMENT MATRICES
C
      ,MLIB,INTP,XLD ,TR,   ,KEL,FTEL,SEL,STEL,,,SC,EM,=,,      ,,USER04,
C
C         FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C         DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC



      DIFF = I1 .SMULT. SC(9,1)
C
C         ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      STIFF= EM .ASSEM. SC,(1)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
      PRINT(FORCE,DISP,,) STIFF
C
C         MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C         TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO = TR.MULT.LOADS
C         FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
C         FORM REDUCED TOTAL LOAD COLUMN
      TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
C
C         PRINT FLEXIBILITY  MATRIX
C
      FLEX = STIFF.INVERS.
      PRINT (DISP,FORCE,,) FLEX
C
C         SOLVE FOR DISPLACEMENTS
C
      XR= FLEX.MULT.TLOADR
      TRO,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XR
      XO = TR.MULT.X
      IF (DIFF.NULL.) GO TO 10
C
C         PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
C
C         ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,  ) X
      IF (I3.NULL.) GO TO 60
```

Figure II-8 - Alternate Stability Instruction Sequence Using Matrix Inversion

```
      ELEMENTS HAVE 3 DEGREES OF FREEDOM

10    GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC,    ) X

      GENERATE STRESSES

50    STRESS = EM,X0 .STRESS. (4,)

      GENERATE ELEMENT INCREMENTAL STIFFNESS MATRIX

      ,,,,,,,,,,NEL,,  ,EL,=,INTP,    ,STRESS.USER04.

      ASSEMBLE AND REDUCE INCREMENTAL MATRIX

      INCR = EL .ASSEM. SC,(3)
      PRINT(,,,) INCR




      CREATE INPUT EIGENVALUE MATRIX

      EIG = FLEX.MULT.INCR
      PRINT (,,,) EIG

      CALCULATE AND PRINT E-VALUES,E-VECTORS,FREQUENCIES

      EVALUE,EVECTR,, = EIG, .EIGEN1. SC
      GPRINT(3,,,,SC,TR12) EVECTR,EVALUE
```

Figure II-8 (Concluded)

(8) Dynamics Analysis Instruction Sequence (DYNAMICS)

Figure II-9 presents the suggested set of abstraction instructions for use in performance of a vibration analysis. This particular set of instructions provides modes and frequencies for a structural system in which the rigid body modes have been suppressed (i.e. the assembled stiffness matrix has been rendered non-singular by the appropriate application of physical boundary conditions. As seen from Figure II-9 the .EIGEN 1. abstraction instruction is used in this sequence. This instruction is based on the "power method" of extracting eigenvalues and eigenvectors. The desired number of modes and frequencies are supplied as input by the User in the Structural Analysis Input Section. This information is contained on a specialized preprinted input data form entitled DYNAM. This form was described in detail in the Structural Input Data Section of Reference 5.

The Dynamics Analysis Instruction Sequence has been written to accommodate non-structural lumped masses to augment the structural mass matrix generated by the MAGIC III System. A specialized preprinted input data form entitled Lumped Masses has been provided for input of the lumped mass values and is displayed in Figure II-16 of Section II.C.5. It is noted that this data form can also be utilized to input lumped structural mass values at the option of the User.

If this were the case, the User would specify a mass density value of zero (0.0) on the Material Tape Input Section data form which is described in detail on pp. 97 - 101 of Reference 5. In addition, output matrix position twelve (OMP 12) of the USER04. instruction. Statement No. 401 of Figure II-9 would be left blank so that the MAGIC III System would not generate element mass matrices (MEL) for the application in question.

Additional output data from this set of instructions include generalized mass and generalized stiffness values for each mode requested.

Table V is provided as a supplement to Figure II-9. This Table provides engineering and matrix definition for each abstraction instruction listed in Figure II-9.

```
$DYNAMICS
:
:-----DYNAMICS AGENDUM ANALYSIS
:
:       DYNAMICS ANALYSIS INSTRUCTION SEQUENCE
:
:       GENERATE ELEMENT MATRICES
:
    ,MLIB,,MLD,TR,,KEL,,,,,MEL,SC,EM, = ,,,,USER04.
:
:       ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX
:
    STIFF= EM .ASSEM. SC,(1)
    MASSM = EM .ASSEM. SC,(2)
:
:   DEFINE LUMP MASS AND TOTAL MASS MATRIX
:
    MSCAL,LMASS = MLD .DEJOIN. (1,1)
    LUMPC = TR .MULT. LMASS
    LL,LUMP = LUMPO .DEJOIN. (SC(5,1),1)
    DLUMP = LUMP .DIAGON.




    MASS = MASSM .ADD. DLUMP

        PRINT STIFFNESS MATRIX AND MASS MATRIX

    PRINT(FORCE,DISP,,) STIFF

    PRINT(FORCE,ACCEL,,) MASS

        GENERATE DYNAMICS MATRIX

    KINV,DYNAM = STIFF,MASS .CHTRIA.

        FIND E-VALUES, E-VECTORS, NORMAL MODES,
        FREQUENCIES AND PRINT

    EVALUE,EVECT,, = DYNAM, .EIGEN1. SC

    TRO,TR12 = TR .DEJOIN. (SC(5,1),1)
    GPRINT(3,,,,SC,TR12) EVECT,EVALUE

        GENERATE STIFFNESS AND GENERALIZED MASS
        MATRICES AND PRINT

    KGEN1 = EVECT.TMULT.STIFF
    KGEN = KGEN1.MULT.EVECT
    MGEN1 = EVECT.TMULT.MASS
    MGEN = MGEN1.MULT.EVECT
    PRINT(,,,) MGEN,KGEN,KINV,DYNAM
```

Figure II-9 - Dynamics Analysis Instruction Sequence

TABLE V

DYNAMICS INSTRUCTION SEQUENCE

(STEP BY STEP DESCRIPTION)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
401	,MLIB,,MLD,TR,,KEL,,,,,MEL,SC,EM,=,,,.USER04. Generates the element stiffness matrices KEL, lumped mass matrix column MLD, and element mass matrices MEL, required for the dynamics problem.
405	STIFF=EM.ASSEM.SC,(1) Forms the assembled reduced stiffness matrix, STIFF from the element stiffness matrices stored in EM. SC contains system constants required by the .ASSEM. routine.
406	MASSM=EM.ASSEM.SC,(2) Forms the assembled reduced mass matrix, MASS from the element mass matrices stored in EM. System information required by .ASSEM. is input in SC.
410	MSCAL,LMASS=MLD.DEJOIN.(1,1) $\begin{bmatrix} MSCAL \\ LMASS \end{bmatrix} = MLD$ The mass scalar, MSCAL and the lumped mass column LMASS are dejoined in the MLD matrix. It is noted that MSCAL is the first row of MLD.
411	LUMPO=TR.MULT.LMASS $[LUMPO] = [TR] \; [LMASS]$ Transforms the unordered total lumped mass column, LMASS, to the 0-1-2 ordered assembled column, LUMPO.
412	LL,LUMP=LUMPO.DEJOIN.(SC(5,1),1) $\begin{bmatrix} LL \\ LUMP \end{bmatrix} = [LUMPO]$ Forms the reduced total lumped mass column, LUMP, which reflects 1's and 2's.
413	DLUMP=LUMP.DIAGON. Diagonalizes the vector, LUMP, to form a square diagonal matrix, DLUMP.

TABLE V
(CONTINUED)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
414	MASS=MASSM.ADD.DLUMP $[\mathrm{MASS}] = [\mathrm{MASSM}] + [\mathrm{DLUMP}]$ Augments the assembled structural mass matrix, MASSM with the additional (non-structural) contribution DLUMP to form the total mass matrix, MASS.
418	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
420	PRINT(FORCE,ACCEL,,) MASS Prints the reduced mass matrix.
424	KINV,DYNAM=STIFF,MASS.CHTRIA. Solves the following set of equations: $[\mathrm{STIFF}][\mathrm{DYNAM}] = [\mathrm{MASS}]$ $[\mathrm{KINV}]$ = Triangularized stiffness matrix $[\mathrm{DYNAM}]$ is the dynamic matrix and is equivalent to the inverse of the stiffness matrix times the mass matrix, i.e., $[K]^{-1}[M]$.
429	EVALUE,,EVECT,,=DYNAM,.EIGEN1.SC solve $\left[[\mathrm{DYNAM}] - [\mathrm{EVALUE}][I]\right][\mathrm{EVECT}] = [0]$ Computes the required eigenvalues and corresponding eigenvectors of the dynamics matrix using the power method. The eigenvalues are stored in the column matrix EVALUE and the corresponding eigenvectors are stored as columns in EVECT. The frequencies and mode shapes are also printed out.
431	TRO,TR12 = TR.DEJOIN.(SC(5,1),1) $\left[\begin{array}{c} \mathrm{TRO} \\ \hline \mathrm{TR12} \end{array}\right] = [\mathrm{TR}]$ Forms the matrix TR12 which will be used by the .GPRINT. instruction.
432	.GPRINT.(3,,,,SC,TR12)EVECT,EVALUE Prints the eigenvalue column and the eigenvector in engineering format.

TABLE V
(CONTINUED)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
437	KGEN1=EVECT.TMULT.STIFF $[\text{KGEN1}] = [\text{EVECT}]^{T} [\text{STIFF}]$ Forms the product of the transpose of the eigenvector matrix and the reduced stiffness matrix.
438	KGEN=KGEN1.MULT.EVECT $[\text{KGEN}] = [\text{EVECT}]^{T} [\text{STIFF}][\text{EVECT}]$ Forms the generalized stiffness matrix in KGEN by forming the product of KGEN1 and EVECT.
439	MGEN1=EVECT.TMULT.MASS $[\text{MGEN1}] = [\text{EVECT}]^{T} [\text{MASS}]$ Forms the product of the transpose of the eigenvalue matrix and the reduced mass matrix.
440	MGEN=MGEN1.MULT.EVECT $[\text{MGEN}] = [\text{EVECT}]^{T} [\text{MASS}] [\text{EVECT}]$ Forms the generalized mass matrix in MGEN by forming the product of MGEN1 and EVECT.
441	PRINT(,,,)MGEN,KGEN,KINV,DYNAM Prints the generalized stiffness matrix, the generalized mass matrix, the triangularized stiffness matrix and the dynamic matrix.

(9) Free-Free Dynamics Analysis Instruction Sequence (DYNAMICSF)

Figure II-10 presents the suggested set of abstraction instructions for use in performance of a free-free vibration analysis. This particular set of instructions provides modes and frequencies for a structural system in which the rigid body modes are present. Provision for lumped non-structural mass is provided as well as the provision for lumped structural mass. The values are input, if required, via the lumped mass preprinted input data form shown in Figure II-16. It is noted from the lumped mass form that provision is made to input a mass scalar value. This value is utilized in the performance of a free-free vibration analysis as follows.

Given the equations of motion of a free-free system:

$$[M]\{\ddot{q}\} + [K_f]\{q\} = \{0\} \qquad (1)$$

where $[K_f]$ is a singular stiffness matrix. The natural frequencies and corresponding mode shapes can be determined from lowest to highest by solution of the following eigenvalue problem.

$$\left[a_o [M] + [K_f]\right]^{-1} [M] \{\phi_i\} = \lambda_i \{\phi_i\} \qquad (2)$$

from which the natural frequencies may be recovered as follows:

$$f_{n_i} = \frac{1}{2\pi} \sqrt{\left(\frac{1}{\lambda_i}\right) - a_o} \qquad (3)$$

where a_o is the mass scalar value input on the lumped mass input data form. Detailed discussion of the above procedure can be found in References 12 and 13.

It is noted that when the above technique is utilized, caution must be exercised in choosing the value of the scalar a_o. Problems arise in some cases when diagonal mass matrices are employed whose terms are on the order of 10^{-2} compared to terms on

```
$DYNAMICSF
C
C     *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C-----DYNAMICS (FREE-FREE) AGENDUM ANALYSIS.
C       DYNAMICS ANALYSIS INSTRUCTION SEQUENCE
C       GENERATE ELEMENT MATRICES
      ,MLIB,,M, TR,, KEL,,,,,MEL,SC,EM,  = ,,, .USER04.
C
C     ASSEMBLE STIFFNESS AND CONSISTENT MASS MATRICES
C
      STIFF =  EM .ASSEM. SC, (1)
      MASSM = EM .ASSEM. SC, (2)
C     DEFINE LUMP MASS
      MSCAL, LMASS =  M .DEJOIN.(1,1)
      LUMPO = TR .MULT. LMASS
      LL, LUMP = LUMPO .DEJOIN. ( SC(5,1),1)
      DLUMP =  LUMP .DIAGON.
C
C     DEFINE TOTAL MASS MATRIX
      MASS   =  MASSM .ADD. DLUMP
      MASS1 =   MASS  .SMULT.  MSCAL(1,1)
C
C     PRINT STIFFNESS AND MASS MATRICES
      PRINT (FORCE, DISP,,) STIFF
      PRINT (  FORCE, ACCEL,,)  MASS
C
C     COMPUTE DYNAMIC MATRIX
C
      STIFFM =  MASS1 .ADD. STIFF
      FLEX, DYNAM =  STIFFM, MASS .CHTRIA.
C
C     GENERATE  E-VALUES  AND  FREQUENCIES  AND PRINT
C
      EVALUE, EVECT,, =  DYNAM, .EIGEN1. SC
      TRO,TR12 = TR .DEJOIN.(SC(5,1),1)
      GPRINT ( 3,,,, SC, TR12)   EVECT,EVALUE
C
C     GENERATE  GENERALIZED STIFF  AND MASS , PRINT
C
      KGEN1 =  EVECT  .TMULT. STIFF
      KGEN  =  KGEN1 .MULT.  EVECT.
      MGEN1 =  EVECT .TMULT. MASS
      MGEN = MGEN1 .MULT. EVECT
      PRINT (,,,)   MGEN, KGEN, FLEX, DYNAM
```

Figure II-10 - Free-Free Dynamics Analysis Instruction Sequence the order of 10^6 in the stiffness matrix. This requires the analyst to adjust the value of a_0 , so that the matrix product $a_0 [M]$ when added to the stiffness matrix will render it non-singular. A large value of a_0 can cause problems when the elastic frequencies of interest are low (say below 10 to 15 cps) since the frequencies being calculated are a function of:

$$\sqrt{\left(\frac{1}{\lambda_i}\right) - a_0}$$

It has been found, in general, that when consistent mass matrices are employed in the vibration analysis, a value of a_0 = 1.0 will usually suffice as the scalar value of the mass matrix multiplier.

Table VI is provided as a supplement to Figure II-10. This Table provides engineering and matrix definition for each abstraction instruction listed in Figure II-10.

TABLE VI

FREE-FREE DYNAMICS INSTRUCTION SEQUENCE

(STEP BY STEP DESCRIPTION)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
448	,MLIB,,M,TR,,KEL,,,,,MEL,SC,EM,=,,,.USER04. Generates the element stiffness matrices, KEL, lumped mass matrix column, M and element mass matrices MEL, required for the dynamics problem.
452	STIFF=EM.ASSEM.SC,(1) Forms the assembled reduced stiffness matrix, STIFF from the element stiffness matrices stored in EM. SC contains system constants required by the .ASSEM. routine.
453	MASSM=EM.ASSEM.SC,(2) Forms the assembled reduced mass matrix, MASS from the element mass matrices stored in EM. System information required by .ASSEM. is input in SC.
455	MSCAL,LMASS=M.DEJOIN.(1,1) $\left[\begin{array}{c}\text{MSCAL}\\ \hline \text{LMASS}\end{array}\right] = \left[\text{M}\right]$ The mass scalar, MSCAL and the lumped mass column LMASS are dejoined in the M matrix. It is noted that MSCAL is the first row of M.
456	LUMPO = TR.MULT.LMASS $\left[\text{LUMPO}\right] = \left[\text{TR}\right]\left[\text{LMASS}\right]$ Transforms the unordered total lumped mass column, LMASS, to the 0-1-2 ordered assembled column, LUMPO.
457	LL,LUMP=LUMPO.DEJOIN.(SC(5,1),1) $\left[\begin{array}{c}\text{LL}\\ \hdashline \text{LUMP}\end{array}\right] = \left[\text{LUMPO}\right]$ Forms the reduced total lumped mass column, LUMP, which reflects 1's and 2's.

TABLE VI
(CONTINUED)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
458	DLUMP=LUMP.DIAGON. Diagonalizes the vector, LUMP, to form a square diagonal matrix, DLUMP.
461	MASS=MASSM.ADD.DLUMP $[\text{MASS}] = [\text{MASSM}] + [\text{DLUMP}]$ Augments the assembled structural mass matrix, MASSM, with the additional (non-structural) contribution DLUMP to form the total mass matrix, MASS.
462	MASS1=MASS.SMULT.MSCAL(1,1) $[\text{MASS1}] = \text{MSCAL}\,[\text{MASS}]$ Performs the scalar multiplication of MSCAL times MASS. This is equivalent to $a_0 [M]$ detailed in the writeup.
465	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
466	PRINT(FORCE,ACCEL,,) MASS Prints the reduced mass matrix.
470	STIFFM=MASS1.ADD.STIFF $[\text{STIFFM}] = [\text{MASS1}] + [\text{STIFF}]$ Adds $[\text{MASS1}]$ to $[\text{STIFF}]$ to form $[\text{STIFFM}]$. This is equivalent to $\left[a_0 [M] + [K]\right]$ as described in the writeup.
471	FLEX,DYNAM=STIFFM,MASS.CHTRIA. Solves the following set of equations $[\text{STIFFM}]\,[\text{DYNAM}] = [\text{MASS}]$ $[\text{FLEX}]$ = Triangularized Stiffness Matrix $[\text{DYNAM}]$ is the dynamic matrix and is equivalent to the inverse of the stiffness matrix times the mass matrix, i.e., $[K]^{-1}\,[M]$.

TABLE VI
(CONTINUED)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
475	EVALUE,EVECT,,=DYNAM,.EIGEN1.SC solve $\big[[DYNAM] - [EVALUE][I]\big]\,[EVECT] = [0]$ Computes the required eigenvalues and corresponding eigenvectors of the dynamics matrix using the power method. The eigenvalues are stored in the column matrix EVALUE and the corresponding eigenvectors are stored as columns in EVECT. The frequencies and mode shapes are also printed out.
476	TRO,TR12=TR.DEJOIN.(SC(5,1),1) $\begin{bmatrix} TRO \\ TR12 \end{bmatrix} = [TR]$ Forms the matrix TR12 which is used by the .GPRINT. instruction.
477	.GPRINT.(3,,,,SC,TR12)EVECT,EVALUE Prints the eigenvalue column and the eigenvector matrix in engineering format.
481	KGEN1=EVECT.TMULT.STIFF $[KGEN1] = [EVECT]^T\,[STIFF]$ Forms the product of the transpose of the eigenvector matrix and the reduced stiffness matrix.
482	KGEN=KGEN1.MULT.EVECT $[KGEN] = [EVECT]^T\,[STIFF][EVECT]$ Forms the generalized stiffness matrix in KGEN by forming the product of KGEN1 and EVECT.
483	MGEN1=EVECT.TMULT.MASS $[MGEN1] = [EVECT]^T\,[MASS]$ Forms the product of the transpose of the eigenvalue matrix and the reduced mass matrix.
484	MGEN=MGEN1.MULT.EVECT $[MGEN] = [EVECT]^T\,[MASS]\,[EVECT]$ Forms the generalized mass matrix in MGEN by forming the product of MGEN1 and EVECT.

TABLE VI
(CONTINUED)

STATEMENT SEQUENCE NUMBER	INSTRUCTION AND EXPLANATION
485	PRINT(,,,)MGEN,KGEN,FLEX,DYNAM Prints the generalized stiffness matrix, the generalized mass matrix, the triangularized stiffness matrix, and the dynamic matrix.

(10) Dynamics Analysis Instruction Sequence With Condensation (DYNAMICSC)

Figure II-11 presents the suggested set of abstraction instructions for use in performance of a vibration analysis utilizing condensation. The condensation technique used is that of Guyan (Reference 11).

The use of this technique allows degrees of freedom considered to be superfluous to be eliminated through the use of a condensation transformation. The technique is analogous to that of Statics with Condensation (STATICSC) with the additional step of applying the condensation transformation to the mass matrix as well as the stiffness matrix. This technique yields an eigenvalue problem which is much reduced in size.

As with the standard dynamics agendum of Figure II-9 (DYNAMICS), lumped structural and non-structural masses are accommodated. The specialized preprinted input data form entitled Lumped Masses (Figure II-16) is utilized, if required.

Degrees of freedom that are considered superfluous and are to be condensed (eliminated) in a particular analysis are designated by the number '2' in the Boundary Condition Section which was discussed in detail on pp. 129-133 of Reference 5.

A detailed algebraic statement of the condensation procedure which is performed using the instructions of Figure II-11 is given on pp. 87-89 of Reference 5.

```
DYNAMICSC

----- DYNAMICS AGENDUM, WITH CONDENSATION

-----DYNAMICS AGENDUM ANALYSIS

        DYNAMICS ANALYSIS INSTRUCTION SEQUENCE

        GENERATE ELEMENT MATRICES

     ,MLIB,,MLD,TR,,KEL,,,,,MEL,SC,EM,  =  ,,,,.USER04.

        ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX

     STIFF = EM .ASSEM. SC,(1)
     MASSM = EM .ASSEM. SC,(2)

     DEFINE LUMP MASS AND TOTAL MASS MATRIX

     MSCAL,LMASS = MLD .DEJOIN. (1,1)
     LUMPO = TR .MULT. LMASS
     LL,LUMP = LUMPO .DEJOIN. (SC(5,1),1)
     DLUMP = LUMP .DIAGON.
     MASS = MASSM .ADD. DLUMP

        PRINT STIFFNESS MATRIX AND MASS MATRIX
     PRINT(FORCE,DISP,,) STIFF

     PRINT(FORCE,ACCEL,,) MASS

        GENERATE DYNAMICS MATRIX

     TOP,BOT  = STIFF .DEJOIN. (SC(6,1),1)
     K11,K12  = TOP .DEJOIN. (SC(6,1),0)
     K12T,K22  = BOT.DEJOIN. (SC(6,1),0)
     K22I,KR1 = K22,K12T .CHTRIA.
     KR2 = K12 .MULT. -KR1
     KR   = K11  .ADD.  KR2
     IDENT = K11 .IDENTR.
     KR1T = -KR1 .TRANSP.
     GAMT  = IDENT .ADJOIN. KR1T
     GAM   = GAMT .TRANSP.
     MR1   = GAMT .MULT. MASS
     MR   = MR1 .MULT. GAM
     KRI,DYNAM = KR,MR .CHTRIA.
```

Figure II-11 - Dynamics Analysis Instruction Sequence with Condensation

```
   FIND E-VALUES, E-VECTORS, NORMAL MODES,                      00005320
   FREQUENCIES AND PRINT                                        00005330
                                                                00005340
EVALUE,EVECT,, = DYNAM, .EIGEN1. SC                             00005350
                                                                00005360
TR01, TR2 = TR .DEJOIN. (SC(8,1),1)                             00005370
TR0,TR1 = TR01 .DEJOIN. (SC(5,1),1)                             00005380
GPRINT (3,,,,SC,TR1) EVECT,EVALUE                               00005390
                                                                00005400
   GENERATE STIFFNESS AND GENERALIZED MASS                      00005410
   MATRICES AND PRINT                                           00005420
                                                                00005430
KGEN1 = EVECT.TMULT.KR                                          00005440
KGEN = KGEN1.MULT.EVECT                                         00005450
MGEN1 = EVECT.TMULT.MR                                          00005460
MGEN = MGEN1.MULT.EVECT                                         00005470
                                                                00005480
PRINT(...) MGEN,KGEN,DYNAM,KR,MR                                00005490
```

Figure II-11 -(Concluded)

(11) Free-Free Dynamics Analysis Instruction Sequence with Condensation (DYNAMICSCF)

Figure II-12 presents the suggested set of abstraction instructions for use in performance of a free-free vibration analysis with condensation. This particular set of instructions provides modes and frequencies for a structural system in which the rigid body modes are present and for which the technique of condensation is employed. Provision for lumped non-structural mass is provided as well as the provision for lumped structural mass. The Mass Scalar value, a_0, described in the Free-Free Dynamics Analysis Instruction Sequence previously is available to this set of instructions and is used in exactly the same manner as in DYNAMICSF.

Degrees-of-freedom that are considered superfluous and are to be condensed (eliminated) in a particular analysis are designated by the number '2' in the Boundary Condition Section which was discussed in detail on pp. 129-133 of Reference 5. It is noted that User judgement is required in deciding which degrees-of-freedom in a particular analysis are superfluous and which are essential. An objective approach to this decision making process is presented in Reference 14.

The procedure utilized in Figure II-12 is very similar to that employed in dynamic substructuring. A detailed algebraic statement of the dynamic substructuring process is given on pp. 146-165 of Reference 4.

```
YNAMICSCF

---- CYNAMICS AGENDUM, WITH CONDENSATION

----DYNAMICS AGENDUM ANALYSIS

       DYNAMICS ANALYSIS INSTRUCTION SEQUENCE

       GENERATE ELEMENT MATRICES

   , MLIB, M, TR,, KEL,,,,,MEL,SC,EM,  = ,,, .USER04.

    ASSEMBLE STIFFNESS AND CONSISTENT MASS MATRICES

    STIFF =  EM. ASSEM. SC, (1)
    MASSM =   EM. ASSEM.  SC,(2)
    DEFINE LUMP MASS
    MSCAL, LMASS =  M. DEJOIN.(1,1)
    LUMPO = TR .MULT. LMASS
    LL, LUMP = LUMPO .DEJOIN. (SC(5,1),1)
    DLUMP =  LUMP .DIAGON.

    DEFINE TCTAL MASS MATRIX
    MASS   =  MASSM .ADD. DLUMP

       PRINT STIFFNESS MATRIX AND MASS MATRIX
    PRINT(FORCE,DISP,,) STIFF

    PRINT(FORCE,ACCEL,,) MASS

       GENERATE DYNAMICS MATRIX

    TCP,BOT  = STIFF .DEJOIN. (SC(6,1),1)
    K11,K12  = TOP .DEJOIN. (SC(6,1),0)
    K12T,K22  = BOT.DEJOIN. (SC(6,1),0)
    K22I,KR1 = K22,K12T .CHTRIA.
    KR2 = K12 .MULT. -KR1
    KR   = K11  .ADD.  KR2
    ICENT = K11 .IDENTR.
    KR1T = -KR1 .TRANSP.
    GAMT  = IDENT .ADJOIN. KR1T
```

Figure II-12 - Free-Free Dynamics Analysis Instruction Sequence with Condensation

```
GAM    = GAMT .TRANSP.
MR1   = GAMT .MULT. MASS
MR   = MR1 .MULT. GAM
MM   =    MR.SMULT.  MSCAL(1,1)
KM   =   MM . ADD. KR
KRI,DYNAM = KM,MR .CHTRIA.

   FIND E-VALUES, E-VECTORS, NORMAL MODES,
   FREQUENCIES AND PRINT

EVALUE,EVECT,, = DYNAM, .EIGEN1. SC

TR01, TR2 = TR .DEJOIN. (SC(8,1),1)
TR0,TR1 = TR01 .DEJOIN. (SC(5,1),1)
GPRINT (3,,,,SC,TR1) EVECT,EVALUE

   GENERATE STIFFNESS AND GENERALIZED MASS
   MATRICES AND PRINT

KGEN1 = EVECT.TMULT.KR
KGEN = KGEN1.MULT.EVECT
MGEN1 = EVECT.TMULT.MR
MGEN = MGEN1.MULT.EVECT

PRINT(,,,) MGEN,KGEN,DYNAM,KR,MR
```

Figure II-12 - (Concluded)

d. Agendum Level Abstraction Instructions

The Agendum level abstraction capability incorporated into the MAGIC II System has been retained and expanded in the MAGIC III System. The abstraction instructions for specified analyses will be automatically generated for the User when he specifies the corresponding option on the $INSTRUCTION card. The Agendum library is expandable and the addition of more abstraction instruction sequences (Agendum) only requires the updating of subroutine AGENDM, and of course the Agendum library itself. The use of an Agendum in no way restricts the User because he can include in his input deck his own abstractions to be merged with the selected agendum.

Subroutine AGENDM controls the selection from the Agendum library of the abstraction instruction sequence requested on the $INSTRUCTION card. At present, this subroutine has the capability to select the following Agendums.

1.	STATICSASYM	(Linear Elastic Displacement and Stress Analysis, Triangular Ring -Asymmetric Loading)
2.	STATICS	(Linear Elastic Displacement and Stress Analysis)
3.	STATICSC	(Linear Elastic Displacement and Stress Analysis With Condensation)
4.	STATICS2	(Linear Elastic Displacement and Stress Analysis With Prescribed Displacements)
5.	STABILITY	(Linear Elastic Instability Analysis Using Cholesky Triangularization)
6.	STABILITYA	(Linear Elastic Instability Analysis Using Matrix Inversion)
7.	DYNAMICS	(Vibration Frequencies, Mode Shapes, Generalized Mass and Stiffness for Supported Structures)

8.	<u>DYNAMICSF</u>	(Free-Free Vibration Frequencies, Mode Shapes, Generalized Mass and Generalized Stiffness for Unsupported Structures)
9.	<u>DYNAMICSC</u>	(Vibration Frequencies, Mode Shapes, Generalized Mass and Generalized Stiffness with Condensation for Supported Structures)
10.	<u>DYNAMICSCF</u>	(Free-Free Vibration Frequencies, Mode Shapes, Generalized Mass and Generalized Stiffness with Condensation for Unsupported Structures)

The present AGENDUM Library is designed to be updated as new Agendums become available. The programming procedure utilized to add additional options to the library is discussed in Appendix IX of Reference 8.

It is emphasized that the User is not restricted to the use of the above Agendums. They are included as a convenience feature to automatically generate the required instructions for a given standard analysis.

An example of non-agendum usage is as follows

```
CC
1     7        16
$MAGIC
$RUN           GO
$INSTRUCTION   SOURCE
   [User Input Abstraction Instructions]
$SPECIAL
   [Report From Input Deck for .USER04. Instruction]
$END
```

C. STRUCTURAL INPUT DATA

1. General Description

Significant portions of the labor and computer costs of structural analysis are occasioned by incomplete or improper specification of structural input data. In recognition of this, a number of features have been incorporated into the MAGIC System to assist in the confirmation of problem data prior to execution. The most important of these are the prelabeled input data forms which are an integral part of the MAGIC System.

All features which were incorporated into MAGIC I and II are retained and expanded in MAGIC III. Additional prelabeled input data forms have been added to MAGIC III to support the expanded capability of the System. These input data forms contain a number of special features, e.g.,

(1) "MODAL" Options are provided which preset a table to a given set of values. This MODAL option may be used where indicated.

(2) "REPEAT" Options are provided which minimize the input data specified by the User. This REPEAT option may be used where indicated.

(3) The User exercises control options simply by placing an 'X' in a given location on a prelabeled input data form.

(4) The prelabeled input data forms have permanent label cards which automatically precede subsets of data thereby allowing flexibility in the arrangement of input decks.

(5) Zeros must be indicated where pertinent. Blanks are never zeros except where specifically indicated.

(6) Only prelabeled input forms associated with options that are exercised in any particular problem are needed. Data associated with options not exercised are simply omitted.

Prelabeled input data forms new to the MAGIC III System are as follows:

(1) Element Temperature Input Section
(2) Element Pressure Input Section
(3) Element Pre-Strain and Pre-Stress Input Section
(4) Lumped Mass and Free-Free Input Data Section

Additional prelabeled input data forms peculiar to the triangular ring element which accommodates asymmetric loading have also been added to MAGIC III. These data forms will be described in detail in the Element Input Section which appears later in this document.

The numerical input pertinent to the above data is presented in floating point and fixed point notations. In floating point notation, the decimal point is always shown on the input data and in fixed point notation the decimal is never shown. The floating point notation is applicable, for example, to measurable quantities such as loads, coordinates, etc. The fixed point notation is limited to whole numbers or integers such as grid point numbers.

In floating point notation, a number may be written in either the conventional manner or as a factor of 10^n; for example, the number 30 000 000 = 30×10^6 can be written as either 30 000 000 or 30.0 E6. For numerical input data (both fixed and floating point) plus signs are not normally used. Negative numbers and negative exponents, however, must be preceded by a minus sign.

It is to be noted that the prelabeled input data forms discussed in this section are to be used in conjunction (when necessary) with the existing MAGIC System prelabeled data forms. The description for proper usage of existing forms is delineated in detail on pp. 93 - 213 of Reference 5.

The procedure used in the preparation of the additional prelabeled data forms will now be explained in detail. It is important to note that slashes (/) which appear on the prelabeled input data forms, instruct the Keypunch Operator to proceed to the next entry position on the input data form, or if all entries have been punched, to the next data section.

2. Element Temperature Input Section (Figure II-13)

Loading which arises from elevated temperature is considered as element applied loading and is transformed into consistent energy equivalent grid point loads according to element type. For convenience to the User, temperature values (or temperature gradients) can either be input at each grid point, or as element related data.

To provide for grid point temperature input, the Grid Point Temperature labeled data form was provided in the MAGIC II System and is detailed on pp. 114-117 of Reference 5.

An additional option is provided in MAGIC III for element related temperature data. In this section, the User may employ two time saving devices:

(1) MODAL - The MODAL option automates the specification of recurring values within a subset of input data. This feature enables data-prescribed initialization of tables. Explicit data requirements are thereby limited to the specification of exceptions to the MODAL initialization.

(2) REPEAT - A REPEAT option is available which allows the User to retain data from a previous point for the indicated point.

The prelabeled input data form provided for the Element Temperature Input Section is shown in Figure II-13 The first entry on the form is prelabeled ELTEMP and requires no information from the User.

The second entry on the form is the MODAL entry which allows the User to input element temperature data which the System assumes to apply to every element unless otherwise indicated in the Element Number Entries which follow the MODAL entry. MODAL is pre-labeled in Columns 1 through 5. Columns 6 through 12 are left blank. The number of temperatures to be entered as MODAL values is entered as a right justified fixed point number in Columns 13 and 14. The next sixty columns of this card (Columns 15 through 74) and the same sixty columns of the next card combine to form twelve ten column fields. Up to twelve temperatures per element may be entered as MODAL values. If six or less temperatures are entered. only one card is used for the MODAL values. The number and sequence of temperatures which are entered in these locations are functions of the type of element being employed in the analysis. This input is element related and will be explained in detail for each element in the sections which delineate the element descriptions.

The third and following entries in the section contain information pertaining to the Element Numbers, Repeat Option, Number of Temperatures, and Element Temperature Input, e.g.,

Element Number - (Col. 7 - 11)

(1) Element numbers are entered as fixed point numbers.

(2) Element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

The repeat option provides the User with the opportunity to repeat Temperature Input from element to element. This is accomplished in the following manner. If the Temperature Input for a number of elements is identical, the User enters the element number and associated input for the first element. For the following elements having the same input, only the Element Number (Col. 7 - 11) and an 'X' in the Repeat column need be entered. If the Repeat option is used, do not make any further entires on this card. (Be sure to leave Cols. 13 and 14 blank.)

Number of Temperatures (Cols. 13 - 14)

The number of temperatures to be entered for the element is entered as a fixed point number in Cols. 13 and 14. This field must be left blank for subsequent entries if they are being repeated from previous entries.

Temperatures (Cols. 15 - 72)

Up to twelve temperatures are entered in fields of ten starting in Column 15 and continuing to 74 for the first six, and again in Cols. 15 through 74 of a second card if necessary. The number of temperatures needed depends upon the element being described. This information is delineated in detail in the section on Element Descriptions.

REMEMBER:

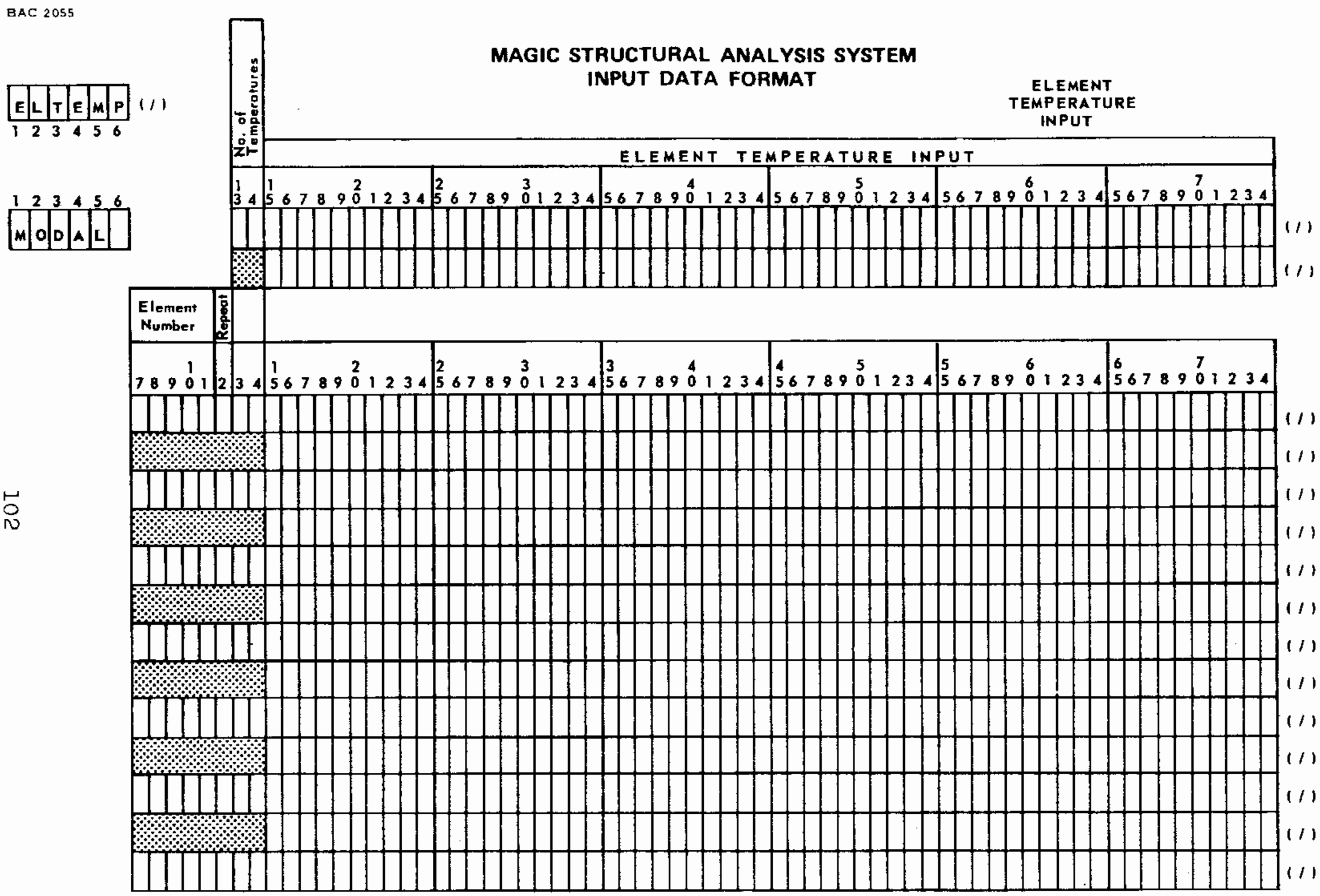
(1) For a problem with identical input for every element only the MODAL entry is required.

(2) The repeat option can be used effectively for sets of elements that have the same input. However, element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

(3) If the repeat option is used, leave the field for the number of temperatures blank (Cols. 13 and 14) for subsequent entries if they are being repeated from previous entries.

(4) If six or less temperatues are entered, only one card is used for that particular element number. Do not put in an extra blank card.

(5) The type of temperature input required for an element is a function of element type.



BAC 2055

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT
TEMPERATURE
INPUT

E L T E M P (/)
1 2 3 4 5 6

1 2 3 4 5 6
M O D A L

No. of Temperatures

ELEMENT TEMPERATURE INPUT

Element Number

Repeat

Figure II-13 - Element Temperature Input Data Form

3. Element Pressure Input Section (Figure II-14)

Loading which arises from distributed pressure is considered as element applied loading and is transformed into consistent energy equivalent grid point loads according to element type. For convenience to the User, pressure values can either be input at each grid point, or as element related data.

To provide for grid point pressure input, the Grid Point Pressure labeled data form was provided in the MAGIC II System and is detailed on pp. 110-113 of Reference 5.

An additional option is provided in MAGIC III for element related pressure data. In this section, the User may employ the same two time saving devices as previously described in the Element Temperature Section, e.g., The MODAL and Repeat Options.

The prelabeled input data form provided for the Element Pressure Input Section is shown in Figure II-14. The first entry on the form is prelabeled ELPRESS and requires no information from the User.

The second entry on the form is the MODAL entry which allows the User to input element pressure data which the System assumes to apply to every element unless otherwise indicated in the Element Number Entries which follow the MODAL entry. MODAL is pre-labeled in Cols. 1 through 5. Columns 6 through 12 are left blank. The number of pressures to be entered as MODAL values is entered as a right justified fixed point number in Columns 13 and 14. The next sixty columns of this card (Cols. 15 through 74) and the same sixty columns of the next card combine to form twelve ten column fields. Up to twelve pressures may be entered as MODAL values. If six or less pressures are entered, only one card is used for the MODAL values. The number and sequence of pressures which are entered in these locations are functions of the type of element being employed in the analysis. This input is element related and will be explained in detail for each element in the sections which delineate the element descriptions.

The third and following entries in the section contain information pertaining to the Element Numbers, Repeat Option, Number of Pressures, and Element Pressure Input, e.g.,

Element Number - (Col. 7 - 11)

(1) Element numbers are entered as fixed point numbers.

(2) Element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

The repeat option provides the User with the opportunity to repeat Pressure Input from element to element. This is accomplished in the following manner. If the Pressure Input for a number of elements is identical, the User enters the element number and associated input for the first element. For the following elements having the same input, only the Element Number (Col. 7 - 11) and an 'X' in the Repeat column need be entered. If the Repeat option is used, do not make any further entries on this card. (Be sure to leave Cols. 13 and 14 blank.)

Number of Pressures - (Col. 13 - 14)

The number of pressures to be entered for the element is entered as a fixed point number in Cols. 13 and 14. This field must be left blank for subsequent entries if they are being repeated from previous entries.

Pressures (Col. 15 - 74)

Up to twelve pressures are entered in fields of ten starting in Column 15 and continuing to 74 for the first six, and again in Cols. 15 through 74 of a second card if necessary. The number of pressures needed depends upon the element being described. This information is delineated in detail in the section on element description.

REMEMBER:

(1) For a problem with identical input for every element only the MODAL entry is required.

(2) The repeat option can be used effectively for sets of elements that have the same input. However, element numbers must be entered consistent with the order in which they were entered in the Element Control Data section.

(3) If the repeat option is used, leave the field for the number of pressures blank (Cols. 13 and 14) for subsequent entries if they are being repeated from previous entries.

(4) If six or less pressures are entered, only one card is used for that particular element number. Do not put in an extra blank card.

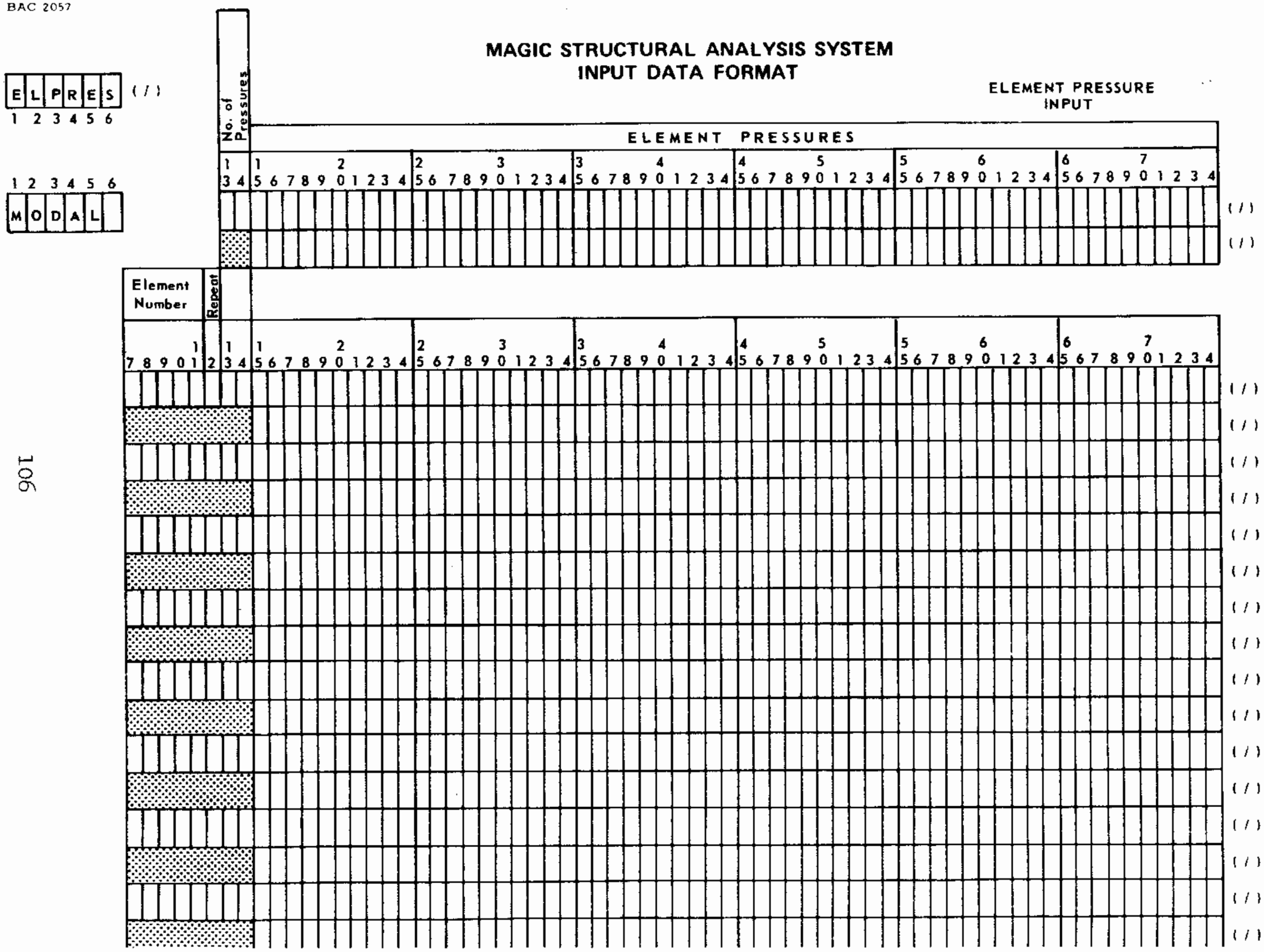
(5) The type of pressure input required for an element is a function of element type.

4. Element Pre-Strain and Pre-Stress Input Section (Figure II-15)

A prelabeled input data form is provided for element pre-strain and pre-stress input. This form is used for elements which accommodate pre-strain and/or pre-stress input (Figure II-15).

The first entry on the input data form is prelabeled STST and requires no information from the user.

The second entry on the form identifies all the following information as pertaining only to strain, only to stress, or both strain and stress. Columns seven and eight are the only columns that contain information on the second card. An 'X' in Column 7 and Column 8 left blank identifies that only pre-strain data will follow. A blank in Column 7 and an 'X' in Column 8 means that only pre-stress data will follow. If both Columns 7 and 8 contain an 'X', both pre-strain and pre-stress data will follow. Note that this card must be present in an 'STST' input section, and an 'X'



BAC 2057

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESSURE INPUT

E L P R E S (/)
1 2 3 4 5 6

1 2 3 4 5 6
M O D A L

No. of Pressures

ELEMENT PRESSURES

1 3 4 | 1 5 6 7 8 9 2 0 1 2 3 4 | 2 5 6 7 8 9 3 0 1 2 3 4 | 3 5 6 7 8 9 4 0 1 2 3 4 | 4 5 6 7 8 9 5 0 1 2 3 4 | 5 5 6 7 8 9 6 0 1 2 3 4 | 6 5 6 7 8 9 7 0 1 2 3 4

(/)
(/)

Element Number | Repeat

7 8 9 1 0 1 | 2 | 1 3 4 | 1 5 6 7 8 9 2 0 1 2 3 4 | 2 5 6 7 8 9 3 0 1 2 3 4 | 3 5 6 7 8 9 4 0 1 2 3 4 | 4 5 6 7 8 9 5 0 1 2 3 4 | 5 5 6 7 8 9 6 0 1 2 3 4 | 6 5 6 7 8 9 7 0 1 2 3 4

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(/)
(/)
(/)

Figure II-14 - Element Pressure Input Data Form must appear in either Column 7 and/or Column 8. No default has been allowed for this card, and its omission is an error.

The third entry on the input data form is the MODAL entry. This entry allows the user to input pre-strain and/or pre-stress data (depending on what was indicated on card number two) which the System assumes to apply to every element unless otherwise indicated in the Element Number entries which follow the MODAL entry.

MODAL is pre-labeled in Cols. 1 through 5. Column 6 through 12 are left blank. The next sixty columns (Cols. 13 - 72) are divided into six ten column fields. If only pre-strain input is indicated on card two, six values of pre-strain are placed on this card. If only pre-stress input is indicated, six values of pre-stress are placed on this card. If both pre-strain and pre-stress are indicated, six values of pre-strain are placed on this card and six values of pre-stress are placed on the next card in the corresponding fields. The MODAL entry is optional and should be employed only when the User wishes to input pre-strain and/or pre-stress data for every element.

The following entries in this section contain information pertaining to Element Numbers, Repeat Option and Pre-Strain and/or Pre-Stress Input, e.g.,

Element Number - (Cols. 7 - 11)

(1) Element numbers are entered as fixed point numbers.

(2) Element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

The repeat option provides the User with the opportunity to repeat pre-strain and/or pre-stress input from element to element. This is accomplished in the following manner. If the input for a number of elements is identical, the User enters the element number and associated element input for the first element. For the following elements having the same input, only the Element Number (Col. 7 - 11) and an 'X' in the Repeat column need be entered.

Pre-Strain or Pre-Stress Data (Col. 13 - 72)

The format of this data is analogous to that of the MODAL entry. One or two cards are used depending upon whether only pre-strain, only pre-stress, or both pre-strain and pre-stress are indicated on card number two.

The information describing the sequence of pre-strain or pre-stress data is element dependent and is presented for each of the applicable element types in the section on element description.

REMEMBER:

(1) For a problem with identical input for every element only the MODAL entry is required.

(2) The repeat option can be used effectively for sets of elements that have the same input. However, element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

(3) The type of pre-strain and/or pre-stress input required for an element is a function of element type.

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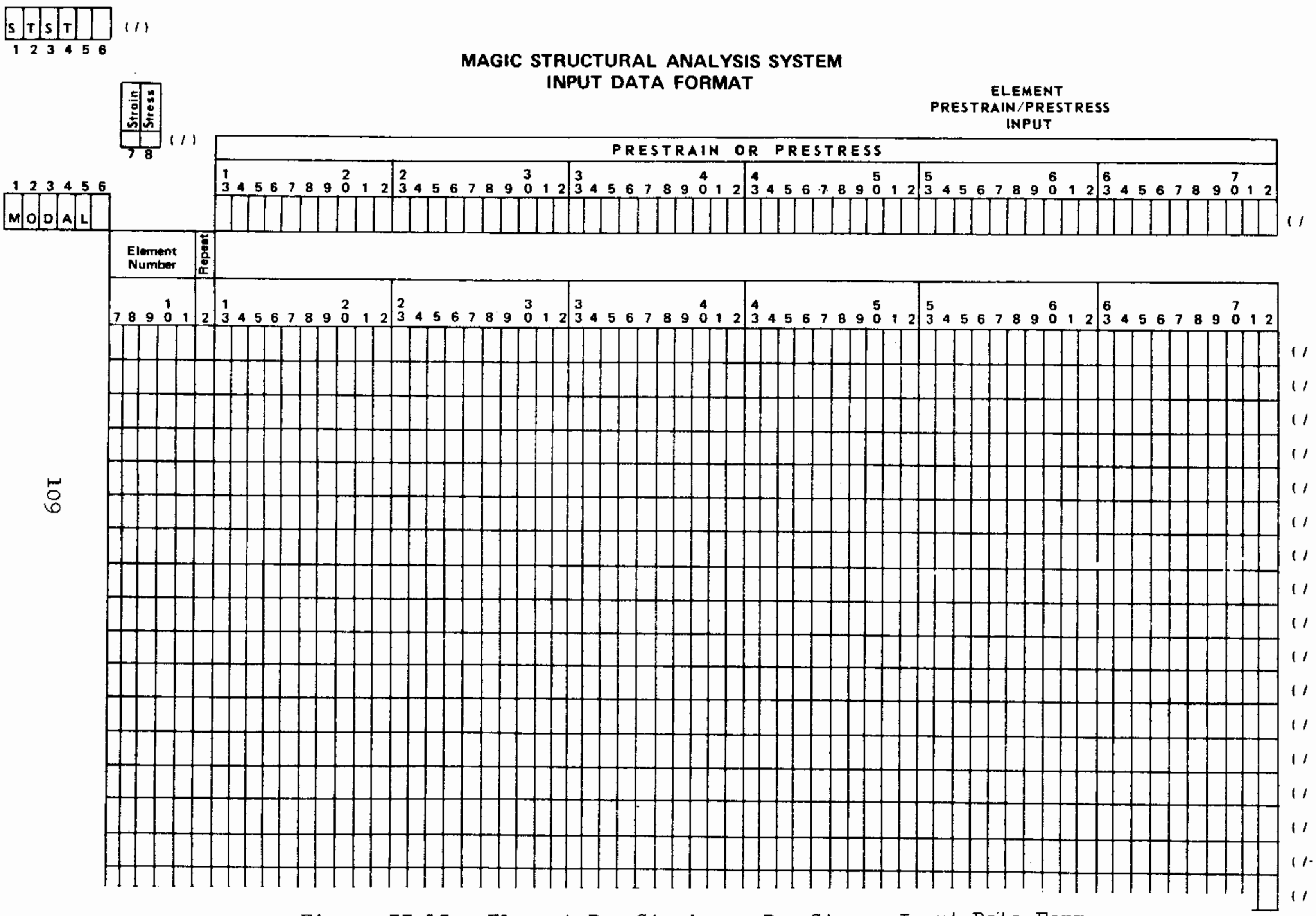
MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESTRAIN/PRESTRESS INPUT



S T S T (/)
1 2 3 4 5 6

Strain | Stress (/)
7 8

M O D A L
1 2 3 4 5 6

PRESTRAIN OR PRESTRESS
13 14 15 16 17 18 19 20 21 22 | 23 24 25 26 27 28 29 30 31 32 | 33 34 35 36 37 38 39 40 41 42 | 43 44 45 46 47 48 49 50 51 52 | 53 54 55 56 57 58 59 60 61 62 | 63 64 65 66 67 68 69 70 71 72 (/

Element Number 7 8 9 10 11 | Repeat 12 | 13 14 15 16 17 18 19 20 21 22 | 23 24 25 26 27 28 29 30 31 32 | 33 34 35 36 37 38 39 40 41 42 | 43 44 45 46 47 48 49 50 51 52 | 53 54 55 56 57 58 59 60 61 62 | 63 64 65 66 67 68 69 70 71 72 (/

Figure II-15 - Element Pre-Strain or Pre-Stress Input Data Form

5. Lumped Mass and Free-Free Input Section (Figure II-16)

Lumped structural and non-structural masses are specified by component against grid point number. The axes of reference are specified with reference to the Global System.

The labeled input data format provided for the Lumped Mass Section is shown in Figure II-16. A total of nine possible mass values are provided for in this section. These are as follows:

(1) Three Direct Inertias (M_x, M_y, M_z)

(2) Three Rotational Inertias ($M_{\theta x}$, $M_{\theta y}$, $M_{\theta z}$) and

(3) Three Generalized Inertias (M_1, M_2, M_3).

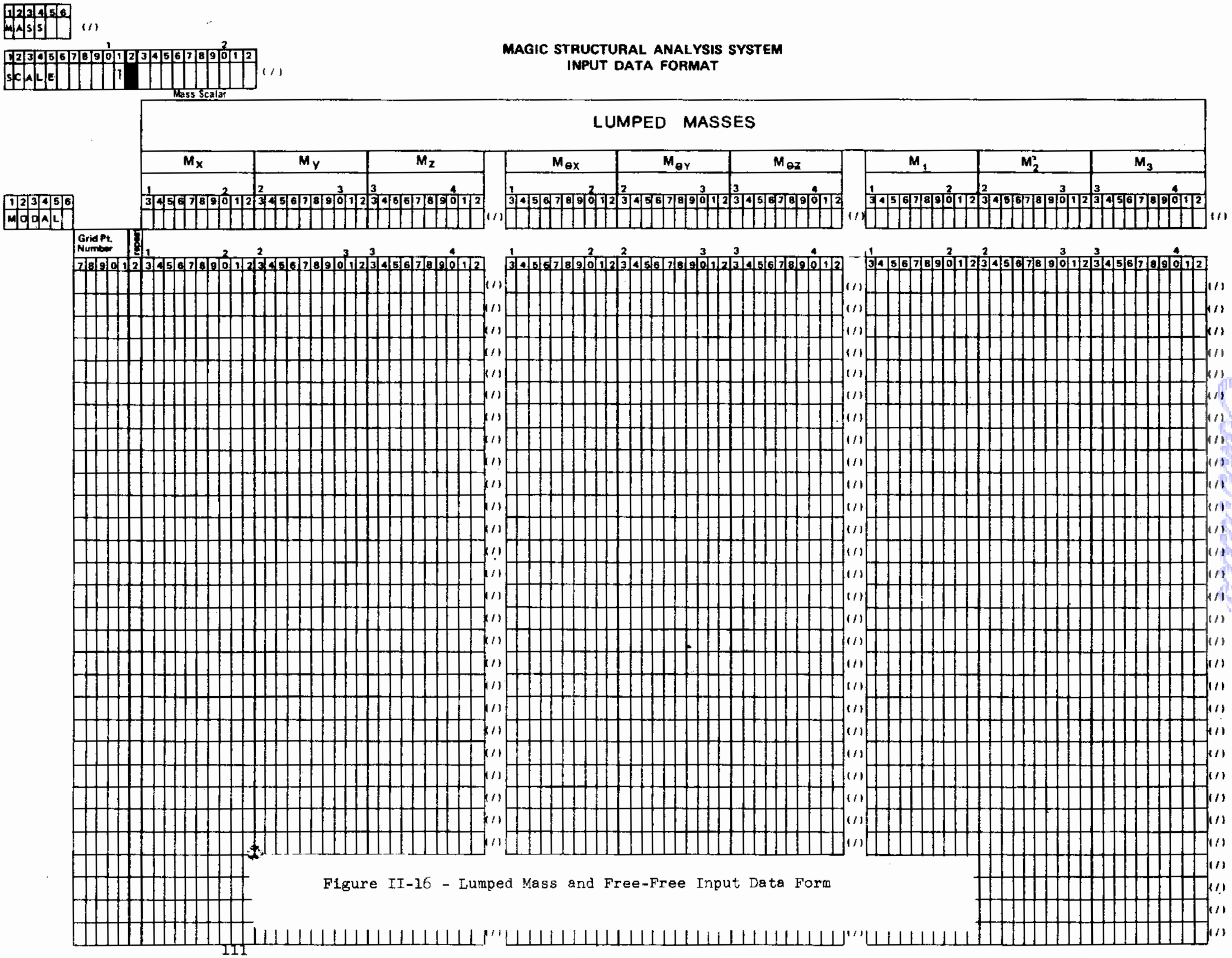
The total number of degrees of freedom entries per grid point is dependent on the element type being employed in the analysis. Three types appear in the MAGIC III System, i.e.,

(1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree-of-Freedom entries per point: Possible Inertia Values (M_x, M_y, M_z).

(2) Frame Element, Incremental Frame, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate Elements, Symmetric Shear Web, High Aspect Ratio Quadrilateral Thin Shell, Tetrahedron, Triangular Prism, Rectangular Prism - Six Degree-of-Freedom entries per point: Possible Interia Values (M_x, M_y, M_z, $M_{\theta x}$, $M_{\theta y}$, $M_{\theta z}$).

(3) Toroidal Thin Shell Ring - Nine Degree-of-Freedom entries per point: Possible Inertia Values (M_x, 0, M_z, 0, $M_{\theta y}$, 0, M_1, 0, M_3). The M_1, 0 and M_3 are a set of generalized masses which correspond to non-physical derivative degrees-of-freedom for the toroidal ring. In general, these values are set equal to zero.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT



1	2	3	4	5	6	
M	A	S	S			(/)

1	2	3	4	5	6	7	8	9	10	11	12	13–22	
S	C	A	L	E						1		Mass Scalar	(/)

LUMPED MASSES

1	2	3	4	5	6
M	O	D	A	L	

Mx	My	Mz		Mθx	Mθy	Mθz		M1	M2	M3	
13–22	23–32	33–42	(/)	13–22	23–32	33–42	(/)	13–22	23–32	33–42	(/)

Grid Pt. Number	repeat	Mx	My	Mz		Mθx	Mθy	Mθz		M1	M2	M3	
7–11	12	13–22	23–32	33–42	(/)	13–22	23–32	33–42	(/)	13–22	23–32	33–42	(/)

Figure II-16 - Lumped Mass and Free-Free Input Data Form

The applicable concentrated masses are entered as floating point numbers. It is important to note that Keypunch Personnel have been instructed to ignore entries that are not filled in. Blank entries are not considered as zeros. Zeros must be entered in an entry when applicable.

The first entry on the Lumped Mass input data form is prelabeled MASS and requires no information from the User. The second entry is prelabeled SCALE in Columns 1-5 and the integer 1 in Column 11. The User supplies one item of information for this entry as follows:

Mass Scalar - (Cols. 13-22)

The Mass Scalar value is entered as a floating point number and is used when performing a free-free vibration analysis with or without condensation.

The value of the mass scalar corresponds to the value of the constant, a_0 , which multiplies the assembled mass matrix. (Note the descriptions of free-free dynamics analysis (DYNAMICSF) and free-free dynamics analysis with condensation (DYNAMICSCF) which appear on pp. 82-84 and 92 of this report.)

It is noted that if a free-free analysis is not being performed, the mass scalar is not utilized. Furthermore, this input data form need only be utilized for the following:

(1) Free-free vibration analyses with or without condensation and with or without lumped structural or non-structural masses.

(2) Vibration analysis (rigid body modes suppressed) with or without condensation and with lumped structural or non-structural masses.

The next entry on the form is the MODAL entry. This entry allows the User to input a set of mass values which the program assumes to apply to every grid point unless otherwise indicated by a separate grid point entry on the grid point cards. MODAL is prelabeled on this card and the only information required by the User are the lumped mass values which have been discussed previously.

The third and following entries contain information pertaining to the Grid Point Numbers, Repeat Option and Lumped Masses, as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid Point Numbers are entered as fixed point numbers.

(2) Grid Point Numbers can be entered in any sequence desired.

Repeat - (Col. 12)

The repeat option allows the User to repeat values of lumped mass from grid point to grid point. This is accomplished in the following manner. If the lumped mass values at a number of grid points are identical, the User enters the grid point number and associated lumped mass values for the first grid point. For the following points baring identical lumped masses only, the grid point number (Col. 7-11) and an "X" in the repeat (Col. 12) need be entered. If the repeat option is employed, only one card per grid point is required for the repeated entry irregardless of whether the degree-of-freedom entries per grid point are three, six or nine.

Remember:

(1) The Lumped Mass input data section is utilized for the following:

  a. Free-Free vibration analysis with or without condensation and with or without lumped structural or non-structural masses. Note that for free-free analysis a mass scalar value not equal to zero is required to properly perform the analyses as defined by the DYNAMICSF and DYNAMICSCF Agendums.

  b. Vibration analyses with or without condensation (in which the rigid body modes have been suppressed) with lumped structural or non-structural masses. For this case the mass scalar value is set equal to 0.0 or it is not entered. If there are no lumped masses present, the form is omitted.

(2) The Repeat option can be used effectively for sets of grid points having identical lumped masses.

(3) Lumped masses are not element related and should not be confused with element generated mass matrices.

(4) Zeros must be entered when applicable. Blanks are not zeros.

(5) If the number of degree-of-freedom entries per grid point is equal to three (3) then only the inertia values (M_x, M_y, M_z) are applicable. The other two entries (Rotational and Generalized Masses) are ignored by the User.

(6) If the number of degrees-of-freedom entries per grid point is equal to six (6) then the Translational and Rotational Inertia values must be considered. If, for instance, at a certain grid point there are translational inertias but no rotational inertias,

zeros must be entered for the rotational inertia values or this entry will be ignored by the Keypunch Operator. This would cause premature termination of the run since six degree-of-freedom elements require two lumped mass cards per grid point.

(7) If the number of degree-of-freedom entries per grid point is equal to (9), then Translational, Rotational and Generalized Masses must be entered. If some of these entries are equal to zero, these zero values must still be entered; otherwise, the entries will be ignored by the Keypunch Operator causing premature termination of the run.

(8) Repeated grid points require only one card.

6. Element Control Data Section (Figure II-17)

The Element Control Data Section establishes control on the types and number of elements which are to be used in a specific analysis. A prelabeled input data form is provided for the Element Control Data Section and is shown in Figure II-17. This form is applicable to all finite elements which are contained in the MAGIC Library. Upon examination of the form, it is seen that certain data are applicable to all of the elements in the library while other data are element dependent.

The first entry on the form is prelabeled ELEM and requires no information from the User. The second and following entries contain the following information.

Element Number - (Cols. 7-10)

(1) The element number which defines the element being considered is entered in this location.
(2) Elements can be entered in any sequence desired.
(3) The element number is entered as a fixed point number.

Plug Number - (Cols. 11-12)

(1) Each additional finite element in the Element Library has an identification number as follows:
    (a) Number 52 - (Rectangular Prism)
    (b) Number 50 - (Tetrahedron)
    (c) Number 51 - (Triangular Prism and Symmetric Triangular Prism)
    (d) Number 29 - (Symmetric Shear Web)
    (e) Number 38 - (High Aspect Ratio Quadrilateral Thin Shell)
    (f) Number 31 - (Triangular Cross-Section Ring, Asymmetric Loading)
(2) Identification Numbers are entered as fixed point numbers.

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E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	Supress Pressure	NODE POINTS												
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	1 2	3 4 5 6 7 8	19	20 1 2 3 4 5 6 7	28	29	30	31	32	33 34	35	36 7 8	9 40 1	2 3 4	5 6 7	8 9 50	1 2 3	4 5 6	7 8 9	60 1 2	3 4 5	6 7 8	9 70 1	
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Figure II-17 - Element Control Data Form

Material Number - (Cols. 13-18)

The material number is the number of the material associated with the element in question. This number is referenced to the material tape. For instance, if the User were using material number 138, this material would have had to be on the tape at the time of the run or be a material that the User was adding to the tape for this particular run. The material number must appear exactly as it was in Cols. 10-15 of the MATER section.

Temperature Interpolate Option - (Col. 19)

The Temperature Interpolate Option is exercised in the following manner:

(1) If an entry is not made in Column 19, the program will average the node point temperatures of the element in question and use this average temperature when establishing material properties from the material tape.

(2) If a '1' is entered in Column 19, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

(3) If a number n ($n > 1$) is entered in Column 19, then this number is equal to the number of node points which will participate in the averaging process. The first n node points entered in Columns 36-71 (Node Point Section), of the Element Control Data Section will then be used in the averaging process.

Material Temperature - (Cols. 20-27)

If the User exercises the Temperature Interpolate Option by placing a '1' in Column 19, then a temperature associated with the element in question should be entered in Columns 20-27 in a thermal stress analysis. The program will then use this temperature when establishing material properties from the Material Tape.

Repeat Element Matrices - (Col. 28)

Element matrices generated for assembly against a particular finite element specification can also be used for the next element in the calculation sequence. This avoids repeated calculation of identical element matrices. Experience indicates a high frequency of opportunities for exploiting this feature. Input data requirements and execution times can be significantly reduced with use of this feature. The option is exercised by the User by placing an 'X' in Col. 28 opposite the Element Number for which element matrices are to be repeated.

Element Input - (Col. 29)

Certain of the additional elements contained in the MAGIC III System Element Library require element input. The rectangular prism, symmetric shear web, high aspect ratio quadrilateral thin shell, and triangular cross-section ring elements always require element input. An 'X' is placed in Column 29 for these elements.

A prelabeled input data form is provided especially for element input. This form will be discussed in detail immediately following the discussion of the Element Control Data input form.

Interpolated Input Print - (Col. 30)

If the User places an 'X' in Column 30, the following information is obtained:

(1) Material Number
(2) Material Identification
(3) Type of Material; i.e., Isotropic or Orthotropic

(4) Interpolated Material Properties, which include
    (a) Temperature
    (b) Young's Modulus
    (c) Poisson's Ratio
    (d) Thermal Expansion Coefficients
    (e) Rigidity Moduli

Element Matrix Print - (Col. 31)

If the User places an 'X' in Column 31, a print of element matrices associated with the element in question is obtained.

Full Print (Col. 32)

If the User places an 'X' in Column 32 a total print of all element matrices and intermediate computations is obtained for the element in question. In general, this option is exercised when debugging a problem.

Number of Input Nodes - (Cols. 33-34)

The number of input nodes is the number of node points which define an element. The following number of code points are applicable to the additional elements in the MAGIC Library.

(1)	Rectangular Prism	8 Node Points
(2)	Tetrahedron	4 Node Points
(3)	Triangular Prism	6 Node Points
(4)	Symmetric Prism	3 Node Points
(5)	Symmetric Shear Web	2 Node Points
(6)	High Aspect Ratio Quadrilateral	8 Node Points
(7)	Triangular Ring (Asymmetric Load)	3 Node Points

Pressure Suppression Option - (Col. 35)

Pressure Load Matrices are generated at the element level in the MAGIC System. The User has the option of placing an "X" in Column 35, if it is desired to suppress the generation of the pressure Load Vector for any particular element.

Node Points - (Cols. 36-71)

These locations are reserved for the node points which describe the element in question. The User should note that three column fields are set aside for each node point. There are 12 locations set aside for node points.

7. Element Input Section - (Figure II-18)

A labeled input data form is provided for the Element Input Section. This form is used for elements which require Element Input: (Column 29 of the Element Control Data Section).

The first entry on the form is prelabeled EXTERN and requires no information from the User. The second entry on the input data form is the MODAL entry which allows the User to input element input which the program assumes to apply to every element unless otherwise indicated in the Element Number entries which follow the MODAL card. It can be seen from the input data form that the Element Input is labeled A, B, C, D, E, F with each item contained in a ten column field. These are the locations where the element input is entered, if the element being used requires element input. The entries made in Locations A through F are entered as floating point numbers. The values which are entered in these locations are functions of the type of element being employed in the analysis. This input, therefore, is element related and will be explained in detail for each element in the following section.

The third and following entries in the section contain information pertaining to the Element Numbers, Repeat Option and Element Input, i.e.:

Element Number - (Cols. 7-11)

(1) Element Numbers are entered as fixed point numbers.

(2) Element Numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

The repeat option provides the User with the opportunity to repeat Element Input from element to element. This is accomplished in the following manner. If the element input for a number of elements is identical, the User enters the element number and associated element input for the first element. For the following elements having the same element input, only the Element Number (Col. 7-11) and an 'X' in the Repeat column need be entered.

REMEMBER:

(1) For a problem with identical Element Input for every element only the MODAL entry is required.

(2) The repeat option can be used effectively for sets of elements that have the same Element Input.

(3) The type of element input required for an element is a function of element type. This element input will be completely described in the following sections.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

ELEMENT INPUT

1 2 3 4 5 6	A 1 2 3 4 5 6 7 8 9 0 1 2	B 2 3 3 4 5 6 7 8 9 0 1 2	C 3 4 3 4 5 6 7 8 9 0 1 2	D 4 5 3 4 5 6 7 8 9 0 1 2	E 5 6 3 4 5 6 7 8 9 0 1 2	F 6 7 3 4 5 6 7 8 9 0 1 2
M O D A L						

Element Number 1 7 8 9 0 1	Repeat 2	1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2	
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								(/)

Figure II-18 - Element Input Data Form

8. Element Input Description

a. Rectangular Prism (Ident. No. 52)

The rectangular prism element, Figure II-19, is a powerful tool for the analysis of solid structures, thick plates and beams. It can be used in conjunction with the triangular prism and tetrahedral discrete elements for the analysis of arbitrary solid geometries, or with plate elements for the analysis of built-up regions. The shape of the element is defined by the coordinates of the eight corner points.

Trilinear Lagrangian interpolation formulas were used as assumed displacement functions in the development of the subject element. Due to the assumption of linear interpolation formulas, the edges of the prism remain linear in deformation. A direct consequence is that, although a single element may warp under a force-couple, it may not bend under any conditions. The foregoing assumed displacement functions lead to three translational displacement degrees of freedom at each of the eight corner grid points; thus, the complete element deformation is described by twenty-four (24) displacement degrees of freedom.

The element is written to accommodate three dimensional orthotropic material. Element stresses are given at the centroid of the element and include stresses due to displacements of the element (apparent stress), stresses due to the pre-strain state within the element and stresses due to temperature within the element. Two specific cases are denoted with respect to the prestrain and thermal stress (and associated loads) states. These are called out under "Strain Control" below and represent a constant strain (or temperature) state throughout the element and a non-constant strain (or temperature) state throughout the element.

The following element matrices are provided for the rectangular prism in the MAGIC System:

STIFFNESS	
STRESS	
APPLIED LOAD	(includes thermal, pressure and initial strain contributions)
APPLIED STRESS	(includes thermal and initial strain contributions)
CONSISTENT MASS	

Element referenced temperatures are provided by listing eight grid point temperatures on the Element Temperature Data Form (Figure II-13). The User has the option of calling out a constant temperature state or a temperature state which is of the same functional form as the assumed displacement mode shapes (i.e., trilinear Lagrangian interpolation formulas). The option is specified on the Element Input form as described below. Temperatures must be listed consistent with element numbering system.

The rectangular prism is provided with uniform pressures acting on the 6 faces of the element. The normal pressure is considered positive when acting away from the face in question (See Figure II-19). The pressures are input on the element level according to the Element Pressure Data Form (See Figure II-14). in the following manner:

Number of pressures = 6

Col. 15 - 24	is the pressure acting on face	1234
25 - 34	is the pressure acting on face	5678
35 - 44	is the pressure acting on face	1458
45 - 54	is the pressure acting on face	2367
55 - 64	is the pressure acting on face	1256
65 - 74	is the pressure acting on face	3478

Initial strains are input on the element level according to the Element Strain-Stress Input Data Form (See Figure II-15) in the following manner:

Col. 13 - 22 is ϵ_{xx}

23 - 32 is ϵ_{yy}

33 - 42 is ϵ_{zz}

43 - 52 is ϵ_{xy}

53 - 62 is ϵ_{yz}

63 - 72 is ϵ_{zx} .

The element formulation does not use the initial stress data so blank cards must be inserted.

The element control data which is required for the Rectangular Prism Element is as follows (See Figure II-17).

Element Number - Cols. 7-10

Refer to Element Control Section.

Plug Number - Cols. 11-12

The Rectangular Prism Element is identified as Number 52.

Material Number - Cols. 13-18

Refer to Element Control Section.

Temperature Interpolate Option - Col. 19

If the User exercises this option by not making an entry in Col. 19, the program will average the 8 node point temperatures when establishing material properties from the material tape. If the user wishes to employ a specific number of node points, n, in the average process $(1 < n < 8)$, then this number is entered in Column 19 and the first n node points entered in Cols. 36-71 will be used for the averaging process. If a "1" is entered in this location, the program will use the material temperature entered in Cols. 20-27 when establishing material properties from the material tape.

Material Temperature - Cols. 20-27

Refer to Element Control Section.

Repeat Element Matrices - Col. 28

Refer to Element Control Section.

Element Input - Col. 29

The rectangular prism element always requires Element Input; therefore, an 'X' is always placed in Column 29 when a rectangular prism element is being used. The Element Input (Figure II-18) required for the Rectangular Prism consists of the following information:

Location A - Cols. 13-22

Strain Control, SC

if SC = 0.0, the element is under a constant strain (temperature).

if SC = 1.0, the element is not at a constant strain (temperature).

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - Col. 30

Refer to Element Control Section.

Element Matrix Print - Col. 31

Refer to Element Control Section

Full Print - Col. 32

Refer to Element Control Section.

Number of Input Nodes - Cols. 33-34

The Rectangular Prism Element is always defined by eight input nodes.

Pressure Suppression Option - Col. 35

Refer to Element Control Section.

Node Points (Cols. 36-71)

The Rectangular Prism Element is defined by 8 grid points.

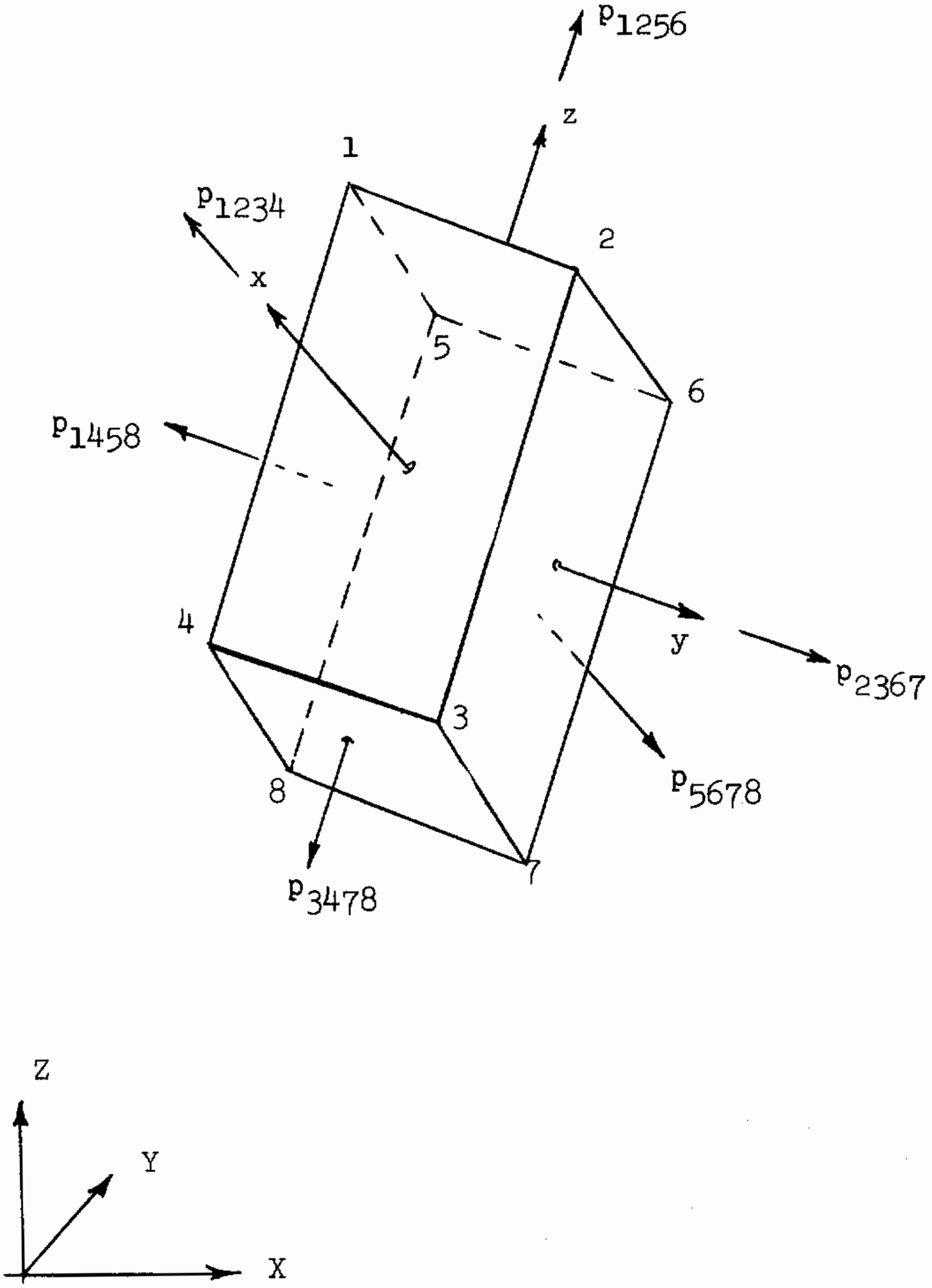

Figure II-19 - Rectangular Prism Element

b. Tetrahedron (Ident. No. 50)

The tetrahedron discrete element, Figure II-20, can be used to analyze solid structures such as beams and plates. It can also be used in conjunction with the rectangular prism and triangular prism solid elements and in fact is used to generate the triangular prism element. The shape of the element is defined by the coordinates of the four corner points.

A linear polynomial is used for each of the three displacement modes. These mode shapes lead to a total of twelve (12) undetermined coefficients for the element which are chosen to correspond to three translational displacement degrees of freedom at each of the four vertices of the element. The nature of the assumed displacement modes is such that the strains throughout the element are constant.

The element is written to accommodate three dimensional orthotropic material. Element stresses include stresses due to displacement (apparent stress), stresses due to the prestrain state within the element and stresses due to temperature within the element.

The following element matrices are provided for the tetrahedron in the MAGIC System:

STIFFNESS
STRESS
APPLIED LOAD (includes thermal, pressure and initial strain contributions)
APPLIED STRESS (includes thermal and initial strain contributions)
CONSISTENT MASS

Element referenced temperatures are provided by listing four grid point temperatures on the Element Temperature Data Form (Figure II-13). These temperatures are then averaged in the MAGIC System to provide a weighted element input temperature. Temperatures must be listed consistent with element numbering system.

The tetrahedron is provided with uniform pressures acting on the 4 faces of the element. The normal pressure is considered positive when acting away from the face in question (see Figure II-20). The pressures are input on the element level according to the Element Pressure Data form (See Figure II-14) in the following manner:

Number of pressures = 4

Col. 15-24 is the pressure acting on face 134
25-34 is the pressure acting on face 234
35-44 is the pressure acting on face 124
45-54 is the pressure acting on face 123

Initial strains are input on the element level according to the Element Strain-Stress Input Data Form (see Figure II-15) in the following manner:

Col. 13-22 is ϵ_{xx}
23-32 is ϵ_{yy}
33-42 is ϵ_{zz}
43-52 is ϵ_{xy}
53-62 is ϵ_{yz}
63-72 is ϵ_{zx}

The element formulation does not use the initial stress data so blank cards must be inserted.

The element Control Data which is required for the Tetrahedron Element is as follows (see Figure II-17).

Element Number - Cols. 7-10

Refer to Element Control Section.

Plug Number - Cols. 11-12

The Tetrahedron Element is identified as Number 50.

Material Number - Cols. 13-18

Refer to Element Control Section.

Temperature Interpolate Option (Col. 19)

If the user exercises this option by not making an entry in Column 19, the program will average the 4 node point temperatures when establishing material properties from the material tape. If the user wishes to employ a specific number of node points, n, in the average process ($1 < n < 4$), then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a "1" is entered in this location, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - Cols. 20-27

Refer to Element Control Section.

Repeat Element Matrices - Col. 28

Refer to Element Control Section.

Element Input - Col. 29

The tetrahedron element requires no element input.

Interpolated Input Print - Col. 30

Refer to Element Control Section.

Element Matrix Print - Col. 31

Refer to Element Control Section.

Full Print - Col. 32

Refer to Element Control Section.

Number of Input Nodes - Cols. 33-34

The tetrahedron element is always defined by 4 input nodes.

Pressure Suppression Option - Col. 35

Refer to Element Control Section.

Node Points - Col. 36-71

The tetrahedron element is defined by 4 grid points.

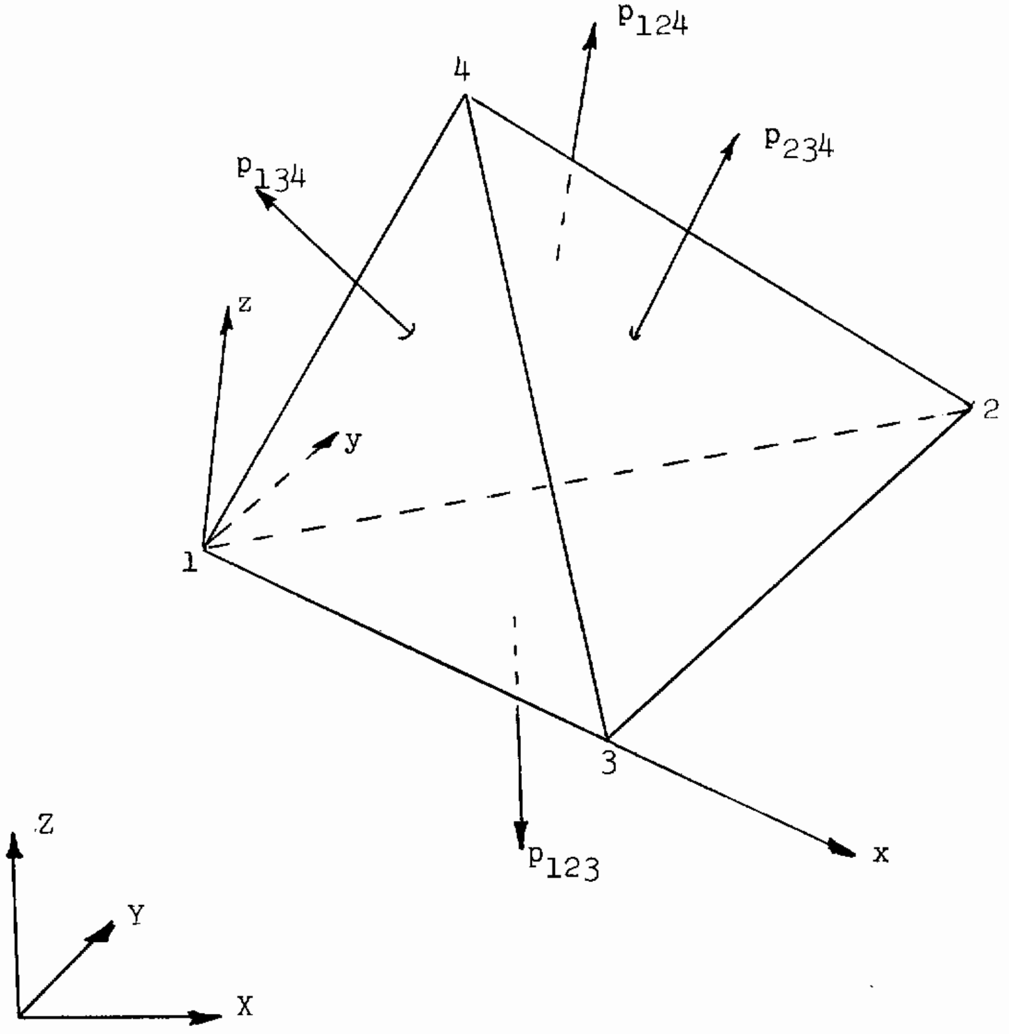

FIGURE II-20 - TETRAHEDRON ELEMENT

c. Triangular Prism (Ident. No. 51)

Three tetrahedrons are assembled as shown in Figure II-21 to form a triangular prism. Using this approach element matrices for three tetrahedrons are computed and assembled automatically within the MAGIC III System. A considerable reduction in input is realized which leads to a corresponding reduction in the possibility of input error when large scale analyses are performed. The input for one triangular prism element is identical to that for one tetrahedron except that six grid points define the prism instead of four which define the tetrahedron.

Element stresses are output for each tetrahedron which comprise the triangular prism. These include stresses due to displacement (apparent stress), stresses due to the prestrain state within the element and stresses due to temperature within the element.

The symmetric triangular prism finite element shown in Figure II-22 is a special case of the full, triangular prism element. This element was developed to eliminate conditioning problems inherent in the analysis of thin symmetric sections. As an example, in the analysis of aircraft wing or tail sections, the element can be used very effectively to model full-depth honeycomb core constructions which are used for shear transfer between the top and bottom skins. The use of this element allows the analysis to be performed using either the top or bottom symmetric half of the structure.

Appropriate boundary conditions are applied at the element level which specialize the full-depth prism into the symmetric element. The procedure employed in the reduction is as follows. Six tetrahedron elements are automatically assembled within the program with the three on the lower side of the axis of symmetry being the mirror images of the corresponding three tetrahedrons on the upper side. This approach assures that symmetric and antisymmetric modes will uncouple when the element is specialized to a symmetric representation. Appropriate symmetric and antisymmetric boundary conditions are imposed on the centerline of symmetry at the element level. Based on these conditions, the degrees of freedom associated with the bottom symmetric half of the structure are expressed in terms of the remaining degrees of freedom. Thus, a transformation between deformations on the full prism and symmetric prism is derived which is used in a simple fashion to generate the desired matrices.

The following element matrices are provided for the triangular prism in the MAGIC system.

STIFFNESS
STRESS
APPLIED LOAD (includes thermal, pressure and initial strain contributions)
APPLIED STRESS (includes thermal and initial strain contributions)
CONSISTENT MASS

Element referenced temperatures are provided by listing six grid point temperatures on the Element Temperature Data Form (Figure II-13). Temperatures must be listed consistent with element numbering system.

The triangular prism is provided with uniform pressures acting on the 5 faces of the element. The normal pressure is considered positive when acting away from the face in question (see Figure II-21). The pressures are input on the element level according to the Element Pressure Data Form (See Figure II-14) in the following manner:

Number of pressures = 5

Col. 15-24 is the pressure acting on face 123
25-34 is the pressure acting on face 456
35-44 is the pressure acting on face 2365
45-54 is the pressure acting on face 1364
55-64 is the pressure acting on face 2541

Initial strains are input on the element level according to the Element Strain-Stress Input Data Form (See Figure II-15) in the following manner:

Col. 13-22 is ϵ_{xx}
23-32 is ϵ_{yy}
33-42 is ϵ_{zz}
43-52 is ϵ_{xy}
53-62 is ϵ_{yz}
63-72 is ϵ_{zx}

The element formulation does not use the initial stress data so blank cards must be inserted.

The element Control Data which is required for the Triangular Prism Element is as follows (See Figure II-17)

<u>Element Number - Cols. 7-10</u>

Refer to Element Control Section.

<u>Plug Number - Cols. 11-12</u>

The triangular prism element is identified as number 51.

<u>Material Number - Cols. 13-18</u>

Refer to Element Control Section.

<u>Temperature Interpolate Option - Col. 19</u>

If the user exercises this option by <u>not</u> making an entry in Col. 19, the program will average the 6 node point temperatures when establishing material properties from the material tape. If the user wishes to employ a specific number of node points, n, in the average process

(1<n<6), then this number is entered in Col. 19 and the first n node points entered in Cols. 36-71 will be used for the averaging process. If a "1" is entered in this location, the program will use the material temperature entered in Cols. 20-27 when establishing material properties from the material tape.

Material Temperature - Cols. 20-27

Refer to Element Control Section.

Repeat Element Matrices - Col. 28

Refer to Element Control Section.

Element Input - Col. 29

The triangular prism element requires no element input.

Interpolated Input Print - Col. 30

Refer to Element Control Section.

Element Matrix Print - Col. 31

Refer to Element Control Section.

Full Print - Col. 32

Refer to Element Control Section.

Number of Input Nodes - Cols. 33-34

The triangular and symmetric triangular prism elements are always defined by 6 input nodes.

Pressure Suppression Option - Col. 35

Refer to Element Control Section.

Node Points - Cols. 36-71

The triangular prism element is defined by 6 grid points.

If node points 4, 5, and 6 do not exist (that is, are not input), the element then becomes a symmetrical triangular prism with the plane of symmetry being midway between node points 1, 2, 3 and node points 4, 5 and 6 (namely the XY plane of the structure - See Figure II-22).

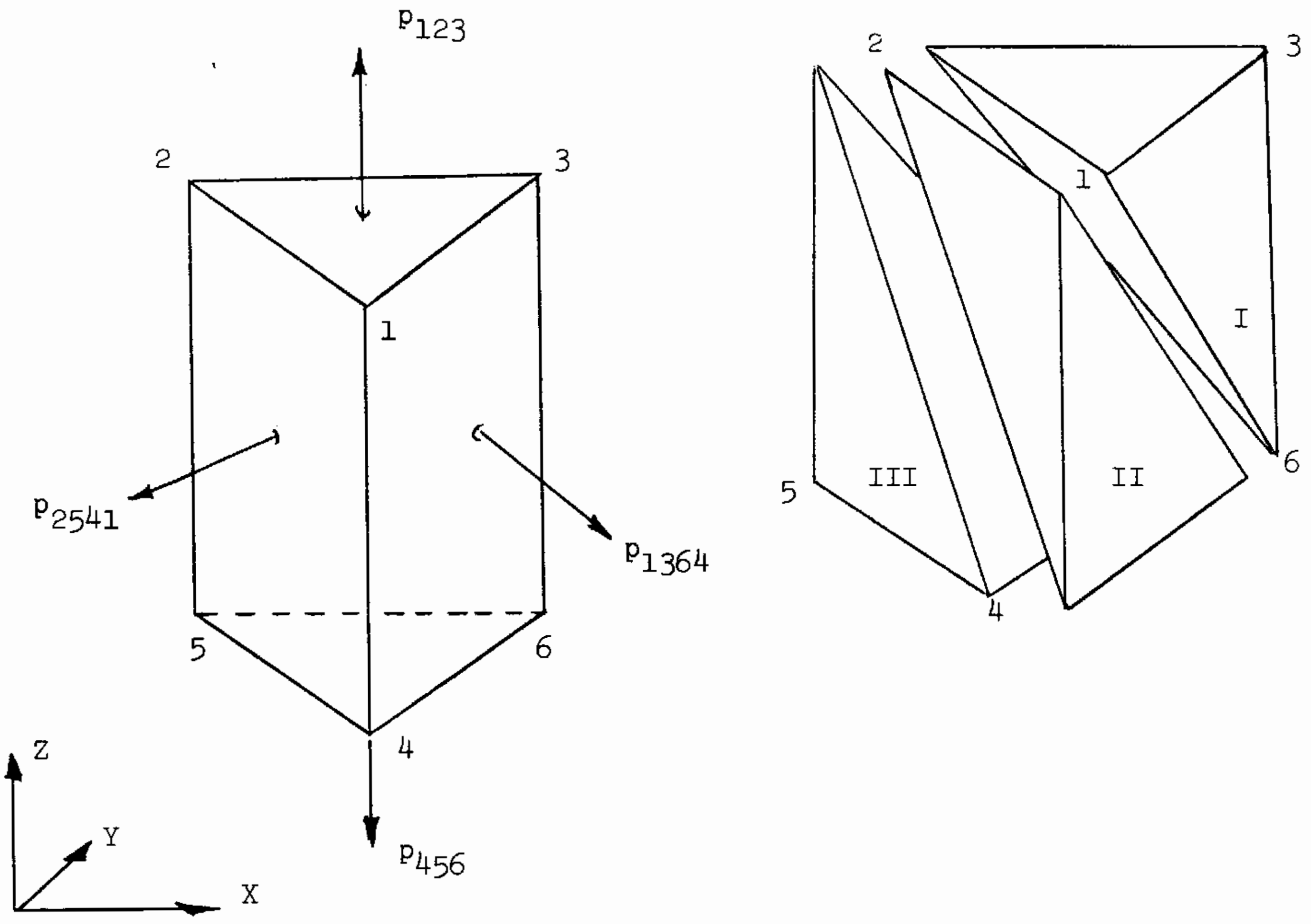

FIGURE II-21 TRIANGULAR PRISM ELEMENT

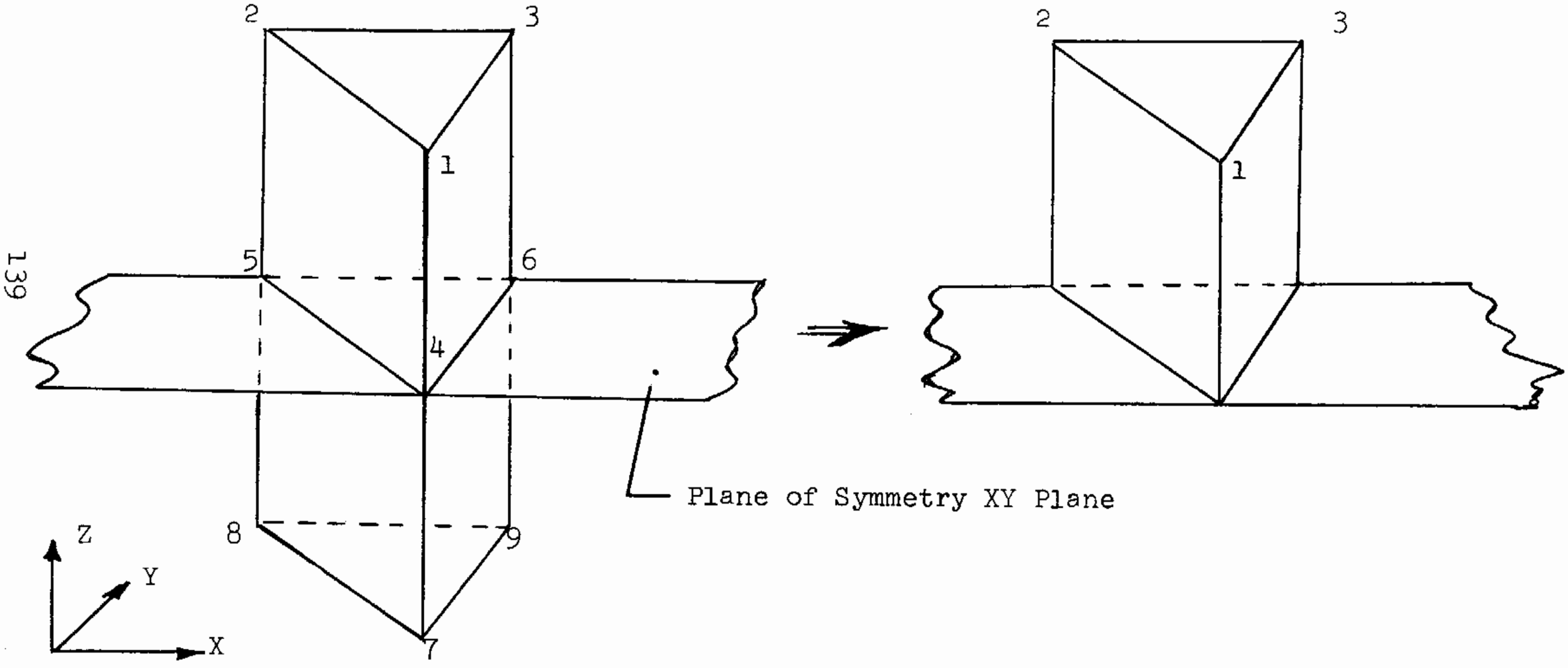

FIGURE II-22 SYMMETRIC TRIANGULAR PRISM ELEMENT

d. Symmetrical Shear Web (Ident. No. 29)

The symmetric shear web element as shown in Figure II-23 was developed to conduct analyses of the type discussed in the previous section, Section C.8.b, Triangular Prism. Appropriate symmetric and antisymmetric boundary conditions are imposed on the centerline of symmetry at the element level. Based on these conditions, element matrices can be readily derived using only the two upper grid points as reference points.

The assumed displacement method is utilized to derive the stiffness and stress matrices. These displacement functions in the local coordinate system are:

$$\mu\ (x,z) = (a_1 + a_2 x)z$$

$$w\ (x) = b_1 + b_2 x + b_3 x^2 + b_4 x^3$$

These functions yield six translational deformations, three translations at each of two grid points. Element stresses are evaluated at the midpoint of the element's length and yield the shearing stress at that point.

The following element matrices are provided for the symmetric shear web in the MAGIC System:

STIFFNESS
STRESS

The element Control Data which is required for the Symmetrical Shear Web is as follows (See Figure II-17):

Element Number - Cols. 7-10

Refer to Element Control Section.

Plug Number - Cols. 11-12

The Symmetrical shear web element is identified as Number 29.

Material Number - Cols. 13-18

Refer to Element Control Section.

Temperature Interpolate Option - Col. 19

If the user exercises this option by not making an entry in Col. 19, the program will average the 2 node point temperatures when establishing material properties from the material tape. If the user wishes to employ a specific number of node points, n, in the average process ($1 \leq n \leq 2$), then this number is entered in Col. 19 and the first n node points entered in Cols. 36-71 will be used for the averaging process. If a "1" is entered in this location, the program will use the Material Temperature entered in Cols. 20-27 when establishing material properties from the material tape.

Material Temperature - Cols. 20-27

Refer to Element Control Section.

Repeat Element Matrices - Col. 28

Refer to Element Control Section.

Element Input - Col. 29

The symmetrical shear web element always requires Element Input. Therefore, an 'X' is always placed in Col. 29 when the symmetrical shear web is being employed.

The Element Input (Figure II-18) required for the symmetrical shear web consists of the following information:

Location A - Cols. 13-22

THICKNESS, (t)

The above is the only Element Input which is required for the shear web.

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - Col. 30

Refer to Element Control Section.

Element Matrix Print - Col. 31

Refer to Element Control Section

Full Print - Col. 32

Refer to Element Control Section.

Number of Input Nodes - Cols. 33-34

The symmetrical shear web element is always defined by 2 input nodes.

Pressure Suppression Option - Col. 35

Refer to Element Control Section.

Node Points - Cols. 36-71

The symmetrical shear web element is defined by 2 grid points.

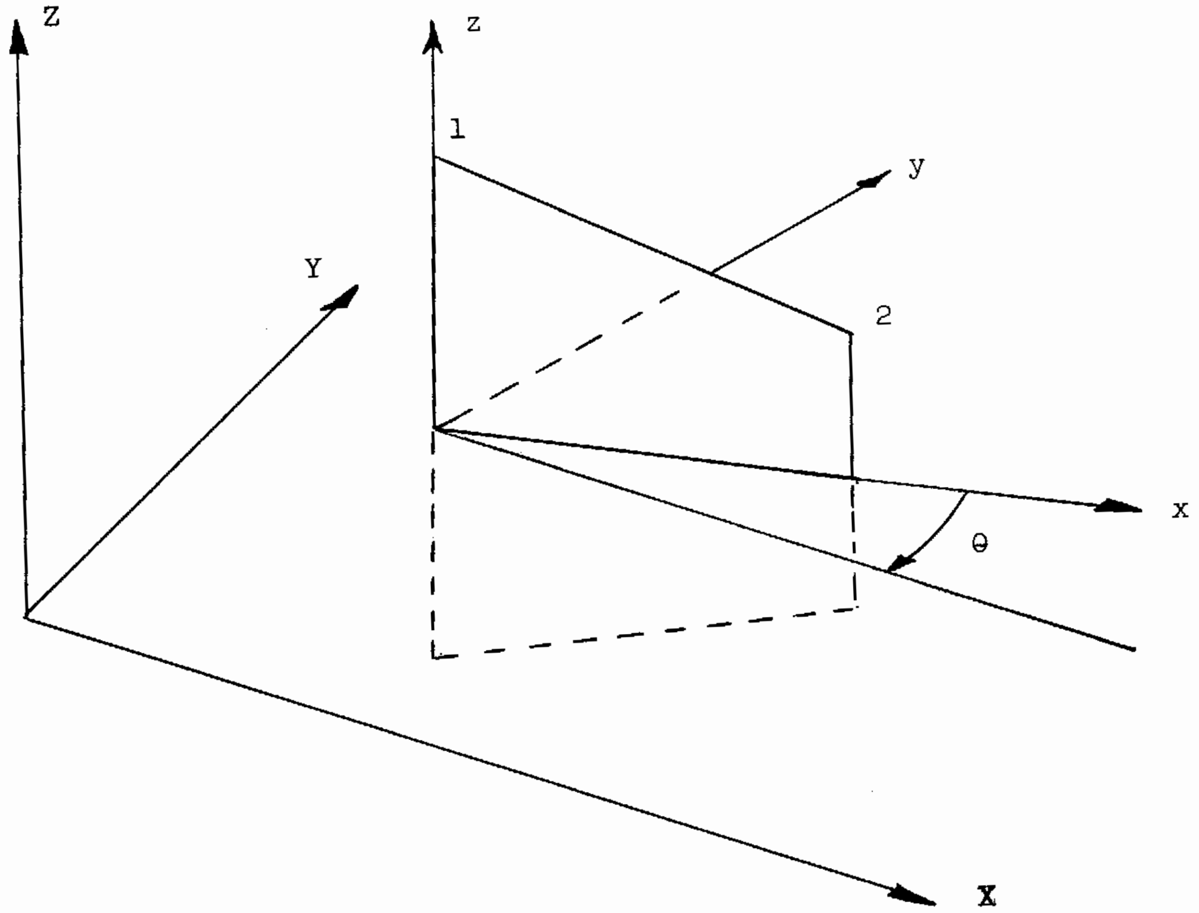

FIGURE II-23 - SYMMETRIC SHEAR WEB ELEMENT

e. High Aspect Ratio Quadrilateral Thin Shell (Ident. No. 38)

This finite element differs from the present MAGIC II quadrilateral thin shell element (Ident. No. 21) only in the approximation of in-plane behavior. No difference other than the identification number is evident to the User.

This additional finite element representation is included in the MAGIC III System for use in the idealization of membranes and plane-strain sections that require elongated finite element shapes. This circumstance is frequently encountered. One important class of applications requiring high aspect ratio finite elements is the stress analysis of structural joints. A rule of thumb that may be applied to guide the choice of element type for such applications is to use the modified quadrilateral thin shell element for those elements whose aspect ratio exceeds six.

All element matrices available to Element Ident. No. 21 are available to this element as well, i.e., stiffness, stress, distributed loading, thermal loading and consistent mass.

All input data required for this element is identical to that required for the original Quadrilateral Thin Shell (Ident. No. 21). Therefore, in the interest of conciseness, the reader is referred to Pages 175 thru 184 of Reference 5 for detailed element input description.

An example application utilizing this finite element is presented in Section II - C.8.e of this report.

f. Triangular Ring (Asymmetrical Load) - (Ident. No. 31)

The triangular ring (asymmetrical loading), hereafter called the asymmetric triangular ring, is a new tool which can be used for the analysis of thick-walled and solid axisymmetric structures of finite length. It may be used to idealize any axisymmetric structure taking into account

1) arbitrary axial variations in geometry,
2) axial variation in orientation of material axes of orthotropy,
3) radial and axial variations in material properties,
4) any asymmetric loading system including distributed mechanical and thermal loads.

The asymmetric triangular ring element and its accompanying applied mechanical loadings are pictured in Figure II-24. These mechanical loads are assumed evenly distributed over the loaded face, possessed of circumferential variation of magnitude and acting (or directed) parallel to the axial and radial direction of the ring (see Figure II-24). Positive directions of loading are illustrated in this figure. The complete theoretical development of this element is presented in the Engineer's Manual. A brief review of this development is given below.

The load and displacement fields for the asymmetric triangular ring element are assumed expressed in a Fourier series form in terms of the circumferential coordinate θ. Utilizing these expressions to write the total potential energy, the energy (and consequently the analysis) can be shown to decompose into an uncoupled form. Thus the three dimensional problem represented by an asymmetrically loaded solid of revolution can be solved by the carrying out of a sequence of two dimensional analyses. The resulting economy and accuracy introduced is obvious.

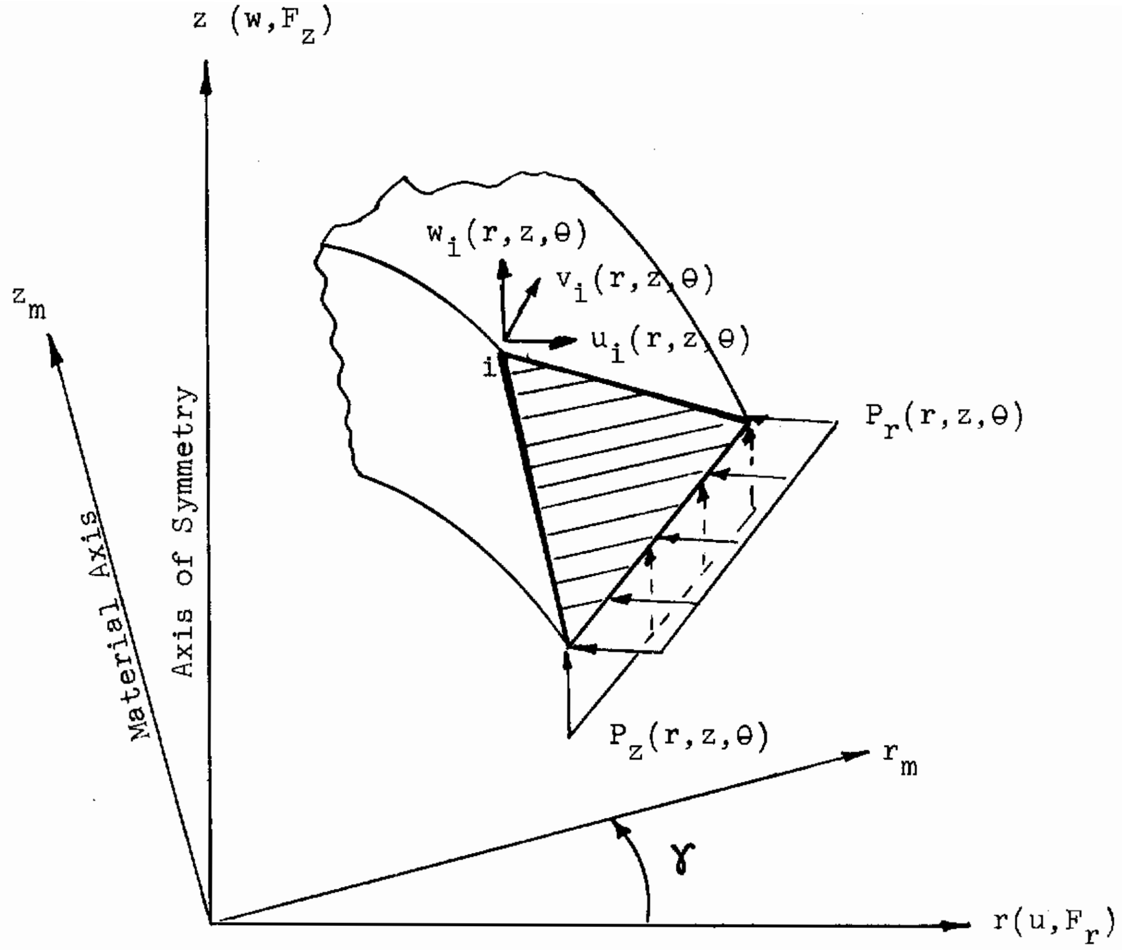

Figure II-24 - Triangular Ring Element (Asymmetric Loading)

The steps inherent in the analysis procedure can be listed as follows:

1) Utilizing input values of the applied load at regular circumferential stations around the structure, the Magic III program automatically generates a Fourier series representation of the loading system,

$$\{P\} = \{P_o\} + \sum_{n=1}^{m} \{P_n\}\lceil C_n \rfloor + \sum_{n=1}^{m} \{\bar{P}_n\}\lceil \bar{C}_n \rfloor \qquad (1)$$

where $\{P_o\}$, $\{P_n\}$ and $\{\bar{P}_n\}$ can be interpreted as harmonic load vectors and the diagonal matrices $\lceil C_n \rfloor$ $\lceil \bar{C}_n \rfloor$ are composed of appropriate combinations of trigorometric elements $\cos n\theta$ and $\sin n\theta$.

2) The User specifies a maximum number of harmonics (m) to be considered in the analysis. In response to this definition, the Magic III program automatically selects the (m) most significant harmonics. The harmonics selected by the program are a function of the applied loading system.

3) (m) individual two dimensional analyses are then carried out. Harmonic displacements and stresses are obtained and combined to obtain the gross stresses and displacements of the structure.

An example of this analysis procedure is given below (with Reference to the theoretical development in the Engineer's Manual, Reference 9.)

Assume that a limit on the harmonic analyses has been set at three (m=3) and that the most significant description of the load system has been selected by the Magic III program as

$$\{P\} = \{P_o\} + \{P_1\}\lceil C_1 \rfloor + \{\bar{P}_2\}\lceil \bar{C}_2 \rfloor \qquad (2)$$

The following individual harmonic analyses are then carried out

$$\{P_0\} = [K_0]\{\delta_0\}$$
$$\{P_1\} = [K_1]\{\delta_1\} \qquad (3)$$
$$\{\bar{P}_2\} = [\bar{K}_2]\{\bar{\delta}_2\}$$

to determine the harmonic displacements $\{\delta_0\}$, $\{\delta_1\}$ and $\{\bar{\delta}_2\}$ for the structure. The gross (actual) displacements of the structure $\{\delta\}$ can now be determined by combining $\{\delta_0\}$, $\{\delta_1\}$ and $\{\bar{\delta}_2\}$ in the following series.

$$\{\delta\} = \{\delta_0\} + [C_1]\{\delta_1\} + [\bar{C}_2]\{\bar{\delta}_2\} . \qquad (4)$$

Harmonic $\{\sigma_m\}$ and actual $\{\sigma\}$ stresses can be obtained in a similar manner.

The ring element geometry is defined with respect to cylindrical coordinate axes. The configuration of the element, as pictured in Figure II-24, is completely defined by specifying the radial and axial coordinates of the corner points.

The orthotropy (cylindrical anisotropy) is provided for in the mechanical and physical material properties of the ring element. The orientation of this orthotropy is assumed oriented in the r_m, z_m and θ directions (see Figure II-24). Transformation to the geometrical or structural system is accomplished utilizing the material angle γ .

The development of the asymmetric triangular ring element is an expansion of that utilized in deriving the axisymmetric triangular ring element (Ident. No. 40). Similar linear polynomial functions are employed in both elements and are employed for displacement mode shapes leading to constant element strain and stress states.

Due to the asymmetric deformations which the asymmetric ring can accomodate, 9 degrees of freedom (as opposed to six for the axisymmetric ring) are required to define the deformational behavior of this element. The predicted element stress behavior is constant over the triangular cross-section. Radial, circumferential and axial stresses are predicted. As in the axisymmetric ring element (Ident. No. 40) the asymmetric ring is numbered in the following manner. The element is numbered in the counter-clockwise direction.

A major difference between the two elements (asymmetric and axisymmetric ring), other than the accomodation of asymmetric loads in the former, is the interpretation of the applied loads themselves. Loads applied to the axisymmetric ring (Ident. No. 40) are assumed applied at grid points while loads applied to the asymmetric ring (Ident. No. 31) are assumed applied to the element.

In order to account for this difference as well as the circumferential variation of the magnitude of the loads an alternate set of load and data input cards must be provided to accomodate the asymmetric ring. These are provided and discussed in the discussion which follows. For solids of revolution subjected to axisymmetric loadings, it is suggested that the axisymmetric element be used.

The Element Control Data which is required for the Asymmetric Triangular Ring Element is as follows: (see Figure II-17)

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Triangular Cross-section Ring Element is identified as Number 31.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

Not available for this element.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section.

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section.

Element Input - (Col. 29)

To utilize this option, place an X in Col. 29.

Note: The Asymmetric Triangular Cross-Section Ring Element only requires Element Input under certain special conditions as follows: Referring to Figure II-24, it is seen that there is a possibility that in some cases the material axis, and element geometric axis of the element will not coincide. If this is the case the Element Input (Figure II-18) required for the Triangular Cross-Section Ring consists of the following:

Location A - (Cols. 13-22)

Material Axes Angle (Gamma - Υ_{mg})

Since the Triangular Cross-Section Ring Element is written to accommodate anisotropy of mechanical and physical properties, provision is made in the program for differences in orientation of material and element geometric axes for an element. The User inputs the angle between the element material axis (X_m) and the element geometric axis (X_g). The angle gamma (Υ_{mg}) is input in degrees and is considered positive when measured from the material axes to the element geometric axes, in a counter-clock-wise direction (Figure II-24).

Remember

Element Input is not required for the Triangular Ring if the material and geometric axes coincide, i.e., $\gamma_{mg} = 0$.

Interpolated Input Print - (Col. 30)

Element Matrix Print - (Col. 31)

Full Print (Col. 32)

} Refer to Element Control Section

Number of Input Nodes (Col. 33-34)

The Asymmetric Triangular Cross-Section Ring Element is always defined by 3 input nodes.

Pressure Suppression Option (Col. 35)

Not available for this element.

Node Points - (Cols. 36-71)

The three node points which define each Triangular Ring are entered in the first three entires provided in the Node Point Section of the Element Control Data Form.

As previously mentioned an alternate set of load and data input cards are provided in the MAGIC III system to accomodate this particular element. These input cards replace the element pressure and temperature data cards shown in Figures II-14 and II-13 and are explained in detail below.

Stress and Displacement Output Section

The first entry on the input data form Figure II-25 is a prelabeled HSDC and requires no other information from the User.. The second entry contains the reference, incremental and final circumferential angular values at which output stress and displacement data is desired. These entries are described below:

Reference Value Col. (7-11)

The entry in these columns is a fixed point right adjusted number representing the reference angle in degrees. The entry must not be less than zero nor greater than 359°.

Increment Value Col. (12-16)

The entry in these columns is a fixed point right adjusted number representing the increment value in degrees. The entry must not be less than 1° nor greater than 360°.

Final Circumferential Value Col. (17-21)

The entry in these columns is a fixed point right adjusted number representing the final circumferential value in degrees. This entry must not be greater than 360°.

Defining

RV = Reference Value

IV = Increment Value,

and FV = Final Value.

The following inequalities must hold

$$IV < FV - RV$$

$$0 \leq FV - RV .$$

The values defined above are utilized to define the region and quantity of information (output) desired for a given structure.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)
HARMONIC INCREMENTS

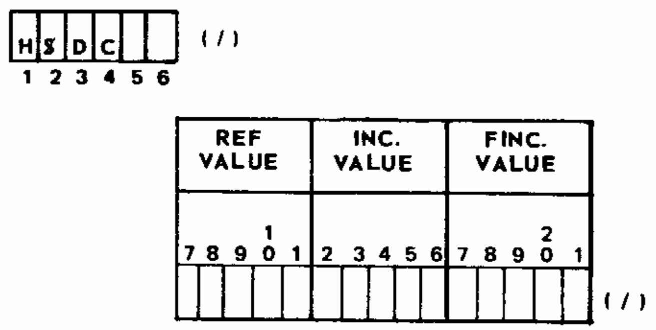

Figure II-25 - Harmonic Stress and Displacement Output Control

Harmonic Pressure Loading Section

A pre-labeled input data form entitled HARM is provided for the entry of pressure load data and is shown in Figure II-26. The first entry on the form is labeled HARM and requires no other information from the User. The second entry pertains to the number of loaded elements, the maximum number of harmonics to be used per element, and the maximum number of output harmonics for the system. The third set of input data is concerned with element number, an element loading repeat option, the number of loading points and the harmonic pressure values. The last two sets of data must be input by the User and the instructions for doing so are described below. Entries on the second input data card, Figure II-26 are:

Number of Loaded Elements (Cols. 7-9)

The entry in three columns is a fixed point right adjusted number which represents the elements which have imposed pressure loads. Only the quantity of such elements is entered.

Number of Harmonics per Element (Col. 10)

The maximum number of harmonics to be used to represent the pressure loading for each element is entered as a fixed point number in column 10. This entry must be greater than zero and less than nine in value.

Number of Harmonics Output (Col. 11)

The maximum number of harmonics to be used in the calculation of output data for the entire element structure is entered as a fixed point number in column 11. This entry must be less than or equal to the number of harmonics per element.

Entries on the third and following input data cards Figure II-26, is described below:

Element Number (Cols. 7-9)

The number of the element on which the pressure load is to be applied is entered in Cols 7-9 using a fixed point right adjusted format. The element numbers are to be entered in ascending order and a maximum of 500 elements may be entered loaded.

Element Loading Repeat Option (Col. 10)

This piece of input data determines whether or not the element pressure loadings are to be repeated for succeeding elements. If these loadings are to be repeated the User enters an "X" in column 10 and omits remaining load data pertaining to this element. The pressure data from the proceeding element is automatically applied to this element. If these loadings are not to be repeated the User leaves column 10 blank.

Number of Radial Loading Points (Cols. 11-13)

The entry in these columns is a fixed point right adjusted number representing the number of points at which radial pressures will be defined. These points are spaced at equal intervals about the circumference of the element. The value of this entry must be greater than zero and less than 60 if a radial pressure is to be applied. If no radial pressure is present, a zero is entered and radial pressure values are omitted.

Number of Axial Loading Points (Cols. 14-16)

The entry in these columns is a fixed point right adjusted number representing the number of points at which axial pressures will be defined. These points are spaced at equal intervals about the circumference of the element. The value of this entry must be greater than zero and less than 60 if an axial load is to be applied on this element. Note that this entry does not have to be the same as the previous entry. If no axial pressure is present a zero is entered and axial pressure values are omitted.

Pressure Loading Values (Cols. 17-76)

The User enters pressure load values which are equal in quantity to the sum of the number of radial and axial loading points (Cols. 11-16). The radial values are entered first followed by the axial values. These values are entered in columns 17-76 in a floating point right adjusted format six to a card as shown in Figure II-26. A maximum of 20 such cards are allowed permitting a maximum entry of 120 pressure values per element. Note that the 2nd to 20th cards do not contain entries in columns 7 to 16. Pressures are applied on face number one (between nodes 1 and 2) and have same sense as the global coordinate system.

Harmonic Thermal Loading Section

A pre-labeled input data form entitled HTEM is provided for the entry of thermal load data and is shown in Figure II-27. The first entry on the form is labeled HTEM, and requires no other information from the User. The second entry pertains to the number of loaded elements, the maximum number of harmonics to be used per element, and the maximum number of output harmonics for the system. The third set of input data is concerned with element number, an element loading repeat option, the number of temperature loading points and the harmonic thermal values. The last two sets of data must be input by the User and the instructions for doing so are described below. Entries on the second input data card, Figure II-27 are:

Number of Loaded Elements (Cols. 7-9)

The entry in these columns is a fixed point right adjusted number which represents the elements which have imposed thermal loads. Only the quantity of such elements is entered.

1	2	3	4	5	6	
H	A	R	M			(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)

HARMONIC DEPENDENT ELEMENT PRESSURE LOADS

No. of Loaded Elements	No. Harmonics–Element	No. Harmonics–Output	
7 8 9	10	1	
			(/)

Element Number	Repeat Option	No. of Radial Loading Points	No. of Axial Loading Points	PRESSURE LOAD VALUES						
7 8 9	10	1 2 3	4 5 6	17 8 9 20 1 2 3 4 5 6	27 8 9 0 1 2 3 4 5 6	37 8 9 40 1 2 3 4 5 6	47 8 9 50 1 2 3 4 5 6	57 8 9 60 1 2 3 4 5 6	67 8 9 70 1 2 3 4 5 6	
										(/)
										(/)
										(/)
										(/)
										(/)
										(/)
										(/)
										(/)
										(/)

Figure II-26 - Harmonic Dependent Pressure Loads

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

HARMONIC DEPENDENT ELEMENT PRESSURE LOADS (CONTINUED)

Element Number	Repeat Option	No. of Radial Loading Points	No. of Axial Loading Points	PRESSURE LOAD VALUES						
7 8 9	10	1 2 3	14 5 6	17 8 9 20 1 2 3 4 5 6	27 8 9 30 1 2 3 4 5 6	37 8 9 40 1 2 3 4 5 6	47 8 9 50 1 2 3 4 5 6	57 8 9 60 1 2 3 4 5 6	67 8 9 70 1 2 3 4 5 6	
										(/)
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										(/)

Figure II-26 (Concluded)

Number of Harmonics per Element (Col. 10)

The maximum number of harmonics to be used to represent the thermal loading for each element is entered as a fixed point number in column 10. This entry must be greater than zero and less than nine in value.

Number of Harmonics Output (Col. 11)

The maximum number of harmonics to be used in the calculation of output data for the entire structure is entered as a fixed point number in column 11. This entry must be less than or equal to the number of harmonics per element.

Entries on the third and following input data cards, Figure II-27, is described below:

Element Number (Cols. 7-9)

The number of the element on which the thermal load is to be applied is entered in Cols. 7-9 using a fixed point right adjusted format. The element numbers are to be entered in ascending order and a maximum of 500 elements may be entered (loaded).

Element Loading Repeat Option (Cols. 10)

This piece of input data determines whether or not the element thermal loadings are to be repeated for succeeding elements. If these loadings are to be repeated the User enters an "X" in column 10 and omits remaining load data pertaining to this element. The thermal data from the proceeding element is automatically applied to this element. If these loadings are not to be repeated the User leaves column 10 blank.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
H	T	E	M			(/)

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)

No. of Loaded Elements	No. Harmonics–Element	No. Harmonics–Output	
7 8 9	10	11	
			(/)

HARMONIC DEPENDENT ELEMENT THERMAL LOADS

Element Number	Repeat Option	No. of Temperature Points		THERMAL LOAD VALUES						
7 8 9	10	11 12 13	14 15 16	17 18 19 20 21 22 23 24 25 26	27 28 29 30 31 32 33 34 35 36	37 38 39 40 41 42 43 44 45 46	47 48 49 50 51 52 53 54 55 56	57 58 59 60 61 62 63 64 65 66	67 68 69 70 71 72 73 74 75 76	
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)

Figure II-27 - Harmonic Dependent Temperature Loads

BAC 2058 Sht. 2

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

HARMONIC DEPENDENT
ELEMENT THERMAL LOADS
(CONTINUED)

Element Number	Repeat Option	No. of Temperature Points	THERMAL LOAD VALUES							
7 8 9	10	11 12 13	14 15 16	17 18 19 20 21 22 23 24 25 26	27 28 29 30 31 32 33 34 35 36	37 38 39 40 41 42 43 44 45 46	47 48 49 50 51 52 53 54 55 56	57 58 59 60 61 62 63 64 65 66	67 68 69 70 71 72 73 74 75 76	
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
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			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)
			▨							(/)

Figure II-27 (Concluded)

Number of Thermal Loading Points (Cols. 11-13)

The entry in these columns is a fixed point right adjusted number representing the number of points at which thermal loads will be defined. These points are spaced at equal intervals about the circumference of the element. The value of this entry must be greater than zero and less than 60.

Thermal Loading Values (Cols. 17-76)

The User enters thermal load values which are equal in quantity to the number of thermal loading points (Cols. 11-13). These values are entered in Columns 17-76 in a floating point right adjusted format six to a card as shown in Figure II-27. A maximum of 10 such cards are allowed permitting a maximum entry of 60 pressure values per element. Note that the 2nd to 10th cards do not contain entries in Columns 7 to 13. Temperatures which are input are assumed applied to the element as a whole and must be interpreted as temperature changes (either increase (+) or decrease (-) from a thermal stress free state) to which the element is subjected.

SECTION III

INPUT AND OUTPUT OF MAGIC III SYSTEM

A. GENERAL DESCRIPTION

In this section, the proper interpretation of the input supplied to the MAGIC III system and the output supplied by the MAGIC III system is provided by reference to specific example problems. These examples will use the finite elements added to the MAGIC system; namely,

1) Rectangular Prism
2) Tetrahedron
3) Triangular Prism
4) Symmetric Triangular Prism
5) Symmetric Shear Web
6) Revised Quadrilateral Thin Shell
7) Triangular Cross-Section Ring

B. RECTANGULAR PRISM ELEMENT

A three-element cantilever beam subjected to an end moment is shown in Figure III-B.1 as the first example. This figure shows the loading, idealization, dimensions and material properties. The preprinted input data forms associated with this example are given in Figures III-B.2 to III-B.10.

Figure III-B.6, Boundary Condition Section, shows the use of the MODAL and REPEAT options. There are 4 exceptions to the MODAL card (Grid points 1, 5, 9 and 13). Grid points 5, 9 and 13 have exactly the same boundary conditions as grid point 1, therefore the REPEAT option is employed by placing an ''X'' in column 12 opposite the entry for grid points 5, 9, and 13. Note that the four exceptions to the MODAL card are called out on the System Control Information Data Form, Figure III-B.4.

The following load data is evident by inspection of Figure III-B.7, External Loads Section.

1) One load condition is input.
2) The external applied load scalar equals zero.

3) Grid point 4 is loaded with a force in the -Y direction equal to 66.66667 pounds. The REPEAT option is used for grid point 12 which is subjected to the same load. Grid point 8 is loaded with a force in the +Y direction equal to 66.66667 pounds. Again the REPEAT option is used for grid point 16 which is subjected to the same load. Note that no entries corresponding to External Moments are made since the rectangular prism element only admits translational displacements.

In Figure III-B.9, Element Input, it is noted that only the MODAL entry is used. This means that every element in this example problem is subjected to a constant pre-strain state. Reference to the Engineers Manual (Reference 7) shows that the User has the option of calling out a constant element pre-strain or temperature state or an element pre-strain or temperature state which is the same functional form as the assumed displacement mode shapes (i.e., trilinear Lagrangion interpolation formulas). It was decided to use the former in this problem, hence the entry 0.0 was made. The User must be aware of his choice and be consistent throughout the analysis. Actually in this problem no element pre-strain or temperatures were considered so that either of the above options could have been chosen.

The output supplied by the MAGIC III system for this particular example is described below and shown in Figures III-B.11 to III-B.26.

Figure III-B.11 shows the matrix abstraction instructions associated with this example. A complete description of these instructions is provided in Reference 5. Figures III-B.12 to III-B.15 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

Figure III-B.12 displays the problem title and material data output. The gridpoint coordinates, temperatures and pressures are given in Figure III-B.13. Boundary condition information and finite element description is shown on Figure III-B.14. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed (i.e., no motion), ones ('1') represent degrees of freedom that are free or have unknown values of displacement, and twos ('2') represent degrees of freedom that are eliminated in the analysis procedure through the condensation technique. The second last column represents the cumulative number of degrees of freedom which actively participate in the equation solving process for displacements. The last column accumulates the number of two which participate in the calculation of the reduced stiffness matrix. The second portion of Figure III-B.14 shows the finite element description. Each of the three elements is called out in turn with grid points, print options and material number. Note that no extra grid points are listed nor needed for this element. The same comment also holds for section properties since all pertinent data are calculated within the program.

Figure III-B.15 displays the external load condition and the transformed external assembled load column. This 48 x 1 vector is the total unreduced load which is read row-wise. The ordering of this vector is consistent with that of the boundary condition table given in Figure III-B.14. Note that a load of 66.66667 pounds is applied at node point 4 in the negative global Y direction. This is position (11,1) in the load vector which corresponds to the eleventh entry in the boundary condition table which is the global V displacement for node point 4. The other loads shown follow the same pattern.

MAGIC III system output of final results are displayed in Figures III-B.16 to III-B.26. Figure III-B.17 shows the stiffness matrix for this problem. It is noted that only the non-zero terms are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary condition table previously discussed. In this problem the ordering is

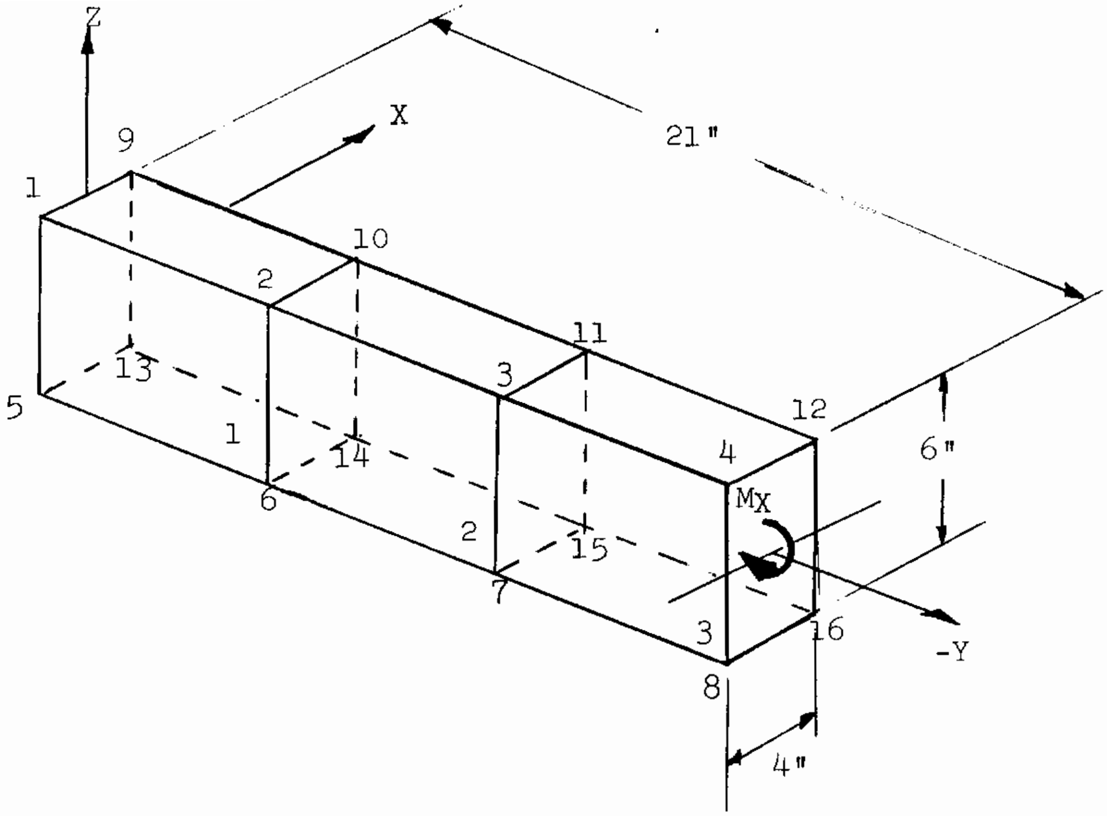
$$\{\Delta\}^T = \lfloor V_2, W_2, V_3, W_3, \ldots\ldots, V_{16}, W_{16} \rfloor$$

The externally applied load vector (GPRINT OF MATRIX LOADS) is presented in Figure III-B.18. This figure shows that forces (F_Y) are applied in the negative and positive global Y directions at node points 4, 8, 12 and 16. These forces are numerically equal to ±66.66667 pounds and are directed to form a moment of $M_X = 800$ in. pounds applied at the tip of the cantilever.

The displacements of the cantilever beam resulting from the above loads are given in Figure III-B.19. It is noted that the displacements (U, V, W) are output corresponding to node point number and are referenced to the global axes unless otherwise specified. Figure III-B.20 shows the reactions (F_X, F_Y, F_Z). These are output corresponding to node point number and are referenced to the global axes system unless otherwise specified.

The stresses arising in the structure are displayed in tabular form in Figures III-B.21 to III-B.23. Stresses are referenced to the local coordinate system and for this element are defined at the centroid. Six stress values are printed for the apparent element stress, element applied stress and net element stress categories. The apparent stress arises from element deformations and the applied stress arises from pre-strain and thermal effects. The net stress is the difference between the apparent and applied stress values. These stresses are given mathematical symbolism description in Reference 7.

The last set of output is given in Figures III-B.24 to III-B.26 and consist of the global oriented element forces. Three sets of forces are given and are categorized as above. The forces points 1 through 8, in this example, correspond to element grid point numbers. For element number one, for example, force points 1, 2, 3, 4, 5, 6, 7, 8 correspond to element grid points 1, 2, 6, 5, 9, 10, 14, and 13 respectively.



$E_X = E_y = E_Z = E = 30.0 \times 10^6$ psi

$\nu_{XY} = \nu_{YX} = \nu_{YZ} = \nu_{ZY} = \nu_{ZX} = \nu_{XZ} = \nu = .333$

$\rho = .00073395\ \#\text{sec}^2/\text{in}^4$

$\bar{\epsilon}_X = \bar{\epsilon}_Y = \bar{\epsilon}_Z = 0$, $T_1 = T_2 = \ldots T_{16} = 0.0$

$M_X = 800$ in.lbs.

FIG. III-B.1 RECTANGULAR PRISM ELEMENT - CANTILEVER BEAM WITH END MOMENT

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

REPORT (/)

1 2 3 4 5 6
TITLE (/)

7 8 9
3 (/) NUMBER OF TITLE CARDS

THREE ELEMENT CANTILEVERED BEAM SUBJECTED TØ AN END (/

MOMENT RECTANGULAR PRISM ELEMENT IDEN. NØ. 52 (/

STATICS ANALYSIS CØNCENTRATED LØADS EQUIVELANT TO MØMENT (/

(/

(/

(/

(/

(/

(/

FIGURE III-B.2 TITLE INFORMATION - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

M	A	T	E	R
1	2	3	4	5 6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

		1
7	8	9

No. of Requests (/)

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	1	JB	STEEL	X									1	0	.00073954	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	30.0 E6	ν_{xy}	.333	α_x	6.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-B.3 MATERIAL TAPE INPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	SYSTEM	1 2 3 4 5 6	(/)
1. Number of System Grid Points	16	1 2 3 4 5 6	
2. Number of Input Grid Points	16	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	3	13 14	
4. Number of Load Conditions	1	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	3	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	4	39 40 41 42 43 44	
11. T_0 For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-B.4 SYSTEM CONTROL INFORMATION - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6
COORD (/)

GRIDPOINT COORDINATE

	DIRECTIONS			
Grid Point Number	X – R	Y – θ	Z – Z	
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
1	-2.0	0.0	3.0	(/)
2	-2.0	-7.0	3.0	(/)
3	-2.0	-14.0	3.0	(/)
4	-2.0	-21.0	3.0	(/)
5	-2.0	0.0	-3.0	(/)
6	-2.0	-7.0	-3.0	(/)
7	-2.0	-14.0	-3.0	(/)
8	-2.0	-21.0	-3.0	(/)
9	2.0	0.0	3.0	(/)
10	2.0	-7.0	3.0	(/)
11	2.0	-14.0	3.0	(/)
12	2.0	-21.0	3.0	(/)
13	2.0	0.0	-3.0	(/)
14	2.0	-7.0	-3.0	(/)
15	2.0	-14.0	-3.0	(/)
16	2.0	-21.0	-3.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-B.5 GRID POINT COORDINATES - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - No Displacement Allowed 1 - Unknown Displacement 2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
2	1	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	0							(/)
				5	X										(/)
				9	X										(/)
			1	3	X										(/)
															(/)
															(/)
															(/)
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															(/)
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															(/)
															(/)
															(/)
															(/)

FIGURE III-B.6 BOUNDARY CONDITIONS - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
L	O	A	D	S		(/)

Columns 1–5	Condition Number (cols. 6–11)	Scalar (cols. 12–22)	
LCOND	1	0.0	(/)

EXTERNAL LOADS

1–6	Fx (cols. 13–22)	Fy (cols. 23–32)	Fz (cols. 33–42)	
MODAL	0.0	0.0	0.0	(/)

Grid Pt. Number (cols. 7–11)	repeat (col. 12)	FORCE VALUES Fx	FORCE VALUES Fy	FORCE VALUES Fz		MOMENT VALUES Mx	MOMENT VALUES My	MOMENT VALUES Mz		GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3	
4		0.0	-66.6667	0.0	(/)				(/)				(/)
12	X				(/)				(/)				(/)
8		0.0	66.6667	0.0	(/)				(/)				(/)
16	X				(/)				(/)				(/)

FIGURE III-B.7 EXTERNAL LOADS - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1628

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT Print	PRINT Elem. Mat.	PRINT Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	1 2	3 4 5 6 7 8	19	20 1 2 3 4 5 6 7	28	29	30	31	32	33 34	35	36 7 8	9 40 1	2 3 4	5 6 7	8 9 50	1 2 3	4 5 6	7 8 9	60 1 2	3 4 5	6 7 8	9 70 1	
1	52	1 1	8			X				8		1	2	6	5	9	10	14	13					(/)
2	52	1 1	8			X				8		3	2	10	11	7	6	14	15					(/)
3	52	1 1	8			X				8		4	12	16	8	3	11	15	7					(/)
																								(/)
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FIGURE III-B.8 ELEMENT CONTROL DATA - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

1	2	3	4	5	6
M	O	D	A	L	

ELEMENT INPUT

A	B	C	D	E	F
1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2
0.0					

Element Number	Repeat	A	B	C	D	E	F	
1 7 8 9 0 1	2	1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2	
								(/)
								(/)
								(/)
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								(/)
								(/)
								(/)
								(/)

FIGURE III-B.9 ELEMENT INPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-B.10 END CARD - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
            MAGIC  ABSTRACTION INSTRUCTION LISTING          PAGE  1


$INSTRUCTION    SOURCE


         C-----STATICS AGENDUM, WITH CCNDENSATICN                                AGEN0348
         C                                                                       AGEN0349
         C          *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *AGEN0350
         C                                                                       AGEN0351
         C          STATICS INSTRUCTION SEQUENCE                                 AGEN0352
         C                                                                       AGEN0353
         C          *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *AGEN0354
         C                                                                       AGEN0355
         C          GENERATE ELEMENT MATRICES                                    AGEN0356
         C                                                                       AGEN0357
   1           ,MLIB,,XLD,TR,   ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,     ,.USER04.   AGEN0358
         C                                                                       AGEN0359
         C          FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                  AGEN0360
         C          DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED             AGEN0361
   2           I1 = SC.IDENTC.                                                   AGEN0362
   3           I3 = I1.NULL.SC                                                   AGEN0363
   4           DIFF = I1 .SMULT. SC(9,1)                                         AGEN0364
         C                                                                       AGEN0365
         C          ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS          AGEN0366
         C                                                                       AGEN0367
   5           KELA = EM .ASSEM. SC,(10)                                         AGEN0368
   6           FTELA = EM .ASSEM .SC,(40)                                        AGEN0369
         C                                                                       AGEN0370
         C          REDUCE STIFFNESS MATRIX AND PRINT                            AGEN0371
         C                                                                       AGEN0372
   7           KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                AGEN0373
   8           KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                               AGEN0374
   9           PRINT(FORCE,DISP,,) STIFF                                         AGEN0375
         C                                                                       AGEN0376
         C          FORM REDUCED TOTAL LOAD CCLUMN                               AGEN0377
         C                                                                       AGEN0378
  10           LSCALE,LOADS = XLD .DEJOIN.(1,1)                                  AGEN0379
         C          MULTIPLY ELEMENT APPLIED LCADS BY LOAD SCALAR                AGEN0380
  11           FTELS = FTELA.MULT.LSCALE                                         AGEN0381
         C-----TRANSFORM EXTERNAL LOADS TO CRDERED SYSTEM, FORM TOTAL LOADS
  12           LOADO = TR .MULT. LOADS
  13           TLOAD = FTELS .ADD. LOADO
         C-----CONDENSE ASSEMBLED STIFFNESS MATRIX                               AGEN0382
  14           TOP,BOT = STIFF .DEJOIN. (SC(6,1),1)                              AGEN0383
  15           K11,K12 = TOP .DEJOIN. (SC(6,1),0)                                AGEN0384
  16           K12T,K22 = BOT .DEJOIN. (SC(6,1),0)                               AGEN0385
         C                                                                       AGEN0386
  17           PO,P12 = TLOAD .DEJOIN. (SC(5,1),1)                               AGEN0388
         C-----CONDENSE EXTERNAL LOAD COLUMNS                                    AGEN0387
  18           P1,P2  = P12 .DEJOIN. (SC(6,1),1)                                 AGEN0389
         C                                                                       AGEN0390
         C-----FORM (K11 - K12*K22(INVS)*K12T)                                   AGEN0391
         C                                                                       AGEN0392
  19           K22I =  -K22 .INVERS.                                             AGEN0393
  20           KR1  = K22I .MULT. K12T                                           AGEN0394
```

FIGURE III-B.11 MAGIC ABSTRACTION INSTRUCTION LISTING - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
          MAGIC   ABSTRACTION INSTRUCTICN LISTING          PAGE  2


 21           KR2  = K12 .MULT.KR1                                           AGEN0395
 22           KR =  K11 .ADD. KR2                                            AGEN0396
       C-----SOLVE FOR DISPLACEMENTS D1                                      AGEN0397
 23           TRIA,D1 = KR,P1 .CHTRIA.                                       00004010
       C-----SOLVE FOR DISPLACEMENTS D2                                      AGEN0399
 24           D2 =  KR1 .MULT. D1                                            AGEN0400
       C-----FORM TJTAL DISPLACEMET VECTOR                                   AGEN0401
 25           D1T = D1 .TRANSP.                                              AGEN0402
 26           D2T = D2 .TRANSP.                                              AGEN0403
 27           D12 = D1T .ADJOIN. D2T                                         AGEN0404
 28           XX   = D12 .TRANSP.                                            AGEN0405
       C-----EXPAND DISPLACEMENTS TO TCTAL SYSTEM DEGREES OF                  AGEN0406
       C-----FREEDOM AND REARRANGE TO C-1-2 SYSTEM                           AGEN0407
 29           TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                               AGEN0408
 30           X = TR12.TMULT.XX                                              AGEN0409
 31           XO = TR.MULT.X                                                 AGEN0410
       C                                                                     AGEN0411
       C         CALCULATE REACTIONS AND INVERSE CHECK                       AGEN0412
       C                                                                     AGEN0413
 32           REACTS = KELA.MULT. XO                                         AGEN0414
 33           REACTP= REACTS.SUBT.TLOAD                                      AGEN0415
 34           IF (DIFF.NULL.) GO TO 10                                       AGEN0416
       C                                                                     AGEN0417
       C         PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS, AGEN0418
       C           REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT         AGEN0419
       C                                                                     AGEN0420
       C         ELEMENTS HAVE 1 OR 2 DEGREES CF FREEDOM                     AGEN0421
       C                                                                     AGEN0422
 35           GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA                      AGEN0423
 36           GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS                     AGEN0424
 37           GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X                    AGEN0425
 38           GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP                     AGEN0426
 39           IF (I3.NULL.) GO TO 600                                        AGEN0427
       C                                                                     AGEN0428
       C         ELEMENTS HAVE 3 DEGREES CF FREEDCM                          AGEN0429
       C                                                                     AGEN0430
 40     10    GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA              AGEN0431
 41           GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS             AGEN0432
 42           GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X                    AGEN0433
 43           GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP             AGEN0434
       C                                                                     AGEN0435
       C         GENERATE STRESSES  AND FORCES                               AGEN0436
       C                                                                     AGEN0437
 44    600    STRESP = EM,XO .STRESS. (4,)                                   AGEN0438
 45           FORCEP = EM,XO .FORCE. (4,)                                    AGEN0439
```

FIGURE III-B.11 MAGIC ABSTRACTION INSTRUCTION LISTING - RECTANTULAR PRISM ELEMENT, CANTILEVER BEAM (CONCLUDED)

```
                         THREE ELEMENT CANTILEVERED BEAM SUBJECTED TO AN END

                         MOMENT. RECTANGULAR PRISM ELEMENT IDEN. NO.52

                         STATICS ANALYSIS CCNCENTRATEC LOADS EQUIVALENT TO MOMENT

                                    REVISICNS OF MATERIAL TAPE

                                  ASTERISK (*) PRECEEDING MATERIAL
                                  IDENTIFICATION INDICATES THAT INPUT
                                  ERRCR RETURNS WILL NOT RESULT IN
                                     TERMINATION OF EXECUTION


*******************************************************************************************************************

   REVISION
    MATERIAL NUMBER       1
    MATERIAL IDENTIFICATION STEEL                                      INPUT CODE   I
      NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
      NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
      MASS DENSITY. . . . . . . . . . . . . . .  0.73394994E-03

    MATERIAL PROPERTIES


                     YOUNG'S MODULI                                    POISSON'S RATIOS

                           DIRECTICNS                                                           DIRECTIONS
 TEMPERATURE
                    XX              YY              ZZ                    XY               YZ              ZX
     0.0       0.300000E 08    0.300000E 08    0.300000E 08          0.333000E 00     0.333000E 00    0.333000E 00
                     TH. EXP.COEF.                                     RIGIDITY MODULI

                           DIRECTIONS                                                           DIRECTIONS
 TEMPERATURE
                    XX              YY              ZZ                    XY               YZ              ZX
     0.0       0.650000E-05    0.650000E-05    0.650000E-05          0.112528E 08     0.112528E 08    0.112528E 08

*******************************************************************************************************************
```

FIGURE III-B.12 TITLE AND MATERIAL DATA OUTPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                        16 REF. POINTS

   NO. DIRECTIONS  =     3      NO. DEGREES CF FREEDOM =    1


                                     GRIDPCINT DATA
                                (IN RECTANGULAR COORDINATES)

POINT          X                  Y                  Z              TEMPERATURES          PRESSURES
  1     -0.20000000E 01     0.0               0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  2     -0.20000000E 01    -0.70000000E 01    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  3     -0.20000000E 01    -0.14000000E C2    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  4     -0.20000000E 01    -0.21000000E 02    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  5     -0.20000000E 01     C.0              -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  6     -0.20000000E 01    -C.70000000E 01   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  7     -0.20000000E 01    -0.14000000E 02   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  8     -0.20000000E 01    -0.21000000E 02   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
  9      0.20000000E 01     C.0               0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 10      0.20000000E 01    -0.70000000E 01    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 11      0.20000000E 01    -C.14000000E 02    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 12      0.20000000E 01    -C.21000000E 02    0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 13      0.20000000E 01     C.0              -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 14      0.20000000E 01    -C.70000000E 01   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 15      0.20000000E 01    -C.14000000E C2   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
                                                                 0.0                 0.0
 16      0.20000000E 01    -0.21000000E 02   -0.30000000E 01     0.0                 0.0
                                                                 0.0                 0.0
```

FIGURE III-B.13 GRID POINT DATA OUTPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                BOUNDARY CONDITION INFORMATION

      NODES                  DEGREES OF FREEDOM                       NO. OF ONES   NO. OF TWOS

        1         0      0      0                                          0             0
        2         2      1      1                                          2             1
        3         2      1      1                                          4             2
        4         2      1      1                                          6             3
        5         0      0      0                                          6             3
        6         2      1      1                                          8             4
        7         2      1      1                                         10             5
        8         2      1      1                                         12             6
        9         0      0      0                                         12             6
       10         2      1      1                                         14             7
       11         2      1      1                                         16             8
       12         2      1      1                                         18             9
       13         0      0      0                                         18             9
       14         2      1      1                                         20            10
       15         2      1      1                                         22            11
       16         2      1      1                                         24            12


                                     TOTAL NO. ELEMENTS =       3


ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS   ------SECTION PROPERTIES------
   1  52        1     8  0.0          0    8    1   2   6   5   9  10  14  13                    0.0          0.0          0.0
   2  52        1     8  0.0          0    8    3   2  10  11   7   6  14  15                    0.0          0.0          0.0
   2  52        1     8  0.0          0    8    4  12  16   8   3  11  15   7                    0.0          0.0          0.0
```

FIGURE III-B.14 BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                   EXTERNAL LOAD CONDITIONS    1


    LOAD NO.   1

      NUMBER OF LOADED NODES   16          ELEMENT LCAD SCALAR =  0.0
  4  0.0         -0.66667E 02  0. C
 12  0.0         -0.66667E 02  0. 0
  8  0.0          0.66667E 02  0. 0
 16  0.0          0.66667E 02  0. 0
  1  0.0          0.0          0. 0
  2  0.0          0.0          0. C
  3  0.0          0.0          0. 0
  5  0.0          0.0          0. C
  6  0.0          0.0          0. 0
  7  0.0          0.0          0. 0
  9  0.0          0.0          0. 0
 10  0.0          0.0          0. 0
 11  0.0          0.0          0. 0
 13  0.0          0.0          0. 0
 14  0.0          0.0          0. 0
 15  0.0          0.0          0. 0
```

FIGURE III-B.15 EXTERNAL LOAD CONDITIONS - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                          TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                            48 X 1

  0.0          0.0          0.0          0.0          0.0                0.0

  0.0          0.0          0.0          0.0         -0.66666992E 02     0.0

  0.0          0.0          0.0          0.0          0.0                0.0

  0.0          0.0          0.0          0.0          0.66666992E 02     0.0

  0.0          0.C          0.0          0.0          0.0                0.0

  0.0          0.0          0.0          0.0         -0.66666992E 02     0.0

  0.0          0.0          0.0          0.0          0.0                0.0

  0.0          0.0          0.0          0.0          0.66666992E 02     0.0


                              T-ZERO FOR STRUCTURE =  0.0
```

FIGURE III-B.16 TRANSFORMED EXTERNAL ASSEMBLED LOAD OUTPUT - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                        MATRIX  STIFF /    1/                                              PAGE    1

                      CUTOFF =    0.0                                       SIZE    36  BY    36

            FORCE                   FORCE                  FORCE                  FORCE                  FORCE

DISP     1     1   0.721690E 08    3  -0.763991E 07    4   0.372846E 07    7   0.185801E 08    9  -0.819605E 07
              10  -0.112303E 08   13  -0.330032E 07   15  -0.136662E 08   16   0.186423E 07   19  -0.104023E 08
              21  -0.902113E 07   22  -0.561516E 07   26  -0.559269E 07   29  -0.279634E 07   32   0.168455E 08
              35   0.842275E 07

DISP     2     2   0.814384E 08    3  -0.372846E 07    4   0.139294E 08    8  -0.291933E 08    9  -0.112303E 08
              10  -0.105134E 08   14   0.133441E 07   15  -0.186423E 07   16  -0.288149E 07   20  -0.342890E 08
              21  -0.561516E 07   22  -0.101798E 08   25  -0.393061E 08   26  -0.982654E 07   28  -0.130496E 08
              29  -0.326240E 07   31   0.130496E 08   32   0.326240E 07   34   0.393061E 08   35   0.982654E 07

DISP     3     1  -0.763991E 07    2  -0.372846E 07    3   0.721690E 08    5  -0.763991E 07    6   0.372846E 07
               7  -0.819605E 07    8   0.112303E 08    9   0.185801E 08   11  -0.819605E 07   12  -0.112303E 08
              13  -0.136662E 08   14  -0.186423E 07   15  -0.330032E 07   17  -0.136662E 08   18   0.186423E 07
              19  -0.902113E 07   20   0.561516E 07   21  -0.104023E 08   23  -0.902113E 07   24  -0.561516E 07
              25   0.559269E 07   27  -0.559269E 07   28   0.279634E 07   30  -0.279634E 07   31  -0.168455E 08
              33   0.168455E 08   34  -0.842275E 07   36   0.842275E 07

DISP     4     1   0.372846E 07    2   0.139294E 08    4   0.814384E 08    5  -0.372846E 07    6   0.139294E 08
               7   0.112303E 08    8  -0.105134E 08   10  -0.291933E 08   11  -0.112303E 08   12  -0.105134E 08
              13   0.186423E 07   14  -0.288149E 07   16   0.133441E 07   17  -0.186423E 07   18  -0.288148E 07
              19   0.561516E 07   20  -0.101798E 08   22  -0.342890E 08   23  -0.561516E 07   24  -0.101798E 08
              25  -0.982654E 07   26  -0.393061E 08   27  -0.982654E 07   28  -0.326240E 07   29  -0.130496E 08
              30  -0.326240E 07   31   0.326240E 07   32   0.130496E 08   33   0.326240E 07   34   0.982654E 07
              35   0.393061E 08   36   0.982654E 07

DISP     5     3  -0.763991E 07    4  -0.372846E 07    5   0.360845E 08    6  -0.112303E 08    9  -0.819605E 07
              10   0.112303E 08   11   0.929007E 07   12   0.372846E 07   15  -0.136662E 08   16  -0.186423E 07
              17  -0.165016E 07   18  -0.561516E 07   21  -0.902113E 07   22   0.561516E 07   23  -0.520117E 07
              24   0.186423E 07   26   0.559269E 07   27   0.168455E 08   29   0.279634E 07   30   0.842275E 07
              32  -0.168455E 08   33  -0.559269E 07   35  -0.842275E 07   36  -0.279634E 07

DISP     6     3   0.372846E 07    4   0.139294E 08    5  -0.112303E 08    6   0.407192E 08    9   0.112303E 08
              10  -0.105134E 08   11  -0.372846E 07   12  -0.145967E 08   15   0.186423E 07   16  -0.288148E 07
              17  -0.561516E 07   18   0.667204E 06   21   0.561516E 07   22  -0.101798E 08   23  -0.186423E 07
              24  -0.171445E 08   26  -0.982654E 07   27  -0.196531E 08   29  -0.326240E 07   30  -0.652481E 07
              32   0.326240E 07   33   0.652481E 07   35   0.982654E 07   36   0.196531E 08

DISP     7     1   0.185801E 08    3  -0.819605E 07    4   0.112303E 08    7   0.721690E 08    9  -0.763991E 07
              10  -0.372846E 07   13  -0.104023E 08   15  -0.902113E 07   16   0.561516E 07   19  -0.330032E 07
              21  -0.136662E 08   22  -0.186423E 07   26  -0.279634E 07   29  -0.559269E 07   32   0.842275E 07
              35   0.168455E 08

DISP     8     2  -0.291933E 08    3   0.112303E 08    4  -0.105134E 08    8   0.814384E 08    9   0.372846E 07
              10   0.139294E 08   14  -0.342890E 08   15   0.561516E 07   16  -0.101798E 08   20   0.133441E 07
              21   0.186423E 07   22  -0.288149E 07   25   0.130496E 08   26   0.326240E 07   28   0.393061E 08
              29   0.982654E 07   31  -0.393061E 08   32  -0.982654E 07   34  -0.130496E 08   35  -0.326240E 07
```

FIGURE III-B.17 STIFFNESS MATRIX - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                            MATRIX  STIFF /    1/                                    PAGE    2

                     CUTOFF  =    0.0                               SIZE    36  BY    36

              FORCE                FORCE                   FORCE                  FORCE                  FORCE

DISP    9    1  -0.819605E 07    2  -0.112303E 08    3   0.185801E 08    5  -0.819605E 07    6   0.112303E 08
             7  -0.763991E 07    8   0.372846E 07    9   0.721690E 08   11  -0.763991E 07   12  -0.372846E 07
            13  -0.902113E 07   14  -0.561516E 07   15  -0.104023E 08   17  -0.902113E 07   18   0.561516E 07
            19  -0.136662E 08   20   0.186423E 07   21  -0.330032E 07   23  -0.136662E 08   24  -0.186423E 07
            25   0.279634E 07   27  -0.279634E 07   28   0.559269E 07   30  -0.559269E 07   31  -0.842275E 07
            33   0.842275E C7   34  -0.168455E 08   36   0.168455E 08

DISP   10    1  -0.112303E 08    2  -0.105134E 08    4  -0.291933E 08    5   0.112303E 08    6  -0.105134E 08
             7  -0.372846E 07    8   0.139294E 08   10   0.814384E 08   11   0.372846E 07   12   0.139294E 08
            13  -0.561516E 07   14  -0.101798E 08   16  -0.342890E 08   17   0.561516E 07   18  -0.101798E 08
            19  -0.186423E 07   20  -0.288149E 07   22   0.133441E 07   23   0.186423E 07   24  -0.288148E 07
            25   0.326240E 07   26   C.130496E 08   27   0.326240E 07   28   0.982654E 07   29   0.393061E 08
            30   0.982654E 07   31  -0.982654E 07   32  -0.393061E 08   33  -0.982654E 07   34  -0.326240E 07
            35  -0.130496E 08   36  -0.326240E 07

DISP   11    3  -0.819605E 07    4  -0.112303E 08    5   0.929007E 07    6  -0.372846E 07    9  -0.763991E 07
            10   0.372846E 07   11   0.360845E 08   12   0.112303E 08   15  -0.902113E 07   16  -0.561516E 07
            17  -0.520117E 07   18  -0.186423E 07   21  -0.136662E 08   22   0.186423E 07   23  -0.165016E 07
            24   0.561516E 07   26   0.279634E 07   27   0.842275E 07   29   0.559269E 07   30   0.168455E 08
            32  -0.842275E C7   33  -0.279634E 07   35  -0.168455E 08   36  -0.559269E 07

DISP   12    3  -0.112303E 08    4  -0.105134E 08    5   0.372846E 07    6  -0.145967E 08    9  -0.372846E 07
            10   0.139294E 08   11   0.112303E 08   12   0.407192E 08   15  -0.561516E 07   16  -0.101798E 08
            17   0.186423E 07   18  -0.171445E 08   21  -0.186423E 07   22  -0.288148E 07   23   0.561516E 07
            24   0.667204E 06   26   0.326240E 07   27   0.652481E 07   29   0.982654E 07   30   0.196531E 08
            32  -0.982654E 07   33  -0.196531E 08   35  -0.326240E 07   36  -0.652481E 07

DISP   13    1  -0.330032E 07    3  -0.136662E 08    4   0.186423E 07    7  -0.104023E 08    9  -0.902113E 07
            10  -0.561516E 07   13   0.721690E 08   15  -0.763991E 07   16   0.372846E 07   19   0.185801E 08
            21  -0.819605E 07   22  -0.112303E 08   26  -0.168455E 08   29  -0.842275E 07   32   0.559269E 07
            35   0.279634E 07

DISP   14    2   0.133441E 07    3  -0.186423E 07    4  -0.288149E 07    8  -0.342890E 08    9  -0.561516E 07
            10  -0.101798E 08   14   0.814384E 08   15  -0.372846E 07   16   0.139294E 08   20  -0.291933E 08
            21  -0.112303E 08   22  -0.105134E 08   25  -0.130496E 08   26  -0.326240E 07   28  -0.393061E 08
            29  -0.982654E 07   31   0.393061E 08   32   0.982654E 07   34   0.130496E 08   35   0.326240E 07

DISP   15    1  -0.136662E 08    2  -0.186423E 07    3  -0.330032E 07    5  -0.136662E 08    6   0.186423E 07
             7  -0.902113E 07    8   0.561516E 07    9  -0.104023E 08   11  -0.902113E 07   12  -0.561516E 07
            13  -0.763991E 07   14  -0.372846E 07   15   0.721690E 08   17  -0.763991E 07   18   0.372846E 07
            19  -0.819605E 07   20   0.112303E 08   21   0.185801E 08   23  -0.819605E 07   24  -0.112303E 08
            25   0.168455E 08   27  -0.168455E 08   28   0.842275E 07   30  -0.842275E 07   31  -0.559269E 07
            33   0.559269E 07   34  -0.279634E 07   36   0.279634E 07

DISP   16    1   0.186423E 07    2  -0.288149E 07    4   0.133441E 07    5  -0.186423E 07    6  -0.288148E 07
             7   0.561516E C7    8  -0.101798E 08   10  -0.342890E 08   11  -0.561516E 07   12  -0.101798E 08
```

FIGURE III-B.17 CONTINUED

```
                                         MATRIX  STIFF /    1/                                                 PAGE    3

                        CUTOFF  =    0.0                                        SIZE     36  BY     36

              FORCE               FORCE                 FORCE                 FORCE                 FORCE

DISP     16    13   0.372846E 07   14   0.139294E 08   16   0.814384E 08   17  -0.372846E 07   18   0.139294E 08
               19   0.112303E 08   20  -0.105134E 08   22  -0.291933E 08   23  -0.112303E 08   24  -0.105134E 08
               25  -0.326240E 07   26  -0.130496E 08   27  -0.326240E 07   28  -0.982654E 07   29  -0.393061E 08
               30  -0.982654E 07   31   0.982654E 07   32   0.393061E 08   33   0.982654E 07   34   0.326240E 07
               35   0.130496E 08   36   0.326240E 07

DISP     17     3  -0.136662E 08    4  -0.186423E 07    5  -0.165016E 07    6  -0.561516E 07    9  -0.902113E 07
               10   0.561516E 07   11  -0.520117E 07   12   0.186423E 07   15  -0.763991E 07   16  -0.372846E 07
               17   0.360845E 08   18  -0.112303E 08   21  -0.819605E 07   22   0.112303E 08   23   0.929007E 07
               24   0.372846E 07   26   0.168455E 08   27   0.559269E 07   29   0.842275E 07   30   0.279634E 07
               32  -0.559269E 07   33  -0.168455E 08   35  -0.279634E 07   36  -0.842275E 07

DISP     18     3   0.186423E 07    4  -0.288148E 07    5  -0.561516E 07    6   0.667204E 06    9   0.561516E 07
               10  -0.101798E 08   11  -0.186423E 07   12  -0.171445E 08   15   0.372846E 07   16   0.139294E 08
               17  -0.112303E 08   18   0.407192E 08   21   0.112303E 08   22  -0.105134E 08   23  -0.372846E 07
               24  -0.145967E 08   26  -0.326240E 07   27  -0.652481E 07   29  -0.982654E 07   30  -0.196531E 08
               32   0.982654E 07   33   0.196531E 08   35   0.326240E 07   36   0.652481E 07

DISP     19     1  -0.104023E 08    3  -0.902113E 07    4   0.561516E 07    7  -0.330032E 07    9  -0.136662E 08
               10  -0.186423E 07   13   0.185801E 08   15  -0.819605E 07   16   0.112303E 08   19   0.721690E 08
               21  -0.763991E 07   22  -0.372846E 07   26  -0.842275E 07   29  -0.168455E 08   32   0.279634E 07
               35   0.559269E 07

DISP     20     2  -0.342890E 08    3   0.561516E 07    4  -0.101798E 08    8   0.133441E 07    9   0.186423E 07
               10  -0.288149E 07   14  -0.291933E 08   15   0.112303E 08   16  -0.105134E 08   20   0.814384E 08
               21   0.372846E 07   22   0.139294E 08   25   0.393061E 08   26   0.982654E 07   28   0.130496E 08
               29   0.326240E 07   31  -0.130496E 08   32  -0.326240E 07   34  -0.393061E 08   35  -0.982654E 07

DISP     21     1  -0.902113E 07    2  -0.561516E 07    3  -0.104023E 08    5  -0.902113E 07    6   0.561516E 07
                7  -0.136662E 08    8   0.186423E 07    9  -0.330032E 07   11  -0.136662E 08   12  -0.186423E 07
               13  -0.819605E 07   14  -0.112303E 08   15   0.185801E 08   17  -0.819605E 07   18   0.112303E 08
               19  -0.763991E 07   20   0.372846E 07   21   0.721690E 08   23  -0.763991E 07   24  -0.372846E 07
               25   0.842275E 07   27  -0.842275E 07   28   0.168455E 08   30  -0.168455E 08   31  -0.279634E 07
               33   0.279634E 07   34  -0.559269E 07   36   0.559269E 07

DISP     22     1  -0.561516E 07    2  -0.101798E 08    4  -0.342890E 08    5   0.561516E 07    6  -0.101798E 08
                7  -0.186423E 07    8  -0.288149E 07   10   0.133441E 07   11   0.186423E 07   12  -0.288148E 07
               13  -0.112303E 08   14  -0.105134E 08   16  -0.291933E 08   17   0.112303E 08   18  -0.105134E 08
               19  -0.372846E 07   20   0.139294E 08   22   0.814384E 08   23   0.372846E 07   24   0.139294E 08
               25   0.982654E 07   26   0.393061E 08   27   0.982654E 07   28   0.326240E 07   29   0.130496E 08
               30   0.326240E 07   31  -0.326240E 07   32  -0.130496E 08   33  -0.326240E 07   34  -0.982654E 07
               35  -0.393061E 08   36  -0.982654E 07

DISP     23     3  -0.902113E 07    4  -0.561516E 07    5  -0.520117E 07    6  -0.186423E 07    9  -0.136662E 08
               10   0.186423E 07   11  -0.165016E 07   12   0.561516E 07   15  -0.819605E 07   16  -0.112303E 08
               17   0.929007E 07   18  -0.372846E 07   21  -0.763991E 07   22   0.372846E 07   23   0.360845E 08
```

FIGURE III-B.17 CONTINUED

```
                                         MATRIX  STIFF /    1/                                                  PAGE     4

                     CUTOFF  =    0.0                                        SIZE     36  BY     36

            FORCE              FORCE              FORCE              FORCE              FORCE

DISP     23   24   0.112303E 08   26   0.842275E 07   27   0.279634E 07   29   0.168455E 08   30   0.559269E 07
              32  -0.279634E 07   33  -0.842275E 07   35  -0.559269E 07   36  -0.168455E 08

DISP     24    3  -0.561516E 07    4  -0.101798E 08    5   0.186423E 07    6  -0.171445E 08    9  -0.186423E 07
              10  -0.288148E 07   11   0.561516E 07   12   0.667204E 06   15  -0.112303E 08   16  -0.105134E 08
              17   0.372846E 07   18  -0.145967E 08   21  -0.372846E 07   22   0.139294E 08   23   0.112303E 08
              24   0.407192E 08   26   0.982654E 07   27   0.196531E 08   29   0.326240E 07   30   0.652481E 07
              32  -0.326240E 07   33  -0.652481E 07   35  -0.982654E 07   36  -0.196531E 08

DISP     25    2  -0.393061E 08    3   0.559269E 07    4  -0.982654E 07    8   0.130496E 08    9   0.279634E 07
              10   0.326240E 07   14  -0.130496E 08   15   0.168455E 08   16  -0.326240E 07   20   0.393061E 08
              21   0.842275E 07   22   0.982654E 07   25   0.125112E 09   26   0.248478E 08   28   0.450516E 08
              29   0.804782E 07   31  -0.947472E 08   32  -0.269019E 08   34  -0.561258E 08   35  -0.156390E 08

DISP     26    1  -0.559269E 07    2  -0.982654E 07    4  -0.393061E 08    5   0.559269E 07    6  -0.982654E 07
               7  -0.279634E 07    8   0.326240E 07   10   0.130496E 08   11   0.279634E 07   12   0.326240E 07
              13  -0.168455E 08   14  -0.326240E 07   16  -0.130496E 08   17   0.168455E 08   18  -0.326240E 07
              19  -0.842275E 07   20   0.982654E 07   22   0.393061E 08   23   0.842275E 07   24   0.982654E 07
              25   0.248478E 08   26   0.125112E 09   27   0.248478E 08   28   0.804782E 07   29   0.450516E 08
              30   0.804782E 07   31  -0.269019E 08   32  -0.947472E 08   33  -0.269019E 08   34  -0.156390E 08
              35  -0.561258E 08   36  -0.156390E 08

DISP     27    3  -0.559269E 07    4  -0.982654E 07    5   0.168455E 08    6  -0.196531E 08    9  -0.279634E 07
              10   0.326240E 07   11   0.842275E 07   12   0.652481E 07   15  -0.168455E 08   16  -0.326240E 07
              17   0.559269E 07   18  -0.652481E 07   21  -0.842275E 07   22   0.982654E 07   23   0.279634E 07
              24   0.196531E 08   26   0.248478E 08   27   0.625560E 08   29   0.804782E 07   30   0.225258E 08
              32  -0.269019E 08   33  -0.473736E 08   35  -0.156390E 08   36  -0.280629E 08

DISP     28    2  -0.130496E 08    3   0.279634E 07    4  -0.326240E 07    8   0.393061E 08    9   0.559269E 07
              10   0.982654E 07   14  -0.393061E 08   15   0.842275E 07   16  -0.982654E 07   20   0.130496E 08
              21   0.168455E 08   22   0.326240E 07   25   0.450516E 08   26   0.804782E 07   28   0.125112E 09
              29   0.248478E 08   31  -0.561258E 08   32  -0.156390E 08   34  -0.947472E 08   35  -0.269019E 08

DISP     29    1  -0.279634E 07    2  -0.326240E 07    4  -0.130496E 08    5   0.279634E 07    6  -0.326240E 07
               7  -0.559269E 07    8   0.982654E 07   10   0.393061E 08   11   0.559269E 07   12   0.982654E 07
              13  -0.842275E 07   14  -0.982654E 07   16  -0.393061E 08   17   0.842275E 07   18  -0.982654E 07
              19  -0.168455E 08   20   0.326240E 07   22   0.130496E 08   23   0.168455E 08   24   0.326240E 07
              25   0.804782E 07   26   0.450516E 08   27   0.804782E 07   28   0.248478E 08   29   0.125112E 09
              30   0.248478E 08   31  -0.156390E 08   32  -0.561258E 08   33  -0.156390E 08   34  -0.269019E 08
              35  -0.947472E 08   36  -0.269019E 08

DISP     30    3  -0.279634E 07    4  -0.326240E 07    5   0.842275E 07    6  -0.652481E 07    9  -0.559269E 07
              10   0.982654E 07   11   0.168455E 08   12   0.196531E 08   15  -0.842275E 07   16  -0.982654E 07
              17   0.279634E 07   18  -0.196531E 08   21  -0.168455E 08   22   0.326240E 07   23   0.559269E 07
              24   0.652481E 07   26   0.804782E 07   27   0.225258E 08   29   0.248478E 08   30   0.625560E 08
```

FIGURE III-B 17 CONTINUED

```
                                        MATRIX  STIFF /   1/                                               PAGE    5
                         CUTOFF =    0.0                                  SIZE    36  BY    36

                FORCE                 FORCE                 FORCE                 FORCE                 FORCE

DISP     30    32  -0.156390E 08   33  -0.280629E 08   35  -0.269019E 08   36  -0.473736E 08

DISP     31     2   0.130496E 08    3  -0.168455E 08    4   0.326240E 07    8  -0.393061E 08    9  -0.842275E 07
               10  -0.982654E 07   14   0.393061E 08   15  -0.559269E 07   16   0.982654E 07   20  -0.130496E 08
               21  -0.279634E 07   22  -0.326240E 07   25  -0.947472E 08   26  -0.269019E 08   28  -0.561258E 08
               29  -0.156390E 08   31   0.125112E 09   32   0.248478E 08   34   0.450516E 08   35   0.804782E 07

DISP     32     1   0.168455E 08    2   0.326240E 07    4   0.130496E 08    5  -0.168455E 08    6   0.326240E 07
                7   0.842275E 07    8  -0.982654E 07   10  -0.393061E 08   11  -0.842275E 07   12  -0.982654E 07
               13   0.559269E 07   14   0.982654E 07   16   0.393061E 08   17  -0.559269E 07   18   0.982654E 07
               19   0.279634E 07   20  -0.326240E 07   22  -0.130496E 08   23  -0.279634E 07   24  -0.326240E 07
               25  -0.269019E 08   26  -0.947472E 08   27  -0.269019E 08   28  -0.156390E 08   29  -0.561258E 08
               30  -0.156390E 08   31   0.248478E 08   32   0.125112E 09   33   0.248478E 08   34   0.804782E 07
               35   0.450516E 08   36   0.804782E 07

DISP     33     3   0.168455E 08    4   0.326240E 07    5  -0.559269E 07    6   0.652481E 07    9   0.842275E 07
               10  -0.982654E 07   11  -0.279634E 07   12  -0.196531E 08   15   0.559269E 07   16   0.982654E 07
               17  -0.168455E 08   18   0.196531E 08   21   0.279634E 07   22  -0.326240E 07   23  -0.842275E 07
               24  -0.652481E 07   26  -0.269019E 08   27  -0.473736E 08   29  -0.156390E 08   30  -0.280629E 08
               32   0.248478E 08   33   0.625560E 08   35   0.804782E 07   36   0.225258E 08

DISP     34     2   0.393061E 08    3  -0.842275E 07    4   0.982654E 07    8  -0.130496E 08    9  -0.168455E 08
               10  -0.326240E 07   14   0.130496E 08   15  -0.279634E 07   16   0.326240E 07   20  -0.393061E 08
               21  -0.559269E 07   22  -0.982654E 07   25  -0.561258E 08   26  -0.156390E 08   28  -0.947472E 08
               29  -0.269019E 08   31   0.450516E 08   32   0.804782E 07   34   0.125112E 09   35   0.248478E 08

DISP     35     1   0.842275E 07    2   0.982654E 07    4   0.393061E 08    5  -0.842275E 07    6   0.982654E 07
                7   0.168455E 08    8  -0.326240E 07   10  -0.130496E 08   11  -0.168455E 08   12  -0.326240E 07
               13   0.279634E 07   14   0.326240E 07   16   0.130496E 08   17  -0.279634E 07   18   0.326240E 07
               19   0.559269E 07   20  -0.982654E 07   22  -0.393061E 08   23  -0.559269E 07   24  -0.982654E 07
               25  -0.156390E 08   26  -0.561258E 08   27  -0.156390E 08   28  -0.269019E 08   29  -0.947472E 08
               30  -0.269019E 08   31   0.804782E 07   32   0.450516E 08   33   0.804782E 07   34   0.248478E 08
               35   0.125112E 09   36   0.248478E 08

DISP     36     3   0.842275E 07    4   0.982654E 07    5  -0.279634E 07    6   0.196531E 08    9   0.168455E 08
               10  -0.326240E 07   11  -0.559269E 07   12  -0.652481E 07   15   0.279634E 07   16   0.326240E 07
               17  -0.842275E 07   18   0.652481E 07   21   0.559269E 07   22  -0.982654E 07   23  -0.168455E 08
               24  -0.196531E 08   26  -0.156390E 08   27  -0.280629E 08   29  -0.269019E 08   30  -0.473736E 08
               32   0.804782E 07   33   0.225258E 08   35   0.248478E 08   36   0.625560E 08
```

FIGURE III-B.17 CONCLUDED

```
                              GPRIAT CF MATRIX  LOADS    (SET   1)

ROW        FX             FY               FZ
    1      0.0           0.0             0.0
    2      0.0           0.0             0.0
    3      0.0           0.0             0.0
    4      0.0          -0.66666992E 02  0.0
    5      0.0           0.0             0.0
    6      0.0           0.0             0.0
    7      0.0           0.0             0.0
    8      0.0           0.66666992E 02  0.0
    9      0.0           0.0             0.0
   10      0.0           0.0             0.0
   11      0.0           0.0             0.0
   12      0.0          -0.66666992E 02  0.0
   13      0.0           0.0             0.0
   14      0.0           0.0             0.0
   15      0.0           0.0             0.0
   16      0.0           0.66666992E 02  0.0
```

FIGURE III-B.18 GPRINT OF MATRIX LOADS - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                         DISPLACEMENT MATRIX FOR LOAD CONDITION    1
                                        48 X 1

ROW          U                  V                  W
   1      0.0                0.0                0.0
   2      0.72126363E-06    -0.43426453E-05    -0.50667686E-05
   3      0.57006582E-06    -0.90564117E-05    -0.20699066E-04
   4      0.60850289E-06    -0.13695938E-04    -0.47243157E-04
   5      0.0                0.0                0.0
   6     -0.72112090E-06     0.43425607E-05    -0.50667450E-05
   7     -0.56904446E-06     0.90560370E-05    -0.20699066E-04
   8     -0.60586717E-06     0.13695391E-04    -0.47243229E-04
   9      0.0                0.0                0.0
  10     -0.72141148E-06    -0.43426089E-05    -0.50665412E-05
  11     -0.56976023E-06    -0.90560670E-05    -0.20698557E-04
  12     -0.60687034E-06    -0.13695461E-04    -0.47242473E-04
  13      0.0                0.0                0.0
  14      0.72154944E-06     0.43426799E-05    -0.50665967E-05
  15      0.57072793E-06     0.90564772E-05    -0.20698542E-04
  16      0.60934690E-06     0.13695978E-04    -0.47242473E-04
```

FIGURE III-B.19 DISPLACEMENT MATRIX - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                              REACTIONS AND INVERSE CHECK FOR LOAD CONDITION      1

ROW         FX                 FY                 FZ
   1   -0.28477386E 02    0.66678650E 02    0.32339096E-02
   2    0.47016144E-03    0.78678131E-03   -0.41007996E-04
   3    0.70276260E-02    0.55789948E-03   -0.27370453E-02
   4    0.74005127E-02    0.38146973E-03   -0.18739700E-02
   5    0.28476883E 02   -0.66676590E 02    0.27313232E-02
   6    0.84018707E-03    0.32854080E-02   -0.14524460E-02
   7    0.63781738E-02   -0.36373138E-02   -0.41780472E-02
   8    0.26702881E-02   -0.40283203E-02   -0.41713715E-02
   9    0.28478012E 02    0.66677841E 02    0.24719238E-02
  10   -0.57220459E-03   -0.57306290E-02   -0.85163116E-03
  11   -0.35266876E-02    0.29077530E-02   -0.14371872E-02
  12   -0.57754517E-02    0.32806396E-02   -0.40054321E-04
  13   -0.28477570E 02   -0.66678787E 02    0.17709732E-02
  14   -0.62942505E-03   -0.24547577E-02   -0.23851395E-02
  15   -0.79050064E-02    0.22563934E-02    0.51784515E-02
  16   -0.59204102E-02    0.22430420E-02    0.30946732E-02
```

FIGURE III-B.20 REACTION MATRIX - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                     S T R E S S E S   F C R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T
                                        (STRESSES EVALUATED AT THE ELEMENT CENTROID)

        LOAD CONDITION NUMBER     ELEMEAT ALMBER     ELEMENT TYPE        ELEMENT GRID POINTS

                     1                  1                 52              1   2   6   5   5  10  14  13

APPARENT ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y           SIGMA-Z            SIGMA-XY           SIGMA-YZ            SIGMA-ZX
   1      0.28610229E-04     0.44822693E-04     0.63896179E-04    -0.28610229E-05    -0.42515344E-03     0.66757202E-05

ELEMENT APPLIED STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y           SIGMA-Z            SIGMA-XY           SIGMA-YZ            SIGMA-ZX
   1      0.0                0.0                0.0                0.0                0.0                 0.0

NET ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y           SIGMA-Z            SIGMA-XY           SIGMA-YZ            SIGMA-ZX
   1      0.28610229E-04     0.44822693E-04     0.63896179E-04    -0.28610229E-05    -0.42515344E-03     0.66757202E-05
```

FIGURE III-B.21 STRESS OUTPUT, ELEMENT NO. 1 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T
                                  (STRESSES EVALUATED AT THE ELEMENT CENTROID)

      LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

                1                      2                52              3    2   10   11    7    6   14   15

APPARENT ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X             SIGMA-Y             SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
   1       0.30517578E-04     -0.30517578E-04     -0.10681152E-03      0.20313263E-03      0.24795532E-04     -0.46730042E-04

ELEMENT APPLIED STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X             SIGMA-Y             SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
   1       0.0                 0.0                 0.0                 0.0                 0.0                 0.0

NET ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X             SIGMA-Y             SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
   1       0.30517578E-04     -0.30517578E-04     -0.10681152E-03      0.20313263E-03      0.24795532E-04     -0.46730042E-04
```

FIGURE III-B.22 STRESS OUTPUT, ELEMENT NO. 2 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T
                                          (STRESSES EVALUATED AT THE ELEMENT CENTROID)

     LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE        ELEMENT GRID POINTS

               1                      3                  52               4   12   16    8    3   11   15    7

APPARENT ELEMENT STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT         SIGMA-X           SIGMA-Y           SIGMA-Z           SIGMA-XY            SIGMA-YZ           SIGMA-ZX
   1      -0.61035156E-04   -0.39672852E-03   -0.30517578E-04   -0.40054321E-04    0.20217896E-03   -0.49591064E-04

ELEMENT APPLIED STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT         SIGMA-X           SIGMA-Y           SIGMA-Z           SIGMA-XY            SIGMA-YZ           SIGMA-ZX
   1        0.0               0.0               0.0               0.0                0.0                0.0

NET ELEMENT STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT         SIGMA-X           SIGMA-Y           SIGMA-Z           SIGMA-XY            SIGMA-YZ           SIGMA-ZX
   1      -0.61035156E-04   -0.39672852E-03   -0.30517578E-04   -0.40054321E-04    0.20217896E-03   -0.49591064E-04
```

FIGURE III-B.23 STRESS OUTPUT, ELEMENT NO. 3 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                      F O R C E S   F O R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T

     LOAD CONDITION NUMBER     ELEMENT NUMBER    ELEMENT TYPE       ELEMENT GRID POINTS

                1                     1                52            1    2    6    5    9   10   14   13


APPARENT ELEMENT FORCES
POINT                                FORCES
                 FX                    FY                     FZ
     1     -0.28477417E 02       0.66678665E 02       0.32653809E-02
     2     -0.59162750E 01      -0.66672806E 02      -0.27008057E-02
     3      0.59156494E 01       0.66670883E 02      -0.29954910E-02
     4      0.28476898E 02      -0.66676605E 02       0.27618408E-02
     5      0.28478012E 02       0.66677841E 02       0.24566650E-02
     6      0.59155121E 01      -0.66671478E 02      -0.12664795E-02
     7     -0.59147644E C1       0.66672318E 02      -0.33569336E-02
     8     -0.28477585E 02      -0.66678818E 02       0.17547607E-02


ELEMENT APPLIED FORCES
POINT                                FORCES
                 FX                    FY                     FZ
     1      0.0                  0.0                  0.0
     2      0.0                  0.0                  0.0
     3      0.0                  0.0                  0.0
     4      0.0                  0.0                  0.0
     5      0.0                  0.0                  0.0
     6      0.0                  0.0                  0.0
     7      0.0                  0.0                  0.0
     8      0.0                  0.0                  0.0


NET ELEMENT FORCES
POINT                                FORCES
                 FX                    FY                     FZ
     1     -0.28477417E 02       0.66678665E 02       0.32653809E-02
     2     -0.59162750E C1      -0.66672806E 02      -0.27008057E-02
     3      0.59156494E 01       0.66670883E 02      -0.29954910E-02
     4      0.28476898E 02      -0.66676605E 02       0.27618408E-02
     5      0.28478012E 02       0.66677841E 02       0.24566650E-02
     6      0.59155121E 01      -0.66671478E 02      -0.12664795E-02
     7     -0.59147644E 01       0.66672318E 02      -0.33569336E-02
     8     -0.28477585E C2      -0.66678818E 02       0.17547607E-02
```

FIGURE III-B.24 FORCE OUTPUT, ELEMENT NO. 1 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                         F O R C E S   F O R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE          ELEMENT GRID POINTS

                1                       2                  52              3    2   10   11    7    6   14   15


APPARENT ELEMENT FORCES
POINT                                    FORCES
                   FX                      FY                      FZ
     1       0.11796875E  01     -0.66669357E  02     -0.12207031E-02
     2       0.59157715E  01      0.66673553E  02      0.33721924E-02
     3      -0.59153137E  01      0.66665924E  02      0.10223389E-02
     4      -0.11799622E  01     -0.66663589E  02     -0.48828125E-03
     5      -0.11765747E  01      0.66663559E  02     -0.40235519E-02
     6      -0.59152527E  01     -0.66667511E  02      0.71716309E-03
     7       0.59148560E  01     -0.66673813E  02      0.24414063E-03
     8       0.11774902E  01      0.66671112E  02      0.73242188E-03


ELEMENT APPLIED FORCES
POINT                                    FORCES
                   FX                      FY                      FZ
     1       0.0                  0.0                  0.0
     2       0.0                  0.0                  0.0
     3       0.0                  0.0                  0.0
     4       0.0                  0.0                  0.0
     5       0.0                  0.0                  0.0
     6       0.0                  0.0                  0.0
     7       0.0                  0.0                  0.0
     8       0.0                  0.0                  0.0


NET ELEMENT FORCES
POINT                                    FORCES
                   FX                      FY                      FZ
     1       0.11796875E  01     -0.66669357E  02     -0.12207031E-02
     2       0.59157715E  01      0.66673553E  02      0.33721924E-02
     3      -0.59153137E  01      0.66665924E  02      0.10223389E-02
     4      -0.11799622E  01     -0.66663589E  02     -0.48828125E-03
     5      -0.11765747E  01      0.66663559E  02     -0.40235519E-02
     6      -0.59152527E  01     -0.66667511E  02      0.71716309E-03
     7       0.59148560E  01     -0.66673813E  02      0.24414063E-03
     8       0.11774902E  01      0.66671112E  02      0.73242188E-03
```

FIGURE III-B.25 FORCE OUTPUT, ELEMENT NO. 2 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                F O R C E S   F C R   T H E   R E C T A N G U L A R   P R I S M   E L E M E N T

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE        ELEMENT GRID POINTS

                1                      3                   52            4   12   16    8    3   11   15    7

APPARENT ELEMENT FORCES
POINT                                   FORCES
                 FX                       FY                      FZ
   1       0.75988770E-02         -0.66667648E 02         -0.12512207E-02
   2      -0.39520264E-02         -0.66665237E 02          0.16021729E-02
   3      -0.57678223E-02          0.66665312E 02          0.41198730E-02
   4       0.18768311E-02          0.66663513E 02         -0.58593750E-02
   5      -0.11749878E 01          0.66669052E 02         -0.24414063E-03
   6       0.11782227E 01          0.66665009E 02          0.24414063E-03
   7      -0.11833191E 01         -0.66668015E 02          0.31633377E-02
   8       0.11813965E 01         -0.66666159E 02         -0.26855469E-02

ELEMENT APPLIED FORCES
POINT                                   FORCES
                 FX                       FY                      FZ
   1       0.0                     0.0                     0.0
   2       0.0                     0.0                     0.0
   3       0.0                     0.0                     0.0
   4       0.0                     0.0                     0.0
   5       0.0                     0.0                     0.0
   6       0.0                     0.0                     0.0
   7       0.0                     0.0                     0.0
   8       0.0                     0.0                     0.0

NET ELEMENT FORCES
POINT                                   FORCES
                 FX                       FY                      FZ
   1       0.75988770E-02         -0.66667648E 02         -0.12512207E-02
   2      -0.39520264E-02         -0.66665237E 02          0.16021729E-02
   3      -0.57678223E-02          0.66669312E 02          0.41198730E-02
   4       0.18768311E-02          0.66663513E 02         -0.58593750E-02
   5      -0.11749878E 01          0.66669052E 02         -0.24414063E-03
   6       0.11782227E 01          0.66665009E 02          0.24414063E-03
   7      -0.11833191E 01         -0.66668015E 02          0.31633377E-02
   8       0.11813965E 01         -0.66666159E 02         -0.26855469E-02
```

FIGURE III-B.26 FORCE OUTPUT, ELEMENT NO. 3 - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

C. TETRAHEDRON ELEMENT

An eighteen element cantilever beam subjected to a constant pressure load is shown in Figure III-C.1 as the second example. This figure shows the loading, idealization, dimensions and material properties. The preprinted input data forms for this example problem is given in Figures III-C.2 to III-C.10.

Inspection of the figures shows that the input data is very similar to that given in the preceding example with the exception of the element pressure input data form, Figure III-C.9. On that form element related pressure data is recorded for each of the eighteen elements. The MODAL and REPEAT options are used to efficiently enter these data. The MODAL data indicates that a zero pressure is input for each of the four faces of each tetrahedron. The exceptions to this are given by the data cards following the MODAL inputs. In this particular example face 134 of elements, 1, 7 and 13 is pressurized and face 123 of elements 2, 8 and 14 is pressurized. It must be noted that the face numbers given above correspond to tetrahedron local numbering system.

The output supplied by the MAGIC III System for this example is described below and shown in Figures III-C.11 to III-C.27.

Figure III-C.11 displays the matrix abstraction instructions associated with this example. A complete description of these instructions is provided in Reference 5. Figures III-C.12 to III-C.16 show the output data obtained from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

An alternative means of obtaining the output shown in Figure III-C.12 to Figure III-C.27 is to use the .ANALIC. instruction sequence, Figure III-C.11A, in place of the standard STATICS AGENDUM shown on Figure III-C.11. Comparison of these two sets of abstraction instructions shows that the .ANALIC. sequence requires only two statements whereas the STATICS AGENDUM requires forty-five such statements. A considerable difference is evident.

Reference to Section II.B.4 of this report allows the reader to interpret the .ANALIC. instruction listing. To make use of .ANALIC. the User must input the following three cards; $MAGIC, $RUN-GO and $INSTRUCTION-SOURCE. The next two cards contain the .ANALIC. instructions. The first card is identical to the first card in the standard STATICS AGENDUM of Figure III-C.11. The second card pertains to the .ANALIC. instruction and each entry (DISPL, STR, etc) is defined on pp 25 thru 27 of this report. In this example problem, the three scalar values KALC, NNOM and NRSLEM were suppressed and the default values were used. Table I Page 27 shows that the default for KALC results in the use of the Cholesky triangularization method for solution of the governing equations. The default value for NNOM is eight which means that a maximum number of eight grid points can be used to define the element. The default value is forty for NRSLEM. This entry indicates the maximum number of rows in the element stress matrix. Consultation of Table II page 28 shows that NNOM equals 4 and NRSLEM equals 6 for the tetrahedron element used in this example problem. These values could have been used in place of the default values.

It is emphasized that .ANALIC. should be utilized for problems which are of the size that can be executed entirely in core. Depending on the type of finite elements being employed, the upper limit in the MAGIC III System for .ANALIC. is approximately two-hundred reduced degrees-of-freedom.

Figure III-C.12 displays the problem title and material data output. The gridpoint coordinates, temperatures and pressures are given in Figure III-C.13. Boundary condition information and finite element description is shown on Figure III-C.14. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed, (i.e. no motion) and ones ('1') represent degrees of freedom that are free (have unknown values of displacement). Note that no condensation procedure is used in this problem hence twos ('2') are not used. The second last column accumulates the number of active degrees of freedom which in this problem is 36. The second portion of Figure III-C.14 shows the finite element description. Each of the eighteen elements is called out in turn with grid points, print options and material number. Note that neither grid points nor section properties are presented since these are not required for the tetrahedron element.

Element input pressures are given on the Element Pressure Table in Figure III-C.15 for those elements subjected to such pressures. Four columns of pressure data are presented and reflect the input pressure on tetrahedra faces 134, 234, 124 and 123 respectively. Note again that these face numbers refer to local coordinate systems.

Figure III-C.16 displays the external load condition and transformed external assembled load column. Note that all loads are of zero magnitude since the only loading present in this example is the pressure which is considered an element applied load and not an external load as such.

MAGIC III System output of final results are displayed in Figures III-C.17 to III-C.27. The stiffness matrix is shown in Figure III-C.17. Only the non-zero terms are displayed and it is presented row-wise. It's ordering is consistent with that of the boundary condition table.

In this problem the ordering is

$$\{\bar{U}\}^T = \lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots.., U_{16}, V_{16}, W_{16} \rfloor$$

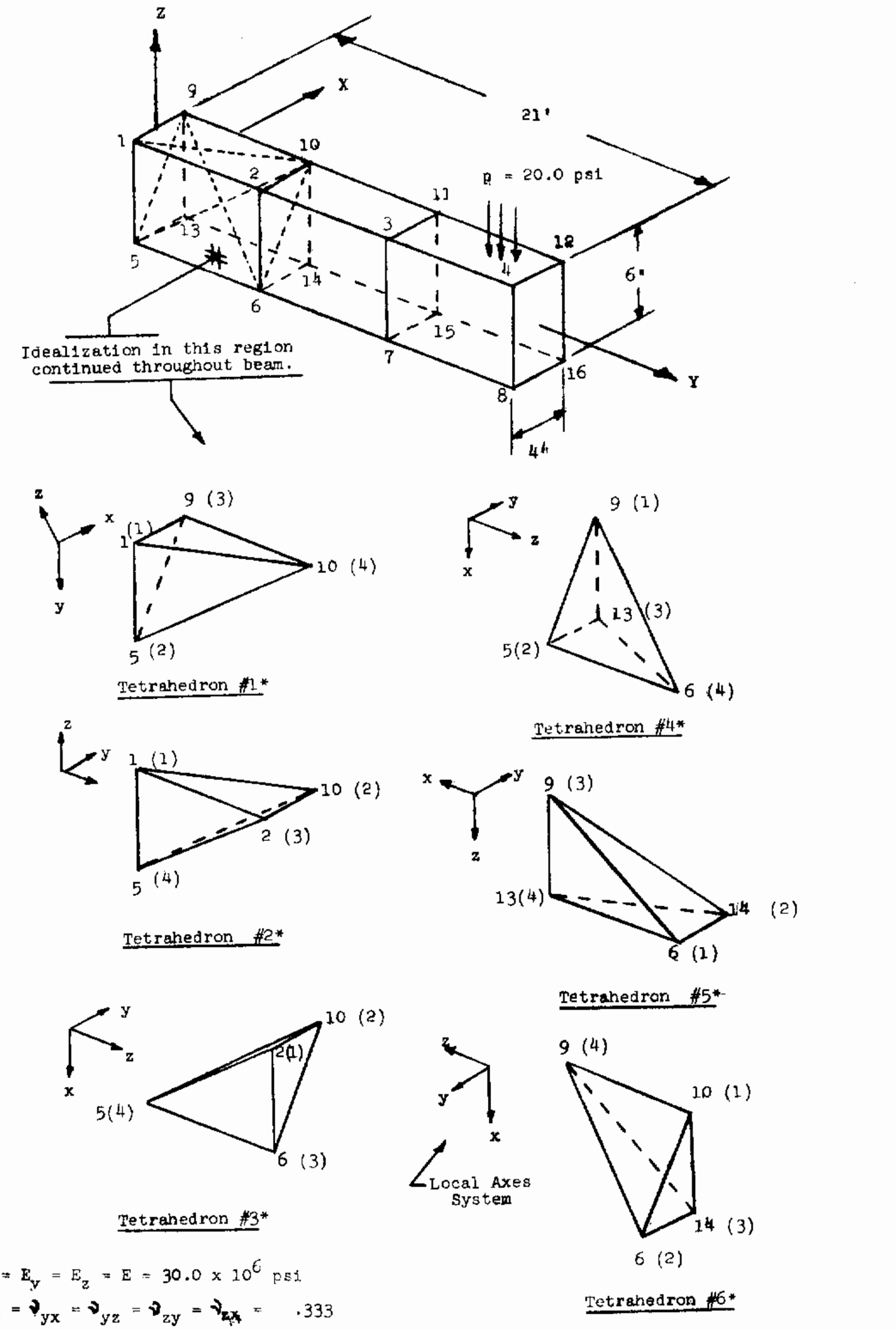
with degrees of freedom U_1, V_1, W_1, U_5, V_5, W_5, U_9, V_9, W_9 and U_{13}, V_{13} W_{13} fixed.

The matrix of element applied loads (GPRINT OF MATRIX FTELA) is shown in Figure III-C.18. This represents the work equivalent loads due to element applied pressure. It is this force vector, defined at each grid point, which loads the structure. This figure shows that loads of varying magnitude are applied in the negative global Z direction. The next figure, Figure III-C.19, shows the externally applied load vector (GPRINT OF MATRIX LOADS) which as discussed in the previous paragraph, are of zero magnitude.

The displacements of the cantilever beam resulting from the above loads are presented in Figure III-C.20. It is noted that the displacements (U, V, W) are output corresponding to node point numbers and are referenced to the global axes. Figure III-C.21 shows the reactions (F_x, F_y, F_z). These are also output corresponding to node point number and are referenced to the global axes unless otherwise specified.

The stresses arising in the structure are displayed in tabular form for each element. Typical results are presented in Figures III-C.22 to III-C.24 for elements 1, 7 and 18 respectively. Stresses are referenced to the global axes system and are defined for any point in the tetrahedron element since this element is a constant strain element. (See Reference 7). Normally the user will consider the stresses to be defined at the element's centroid, and the labeling (STRESSES EVALUATED AT ELEMENT CENTROID) reflects this consideration. Since no pre-strain or temperatures were considered in this problem the element applied stresses are zero and only the apparent element stresses are of significance. Thus the net element stresses and apparent element stresses are equal.

The last set of output is given in Figures III-C.25 to III-C.27 and consist of the global oriented element forces. Output labeling is analogous to the stress output labeling. The apparent element forces arise from the cantilever deformation and the element applied forces exist due to the element applied pressure. The force point 1, 2, 3,4, in this example correspond to element grid point numbers. For element number one, for example, force points 1,2,3,4 correspond to element grid points 1, 5, 9, 10 respectively.



$E_x = E_y = E_z = E = 30.0 \times 10^6$ psi

$\nu_{xy} = \nu_{yx} = \nu_{yz} = \nu_{zy} = \nu_{zx} = .333$

$F_x = F_y = F_z = 0,\ T_1 = T_2 = T_3 = \ldots T_{16}\quad 0.0$

p = 20.0 psi

* Numbers in parenthesis refer to local coordinate system x, y, z.

FIGURE III-C.1 TETRAHEDRON ELEMENT - CANTILEVER BEAM WITH PRESSURE LOAD, EIGHTEEN ELEMENTS

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6
TITLE (/)

7 8 9
2 (/) NUMBER OF TITLE CARDS

EIGHTEEN ELEMENT CANTILEVERED BEAM SUBJECTED TØ A PRESSURE

LØAD. TETRAHEDRØN ELEMENT IDEN. NØ. 50 STATICS ANALYSIS.

FIGURE III-C.2 TITLE INFORMATION - TETRAHEDRON ELEMENT, CANTILEVER BEAM

BAC 1616-1

M	A	T	E	R		(/)
1	2	3	4	5	6	

		1	(/)
7	8	9	

No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	1	JB	STEEL	X									1	0	.000733954	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13–22		23–32		33–42		43–52		53–62	
0.0	E_x	30.0 E6	ν_{xy}	.333	α_x	6.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-C.3 MATERIAL TAPE INPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

S	Y	S	T	E	M	(/)
1	2	3	4	5	6	

1. Number of System Grid Points

				1	6
1	2	3	4	5	6

2. Number of Input Grid Points

				1	6
7	8	9	10	11	12

3. Number of Degrees of Freedom/Grid Point

	3
13	14

4. Number of Load Conditions

	1
15	16

5. Number of Initially Displaced Grid Points

					0
17	18	19	20	21	22

6. Number of Prescribed Displaced Grid Points

					0
23	24	25	26	27	28

7. Number of Grid Point Axes Transformation Systems

	0
29	30

8. Number of Elements

				1	8
31	32	33	34	35	36

9. Number of Requests and/or Revisions of Material Tape.

	1
37	38

10. Number of Input Boundary Condition Points

					4
39	40	41	42	43	44

11. T_o For Structure (With Decimal Point)

					0	.	0	(/)
45	46	47	48	49	50	51	52	

FIGURE III-C.4 SYSTEM CONTROL INFORMATION - TETRAHEDRON ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C O O R D (/)

GRIDPOINT COORDINATE

Grid Point Number	X – R	Y – θ	Z – Z	
	DIRECTIONS			
1	1 2	2 3	3 4	
7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
1	-2.0	0.0	3.0	(/)
2	-2.0	-7.0	3.0	(/)
3	-2.0	-14.0	3.0	(/)
4	-2.0	-21.0	3.0	(/)
5	-2.0	0.0	-3.0	(/)
6	-2.0	-7.0	-3.0	(/)
7	-2.0	-14.0	-3.0	(/)
8	-2.0	-21.0	-3.0	(/)
9	2.0	0.0	3.0	(/)
10	2.0	-7.0	3.0	(/)
11	2.0	-14.0	3.0	(/)
12	2.0	-21.0	3.0	(/)
13	2.0	0.0	-3.0	(/)
14	2.0	-7.0	-3.0	(/)
15	2.0	-14.0	-3.0	(/)
16	2.0	-21.0	-3.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-C.5 GRIDPOINT COORDINATES - TETRAHEDRON ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -
0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	0							(/)
				5	X										(/)
				9	X										(/)
			1	3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-C.6 BOUNDARY CONDITIONS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS (/)

LCOND 1 1.0 (/)

Condition Number — Scaler

EXTERNAL LOADS

	FORCE VALUES				MOMENT VALUES				GENERALIZED VALUES			
	Fx	Fy	Fz		Mx	My	Mz		1	2	3	
MODAL	0.0	0.0	0.0	(/)				(/)				(/)
Grid Pt. Number / repeat				(/)				(/)				(/)

FIGURE III-C.7 EXTERNAL LOADS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	No. of Assem. Nodes	NODE POINTS											
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71
1	50	1	4							4		1	5	9	10								
7	50	1	4							4		2	6	10	11								
13	50	1	4							4		3	7	11	12								
2	50	1	4							4		1	10	2	5								
8	50	1	4							4		2	11	3	6								
14	50	1	4							4		3	12	4	7								
3	50	1	4							4		2	10	6	5								
4	50	1	4							4		9	5	13	6								
5	50	1	4							4		6	14	9	13								
6	50	1	4							4		10	6	14	9								
9	50	1	4							4		3	11	7	6								
10	50	1	4							4		10	6	14	7								
11	50	1	4							4		7	15	10	14								
12	50	1	4							4		11	7	15	10								
15	50	1	4							4		4	12	8	7								
16	50	1	4							4		11	7	15	8								
17	50	1	4							4		8	16	11	15								
18	50	1	4							4		12	8	16	11								

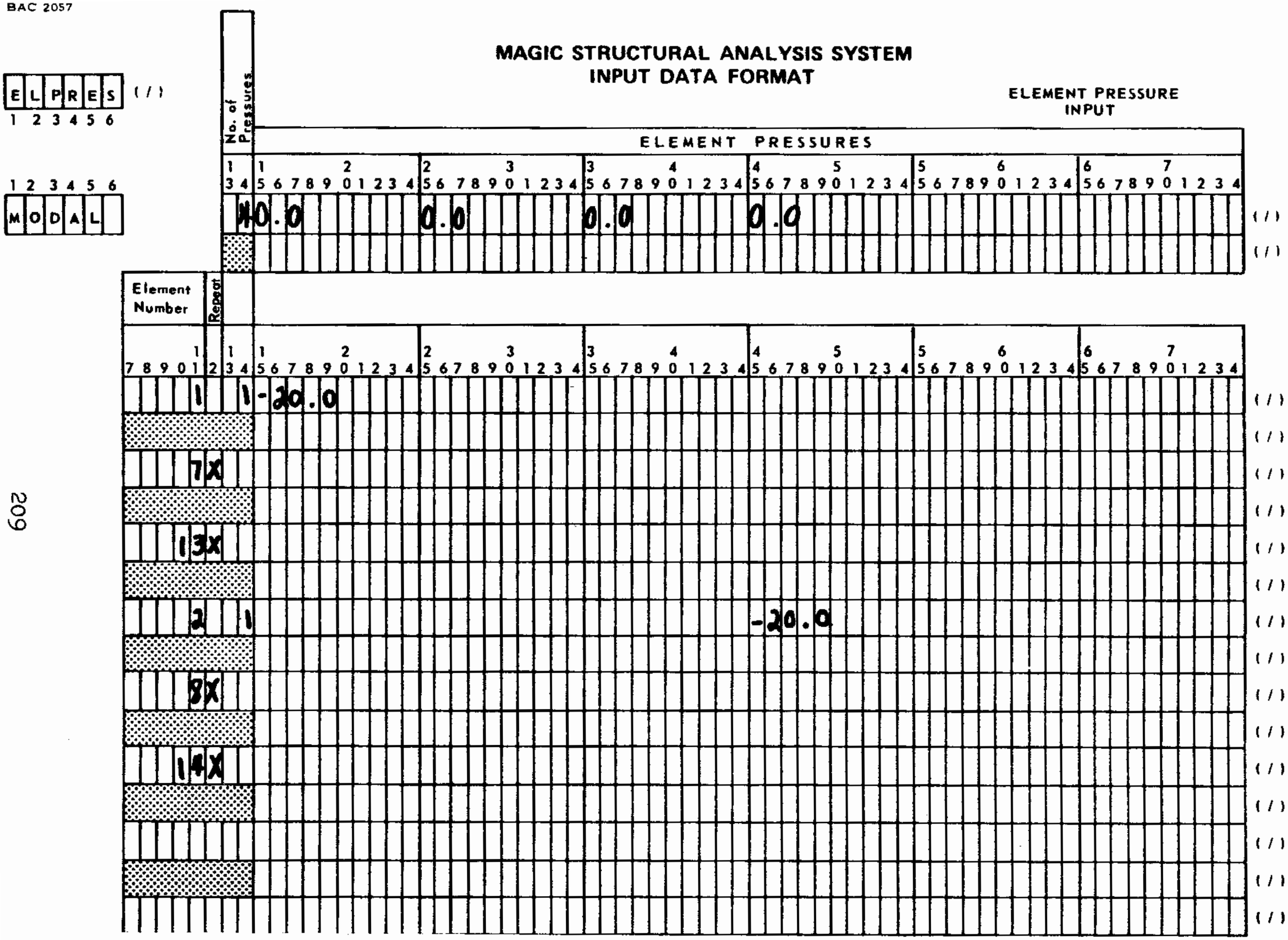
FIGURE III-C.8 ELEMENT CONTROL DATA - TETRAHEDRON ELEMENT, CANTILEVER BEAM

Page 1 of 1

BAC 2057

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESSURE INPUT



ELPRES (/)

MODAL

No. of Pressures	ELEMENT PRESSURES 1	2	3	4	5	6	7	
4	0.0	0.0	0.0	0.0				(/)
								(/)

Element Number	Repeat	No. of Pressures	1	2	3	4	5	6	7	
1		1	-20.0							(/)
										(/)
7X										(/)
										(/)
13X										(/)
										(/)
2		1				-20.0				(/)
										(/)
8X										(/)
										(/)
14X										(/)
										(/)
										(/)
										(/)
										(/)

FIGURE III-C.9 ELEMENT PRESSURE INPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-C.10 END CARD - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
          MAGIC  ABSTRACTION INSTRLCTICN LISTING          PAGE  1

        TEST MAGIC

$INSTRUCTION    SOURCE                                                TESTF004

        C-----STATICS AGENDUM bITHOLT PRESCPIBEC DISPLACEMENTS                  TESTF005
        C                                                                       TESTF006
        C        *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *TESTF007
        C                                                                       TESTF008
        C        STATICS INSTRUCTION SECLENCE                                   TESTF009
        C                                                                       TESTF010
        C        *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   *   * *TESTF011
        C                                                                       TESTF012
        C        GENERATE ELEMENT MATRICES                                      TESTF013
        C                                                                       TESTF014
   1          .MLIB.,XLD.TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.     TESTF015
        C                                                                       TESTF016
        C                                                                       TESTF017
        C        FORM (1 X 1) LNIT AND (1 X 1) NULL MATRICES                    TESTF018
        C        DETERMINE PRINT FORMAT FCR TYPE CF ELEMENTS USED               TESTF019
        C                                                                       TESTF020
   2          I1 = SC.IDENTC.                                                   TESTF021
   3          I3 = I1.NULL.SC                                                   TESTF022
   4          DIFF = I1 .SMULT. SC(9,1)                                         TESTF023
        C                                                                       TESTF024
        C        ASSEMBLE STIFFNESS MATRIX ANC ELEMENT APPLIED LOADS            TESTF025
        C                                                                       TESTF026
   5          KELA = EM .ASSEM. SC,(10)                                         TESTF027
   6          FTELA = EM .ASSEP .SC,(40)                                        TESTF028
   7          LSCALE,LOADS = XLD .DEJCIN.(1,1)                                  TESTF029
        C                                                                       TESTF030
        C        REDUCE STIFFNESS MATRIX AND PRINT                              TESTF031
        C                                                                       TESTF032
   8          KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                TESTF033
   9          KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                               TESTF034
  10          PRINT(FORCE,DISP,,) STIFF                                         TESTF035
        C                                                                       TESTF036
        C        FORM REDUCED TOTAL LCAD CCLUMN                                 TESTF037
        C                                                                       TESTF038
        C        MULTIPLY ELEMENT APPLIED LCADS BY LOAD SCALAR                  TESTF039
  11          FTELS = FTELA.MULT.LSCALE                                         TESTF040
        C        TRANSFORM EXTERNAL LCADS TC 0-1-2 ASSEMBLEC SYSTEM             TESTF041
  12          LOADO = TR.MULT.LOADS                                             TESTF042
        C        FORM TOTAL LOAD COLLMNS                                        TESTF043
  13          TLOAD = FTELS.ADD.LOADC                                           TESTF044
  14          TL,TLOADR = TLOAD.DEJCIN.( SC(5,1),1)                             TESTF045
        C                                                                       TESTF046
        C        SOLVE FOR DISPLACEMENTS                                        TESTF047
        C                                                                       TESTF048
  15          XX = STIFF.SEQEL.TLOADR                                           TESTF049
  16          TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                                  TESTF050
  17          X = TR12.TMULT.XX                                                 TESTF051
  18          XO = TR.MULT.X                                                    TESTF052
        C                                                                       TESTF053
        C        CALCULATE REACTIONS ANC INVERSE CHECK                          TESTF054
```

FIGURE III-C.11 MAGIC ABSTRACTION INSTRUCTION LISTING - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
          MAGIC   ABSTRACTION INSTRUCTION LISTING          PAGE  2

        TEST MAGIC

     C                                                                    TESTF055
19          REACTS = KELA.MULT.XO                                         TESTF056
20          REACTP= REACTS.SUBT.TLOAD                                     TESTF057
21          IF (DIFF.NULL.) GO TO 10                                      TESTF058
     C                                                                    TESTF059
     C         PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS. TESTF060
     C           REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT        TESTF061
     C                                                                    TESTF062
     C         ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM                    TESTF063
     C                                                                    TESTF064
22          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,TR )FTELA                     TESTF065
23          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,    )LOADS                    TESTF066
24          GPRINT(2,,,U,V,W,THETAX,THETAY,THETAZ,SC,)X                   TESTF067
25          GPRINT(1,,,FX,FY,FZ,MX,MY,MZ,SC,TR )REACTP                    TESTF068
26          IF (I3.NULL.) GO TO 600                                       TESTF069
     C                                                                    TESTF070
     C         ELEMENTS HAVE 3 DEGREES OF FREEDOM                         TESTF071
     C                                                                    TESTF072
27      10  GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )FTELA             TESTF073
28          GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,    )LOADS            TESTF074
29          GPRINT(2,,,U,0,W,0,THETAY,0,W*,0,W**,SC, )X                   TESTF075
30          GPRINT(1,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )REACTP            TESTF076
     C                                                                    TESTF077
     C         GENERATE STRESSES  AND FORCES                              TESTF078
     C                                                                    TESTF079
31     600  STRESP=EM,XO .STRESS.(4,)                                     TESTF080
32          FORCEP=EM,XO .FORCE.(4,)                                      TESTF081
```

FIGURE III-C.11 CONCLUDED

```
            MAGIC - MATRIX ANALYSIS VIA GENERATIVE AND INTERPRETIVE COMPUTATIONS

IAGIC



                      MAGIC PROBLEM SPECIFICATION DATA

 $RUN             GO




                    MAGIC   ABSTRACTION INSTRUCTION LISTING            PAGE   1



 $INSTRUCTION    SOURCE

    1           ,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC,EM,= ,,,.USER04.
    2           DISPL,STR,FOR,REACT = TR,SC,EM,XLD,,,,, .ANALIC.(,,)
```

FIGURE III-C.11A .ANALIC. ABSTRACTION INSTRUCTION LISTING

```
                     EIGHTEEN ELEPENT CANTILEVEREC BEAM SUBJECTED TO A PRESSURE

                     LOAD. TETRAHEDRCN ELEPENT IDEN. NO.50 STATICS ANALYSIS.

                                        REVISICNS OF MATERIAL TAPE

                                      ASTERISK (*) PRECEEDING MATERIAL
                                      IDENTIFICATION INDICATES THAT INPUT
                                      ERRCR RETURNS WILL NOT RESULT IN
                                         TERMINATION OF EXECUTION


 ****************************************************************************************************

     REVISION
       MATERIAL NUMBER       1
       MATERIAL IDENTIFICATION STEEL                                  INPUT CODE   I
         NUMBER OF MATERIAL PROPERTY PCINTS. . . .  1
         NUMBER OF PLASTIC PROPERTY PCINTS . . . .  0
         MASS DENSITY. . . . . . . . . . . . . . .  0.73394994E-03

       MATERIAL PROPERTIES


                      YOUNG'S MODULI                                  POISSON'S RATIOS

                                 DIRECTICNS                                                 DIRECTIONS
  TEMPERATURE
                    XX           YY            ZZ               XY             YZ             ZX
      0.0       0.300000E 08  0.300000E 08  0.300000E 08    0.333000E 00  0.333000E 00  0.333000E 00

                      TH. EXP.COEF.                                   RIGIDITY MODULI

                                 DIRECTICNS                                                 DIRECTIONS
  TEMPERATURE
                    XX           YY            ZZ               XY             YZ             ZX
      0.0       0.650000E-05  0.650000E-05  0.650000E-05    0.112528E 08  0.112528E 08  0.112528E 08

 ****************************************************************************************************
```

FIGURE III-C.12 TITLE AND MATERIAL DATA OUTPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                                        16 REF. POINTS

     NO. DIRECTIONS  =    3      NO. DEGREES OF FREEDOM =    1


                                       GRIDPOINT DATA
                                 (IN RECTANGULAR COORDINATES)
POINT           X                 Y                 Z              TEMPERATURES          PRESSURES
  1    -0.20000000E 01    0.0               0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  2    -0.20000000E 01   -0.70000000E 01    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  3    -0.20000000E 01   -0.14000000E 02    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  4    -0.20000000E 01   -0.21000000E 02    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  5    -0.20000000E 01    0.0              -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  6    -0.20000000E 01   -0.70000000E 01   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  7    -0.20000000E 01   -0.14000000E 02   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  8    -0.20000000E 01   -0.21000000E 02   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
  9     0.20000000E 01    0.0               0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 10     0.20000000E 01   -0.70000000E 01    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 11     0.20000000E 01   -0.14000000E 02    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 12     0.20000000E 01   -0.21000000E 02    0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 13     0.20000000E 01    0.0              -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 14     0.20000000E 01   -0.70000000E 01   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 15     0.20000000E 01   -0.14000000E 02   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
 16     0.20000000E 01   -0.21000000E 02   -0.30000000E 01       0.0              0.0
                                                                 0.0              0.0
                                                                 0.0              0.0
```

FIGURE III-C.13 GRIDPOINT DATA OUTPUT TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                           BOUNDARY CONDITION INFORMATION

      NODES                 DEGREES OF FREEDOM                   NO. OF ONES   NO. OF TWOS

        1        0     0     0                                        0             0
        2        1     1     1                                        3             0
        3        1     1     1                                        6             0
        4        1     1     1                                        9             0
        5        0     0     0                                        9             0
        6        1     1     1                                       12             0
        7        1     1     1                                       15             0
        8        1     1     1                                       18             0
        9        0     0     0                                       18             0
       10        1     1     1                                       21             0
       11        1     1     1                                       24             0
       12        1     1     1                                       27             0
       13        0     0     0                                       27             0
       14        1     1     1                                       30             0
       15        1     1     1                                       33             0
       16        1     1     1                                       36             0


                                TOTAL NO. ELEMENTS =      18


ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
   1  50        1    4  0.0          0     4     1   5   9  10                                   0.0          0.0          0.0
   7  50        1    4  0.0          0     4     2   6  10  11                                   0.0          0.0          0.0
  13  50        1    4  0.0          0     4     3   7  11  12                                   0.0          0.0          0.0
   2  50        1    4  0.0          0     4     1  10   2   5                                   0.0          0.0          0.0
   8  50        1    4  0.0          0     4     2  11   3   6                                   0.0          0.0          0.0
  14  50        1    4  0.0          0     4     3  12   4   7                                   0.0          0.0          0.0
   3  50        1    4  0.0          0     4     2  10   6   5                                   0.0          0.0          0.0
   4  50        1    4  0.0          0     4     9   5  13   6                                   0.0          0.0          0.0
   5  50        1    4  0.0          0     4     6  14   9  13                                   0.0          0.0          0.0
   6  50        1    4  0.0          0     4    10   6  14   9                                   0.0          0.0          0.0
   9  50        1    4  0.0          0     4     3  11   7   6                                   0.0          0.0          0.0
  10  50        1    4  0.0          0     4    10   6  14   7                                   0.0          0.0          0.0
  11  50        1    4  0.0          0     4     7  15  10  14                                   0.0          0.0          0.0
  12  50        1    4  0.0          0     4    11   7  15  10                                   0.0          0.0          0.0
  15  50        1    4  0.0          0     4     4  12   8   7                                   0.0          0.0          0.0
  16  50        1    4  0.0          0     4    11   7  15   8                                   0.0          0.0          0.0
  17  50        1    4  0.0          0     4     8  16  11  15                                   0.0          0.0          0.0
  18  50        1    4  0.0          0     4    12   8  16  11                                   0.0          0.0          0.0
```

FIGURE III-C.14 BOUNDARY CONDITION & FINITE ELEMENT DESCRIPTION - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                              ELEMENT PRESSURE TABLE

ELEM    NO. OF PRESS.    LIST OF PRESSURES
  1           1          -0.200000E 02

  7           1          -0.200000E 02
 13           1          -0.200000E 02
  2           4           0.0           0.0           0.0          -0.200000E 02
  8           4           0.0           0.0           0.0          -0.200000E 02
 14           4           0.0           0.0           0.0          -0.200000E 02
  3           4           0.0           0.0           0.0           0.0
  4           4           0.0           0.0           0.0           0.0
  5           4           0.0           0.0           0.0           0.0
  6           4           0.0           0.0           0.0           0.0
  9           4           0.0           0.0           0.0           0.0
 10           4           0.0           0.0           0.0           0.0
 11           4           0.0           0.0           0.0           0.0
 12           4           0.0           0.0           0.0           0.0
 15           4           0.0           0.0           0.0           0.0
 16           4           0.0           0.0           0.0           0.0
 17           4           0.0           0.0           0.0           0.0
 18           4           0.0           0.0           0.0           0.0
```

FIGURE III-C.15 ELEMENT PRESSURE TABLE OUTPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                              EXTERNAL LOAD CONDITIONS    1


   LOAD NO.    1

     NUMBER OF LOADED NODES    16          ELEMENT LOAD SCALAR =  0.10000000E 01
 1  0.0          0.0          0.0
 2  0.0          0.0          0.0
 3  0.0          0.0          0.0
 4  0.0          0.0          0.0
 5  0.0          0.0          0.0
 6  0.0          0.0          0.0
 7  0.0          0.0          0.0
 8  0.0          0.0          0.0
 9  0.0          0.0          0.0
10  0.0          0.0          0.0
11  0.0          0.0          0.0
12  0.0          0.0          0.0
13  0.0          0.0          0.0
14  0.0          0.0          0.0
15  0.0          0.0          0.0
16  0.0          0.0          0.0


                        TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                     48 X 1

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0

  0.0          0.0          0.0          0.0          0.0          0.0


                           T-ZERO FOR STRUCTURE =  0.0
```

FIGURE III-C.16 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                                         MATRIX  STIFF /    1/                                        PAGE    1

                     CUTOFF =    0.0                                   SIZE    36  BY    36

           FORCE                  FORCE                   FORCE                   FORCE                   FORCE

DISP    1    1   0.275072E 09    2   0.336910E 08    3  -0.786124E 08    4  -0.643016E 07    5  -0.112528E 08
             6  -0.131283E 08   10  -0.262565E 08   11   0.224382E 08   12   0.523558E 08   19  -0.235955E 09
            20  -0.336910E 08   21   0.262566E 08   22  -0.203010E 02   23   0.336910E 08   24   0.131283E 08

DISP    2    1   0.336910E 08    2   0.136698E 09    3   0.224606E 08    4  -0.224382E 08    5  -0.256821E 08
             6  -0.750186E 07   10   0.112528E 08   11  -0.262565E 08   12  -0.224606E 08   19  -0.336910E 08
            20  -0.590772E 08   21   0.750187E 07   22   0.336910E 08   23  -0.853910E 01   24  -0.750187E 07

DISP    3    1  -0.786124E 08    2   0.224606E 08    3   0.176806E 09    4  -0.261779E 08    5  -0.149588E 08
             6  -0.643015E 07   10   0.262566E 08   11  -0.224607E 08   12  -0.104869E 09   19   0.523558E 08
            20   0.149588E 08   21  -0.590772E 08   22   0.261779E 08   23  -0.149588E 08   24  -0.858691E 01

DISP    4    1  -0.643016E 07    2  -0.224382E 08    3  -0.261779E 08    4   0.275072E 09    5   0.336909E 08
             6  -0.786124E 08    7  -0.643017E 07    8  -0.112528E 08    9  -0.131283E 08   10  -0.447149E 00
            11  -0.224382E 08   12   0.261779E 08   13  -0.262565E 08   14   0.224382E 08   15   0.523558E 08
            22  -0.235959E 09   23  -0.336910E 08   24   0.262566E 08   25   0.269885E 01   26   0.336910E 08
            27   0.131283E 08

DISP    5    1  -0.112528E 08    2  -0.256821E 08    3  -0.149588E 08    4   0.336909E 08    5   0.136698E 09
             6   0.224606E 08    7  -0.224382E 08    8  -0.256821E 08    9  -0.750186E 07   10  -0.112528E 08
            11   0.758540E 01   12   0.224606E 08   13   0.112528E 08   14  -0.262565E 08   15  -0.224607E 08
            22  -0.336909E 08   23  -0.590772E 08   24   0.750187E 07   25   0.336910E 08   26   0.140790E 01
            27  -0.750187E 07

DISP    6    1  -0.131283E 08    2  -0.750186E 07    3  -0.643015E 07    4  -0.786124E 08    5   0.224606E 08
             6   0.176806E 09    7  -0.261779E 08    8  -0.149588E 08    9  -0.643016E 07   10   0.131283E 08
            11   0.224606E 08   12  -0.981047E 01   13   0.262566E 08   14  -0.224607E 08   15  -0.104869E 09
            22   0.523558E 08   23   0.149588E 08   24  -0.590772E 08   25   0.261779E 08   26  -0.149588E 08
            27   0.120702E 02

DISP    7    4  -0.643017E 07    5  -0.224382E 08    6  -0.261779E 08    7   0.172488E 09    8   0.336910E 08
             9  -0.393062E 08   13  -0.533382E 01   14  -0.224382E 08   15   0.261779E 08   16  -0.875218E 07
            17   0.224382E 08   18   0.261779E 08   25  -0.157303E 09   26  -0.112528E 08   27   0.131283E 08

DISP    8    4  -0.112528E 08    5  -0.256821E 08    6  -0.149588E 08    7   0.336910E 08    8   0.738192E 08
             9  -0.133876E 02   13  -0.112528E 08   14  -0.119320E 02   15   0.224607E 08   16   0.112528E 08
            17  -0.875210E 07   18  -0.750187E 07   25  -0.224382E 08   26  -0.393848E 08   27  -0.419769E-06

DISP    9    4  -0.131283E 08    5  -0.750186E 07    6  -0.643016E 07    7  -0.393062E 08    8  -0.133876E 02
             9   0.807713E 08   13   0.131283E 08   14   0.224607E 08   15  -0.147051E 02   16   0.131283E 08
            17  -0.149588E 08   18  -0.349563E 08   25   0.261779E 08   26  -0.837024E-08   27  -0.393848E 08
```

FIGURE III-C.17 STIFFNESS MATRIX OUTPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                                  MATRIX  STIFF /    1/                                           PAGE     2

                    CUTOFF  =    0.0                                SIZE    36  BY    36

          FORCE                  FORCE                  FORCE                  FORCE                  FORCE

DISP     10     1  -0.262565E 08     2   0.112528E 08     3   0.262566E 08     4  -0.447149E 00     5  -0.112528E 08
                6   0.131283E 08    10   0.287932E 09    11  -0.336910E 08    13  -0.128603E 08    14   0.224382E 08
               19  -0.368896E 01    20   0.111854E 08    21  -0.786123E 08    22   0.195626E 01    23   0.112528E 08
               24  -0.131283E 08    28  -0.235955E 09    29   0.336910E 08    30   0.523558E 08

DISP     11     1   0.224382E 08     2  -0.262565E 08     3  -0.224607E 08     4  -0.224382E 08     5   0.758540E 01
                6   0.224606E 08    10  -0.336910E 08    11   0.188062E 09    12   0.224607E 08    13   0.112528E 08
               14  -0.513643E 08    15  -0.149588E 08    19  -0.111854E 08    20  -0.147337E 02    21   0.745692E 07
               22   0.224382E 08    23   0.547051E 01    24   0.750187E 07    28   0.336910E 08    29  -0.590772E 08
               30  -0.149588E 08

DISP     12     1   0.523558E 08     2  -0.224606E 08     3  -0.104869E 09     4   0.261779E 08     5   0.224606E 08
                6  -0.981847E 01    11   0.224607E 08    12   0.189667E 09    14  -0.750187E 07    15  -0.128603E 08
               19  -0.786123E 08    20  -0.745692E 07    21  -0.368896E 01    22  -0.261779E 08    23   0.149588E 08
               24   0.429909E 01    28   0.262566E 08    29  -0.750187E 07    30  -0.590772E 08

DISP     13     4  -0.262565E 08     5   0.112528E 08     6   0.262566E 08     7  -0.533382E 01     8  -0.112528E 08
                9   0.131283E 08    10  -0.128603E 08    11   0.112528E 08    13   0.287932E 09    14  -0.336910E 08
               15  -0.117142E 01    16  -0.128603E 08    17   0.224382E 08    18   0.936195E 01    19   0.162090E 01
               20  -0.224382E 08    21  -0.261779E 08    22  -0.702849E 01    23   0.111854E 08    24  -0.786123E 08
               25  -0.346539E 01    26   0.112528E 08    27  -0.131283E 08    28  -0.203010E 02    29  -0.336910E 08
               30   0.261779E 08    31  -0.235955E 09    32   0.336909E 08    33   0.523558E 08

DISP     14     4   0.224382E 08     5  -0.262565E 08     6  -0.224607E 08     7  -0.224382E 08     8  -0.119320E 02
                9   0.224607E 08    10   0.224382E 08    11  -0.513643E 08    12  -0.750187E 07    13  -0.336910E 08
               14   0.188062E 09    15   0.224606E 08    16   0.112528E 08    17  -0.513643E 08    18  -0.149588E 08
               19  -0.112528E 08    20   0.413108E 01    21  -0.149588E 08    22  -0.111854E 08    23   0.702848E 01
               24   0.745692E 07    25   0.224382E 08    26  -0.446945E 01    27   0.750187E 07    28  -0.336910E 08
               29  -0.853910E 01    30   0.149588E 08    31   0.336910E 08    32  -0.590772E 08    33  -0.149588E 08

DISP     15     4   0.523558E 08     5  -0.224607E 08     6  -0.104869E 09     7   0.261779E 08     8   0.224607E 08
                9  -0.147051E 02    11  -0.149588E 08    12  -0.128603E 08    13  -0.117142E 01    14   0.224606E 08
               15   0.189667E 09    16   0.469504E 01    17  -0.750187E 07    18  -0.128603E 08    19  -0.131283E 08
               20  -0.750187E 07    21   0.396373E 01    22  -0.786123E 08    23  -0.745692E 07    24  -0.230419E-05
               25  -0.261779E 08    26   0.149588E 08    27  -0.128367E 02    28   0.131283E 08    29   0.750187E 07
               30  -0.858691E 01    31   0.262566E 08    32  -0.750187E 07    33  -0.590772E 08

DISP     16     7  -0.875218E 07     8   0.112528E 08     9   0.131283E 08    13  -0.128603E 08    14   0.112528E 08
               15   0.469504E 01    16   0.178916E 09    17   0.527137E 01    22  -0.346539E 01    23  -0.224382E 08
               24  -0.261779E 08    26   0.111854E 08    27  -0.393062E 08    31   0.269889E 01    32  -0.336910E 08
               33   0.261779E 08    34  -0.157303E 09    35   0.224382E 08    36   0.261779E 08

DISP     17     7   0.224382E 08     8  -0.875218E 07     9  -0.149588E 08    13   0.224382E 08    14  -0.513643E 08
               15  -0.750187E 07    16   0.527137E 01    17   0.995013E 08    18   0.224606E 08    22  -0.112528E 08
               23  -0.446945E 01    24  -0.149588E 08    25  -0.111854E 08    31  -0.336910E 08    32   0.140790E 01
               33   0.149588E 08    34   0.112528E 08    35  -0.393848E 08    36   0.837024E-06
```

FIGURE III-C.17 CONTINUED

```
                                         MATRIX  STIFF /    1/                                                 PAGE     3

                      CUTOFF  =    0.0                                         SIZE    36  BY    36

              FORCE                 FORCE                 FORCE                 FORCE                 FORCE

DISP    18       7   0.261779E 08    8  -0.750187E 07    9  -0.349563E 08   13   0.936195E 01   14  -0.149588E 08
                15  -0.128603E 08   17   0.224606E 08   18   0.872014E 08   22  -0.131283E 08   23  -0.750187E 07
                24  -0.128367E 02   25  -0.393062E 08   31   0.131283E 08   32   0.750187E 07   33   0.120702E 02
                34   0.131283E 08   35   0.419769E-06   36  -0.393848E 08

DISP    19       1  -0.235955E 09    2  -0.336910E 08    3   0.523558E 08   10  -0.368896E 01   11  -0.111854E 08
                12  -0.786123E 08   13   0.162090E 01   14  -0.112528E 08   15  -0.131283E 08   19   0.287932E 09
                20   0.336909E 08   22  -0.128603E 08   23  -0.224382E 08   28  -0.262565E 08   29  -0.112528E 08
                30   0.262566E 08   31  -0.782508E 00   32   0.112528E 08   33   0.131283E 08

DISP    20       1  -0.336910E 08    2  -0.590772E 08    3   0.149588E 08   10   0.111854E 08   11  -0.147337E 02
                12  -0.745692E 07   13  -0.224382E 08   14   0.413108E 01   15  -0.750187E 07   19   0.336909E 08
                20   0.188062E 09   21  -0.224607E 08   22  -0.112528E 08   23  -0.513643E 08   24   0.149588E 08
                28  -0.224382E 08   29  -0.262565E 08   30   0.224607E 08   31   0.224382E 08   32   0.624597E 01
                33  -0.224606E 08

DISP    21       1   0.262566E 08    2   0.750187E 07    3  -0.590772E 08   10  -0.786123E 08   11   0.745692E 07
                12  -0.368896E 01   13  -0.261779E 08   14  -0.149588E 08   15   0.396373E 01   20  -0.224607E 08
                21   0.189667E 09   23   0.750187E 07   24  -0.128603E 08   28   0.523558E 08   29   0.224607E 08
                30  -0.104869E 09   31   0.261779E 08   32  -0.224606E 08   33  -0.101538E 02

DISP    22       1  -0.203010E 02    2   0.336910E 08    3   0.261779E 08    4  -0.235955E 09    5  -0.336909E 08
                 6   0.523558E 08   10   0.195626E 01   11   0.224382E 08   12  -0.261779E 08   13  -0.702849E 01
                14  -0.111854E 08   15  -0.786123E 08   16  -0.346539E 01   17  -0.112528E 08   18  -0.131283E 08
                19  -0.128603E 08   20  -0.112528E 08   22   0.287932E 09   23   0.336909E 08   24  -0.117142E 01
                25  -0.128603E 08   26  -0.224382E 08   27   0.936195E 01   31  -0.262565E 08   32  -0.112528E 08
                33   0.262566E 08   34  -0.341748E 01   35   0.112528E 08   36   0.131283E 08

DISP    23       1   0.336910E 08    2  -0.853910E 01    3  -0.149588E 08    4  -0.336910E 08    5  -0.590772E 08
                 6   0.149588E 08   10   0.112528E 08   11   0.547051E 01   12   0.149588E 08   13   0.111854E 08
                14   0.702848E 01   15  -0.745692E 07   16  -0.224382E 08   17  -0.446945E 01   18  -0.750187E 07
                19  -0.224382E 08   20  -0.513643E 08   21   0.750187E 07   22   0.336909E 08   23   0.188062E 09
                24  -0.224606E 08   25  -0.112528E 08   26  -0.513643E 08   27   0.149588E 08   31  -0.224382E 08
                32  -0.262565E 08   33   0.224606E 08   34   0.224382E 08   35  -0.427811E 01   36  -0.224607E 08

DISP    24       1   0.131283E 08    2  -0.750187E 07    3  -0.858691E 01    4   0.262566E 08    5   0.750187E 07
                 6  -0.590772E 08   10  -0.131283E 08   11   0.750187E 07   12   0.429909E 01   13  -0.786123E 08
                14   0.745692E 07   15  -0.238419E-05   16  -0.261779E 08   17  -0.149588E 08   18  -0.128367E 02
                20   0.149588E 08   21  -0.128603E 08   22  -0.117142E 01   23  -0.224606E 08   24   0.189667E 09
                25   0.469504E 01   26   0.750187E 07   27  -0.128603E 08   31   0.523558E 08   32   0.224606E 08
                33  -0.104869E 09   34   0.261779E 08   35  -0.224607E 08   36  -0.127888E 02

DISP    25       4   0.269889E 01    5   0.336910E 08    6   0.261779E 08    7  -0.157303E 09    8  -0.224382E 08
                 9   0.261779E 08   13  -0.346539E 01   14   0.224382E 08   15  -0.261779E 08   17  -0.111854E 08
                18  -0.393062E 08   22  -0.128603E 08   23  -0.112528E 08   24   0.469504E 01   25   0.178916E 09
                26  -0.527137E 01   34  -0.875219E 07   35  -0.112528E 08   36   0.131283E 08
```

FIGURE III-C.17 CONTINUED

```
                                  MATRIX  STIFF /    1/                                              PAGE     4

                    CUTOFF  =    0.0                                    SIZE    36  BY    36

          FORCE                    FORCE                     FORCE                     FORCE                     FORCE

DISP     26     4    0.336910E 08     5    0.140790E 01     6   -0.149588E 08     7   -0.112528E 08     8   -0.393848E 08
                9   -0.837024E-06    13    0.112528E 08    14   -0.446945E 01    15    0.149588E 08    16    0.111854E 08
               22   -0.224382E 08    23   -0.513643E 08    24    0.750187E 07    25   -0.527137E 01    26    0.995013E 08
               27   -0.224606E 08    34   -0.224382E 08    35   -0.875219E 07    36    0.149588E 08

DISP     27     4    0.131283E 08     5   -0.750187E 07     6    0.120702E 02     7    0.131283E 08     8   -0.419769E-06
                9   -0.393848E 08    13   -0.131283E 08    14    0.750187E 07    15   -0.128367E 02    16   -0.393062E 08
               22    0.936195E 01    23    0.149588E 08    24   -0.128603E 08    26   -0.224606E 08    27    0.872014E 08
               34    0.261779E 08    35    0.750187E 07    36   -0.349563E 08

DISP     28    10   -0.235955E 09    11    0.336910E 08    12    0.262566E 08    13   -0.203010E 02    14   -0.336910E 08
               15    0.131283E 08    19   -0.262565E 08    20   -0.224382E 08    21    0.523558E 08    28    0.275072E 09
               29   -0.336910E 08    30   -0.786124E 08    31   -0.643016E 07    32    0.112528E 08    33   -0.131283E 08

DISP     29    10    0.336910E 08    11   -0.590772E 08    12   -0.750187E 07    13   -0.336910E 08    14   -0.853910E 01
               15    0.750187E 07    19   -0.112528E 08    20   -0.262565E 08    21    0.224607E 08    28   -0.336910E 08
               29    0.136698E 09    30   -0.224606E 08    31    0.224382E 08    32   -0.256821E 08    33    0.750186E 07

DISP     30    10    0.523558E 08    11   -0.149588E 08    12   -0.590772E 08    13    0.261779E 08    14    0.149588E 08
               15   -0.858691E 01    19    0.262566E 08    20    0.224607E 08    21   -0.104869E 09    28   -0.786124E 08
               29   -0.224606E 08    30    0.176806E 09    31   -0.261779E 08    32    0.149588E 08    33   -0.643015E 07

DISP     31    13   -0.235955E 09    14    0.336910E 08    15    0.262566E 08    16    0.269885E 01    17   -0.336910E 08
               18    0.131283E 08    19   -0.782508E 00    20    0.224382E 08    21    0.261779E 08    22   -0.262565E 08
               23   -0.224382E 08    24    0.523558E 08    28   -0.643016E 07    29    0.224382E 08    30   -0.261779E 08
               31    0.275072E 09    32   -0.336909E 08    33   -0.786124E 08    34   -0.643017E 07    35    0.112528E 08
               36   -0.131283E 08

DISP     32    13    0.336909E 08    14   -0.590772E 08    15   -0.750187E 07    16   -0.336910E 08    17    0.140790E 01
               18    0.750187E 07    19    0.112528E 08    20    0.624597E 01    21   -0.224606E 08    22   -0.112528E 08
               23   -0.262565E 08    24    0.224606E 08    28    0.112528E 08    29   -0.256821E 08    30    0.149588E 08
               31   -0.336909E 08    32    0.136698E 09    33   -0.224606E 08    34    0.224382E 08    35   -0.256821E 08
               36    0.750186E 07

DISP     33    13    0.523558E 08    14   -0.149588E 08    15   -0.590772E 08    16    0.261779E 08    17    0.149588E 08
               18    0.120702E 02    19    0.131283E 08    20   -0.224606E 08    21   -0.101538E 02    22    0.262566E 08
               23    0.224606E 08    24   -0.104869E 09    28   -0.131283E 08    29    0.750186E 07    30   -0.643015E 07
               31   -0.786124E 08    32   -0.224606E 08    33    0.176806E 09    34   -0.261779E 08    35    0.149588E 08
               36   -0.643016E 07

DISP     34    16   -0.157303E 09    17    0.112528E 08    18    0.131283E 08    22   -0.341748E 01    23    0.224382E 08
               24    0.261779E 08    25   -0.875219E 07    26   -0.224382E 08    27    0.261779E 08    31   -0.643017E 07
               32    0.224382E 08    33   -0.261779E 08    34    0.172486E 09    35   -0.336910E 08    36   -0.393062E 08
```

FIGURE III-C.17 CONTINUED

```
                                                         MATRIX  STIFF /   1/                                          PAGE    5
                          CUTOFF =   0.0                                              SIZE    36  BY    36

             FORCE                 FORCE                  FORCE                  FORCE                  FORCE

DISP     35   16   0.224382E 08   17  -0.393848E 08   18   0.419769E-06   22   0.112528E 08   23  -0.427811E 01
              24  -0.224607E 08   25  -0.112528E 08   26  -0.875219E 07   27   0.750187E 07   31   0.112528E 08
              32  -0.256821E 08   33   0.149588E 08   34  -0.336910E 08   35   0.738192E 08   36   0.669380E 01

DISP     36   16   0.261779E 08   17   0.837024E-06   18  -0.393848E 08   22   0.131283E 08   23  -0.224607E 08
              24  -0.127888E 02   25   0.131283E 08   26   0.149588E 08   27  -0.349563E 08   31  -0.131283E 08
              32   0.750186E 07   33  -0.643016E 07   34  -0.393062E 08   35   0.669380E 01   36   0.807713E 08
```

FIGURE III-C.17 CONCLUDED

```
                         GPRINT OF MATRIX   FTELA    (SET   1)

ROW        FX             FY             FZ

   1     0.0            0.0          -0.18666650E 03
   2     0.0            0.0          -0.27999976E 03
   3     0.0            0.0          -0.27999976E 03
   4     0.0            0.0          -0.93333252E 02
   5     0.0            0.0           0.0
   6     0.0            0.0           0.0
   7     0.0            0.0           0.0
   8     0.0            0.0           0.0
   9     0.0            0.0          -0.93333252E 02
  10     0.0            0.0          -0.27999976E 03
  11     0.0            0.0          -0.27999976E 03
  12     0.0            0.0          -0.18666650E 03
  13     0.0            0.0           0.0
  14     0.0            0.0           0.0
  15     0.0            0.0           0.0
  16     0.0            0.0           0.0
```

FIGURE III-C.18 GPRINT OF MATRIX LOADS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                         MATRIX LOADS          SIZE    48  BY    1
                                   NULL MATRIX
```

FIGURE III-C.19 MATRIX LOADS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                    DISPLACEMENT MATRIX FOR LOAD CONDITION     1
                                        48 X 1

ROW           U                    V                    W
    1      0.0                  0.0                  0.0
    2      0.11979033E-04      -0.24384004E-04      -0.51589872E-04
    3      0.30256560E-04      -0.33360440E-04      -0.12496015E-03
    4      0.50328206E-04      -0.35343779E-04      -0.19549463E-03
    5      0.0                  0.0                  0.0
    6      0.91729371E-05       0.15122847E-04      -0.50923380E-04
    7      0.27327595E-04       0.20157197E-04      -0.12367318E-03
    8      0.47134061E-04       0.20220963E-04      -0.19335645E-03
    9      0.0                  0.0                  0.0
   10      0.10999482E-04      -0.15532758E-04      -0.93194657E-04
   11      0.29959934E-04      -0.22020060E-04      -0.12694841E-03
   12      0.50579853E-04      -0.23972592E-04      -0.19824316E-03
   13      0.0                  0.0                  0.0
   14      0.11155033E-04       0.24179215E-04      -0.50296454E-04
   15      0.28405630E-04       0.31450443E-04      -0.12420131E-03
   16      0.47979382E-04       0.31960735E-04      -0.19497190E-03
```

FIGURE III-C.20 DISPLACEMENT MATRIX - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                    REACTICAS AND INVERSE CHECK FOR LOAD CONDITION      1

ROW          FX                   FY                   FZ
    1    -0.34702160E 03      0.15006333E 04      0.10793909E 04
    2    -0.17333984E-01      0.14648438E-01      0.25634766E-01
    3    -0.40039063E-01      0.32226563E-01      0.57861328E-01
    4    -0.25146484E-01      0.48828125E-03      0.20751953E-01
    5     0.34203149E 03     -0.15005569E 04     -0.20247501E 03
    6    -0.95214844E-02     -0.17822266E-01      0.51269531E-02
    7     0.0                -0.19531250E-01      0.35156250E-01
    8     0.78125000E-02     -0.78125C00E-02      0.15625000E-01
    9     0.32235352E 03      0.14390151E 04     -0.56502991E 02
   10     0.29296875E-02      0.58593750E-02      0.23925781E-01
   11    -0.390625C0E-C2      0.0                 0.95214844E-02
   12     0.20507813E-01     -0.63476563E-02     -0.13183594E-01
   13    -0.31737866E 03     -0.14390593E 04      0.85943945E 03
   14     0.18310547E-01     -0.12207031E-01     -0.10253906E-01
   15     0.234375C0E-01     -0.12695313E-01     -0.21728516E-01
   16     0.39062500E-02      0.28452876E-02     -0.31250000E-01
```

FIGURE III-C.21 REACTION MATRIX - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                         S T R E S S E S   F O R   T H E   T E T R A H E D R O N   E L E M E N T
                                        (STRESSES EVALUATED AT THE ELEMENT CENTROID)

      LOAD CONDITION NUMBER     ELEMENT NUMBER      ELEMENT TYPE        ELEMENT GRID POINTS

                  1                     1                 50              1    5    9   10

APPARENT ELEMENT STRESSES
STRESS                                                  MEMBRANE STRESSES
POINT         SIGMA-X          SIGMA-Y          SIGMA-Z          SIGMA-XY          SIGMA-YZ         SIGMA-ZX
   1     0.49789597E 02   0.99728760E 02   0.49789597E 02   -0.17039139E 02   0.85512802E 02   0.0

ELEMENT APPLIED STRESSES
STRESS                                                  MEMBRANE STRESSES
POINT         SIGMA-X          SIGMA-Y          SIGMA-Z          SIGMA-XY          SIGMA-YZ         SIGMA-ZX
   1     0.0              0.0              0.0              0.0               0.0              0.0

NET ELEMENT STRESSES
STRESS                                                  MEMBRANE STRESSES
POINT         SIGMA-X          SIGMA-Y          SIGMA-Z          SIGMA-XY          SIGMA-YZ         SIGMA-ZX
   1     0.49789597E 02   0.99728760E 02   0.49789597E 02   -0.17039139E 02   0.85512802E 02   0.0
```

FIGURE III-C.22 STRESS OUTPUT, ELEMENT NO. 1 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   T E T R A H E D R O N   E L E M E N T
                                      (STRESSES EVALUATED AT THE ELEMENT CENTROID)

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE       ELEMENT GRID POINTS

                 1                    7                 50              2    6    10   11

APPARENT ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.28019104E 01     0.31420776E 02     0.80636597E 01     -0.62224417E 01     0.44468430E 02     0.74808377E 00

ELEMENT APPLIED STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.0                0.0                0.0                0.0                 0.0                 0.0

NET ELEMENT STRESSES
STRESS                                                     MEMBRANE STRESSES
POINT          SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.28019104E 01     0.31420776E 02     0.80636597E 01     -0.62224417E 01     0.44468430E 02     0.74808377E 00
```

FIGURE III-C.23 STRESS OUTPUT, ELEMENT NO. 7 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                 S T R E S S E S   F O R   T H E   T E T R A H E D R O N   E L E M E N T
                              (STRESSES EVALUATED AT THE ELEMENT CENTROID)

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE       ELEMENT GRID POINTS

               1                     18                50             12    8    16    11


APPARENT ELEMENT STRESSES
STRESS                                                         MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY             SIGMA-YZ            SIGMA-ZX
   1     0.35231018E 01     0.50445557E 01    -0.13503021E 02    -0.12101746E 00      0.97C80841E 01      0.33227539E 00

ELEMENT APPLIED STRESSES
STRESS                                                         MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY             SIGMA-YZ            SIGMA-ZX
   1     0.0                0.0                0.0                0.0                  0.0                 0.0

NET ELEMENT STRESSES
STRESS                                                         MEMBRANE STRESSES
POINT         SIGMA-X            SIGMA-Y            SIGMA-Z            SIGMA-XY             SIGMA-YZ            SIGMA-ZX
   1     0.35231018E 01     0.50445557E 01    -0.13503021E 02    -0.12101746E 00      0.97C80841E 01      0.33227539E 00
```

FIGURE III-C.24 STRESS OUTPUT, ELEMENT NO. 18 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                    F O R C E S   F O R   T H E   T E T R A H E D R O N   E L E M E N T

    LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE       ELEMENT GRID POINTS

              1                      1                 50              1    5    9   10

APPARENT ELEMENT FORCES
POINT                                FORCES
                 FX                    FY                    FZ
   1     -0.34852686E 03      0.51833325E 03       0.23235138E 03
   2      0.0                -0.39905933E 03      -0.23235138E 03
   3      0.28037012E 03      0.27964063E 03       0.34205103E 03
   4      0.68156555E 02     -0.39891479E 03      -0.34205103E 03

ELEMENT APPLIED FORCES
POINT                                FORCES
                 FX                    FY                    FZ
   1      0.0                 0.0                 -0.93333252E 02
   2      0.0                 0.0                  0.0
   3      0.0                 0.0                 -0.93333252E 02
   4      0.0                 0.0                 -0.93333252E 02

NET ELEMENT FORCES
POINT                                FORCES
                 FX                    FY                    FZ
   1     -0.34852686E 03      0.51833325E 03       0.32568457E 03
   2      0.0                -0.39905933E 03      -0.23235138E 03
   3      0.28037012E 03      0.27964063E 03       0.43538428E 03
   4      0.68156555E 02     -0.39891479E 03      -0.24871777E 03
```

FIGURE III-C.25 FORCE OUTPUT, ELEMENT NO. 1 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                      F O R C E S   F C F   T H E   T E T R A H E D R O N   E L E M E N T

      LOAD CONDITION NUMBER     ELEPENT NLPBEF     ELEPENT TYPE       ELEMENT GRID POINTS

                 1                     7                  50            2    6    10    11


APPARENT ELEMENT FORCES
POINT                                 FCRCES
                   FX                   FY                     FZ
    1     -0.16121735E C2     0.25107715E C3      0.32393829E 02
    2     -0.34907579E 01    -0.20752CC2E C3     -0.37628891E 02
    3     -0.52778320E 01     0.82125488E C2      0.18310889E 03
    4      0.24890640E 02    -0.12568311E C3     -0.17787378E 03


ELEMENT APPLIED FORCES
POINT                                 FCRCES
                   FX                   FY                     FZ
    1      0.0                0.0                -0.93333252E 02
    2      0.0                0.0                 0.0
    3      0.0                0.0                -0.93333252E 02
    4      0.0                0.0                -0.93333252E 02


NET ELEMENT FORCES
POINT                                 FCRCES
                   FX                   FY                     FZ
    1     -0.16121735E C2     0.25107715E 03      0.12572708E 03
    2     -0.34907579E 01    -0.20752002E 03     -0.37628891E 02
    3     -0.52778320E 01     0.82125488E 02      0.27644214E 03
    4      0.24890640E 02    -0.12568311E C3     -0.84540527E 02
```

FIGURE III-C.26 FORCE OUTPUT, ELEMENT NO. 7 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

```
                    F O R C E S   F O R   T H E   T E T R A H E D R O N   E L E M E N T

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE       ELEMENT GRID POINTS

              1                      18                 50            12     8    16    11

APPARENT ELEMENT FORCES
POINT                                  FORCES
                 FX                      FY                   FZ
  1       0.20361328E 01      0.25122803E 02      -0.10183960E 03
  2      -0.24663574E 02      0.84692383E 00      -0.23251953E 01
  3       0.23112793E 02     -0.46151123E 02       0.65326843E 02
  4      -0.48358154E 00      0.20179199E 02       0.38832031E 02

ELEMENT APPLIED FORCES
POINT                                  FORCES
                 FX                      FY                   FZ
  1       0.0                 0.0                  0.0
  2       0.0                 0.0                  0.0
  3       0.0                 0.0                  0.0
  4       0.0                 0.0                  0.0

NET ELEMENT FORCES
POINT                                  FORCES
                 FX                      FY                   FZ
  1       0.20361328E 01      0.25122803E 02      -0.10183960E 03
  2      -0.24663574E 02      0.84692383E 00      -0.23251953E 01
  3       0.23112793E 02     -0.46151123E 02       0.65326843E 02
  4      -0.48358154E 00      0.20179199E 02       0.38832031E 02
```

FIGURE III-C 27 FORCE OUTPUT, ELEMENT NO. 18 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

D. Triangular Prism

A six element cantilever beam subjected to an end moment is shown in Figure III-D.1. This figure displays the loading, idealization, dimensions and material properties. The preprinted input date forms associated with this example are given in Figures III-D.2 to III-D.9. No comments need to be made with respect to the input for this element since no pecularities exist. The reader, however, should review the input data sheets and compare them to the previous examples for clarification purposes.

The output supplied by the MAGIC III System for this example is described below and shown in Figures III-D.10 to III-D.22. The matrix abstraction instructions are shown in Figure III-D.10. A complete description of these instructions is provided in Reference 5. Figures III-D.11 to III-D.14 show the output data obtained from the Structural Systems Monitor. These figures record the data pertinent to the problem being solved.

Figure III-D.11 displays the problem title and material data output. The gridpoint coordinates, temperatures and pressures are given in Figure III-D.12. Boundary condition information and finite element description is presented in Figure III-D.13. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed (i.e., no motion) and ones ('1') represent degrees of freedom that are free (have unknown values of displacement). The second last column accumulates the number of ones which in this problem is 36. The second portion of Figure III-D.13 shows the finite element description. Each of the six elements is called out in turn with gridpoints, print options and material number. Note that neither extra gridpoint nor section properties are presented since they are not required for this element.

Figure III-D.14 presents the external load condition and transformed external assembled load column. This 48x1 vector is the total unreduced load which is read row-wise. The ordering of this vector is consistent with that of the boundary condition table given in Figure III-D.13. Note that a load of 66.66667 pounds is applied at node point 4 in the negative global Y direction. This is position (11,1) in the load vector which corresponds to the eleventh entry in the boundary condition table which is the global V displacement node point 4. The other loads follow the same pattern.

MAGIC III System output of final results are displayed in Figures III-D.15 to III-D.22. Figure III-D.15 shows the stiffness matrix which is presented row-wise and it's ordering is consistent with that of the boundary condition table previously discussed. In this problem the ordering is

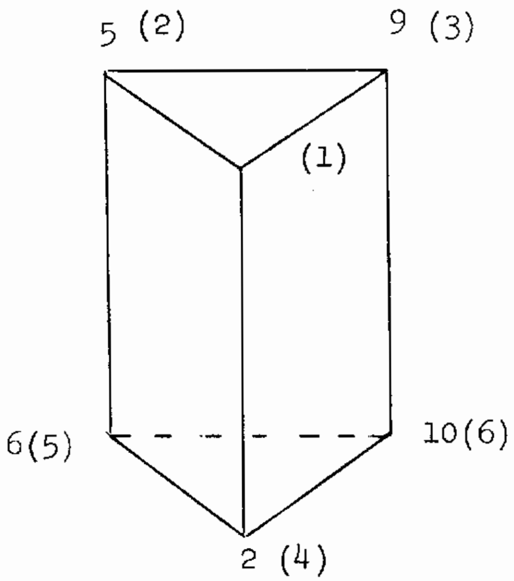
$$\left\{\Delta^P\right\}^T = \lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots\ldots, U_{16}, V_{16}, W_{16} \rfloor \text{ with}$$

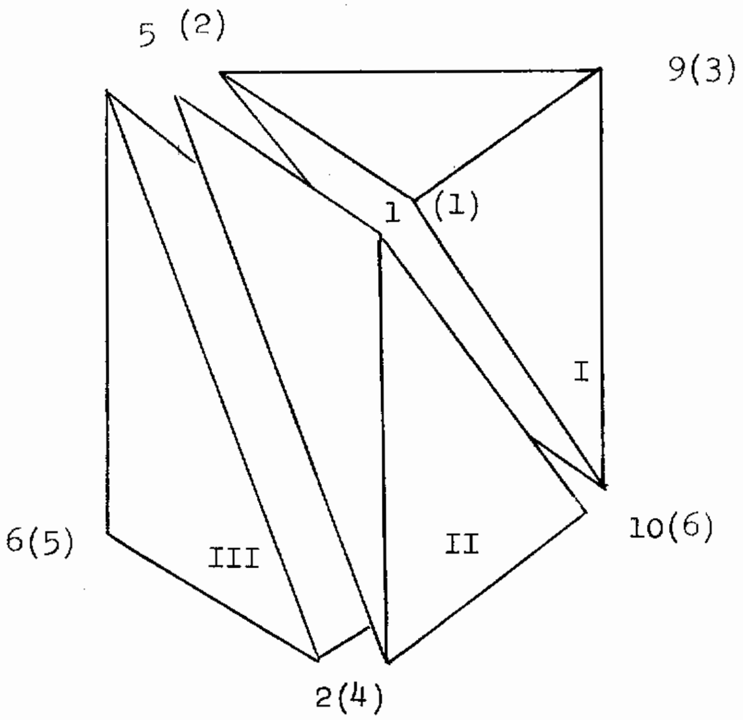
degrees of freedom $U_1, V_1, W_1, U_5, V_5, W_5, U_9, V_9, W_9$, and U_{13}, V_{13}, W_{13} fixed.

The externally applied load vector (GPRINT OF MATRIX LOADS) is presented in Figure III-D.16. This figure shows that forces (F_y) are applied in the negative and positive global Y directions at node points 4, 8, 12 and 16. These forces are numerically equal to ±66.66667 pounds and are directed to form a moment of $M_x = 800$ in pounds applied to the tip of the cantilever.

The displacements of the cantilever beam resulting from the above loads are given in Figure III-D.17. It is noted that the displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis. Figure III-D.18 shows the reactions (F_x, F_y, F_z). These are output corresponding to node point number and are referenced to the global axes system.

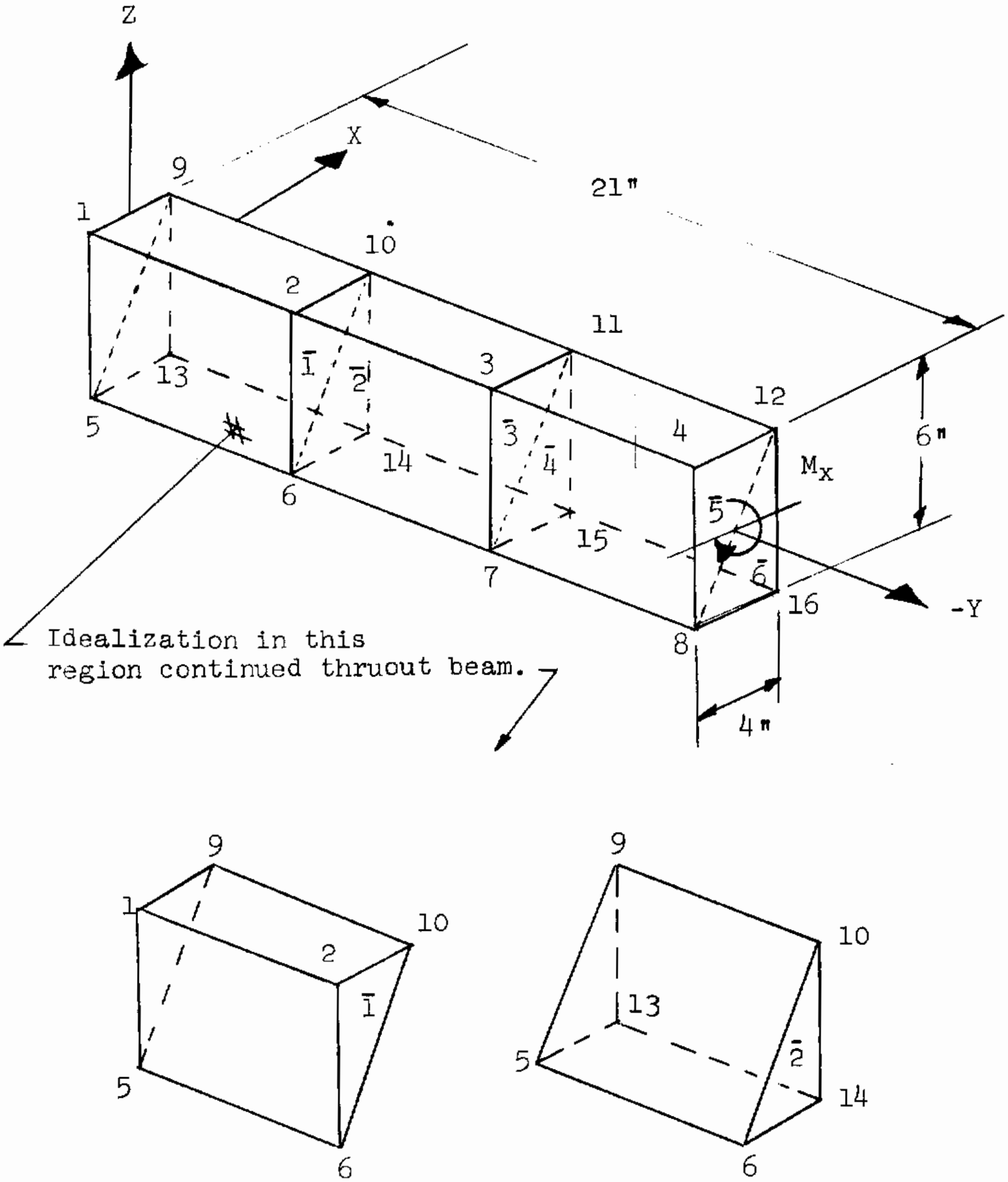
The stresses arising in the structure are displayed in tabular form in Figures III-D.19 and III-D.20 for elements 1 and 6 for example. Stresses are defined at the centroid and are referenced to the global axes for each tetrahedron which makes up a particular triangular prism element. Three stress points are given under each stress category for each triangular prism. These stress points correspond to the stresses in particular tetrahedrons which are defined in the heading of the stress data. The tetrahedron nodes listed are the local node numbering system and these must be correlated with the grid point numbering system. In the present case, element number one is defined as shown in the sketch below:





The numbers in parenthesis are the local element numbering system (See Reference 7) and the other numbers are global gridpoints. The Roman numerals on the right hand sketch are the tetrahedron numbering system. The remaining elements in the idealization are handled in the same fashion.

The last set of output is given in Figures III-D.21 to III-D.22 and consist of the global oriented element forces. Output labeling is analogous to the stress output except that the element forces are defined only at the six corner points of the triangular prism element. Six force points are given and for element number one for example, force points 1, 2, 3, 4, 5, 6 correspond to element grid point numbers 1, 5, 9, 2, 6, 10 respectively.



Idealization in this region continued thruout beam.

Prism #$\bar{1}$ **Prism #$\bar{2}$**

$E_x = E_y = E_t = E = 30.0 \times 10^6$ psi

$\nu_{xy} = \nu_{yx} = \nu_{yz} = \nu_{zy} = \nu_{zx} = \nu_{xz} = \nu = .333$

$E_x = E_y = E_z = 0, \quad T_1 = T_2 = \quad T_{16} = 0.0$

Figure III-D.1 Triangular Prism Cantilever Beam With End Moment

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6
TITLE (/)

7 8 9
2 (/) NUMBER OF TITLE CARDS

SIX ELEMENT CANTILEVER BEAM SUBJECTED TO AN END MOMENT.

TRIANGULAR PRISM ELEMENT.STATICS ANALYSIS

FIGURE III-D.2 TITLE INFORMATION - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1616-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
M	A	T	E	R		(/)

7	8	9	
		1	(/)

No. of Requests

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 11 12 13 14 15	16 17	18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41	42	43	44	45	46	47	48	49	50	51 52	53 54	55 56 57 58 59 60 61 62 63 64	
1	1	JB	STEEL	X									1	0	.000733954	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 14 15 16 17 18 19 20 21 22		23 24 25 26 27 28 29 30 31 32		33 34 35 36 37 38 39 40 41 42		43 44 45 46 47 48 49 50 51 52		53 54 55 56 57 58 59 60 61 62	
0.0	E_x	30.0 E6	ν_{xy}	.333	α_x	6.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-D.3 MATERIAL TAPE INPUT - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M	1 2 3 4 5 6	(/)
1. Number of System Grid Points	16	1 2 3 4 5 6	
2. Number of Input Grid Points	16	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	3	13 14	
4. Number of Load Conditions	2	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	6	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	4	39 40 41 42 43 44	
11. T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-D.4 SYSTEM CONTROL INFORMATION - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

	DIRECTIONS			
Grid Point Number	X – R	Y – θ	Z – Z	
7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
1	-2.0	0.0	3.0	(/)
2	-2.0	-7.0	3.0	(/)
3	-2.0	-14.0	3.0	(/)
4	-2.0	-21.0	3.0	(/)
5	-2.0	0.0	-3.0	(/)
6	-2.0	-7.0	-3.0	(/)
7	-2.0	-14.0	-3.0	(/)
8	-2.0	-21.0	-3.0	(/)
9	2.0	0.0	3.0	(/)
10	2.0	-7.0	3.0	(/)
11	2.0	-14.0	3.0	(/)
12	2.0	-21.0	3.0	(/)
13	2.0	0.0	-3.0	(/)
14	2.0	-7.0	-3.0	(/)
15	2.0	-14.0	-3.0	(/)
16	2.0	-21.0	-3.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-D.5 GRIDPOINT COORDINATES - TRIANGULAR PRISM ELEMENT, CANTILEVER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	0							(/)
				5	X										(/)
				9	X										(/)
			1	3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-D.6 BOUNDARY CONDITIONS - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS (/)

LCOND	Condition Number	Scalar	
LCOND	1	0.0	(/)

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	Fx	Fy	Fz	Mx	My	Mz	1	2	3
MODAL	0.0	0.0	0.0						

Grid Pt. Number	repeat	Fx	Fy	Fz	Mx	My	Mz	1	2	3
4		0.0	-66.66667	0.0						
	12X									
8		0.0	66.66667	0.0						
	16X									

FIGURE III-D.7 EXTERNAL LOADS - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

ELEM 1 2 3 4 5 6 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT Print	PRINT Elem. Mat.	PRINT Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	51	1	6							6		1	5	9	2	6	10							(/
2	51	1	6							6		5	13	9	6	14	10							(/
3	51	1	6							6		2	6	10	3	7	11							(/
4	51	1	6							6		6	14	10	7	15	11							(/
5	51	1	6							6		3	7	11	4	8	12							(/
6	51	1	6							6		7	15	11	8	16	12							(/
																								(/
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FIGURE III-D.8 ELEMENT CONTROL DATA - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-D.9 END CARD - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
          MAGIC   ABSTRACTION INSTRUCTION LISTING          PAGE  1

       TEST MAGIC

$INSTRUCTION    SOURCE                                                  TESTE004

       C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS                   TESTE005
       C                                                                        TESTE006
       C          *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *TESTE007
       C                                                                        TESTE008
       C          STATICS INSTRUCTION SEQUENCE                                  TESTE009
       C                                                                        TESTE010
       C          *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *TESTE011
       C                                                                        TESTE012
       C          GENERATE ELEMENT MATRICES                                     TESTE013
       C                                                                        TESTE014
   1         ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.      TESTE015
       C                                                                        TESTE016
       C                                                                        TESTE017
       C          FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                   TESTE018
       C          DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED              TESTE019
       C                                                                        TESTE020
   2         I1 = SC.IDENTC.                                                    TESTE021
   3         I3 = I1.NULL.SC                                                    TESTE022
   4         DIFF = I1 .SMULT. SC(9,1)                                          TESTE023
       C                                                                        TESTE024
       C          ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS           TESTE025
       C                                                                        TESTE026
   5         KELA = EM .ASSEM. SC,(10)                                          TESTE027
   6         FTELA = EM .ASSEM .SC,(40)                                         TESTE028
   7         LSCALE,LOADS = XLD .DEJOIN.(1,1)                                   TESTE029
       C                                                                        TESTE030
       C          REDUCE STIFFNESS MATRIX AND PRINT                             TESTE031
       C                                                                        TESTE032
   8         KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                 TESTE033
   9         KCO,STIFF = KNO.DEJOIN.( SC(9,1),0)                                TESTE034
  10         PRINT(FORCE,DISP,,) STIFF                                          TESTE035
       C                                                                        TESTE036
       C          FORM REDUCED TOTAL LOAD COLUMN                                TESTE037
       C                                                                        TESTE038
       C          MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR                 TESTE039
  11         FTELS = FTELA.MULT.LSCALE                                          TESTE040
       C          TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM            TESTE041
  12         LOADO = TR.MULT.LOADS                                              TESTE042
       C          FORM TOTAL LOAD COLUMNS                                       TESTE043
  13         TLOAD = FTELS.ADD.LOADO                                            TESTE044
  14         TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)                              TESTE045
       C                                                                        TESTE046
       C          SOLVE FOR DISPLACEMENTS                                       TESTE047
       C                                                                        TESTE048
  15         XX = STIFF.SEQEL.TLOADR                                            TESTE049
  16         TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                                   TESTE050
  17         X = TR12.TMULT.XX                                                  TESTE051
  18         XD = TR.MULT.X                                                     TESTE052
       C                                                                        TESTE053
       C          CALCULATE REACTIONS AND INVERSE CHECK                         TESTE054
```

FIGURE III-D.10 MAGIC ABSTRACT INSTRUCTION LISTING - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
          MAGIC   ABSTRACTION INSTRUCTION LISTING          PAGE  2

        TEST MAGIC

      C                                                                    TESTE055
                REACTS = KELA.MULT.XO                                      TESTE056
                REACTP= REACTS.SUBT.TLOAD                                  TESTE057
                IF (DIFF.NULL.) GO TO 10                                   TESTE058
      C                                                                    TESTE059
      C            PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,  TESTE060
      C              REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT     TESTE061
      C                                                                    TESTE062
      C            ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM                 TESTE063
      C                                                                    TESTE064
                GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA                  TESTE065
                GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LCADS                 TESTE066
                GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X                TESTE067
                GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP                 TESTE068
                IF (I3.NULL.) GO TO 600                                    TESTE069
      C                                                                    TESTE070
      C            ELEMENTS HAVE 3 DEGREES OF FREEDOM                      TESTE071
      C                                                                    TESTE072
         10     GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA          TESTE073
                GPRINT(4,,,FR.0.FZ.0.MBETA.C.F1.0.F3,SC,    )LCADS         TESTE074
                GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X                TESTE075
                GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP         TESTE076
      C                                                                    TESTE077
      C            GENERATE STRESSES  AND FORCES                           TESTE078
      C                                                                    TESTE079
        600     STRESP=EM,XO .STRESS.(4,)                                  TESTE080
                FORCEP=EM,XO .FORCE.(4,)                                   TESTE081
```

FIGURE III-D.10 CONCLUDED

```
                    SIX ELEMENT CANTILEVER BEAM SUBJECTED TO AN END MOMENT.

                    TRIANGULAR PRISM ELEMENT IDEN. NO. 51 STATICS ANALYSIS

                                    REVISIONS OF MATERIAL TAPE

                                 ASTERISK (*) PRECEEDING MATERIAL
                                 IDENTIFICATION INDICATES THAT INPUT
                                 ERROR RETURNS WILL NOT RESULT IN
                                    TERMINATION OF EXECUTION


*************************************************************************************************

    REVISION
      MATERIAL NUMBER        1
      MATERIAL IDENTIFICATION STEEL                          INPUT CODE    1
        NUMBER OF MATERIAL PROPERTY POINTS. . . . .  1
        NUMBER OF PLASTIC PROPERTY POINTS . . . .   0
        MASS DENSITY. . . . . . . . . . . . . . . . 0.73394994E-03

      MATERIAL PROPERTIES


                       YOUNG'S MODULI                          POISSON'S RATIOS

                              DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                    XX              YY             ZZ              XY              YZ             ZX
    0.0        0.300000E 08   0.300000E 08   0.300000E 08     0.333000E 00   0.333000E 00   0.333000E 00
                       TH. EXP.COEF.                           RIGIDITY MODULI

                              DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                    XX              YY             ZZ              XY              YZ             ZX
    0.0        0.650000E-05   0.650000E-05   0.650000E-05     0.112528E 08   0.112528E 08   0.112528E 08

*************************************************************************************************
```

FIGURE III-D.11 TITLE AND MATERIAL DATA OUTPUT - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                        16 REF. PCINTS

      NO. DIRECTIONS  =    3      NC. DEGREES CF FREEDCM =    1


                                     GRIDFCINT DATA
                                  (IN RECTANGULAR COORCINATES)
POINT          X                  Y                  Z              TEMPERATURES            PRESSURES
  1    -0.20000000E 01    C.0                0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  2    -0.20000000E 01   -0.70000000E 01     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  3    -0.20000000E 01   -C.14000000E C2     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  4    -0.20000000E 01   -0.21000000E 02     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  5    -0.20000000E 01    C.0               -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  6    -0.20000000E 01   -0.70000000E 01    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  7    -0.20000000E 01   -0.14000000E 02    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  8    -0.20000000E 01   -C.21000000E 02    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
  9     0.20000000E 01    0.0                0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 10     0.20000000E 01   -C.70000000E 01     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 11     0.20000000E 01   -C.14000000E C2     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 12     0.20000000E 01   -C.21000000E C2     0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 13     0.20000000E 01    0.0               -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 14     0.20000000E 01   -C.70000000E C1    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 15     0.20000000E 01   -C.14000000E C2    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
 16     0.20000000E 01   -C.21000000E 02    -0.30000000E 01     0.0                0.0
                                                                  0.0                0.0
                                                                  0.0                0.0
```

FIGURE III.D.12 GRIDPOINT DATA OUTPUT - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                          BOUNDARY CONDITION INFORMATION

 NODES                 DEGREES OF FREEDOM                     NO. OF ONES   NO. OF TWOS

    1        0      0      0                                       0            0
    2        1      1      1                                       3            0
    3        1      1      1                                       6            0
    4        1      1      1                                       9            0
    5        0      0      0                                       9            0
    6        1      1      1                                      12            0
    7        1      1      1                                      15            0
    8        1      1      1                                      18            0
    9        0      0      0                                      18            0
   10        1      1      1                                      21            0
   11        1      1      1                                      24            0
   12        1      1      1                                      27            0
   13        0      0      0                                      27            0
   14        1      1      1                                      30            0
   15        1      1      1                                      33            0
   16        1      1      1                                      36            0


                          TOTAL NO. ELEMENTS =      6


ELEM TYPE   MAT.NO. CODE   TEMP.    PRNT   NC.   --------GRID POINTS--------    EXTRA GRID PTS   ------SECTION PROPERTIES------
  1   51       1     6    0.0       0      6     1   5   9   2   6  10                           0.0         0.0         0.0
  2   51       1     6    0.0       0      6     5  13   9   6  14  10                           0.0         0.0         0.0
  3   51       1     6    0.0       0      6     2   6  10   3   7  11                           0.0         0.0         0.0
  4   51       1     6    0.0       0      6     6  14  10   7  15  11                           0.0         0.0         0.0
  5   51       1     6    0.0       0      6     3   7  11   4   8  12                           0.0         0.0         0.0
  6   51       1     6    0.0       0      6     7  15  11   8  16  12                           0.0         0.0         0.0
```

FIGURE III-D.13 BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                EXTERNAL LOAC CONDITIONS    1

     LOAD NO.    1

       NUMBER OF LOADED NODES    16           ELEMENT LCAD SCALAR =  0.0
  4  0.0          -0.66667E 02  0.0
 12  0.0          -0.66667E 02  0.0
  8  0.0           0.66667E 02  0.0
 16  0.0           0.66667E 02  0.0
  1  0.0           0.0          0.0
  2  0.0           0.0          0.0
  3  0.0           0.0          0.0
  5  0.0           0.0          0.0
  6  0.0           0.0          0.0
  7  0.0           0.0          0.0
  9  0.0           0.0          0.0
 10  0.0           0.0          0.0
 11  0.0           0.0          0.0
 13  0.0           0.0          0.0
 14  0.0           0.0          0.0
 15  0.0           0.0          0.0


                         TRANSFCRPED EXTERNAL ASSEMBLED LOAD COLUMN

                                        48 X 1

     0.0           0.0           0.0           0.0           0.0               0.0

     0.0           0.0           0.0           0.0          -0.66666992E 02    0.0

     0.0           0.0           0.0           0.0           0.0               0.0

     0.0           0.0           0.0           0.0           0.66666992E 02    0.0

     0.0           0.0           0.0           0.0           0.0               0.0

     0.0           0.0           0.0           0.0          -0.66666992E 02    0.0

     0.0           0.0           0.0           0.0           0.0               0.0

     0.0           0.0           0.0           0.0           0.66666992E C2    0.


                              T-ZERC FCF STRUCTURE =  0.0
```

FIGURE III-D.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                             MATRIX  STIFF /    1/                                                 PAGE    1

                           CUTOFF =    0.0                                      SIZE    36  BY    36

             FORCE                   FORCE                    FORCE                    FORCE                    FORCE

DISP    1     1   0.275072E 09    2   0.336910E 08    3   -0.786124E 08    4   -0.643016E 07    5   -0.112528E 08
              6  -0.131283E 08   10  -0.262565E 08   11    0.224382E 08   12    0.523558E 08   19   -0.235955E 09
             20  -0.336910E 08   21   0.262566E 08   22   -0.203010E 02   23    0.336910E 08   24    0.131283E 08

DISP    2     1   0.336910E 08    2   0.136698E 09    3    0.224606E 08    4   -0.224382E 08    5   -0.256821E 08
              6  -0.750186E 07   10   0.112528E 08   11   -0.262565E 08   12   -0.224606E 08   19   -0.336910E 08
             20  -0.590772E 08   21   0.750187E 07   22    0.336910E 08   23   -0.853910E 01   24   -0.750187E 07

DISP    3     1  -0.786124E 08    2   0.224606E 08    3    0.176806E 09    4   -0.261779E 08    5   -0.149588E 08
              6  -0.643015E 07   10   0.262566E 08   11   -0.224607E 08   12   -0.104869E 09   19    0.523558E 08
             20   0.149588E 08   21  -0.590772E 08   22    0.261779E 08   23   -0.149588E 08   24   -0.858691E 01

DISP    4     1  -0.643016E 07    2  -0.224382E 08    3   -0.261779E 08    4    0.275072E 09    5    0.336910E 08
              6  -0.786124E 08    7  -0.643017E 07    8   -0.112528E 08    9   -0.131283E 08   10   -0.212395E 01
             11  -0.224382E 08   12   0.261779E 08   13   -0.262565E 08   14    0.224382E 08   15    0.523558E 08
             22  -0.235955E 09   23  -0.336910E 08   24    0.262566E 08   25    0.582887E 01   26    0.336910E 08
             27   0.131283E 08

DISP    5     1  -0.112528E 08    2  -0.256821E 08    3   -0.149588E 08    4    0.336910E 08    5    0.136698E 09
              6   0.224606E 08    7  -0.224382E 08    8   -0.256821E 08    9   -0.750187E 07   10   -0.112528E 08
             11   0.888256E 00   12   0.224606E 08   13    0.112528E 08   14   -0.262565E 08   15   -0.224607E 08
             22  -0.336910E 08   23  -0.590772E 08   24    0.750187E 07   25    0.336910E 08   26    0.453793E 01
             27  -0.750187E 07

DISP    6     1  -0.131283E 08    2  -0.750186E 07    3   -0.643015E 07    4   -0.786124E 08    5    0.224606E 08
              6   0.176806E 09    7  -0.261779E 08    8   -0.149588E 08    9   -0.643017E 07   10    0.131283E 08
             11   0.224607E 08   12  -0.114953E 02   13    0.262566E 08   14   -0.224606E 08   15   -0.104869E 09
             22   0.523558E 08   23   0.149588E 08   24   -0.590772E 08   25    0.261779E 08   26   -0.149588E 08
             27   0.245715E 02

DISP    7     4  -0.643017E 07    5  -0.224382E 08    6   -0.261779E 08    7    0.172486E 09    8    0.336910E 08
              9  -0.393062E 08   13  -0.220379E 01   14   -0.224382E 08   15    0.261779E 08   16   -0.875218E 07
             17   0.224382E 08   18   0.261779E 08   25   -0.157303E 09   26   -0.112528E 08   27    0.131283E 08

DISP    8     4  -0.112528E 08    5  -0.256821E 08    6   -0.149588E 08    7    0.336910E 08    8    0.738192E 08
              9  -0.535504E 01   13  -0.112528E 08   14   -0.880196E 01   15    0.224607E 08   16    0.112528E 08
             17  -0.875218E 07   18  -0.750187E 07   25   -0.224382E 08   26   -0.393848E 08   27   -0.534968E 01

DISP    9     4  -0.131283E 08    5  -0.750187E 07    6   -0.643017E 07    7   -0.393062E 08    8   -0.535504E 01
              9   0.807713E 08   13   0.131283E 08   14    0.224607E 08   15   -0.220379E 01   16    0.131283E 08
             17  -0.149588E 08   18  -0.349563E 08   25    0.261779E 08   26   -0.268288E 01   27   -0.393848E 08
```

FIGURE III-D 15 STIFFNESS MATRIX OUTPUT - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                                           MATRIX  STIFF /    1/                                                    PAGE     2

                         CUTOFF  =    0.0                                      SIZE     36   BY     36

              FORCE                    FCRCE                     FCRCE                    FORCE                    FORCE

DISP      10     1   -0.262565E 08     2    0.112528E 08     3    0.262566E 08     4   -0.212395E 01     5   -0.112528E 08
                 6    0.131283E 08    10    0.305436E 09    11   -0.336909E 08    12   -0.393062E 08    13   -0.216125E 08
                14    0.224382E C8    15    C.261779E 08    19   -0.875219E 07    20   -0.336910E 08    21   -0.786123E 08
                22    0.875218E 07    23    C.336910E 08    24   -0.393062E 08    28   -0.244707E 05    29    0.336910E 08
                30    0.916620E 08

DISP      11     1    0.224382E C8     2   -0.262565E 08     3   -0.224607E 08     4   -0.224382E 08     5    0.888256E 00
                 6    0.224607E 08    10   -0.336909E 08    11    0.205567E 09    12    0.673820E 08    13    0.112528E 08
                14   -0.601164E 08    15   -C.374194E 08    19   -0.336910E 08    20   -0.875220E 07    21   -0.224607E 08
                22    0.336910E 08    23    0.875220E 07    24    0.224606E 08    28    0.336910E 08    29   -0.678294E 08
                30   -0.149588E C8

DISP      12     1    0.523550E 08     2   -0.224606E 08     3   -0.104869E 09     4    0.261779E 08     5    0.224606E 08
                 6   -0.114953E 02    10   -0.393062E 08    11    0.673820E 08    12    0.259579E 09    13    0.131283E 08
                14   -0.299625E 08    15   -0.478166E 08    19   -0.786123E 08    20   -0.224606E 08    21   -0.349563E 08
                22   -0.393062E 08    23    0.224606E 08    24    0.349563E 08    28    0.655627E 08    29   -0.750186E 07
                30   -0.940335E C8

DISP      13     4   -0.262565E 08     5    0.112528E 08     6    0.262566E 08     7   -0.220379E 01     8   -0.112528E 08
                 9    0.131283E 08    10   -0.216125E 08    11    0.112528E 08    12    0.131283E 08    13    0.305436E 09
                14   -0.336909E 08    15   -0.393061E 08    16   -0.216125E 08    17    0.224381E 08    18    0.261779E 08
                22   -0.875219E 07    23   -0.336910E 08    24   -0.786123E 08    25    0.875216E 07    26    0.336910E 08
                27   -0.393061E C8    28    0.875218E 07    29   -0.336910E 08    30   -0.131283E 08    31   -0.244707E 09
                32    0.336910E C8    33    0.916619E 08

DISP      14     4    0.224382E C8     5   -0.262565E 08     6   -0.224606E 08     7   -0.224382E 08     8   -0.880196E 01
                 9    0.224607E 08    10    0.224382E 08    11   -0.601164E 08    12   -0.299625E 08    13   -0.336909E 08
                14    0.205567E 09    15    0.673819E 08    16    0.112528E 08    17   -0.601164E 08    18   -0.374194E 08
                22   -0.336910E 08    23   -0.875218E 07    24   -0.224606E 08    25    0.336910E 08    26    0.875216E 07
                27    0.224607E C8    28   -0.336910E 08    29    0.875218E 07    30    0.149588E 08    31    0.336910E 08
                32   -0.678294E 08    33   -0.149588E 08

DISP      15     4    0.523558E C8     5   -C.224607E 08     6   -0.104869E 09     7    0.261779E 08     8    0.224607E 08
                 9   -0.220379E 01    10    0.261779E 08    11   -0.374194E 08    12   -0.478166E 08    13   -0.393061E 08
                14    0.673819E 08    15    0.259579E 09    16    0.131283E 08    17   -0.299625E 08    18   -0.478166E 08
                22   -0.786123E 08    23   -0.224606E 08    24   -0.349563E 08    25   -0.393061E 08    26    0.224607E 08
                27    0.349562E 08    28   -0.261779E 08    29    0.750186E 07    30    0.349563E 08    31    0.655627E 08
                32   -0.750186E 07    33   -C.940335E 08

DISP      16     7   -0.875218E 07     8    0.112528E 08     9    0.131283E 08    13   -0.216125E 08    14    0.112528E 08
                15    0.131283E 08    16    C.109016E 09    17    0.240977E 02    18    0.281140E 02    25   -0.875218E 07
                26   -0.112528E 08    27   -0.393062E 08    31    0.875213E 07    32   -0.336910E 08    33   -0.131283E 08
                34   -0.786517E C8    35    C.224382E 08    36    0.261779E 08

DISP      17     7    0.224382E C8     8   -0.875218E 07     9   -0.149588E 08    13    0.224381E 08    14   -0.601164E 08
                15   -0.299625E C8    16    0.240977E 02    17    0.885610E 08    18    0.449213E 08    25   -0.224382E 08
                26   -0.875218E 07    27   -0.149588E 08    31   -0.336910E 08    32    0.875216E 07    33    0.149588E 08
```

FIGURE III-D.15 CONTINUED

```
                                    MATRIX  STIFF /    1/                                              PAGE    3
                     CUTOFF  =    0.0                                  SIZE    36  BY    36
             FORCE                   FORCE                   FCRCE                   FORCE                   FORCE

DISP     17   34   0.112528E 08   35   -0.196924E 08

DISP     18    7   0.261779E 08    8   -0.750187E 07    9   -0.349563E 08   13    0.261779E 08   14   -0.374194E 08
              15  -0.478166E 08   16    0.281140E 02   17    0.449213E 08   18    0.102465E 09   25   -0.393062E 08
              26  -0.750186E 07   27   -0.349563E 08   31   -0.261779E 08   32    0.750187E 07   33    0.349562E 08
              34   0.131283E 08   36   -0.196924E 08

DISP     19    1  -0.235955E 09    2   -0.336910E 08    3    0.523558E 08   10   -0.875219E 07   11   -0.336910E 08
              12  -0.786123E 08   19    0.287932E 09   20    0.336909E 08   22   -0.128603E 08   23   -0.224382E 08
              28  -0.175044E 08   29    0.112528E 08   30    0.262566E 08

DISP     20    1  -0.336910E 08    2   -0.590772E 08    3    0.149588E 08   10   -0.336910E 08   11   -0.875220E 07
              12  -0.224606E 08   19    0.336909E 08   20    0.188062E 09   21    0.224606E 08   22   -0.112528E 08
              23  -0.513642E 08   24   -0.750186E 07   28    0.224382E 08   29   -0.175044E 08   30   -0.224606E 08

DISP     21    1   0.262566E 08    2    0.750187E 07    3   -0.590772E 08   10   -0.786123E 08   11   -0.224607E 08
              12  -0.349563E 08   20    0.224606E 08   21    0.189667E 09   23   -0.149588E 08   24   -0.128603E 08
              28   0.523558E 08   29   -0.224607E 08   30   -0.699125E 08

DISP     22    1  -0.203010E 02    2    0.336910E 08    3    0.261779E 08    4   -0.235955E 09    5   -0.336910E 08
               6   0.523558E 08   10    0.875218E 07   11    0.336910E 08   12   -0.393062E 08   13   -0.875219E 07
              14  -0.336910E 08   15   -0.786123E 08   19   -0.128603E 08   20   -0.112528E 08   22    0.287932E 09
              23   0.336910E 08   24   -0.351425E 01   25   -0.128603E 08   26   -0.224382E 08   27    0.934195E 01
              28  -0.875218E 07   29   -0.112528E 08   30    0.131283E 08   31   -0.175044E 08   32    0.112528E 08
              33   0.262565E 08

DISP     23    1   0.336910E 08    2   -0.853910E 01    3   -0.149588E 08    4   -0.336910E 08    5   -0.590772E 08
               6   0.149588E 08   10    0.336910E 08   11    0.875220E 07   12    0.224606E 08   13   -0.336910E 08
              14  -0.875218E 07   15   -0.224606E 08   19   -0.224382E 08   20   -0.513642E 08   21   -0.149588E 08
              22   0.336910E 08   23    0.188062E 09   24    0.224606E 08   25   -0.112528E 08   26   -0.513643E 08
              27  -0.750185E 07   28   -0.224382E 08   29   -0.875218E 07   30    0.224606E 08   31    0.224382E 08
              32  -0.175044E 08   33   -0.224606E 08

DISP     24    1   0.131283E 08    2   -0.750187E 07    3   -0.858691E 01    4    0.262566E 08    5    0.750187E 07
               6  -0.590772E 08   10   -0.393062E 08   11    0.224606E 08   12    0.349563E 08   13   -0.786123E 08
              14  -0.224606E 08   15   -C.349563E 08   20   -0.750186E 07   21   -0.128603E 08   22   -0.351425E 01
              23   0.224606E 08   24    0.189667E 09   25    0.469504E 01   26   -0.149588E 08   27   -0.128603E 08
              28   0.261779E 08   29    0.224606E 08   30   -0.349563E 08   31    0.523558E 08   32   -0.224606E 08
              33  -0.659125E 08

DISP     25    4   0.582887E 01    5    0.336910E 08    6    0.261779E 08    7   -0.157303E 09    8   -0.224382E 08
               9   0.261779E 08   13    0.875216E 07   14    0.336910E 08   15   -0.393061E 08   16   -0.875218E 07
              17  -0.224382E 08   18   -0.393062E 08   22   -0.128603E 08   23   -0.112528E 08   24    0.469504E 01
              25   0.187668E 09   26   -0.527137E 01   27    0.199140E 02   31   -0.875218E 07   32   -0.112528E 08
              33   0.131283E 08   34   -0.875218E 07   35   -0.264096E 01   36    0.131283E 08
```

FIGURE III-D.15 CONTINUED

```
                                    MATRIX  STIFF /    1/                                                PAGE    4

                      CUTOFF  =    0.0                                SIZE    36   BY    36

             FORCE                FORCE                    FORCE                   FORCE                   FORCE

DISP   26     4    0.336910E 08     5    0.453793E 01     6   -0.149588E 08     7   -0.112528E 08     8   -0.393848E 08
              9   -0.268288E 01    13    0.336910E 08    14    0.875216E 07    15    0.224607E 08    16   -0.112528E 08
             17   -0.875218E 07    18   -0.750186E 07    22   -0.224382E 08    23   -0.513643E 08    24   -0.149588E 08
             25   -0.527137E 01    26    C.108253E 09    27   -0.346404E 02    31   -0.224382E 08    32   -0.875219E 07
             33    0.224607E 08    34   -0.526610E 01    35   -0.875218E 07    36   -0.750187E 07

DISP   27     4    0.131283E 08     5   -0.750187E 07     6    0.245715E 02     7    0.131283E 08     8   -0.534968E 01
              9   -0.393848E 08    13   -0.393061E 08    14    0.224607E 08    15    0.349562E 08    16   -0.393062E 08
             17   -0.149588E 08    18   -0.349563E 08    22    0.936195E 01    23   -0.750185E 07    24   -0.128603E 08
             25    0.199140E 02    26   -0.346404E 02    27    0.122158E 09    31    0.261779E 08    32    0.224607E 08
             33   -0.349562E 08    34    0.261779E 08    35   -0.149588E 08    36   -0.349563E 08

DISP   28    10   -0.244707E 09    11    0.336910E 08    12    0.655627E 08    13    0.875218E 07    14   -0.336910E 08
             15   -0.261779E 08    19   -0.175044E 08    20    0.224382E 08    21    0.523558E 08    22   -0.875218E 07
             23   -0.224382E C8    24    0.261779E 08    28    0.275072E 09    29   -0.336910E 08    30   -0.117918E 09
             31   -0.643017E 07    32    0.112528E 08

DISP   29    10    0.336910E 08    11   -0.678294E 08    12   -0.750186E 07    13   -0.336910E 08    14    0.875218E 07
             15    0.750186E 07    19    0.112528E 08    20   -0.175044E 08    21   -0.224607E 08    22   -0.112528E 08
             23   -0.875218E 07    24    0.224606E 08    28   -0.336910E 08    29    0.136658E 09    30    0.224607E 08
             31    0.224382E 08    32   -0.256821E 08    33   -0.149588E 08

DISP   30    10    0.916620E 08    11   -0.149588E 08    12   -0.940335E 08    13   -0.131283E 08    14    0.149588E 08
             15    0.349563E C8    19    0.262566E 08    20   -0.224606E 08    21   -0.699129E 08    22    0.131283E 08
             23    0.224606E 08    24   -0.349563E 08    28   -0.117918E 09    29    0.224607E 08    30    0.176806E 09
             32   -0.750187E 07    33   -0.643017E 07

DISP   31    13   -0.244707E C9    14    0.336910E 08    15    0.655627E 08    16    0.875213E 07    17   -0.336910E 08
             18   -0.261779E C8    22   -0.175044E 08    23    0.224382E 08    24    0.523558E 08    25   -0.875218E 07
             26   -0.224382E C8    27    0.261779E 08    28   -0.643017E 07    29    0.224382E 08    31    0.275072E 09
             32   -0.336909E C8    33   -0.117918E 09    34   -0.643017E 07    35    0.112528E 08

DISP   32    13    0.336910E 08    14   -0.678294E 08    15   -0.750186E 07    16   -0.334910E 08    17    0.875214E 07
             18    0.750187E 07    22    0.112528E 08    23   -0.175044E 08    24   -0.224606E 08    25   -0.112528E 08
             26   -0.875219E 07    27    0.224607E 08    28    0.112528E 08    29   -0.256821E 08    30   -0.750187E 07
             31   -0.336909E 08    32    0.134698E 09    33    0.224606E 08    34    0.224382E 08    35   -0.256821E 08
             36   -0.149588E 08

DISP   33    13    0.916619E 08    14   -0.149588E 08    15   -0.940335E 08    16   -0.131283E 08    17    0.149588E 08
             18    0.349562E 08    22    0.262565E 08    23   -0.224606E 08    24   -0.699125E 08    25    0.131283E 08
             26    0.224607E C8    27   -0.349562E 08    29   -0.149588E 08    30   -0.643017E 07    31   -0.117918E 09
             32    0.224606E 08    33    0.176806E 09    35   -0.750187E 07    36   -0.643017E 07

DISP   34    16   -0.786517E 08    17    0.112528E 08    18    0.131283E 08    25   -0.875218E 07    26   -0.526610E 01
             27    0.261779E C8    31   -0.643017E 07    32    0.224382E 08    34    0.938340E 08    35   -0.336910E 08
             36   -0.393062E C8
```

FIGURE III-D.15 CONTINUED

```
                                        MATRIX  STIFF /    1/                                              PAGE    5
                         CUTOFF =    0.0                                   SIZE     36  BY     36

                FORCE                  FORCE                  FORCE                  FORCE                  FORCE

DISP      35     16    0.224382E 08    17   -0.196924E 08    25   -0.264096E 01    26   -0.875218E 07    27   -0.149588E 08
                 31    0.112528E 08    32   -0.256821E 08    33   -0.750187E 07    34   -0.336910E 0E    35    0.541267E 08
                 36    0.224606E C8

DISP      36     16    0.261779E 08    18   -0.196924E 08    25    0.131283E 08    26   -0.750187E 07    27   -0.349563E 08
                 32   -0.149568E 08    33   -C.643017E 07    34   -0.393062E 08    35    0.224606E CE    36    0.610788E 08
```

FIGURE III-D.15 CONCLUDED

```
                              GPRINT CF MATRIX  LOADS     (SET   1)

ROW       FX             FY               FZ
    1    0.0            0.0              0.0
    2    0.0            0.0              0.0
    3    0.0            0.0              0.0
    4    0.0          -0.66666592E 02    0.0
    5    0.0            0.0              0.0
    6    0.0            0.0              0.0
    7    0.0            0.0              0.0
    8    0.0            0.66666592E 02   0.0
    9    0.0            0.0              0.0
   10    0.0            0.0              0.0
   11    0.0            0.0              0.0
   12    0.0          -0.66666992E 02    0.0
   13    0.0            0.0              0.0
   14    0.0            0.0              0.0
   15    0.0            0.0              0.0
   16    0.0            0.66666592E 02   0.0
```

FIGURE III-D.16 GPRINT OF MATRIX LOADS - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                          DISPLACEMENT MATRIX FOR LOAD CONDITION    1
                                            48 X 1

ROW          U                    V                   W
    1     0.0                 0.0                 0.0
    2     0.51942095E-06     -0.18232240E-05     -0.17246730E-05
    3     0.22856448E-05     -0.36443889E-05     -0.67784067E-05
    4     0.54131960E-05     -0.54952980E-05     -0.14936108E-04
    5     0.0                 0.0                 0.0
    6     0.82286385E-06      0.10807307E-05     -0.16738813E-05
    7     0.28437362E-05      0.22012910E-05     -0.67885239E-05
    8     0.59999056E-05      0.38794506E-05     -0.16109276E-04
    9     0.0                 0.0                 0.0
   10     0.38346599E-06     -0.10807571E-05     -0.14056868E-05
   11     0.21245487E-05     -0.22067061E-05     -0.62474273E-05
   12     0.51698862E-05     -0.33873048E-05     -0.14530836E-04
   13     0.0                 0.0                 0.0
   14     0.93951201E-06      0.18082555E-05     -0.13954250E-05
   15     0.29730098E-05      0.35991225E-05     -0.61594055E-05
   16     0.64449150E-05      0.62887530E-05     -0.15540849E-04
```

FIGURE III-D.17 DISPLACEMENT MATRIX - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                              REACTIONS AND INVERSE CHECK FOR LOAD CONDITION      1

ROW          FX                 FY                 FZ
    1   -0.15047638E 02     0.71572342E 02     0.50970963E 02
    2   -0.16326904E-02     0.85449219E-03     0.17931480E-02
    3   -0.28228760E-02     0.25482178E-02     0.23132437E-02
    4   -0.35705566E-02     0.30517578E-04     0.29296875E-02
    5   -0.17282257E 02    -0.71578903E 02    -0.57377411E 02
    6    0.99182129E-03    -0.11596680E-02    -0.11444092E-02
    7    0.17089844E-02    -0.27465820E-03    -0.17089844E-02
    8   -0.73242188E-03    -0.36621094E-03     0.36621094E-02
    9    0.19318710E 02     0.61742584E 02     0.34244446E 02
   10    0.45776367E-03     0.41198730E-03     0.91552734E-04
   11   -0.54931641E-03    -0.64086914E-03     0.48828125E-03
   12    0.21057129E-02    -0.10681152E-02     0.73242188E-03
   13    0.13012527E 02    -0.61735397E 02    -0.27844162E 02
   14   -0.76293945E-03     0.12207031E-03     0.51879883E-03
   15    0.48828125E-03     0.35095215E-03    -0.25939941E-03
   16    0.17089844E-02    -0.97656250E-03    -0.39062500E-02
```

FIGURE III-D.18 REACTION MATRIX - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    S T R E S S E S   F C R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

                    (STRESS POINT ONE ECLAIS ELEPENT STPESSES AT CENTROID OF TETRAHEDRON WITH NUDES(6,2,3,1))
                    (STRESS POINT TWO ECLAIS ELEPENT STPESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,1,4))
                   (STRESS PCINT THREE ECLAIS ELEPENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(2,6,5,4))

      LOAD CONDITION NUMBER      ELEPENT NLPBEF      ELEPENT TYPE        ELEMENT GRID POINTS

                  1                     1                 51              1    5    9    2    6   10

APPARENT ELEMENT STRESSES
STRESS                                                           MEMBRANE STRESSES
POINT        SIGMA-X              SIGMA-Y              SIGPA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1     0.34643211E 01      0.69390488E 01      0.34643211E 01      -0.61643881E 00      0.22597046E 01      0.0
    2     0.43166809E 01      0.10943444E 02      0.50816183E 01       0.12537174E 01      0.27724876E C1      0.89737320E 00
    3    -0.51817627E 01     -0.78914680E 01     -0.46073389E 01       0.76592064E 00     -0.27554369E 01      0.32827568E 00

ELEMENT APPLIED STRESSES
STRESS                                                           MEMBRANE STRESSES
POINT        SIGMA-X              SIGMA-Y              SIGMA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1     0.0                 0.0                 0.0                  0.0                  0.0                  0.0
    2     0.0                 0.0                 0.0                  0.0                  0.0                  0.0
    3     0.0                 0.0                 0.0                  0.0                  0.0                  0.0

NET ELEMENT STRESSES
STRESS                                                           MEMBRANE STRESSES
POINT        SIGMA-X              SIGMA-Y              SIGMA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1     0.34643211E 01      0.69390488E 01      0.34643211E 01      -0.61643881E 00      0.22597046E 01      0.0
    2     0.43166809E 01      0.10943444E 02      0.50816183E 01       0.12537174E 01      0.27724876E 01      0.89737320E 00
    3    -0.51817627E 01     -0.78914680E 01     -0.46073389E 01       0.76592064E 00     -0.27554369E 01      0.32827568E 00
```

FIGURE III-D.19 STRESS OUTPUT, ELEMENT NO. 1 - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

                  (STRESS POINT ONE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,3,1))
                  (STRESS POINT TWO EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,1,4))
                 (STRESS POINT THREE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(2,6,5,4))


     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

               1                     6                 51              7   15   11    8   16   12


APPARENT ELEMENT STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT          SIGMA-X              SIGMA-Y              SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
    1      0.49076519E 01       0.79760122E 01       0.38501024E 01      -0.96312809E 00       0.24272919E 01       0.17858338E 00
    2     -0.37657166E 00      -0.64993439E 01       0.24569702E 01      -0.11413012E 01      -0.12666397E 01      -0.29281031E-01
    3      0.15577698E 00      -0.10995422E 02       0.14404602E 01       0.11966228E 01      -0.30660515E 01      -0.79219818E 00

ELEMENT APPLIED STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT          SIGMA-X              SIGMA-Y              SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
    1      0.0                  0.0                  0.0                 0.0                  0.0                  0.0
    2      0.0                  0.0                  0.0                 0.0                  0.0                  0.0
    3      0.0                  0.0                  0.0                 0.0                  0.0                  0.0

NET ELEMENT STRESSES
STRESS                                                      MEMBRANE STRESSES
POINT          SIGMA-X              SIGMA-Y              SIGMA-Z             SIGMA-XY             SIGMA-YZ             SIGMA-ZX
    1      0.49076519E 01       0.79760122E 01       0.38501024E 01      -0.96312809E 00       0.24272919E 01       0.17858338E 00
    2     -0.37657166E 00      -0.64993439E 01       0.24569702E 01      -0.11413012E 01      -0.12666397E 01      -0.29281031E-01
    3      0.15577698E 00      -0.10995422E 02       0.14404602E 01       0.11966228E 01      -0.30660515E 01      -0.79219818E 00
```

FIGURE III-D.20 STRESS OUTPUT ELEMENT NO. 6 - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    F O R C E S   F O R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

     LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE         ELEMENT GRID POINTS

                 1                     1                  51              1    5    9    2    6   10

APPARENT ELEMENT FORCES
POINT                               FORCES
               FX                     FY                    FZ
    1      -0.15047638E 02       0.71572342E 02       0.50970963E 02
    2      -0.11240540E 01      -0.55049362E 02      -0.50902725E 02
    3       0.21784470E 02       0.23441101E 02       0.90388203E 01
    4       0.25726776E 01      -0.70769852E 02      -0.41170395E 02
    5      -0.45955963E 01       0.44424530E 02       0.32522629E 02
    6      -0.35898285E 01      -0.13618790E 02      -0.45930481E 00

ELEMENT APPLIED FORCES
POINT                               FORCES
               FX                     FY                    FZ
    1       0.0                  0.0                  0.0
    2       0.0                  0.0                  0.0
    3       0.0                  0.0                  0.0
    4       0.0                  0.0                  0.0
    5       0.0                  0.0                  0.0
    6       0.0                  0.0                  0.0

NET ELEMENT FORCES
POINT                               FORCES
               FX                     FY                    FZ
    1      -0.15047638E 02       0.71572342E 02       0.50970963E 02
    2      -0.11240540E 01      -0.55049362E 02      -0.50902725E 02
    3       0.21784470E 02       0.23441101E 02       0.90388203E 01
    4       0.25726776E 01      -0.70769852E 02      -0.41170395E 02
    5      -0.45955963E 01       0.44424530E 02       0.32522629E 02
    6      -0.35898285E 01      -0.13618790E 02      -0.45930481E 00
```

FIGURE III-D.21 FORCE OUTPUT, ELEMENT NO. 1 - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

```
                    F O R C E S   F O R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

     LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE         ELEMENT GRID POINTS

                 1                    6                   51             7   15   11    8   16   12


APPARENT ELEMENT FORCES
POINT                                  FORCES
               FX                        FY                        FZ
   1       -0.36419189E 02        -0.17177475E 02          0.53542480E 01
   2        0.35807129E 02        -0.64129883E 02         -0.40652100E 02
   3       -0.30191040E 01         0.43231583E 02          0.27676498E 02
   4        0.36113281E 01         0.23532303E 02         -0.85327148E 00
   5        0.97656250E-03         0.66666595E 02         -0.31738281E-02
   6        0.19034155E-01        -0.52123230E 02          0.84785156E 01


ELEMENT APPLIED FORCES
POINT                                  FORCES
               FX                        FY                        FZ
   1        0.0                    0.0                     0.0
   2        0.0                    0.0                     0.0
   3        0.0                    0.0                     0.0
   4        0.0                    0.0                     0.0
   5        0.0                    0.0                     0.0
   6        0.0                    0.0                     0.0


NET ELEMENT FORCES
POINT                                  FORCES
               FX                        FY                        FZ
   1       -0.36419189E 02        -0.17177475E 02          0.53542480E 01
   2        0.35807129E 02        -0.64129883E 02         -0.40652100E 02
   3       -0.30191040E 01         0.43231583E 02          0.27676498E 02
   4        0.36113281E 01         0.23532363E 02         -0.85327148E 00
   5        0.97656250E-03         0.66666595E 02         -0.31738281E-02
   6        0.19034155E-01        -0.52123230E 02          0.84785156E 01
```

FIGURE III-D.22 FORCE OUTPUT, ELEMENT NO. 6 - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

E. Symmetric Triangular Prism

A six element cantilever beam subjected to an end moment is shown in Figure III-E.1. This figure depicts the loading, idealization, dimensions, and material properties. The preprinted input data forms for this example are given in Figures III-E.2 to III-E.9. Preparation of input data for this element is straight forward, however, a comment must be made on the ''Element Control Data'' form, Figure III-E.8. Since we are using a symmetric triangular prism element only three (3) node points define the element. Although column 34 in this figure indicates that 6 input nodes are needed the user only inputs the three pertinent node points. Note also that the ''Plug No,'' columns 11 and 12 is the same as used for the symmetric triangular prism element. It is also important to note that the user must define the global XY plane as the plane of symmetry for the symmetric triangular prism.

The output supplied by the MAGIC III System for this particular example is described below and shown in Figures III-E.10 to III-E.21. The matrix abstractions are shown in Figures III-E.10. A complete description of the instructions is provided in Reference 5. Output from the Structural Systems Monitor is given in Figures III-E.11 to III-E.13. These figures record the data pertinent to the problem being solved.

The problem title and material data output are shown in Figure III-E.11. Gridpoint coordinates, temperatures, and pressures are given in Figure III-E.12, as well as boundary condition information and element description. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed (i.e. no motion) and ones ('1') represent degrees of freedom that are free or have unknown values of displacement. The second last column represents the cumulative number of degrees of freedom which actively participate in the equation solving process for displacements. The last column accumulates the number of twos ('2') which participate in the calculation of the reduced stiffness matrix. The third portion of Figure III-E.12

shows the finite element description. Each of the six elements is called out in turn with gridpoints, print options and material number. Note that no extra grid points are listed nor needed for this element. The same comment also holds for section properties since all pertinent data are calculated within the program.

Figure III-E.13 displays the external load condition and transformed external assembled load column. This 24x1 vector is the total unreduced load which is read row-wise. The ordering of this vector is consistent with that of the boundary condition table given in Figure III-E.12. Note that a load of 66.66667 pounds is applied at node 4 in the negative global Y direction. This is position (11,1) in the load vector which corresponds to the eleventh entry in the boundary condition table which is the global V displacement for node point 4. The other loads follow the same pattern.

MAGIC III system output of final results are displayed in Figures III-E.14 to III-E.21. Figure III-E.14 shows the stiffness matrix for this problem. Note that only the non-zero terms are displayed. The stiffness matrix is presented row-wise and it's ordering is consistent with that of the boundary condition table previously discussed. In this problem the ordering is

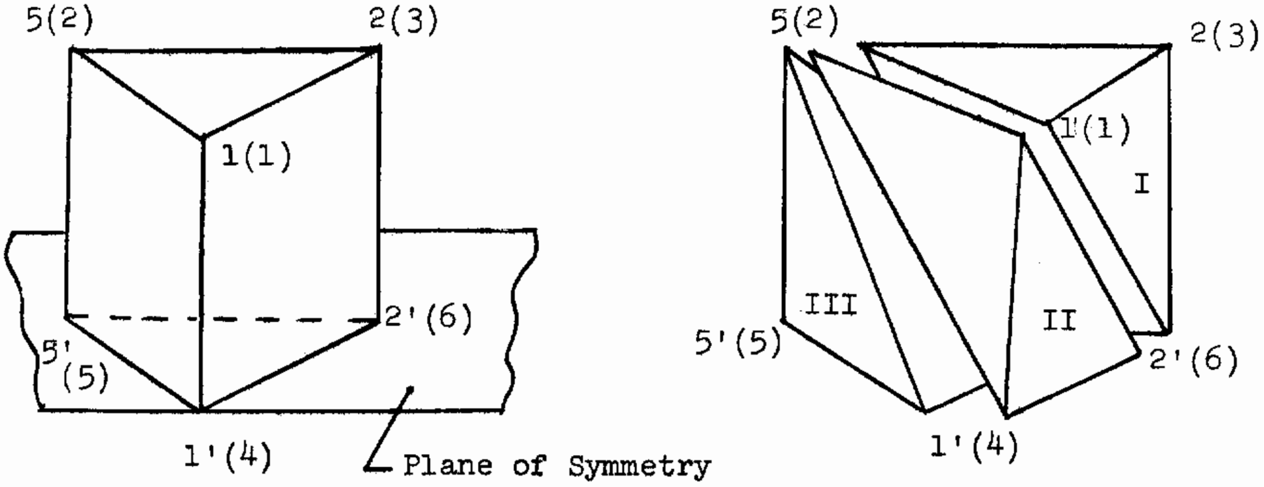
$$\left\{ \Delta^{SP} \right\}^{T} = \left\lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots U_8, V_8, W_8 \right\rfloor$$

with displacements U_1, V_1, W_1 and U_5, V_5 and W_5 fixed.

The externally applied load vector (GPRINT OF MATRIX LOADS) is presented in Figure III-E.15. This figure shows that forces (F_Y) are applied in the negative and positive global Y directions at nodes 4 and 8. These forces are numerically equal to ±66.66667 pounds and are directed to form a moment of $M_x = 800$ in pounds applied at the tip of the cantilever.

The displacements of the cantilever beam resulting from the above loads are given in Figure III-E.16. These displacements (U, V, W) are output corresponding to node point number and are referenced to the global axes unless otherwise noted. Figure III-E.17 shows the reactions (F_x, F_y, F_z). These are also output corresponding to node point number and are referenced to the global axes system unless otherwise specified.

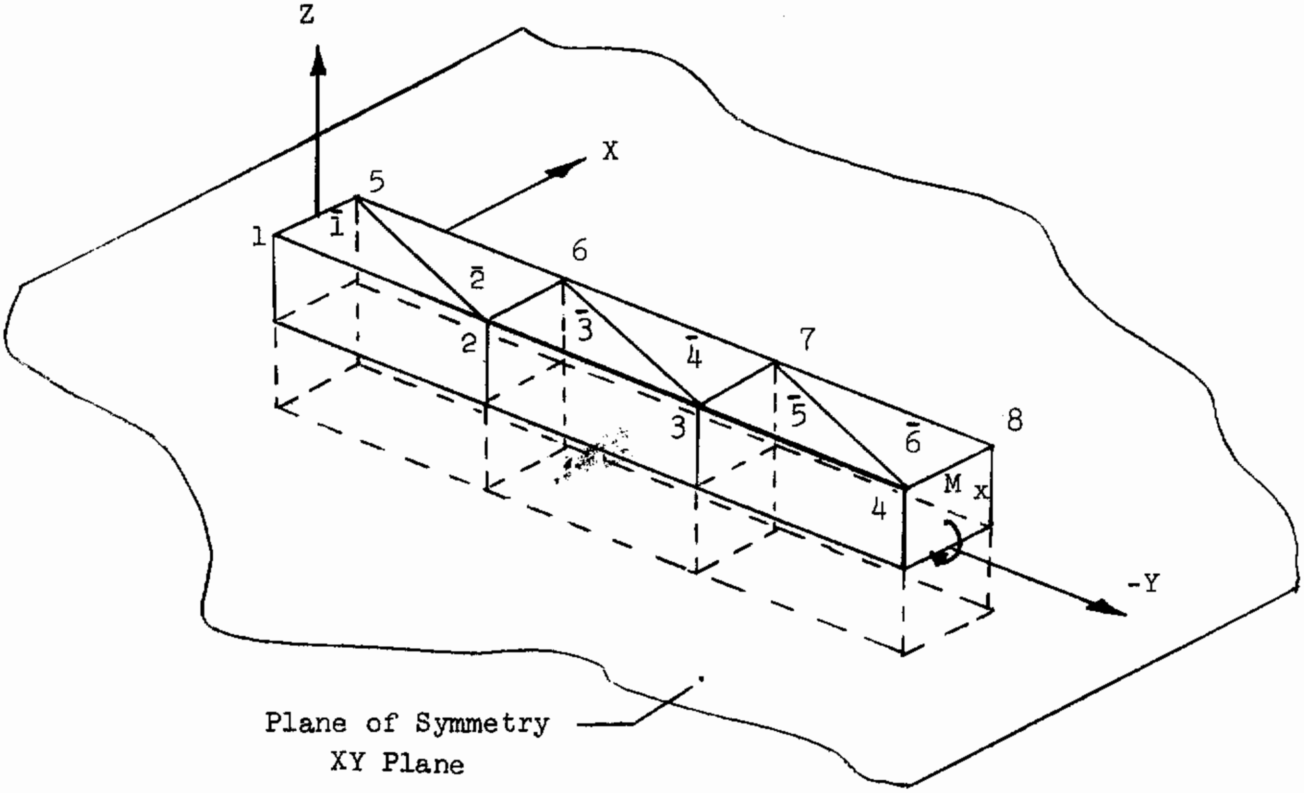
The stresses arising in the structure are displayed in tabular form in Figures III-E.18 and III-E.19 for elements 1 and 6 for example. Stresses are defined at the centroid and are referenced to the global axes for each tetrahedron which makes up a particular symmetric triangular prism element. Three stress points are given under each stress category for each prism. These stress points correspond to the stresses in particular tetrahedrons which are defined in the heading of the stress data. The tetrahedron nodes listed are the local node numbering system and these must be correlated with the gridpoint numbering system. In the present case, element number one is defined as shown in the sketch below:



The numbers in parenthesis correspond to the local element numbering system (See Reference 7) and the other numbers are global gridpoints. The Roman numerals on the right hand sketch are the tetrahedron numbering system. The remaining elements in the idealization are handled in the same fashion.

The last set of output is given in Figures III-E.20 and III-E.21 and consist of the global oriented element forces.

Output labeling is analogous to the stress output except that the element forces are defined only at the three corner points of the symmetric triangular prism element. Three force points are given and for element number one for example, force points 1, 2, 3 correspond to element gridpoint numbers 5, 2, and 6 respectively.



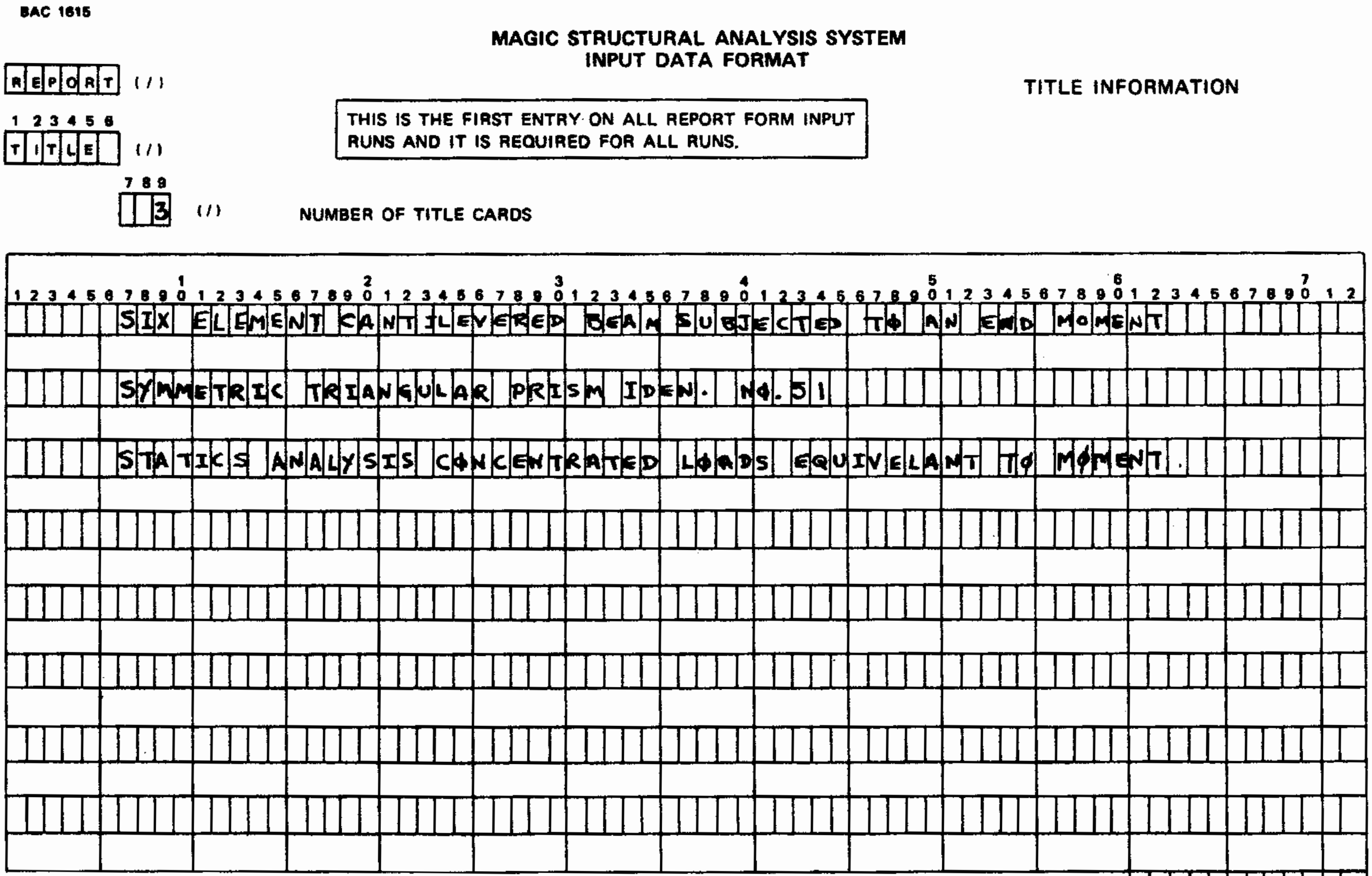
$E_x = E_y = E_z = E = 30.0 \times 10^6$ psi

$\nu_{xy} = \nu_{yx} = \nu_{yz} = \nu_{zy} = \nu_{zx} = \nu_{xz} = \nu = .333$

$\bar{\epsilon}_x = \bar{\epsilon}_x = \bar{\epsilon}_z = 0, \quad T_1 = T_2 = \cdots T_{16} = 0.0$

$M_{xz} \;=\; 800$ in#

Figure III-E.1 Symmetrical Triangular Prism - Cantilevered Beam With End Moment



BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

TITLE (/)

3 (/) NUMBER OF TITLE CARDS

SIX ELEMENT CANTILEVERED BEAM SUBJECTED TO AN END MOMENT

SYMMETRIC TRIANGULAR PRISM IDEN. NO. 51

STATICS ANALYSIS CONCENTRATED LOADS EQUIVELANT TO MOMENT.

FIGURE III-E.2 TITLE INFORMATION - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

M A T E R	(/)
1 2 3 4 5 6	

1	(/)
7 8 9 No. of Requests	

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
	1	JB	STEEL	X									1	0	.000733954	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	30.0 E6	ν_{xy}	.333	α_x	6.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-E.3 MATERIAL TAPE INPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M	1 2 3 4 5 6	(/)
1. Number of System Grid Points	8	1 2 3 4 5 6	
2. Number of Input Grid Points	8	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	3	13 14	
4. Number of Load Conditions	1	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	6	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	2	39 40 41 42 43 44	
11. T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-E.4 SYSTEM CONTROL INFORMATION - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

	DIRECTIONS			
Grid Point Number	X – R	Y – θ	Z – Z	
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
1	-2.0	0.0	3.0	(/)
2	-2.0	-7.0	3.0	(/)
3	-2.0	-14.0	3.0	(/)
4	-2.0	-21.0	3.0	(/)
5	2.0	0.0	3.0	(/)
6	2.0	-7.0	3.0	(/)
7	2.0	-14.0	3.0	(/)
8	2.0	-21.0	3.0	(/)

FIGURE III-E.5 GRIDPOINT COORDINATES - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - No Displacement Allowed 1 - Unknown Displacement 2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	0							(/)
				5	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
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FIGURE III-E.6 BOUNDARY CONDITIONS - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS	(/)

LCOND	1	0.0	(/)
	Condition Number	Scaler	

EXTERNAL LOADS

	FORCE VALUES				MOMENT VALUES				GENERALIZED VALUES			
	Fx	Fy	Fz		Mx	My	Mz		1	2	3	
MODAL	0.0	0.0	0.0	(/)				(/)				(/)

Grid Pt. Number		Fx	Fy	Fz		Mx	My	Mz		1	2	3	
4		0.0	-66.66667	0.0	(/)				(/)				(/)
3	X				(/)				(/)				(/)

FIGURE III-E.7 EXTERNAL LOADS - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	No. of A sem. Nodes	NODE POINTS												
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	51	1	3							6		1	2	5										(/
2	51	1	3							6		5	2	6										(/
3	51	1	3							6		2	3	6										(/
4	51	1	3							6		6	3	7										(/
5	51	1	3							6		3	4	7										(/
6	51	1	3							6		7	4	8										(/
																								(/
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FIGURE III-E.8 ELEMENT CONTROL DATA - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-E.9 END CARD - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

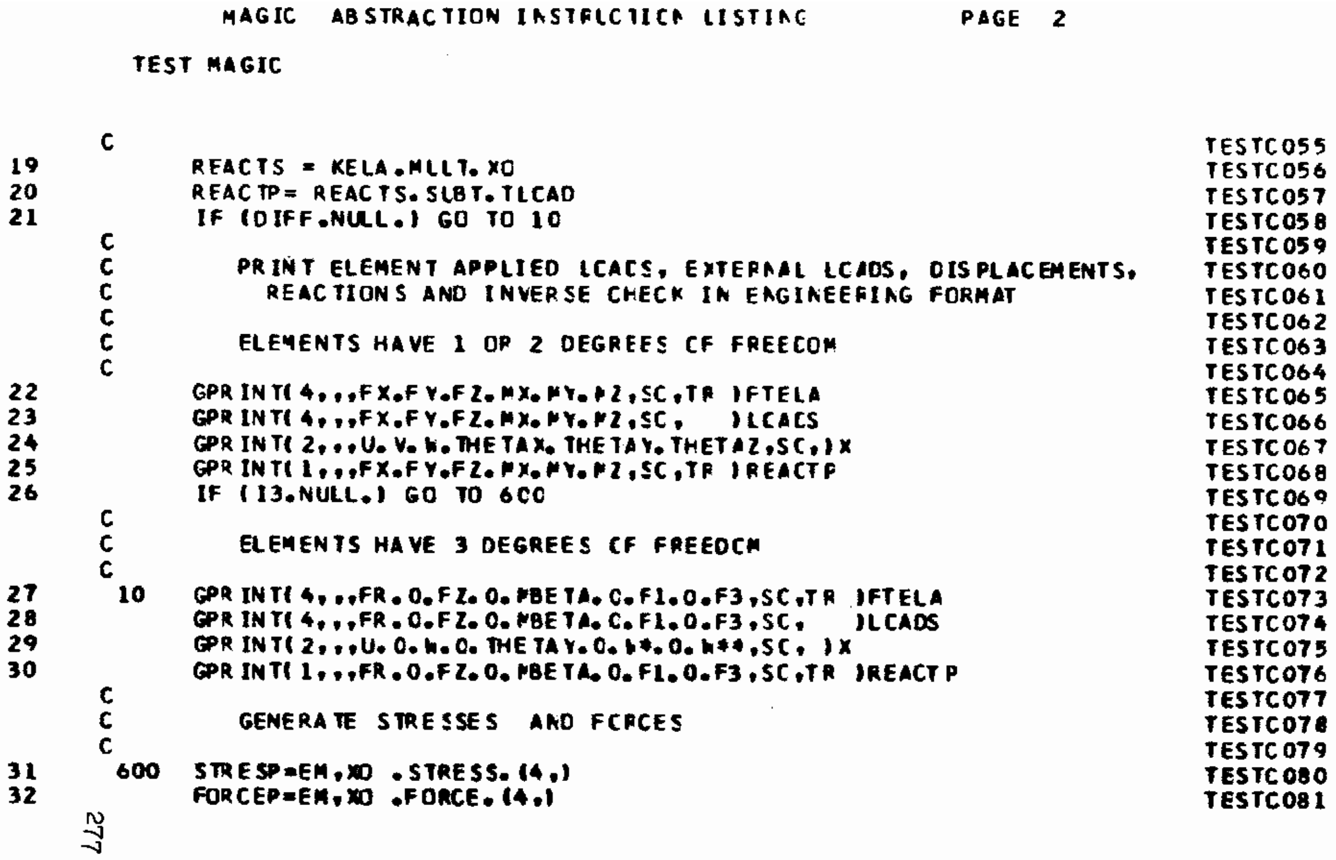
```
          MAGIC   ABSTRACTION INSTRLCTICK LISTING          PAGE  1

       TEST MAGIC

$INSTRUCTION    SOURCE                                                        TESTC004

         C-----STATICS AGENDUM WITHOLT PFESCRIBEC CISPLACEPENTS                    TESTC005
         C                                                                          TESTC006
         C       *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *TESTC007
         C                                                                          TESTC008
         C       STATICS INSTRLCTION SECLENCE                                       TESTC009
         C                                                                          TESTC010
         C       *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *TESTC011
         C                                                                          TESTC012
         C       GENERATE ELEMENT MATRICES                                          TESTC013
         C                                                                          TESTC014
  1            ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.        TESTC015
         C                                                                          TESTC016
         C                                                                          TESTC017
         C       FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                        TESTC018
         C       DETERMINE PRINT FORPAT FCF TYPE CF ELEMENTS USED                   TESTC019
         C                                                                          TESTC020
  2            I1 = SC.IDENTC.                                                      TESTC021
  3            I3 = I1.NULL.SC                                                      TESTC022
  4            DIFF = I1 .SMULT. SC(5,1)                                            TESTC023
         C                                                                          TESTC024
         C       ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS                TESTC025
         C                                                                          TESTC026
  5            KELA = EM .ASSEM. SC,(10)                                            TESTC027
  6            FTELA = EM .ASSEM .SC,(40)                                           TESTC028
  7            LSCALE,LOADS = XLD .DEJCIN.(1,1)                                     TESTC029
         C                                                                          TESTC030
         C       REDUCE STIFFNESS MATRIX AND PRINT                                  TESTC031
         C                                                                          TESTC032
  8            KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                   TESTC033
  9            KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                                  TESTC034
 10            PRINT(FORCE,DISP,,) STIFF                                            TESTC035
         C                                                                          TESTC036
         C       FORM REDUCED TOTAL LCAC CCLUMN                                     TESTC037
         C                                                                          TESTC038
         C       MULTIPLY ELEMENT APPLIED LCADS BY LCAD SCALAR                      TESTC039
 11            FTELS = FTELA.MULT.LSCALE                                            TESTC040
         C       TRANSFORM EXTERNAL LCADS TC 0-1-2 ASSEMBLEC SYSTEM                 TESTC041
 12            LOADO = TR.MULT.LOADS                                                TESTC042
         C       FORM TOTAL LOAD COLLMNS                                            TESTC043
 13            TLOAD = FTELS.ADD.LOADC                                              TESTC044
 14            TL,TLOADR = TLOAC.DEJCIN.( SC(5,1),1)                                TESTC045
         C                                                                          TESTC046
         C       SOLVE FOR DISPLACEMENTS                                            TESTC047
         C                                                                          TESTC048
 15            XX = STIFF.SEQEL.TLOADR                                              TESTC049
 16            TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                                     TESTC050
 17            X = TR12.TMULT.XX                                                    TESTC051
 18            XO = TR.MULT.X                                                       TESTC052
         C                                                                          TESTC053
         C       CALCULATE REACTICNS AND INVERSE CHECK                              TESTC054
```

FIGURE III-E.10 MAGIC ABSTRACT INSTRUCTION LISTING - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM



```
          MAGIC   ABSTRACTION INSTRLCTICN LISTING            PAGE  2

        TEST MAGIC

     C                                                                      TESTC055
              REACTS = KELA.MLLT.XO                                         TESTC056
              REACTP= REACTS.SLBT.TLCAD                                     TESTC057
              IF (DIFF.NULL.) GO TO 10                                      TESTC058
     C                                                                      TESTC059
     C           PRINT ELEMENT APPLIED LCACS, EXTERNAL LCADS, DISPLACEMENTS,TESTC060
     C             REACTIONS AND INVERSE CHECK IN ENGINEEFING FORMAT        TESTC061
     C                                                                      TESTC062
     C           ELEMENTS HAVE 1 OP 2 DEGREES CF FREECOM                    TESTC063
     C                                                                      TESTC064
              GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA                     TESTC065
              GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LCACS                    TESTC066
              GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X                   TESTC067
              GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP                    TESTC068
              IF (I3.NULL.) GO TO 600                                       TESTC069
     C                                                                      TESTC070
     C           ELEMENTS HAVE 3 DEGREES CF FREEDCM                         TESTC071
     C                                                                      TESTC072
       10     GPRINT(4,,,FR.0.FZ.0.MBETA.C.F1.0.F3,SC,TR )FTELA             TESTC073
              GPRINT(4,,,FR.0.FZ.0.MBETA.C.F1.0.F3,SC,    )LCADS            TESTC074
              GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X                   TESTC075
              GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP            TESTC076
     C                                                                      TESTC077
     C           GENERATE  STRESSES  AND FCRCES                             TESTC078
     C                                                                      TESTC079
      600     STRESP=EM,XO .STRESS.(4,)                                     TESTC080
              FORCEP=EM,XO .FORCE.(4,)                                      TESTC081
```

FIGURE III-E.10 MAGIC ABSTRACT INSTRUCTION LISTING - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM (CONCLUDED)

```
                    SIX ELEMENT CANTILEVERED BEAM SUBJECTED TO AN END MOMENT

                    SYMMETRIC TRIANGULAR PRISM IDEN. NO.51

                    STATICS ANALYSIS CONCENTRATED LOADS EQUIVALENT TO MOMENT.

                                  REVISIONS OF MATERIAL TAPE

                                ASTERISK (*) PRECEEDING MATERIAL
                                IDENTIFICATION INDICATES THAT INPUT
                                ERROR RETURNS WILL NOT RESULT IN
                                   TERMINATION OF EXECUTION


****************************************************************************************************

   REVISION
     MATERIAL NUMBER        1
     MATERIAL IDENTIFICATION STEEL                             INPUT CODE   I
       NUMBER OF MATERIAL PROPERTY POINTS. . . . .  1
       NUMBER OF PLASTIC PROPERTY POINTS . . . . .  0
       MASS DENSITY. . . . . . . . . . . . . . . .  0.73394994E-03

     MATERIAL PROPERTIES

                   YOUNG'S MODULI                              POISSON'S RATIOS

                              DIRECTIONS                                           DIRECTIONS
 TEMPERATURE
                     XX            YY            ZZ                XY            YZ            ZX
     0.0       0.300000E 08  0.300000E 08  0.300000E 08      0.333000E 00  0.333000E 00  0.333000E 00
                   TH. EXP.COEF.                               RIGIDITY MODULI

                              DIRECTIONS                                           DIRECTIONS
 TEMPERATURE
                     XX            YY            ZZ                XY            YZ            ZX
     0.0       0.650000E-05  0.650000E-05  0.650000E-05      0.112528E 08  0.112528E 08  0.112528E 08

****************************************************************************************************
```

FIGURE III-E.11 TITLE AND MATERIAL DATA OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NC.     --------GRID POINTS--------     EXTRA GRID PTS    ------SECTION PROPERTIES------
  1   51       1     3  0.0          0     6     1    2    5    0    0    0                      0.0           0.0           0.0
  2   51       1     3  0.0          0     6     5    2    6    0    0    0                      0.0           0.0           0.0
  3   51       1     3  0.0          0     6     2    3    6    0    0    0                      0.0           0.0           0.0
  4   51       1     3  0.0          0     6     6    3    7    0    0    0                      0.0           0.0           0.0
  5   51       1     3  0.0          0     6     3    4    7    0    0    0                      0.0           0.0           0.0
  6   51       1     3  0.0          0     6     7    4    8    0    0    0                      0.0           0.0           0.0
```

FIGURE III-E.12 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRION OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                                   EXTERNAL LOAD CONDITIONS    1

      LOAD NO.    1
        NUMBER OF LOADED NODES     8          ELEMENT LOAD SCALAR =   0.0
  4   0.0           -0.66667E 02  0.0
  8   0.0           -0.66667E 02  0.0
  1   0.0            0.0          0.0
  2   0.0            0.0          0.0
  3   0.0            0.0          0.0
  5   0.0            0.0          0.0
  6   0.0            0.0          0.0
  7   0.0            0.0          0.0


                          TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                        24 X 1

      0.0            0.0            0.0            0.0             0.0              0.0

      0.0            0.0            0.0            0.0            -0.66666992E 02   0.0

      0.0            0.0            0.0            0.0             0.0              0.0

      0.0            0.0            0.0            0.0            -0.66666992E 02   0.0


                                T-ZERO FOR STRUCTURE =   0.0
```

FIGURE III-E.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                                         MATRIX  STIFF /    1/                                                 PAGE     1

                          CUTOFF  =    0.0                                          SIZE    19   BY     19

                FORCE                FORCE                FORCE                FORCE                FORCE

DISP      1     1   0.183351E 09    2  -0.168455E 08    3  -0.262566E 08    4  -0.643016E 07    5   0.112191E 08
               10  -0.786516E 08   11   0.168455E 08   12   0.262566E 08

DISP      2     1  -0.168455E 08    2   0.133416E 09    3  -0.260000E 02    4   0.562640E 07    5  -0.256821E 08
                6  -0.750187E 07   10   0.168455E 08   11  -0.196924E 08   12  -0.750187E 07

DISP      3     1  -0.262566E 08    2  -0.260000E 02    3   0.783678E 08    4  -0.131283E 08    5   0.750187E 07
                6  -0.964524E 07   10  -0.262566E 08   11   0.750187E 07   12  -0.590773E 08

DISP      4     1  -0.643016E 07    2   0.562640E 07    3  -0.131283E 08    4   0.183351E 09    5  -0.168455E 08
                6  -0.262566E 08    7  -0.643014E 07    8   0.112191E 08   10  -0.393258E 08   11  -0.168455E 08
               12   0.131283E 08   13  -0.786516E 08   14   0.168455E 08   15   0.262565E 08

DISP      5     1   0.112191E 08    2  -0.256821E 08    3   0.750187E 07    4  -0.168455E 08    5   0.133416E 09
                6  -0.180000E 02    7   0.562640E 07    8  -0.256821E 08    9  -0.750186E 07   10  -0.168455E 08
               11  -0.984622E 07   12   0.750187E 07   13   0.168455E 08   14  -0.196924E 08   15  -0.750187E 07

DISP      6     2  -0.750187E 07    3  -0.964524E 07    4  -0.262566E 08    5  -0.180000E 02    6   0.783677E 08
                7  -0.131283E 08    8   0.750188E 07    9  -0.964524E 07   10  -0.131283E 08   11  -0.750187E 07
               12  -0.114253E 02   13  -0.262565E 08   14   0.750187E 07   15  -0.590772E 08

DISP      7     4  -0.643014E 07    5   0.562640E 07    6  -0.131283E 08    7   0.120091E 09    8   0.627544E 01
                9  -0.131283E 08   13  -0.393258E 08   14  -0.168455E 08   15   0.131283E 08   16  -0.393258E 08
               17   0.112191E 08   18   0.131283E 08

DISP      8     4   0.112191E 08    5  -0.256821E 08    6   0.750188E 07    7   0.627544E 01    8   0.803533E 08
                9  -0.750189E 07   13  -0.168455E 08   14  -0.984622E 07   15   0.750187E 07   16   0.562641E 07
               17  -0.984621E 07   18  -0.750187E 07

DISP      9     5  -0.750186E 07    6  -0.964524E 07    7  -0.131283E 08    8  -0.750189E 07    9   0.391839E 08
               13  -0.131283E 08   14  -0.750187E 07   15  -0.170547E 02   16  -0.131283E 08   17   0.568981E-01
               18  -0.295386E 08

DISP     10     1  -0.786516E 08    2   0.168455E 08    3  -0.262566E 08    4  -0.393258E 08    5  -0.168455E 08
                6  -0.131283E 08   10   0.176921E 09   11  -0.168455E 08   12   0.262566E 08   13  -0.321506E 07
               14   0.562639E 07   15   0.131283E 08

DISP     11     1   0.168455E 08    2  -0.196924E 08    3   0.750187E 07    4  -0.168455E 08    5  -0.984622E 07
                6  -0.750187E 07   10  -0.168455E 08   11   0.107734E 09   12   0.300000E 01   13   0.112191E 08
               14  -0.128411E 08   15  -0.750188E 07

DISP     12     1   0.262566E 08    2  -0.750187E 07    3  -0.590773E 08    4   0.131283E 08    5   0.750187E 07
                6  -0.114253E 02   10   0.262566E 08   11   0.300000E 01   12   0.783678E 08   13   0.109410E 02
               14   0.750187E 07   15  -0.964525E 07

DISP     13     4  -0.786516E 08    5   0.168455E 08    6  -0.262565E 09    7  -0.393258E 08    8  -0.168455E 08
```

FIGURE III-E.14 STIFFNESS MATRIX OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                                    MATRIX  STIFF /    1/                                          PAGE    2

                     CUTOFF  =    0.0                                  SIZE    18  BY     1

             FORCE              FORCE               FORCE               FORCE               FORCE

DISP    13     9  -0.131283E 08  10  -0.321506E 07  11   0.112191E 08  12   0.109410E 02  13   0.176921E 09
              14  -0.168455E 08  15   0.262566E 08  16  -0.321507E 07  17   0.562639E 07  18   0.131283E 08

DISP    14     4   0.168455E 08   5  -0.196924E 08   6   0.750187E 07   7  -0.168455E 08   8  -0.984622E 07
               9  -0.750187E 07  10   0.562639E 07  11  -0.128411E 08  12   0.750187E 07  13  -0.168455E 08
              14   0.107734E 09  15   0.280000E 02  16   0.112191E 08  17  -0.128411E 08  18  -0.750188E 07

DISP    15     4   0.262565E 08   5  -0.750187E 07   6  -0.590772E 08   7   0.131283E 08   8   0.750187E 07
               9  -0.170547E 02  10   0.131283E 08  11  -0.750188E 07  12  -0.964525E 07  13   0.262566E 08
              14   0.280000E 02  15   0.783678E 08  16   0.109410E 02  17   0.750187E 07  18  -0.964525E 07

DISP    16     7  -0.393258E 08   8   0.562641E 07   9  -0.131283E 08  13  -0.321507E 07  14   0.112191E 08
              15   0.109410E 02  16   0.600452E 08  17  -0.168455E 08  18   0.131283E 08

DISP    17     7   0.112191E 08   8  -0.984621E 07   9   0.568981E-01  13   0.562639E 07  14  -0.128411E 08
              15   0.750187E 07  16  -0.168455E 08  17   0.401916E 08  18  -0.750187E 07

DISP    18     7   0.131283E 08   8  -0.750187E 07   9  -0.295386E 08  13   0.131283E 08  14  -0.750188E 07
              15  -0.964525E 07  16   0.131283E 08  17  -0.750187E 07  18   0.391839E 08
```

FIGURE III-E.14 STIFFNESS MATRIX OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM (CONCLUDED)

```
                         GPRINT OF MATRIX  LOADS     (SET  1)

ROW         FX                  FY                   FZ
   1      0.0                 0.0                  0.0
   2      0.0                 0.0                  0.0
   3      0.0                 0.0                  0.0
   4      0.0               -0.66666592E 02        0.0
   5      0.0                 0.0                  0.0
   6      0.0                 0.0                  0.0
   7      0.0                 0.0                  0.0
   8      0.0               -0.66666592E 02        0.0
```

FIGURE III-E.15 GPRINT OF MATRIX LOADS - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    DISPLACEMENT MATRIX FOR LOAD CONDITION    1
                                   24 X 1

ROW          U                    V                    W
   1      0.0                  0.0                  0.0
   2      0.16454868E-06      -0.16483218E-05      -0.22326640E-05
   3     -0.37463224E-07      -0.36885949E-05      -0.94028337E-05
   4     -0.29041909E-06      -0.58627414E-05      -0.21379325E-04
   5      0.0                  0.0                  0.0
   6     -0.25490073E-06      -0.23282837E-05      -0.21421192E-05
   7     -0.41523072E-06      -0.44505687E-05      -0.90750118E-05
   8     -0.85801020E-06      -0.69309481E-05      -0.21089858E-04
```

FIGURE III-E.16 DISPLACEMENT MATRIX - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    REACTIONS AND INVERSE CHECK FOR LOAD CONDITION    1

ROW          FX                   FY                   FZ
   1     -0.19550768E 02       0.60007462E 02       0.70089073E 01
   2     -0.18310547E-03       0.12207031E-03       0.57983398E-03
   3     -0.93078613E-03       0.16021729E-02       0.12207031E-02
   4     -0.12207031E-02       0.85449219E-03       0.21972656E-02
   5      0.10204147E 02       0.73314774E 02      -0.70104370E 01
   6     -0.15258789E-03       0.91552734E-03      -0.21362305E-03
   7     -0.97656250E-03       0.71716309E-03      -0.94604492E-03
   8     -0.73242188E-03       0.27465820E-03      -0.17089844E-02
```

FIGURE III-E.17 REACTION MATRIX - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

                  (STRESS POINT ONE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,3,1))
                  (STRESS POINT TWO EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,1,4))
                 (STRESS POINT THREE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(2,6,5,4))

         LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE         ELEMENT GRID POINTS

                   1                       1                 51              1    2    5    0    6    0


APPARENT ELEMENT STRESSES
STRESS                                                        MEMBRANE STRESSES
POINT         SIGMA-X             SIGMA-Y             SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.52836256E 01      0.10583124E 02      0.52836256E 01      -0.26451939E 00      0.35891075E 01      0.0
    2     0.52836256E 01      0.10583124E 02      0.52836256E 01      -0.26451939E 00      0.35891075E 01      0.0
    3     0.0                 0.0                 0.0                  0.0                -0.25536470E 01      0.61721206E 00

ELEMENT APPLIED STRESSES
STRESS                                                        MEMBRANE STRESSES
POINT         SIGMA-X             SIGMA-Y             SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.0                 0.0                 0.0                  0.0                 0.0                 0.0
    2     0.0                 0.0                 0.0                  0.0                 0.0                 0.0
    3     0.0                 0.0                 0.0                  0.0                 0.0                 0.0

NET ELEMENT STRESSES
STRESS                                                        MEMBRANE STRESSES
POINT         SIGMA-X             SIGMA-Y             SIGMA-Z            SIGMA-XY            SIGMA-YZ            SIGMA-ZX
    1     0.52836256E 01      0.10583124E 02      0.52836256E 01      -0.26451939E 00      0.35891075E 01      0.0
    2     0.52836256E 01      0.10583124E 02      0.52836256E 01      -0.26451939E 00      0.35891075E 01      0.0
    3     0.0                 0.0                 0.0                  0.0                -0.25536470E 01      0.61721206E 00
```

FIGURE III-E.18 STRESS OUTPUT, ELEMENT NO. 1 - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    S T R E S S E S   F O R   T H E   T R I A N G U L A R   P R I S M   E L E M E N T

                 (STRESS POINT ONE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,3,1))
                 (STRESS POINT TWO EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(6,2,1,4))
                (STRESS POINT THREE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(2,6,5,4))

       LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE         ELEMENT GRID POINTS

                1                       6                  51               7    4    8    0    0    0

APPARENT ELEMENT STRESSES
STRESS                                                       MEMBRANE STRESSES
POINT         SIGMA-X               SIGMA-Y              SIGMA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1      0.15733185E 01        0.12741470E 02       0.47667999E 01      -0.28559265E 01      -0.66831665E 01       -0.24040375E 01
    2     -0.14023790E 01       -0.70013869E 00      -0.70014328E 00       0.34100904E 01       0.26205902E 01       -0.74319458E 00
    3     -0.94668394E-06       -0.18962119E-05      -0.94668394E-06      -0.24349736E-07      -0.19261780E 01       -0.27502441E 00

ELEMENT APPLIED STRESSES
STRESS                                                       MEMBRANE STRESSES
POINT         SIGMA-X               SIGMA-Y              SIGMA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1      0.0                   0.0                  0.0                  0.0                   0.0                   0.0
    2      0.0                   0.0                  0.0                  0.0                   0.0                   0.0
    3      0.0                   0.0                  0.0                  0.0                   0.0                   0.0

NET ELEMENT STRESSES
STRESS                                                       MEMBRANE STRESSES
POINT         SIGMA-X               SIGMA-Y              SIGMA-Z              SIGMA-XY              SIGMA-YZ              SIGMA-ZX
    1      0.15733185E 01        0.12741470E 02       0.47667999E 01      -0.28559265E 01      -0.66831665E 01       -0.24040375E 01
    2     -0.14023790E 01       -0.70013869E 00      -0.70014328E 00       0.34100904E 01       0.26205902E 01       -0.74319458E 00
    3     -0.94668394E-06       -0.18962119E-05      -0.94668394E-06      -0.24349736E-07      -0.19261780E 01       -0.27502441E 00
```

FIGURE III-E.19 STRESS OUTPUT, ELEMENT NO. 6 - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    FORCES FOR THE TRIANGULAR PRISM ELEMENT

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE      ELEMENT GRID POINTS

                1                      1                  51           1    2    5    0    0    0


APPARENT ELEMENT FORCES
POINT                                      FORCES
                   FX                        FY                      FZ
     1       -0.19550766E 02          0.60007462E 02          0.70089073E 01
     2        0.39383974E 01         -0.54436157E 02         -0.91691189E 01
     3        0.18492691E 02          0.15823343E 02          0.21602411E 01
     4        0.0                     0.0                     0.0
     5        0.0                     0.0                     0.0
     6        0.0                     0.0                     0.0

ELEMENT APPLIED FORCES
POINT                                      FORCES
                   FX                        FY                      FZ
     1        0.0                     0.0                     0.0
     2        0.0                     0.0                     0.0
     3        0.0                     0.0                     0.0
     4        0.0                     0.0                     0.0
     5        0.0                     0.0                     0.0
     6        0.0                     0.0                     0.0

NET ELEMENT FORCES
POINT                                      FORCES
                   FX                        FY                      FZ
     1       -0.19550766E 02          0.60007462E 02          0.70089073E 01
     2        0.39383974E 01         -0.54436157E 02         -0.91691189E 01
     3        0.18492691E 02          0.15823343E 02          0.21602411E 01
     4        0.0                     0.0                     0.0
     5        0.0                     0.0                     0.0
     6        0.0                     0.0                     0.0
```

FIGURE III-E.20 FORCE OUTPUT, ELEMENT No. 1 - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
                    FORCES FOR THE TRIANGULAR PRISM ELEMENT

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE     ELEMENT GRID POINTS

              1                      6                 51           7   4   8   0   0   0

APPARENT ELEMENT FORCES
POINT                                FORCES
                FX                   FY                    FZ
   1      -0.14088379E 02      0.49647873E 02      -0.11977249E 02
   2      -0.18815918E 01     -0.10528375E 02       0.11978271E 02
   3      -0.48828125E-03     -0.66666718E 02      -0.12207031E-02
   4       0.0                 0.0                  0.0
   5       0.0                 0.0                  0.0
   6       0.0                 0.0                  0.0

ELEMENT APPLIED FORCES
POINT                                FORCES
                FX                   FY                    FZ
   1       0.0                 0.0                  0.0
   2       0.0                 0.0                  0.0
   3       0.0                 0.0                  0.0
   4       0.0                 0.0                  0.0
   5       0.0                 0.0                  0.0
   6       0.0                 0.0                  0.0

NET ELEMENT FORCES
POINT                                FORCES
                FX                   FY                    FZ
   1      -0.14088379E 02      0.49647873E 02      -0.11977249E 02
   2      -0.18815918E 01     -0.10528375E 02       0.11978271E 02
   3      -0.48828125E-03     -0.66666718E 02      -0.12207031E-02
   4       0.0                 0.0                  0.0
   5       0.0                 0.0                  0.0
   6       0.0                 0.0                  0.0
```

FIGURE III-E.21 FORCE OUTPUT, ELEMENT No. 6 - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

F. SYMMETRIC SHEAR WEB

A two-bay cantilevered box beam is idealized by use of the symmetric shear web, axial force and quadrilateral shear panel finite elements and serves as the fifth example problem. This structure is shown in Figure III-F.1. with the attendant loading, idealization, dimensions and material properties. The preprinted input data forms associated with this example problem are given in Figure III-F.2 to III-F.10. Note the manner in which the boundary conditions Figure III-F.6 are imposed in this example. First, all degrees-of-freedom are fixed through use of the MODAL card, then the exceptions are designated on the following cards. The REPEAT option is used to advantage here also. A comment must be made here with respect to the symmetric shear web element. The plane of symmetry used for this element must always be the global XY plane thus the element is oriented perpendicular to this plane, and z = Z. That is, the local z coordinate of the grid points which define the element are identical to the global Z coordinates of these same points.

The following load data is evident by inspection of Figure III-F.7, External Loads Section.

1) One load condition is input
2) The external applied load scalar is zero
3) Grid point 6 is loaded with a force in the positive Z direction equal to 1000.0 pounds.

Note that no entries corresponding to External Moments are made since the elements used in the idealization do not accomodate such loadings.

Note that external element input data are needed for the finite elements used in this example. The axial force elements require cross-sectional area, the symmetric shear web and quadrilateral shear panel elements require thickness. These data are shown on Figure III-F.9.

The output supplied by the MAGIC III system for this particular example is described below and shown in Figures III-F.11 to III-F.12.

Figure III-F.11 shows the matrix abstraction instructions associated with this example. A complete description of these instructions is provided in Reference 5. Figures III-F.12 to III-F.15 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

Figure III-F.12 displays the problem title and material data output. The grid point coordinates, temperatures and pressures are given in Figure III-F.13. In addition, boundary condition information and finite element descriptions are also shown on this figure. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed (i.e., no motion), ones ('1') represent degrees of freedom that are free or have unknown values of displacement, and two's ('2') represent degrees of freedom that are eliminated in the analysis procedure through the condensation technique. The second last column represents the cumulative number of degrees of freedom which actively participate in the equation solving process for displacements. The last column accumulates the number of twos which participate in the calculation of the reduced stiffness matrix which is not used in the present example. Figure III-F.14 shows the finite element description. Each of the elements is called out in turn with grid points, print options and material number. Note that extra grid points are needed for the axial element in order to define the orientation of the local axes system for this element. The section properties previously discussed are also listed in the right hand column of the figure.

Figure III-F.15 displays the external load condition and the transformed external assembled load column. This 42 x 1 vector is the total unreduced load which is read row-wise. The ordering of this vector is consistent with that of the boundary condition table given in Figure III-F.13. Note that a load of 1000.0 pounds is applied at node point 6 in the positive global Z direction. This is position (33,1) in the load vector which corresponds to the thirty-third entry in the boundary condition table which is the global w displacement for node point 6.

MAGIC III system output of final results are displayed in Figures III-F.16 to III-F.24. Figure III-F.16 shows the stiffness matrix for this problem. It is noted that only the non-zero terms are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary condition table previously discussed. In this problem the ordering is

$$\{\Delta\}^T = \lfloor U_3, V_3, W_3, U_4, V_4, W_4, \ldots, U_6, V_6, W_6 \rfloor .$$

The externally applied load vector (GPRINT OF MATRIX LOADS) is presented in Figure III-F.17. This figure shows that a force (F_z) is applied in the positive global Z direction at node point 6.

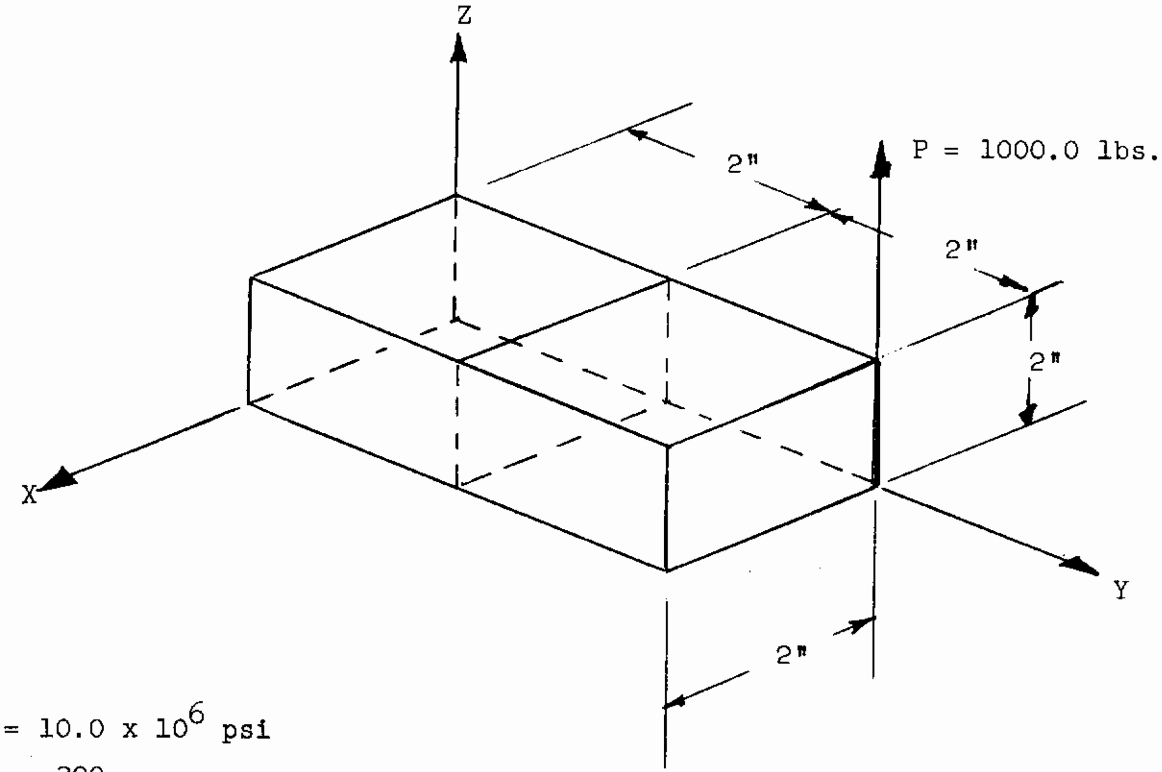
The displacements and reactions of the cantilever beam resulting from the above loads are given in Figure III-F.18. It is noted that the displacements (U, V, W) are output corresponding to node point number and are referenced to the global axes unless otherwise specified. The second portion of Figure III-F.19 shows the reactions (F_X, F_Y, F_Z). These are also output corresponding to node point number and are referenced to the global axes system unless otherwise specified.

The stresses arising in the structure are displayed in tabular form in Figures III-F.19 to III-F.24. Stress data for the axial force elements, elements 1 to 6, are referenced to the element coordinate system and defined to be the axial force acting at the two grid point connections. Figure III-F.19 presents typical results wherein stress points 1 and 2 correspond to the element end grid points.

Six stress value headings are printed for the apparent element stress, element applied stress and net element stress categories. The apparent stress arises from element deformations and the applied stress arises from pre-strain and thermal effects. The net stress is the difference between the apparent and applied stress values. In this instance only the axial heading has entries, the remaining headings are used for the frame element. (See Reference 5 page 227.)

Stress values for the symmetric shear web element are typically presented for element one in Figure III-F.20. The membrane shear stress is listed for each of the three categories for one element stress point, that being the centroid of the element. These stresses are oriented to the local axes system. The final set of stresses are typically displayed for element thirteen in Figure III-F.28 for the quadrilateral shear panel elements and are tabulated in the same fashion as in the shear web element.

The last set of output is given in Figures III-F.22 to III-F.24 which displays the element forces for each of the three elements. These forces are given in the global system. The force points correspond to the end points of the axial elements. In element one, for example, force point 1 corresponds to grid point 1 and force point 2 to grid point 3. Data for the remaining element types is presented in the same fashion.



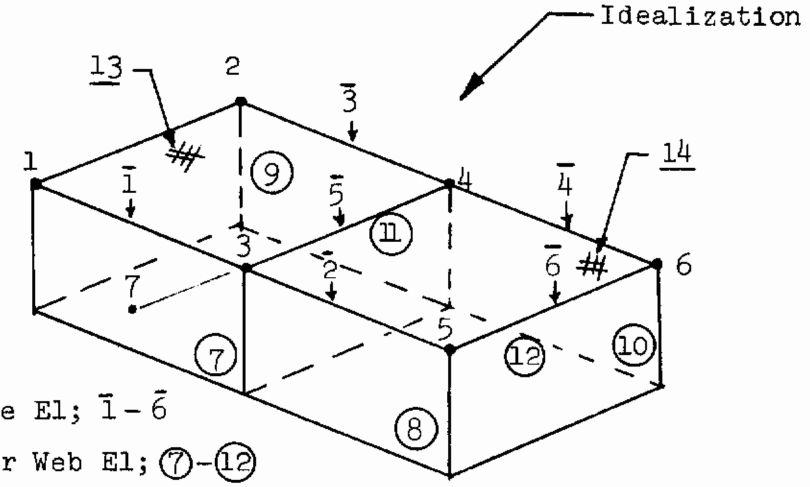
$E = 10.0 \times 10^6$ psi

$\nu = .300$

$E_x = E_y = E_z = 0.0$

$T_1 = T_2 = \cdots = T_6 = 0.0$

P = 1000.0 lbs.



Note:

(1) Axial Force El; $\bar{1} - \bar{6}$

(2) Symm. Shear Web El; ⑦–⑫

(3) Quad. Shear El; $\underline{13} - \underline{14}$

Figure III-F.1 Box Beam With Symmetric Shear Web Element

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

TITLE (/)

7 8 9

3 (/) NUMBER OF TITLE CARDS

BOX BEAM CANTILEVERED WITH TIP LOAD. (/)

SYMMETRIC SHEAR WEB, QUAD. SHEAR PANEL AND AXIAL FORCE ELEMENTS (/)

STATICS ANALYSIS. (/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

FIGURE III-F.2 TITLE INFORMATION - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

		1
7	8	9

No. of Requests (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	77	JB	ALUMINUM	X									1			(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	10.0 E6	ν_{xy}	.300	α_x	.65 E-5	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-F.3 MATERIAL TAPE INPUT - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M	1 2 3 4 5 6	(/)
1. Number of System Grid Points	7	1 2 3 4 5 6	
2. Number of Input Grid Points	7	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	6	13 14	
4. Number of Load Conditions	1	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	14	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	4	39 40 41 42 43 44	
11. T_0 For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-F.4 SYSTEM CONTROL INFORMATION - SYMMETRIC SHEAR WEB CANTILEVERED BEAM

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

	DIRECTIONS			
Grid Point Number	X − R	Y − θ	Z − Z	
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
1	2.0	0.0	2.0	(/)
2	0.0	0.0	2.0	(/)
3	2.0	2.0	2.0	(/)
4	0.0	2.0	2.0	(/)
5	2.0	4.0	2.0	(/)
6	0.0	4.0	2.0	(/)
7	4.0	2.0	2.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-F.5 GRIDPOINT COORDINATES - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

BAC 1626-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	0	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				3		1	1	1							(/)
				4	X										(/)
				5	X										(/)
				6	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-F.6 BOUNDARY CONDITIONS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

BAC 1627

LOADS (/)

LCOND | Condition Number: 1 | Scalar: 1.0 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	Fx	Fy	Fz	Mx	My	Mz	1	2	3
MODAL	0.0	0.0	0.0	0.0	0.0	0.0			

Grid Pt. Number	Fx	Fy	Fz	Mx	My	Mz	1	2	3
6			1000.0						

FIGURE III-F.7 EXTERNAL LOADS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

BAC 1628

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT Print	PRINT Elem. Mat.	PRINT Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	11	77	2							3		1	3	7										(/)
2	11	77	2							3		3	5	7										(/)
3	11	77	2							3		2	4	7										(/)
4	11	77	2							3		4	6	7										(/)
5	11	77	2							3		3	4	7										(/)
6	11	77	2							3		5	6	7										(/)
7	29	77	2							3		1	3											(/)
8	29	77	2							2		3	5											(/)
9	29	77	2							2		2	4											(/)
10	29	77	2							2		4	6											(/)
11	29	77	2							2		3	4											(/)
12	29	77	2							2		5	6											(/)
13	25	77	4							4		1	3	4	2									(/)
14	25	77	4							4		3	5	6	4									(/)
																								(/)
																								(/)
																								(/)
																								(/)
																								(/)
																								(/)

/)

FIGURE III-F.8 ELEMENT CONTROL DATA - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

ELEMENT INPUT

1 2 3 4 5 6	A	B	C	D	E	F
	1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2
M O D A L						

Element Number	Repeat	A	B	C	D	E	F	
1 7 8 9 0 1	2	1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2	
1		.250						(/)
2	X							(/)
3	X							(/)
4	X							(/)
5	X							(/)
6	X							(/)
7		.050						(/)
8	X							(/)
9	X							(/)
10	X							(/)
11	X							(/)
12	X							(/)
13		.050						(/)
14	X							(/)
								(/)
								(/)
								/)

FIGURE III-F.9 ELEMENT INPUT - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-F.10 END CARD - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM'

```
         MAGIC  ABSTRACTION INSTRUCTION LISTING          PAGE  1

   TEST MAGIC

$INSTRUCTION   SOURCE                                         TESTD004

     C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS              TESTD005
     C                                                                   TESTD006
     C         *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *TESTD007
     C                                                                   TESTD008
     C         STATICS INSTRUCTION SEQUENCE                              TESTD009
     C                                                                   TESTD010
     C         *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *TESTD011
     C                                                                   TESTD012
     C         GENERATE ELEMENT MATRICES                                 TESTD013
     C                                                                   TESTD014
  1         ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.  TESTD015
     C                                                                   TESTD016
     C                                                                   TESTD017
     C         FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES               TESTD018
     C         DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED          TESTD019
     C                                                                   TESTD020
  2         I1 = SC.IDENTC.                                              TESTD021
  3         I3 = I1.NULL.SC                                              TESTD022
  4         DIFF = I1 .SMULT. SC(5,1)                                    TESTD023
     C                                                                   TESTD024
     C         ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS       TESTD025
     C                                                                   TESTD026
  5         KELA = EM .ASSEM. SC,(10)                                    TESTD027
  6         FTELA = EM .ASSEM .SC ,(40)                                  TESTD028
  7         LSCALE,LOADS = XLD .DEJOIN. (1,1)                            TESTD029
     C                                                                   TESTD030
     C         REDUCE STIFFNESS MATRIX AND PRINT                         TESTD031
     C                                                                   TESTD032
  8         KO,KNO = KELA .DEJOIN.( SC(5,1),1)                           TESTD033
  9         KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                          TESTD034
 10         PRINT(FORCE,DISP,,) STIFF                                    TESTD035
     C                                                                   TESTD036
     C         FORM REDUCED TOTAL LOAD COLUMN                            TESTD037
     C                                                                   TESTD038
     C         MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR             TESTD039
 11         FTELS = FTELA.MULT.LSCALE                                    TESTD040
     C         TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM        TESTD041
 12         LOADO = TR.MULT.LOADS                                        TESTD042
     C         FORM TOTAL LOAD COLUMNS                                   TESTD043
 13         TLOAD = FTELS.ADD.LOADO                                      TESTD044
 14         TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)                        TESTD045
     C                                                                   TESTD046
     C         SOLVE FOR DISPLACEMENTS                                   TESTD047
     C                                                                   TESTD048
 15         XX = STIFF.SEQEL.TLOADR                                      TESTD049
 16         TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                             TESTD050
 17         X = TR12.TMULT.XX                                            TESTD051
 18         XO = TR.MULT.X                                               TESTD052
     C                                                                   TESTD053
     C         CALCULATE REACTIONS AND INVERSE CHECK                     TESTD054
```

FIGURE III-F.11 FORMAT ABSTRACTION INSTRUCTION LISTING - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
         MAGIC   ABSTRACTION INSTRUCTION LISTING          PAGE  2

      TEST MAGIC

      C                                                                TESTD055
                REACTS = KELA.MULT.XC                                  TESTD056
                REACTP= REACTS.SUBT.TLOAD                              TESTD057
                IF (DIFF.NULL.) GO TO 10                               TESTD058
      C                                                                TESTD059
      C            PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,  TESTD060
      C              REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT TESTD061
      C                                                                TESTD062
      C            ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM             TESTD063
      C                                                                TESTD064
                GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA              TESTD065
                GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS             TESTD066
                GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X            TESTD067
                GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP             TESTD068
                IF (I3.NULL.) GO TO 600                                TESTD069
      C                                                                TESTD070
      C            ELEMENTS HAVE 3 DEGREES OF FREEDOM                  TESTD071
      C                                                                TESTD072
        10      GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )FTELA      TESTD073
                GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,    )LOADS     TESTD074
                GPRINT(2,,,U.O.W.O.THETAY.O.W*.O.W**,SC, )X            TESTD075
                GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )REACTP     TESTD076
      C                                                                TESTD077
      C            GENERATE STRESSES  AND FORCES                       TESTD078
      C                                                                TESTD079
       600      STRESP=EM,XO .STRESS.(4,)                              TESTD080
                FORCEP=EM,XO .FORCE.(4,)                               TESTD081
```

FIGURE III-F.11   MAGIC ABSTRACTION INSTRUCTION LISTING - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM. CONCL'D.

```
                    BOX BEAM CANTILEVERED WITH TIP LOAD.

                    SYMMETRIC SHEAR WEB.QUAD.SHEAR PANEL AND AXIAL FORCE ELEMENTS

                    STATICS ANALYSIS.

                                             REVISIONS OF MATERIAL TAPE

                                          ASTERISK (*) PRECEEDING MATERIAL
                                          IDENTIFICATION INDICATES THAT INPUT
                                          ERROR RETURNS WILL NOT RESULT IN
                                              TERMINATION OF EXECUTION


*******************************************************************************************************************************

  REVISION
    MATERIAL NUMBER        77
    MATERIAL IDENTIFICATION  ALUMINUM                                  INPUT CODE    I
      NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
      NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
      MASS DENSITY. . . . . . . . . . . . . . . 0.0

    MATERIAL PROPERTIES

                     YOUNG'S MODULI                                  POISSON'S RATIOS

                               DIRECTIONS                                                     DIRECTIONS
 TEMPERATURE
                      XX              YY              ZZ                  XY              YZ              ZX
    0.0          0.100000E 08    0.100000E 08    0.100000E 08        0.300000E 00    0.300000E 00    0.300000E 00

                     TH. EXP.COEF.                                   RIGIDITY MODULI

                               DIRECTIONS                                                     DIRECTIONS
 TEMPERATURE
                      XX              YY              ZZ                  XY              YZ              ZX
    0.0          0.650000E-05    0.650000E-05    0.650000E-05        0.384616E 07    0.384616E 07    0.384616E 07

*******************************************************************************************************************************
```

FIGURE III-F.12 TITLE AND MATERIAL DATA OUTPUT - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                                       7 REF. POINTS

    NO. DIRECTIONS  =     3      NO. DEGREES OF FREEDOM =    2


                                    GRIDPOINT DATA
                               (IN RECTANGULAR COORDINATES)

POINT          X                                 Z                TEMPERATURES           PRESSURES
  1     0.20000000E 01     0.0              0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  2     0.0                0.0              0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  3     0.20000000E 01     0.20000000E 01   0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  4     0.0                0.20000000E 01   0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  5     0.20000000E 01     0.40000000E 01   0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  6     0.0                0.40000000E 01   0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0
  7     0.40000000E 01     0.20000000E 01   0.20000000E 01     0.0                0.0
                                                               0.0                0.0
                                                               0.0                0.0


                              BOUNDARY CONDITION INFORMATION

      NODES                 DEGREES OF FREEDOM                     NO. OF ONES    NO. OF TWOS


        1         0    0    0    0    0    0                          0              0
        2         0    0    0    0    0    0                          0              0
        3         1    1    1    0    0    0                          3              0
        4         1    1    1    0    0    0                          6              0
        5         1    1    1    0    0    0                          9              0
        6         1    1    1    0    0    0                         12              0
        7         0    0    0    0    0    0                         12              0
```

FIGURE III-F.13 GRIDPOINT DATA AND BOUNDARY CONDITIONS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                                         TCTAL NC. ELEMENTS =      14


ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NC.    --------GRIC PCINTS--------    EXTRA G ID PTS    ------SECTICN PRCPERTIES------


   1  11       77     2  C.0        C    3     1   3   7                            C.25CCE  CC    C.0         0.0
   2  11       77     2  C.0        0    3     3   5   7                            C.25C0E  C0    0.0         0.0
   3  11       77     2  0.0        0    3     2   4   7                            C.25CCE  C0    0.0         0.0
   4  11       77     2  0.0        C    3     4   6   7                            C.25CCE  C0    C.0         0.0
   5  11       77     2  0.0        0    3     3   4   7                            C.25C0E  C0    0.0         0.0
   6  11       77     2  0.0        0    3     5   6   7                            C.2500E  C0    0.0         0.0
   7  29       77     2  0.0        0    2     1   3                                C.5CC0E-C1     0.0         0.0
   8  29       77     2  0.0        C    2     3   5                                C.50C0E-C1     0.0         0.0
   9  29       77     2  0.0        C    2     2   4                                C.50CCE-C1     C.0         0.0
  10  29       77     2  0.0        C    2     4   6                                C.5000E-C1     C.0         0.0
  11  29       77     2  0.0        C    2     3   4                                C.50C0E-C1     0.0         0.0
  12  29       77     2  0.0        C    2     5   6                                C.50C0E-C1     0.0         0.0
  13  25       77     4  0.0        C    4     1   3   4   2                        C.5000E-C1     0.0         0.0
  14  25       77     4  0.0        C    4     3   5   6   4                        C.50C0E-C1     0.0         0.0
```

FIGURE III-F.14 FINITE ELEMENT DESCRIPTION - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                                 EXTERNAL LCAC CCNDITIONS    1


  LOAD NO.    1

    NUMBER OF LOADED NODES      7            ELEMENT LCAD SCALAR =   0.10000000E 01
 6  0.0           0.0           C.10CCCE C4  0.0           0.0           0.0
 1  0.0           0.0           C.C          0.0           0.0           0.0
 2  0.0           0.0           0.0          0.0           0.0           0.0
 3  0.0           0.0           0.C          0.0           0.0           0.0
 4  0.0           0.0           0.C          0.0           0.0           0.0
 5  0.0           0.0           0.0          0.0           0.0           0.0
 7  0.0           0.0           0.C          0.0           0.0           0.0


                         TRANSFCRMED EXTERNAL ASSEMBLED LOAC COLUMN

                                          42 X 1

  0.0              0.C              0.0                0.0              C.0              0.0

  0.0              0.C              0.0                0.0              0.0              0.0

  0.0              0.C              0.0                0.0              C.0              0.0

  0.0              0.C              0.0                0.0              C.0              0.0

  0.0              0.C              0.0                0.0              C.0              C.0

  0.0              0.C              0.10000000E 04     0.0              C.0              0.0

  0.0              C.C              0.0                0.0              C.0              0.0
```

FIGURE III-F.15 TRANSFORMED EXTERNAL ASSEMBLED LOAD - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                                   MATRIX  STIFF /     1/                                         PAGE    1

                 CUTOFF  =    0.0                                   SIZE     12  BY     12

          FORCE                   FORCE                  FORCE                  FORCE                  FORCE

DISP    1    1   0.139423E 07    3    0.961538E 05    4   -0.110577E 07    6   -0.961538E 05    7   -0.480769E 05
             8  -0.480769E 05   10   -0.480769E 05   11    0.480769E 05

DISP    2    2   0.269230E 07    5   -0.961539E 05    7    0.480769E 05    8   -0.115385E 07    9    0.961539E 05
            10   0.480769E 05   11   -0.480769E 05

DISP    3    1   0.961538E 05    3    0.576923E 06    4    0.961538E 05    6   -0.192308E 06    8   -0.961538E 05
             9  -0.192308E 06

DISP    4    1  -0.110577E 07    3    0.961538E 05    4    0.139423E 07    6   -0.961538E 05    7   -0.480769E 05
             8  -0.480769E 05   10   -0.480769E 05   11    0.480769E 05

DISP    5    2  -0.961539E 05    5    0.269230E 07    7   -0.480769E 05    8   -0.480769E 05   10   -0.480769E 05
            11  -0.115385E 07   12    0.961539E 05

DISP    6    1  -0.961538E 05    3   -0.192308E 06    4   -0.961538E 05    6    0.576923E 06   11   -0.961539E 05
            12  -0.192308E 06

DISP    7    1  -0.480769E 05    2    0.480769E 05    4   -0.480769E 05    5   -0.480769E 05    7    0.134615E 07
             8   0.480769E 05    9    0.961538E 05   10   -0.115385E 07   11   -0.480769E 05   12   -0.961538E 05

DISP    8    1  -0.480769E 05    2   -0.115385E 07    3   -0.961538E 05    4   -0.480769E 05    5   -0.480769E 05
             7   0.480769E 05    8    0.134615E 07    9    0.961538E 05   10    0.480769E 05   11   -0.480769E 05

DISP    9    2   0.961538E 05    3   -0.192308E 06    7    0.961538E 05    8    0.961538E 05    9    0.384615E 06
            10   0.961538E 05   12   -0.192308E 06

DISP   10    1  -0.480769E 05    2    0.480769E 05    4   -0.480769E 05    5   -0.480769E 05    7   -0.115385E 07
             8   0.480769E 05    9    0.961538E 05   10    0.134615E 07   11   -0.480769E 05   12   -0.961538E 05

DISP   11    1   0.480769E 05    2   -0.480769E 05    4    0.480769E 05    5   -0.115385E 07    6   -0.961538E 05
             7  -0.480769E 05    8   -0.480769E 05   10   -0.480769E 05   11    0.134615E 07   12    0.961538E 05

DISP   12    5   0.961538E 05    6   -0.192308E 06    7   -0.961538E 05    9   -0.192308E 06   10   -0.961538E 05
            11   0.961538E 05   12    0.384615E 06
```

FIGURE III-F.16 STIFFNESS MATRIX OUTPUT - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                              GPRINT OF MATRIX  LOADS     (SET   1)

ROW       FX              FY              FZ               MX              MY              MZ
   1    0.0             0.0             0.0              0.0             0.0             0.0
   2    0.0             0.0             0.0              0.0             0.0             0.0
   3    0.0             0.0             0.0              0.0             0.0             0.0
   4    0.0             0.0             0.0              0.0             0.0             0.0
   5    0.0             0.0             0.0              0.0             0.0             0.0
   6    0.0             0.0             0.10000000E 04   0.0             0.0             0.0
   7    0.0             0.0             0.0              0.0             0.0             0.0
```

FIGURE III-F.17 GPRINT OF MATRIX LOADS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                              DISPLACEMENT MATRIX FOR LOAD CONDITION    1
                                             42 X 1

ROW         U                                 W               THETAX          THETAY          THETAZ
   1      0.0            0.0            0.0            0.0            0.0            0.0
   2      0.0            0.0            0.0            0.0            0.0            0.0
   3      0.16555935E-02 -0.65216841E-03 0.19294322E-02 0.0            0.0            0.0
   4      0.16555972E-02 -0.54783281E-03 0.38705571E-02 0.0            0.0            0.0
   5      0.30805431E-02 -0.85491501E-03 0.40009090E-02 0.0            0.0            0.0
   6      0.30805506E-02 -0.74508623E-03 0.83991885E-02 0.0            0.0            0.0
   7      0.0            0.0            0.0            0.0            0.0            0.0
```

```
                              REACTIONS AND INVERSE CHECK FOR LOAD CONDITION    1

ROW         FX              FY              FZ              MX              MY              MZ
   1     -0.15417577E 03 0.11235535E 04 -0.30833594E 03 0.0            0.0            0.0
   2     -0.15417577E 03 0.87644556E 03 -0.69166138E 03 0.0            0.0            0.0
   3     -0.61035156E-02 0.20294189E-02 -0.36621094E-02 0.0            0.0            0.0
   4      0.34179688E-02 0.24414063E-03  0.0           0.0            0.0            0.0
   5     -0.11718750E-01 0.32043457E-03  0.24414063E-03 0.0            0.0            0.0
   6      0.53710938E-02 0.14648438E-02  0.19531250E-02 0.0            0.0            0.0
   7      0.0            0.0             0.0           0.0            0.0            0.0
```

FIGURE III-F.18 DISPLACEMENT AND REACTIONS MATRICES - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
              S T R E S S E S   F O R   T H E   F R A M E   E L E M E N T

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

               1                     1                 11                1     3     7

APPARENT ELEMENT STRESSES
STRESS                                 FORCES                                             FLEXURAL  MOMENTS
POINT          AXIAL(FX)             SHEAR(FY)        SHEAR(FZ)         TORQUE(MX)          NORMAL(MY)         NORMAL(MZ)

   1        0.81521045E 03       0.0              0.0               0.0                 0.0                0.0
   2       -0.81521045E 03       0.0              0.0               0.0                 0.0                0.0

ELEMENT APPLIED STRESSES
STRESS                                 FORCES                                             FLEXURAL  MOMENTS
POINT          AXIAL(FX)             SHEAR(FY)        SHEAR(FZ)         TORQUE(MX)          NORMAL(MY)         NORMAL(MZ)

   1        0.0                  0.0              0.0               0.0                 0.0                0.0
   2        0.0                  0.0              0.0               0.0                 0.0                0.0

NET ELEMENT STRESSES
STRESS                                 FORCES                                             FLEXURAL  MOMENTS
POINT          AXIAL(FX)             SHEAR(FY)        SHEAR(FZ)         TORQUE(MX)          NORMAL(MY)         NORMAL(MZ)

   1        0.81521045E 03       0.0              0.0               0.0                 0.0                0.0
   2       -0.81521045E 03       0.0              0.0               0.0                 0.0                0.0
```

FIGURE III-F.19 STRESS OUTPUT, ELEMENT NO. 1 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                S T R E S S E S   F O R   T H E   S Y M M E T R I C   S H E A R   W E B   E L E M E N T
                                         (STRESSES EVALUATED AT THE ELEMENT CENTROID)

    LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE          ELEMENT GRID POINTS

               1                       7                 29                1     3

APPARENT ELEMENT STRESSES
STRESS
POINT                  MEMBRANE SHEAR STRESS
    1                      0.30833616E 04

ELEMENT APPLIED STRESSES
STRESS
POINT                  MEMBRANE SHEAR STRESS
    1                      0.0

NET ELEMENT STRESSES
STRESS
POINT                  MEMBRANE SHEAR STRESS
    1                      0.30833616E 04
```

FIGURE III-F.20 STRESS OUTPUT, ELEMENT NO. 7 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
        S T R E S S E S   F O R   T H E   Q U A D R I L A T E R A L   S H E A R   P A N E L   E L E M E N T
                                        (STRESSES EVALUATED AT ELEMENT CENTROID)

     LOAD CONDITION NUMBER     ELEMENT NUMBER      ELEMENT TYPE          ELEMENT GRID POINTS

                1                     13                   25                 1     3     4     2

APPARENT ELEMENT STRESSES
STRESS
POINT                   MEMBRANE SHEAR STRESS
    1                      -0.30835161E 04

ELEMENT APPLIED STRESSES
STRESS
POINT                   MEMBRANE SHEAR STRESS
    1                          0.0

NET ELEMENT STRESSES
STRESS
POINT                   MEMBRANE SHEAR STRESS
    1                      -0.30835161E 04
```

FIGURE III-F.21   STRESS OUTPUT, ELEMENT NO. 13 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                        F C F C E S   F C R   T H E   F R A M E   E L E M E N T

     LOAD CONDITION NUMBER     ELEMENT NLMBEF    ELEMENT TYPE      ELEMENT GRID POINTS

                1                    1                11              1    3    7

APPARENT ELEMENT FORCES
POINT                         FCRCES                                                   FLEXURAL  MOMENTS
           AXIAL(FX)          SHEAR(FY)          SHEAR(FZ)        TORQUE(MX)           NORMAL(MY)        NCFMAL(MZ)

   1       0.0                0.81521045E C3     0.0              0.0                  C.0               0.C
   2       0.0               -0.81521045E C3     0.0              0.0                  C.0               0.0
   3       0.0                C.0                0.0              0.0                  C.0               0.C

ELEMENT APPLIED FORCES
POINT                         FCRCES                                                   FLEXURAL  MOMENTS
           AXIAL(FX)          SHEAR(FY)          SHEAR(FZ)        TORQUE(MX)           NORMAL(MY)        NCFMAL(MZ)

   1       0.0                0.0                0.0              0.0                  C.0               0.0
   2       0.0                C.0                0.0              0.0                  C.0               0.0
   3       0.0                C.0                0.0              0.0                  C.0               C.0

NET ELEMENT FORCES
POINT                         FCRCES                                                   FLEXURAL  MOMENTS
           AXIAL(FX)          SHEAR(FY)          SHEAR(FZ)        TORQUE(MX)           NORMAL(MY)        NCFMAL(MZ)

   1       0.0                C.81521045E C3     0.0              0.0                  C.0               0.C
   2       0.0               -0.81521045E C3     0.0              0.0                  C.0               0.C
   3       0.0                C.0                0.0              0.0                  C.0               0.C
```

FIGURE III-F.22 FORCE OUTPUT, ELEMENT NO. 1 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
                     F O R C E S   F O R   T H E   S Y M M E T R I C   S H E A R   W E B   E L E M E N T

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE        ELEMENT GRID POINTS

                    1                   7                   29             1    3

APPARENT ELEMENT FORCES
POINT                                    FORCES
                  FX                       FY                  FZ
    1       0.0                  0.15416800E 03     -0.30833594E 03
    2       0.0                  0.15416800E 03      0.30833594E 03

ELEMENT APPLIED FORCES
POINT                                    FORCES
                  FX                       FY                  FZ
    1       0.0                  0.0                 0.0
    2       0.0                  0.0                 0.0

NET ELEMENT FORCES
POINT                                    FORCES
                  FX                       FY                  FZ
    1       0.0                  0.15416800E 03     -0.30833594E 03
    2       0.0                  0.15416800E 03      0.30833594E 03
```

FIGURE III-F.23 FORCE OUTPUT, ELEMENT NO. 7 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

```
          F O R C E S   F O R   T H E   Q U A D R I L A T E R A L   S H E A R   P A N E L   E L E M E N T

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE     ELEMENT GRID POINTS

                1                    13                25           1    3    4    2

APPARENT ELEMENT FORCES
POINT                             FORCES                                                MOMENTS
              FX                    FY                FZ              MX                  MY                MZ

    1    -0.15417577E 03     0.15417577E 03      0.0             0.0               0.0             0.0
    2     0.15417577E 03     0.15417577E 03      0.0             0.0               0.0             0.0
    3     0.15417577E 03    -0.15417577E 03      0.0             0.0               0.0             0.0
    4    -0.15417577E 03    -0.15417577E 03      0.0             0.0               0.0             0.0

ELEMENT APPLIED FORCES
POINT                             FORCES                                                MOMENTS
              FX                    FY                FZ              MX                  MY                MZ

    1     0.0                0.0                 0.0             0.0               0.0             0.0
    2     0.0                0.0                 0.0             0.0               0.0             0.0
    3     0.0                0.0                 0.0             0.0               0.0             0.0
    4     0.0                0.0                 0.0             0.0               0.0             0.0

NET ELEMENT FORCES
POINT                             FORCES                                                MOMENTS
              FX                    FY                FZ              MX                  MY                MZ

    1    -0.15417577E 03     0.15417577E 03      0.0             0.0               0.0             0.0
    2     0.15417577E 03     0.15417577E 03      0.0             0.0               0.0             0.0
    3     0.15417577E 03    -0.15417577E 03      0.0             0.0               0.0             0.0
    4    -0.15417577E 03    -0.15417577E 03      0.0             0.0               0.0             0.0
```

FIGURE III-F.24 FORCE OUTPUT, ELEMENT NO. 13 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

G. MODIFIED QUADRILATERAL

A four element idealization of a structural joint is shown in Figure III-G.1. This figure shows the loading, idealization, dimension and material properties. The problem is one of those shown in Reference 9 page 329 wherein the effects of the modification of this element were evaluated. The preprinted input data forms associated with this example are given in Figure III-G.2 to III-G.10.

Of interest is the Boundary Condition Section, Figure III-G.6 which shows the use of the MODAL and REPEAT options. There are 8 exceptions to the MODAL card. Grid points 4, 6, 11, and 14 have the same boundary conditions as grid point 1, therefore the option is employed by placing an " X" in column 12 opposite the entry for grid points 4, 6, 11 and 14. The same procedure is followed for grid points 22 and 23. Note the use of symmetrical boundary conditions so that only one-half of the joint need be considered. Note that the eight exceptions to the MODAL card are called out on the System Control Information Data Form, Figure III-G.4.

The following load data is presented in Figure III-G.7, External Loads Section:

(1) One load condition is input

(2) Grid points 1 and 3 are loaded with a force in the +X direction equal to 16.67 pounds and grid point 2 is loaded with a force of 66.66 pounds in the +X direction.

Zero valued entries are made in the External Moments section since these do not exist in this problem.

The Element Control Data Form, Figure III-G.8, displays the use of the REPEAT option. This is used to advantage here since each of the four elements are identical. Although 8 input nodes define the element the User will note that 10 nodes are listed. The last two nodes "6" and "1" in locations 9 and 10 define the X direction for the material properties axes. This allows the User to effectively define stress output direction. The same two points used for the reference element can also be used for the following elements so that output has a common reference.

The output supplied by the MAGIC III System for this illustrative problem is described below and shown on Figures III-G.11 to III-G.27. Figure III-G.11 shows the matrix abstraction instructions which are completely described in Reference 5. Figures III-G.11 to III-G.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

Problem title and material data are given in Figure III-G.12 whereas Figure III-G.13 displays the gridpoint coordinates, temperatures and pressures. Figure III-G.14 presents the boundary conditions and finite element description. In the boundary condition portion of the figure, zeros ('0') represent degrees of freedom that are fixed (i.e., no motion), ones ('1') represent degrees of freedom that are free or have unknown values of displacement, and twos ('2') represent degrees of freedom that are eliminated in the analysis procedure through the condensation technique. The second last column represents the cumulative number of degrees of freedom which actively participate in the equation solving process for displacements. The last column accumulates the number of twos which participate in the calculation of the reduced stiffness matrix. This procedure is not used in this example problem. The second portion of Figure III-G.14 depicts the finite element representation. Each of the four elements is called out in turn with grid points, print options and material number. The use of extra grid points "6" and "1" were explained above. The section properties listed represents the joint thickness.

Figure III-G.15 displays the external load condition and the transformed external assembled load column. This 138x1 vector is the total unreduced load which is read row-wise. The ordering of this vector is consistent with that of the boundary condition table, Figure III-G.14. A load of 16.67 pounds is applied at node point one in the positive X direction. This is position (1,1) in the load vector which corresponds to the first entry in the boundary condition table which is the global U displacement for node point 1. Likewise position (7,1) in the load vector corresponds to the seventh entry in the boundary condition table and the last position (13,1) corresponds to thirteenth entry.

MAGIC III system output of final results are displayed in Figures III-G.16 to III-G.27. The stiffness matrix is shown in Figure III-G.16 where only the non-zero terms are displayed. The stiffness matrix is presented row-wise and it's ordering is consistent with that of the boundary condition table previously discussed. In this problem the ordering is

$$\{\Delta\}^T = \lfloor U_1, U_2, V_2, U_3, V_3, U_4, \ldots V_{21}, V_{22}, V_{23} \rfloor .$$

The externally applied load vector (GPRINT of MATRIX LOADS) is presented in Figure III-G.17. The figure shows that forces (F_x) are applied in the positive X direction at nodes 1, 2 and 3 as previously discussed.

The displacements of the joint are given in Figure III-G.18. These displacements (U,V,W) are output versus node point number and are referenced to the global axes unless otherwise specified. Figure III-G.19 shows the reactions (F_x, F_y, F_z). These are also output versus node point number and are referenced to the global axes system unless otherwise specified.

Stresses arising in the structure are displayed in Figures III-G.20 to III-G.23. Eight stress resultants are evaluated at each corner point of the element and also at the intersection of the diagonals which connect the opposite corner points of the element. The stress resultants are defined as follows:

$$N_x = \int_x \sigma_x \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_y = \int_z \sigma_y \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_{xy} = \int_z \tau_{xy} \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$M_x = \int_z z\, \sigma_x \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

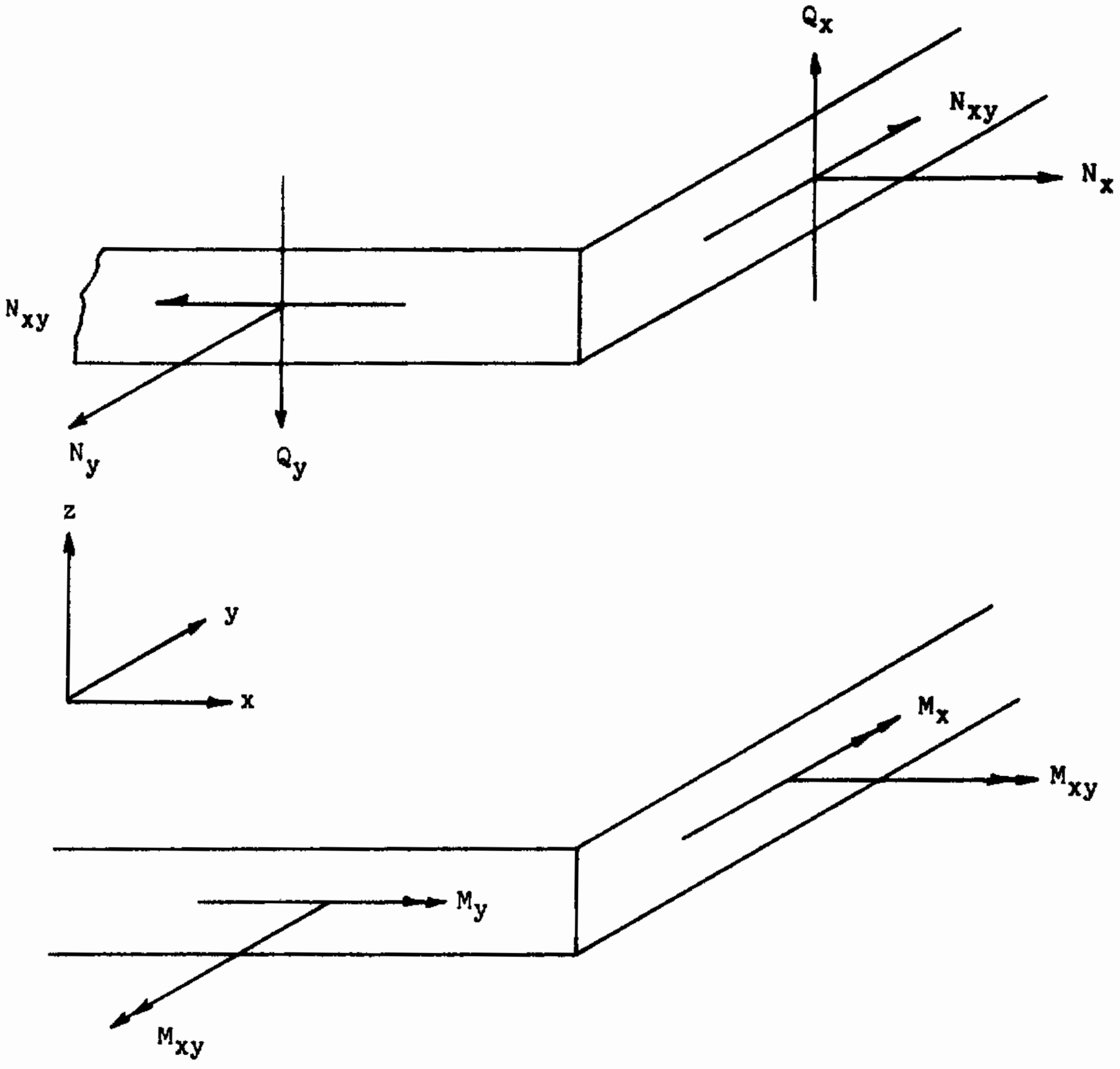
$$M_y = \int_z z\, \sigma_y \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

$$M_{xy} = \int_z z\, \tau_{xy} \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

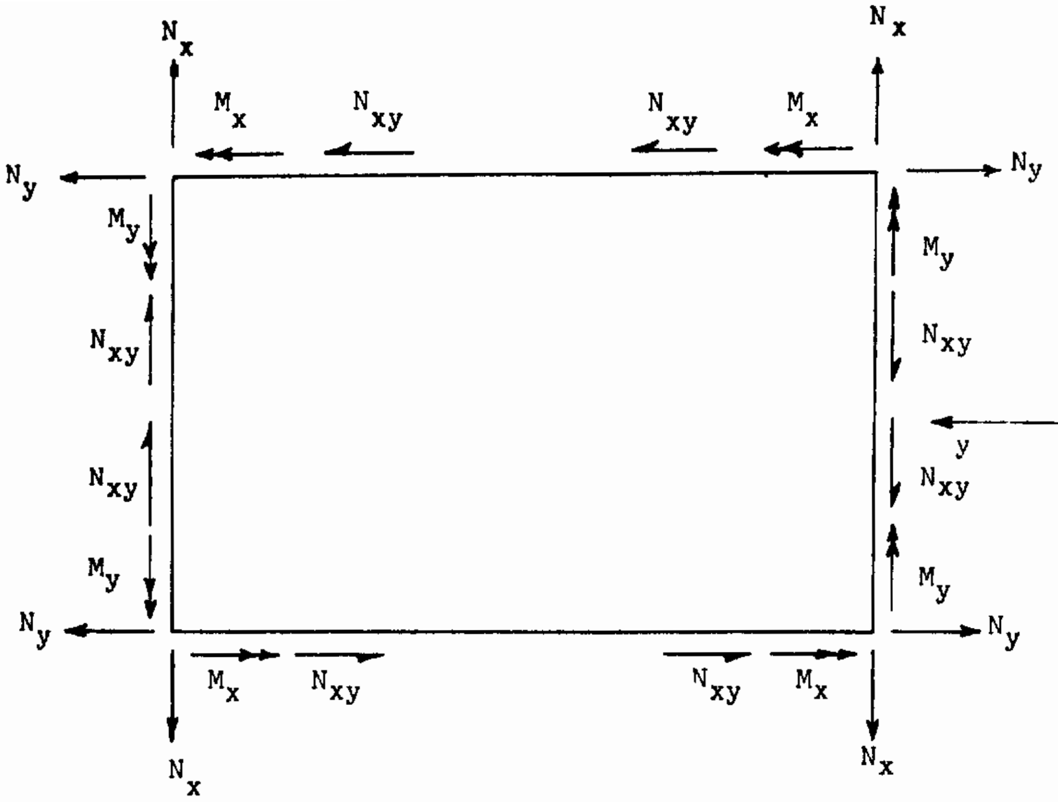
$$Q_x = \int_z z \left(\frac{\partial \sigma_x}{\partial x}\right) d\, z + \int_z z \left(\frac{\partial \tau_{xy}}{\partial y}\right) dz ; \text{ units } \frac{\text{force}}{\text{length}}$$

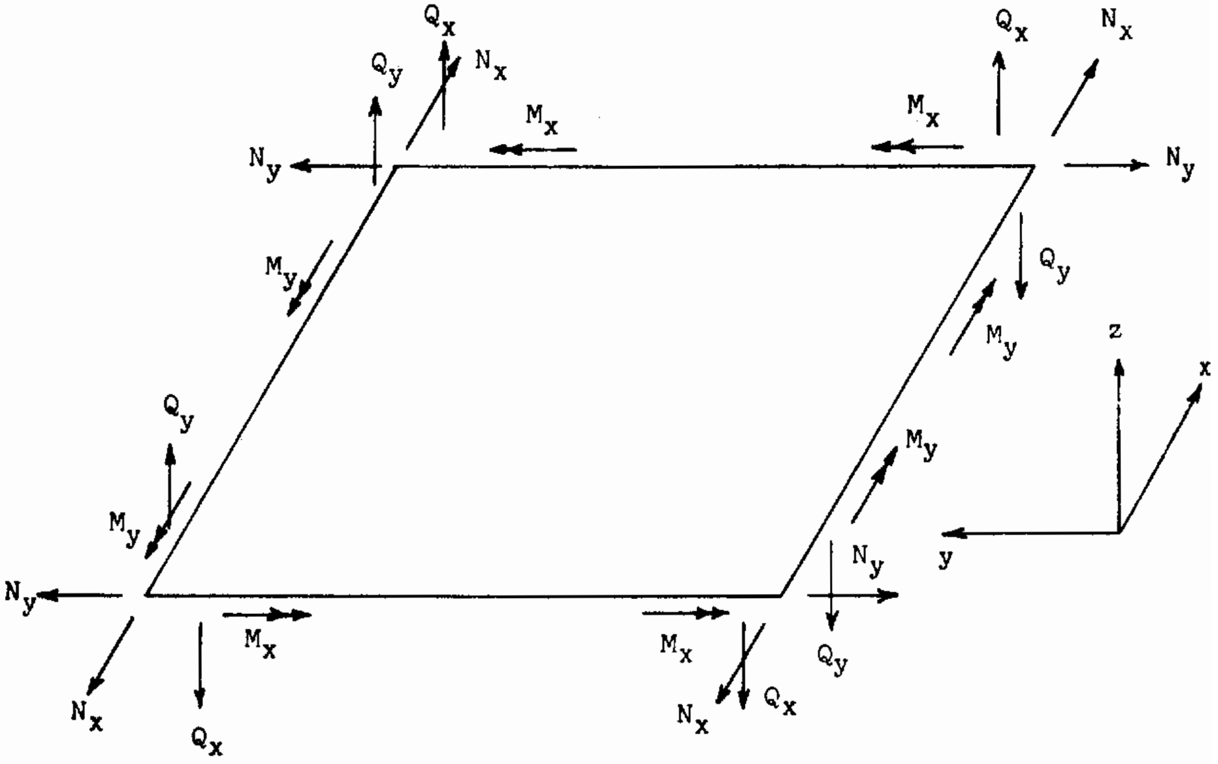
$$Q_y = \int_z z \left(\frac{\partial \sigma_y}{\partial y}\right) d\, z + \int_z z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz \; ; \text{ units } \frac{\text{force}}{\text{length}}$$

The following sketches show the proper manner in which to interpret the stress resultants.



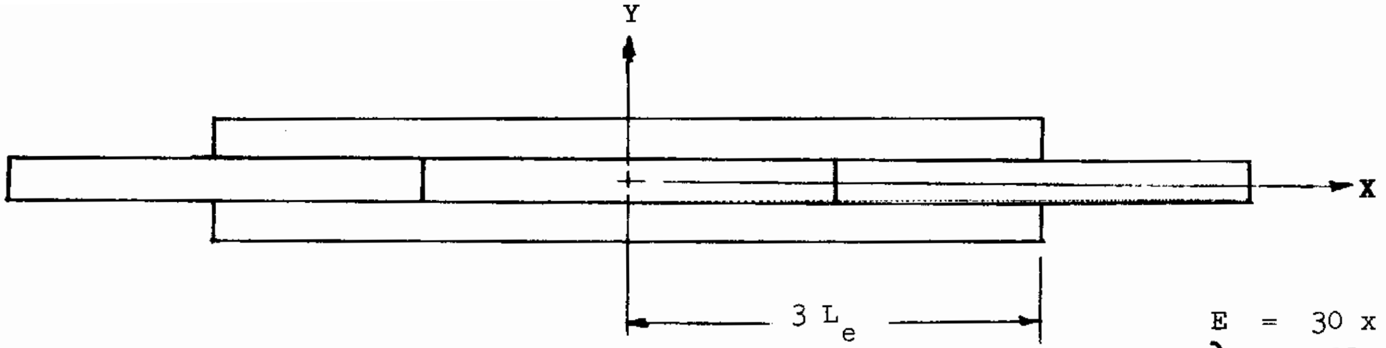
Stress Resultants


N_x
M_x
N_{xy}
N_{xy}
M_x
N_x
N_y
N_y
M_y
M_y
N_{xy}
N_{xy}
N_{xy}
N_{xy}
M_y
M_y
x
y
N_y
N_y
M_x
N_{xy}
N_{xy}
M_x
N_x
N_x


Q_x
Q_y
N_x
M_x
Q_x
N_x
M_x
N_y
N_y
M_y
Q_y
M_y
z
x
Q_y
M_y
M_y
N_y
y
N_y
M_x
M_x
Q_y
N_x
Q_x
N_x
Q_x

Returning to Figure III-G.20 it is noted that there are five stress points at which the stress resultants are evaluated. These correspond to element grid points 1, 3, 8, and 6. The fifth stress point corresponds to the stresses evaluated at the element centroid. The stresses are in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements, however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '6' and '1' were entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points define the X direction of the material properties axes. (Positive X from node point 6 to node point 1.) This axis of reference then becomes the reference axis for the stress output.

The element forces for the Modified Quadrilateral Thin Shell Element are displayed in Figures III-G.24 to III-G.27. The forces (F_X, F_Y, F_Z, M_X, M_Y, M_Z) are defined with respect to the Global coordinate system. The forces are defined at eight points on the element. The first four points are corner points, element grid points 1, 3, 8, and 6, and the last four points are mid-points, element grid points 2, 5, 7, 4 for element 1, for example.



LAP JOINT

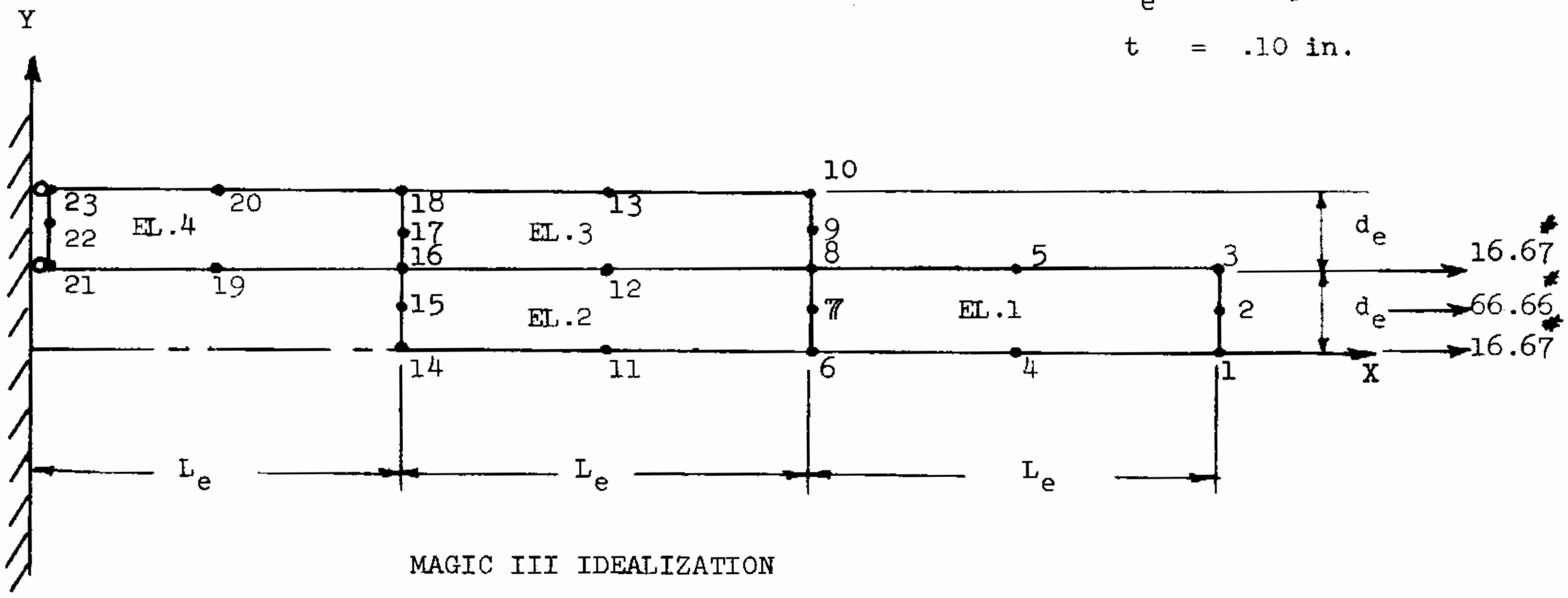
$E = 30 \times 10^6$ psi

$\nu = .30$

$L_e = 10.0$ in.

$d_e = .625$ in.

$t = .10$ in.



MAGIC III IDEALIZATION

FIGURE III-G.1 MODIFIED QUADRILATERAL THIN SHELL ELEMENT - LAP JOINT PROBLEM

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

REPORT (/)

1 2 3 4 5 6

TITLE (/)

7 8 9

3 (/) NUMBER OF TITLE CARDS

```
FOUR ELEMENT PLATE SUBJECTED TO A SHEAR LOAD                (/)
MODIFIED QUADRILATERAL THIN SHELL ELEMENT IDEN. NO. 3B      (/)
ASPECT RATIO 16.0  STATICS ANALYSIS                         (/)
                                                            (/)
                                                            (/)
                                                            (/)
                                                            (/)
                                                            (/)
                                                            (/)
                                                            (/)
```

FIGURE III-G.2 TITLE INFORMATION - LAP JOINT PROBLEM

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

7	8	9
	-	1

No. of Requests (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	99398	24	STEEL	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-G.3 MATERIAL TAPE INPUT - LAP JOINT PROBLEM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M	1 2 3 4 5 6	(/)
1. Number of System Grid Points	23	1 2 3 4 5 6	
2. Number of Input Grid Points	10	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	6	13 14	
4. Number of Load Conditions	1	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	4	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	8	39 40 41 42 43 44	
11. T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-G.4 SYSTEM CONTROL INFORMATION - LAP JOINT PROBLEM

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – θ	DIRECTIONS Z – Z	
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
1	30.0	0.0		(/)
3	30.0	0.625		(/)
6	20.0	0.0		(/)
8	20.0	0.625		(/)
10	20.0	1.25		(/)
14	10.0	0.0		(/)
16	10.0	0.625		(/)
18	10.0	1.25		(/)
21	0.0	0.625		(/)
23	0.0	1.25		(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-G.5 GRIDPOINT COORDINATES - LAP JOINT PROBLEM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	0	0	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		1	0	0	0	0	0				(/)
				4	X										(/)
				6	X										(/)
			1	1	X										(/)
			1	4	X										(/)
			2	1		0	1	0	0	0	0				(/)
			2	2	X										(/)
			2	3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-G.6 BOUNDARY CONDITIONS - LAP JOINT PROBLEM

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS (/)

LCOND Condition Number 1 Scaler 1.0 (/)

MODAL

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F$_x$	FORCE VALUES F$_y$	FORCE VALUES F$_z$		MOMENT VALUES M$_x$	MOMENT VALUES M$_y$	MOMENT VALUES M$_z$		GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3	
1	16.67	0.0	0.0	(/)	0.0	0.0	0.0	(/)				(/)
2	66.66	0.0	0.0	(/)	0.0	0.0	0.0	(/)				(/)
3	16.67	0.0	0.0	(/)	0.0	0.0	0.0	(/)				(/)

FIGURE III-G.7 EXTERNAL LOADS - LAP JOINT PROBLEM

BAC 1628

ELEM (/)
123456

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	No. of Assem. Nodes	NODE POINTS												
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	38	99398		0.0		X				8		1	3	8	6	2	5	7	4	6	1			(/)
2					X							6	8	16	14	7	12	15	11	6	1			(/)
3					X							8	10	18	16	9	13	17	12	6	1			(/)
4					X							16	18	23	21	17	20	22	19	6	1			(/)
																								(/)
																								(/)
																								(/)
																								(/)
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																								(/)
																								(/)

FIGURE III-G.8 ELEMENT CONTROL DATA - LAP JOINT PROBLEM

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

1	2	3	4	5	6	
E	X	T	E	R	N	(/)

1	2	3	4	5	6
M	O	D	A	L	

A 13–22	B 23–32	C 33–42	D 43–52	E 53–62	F 63–72
01.0	0.0	0.0	0.0	0.0	0.0

Element Number 7 8 9 10 11	Repeat 12	A 13–22	B 23–32	C 33–42	D 43–52	E 53–62	F 63–72	
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

FIGURE III-G.9 ELEMENT INPUT DATA - LAP JOINT PROBLEM

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-G.10 END CARD - LAP JOINT PROBLEM

```
              MAGIC  ABSTRACTION INSTRUCTION LISTING          PAGE  1

          TEST MAGIC

$INSTRUCTION    SOURCE                                                    TESTB004

        C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS                     TESTB005
        C                                                                          TESTB006
        C         *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *TESTB007
        C                                                                          TESTB008
        C         STATICS INSTRUCTION SEQUENCE                                     TESTB009
        C                                                                          TESTB010
        C         *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  * *TESTB011
        C                                                                          TESTB012
        C         GENERATE ELEMENT MATRICES                                        TESTB013
        C                                                                          TESTB014
   1          ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,,USER04.       TESTB015
        C                                                                          TESTB016
        C                                                                          TESTB017
        C         FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                      TESTB018
        C         DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED                 TESTB019
        C                                                                          TESTB020
   2          I1 = SC.IDENTC.                                                      TESTB021
   3          I3 = I1.NULL.SC                                                      TESTB022
   4          DIFF = I1 .SMULT. SC(5,1)                                            TESTB023
        C                                                                          TESTB024
        C         ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS              TESTB025
        C                                                                          TESTB026
   5          KELA = EM .ASSEM. SC,(10)                                            TESTB027
   6          FTELA = EM .ASSEM .SC,(40)                                           TESTB028
   7          LSCALE,LOADS = XLD .DEJOIN. (1,1)                                    TESTB029
        C                                                                          TESTB030
        C         REDUCE STIFFNESS MATRIX AND PRINT                                TESTB031
        C                                                                          TESTB032
   8          KO,KNO = KELA .DEJOIN.( SC(5,1),1)                                   TESTB033
   9          KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                                  TESTB034
  10          PRINT(FORCE,DISP,,) STIFF                                            TESTB035
        C                                                                          TESTB036
        C         FORM REDUCED TOTAL LOAD COLUMN                                   TESTB037
        C                                                                          TESTB038
        C         MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR                    TESTB039
  11          FTELS = FTELA.MULT.LSCALE                                            TESTB040
        C         TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM               TESTB041
  12          LOADO = TR.MULT.LOADS                                                TESTB042
        C         FORM TOTAL LOAD COLUMNS                                          TESTB043
  13          TLOAD = FTELS.ADD.LOADO                                              TESTB044
  14          TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)                                TESTB045
        C                                                                          TESTB046
        C         SOLVE FOR DISPLACEMENTS                                          TESTB047
        C                                                                          TESTB048
  15          XX = STIFF.SEQEL.TLOADR                                              TESTB049
  16          TRO,TR12 = TR.DEJOIN.(SC(5,1),1)                                     TESTB050
  17          X = TR12.TMULT.XX                                                    TESTB051
  18          XO = TR.MULT.X                                                       TESTB052
        C                                                                          TESTB053
        C         CALCULATE REACTIONS AND INVERSE CHECK                            TESTB054
```

FIGURE III-G.11 MAGIC ABSTRACTION INSTRUCTION LISTING - LAP JOINT PROBLEM

```
              MAGIC   ABSTRACTION INSTRUCTION LISTING          PAGE  2

         TEST MAGIC

      C                                                                      TESTB055
              REACTS = KELA.MULT.XO                                          TESTB056
              REACTP= REACTS.SUBT.TLOAD                                      TESTB057
              IF (DIFF.NULL.) GO TO 10                                       TESTB058
      C                                                                      TESTB059
      C          PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS, TESTB060
      C            REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT         TESTB061
      C                                                                      TESTB062
      C          ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM                     TESTB063
      C                                                                      TESTB064
              GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA                      TESTB065
              GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS                     TESTB066
              GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X                    TESTB067
              GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP                     TESTB068
              IF (I3.NULL.) GO TO 600                                        TESTB069
      C                                                                      TESTB070
      C          ELEMENTS HAVE 3 DEGREES OF FREEDOM                          TESTB071
      C                                                                      TESTB072
        10    GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA              TESTB073
              GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS             TESTB074
              GPRINT(2,,,U.0.W.0.THETAY.C.W*.0.W**,SC, )X                    TESTB075
              GPRINT(1,,,FR.0.FZ.0.MBETA.C.F1.0.F3,SC,TR )REACTP             TESTB076
      C                                                                      TESTB077
      C          GENERATE STRESSES  AND FORCES                               TESTB078
      C                                                                      TESTB079
        600   STRESP=EM,XO .STRESS.(4,)                                      TESTB080
              FORCEP=EM,XO .FORCE.(4,)                                       TESTB081
```

FIGURE III-G.11 CONCLUDED

```
                    FOUR ELEMENT PLATE SUBJECTED TO A SHEAR LOAD

                    MODIFIED QUADRILATERAL THIN SHELL ELEMENT IDEN. NO.33

                    ASPECT RATIO 16.0    STATICS ANALYSIS

                                        REVISIONS OF MATERIAL TAPE

                                      ASTERISK (*) PRECEEDING MATERIAL
                                      IDENTIFICATION INDICATES THAT INPUT
                                      ERROR RETURNS WILL NOT RESULT IN
                                          TERMINATION OF EXECUTION


*************************************************************************************************

   REVISION
     MATERIAL NUMBER   99358
     MATERIAL IDENTIFICATION     STEEL                          INPUT  CODE    I
       NUMBER OF MATERIAL PROPERTY POINTS. . . . .  1
       NUMBER OF PLASTIC PROPERTY POINTS . . . . .  0
       MASS DENSITY. . . . . . . . . . . . . . . .  0.49999985E-03

     MATERIAL PROPERTIES

                     YOUNG'S MODULI                               POISSON'S RATIOS

                                 DIRECTIONS                                           DIRECTIONS
 TEMPERATURE
                       XX              YY              ZZ               XY              YZ              ZX
     0.0          0.300000E 08    0.300000E 08    0.300000E 08     0.300000E 00    0.300000E 00    0.300000E 00
                     TH. EXP.COEF.                                 RIGIDITY MODULI

                                 DIRECTIONS                                           DIRECTIONS
 TEMPERATURE
                       XX              YY              ZZ               XY              YZ              ZX
     0.0          0.850000E-05    0.850000E-05    0.850000E-05     0.115385E 08    0.115385E 08    0.115385E 08

*************************************************************************************************
```

FIGURE III-G.12 TITLE AND MATERIAL DATA OUTPUT - LAP JOINT PROBLEM

```
                                        23 FEF. PCINTS

      NO. DIRECTIONS  =    3      NC. DEGFEES CF FFEECCM =   2


                                       GFICFCINT CATA
                                    (IN FECTANGULAR CCCPCINATES)

POINT          X                 Y                    Z       TEMPERATURES        PRESSURES .
  1     0.30000000E 02   C.0              0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
  3     0.30000000E 02   C.625CCCCCE C0   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
  6     0.20000000E 02   C.0              0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
  8     0.20000000E 02   C.625CCCCCE CC   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
 10     0.20000000E 02   C.12500CCCE C1   0.0             0.0              C.0
                                                          0.0              0.0
                                                          0.0              0.0
 14     0.10000000E 02   C.0              0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
 16     0.10000000E 02   C.625C00CCE C0   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
 18     0.10000000E 02   C.125C00CCE C1   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
 21     0.0              C.625000CCE C0   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
 23     0.0              C.125000C0E C1   0.0             0.0              0.0
                                                          0.0              0.0
                                                          0.0              0.0
```

FIGURE III-G.13 GRIDPOINT DATA OUTPUT - LAP JOINT PROBLEM

```
                                BOUNDARY CONDITION INFORMATION

       NODES                  DEGREES OF FREEDOM                          NO. OF ONES   NO. OF TWOS

         1        1    0    0    0    0    0                                   1            0
         2        1    1    0    0    0    0                                   3            0
         3        1    1    0    0    0    0                                   5            0
         4        1    0    0    0    0    0                                   6            0
         5        1    1    0    0    0    0                                   8            0
         6        1    0    0    0    0    0                                   9            0
         7        1    1    0    0    0    0                                  11            0
         8        1    1    0    0    0    0                                  13            0
         9        1    1    0    0    0    0                                  15            0


        10        1    1    0    0    0    0                                  17            0
        11        1    0    0    0    0    0                                  18            0
        12        1    1    0    0    0    0                                  20            0
        13        1    1    0    0    0    0                                  22            0
        14        1    0    0    0    0    0                                  23            0
        15        1    1    0    0    0    0                                  25            0
        16        1    1    0    0    0    0                                  27            0
        17        1    1    0    0    0    0                                  29            0
        18        1    1    0    0    0    0                                  31            0
        19        1    1    0    0    0    0                                  33            0
        20        1    1    0    0    0    0                                  35            0
        21        0    1    0    0    0    0                                  36            0
        22        0    1    0    0    0    0                                  37            0
        23        0    1    0    0    0    0                                  38            0


                                   TOTAL NO. ELEMENTS =      4


ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  38    99398    0  0.0      0    8     1   3   8   6   2   5   7   4   6   1            0.10000E 01    0.0         0.0
  2  38    99398    0  0.0      0    8     6   8  16  14   7  12  15  11   6   1              ELEMENT MATRICES REPEATED
                                PRE-STRAIN =  0.0         0.0         0.0         0.0        0.0         0.0
                                PRE-STRESS =  0.0         0.0         0.0         0.0        0.0         0.0
  3  38    99398    0  0.0      0    8     8  10  18  16   9  13  17  12   6   1              ELEMENT MATRICES REPEATED
                                PRE-STRAIN =  0.0         0.0         0.0         0.0        0.0         0.0
                                PRE-STRESS =  0.0         0.0         0.0         0.0        0.0         0.0
  4  38    99398    0  0.0      0    8    16  18  23  21  17  20  22  19   6   1              ELEMENT MATRICES REPEATED
                                PRE-STRAIN =  0.0         0.0         0.0         0.0        0.0         0.0
                                PRE-STRESS =  0.0         0.0         0.0         0.0        0.0         0.0
```

FIGURE III-G.14 BOUNDARY CONDITIONS AND FINITE ELEMENT DESCRIPTION - LAP JOINT PROBLEM

```
                              EXTERNAL LOAC CCNDITIONS    1

    LOAD NO.   1
      NUMBER OF LOADED NODES     3          ELEMENT LCAD SCALAR =  0.10000000E 01
 1  0.16670E 02  0.C           0.0          0.0          0.0          0.0
 2  0.66660E 02  0.0           0.C          0.0          0.0          0.0
 3  0.16670E 02  0.0           0.C          0.0          0.0          0.0


                         TRANSFCRMED EXTERNAL ASSEMBLED LOAD COLUMN

                                        138 X 1

    0.16669998E 02     0.C          0.0          0.0          0.0          0.0
    0.66659988E 02     0.C          0.0          0.0          C.0          0.0
    0.16669998E 02     0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.0          0.0          0.0          C.0          C.0
    0.0                0.C          0.0          0.0          C.0          0.0
    0.0                0.C          0.0          0.0          C.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.0          0.0          0.0          0.0          0.0
    0.0                0.0          0.0          0.0          C.0          0.0
    0.0                0.C          0.0          0.0          C.0          0.0
    0.0                0.0          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.0          0.0          0.0          0.0          0.0
    0.0                0.0          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          C.0          0.0
    0.0                0.C          0.0          0.0          0.0          0.0
    0.0                0.C          0.0          0.0          C.0          C.0
    0.0                0.0          0.0          0.0          0.0          0.0



                              T-ZERC FCF STRUCTURE =  0.0
```

FIGURE III-G.15 TRANSFORMED EXTERNAL ASSEMBLED LOAD OUTPUT - LAP JOINT PROBLEM

```
                                          MATRIX  STIFF /    1/                                                    PAGE    1

                           CUTOFF =    0.0                                          SIZE    38  BY    38

                FORCE                   FORCE                    FORCE                    FORCE                    FORCE

DISP        1      1   0.107857E 09    2  -0.163964E 09    3   0.421242E 07    4   0.578248E 08    5   0.137363E 06
                   6   0.104762E 08    7  -0.132234E 08    8   0.238094E 07    9   0.355126E 08   10  -0.821883E 08
                  11   0.238092E 07   12   0.477058E 08   13  -0.416665E 07

DISP        2      1  -0.163964E 09    2   0.329302E 09    3   0.640000E 02    4  -0.163964E 09    5  -0.531136E 07
                   6  -0.888750E 02    7  -0.606250E 01    8   0.952376E 07    9  -0.821883E 08   10   0.163003E 09
                  11   0.160000E 02   12  -0.821883E 08   13   0.238094E 07

DISP        3      1   0.421242E 07    2   0.640000E 02    3   0.938107E 09    4  -0.421245E 07    5  -0.468813E 09
                   6  -0.952377E 07    7   0.952376E 07    8  -0.308750E 02    9  -0.238096E 07   10   0.280000E 02
                  11   0.468476E 09   12   0.238092E 07   13  -0.234479E 09

DISP        4      1   0.578248E 08    2  -0.163964E 09    3  -0.421245E 07    4   0.107657E 09    5   0.101190E 06
                   6  -0.132234E 08    7   0.104762E 08    8  -0.531133E 07    9   0.477058E 08   10  -0.821883E 08
                  11  -0.238095E 07   12   0.355126E 08   13   0.137361E 06

DISP        5      1   0.137363E 06    2  -0.531136E 07    3  -0.468813E 09    4   0.101190E 08    5   0.305176E 09
                   6  -0.238094E 07    7  -0.421242E 07    8   0.345236E 08    9   0.416665E 07   10  -0.238095E 07
                  11  -0.234479E 09   12  -0.137367E 06   13   0.998574E 08

DISP        6      1   0.104762E 08    2  -0.888750E 02    3  -0.952377E 07    4  -0.132234E 08    5  -0.238094E 07
                   6   0.102124E 09    7  -0.966297E 08    8   0.700000E 01    9   0.104762E 08   10  -0.605625E 02
                  11   0.952376E 07   12  -0.132234E 08   13   0.238095E 07

DISP        7      1  -0.132234E 08    2  -0.606250E 01    3   0.952376E 07    4   0.104762E 08    5  -0.421242E 07
                   6  -0.966297E 08    7   0.102124E 09    8  -0.320000E 02    9  -0.132235E 08   10   0.114750E 03
                  11  -0.952375E 07   12   0.104761E 08   13   0.421243E 07

DISP        8      1   0.238094E 07    2   0.952376E 07    3  -0.308750E 02    4  -0.531133E 07    5   0.345236E 08
                   6   0.700000E 01    7  -0.320000E 02    8   0.282599E 09    9  -0.238096E 07   10  -0.952375E 07
                  11   0.417188E 03   12   0.531133E 07   13   0.345233E 08

DISP        9      1   0.355126E 08    2  -0.821883E 08    3  -0.238096E 07    4   0.477058E 08    5   0.416665E 07
                   6   0.104762E 08    7  -0.132235E 08    8  -0.238096E 07    9   0.215713E 09   10  -0.327929E 09
                  11  -0.320000E 02   12   0.115650E 09   13   0.150000E 02   18   0.104762E 08   19  -0.132234E 08
                  20   0.238094E 07   23   0.355126E 08   24  -0.821883E 08   25   0.238092E 07   26   0.477058E 08
                  27  -0.416665E 07

DISP       10      1  -0.821883E 08    2   0.163003E 09    3   0.280000E 02    4  -0.821883E 08    5  -0.238095E 07
                   6  -0.605625E 02    7   0.114750E 03    8  -0.952375E 07    9  -0.327929E 09   10   0.653603E 09
                  11   0.208000E 03   12  -0.327929E 09   13  -0.350000E 02   18  -0.888750E 02   19  -0.606250E 01
                  20   0.952376E 07   23  -0.821883E 08   24   0.163003E 09   25   0.160000E 02   26  -0.821883E 08
                  27   0.238094E 07

DISP       11      1   0.238092E 07    2   0.160000E 02    3   0.468476E 09    4  -0.238095E 07    5  -0.234479E 09
                   6   0.952376E 07    7  -0.952375E 07    8   0.417188E 03    9  -0.320000E 02   10   0.208000E 03
                  11   0.187622E 10   12  -0.320000E 02   13  -0.937626E 09   18  -0.952377E 07   19   0.952376E 07
```

FIGURE III-G.16 STIFFNESS MATRIX - LAP JOINT PROBLEM

```
                                       MATRIX  STIFF /   1/                                          PAGE    2

                    CUTOFF =    0.0                                       SIZE    38  BY    38

          FORCE                  FORCE                  FORCE                  FORCE                  FORCE

DISP    11   20   -0.308750E 02   23   -0.238096E 07   24    0.280000E 02   25    0.468476E 09   26    0.238092E 07
             27   -0.234479E 09

DISP    12    1    0.477058E 08    2   -0.821883E 08    3    0.238092E 07    4    0.355126E 08    5   -0.137367E 06
              6   -0.132234E 08    7    0.104761E 08    8    0.531133E 07    9    0.115650E 09   10   -0.327929E 09
             11   -0.320000E 02   12    0.323570E 09   13   -0.101190E 08   14   -0.163964E 09   15    0.421242E 07
             16    0.578248E 08   17    0.137363E 06   18   -0.132234E 09   19    0.209524E 08   20   -0.400000E 01
             21   -0.132234E 08   22    0.238094E 07   23    0.477058E 08   24   -0.821883E 08   25   -0.238095E 07
             26    0.710252E 08   28   -0.821883E 08   29    0.238092E 07   30    0.477058E 08   31   -0.416665E 07

DISP    13    1   -0.416665E 07    2    0.238094E 07    3   -0.234479E 09    4    0.137361E 06    5    0.998574E 08
              6    0.238095E 07    7    0.421243E 07    8    0.345233E 08    9    0.150000E 02   10   -0.350000E 02
             11   -0.937626E 09   12   -0.101190E 08   13    0.915527E 09   14    0.531133E 07   15   -0.468813E 09
             16   -0.137361E 06   17    0.164238E 09   18   -0.238094E 07   19   -0.100000E 01   20    0.690473E 08
             21    0.238094E 07   22   -0.354851E 08   23    0.416665E 07   24   -0.238095E 07   25   -0.234479E 09
             26    0.300000E 01   27    0.199715E 09   28    0.238093E 07   29   -0.234479E 09   30   -0.416665E 07
             31    0.134982E 09

DISP    14   12   -0.163964E 09   13    0.531133E 07   14    0.329302E 09   15    0.640000E 02   16   -0.163964E 09
             17   -0.531136E 07   19   -0.888750E 02   20   -0.952377E 07   21   -0.606250E 01   22    0.952376E 07
             26   -0.821883E 08   27   -0.238096E 07   28    0.163003E 09   29    0.160000E 02   30   -0.821883E 08
             31    0.238094E 07

DISP    15   12    0.421242E 07   13   -0.468813E 09   14    0.640000E 02   15    0.938107E 09   16   -0.421245E 07
             17   -0.468813E 09   19   -0.952377E 07   20   -0.289938E 03   21    0.952376E 07   22   -0.308750E 02
             26   -0.238096E 07   27   -0.234479E 09   28    0.280000E 02   29    0.468476E 09   30    0.238092E 07
             31   -0.234479E 09

DISP    16   12    0.578248E 08   13   -0.137361E 06   14   -0.163964E 09   15   -0.421245E 07   16    0.107857E 09
             17    0.101190E 08   19   -0.132234E 08   20   -0.238094E 07   21    0.104762E 08   22   -0.531133E 07
             26    0.477058E 08   27    0.416665E 07   28   -0.821883E 08   29   -0.238095E 07   30    0.355126E 08
             31    0.137361E 06

DISP    17   12    0.137363E 06   13    0.164238E 09   14   -0.531136E 07   15   -0.468813E 09   16    0.101190E 08
             17    0.305176E 09   19   -0.238094E 07   20   -0.354850E 08   21   -0.421242E 07   22    0.345236E 08
             26    0.416665E 07   27    0.134982E 09   28   -0.238095E 07   29   -0.234479E 09   30   -0.137367E 06
             31    0.998574E 08

DISP    18    9    0.104762E 08   10   -0.888750E 02   11   -0.952377E 07   12   -0.132234E 08   13   -0.238094E 07
             18    0.102124E 09   19   -0.966297E 08   20    0.700000E 01   23    0.104762E 08   24   -0.605625E 02
             25    0.952376E 07   26   -0.132234E 08   27    0.238095E 07

DISP    19    9   -0.132234E 08   10   -0.606250E 01   11    0.952376E 07   12    0.209524E 08   13   -0.100000E 01
             14   -0.888750E 02   15   -0.952377E 07   16   -0.132234E 08   17   -0.238094E 07   18   -0.966297E 08
             19    0.204248E 09   20   -0.320000E 02   21   -0.966297E 08   22    0.700000E 01   23   -0.132235E 08
             24    0.114750E 03   25   -0.952375E 07   26    0.209523E 08   27    0.200000E 01   28   -0.605625E 02
```

FIGURE III-G.16 CONTINUED

```
                     CUTOFF =    0.0                                       SIZE    38  BY    38

             FORCE                    FORCE                    FORCE                    FORCE                    FORCE

DISP    19    29   0.952376E 07    30   -0.132234E 08    31    0.238095E 07

DISP    20     9   0.238094E 07    10    0.952376E 07    11   -0.308750E 02    12   -0.400000E 01    13    0.690473E 08
              14  -0.952377E 07    15   -0.289938E 03    16   -0.238094E 07    17   -0.354850E 08    19    0.700000E 01
              19  -0.320000E 02    20    0.565198E 09    22   -0.280676E 09    23   -0.238096E 07    24   -0.952375E 07
              25   0.417188E 03    26   -0.100000E 01    27    0.690471E 08    28    0.952376E 07    29   -0.299125E 03
              30   0.238095E 07    31   -0.354849E 08

DISP    21    12  -0.132234E 08    13    0.238094E 07    14   -0.606250E 01    15    0.952376E 07    16    0.104762E 08
              17  -0.421242E 07    19   -0.966297E 08    21    0.102124E 09    22   -0.320000E 02    26   -0.132235E 08
              27  -0.238096E 07    28    0.114750E 03    29   -0.952375E 07    30    0.104761E 08    31    0.421243E 07

DISP    22    12   0.238094E 07    13   -0.354851E 08    14    0.952376E 07    15   -0.308750E 02    16   -0.531133E 07
              17   0.345236E 08    19    0.700000E 01    20   -0.280676E 09    21   -0.320000E 02    22    0.282599E 09
              26  -0.238096E 07    27   -0.354853E 08    28   -0.952375E 07    29    0.417188E 03    30    0.531133E 07
              31   0.345233E 08

DISP    23     9   0.355126E 08    10   -0.821883E 08    11   -0.238096E 07    12    0.477058E 08    13    0.416665E 07
              18   0.104762E 08    19   -0.132235E 08    20   -0.238096E 07    23    0.107857E 09    24   -0.163965E 09
              25  -0.421245E 07    26    0.578248E 08    27   -0.137348E 06

DISP    24     9  -0.821883E 08    10    0.163003E 09    11    0.280000E 02    12   -0.821883E 08    13   -0.238095E 07
              18  -0.605625E 02    19    0.114750E 03    20   -0.952375E 07    23   -0.163965E 09    24    0.329302E 09
              25   0.144000E 03    26   -0.163964E 09    27    0.531132E 07

DISP    25     9   0.238092E 07    10    0.160000E 02    11    0.468476E 09    12   -0.238095E 07    13   -0.234479E 09
              18   0.952376E 07    19   -0.952375E 07    20    0.417188E 03    23   -0.421245E 07    24    0.144000E 03
              25   0.938108E 09    26    0.421242E 07    27   -0.468813E 09

DISP    26     9   0.477058E 08    10   -0.821883E 08    11    0.238092E 07    12    0.710252E 08    13    0.300000E 01
              14  -0.821883E 08    15   -0.238096E 07    16    0.477058E 08    17    0.416665E 07    18   -0.132234E 08
              19   0.209523E 08    20   -0.100000E 01    21   -0.132235E 08    22   -0.238096E 07    23    0.578248E 08
              24  -0.163964E 09    25    0.421242E 07    26    0.323570E 09    27   -0.101190E 08    28   -0.327929E 09
              29  -0.320000E 02    30    0.115650E 09    31    0.150000E 02    32    0.104762E 08    33    0.531132E 07
              34  -0.132234E 08    35    0.238094E 07    36   -0.137361E 06    37    0.238092E 07    38   -0.416665E 07

DISP    27     9  -0.416665E 07    10    0.238094E 07    11   -0.234479E 09    13    0.195715E 09    14   -0.238096E 07
              15  -0.234479E 09    16    0.416665E 07    17    0.134982E 09    18    0.238095E 07    19    0.200000E 01
              20   0.690471E 08    21   -0.238096E 07    22   -0.354853E 08    23   -0.137348E 06    24    0.531132E 07
              25  -0.468813E 09    26   -0.101190E 08    27    0.915527E 09    28   -0.220000E 02    29   -0.937626E 09
              30   0.130000E 02    31    0.328475E 09    32    0.421242E 07    33    0.345237E 08    34    0.238094E 07
              35  -0.354851E 08    36    0.998573E 08    37   -0.234479E 09    38    0.134982E 09

DISP    28    12  -0.821883E 08    13    0.238093E 07    14    0.163003E 09    15    0.280000E 02    16   -0.821883E 08
              17  -0.238095E 07    19   -0.605625E 02    20    0.952376E 07    21    0.114750E 03    22   -0.952375E 07
```

FIGURE III-G.16 CONTINUED

```
                                         MATRIX  STIFF /    1/                                        PAGE    4

                     CUTOFF  =    0.0                                    SIZE    38  BY    38

         FORCE                FORCE                FORCE                FORCE                FORCE

DISP  28   26   -0.327929E 09   27   -0.220000E 02   28    0.658603E 09   29    0.208000E 03   30   -0.327929E 09
           31   -0.350000E 02   32   -0.888750E 02   33   -0.952377E 07   34   -0.606250E 01   35    0.952376E 07
           36   -0.238096E 07   37    0.160000E 02   38    0.238094E 07

DISP  29   12    0.238092E 07   13   -0.234479E 09   14    0.160000E 02   15    0.468476E 09   16   -0.238095E 07
           17   -0.234479E 09   19    0.952376E 07   20   -0.299125E 03   21   -0.952375E 07   22    0.417188E 03
           26   -0.320000E 02   27   -0.937626E 09   28    0.208000E 03   29    0.187622E 10   30   -0.320000E 02
           31   -0.937626E 09   32   -0.952377E 07   33   -0.289938E 03   34    0.952376E 07   35   -0.308750E 02
           36   -0.234479E 09   37    0.468476E 09   38   -0.234479E 09

DISP  30   12    0.477058E 08   13   -0.416665E 07   14   -0.821883E 08   15    0.238092E 07   16    0.355126E 08
           17   -0.137367E 06   19   -0.132234E 08   20    0.238095E 07   21    0.104761E 08   22    0.531133E 07
           26    0.115650E 09   27    0.130000E 02   28   -0.327929E 09   29   -0.320000E 02   30    0.215713E 09
           31   -0.190000E 02   32   -0.132234E 08   33   -0.238094E 07   34    0.104762E 08   35   -0.531133E 07
           36    0.416665E 07   37   -0.238095E 07   38    0.137361E 06

DISP  31   12   -0.416665E 07   13    0.134982E 09   14    0.238094E 07   15   -0.234479E 09   16    0.137361E 06
           17    0.998574E 08   19    0.238095E 07   20   -0.354849E 08   21    0.421243E 07   22    0.345233E 08
           26    0.150000E 02   27    0.328475E 09   28   -0.350000E 02   29   -0.937626E 09   30   -0.190000E 02
           31    0.610351E 09   32   -0.238094E 07   33   -0.354850E 08   34   -0.421242E 07   35    0.345236E 08
           36    0.134982E 09   37   -0.234479E 09   38    0.998574E 08

DISP  32   26    0.104762E 08   27    0.421242E 07   28   -0.888750E 02   29   -0.952377E 01   30   -0.132234E 08
           31   -0.238094E 07   32    0.102124E 09   34   -0.966297E 08   35    0.700000E 01   36   -0.421242E 07
           37    0.952376E 07   38    0.238095E 07

DISP  33   26    0.531132E 07   27    0.345237E 08   28   -0.952377E 07   29   -0.289938E 03   30   -0.238094E 07
           31   -0.354850E 08   33    0.282599E 09   35   -0.280676E 09   36    0.345238E 08   37   -0.299125E 03
           38   -0.354849E 08

DISP  34   26   -0.132234E 08   27    0.238094E 07   28   -0.606250E 01   29    0.952376E 07   30    0.104762E 08
           31   -0.421242E 07   32   -0.966297E 08   34    0.102124E 09   35   -0.320000E 02   36   -0.238096E 07
           37   -0.952375E 07   38    0.421243E 07

DISP  35   26    0.238094E 07   27   -0.354851E 08   28    0.952376E 07   29   -0.308750E 02   30   -0.531133E 07
           31    0.345236E 08   32    0.700000E 01   33   -0.280676E 09   34   -0.320000E 02   35    0.282599E 09
           36   -0.354853E 08   37    0.417188E 03   38    0.345233E 08

DISP  36   26   -0.137361E 06   27    0.998573E 08   28   -0.238096E 07   29   -0.234479E 09   30    0.416665E 07
           31    0.134982E 09   32   -0.421242E 07   33    0.345238E 08   34   -0.238096E 07   35   -0.354853E 08
           36    0.305177E 09   37   -0.468814E 09   38    0.164238E 09

DISP  37   26    0.238092E 07   27   -0.234479E 09   28    0.160000E 02   29    0.468476E 09   30   -0.238095E 07
           31   -0.234479E 09   32    0.952376E 07   33   -0.299125E 03   34   -0.952375E 07   35    0.417188E 03
           36   -0.468814E 09   37    0.938108E 09   38   -0.468813E 09

DISP  38   26   -0.416665E 07   27    0.134982E 09   28    0.238094E 07   29   -0.234479E 09   30    0.137361E 06
```

FIGURE III-G.16 CONTINUED

```
                                   MATRIX  STIFF /    1/                                 PAGE    5

                   CUTCFF  =    0.0                                    SIZE    38  BY    38

          FORCE                  FCRCE                 FCRCE                 FORCE                 FORCE

DISP      38    31     0.598574E 08    32     0.238095E 07    33    -0.354849E 08    34     0.421243E 07    35     0.345233E 08
                36     0.164238E 09    37    -0.468813E 09    38     0.305175E 09
```

FIGURE III-G.16 CONCLUDED

```
                                GPRINT OF MATRIX  LOADS     (SET   1)

ROW          FX                FY              FZ              MX              MY              MZ
   1    0.16669998E 02    0.0             0.0             0.0             0.0             0.0
   2    0.66659998E 02    0.0             0.0             0.0             0.0             0.0
   3    0.16669998E 02    0.0             0.0             0.0             0.0             0.0
   4    0.0               0.0             0.0             0.0             0.0             0.0
   5    0.0               0.0             0.0             0.0             0.0             0.0
   6    0.0               0.0             0.0             0.0             0.0             0.0
   7    0.0               0.0             0.0             0.0             0.0             0.0
   8    0.0               0.0             0.0             0.0             0.0             0.0
   9    0.0               0.0             0.0             0.0             0.0             0.0
  10    0.0               0.0             0.0             0.0             0.0             0.0
  11    0.0               0.0             0.0             0.0             0.0             0.0
  12    0.0               0.0             0.0             0.0             0.0             0.0
  13    0.0               0.0             0.0             0.0             0.0             0.0
  14    0.0               0.0             0.0             0.0             0.0             0.0
  15    0.0               0.0             0.0             0.0             0.0             0.0
  16    0.0               0.0             0.0             0.0             0.0             0.0
  17    0.0               0.0             0.0             0.0             0.0             0.0
  18    0.0               0.0             0.0             0.0             0.0             0.0
  19    0.0               0.0             0.0             0.0             0.0             0.0
  20    0.0               0.0             0.0             0.0             0.0             0.0
  21    0.0               0.0             0.0             0.0             0.0             0.0
  22    0.0               0.0             0.0             0.0             0.0             0.0
  23    0.0               0.0             0.0             0.0             0.0             0.0
```

FIGURE III-G.17   GPRINT OF MATRIX LOADS - LAP JOINT PROBLEM

```
                         DISPLACEMENT MATRIX FOR LOAD CONDITION    1
                                          138 X 1

ROW        U                 V                W                THETAX          THETAY          THETAZ
   1   0.13501084E-03    0.0             0.0              0.0             0.0             0.0
   2   0.13487609E-03   -0.47329797E-06  0.0              0.0             0.0             0.0
   3   0.13477041E-03   -0.94640393E-06  0.0              0.0             0.0             0.0
   4   0.10810344E-03    0.0             0.0              0.0             0.0             0.0
   5   0.10821772E-03   -0.10245358E-05  0.0              0.0             0.0             0.0
   6   0.81977443E-04    0.0             0.0              0.0             0.0             0.0
   7   0.81662176E-04   -0.38511168E-06  0.0              0.0             0.0             0.0
   8   0.81290957E-04   -0.77687406E-06  0.0              0.0             0.0             0.0
   9   0.80524303E-04   -0.10398908E-05  0.0              0.0             0.0             0.0
  10   0.79940874E-04   -0.12878181E-05  0.0              0.0             0.0             0.0
  11   0.67464265E-04    0.0             0.0              0.0             0.0             0.0
  12   0.67667250E-04   -0.44560721E-06  0.0              0.0             0.0             0.0
  13   0.67976827E-04   -0.91653959E-06  0.0              0.0             0.0             0.0
  14   0.55488752E-04    0.0             0.0              0.0             0.0             0.0
  15   0.54964505E-04   -0.30050563E-06  0.0              0.0             0.0             0.0
  16   0.54258853E-04   -0.61322083E-06  0.0              0.0             0.0             0.0
  17   0.53487762E-04   -0.10038639E-05  0.0              0.0             0.0             0.0
  18   0.52761694E-04   -0.14030793E-05  0.0              0.0             0.0             0.0
  19   0.27219023E-04   -0.94516899E-05  0.0              0.0             0.0             0.0
  20   0.26472917E-04   -0.10488505E-04  0.0              0.0             0.0             0.0
  21   0.0              -0.12465570E-04  0.0              0.0             0.0             0.0
  22   0.0              -0.12947585E-04  0.0              0.0             0.0             0.0
  23   0.0              -0.13410809E-04  0.0              0.0             0.0             0.0
```

FIGURE III-G.18 DISPLACEMENT MATRIX - LAP JOINT PROBLEM

```
                         REACTIONS AND INVERSE CHECK FOR LOAD CONDITION    1

ROW        FX              FY           FZ            MX            MY            MZ
  1    0.21563721E 00   0.88856506E 00  0.0           0.0           0.0           0.0
  2   -0.40031433E 00   0.23086548E-01  0.0           0.0           0.0           0.0
  3    0.19642639E 00  -0.62408447E-02  0.0           0.0           0.0           0.0
  4    0.26968765E 00  -0.37375946E 01  0.0           0.0           0.0           0.0
  5   -0.27252293E 00  -0.10223389E-01  0.0           0.0           0.0           0.0
  6   -0.34629154E 00  -0.72068787E 00  0.0           0.0           0.0           0.0
  7    0.60245800E 00   0.49468594E-01  0.0           0.0           0.0           0.0
  8   -0.80131531E-01  -0.17074585E-01  0.0           0.0           0.0           0.0
  9   -0.29767759E 00  -0.78125000E-02  0.0           0.0           0.0           0.0
 10    0.14369744E 00  -0.23956299E-02  0.0           0.0           0.0           0.0
 11   -0.10095596E-01  -0.35350342E 01  0.0           0.0           0.0           0.0
 12    0.54603577E-01   0.25527954E-01  0.0           0.0           0.0           0.0
 13   -0.15834808E-01  -0.21667480E-01  0.0           0.0           0.0           0.0
 14   -0.20264059E 00   0.70785980E 01  0.0           0.0           0.0           0.0
 15    0.43830109E 00  -0.23925781E-01  0.0           0.0           0.0           0.0
 16   -0.28027344E 00   0.51513672E-01  0.0           0.0           0.0           0.0
 17    0.71563721E-02  -0.31250000E-01  0.0           0.0           0.0           0.0
 18    0.43360710E-01   0.12939453E-01  0.0           0.0           0.0           0.0
 19   -0.10238647E-01  -0.17089844E-02  0.0           0.0           0.0           0.0
 20    0.11032104E-01  -0.41503906E-02  0.0           0.0           0.0           0.0
 21   -0.15227541E 02   0.36621094E-02  0.0           0.0           0.0           0.0
 22   -0.70409378E 02  -0.19531250E-01  0.0           0.0           0.0           0.0
 23   -0.14896011E 02   0.75683594E-02  0.0           0.0           0.0           0.0
```

FIGURE III-G.19 REACTION MATRIX - LAP JOINT PROBLEM

```
     S T R E S S E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                        (STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

   LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

             1                     1                  38              1    3    8    6    2    5    7    4

APPARENT ELEMENT STRESSES
STRESS           MEMBRANE   STRESS  RESULTANTS                            FLEXURAL  MOMENTS                                SHEAR
POINT     NORMAL(NX)      NORMAL(NY)       SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)       TORQUE(MXY)      NORMAL(QX)        NORMAL(QY)

   1    0.165003E 03    0.405542E 01    0.173172E 03    0.0             0.0              0.0              0.0               0.0
   2    0.158868E 03    0.225170E 01    0.169301E 03    0.0             0.0              0.0              0.0               0.0
   3    0.166522E 03    0.127961E 02    0.163610E 03    0.0             0.0              0.0              0.0               0.0
   4    0.157348E 03    0.978467E 01    0.158817E 03    0.0             0.0              0.0              0.0               0.0
   5    0.159217E 03   -0.141223E 01    0.174836E 03    0.0             0.0              0.0              0.0               0.0

ELEMENT APPLIED STRESSES
STRESS           MEMBRANE   STRESS  RESULTANTS                            FLEXURAL  MOMENTS                                SHEAR
POINT     NORMAL(NX)      NORMAL(NY)       SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)       TORQUE(MXY)      NORMAL(QX)        NORMAL(QY)

   1    0.0             0.0             0.0             0.0             0.0              0.0              0.0               0.0
   2    0.0             0.0             0.0             0.0             0.0              0.0              0.0               0.0
   3    0.0             0.0             0.0             0.0             0.0              0.0              0.0               0.0
   4    0.0             0.0             0.0             0.0             0.0              0.0              0.0               0.0
   5    0.0             0.0             0.0             0.0             0.0              0.0              0.0               0.0

NET ELEMENT STRESSES
STRESS           MEMBRANE   STRESS  RESULTANTS                            FLEXURAL  MOMENTS                                SHEAR
POINT     NORMAL(NX)      NORMAL(NY)       SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)       TORQUE(MXY)      NORMAL(QX)        NORMAL(QY)

   1    0.165003E 03    0.405542E 01    0.173172E 03    0.0             0.0              0.0              0.0               0.0
   2    0.158868E 03    0.225170E 01    0.169301E 03    0.0             0.0              0.0              0.0               0.0
   3    0.166522E 03    0.127961E 02    0.163610E 03    0.0             0.0              0.0              0.0               0.0
   4    0.157348E 03    0.978467E 01    0.158817E 03    0.0             0.0              0.0              0.0               0.0
   5    0.159217E 03   -0.141223E 01    0.174836E 03    0.0             0.0              0.0              0.0               0.0
```

FIGURE III-G.20 STRESS OUTPUT, ELEMENT NO. 1 - LAP JOINT PROBLEM

```
S T R E S S E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                    (STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

     LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

               1                      2                38              6    8   16   14    7   12   15   11


APPARENT ELEMENT STRESSES
STRESS            MEMBRANE  STRESS  RESULTANTS                           FLEXURAL  MOMENTS                                   SHEAR
POINT    NORMAL(NX)      NORMAL(NY)      SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)      TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)

    1    0.917195E 02  -0.990356E 01   0.935541E 02   0.0             0.0             0.0             0.0             0.0
    2    0.782852E 02  -0.136744E 02   0.760711E 02   0.0             0.0             0.0             0.0             0.0
    3    0.776077E 02  -0.732472E 01   0.631229E 02   0.0             0.0             0.0             0.0             0.0
    4    0.612771E 02  -0.987964E 01   0.564712E 02   0.0             0.0             0.0             0.0             0.0
    5    0.809624E 02   0.289975E 01   0.895001E 02   0.0             0.0             0.0             0.0             0.0

ELEMENT APPLIED STRESSES
STRESS            MEMBRANE  STRESS  RESULTANTS                           FLEXURAL  MOMENTS                                   SHEAR
POINT    NORMAL(NX)      NORMAL(NY)      SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)      TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)

    1    0.0            0.0            0.0            0.0             0.0             0.0             0.0             0.0
    2    0.0            0.0            0.0            0.0             0.0             0.0             0.0             0.0
    3    0.0            0.0            0.0            0.0             0.0             0.0             0.0             0.0
    4    0.0            0.0            0.0            0.0             0.0             0.0             0.0             0.0
    5    0.0            0.0            0.0            0.0             0.0             0.0             0.0             0.0

NET ELEMENT STRESSES
STRESS            MEMBRANE  STRESS  RESULTANTS                           FLEXURAL  MOMENTS                                   SHEAR
POINT    NORMAL(NX)      NORMAL(NY)      SHEAR(NXY)      NORMAL(MX)      NORMAL(MY)      TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)

    1    0.917195E 02  -0.990356E 01   0.935541E 02   0.0             0.0             0.0             0.0             0.0
    2    0.782852E 02  -0.136744E 02   0.760711E 02   0.0             0.0             0.0             0.0             0.0
    3    0.776077E 02  -0.732472E 01   0.631229E 02   0.0             0.0             0.0             0.0             0.0
    4    0.612771E 02  -0.987964E 01   0.564712E 02   0.0             0.0             0.0             0.0             0.0
    5    0.809624E 02   0.289975E 01   0.895001E 02   0.0             0.0             0.0             0.0             0.0
```

FIGURE III-G.21 STRESS OUTPUT, ELEMENT NO. 2 - LAP JOINT PROBLEM

```
          S T R E S S E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                              (STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

      LOAD CONDITION NUMBER      ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

                 1                     3                  38            8    10    18    16    9    13    17    12

APPARENT ELEMENT STRESSES
STRESS           MEMBRANE   STRESS   RESULTANTS                              FLEXURAL   MOMENTS                                     SHEAR
POINT     NORMAL(NX)        NORMAL(NY)        SHEAR(NXY)       NORMAL(MX)      NORMAL(MY)        TORQUE(MXY)       NORMAL(QX)          NORMAL(QY)

    1   0.819719E 02   -0.138233E 01     0.621751E 02     0.0            0.0             0.0              0.0              0.0
    2   0.605571E 02   -0.490894E 01     0.507861E 02     0.0            0.0             0.0              0.0              0.0
    3   0.982681E 02   -0.925603E 01     0.899258E 02     0.0            0.0             0.0              0.0              0.0
    4   0.754702E 02   -0.144495E 02     0.631821E 02     0.0            0.0             0.0              0.0              0.0
    5   0.816790E 02    0.189908E 01     0.926693E 02     0.0            0.0             0.0              0.0              0.0

ELEMENT APPLIED STRESSES
STRESS           MEMBRANE   STRESS   RESULTANTS                              FLEXURAL   MOMENTS                                     SHEAR
POINT     NORMAL(NX)        NORMAL(NY)        SHEAR(NXY)       NORMAL(MX)      NORMAL(MY)        TORQUE(MXY)       NORMAL(QX)          NORMAL(QY)

    1   0.0              0.0               0.0              0.0            0.0             0.0              0.0              0.0
    2   0.0              0.0               0.0              0.0            0.0             0.0              0.0              0.0
    3   0.0              0.0               0.0              0.0            0.0             0.0              0.0              0.0
    4   0.0              0.0               0.0              0.0            0.0             0.0              0.0              0.0
    5   0.0              0.0               0.0              0.0            0.0             0.0              0.0              0.0

NET ELEMENT STRESSES
STRESS           MEMBRANE   STRESS   RESULTANTS                              FLEXURAL   MOMENTS                                     SHEAR
POINT     NORMAL(NX)        NORMAL(NY)        SHEAR(NXY)       NORMAL(MX)      NORMAL(MY)        TORQUE(MXY)       NORMAL(QX)          NORMAL(QY)

    1   0.819719E 02   -0.138233E 01     0.621751E 02     0.0            0.0             0.0              0.0              0.0
    2   0.605571E 02   -0.490894E 01     0.507861E 02     0.0            0.0             0.0              0.0              0.0
    3   0.982681E 02   -0.925603E 01     0.899258E 02     0.0            0.0             0.0              0.0              0.0
    4   0.754702E 02   -0.144495E 02     0.631821E 02     0.0            0.0             0.0              0.0              0.0
    5   0.816790E 02    0.189908E 01     0.926693E 02     0.0            0.0             0.0              0.0              0.0
```

FIGURE III-G.22 STRESS OUTPUT, ELEMENT NO. 3 - LAP JOINT PROBLEM

```
                 S T R E S S E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                                   (STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE       ELEMENT GRID POINTS

                1                      4                  38              16    18    23    21    17    20    22    19


APPARENT ELEMENT STRESSES                                                FLEXURAL  MOMENTS                                  SHEAR
STRESS             MEMBRANE   STRESS   RESULTANTS
POINT     NORMAL(NX)       NORMAL(NY)       SHEAR(NXY)       NORMAL(MX)       NORMAL(MY)       TORQUE(MXY)       NORMAL(QX)       NORMAL(QY)

    1    0.165465E 03     0.125452E 02     0.173666E 03     0.0              0.0              0.0               0.0              0.0
    2    0.159954E 03     0.925061E 01     0.172278E 03     0.0              0.0              0.0               0.0              0.0
    3    0.160728E 03     0.445972E 01     0.172626E 03     0.0              0.0              0.0               0.0              0.0
    4    0.164694E 03     0.280769E 01     0.177967E 03     0.0              0.0              0.0               0.0              0.0
    5    0.159926E 03    -0.178857E 01     0.174074E 03     0.0              0.0              0.0               0.0              0.0


ELEMENT APPLIED STRESSES                                                 FLEXURAL  MOMENTS                                  SHEAR
STRESS             MEMBRANE   STRESS   RESULTANTS
POINT     NORMAL(NX)       NORMAL(NY)       SHEAR(NXY)       NORMAL(MX)       NORMAL(MY)       TORQUE(MXY)       NORMAL(QX)       NORMAL(QY)

    1    0.0              0.0              0.0              0.0              0.0              0.0               0.0              0.0
    2    0.0              0.0              0.0              0.0              0.0              0.0               0.0              0.0
    3    0.0              0.0              0.0              0.0              0.0              0.0               0.0              0.0
    4    0.0              0.0              0.0              0.0              0.0              0.0               0.0              0.0
    5    0.0              0.0              0.0              0.0              0.0              0.0               0.0              0.0


NET ELEMENT STRESSES                                                     FLEXURAL  MOMENTS                                  SHEAR
STRESS             MEMBRANE   STRESS   RESULTANTS
POINT     NORMAL(NX)       NORMAL(NY)       SHEAR(NXY)       NORMAL(MX)       NORMAL(MY)       TORQUE(MXY)       NORMAL(QX)       NORMAL(QY)

    1    0.165465E 03     0.125452E 02     0.173666E 03     0.0              0.0              0.0               0.0              0.0
    2    0.159954E 03     0.925061E 01     0.172278E 03     0.0              0.0              0.0               0.0              0.0
    3    0.160728E 03     0.445972E 01     0.172626E 03     0.0              0.0              0.0               0.0              0.0
    4    0.164694E 03     0.280769E 01     0.177967E 03     0.0              0.0              0.0               0.0              0.0
    5    0.159926E 03    -0.178857E 01     0.174074E 03     0.0              0.0              0.0               0.0              0.0
```

FIGURE III-G.23 STRESS OUTPUT, ELEMENT NO. 4 - LAP JOINT PROBLEM

```
          F O R C E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                     (THE FIRST FOUR POINTS ARE CORNER POINTS AND THE LAST FOUR POINTS ARE MID-POINTS)

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE       ELEMENT GRID POINTS

                1                      1                  38             1    3    8    6    2    5    7

APPARENT ELEMENT FORCES
POINT                            FORCES                                                       MOMENTS
             FX                    FY                  FZ                 MX                   MY                  MZ

  1      0.16864990E 02     0.88940430E 00     0.0                0.0                  0.0                 0.0
  2      0.16852295E 02    -0.70800781E-02     0.0                0.0                  0.0                 0.0
  3     -0.35993652E 02     0.16681412E 02     0.0                0.0                  0.0                 0.0
  4     -0.57014160E 01    -0.98017578E 01     0.0                0.0                  0.0                 0.0
  5      0.66263809E 02     0.22216797E-01     0.0                0.0                  0.0                 0.0
  6     -0.28125000E 00    -0.99036507E-02     0.0                0.0                  0.0                 0.0
  7     -0.58522217E 02    -0.40375977E 01     0.0                0.0                  0.0                 0.0
  8      0.28125000E 00    -0.37381649E 01     0.0                0.0                  0.0                 0.0

ELEMENT APPLIED FORCES
POINT                            FORCES                                                       MOMENTS
             FX                    FY                  FZ                 MX                   MY                  MZ

  1      0.0                0.0                0.0                0.0                  0.0                 0.0
  2      0.0                0.0                0.0                0.0                  0.0                 0.0
  3      0.0                0.0                0.0                0.0                  0.0                 0.0
  4      0.0                0.0                0.0                0.0                  0.0                 0.0
  5      0.0                0.0                0.0                0.0                  0.0                 0.0
  6      0.0                0.0                0.0                0.0                  0.0                 0.0
  7      0.0                0.0                0.0                0.0                  0.0                 0.0
  8      0.0                0.0                0.0                0.0                  0.0                 0.0

NET ELEMENT FORCES
POINT                            FORCES                                                       MOMENTS
             FX                    FY                  FZ                 MX                   MY                  MZ

  1      0.16864990E 02     0.88940430E 00     0.0                0.0                  0.0                 0.0
  2      0.16852295E 02    -0.70800781E-02     0.0                0.0                  0.0                 0.0
  3     -0.35993652E 02     0.16681412E 02     0.0                0.0                  0.0                 0.0
  4     -0.57014160E 01    -0.98017578E 01     0.0                0.0                  0.0                 0.0
  5      0.66263809E 02     0.22216797E-01     0.0                0.0                  0.0                 0.0
  6     -0.28125000E 00    -0.99036507E-02     0.0                0.0                  0.0                 0.0
  7     -0.58522217E 02    -0.40375977E 01     0.0                0.0                  0.0                 0.0
  8      0.28125000E 00    -0.37381649E 01     0.0                0.0                  0.0                 0.0
```

FIGURE III-G.24 FORCE OUTPUT, ELEMENT NO. 1 - LAP JOINT PROBLEM

```
          F O R C E S   F O R   T H E   H I G H   A S P E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                     (THE FIRST FOUR POINTS ARE CORNER POINTS AND THE LAST FOUR POINTS ARE MID-POINTS)

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE      ELEMENT GRID POINTS

               1                       2                  38            6    8   16   14    7   12   15   11

APPARENT ELEMENT FORCES
POINT                              FORCES                                                    MOMENTS
                 FX                  FY                  FZ                  MX                  MY                  MZ

   1      0.53361816E 01    0.90810547E 01    0.0                 0.0                 0.0                 0.0
   2     -0.11475586E 02   -0.13504669E 02    0.0                 0.0                 0.0                 0.0
   3     -0.46917236E 02   -0.30122070E 01    0.0                 0.0                 0.0                 0.0
   4     -0.21386719E 00    0.70776367E 01    0.0                 0.0                 0.0                 0.0
   5      0.59134613E 02    0.40854492E 01    0.0                 0.0                 0.0                 0.0
   6     -0.64804688E 01   -0.16737771E 00    0.0                 0.0                 0.0                 0.0
   7      0.44508964E 00   -0.24169922E-01    0.0                 0.0                 0.0                 0.0
   8      0.0              -0.35355539E 01    0.0                 0.0                 0.0                 0.0

ELEMENT APPLIED FORCES
POINT                              FORCES                                                    MOMENTS
                 FX                  FY                  FZ                  MX                  MY                  MZ

   1      0.0               0.0               0.0                 0.0                 0.0                 0.0
   2      0.0               0.0               0.0                 0.0                 0.0                 0.0
   3      0.0               0.0               0.0                 0.0                 0.0                 0.0
   4      0.0               0.0               0.0                 0.0                 0.0                 0.0
   5      0.0               0.0               0.0                 0.0                 0.0                 0.0
   6      0.0               0.0               0.0                 0.0                 0.0                 0.0
   7      0.0               0.0               0.0                 0.0                 0.0                 0.0
   8      0.0               0.0               0.0                 0.0                 0.0                 0.0

NET ELEMENT FORCES
POINT                              FORCES                                                    MOMENTS
                 FX                  FY                  FZ                  MX                  MY                  MZ

   1      0.53361816E 01    0.90810547E 01    0.0                 0.0                 0.0                 0.0
   2     -0.11475586E 02   -0.13504669E 02    0.0                 0.0                 0.0                 0.0
   3     -0.46917236E 02   -0.30122070E 01    0.0                 0.0                 0.0                 0.0
   4     -0.21386719E 00    0.70776367E 01    0.0                 0.0                 0.0                 0.0
   5      0.59134613E 02    0.40854452E 01    0.0                 0.0                 0.0                 0.0
   6     -0.64804688E 01   -0.16737771E 00    0.0                 0.0                 0.0                 0.0
   7      0.44508964E 00   -0.24169922E-01    0.0                 0.0                 0.0                 0.0
   8      0.0              -0.35355539E 01    0.0                 0.0                 0.0                 0.0
```

FIGURE III-G.25 FORCE OUTPUT, ELEMENT NO. 2 - LAP JOINT PROBLEM

```
           F O R C E S   F O R   T H E   H I G H   A S F E C T   R A T I O   Q U A D R I L A T E R A L   E L E M E N T
                     (THE FIRST FCLR FCINTS AFE CCFNEF PCINTS ANC THE LAST FOUR POINTS ARE MID-POINTS)

     LOAD CONDITION NUMBER     ELEMENT NLMBER     ELEMENT TYPE      ELEMENT GRID POINTS

               1                    3                  38            8   10   18   16    9   13   17   12

APPARENT ELEMENT FORCES
POINT                            FORCES                                                     MOMENTS
             FX                    FY                  FZ                 MX                  MY                 MZ

  1       0.47354660E 02      -0.31923780E C1      0.0                 0.0                 C.0                 0.C
  2       0.12687969E 00      -0.31375885E-C2      0.0                 0.0                 0.0                 0.C
  3      -0.20855637E 02      -0.95370646E C1      0.0                 0.0                 C.0                 0.C
  4       0.25125061E 02       0.18111542E C2      0.0                 0.0                 0.0                 0.0
  5      -0.29732704E C0      -C.84157214E-C2      0.0                 0.0                 0.0                 0.C
  6      -0.23437500E-01      -0.21057129E-C1      0.0                 0.0                 C.0                 0.0
  7      -0.58130890E 02      -0.55389290E 01      0.0                 0.0                 0.0                 0.0
  8       0.65273438E 01       0.19206238E C0      0.0                 0.0                 C.0                 0.0

ELEMENT APPLIED FORCES
POINT                            FCRCES                                                     MOMENTS
             FX                    FY                  FZ                 MX                  MY                 MZ

  1       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  2       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  3       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  4       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  5       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  6       0.0                  0.0                 0.0                 0.0                 0.0                 0.0
  7       0.0                  0.0                 0.0                 0.0                 0.0                 0.C
  8       0.0                  0.0                 0.0                 0.0                 C.0                 0.0

NET ELEMENT FORCES
POINT                            FORCES                                                     MOMENTS
             FX                    FY                  FZ                 MX                  MY                 MZ

  1       0.47354660E 02      -0.31923780E 01      0.0                 0.0                 C.0                 0.0
  2       0.12687969E 00      -0.31375885E-02      0.0                 0.0                 C.0                 0.0
  3      -0.20855637E 02      -0.95370646E 01      0.0                 0.0                 0.0                 0.0
  4       0.25125061E 02       0.18111542E C2      0.0                 0.0                 C.0                 0.0
  5      -0.29732704E 00      -0.84157214E-02      0.0                 0.0                 C.0                 0.0
  6      -0.23437500E-01      -C.21057129E-C1      0.0                 0.0                 C.0                 0.0
  7      -0.58130890E 02      -0.55389290E 01      0.0                 0.0                 C.0                 0.C
  8       0.65273438E 01       0.19206238E 00      0.0                 0.0                 0.0                 0.0
```

FIGURE III-G.26 FORCE OUTPUT, ELEMENT NO. 3 - LAP JOINT PROBLEM

```
                    FORCES FOR THE HIGH ASPECT RATIO QUADRILATERAL ELEMENT
            (THE FIRST FOUR POINTS ARE CORNER POINTS AND THE LAST FOUR POINTS ARE MID-POINTS)

      LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE       ELEMENT GRID POINTS

                1                      4                30            16   18   23   21   17   20   22   19

APPARENT ELEMENT FORCES
POINT                          FORCES                                          MOMENTS
              FX                 FY                 FZ                 MX                 MY                 MZ

   1      0.21474731E 02    -0.15047119E 02    0.0                0.0                0.0                0.0
   2      0.20874466E 02     0.95520020E 01    0.0                0.0                0.0                0.0
   3     -0.14901428E 02     0.16113281E-01    0.0                0.0                0.0                0.0
   4     -0.15232101E 02     0.14160156E-01    0.0                0.0                0.0                0.0
   5      0.98146286E 02     0.54939568E 01    0.0                0.0                0.0                0.0
   6      0.10498047E-01    -0.31738281E-02    0.0                0.0                0.0                0.0
   7     -0.70403564E 02    -0.31596590E-01    0.0                0.0                0.0                0.0
   8     -0.97656250E-02    -0.19531250E-02    0.0                0.0                0.0                0.0

ELEMENT APPLIED FORCES
POINT                          FORCES                                          MOMENTS
              FX                 FY                 FZ                 MX                 MY                 MZ

   1      0.0                0.0                0.0                0.0                0.0                0.0
   2      0.0                0.0                0.0                0.0                0.0                0.0
   3      0.0                0.0                0.0                0.0                0.0                0.0
   4      0.0                0.0                0.0                0.0                0.0                0.0
   5      0.0                0.0                0.0                0.0                0.0                0.0
   6      0.0                0.0                0.0                0.0                0.0                0.0
   7      0.0                0.0                0.0                0.0                0.0                0.0
   8      0.0                0.0                0.0                0.0                0.0                0.0

NET ELEMENT FORCES
POINT                          FORCES                                          MOMENTS
              FX                 FY                 FZ                 MX                 MY                 MZ

   1      0.21474731E 02    -0.15047119E 02    0.0                0.0                0.0                0.0
   2      0.20874466E 02     0.95520020E 01    0.0                0.0                0.0                0.0
   3     -0.14901428E 02     0.16113281E-01    0.0                0.0                0.0                0.0
   4     -0.15232101E 02     0.14160156E-01    0.0                0.0                0.0                0.0
   5      0.58146286E 02     0.54939508E 01    0.0                0.0                0.0                0.0
   6      0.10498047E-01    -0.31738281E-02    0.0                0.0                0.0                0.0
   7     -0.70403564E 02    -0.31596590E-01    0.0                0.0                0.0                0.0
   8     -0.97656250E-02    -0.19531250E-02    0.0                0.0                0.0                0.0
```

FIGURE III-G.27 FORCE OUTPUT, ELEMENT NO. 4 - LAP JOINT PROBLEM

H. TRIANGULAR RING ASYMMETRIC LOADING (THICK WALLED DISC)

A thick walled disc was analyzed to determine its response to typical asymmetric pressure and thermal loadings. The dimensions of the disc, its pertinent material properties and the subsequent three element idealization are pictured in Figure III-H.1.

Individual analyses of the disc were carried out for the pressure and thermal loadings respectively. The input and output for the pressure loading will be discussed first. Changes in the input and output brought about by application of the thermal loading will be discussed later in this section. Both the applied pressure and thermal loads chosen possessed the same variation (1 + cos 2θ) in the circumferential coordinate θ. This variation was chosen because it could be described exactly by the MAGIC III program utilizing the (0) and (+2) harmonics.

Asymmetric Pressure Loading

The preprinted input data forms associated with the asymmetric pressure load problem are shown in Figures III-H.2 through III-H.9. The input illustrated in Figures III-H.2 through III-H.7 is completed in a similar manner as that provided for the Axisymmetric Triangular Ring Element (See Reference 5). The only noteable difference between the two elements (Axi and Asymmetric Triangular Ring) being in the input linked to the external loading conditions.

As has been previously indicated (See Section II.C) the difference in manner ofinput for external loads is quite large between the Axisymmetric and Asymmetric Triangular Ring Elements. Input options specialized and linked to the former must be abandoned when utilizing the Asymmetric Triangular Ring Element. Examples of the options to be ignored in this instance are the Temperature Interpolate Option and Pressure Suppression Options of the Axisymmetric Triangular Ring (See Sections II.C.8).

The only element of the Thick Walled Disc assumed loaded (See Figures III-H.1 and III-H.8) is element number 1. This loading was assumed acting radially outward and possessed a circumferential (1 + cos 2θ) variation.

The Asymmetric Pressure Load Input is accomplished through the form illustrated in Figure III-H.8. The first entry on the form is prelabeled HARM, and requires no input from the user. The second entry on the form contains the information that our problem includes:

a) one loaded element,
b) a maximum of two harmonics will be chosen to represent the loading on the element,
c) and a maximum of two harmonics are to be used for the analysis of the thick walled disc.

The third entry on the form provides that:

a) the loaded element is Element Number One,
b) it is loaded in the radial direction only and (36) values of the loading at equally spaced intervals are being provided,
c) and finally the actual values at these 36 intervals are input.

Designation of points about the structure, in this case the Thick Walled Disc, where output of stresses and displacements are to be provided is accomplished by the form illustrated in Figure III-H.9. The first entry on the form is prelabeled HSDC and requires no input from the user. The second entry on the form provides that output of stresses and displacements will be provided over the entire circumference of the Thick Walled Disc (360°) at (30°) intervals.

A sampling of the output derived from the analysis of the previously described Thick Walled Disc under the Asymmetric Radial Pressure Loading is presented and discussed. Reference should be made to Figures III-H.10 through III-H.19.

Figures III-H.10, III-H.11 and III-H.12 present typical element data output of pertinent material data, gridpoint coordinates, boundary conditions and element definitions (for Elements 1 and 2). This output is consistent with that presented for the Axisymmetric ring element.

The output presented in Figures III-H.13 and III-H.14 describes the asymmetric loading applied to the thick walled disc. Figure III-H.13 confirms that a radial loading has been placed on Element No. (1), that a limit of two harmonics describing the loading has been set and also presents the 36 circumferential values of the radial load used to describe the loading. Figure III-H.14 presents the harmonic loads which result from the Fourier decomposition, carried out automatically by the MAGIC III Program, of the loading defined in Figure III-H.13. In the question of the Thick Walled Disc under consideration, the program has determined that the radial loading on Element (1) for a given circumferential location (θ) can be expressed as follows (with reference to Figure H.14)

$$P_{r_1}(\theta) = - \left\{ 100.027 + 98.9766 \text{ Cos } 2\,\theta \right\} \qquad (1)$$

Referencing Sections III-C.8f, it is evident that complete two dimensional analyses for the (m = 0) and (m = +2) harmonics are required to carry out the analysis of the Thick Walled Disc. This envolves the MAGIC III program assembling structure stiffness matrices for the (m = 0) and (m = +2) harmonics. Figures III-H.15 a and b provide the element (for Element #1) harmonic stiffness and load matrices for harmonics (m = 0) and (m = +2) which are used in assembling the structure (Disc) stiffness and load matrices.

Figures III-H.16a and b present the harmonic stresses (for m = 0 and m = +2) for Element #1 which result from the above analyses. The harmonic stresses presented in these two figures can be combined as shown below to evaluate the stress in Element #1 at a centroidal location (cross-section) and at an arbitrary circumferential location θ.

$$\begin{bmatrix} \sigma_{rr_1}(\theta) \\ \sigma_{zz_1}(\theta) \\ \sigma_{\theta\theta_1}(\theta) \\ \sigma_{rz_1}(\theta) \\ \sigma_{r\theta_1}(\theta) \\ \sigma_{z\theta_1}(\theta) \end{bmatrix} = \begin{bmatrix} -75.384766 \\ 3.0233459 \\ -163.20439 \\ -\ 7.5593872 \\ 0 \\ 0 \end{bmatrix} + \left[C_2(\theta) \right] \begin{bmatrix} -111.55794 \\ -\ 10.439285 \\ -\ 458.28198 \\ 25.463989 \\ 101.23071 \\ -\ 3.4822311 \end{bmatrix} \qquad (2)$$

The matrix C_2 (θ) is the diagonal matrix

$$\lceil C_2\ (\theta) \rfloor = \lceil \text{Cos } 2\theta,\ \text{Cos } 2\theta,\ \text{Cos } 2\theta,\ \text{Cos } 2\theta,\ \text{Sin } 2\theta, \text{Sin } 2\theta \rfloor. \quad (3)$$

Expressions similar to that given by Equation (2) above can be obtained for the displacements and reactions at the nodes of Element #1 for an arbitrary circumferential location θ.

The expressions for the circumferentially varying displacements, reactions and stresses of the nodes (and consequently elements) which define the Thick Walled Disc were evaluated in accordance with the information provided on the HSDC form (Figure III-H.9) by the MAGIC III Program. Displacements, reactions and stresses were consequently provided for all elements at 30° intervals completely around the structure. Figures III-H.17 and III-H.18 provide the displacements and reactions for all five of the structures nodes for two selected circumferential positions ($\theta = 0°$ and $\theta = 60°$). Figure III-H.19 provides the stresses at the centroid of Element 1 for all 12 specified locations.

Asymmetric Thermal Loading

The Thick Walled Disc was analyzed to determine the effects of an applied asymmetric thermal loading. The loading possessed an (1 + Cos 2θ) circumferential variation in magnitude and varied non-linearly through the cross-section.

The asymmetric temperature load input for this test case is accomplished through the form illustrated in Figures III-H.20 a and b. The first entry on the form is prelabeled HTEM, and requires no input from the user. The second entry on the form contains the information that the test case includes:

a) three elements loaded by asymmetric temperature distributions,

b) a maximum of two harmonics to be chosen to represent the thermal loadings on the elements,

c) and a maximum of two harmonics to be used for the analysis of the thick walled disc.

The following three entries in Figures III-H.20 a and b provide

a) the numbers of the three loaded elements,

b) the information that (36) values of the loadings will be provided for each of the three elements,

c) and the values of these loadings at (36) intervals for the three loaded elements.

The thermal run is accomplished by substituting the HTEM input for the HARM input provided earlier (Figure III-H.8) and providing the remainder of the input as before. The input for the case of the asymmetrically loaded Thick Walled Disc is reviewed by Figure III-H.21. Selected output from the MAGIC III Program is provided for this analysis in Figure III-H 22 through Figure III-H.26.

Figure III-H.22 describes the asymmetric thermal loading applied to Element (1). The values provided in this figure which comprise the loading must be interpreted as <u>changes in temperature</u> to which the element is subjected at varying circumferential locations. These temperature changes can be imagined as occurring at the centroid of the element cross-section. Figure III-H.23 presents the harmonic loads (coefficients) which result from the Fourier decomposition, carried out automatically by the MAGIC III program, of the loading defined in Figure III-H.22.

Figures III-H.24 a and b present the net harmonic stresses (coefficients in the Fourier series which represent the net stresses on Element 1) for harmonics $m = 0$ and $m = +2$. The net stress of Element 1 can be expressed in the following Fourier series form

$$\{\sigma\} = \{\sigma_0\} + \sum_m \lceil C_{0m} \rfloor + \sum_m \lceil \bar{C}_{0m} \rfloor \{\bar{\sigma}_m\} \tag{4}$$

where the diagonal matrices $\lceil C_{0m} \rfloor$ and $\lceil \bar{C}_{0m} \rfloor$ appear as

$$\lceil C_{0m} \rfloor = \lceil \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta \rfloor \tag{5}$$

and

$$\lceil \bar{C}_{0m} \rfloor = \lceil \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta \rfloor .$$

The net harmonic stress for the A-series, m^{th} harmonic can be expressed as

$$\{\sigma_m\} = [\ \text{E}\ ]\{\epsilon_m\} \quad - \{\text{SZAEL } (m)\} \tag{6}$$

where

$$[\ \text{E}\ ]\{\epsilon_m\} = \underline{\text{harmonic}} \text{ apparent element stress,} \tag{7}$$

and

$$\{\text{SZAEL } (m)\} = \text{harmonic element applied stress.} \tag{8}$$

The vector $\{SZAEL(m)\}$ is a harmonic stress coefficient correction vector for any element possessing an applied asymmetric (or axisymmetric) temperature load. $\{SZAEL(m)\}$ is calculated as follows (for the A series, m^{th} harmonic):

$$\{SZAEL(m)\} = T(m)\,[E]\,\{\alpha\} \tag{9}$$

where $[E]$ is the material property matrix which has the form

$$[E] = \frac{1}{\Delta}\begin{bmatrix} E_r(1-\nu_{\theta z}\nu_{z\theta}), & E_r(\nu_{zr}+\nu_{z\theta}\nu_{\theta r}); & E_r(\nu_{\theta r}+\nu_{zr}\nu_{\theta z}); & 0 & ; & 0 & ; & 0 \\ & E_z(1-\nu_{r\theta}\nu_{\theta r}); & E_\theta(\nu_{z\theta}+\nu_{r\theta}\nu_{zr}); & 0 & ; & 0 & ; & 0 \\ & & E_\theta(1-\nu_{rz}\nu_{zr}); & 0 & ; & 0 & ; & 0 \\ & & & \Delta G_{rz} & ; & 0 & ; & 0 \\ & & & & & \Delta G_{r\theta} & ; & 0 \\ & & & & & & & \Delta G_{z\theta} \end{bmatrix} \tag{10}$$

and where $\Delta = (1-\nu_{r\theta}\nu_{\theta r}-\nu_{\theta z}\nu_{z\theta}-\nu_{zr}\nu_{rz}-\nu_{r\theta}\nu_{\theta z}\nu_{zr}-\nu_{rz}\nu_{\theta r}\nu_{z\theta})$.

The matrix $[E]$ for the Thick Walled Disc (which is constructed using an isotropic material) is

$$[E]=\frac{E}{\Delta}\left[\begin{array}{cccccc} 1-\nu^2 ; & \nu(1+\nu) ; & \nu(1+\nu) ; & 0 ; & 0 ; & 0 \\ & (1-\nu^2) ; & \nu(1+\nu) ; & 0 ; & 0 ; & 0 \\ & & (1-\nu^2) ; & 0 ; & 0 ; & 0 \\ & & & \frac{\Delta}{2(1+\nu)} ; & 0 ; & 0 \\ & & & & \frac{\Delta}{2(1+\nu)} ; & 0 \\ & & & & & \frac{\Delta}{2(1+\nu)} \end{array}\right] \qquad (12)$$

where $\Delta = 1 - 3\nu^2 - 2\nu^3$. (13)

The thermal coefficient vector for the Thick Walled Disc (isotropic material) is

$$\{\alpha\}^T = \lfloor \alpha, \alpha, \alpha, 0, 0, 0 \rfloor \qquad (14)$$

The properties utilized in the analysis (Figure III-H.21) are defined below

$$
\begin{aligned}
E &= 30 \times 10^{6} && \text{a)}\\
\nu &= 0.3 && \text{b)}\\
\alpha &= 6 \times 10^{-6} && \text{c)}
\end{aligned}
\qquad (15)
$$

The scalor $T(m)$ is the harmonic temperature (coefficient in the Fourier series representing the applied asymmetric temperature loading on the element) and assumes the following values for harmonics $m = 0$ and $m = +2$ for Element of the Thick Walled Disc (see Figure III-H.23).

$$
\begin{aligned}
T\,(0) &= 353.526\\
T\,(+2) &= 349.965
\end{aligned}
\qquad (16)
$$

The vector $\{SZAEL(m)\}$ for an isotropic material can be expressed as

$$
\{SZAEL\,(m)\} = \begin{bmatrix} \sigma_{\beta m} \\ \sigma_{\beta m} \\ \sigma_{\beta m} \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad (17)
$$

where

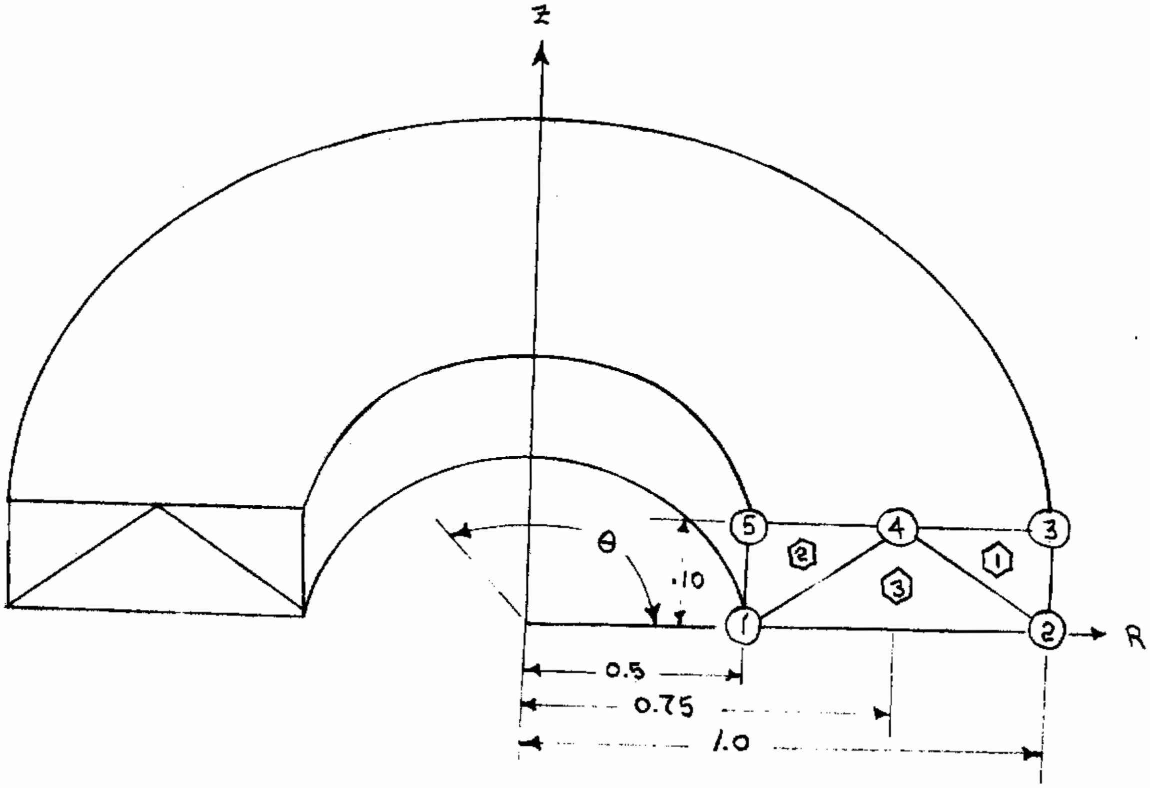
$$
\sigma_{\beta m} = \frac{(1+\nu)^{2}}{1 - 3\nu^{2} - 2\nu^{3}}\, E\, \alpha\, T_{m} \quad . \qquad (18)
$$

Evaluating Equation III-H.18 for harmonics $m = 0$, $m = +2$ for Element Number 1 of the Thick Walled Disc:

$$
\begin{aligned}
\sigma_{\beta}(0) &= .15908656 \text{ E } 06 && \text{a)}\\
\sigma_{\beta}(+2) &= .15748388 \text{ E } 06 && \text{b)}
\end{aligned}
\qquad (19)
$$

The quantities $\sigma_{\beta}(0)$ and $\sigma_{\beta}(+2)$ appear as harmonic element applied stresses in Figures III-H.24 a and b.

The displacements for the 5 nodes of the Thick Walled Disc are provided for $\theta = 0^\circ$ and $\theta = 60^\circ$ (Figures III-H.25 a and b). The net stress distribution in Element 1 is provided in Figure III-H.26.



$E = 3.0 \times 10^{7}$ PSI

$\mu = 0.3$

$\alpha = 6.0 \times 10^{-6}$

FIGURE III-H.1 IDEALIZED THICK WALLED DISC

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

1 2 3 4 5 6
TITLE (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

7 8 9
1 (/) NUMBER OF TITLE CARDS

1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7 8 9 50 1 2 3 4 5 6 7 8 9 60 1 2 3 4 5 6 7 8 9 70 1 2

THICK WALLED DISC SUBJECTED TO NON-AXISYMMETRIC LOADING (/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

FIGURE III-H.2 TITLE INFORMATION, THICK WALLED DISC

BAC 1616-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

M	A	T	E	R	
1	2	3	4	5	6

(/)

		1
7	8	9

No. of Requests (/)

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	12	TM	STEEL E=30E6,MU=0.3	X									1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	6.0 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

)

FIGURE III-H.3 MATERIAL TAPE INPUT, THICK WALLED DISC

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	SYSTEM	1 2 3 4 5 6	(/)
1. Number of System Grid Points	5	1 2 3 4 5 6	
2. Number of Input Grid Points	5	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	3	13 14	
4. Number of Load Conditions	0	15 16	
5. Number of Initially Displaced Grid Points	0	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	0	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	0	29 30	
8. Number of Elements	3	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	1	37 38	
10. Number of Input Boundary Condition Points	5	39 40 41 42 43 44	
11. T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52	(/)

FIGURE III-H.4 SYSTEM CONTROL INFORMATION, THICK WALLED DISC

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
C	O	O	R	D		(/)

GRIDPOINT COORDINATES

S		Grid Point Number	DIRECTIONS			
			X – R	Y – θ	Z – Z	
5	6	7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
		1	0.50	0.0	0.0	(/)
		2	1.00	0.0	0.0	(/)
		3	1.00	0.0	0.1	(/)
		4	0.75	0.0	0.1	(/)
		5	0.50	0.0	0.1	(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)
						(/)

FIGURE III-H.5 GRIDPOINT COORDINATES, THICK WALLED DISC

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6
B	O	U	N	D	

(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
									(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		1	1	1							(/)
				2		1	1	1							(/)
				3		1	1	1							(/)
				4		1	1	1							(/)
				5		1	1	0							(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-H.6 BOUNDARY CONDITIONS, THICK WALLED DISC

BAC 1628

E	L	E	M			
1	2	3	4	5	6	(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	No. of Assem. Nodes	NODE POINTS												
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	31	12							X	3		2	3	4										(/)
2	31	12							X	3		1	4	5										(/)
3	31	12							X	3		1	2	4										(/)
																								(/)
																								(/)
																								(/)
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																								(/)
																								(/)
																								(/)
																								(/)
																								(/)

FIGURE III-H.7 ELEMENT CONTROL DATA, THICK WALLED DISC

1	2	3	4
H	A	R	M

(/)

NUMBER OF ELEMENTS 7 8 9	No. OF HARMONICS PER ELEMENT 10	No. OF HARMONICS REQUESTED 11
1	2	2

(/)

ELEMENT ID	REPEAT ELEMENT LOADING OPTION	NUMBER OF RADIAL LOADING POINTS	NUMBER OF AXIAL LOADING POINTS	HARMONIC PRESSURE LOAD VALUES					
7 8 9	10	11 12 13	14 15 16	17	27	37	47	57	67
1		36		-200.00	-193.97	176.60	-150.00	-117.37	-82.62
				-50.00	-23.40	-6.03	-0.00	-6.03	-23.40
				-50.00	-82.63	-117.37	-150.00	-176.60	-193.97
				-200.00	-193.97	-176.60	-150.00	-117.37	-83.63
				-50.00	-23.40	-6.03	-0.00	-6.03	-23.40
				-50.00	-82.63	-117.37	-150.00	-176.60	-193.97

FIGURE III-4.8 HARMONIC PRESSURE LOAD INPUT, THICK WALLED DISK

BAC 2060

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)
HARMONIC INCREMENTS

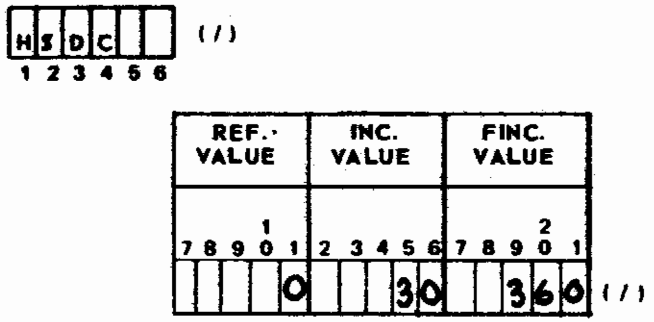

FIGURE III-H.9 DESIGNATION OF STRESS AND DISPLACEMENT OUTPUT LOCATIONS; THICK WALLED DISC

```
                THICK WALLED DISC SUBJECTED TO NON-AXISYMMETRIC LOADING

                             REVISIONS OF MATERIAL TAPE

                           ASTERISK (*) PRECEEDING MATERIAL
                           IDENTIFICATION INDICATES THAT INPUT
                           ERROR RETURNS WILL NOT RESULT IN
                               TERMINATION OF EXECUTION


***************************************************************************************************

   REVISION
     MATERIAL NUMBER      12
     MATERIAL IDENTIFICATION  STEEL - E=30E6, MU=0.3           INPUT CODE    I
       NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
       NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
       MASS DENSITY. . . . . . . . . . . . . . . 0.49999985E-03

     MATERIAL PROPERTIES


                   YOUNG'S MODULI                           POISSON'S RATIOS

                          DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                   XX            YY            ZZ              XY            YZ            ZX
    0.0       0.300000E 08  0.300000E 08  0.300000E 08    0.300000E 00  0.300000E 00  0.300000E 00

                   TH. EXP.COEF.                            RIGIDITY MODULI

                          DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                   XX            YY            ZZ              XY            YZ            ZX
    0.0       0.600000E-05  0.600000E-05  0.600000E-05    0.115385E 08  0.115385E 08  0.115385E 08

***************************************************************************************************
```

FIGURE III-H.10 TITLE AND MATERIAL DATA OUTPUT, THICK WALLED DISC

```
                                                  5 REF. POINTS

      NO. DIRECTIJNS  =     3      NO. DEGREES OF FREEDCM =    1


                                                 GRIDPOINT DATA
                                           (IN RECTANGULAR COORDINATES)

POINT        X                    Y                  Z                 TEMPERATURES          PRESSURES
  1    0.50000000E 00     0.0                 0.0               0.0                  0.0
                                                                0.0                  0.0
                                                                0.0                  0.0
  2    0.1C000000E 01     0.0                 0.0               0.0                  0.0
                                                                0.0                  0.0
                                                                0.0                  0.0
  3    0.10000000E 01     0.0                 0.99999964E-01    0.0                  0.0
                                                                0.0                  0.0
                                                                0.0                  0.0
  4    0.75C00000E 00     0.0                 0.99999964E-01    0.0                  0.0
                                                                0.0                  0.0
                                                                0.0                  0.0
  5    0.50000000E 00     0.0                 0.99999964E-01    0.0                  0.0
                                                                0.0                  0.0
                                                                0.0                  0.0


                                        BOUNDARY CCNDITICN INFORMATION

       NODES                    DEGREES CF FREEDOM                          NO. OF JNES    NO. OF TWOS

        1          1      1      1                                               3              0
        2          1      1      1                                               6              0
        3          1      1      1                                               9              0
        4          1      1      1                                              12              0
        5          1      1      0                                              14              0
```

FIGURE III-H.11 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, THICK WALLED DISC

```
ELEM TYPE  MAT.NO. CODE    TEMP.    PRNT  NO.     --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  31        12    0  0.0          2     3     2   3   4

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, MU=0.3
      ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
      INPUT PRINT CODE . . . . . . . . 1
      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        0.0
      YOUNG'S MODULI          0.30000000E 08        0.30000000E 08        0.30000000E 08
      POISSON'S RATIO         0.29999995E 00        0.29999995E 00        0.29999995E 00
      TH. EXP. COEF.          0.59999993E-05        0.59999993E-05        0.59999993E-05
      RIGIDITY MODULI         0.11538468E 08        0.11538468E 08        0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
      NONE


ELEM TYPE  MAT.NO. CODE    TEMP.    PRNT  NO.     --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  31        12    0  0.0          2     3     1   4   5

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, MU=0.3
      ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
      INPUT PRINT CODE . . . . . . . . 1
      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        0.0
      YOUNG'S MODULI          0.30000000E 08        0.30000000E 08        0.30000000E 08
      POISSON'S RATIO         0.29999995E 00        0.29999995E 00        0.29999995E 00
      TH. EXP. COEF.          0.59999993E-05        0.59999993E-05        0.59999993E-05
      RIGIDITY MODULI         0.11538468E 08        0.11538468E 08        0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
      NONE


ELEM TYPE  MAT.NO. CODE    TEMP.    PRNT  NO.     --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  3  31        12    0  0.0          2     3     1   2   4

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, MU=0.3
      ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
      INPUT PRINT CODE . . . . . . . . 1
      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        0.0
      YOUNG'S MODULI          0.30000000E 08        0.30000000E 08        0.30000000E 08
      POISSON'S RATIO         0.29999995E 00        0.29999995E 00        0.29999995E 00
      TH. EXP. COEF.          0.59999993E-05        0.59999993E-05        0.59999993E-05
      RIGIDITY MODULI         0.11538468E 08        0.11538468E 08        0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
      NONE
```

FIGURE III-H.12   FINITE ELEMENT DESCRIPTION OUTPUT, THICK WALLED DISC

```
                                  H A R M O N I C   L O A D S (PRESSURE)

ELEMENT  DIRECTION OF  NUMBER OF LOADING  NUMBER OF HARMONIC                                   LOADS
NO       LOADING              POINTS             REQUESTS      POINT                 POINT                  POINT
 1       RADIAL                 36                  2                1  -0.200000E 03   2  -0.193970E 03   3  -0.176600E 03
                                                                 4  -0.150000E 03   5  -0.117370E 03   6  -0.826200E 02
                                                                 7  -0.500000E 02   8  -0.234000E 02   9  -0.603000E 01
                                                                10   0.0           11  -0.603000E 01  12  -0.234000E 02
                                                                13  -0.500000E 02  14  -0.826300E 02  15  -0.117370E 03
                                                                16  -0.150000E 03  17  -0.176600E 03  18  -0.193970E 03
                                                                19  -0.200000E 03  20  -0.193970E 03  21  -0.176600E 03
                                                                22  -0.150000E 03  23  -0.117370E 03  24  -0.836300E 02
                                                                25  -0.500000E 02  26  -0.234000E 02  27  -0.603000E 01
                                                                28   0.0           29  -0.603000E 01  30  -0.234000E 02
                                                                31  -0.500000E 02  32  -0.826300E 02  33  -0.117370E 03
                                                                34  -0.150000E 03  35  -0.176600E 03  36  -0.193970E 03
```

FIGURE III-H.13 ASYMMETRIC LOAD DATA OUTPUT, THICK WALLED DISC

```
                    R E S U L T   O F   H A R O N I C   A N A L Y S I S

        ELEMENT  HARMONIC  COEFFICIENT        FOURIER  COEFFICIENT
          NO
          1               0.0                          -0.100027E 03
                          0.200000E 01                 -0.989766E 02
```

FIGURE III-H.14 HARMONIC LOAD OUTPUT, THICK WALLED DISC

```
              ELEMENT NUMBER     1          PLUG NUMBER    31

              GRID POINT NUMBERS
                  2     3     4

              STIFFNESS MATRIX
                  (    9 X    9 )

ROW          1
 0.83455248E 08

ROW          2
 0.0                0.10000000E 01

ROW          3
-0.45311510E 07     0.0                0.29074739E 09

ROW          4
-0.80873872E 08     0.0               -0.54373472E 08     0.13359970E 09

ROW          5
 0.0                0.0                0.0                0.0                0.10000000E 01

ROW          6
-0.28697152E 08     0.0               -0.29074739E 09     0.87601744E 08     0.0                0.30403866E 09

ROW          7
-0.14275960E 07     0.0                0.45311232E 08    -0.46135072E 08     0.0               -0.45311232E 08
 0.43279088E 08

ROW          8
 0.0                0.0                0.0                0.0                0.0                0.0
 0.0                0.10000000E 01

ROW          9
 0.33228304E 08     0.0                0.0               -0.33228304E 08     0.0               -0.13291322E 08
 0.0                0.0                0.13291322E 08

              THERMAL AND PRESSURE LOAD MATRIX
                  ('   9 X    1 )
-0.31424088E 02     0.0                0.0               -0.31424088E 02     0.0                0.0
 0.0                0.0                0.0
```

FIGURE III-H.15a HARMONIC STIFFNESS AND NODAL LOAD MATRICES FOR HARMONIC ($m = 0$), ELEMENT NO. (1), THICK WALLED DISC

```
                 ELEMENT NUMBER     1            PLUG NUMBER     31

                 GRID POINT NUMBERS
                     2     3     4

                 STIFFNESS MATRIX
                     (    9 X    9 )

    ROW          1
     0.41947296E 08

    ROW          2
     0.49431456E 06      0.42359232E 08

    ROW          3
    -0.22655770E 07     -0.15103760E 07      0.14559336E 09

    ROW          4
    -0.40217200E 08      0.23067650E 07     -0.27186704E 08      0.67019424E 08

    ROW          5
    -0.71400300E 06     -0.41315696E 08     -0.75518770E 07      0.10984190E 07      0.47796560E 08

    ROW          6
    -0.14348564E 08      0.75518960E 07     -0.14515397E 09      0.43800848E 08      0.15103490E 07      0.15223901E 09

    ROW          7
    -0.49432019E 06     -0.13181520E 07      0.22655584E 08     -0.22847728E 08     -0.25263960E 07     -0.22655584E 08
     0.21859136E 08

    ROW          8
     0.17026160E 07      0.14280020E 07     -0.45311430E 07      0.35151000E 07     -0.58217640E 07      0.45311430E 07
    -0.10990400E 06      0.86777290E 07

    ROW          9
     0.16614154E 08      0.30207650E 07      0.21969431E 06     -0.16614154E 08     -0.30207650E 07     -0.64259530E 07
     0.0                 0.0                 0.68653290E 07

                 THERMAL AND PRESSURE LOAD MATRIX
                     (    9 X    1 )
    -0.15546733E 02      0.0                 0.0                -0.15546733E 02      0.0                 0.0
     0.0                 0.0                 0.0
```

FIGURE III-H.15b HARMONIC STIFFNESS AND NODAL LOAD MATRICES FOR HARMONIC ($m = +2$), ELEMENT No. (1), THICK WALLED DISC

```
S T R E S S E S   F O R   T H E   A S Y M M E T R I C   T R I A N G U L A R   C R O S S   S E C T I O N   R I N G   E L E M E N T
                                     (STRESSES EVALUATED AT THE ELEMENT CENTROID)

       LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE          ELEMENT GRID POINTS

                   1                     1                  31                 2    3    4

APPARENT ELEMENT STRESSES
STRESS          RADIAL                AXIAL           CIRCUMFERENTIAL                      S H E A R   S T R E S S E S
POINT            (RR)                  (ZZ)            (THETA-THETA)             (RZ)                (R-THETA)             (Z-THETA)

   1      -0.75384766E 02      0.30233459E 01      -0.16320439E 03      -0.75593872E 01       0.0                  0.0

ELEMENT APPLIED STRESSES
STRESS          RADIAL                AXIAL           CIRCUMFERENTIAL                      S H E A R   S T R E S S E S
POINT            (RR)                  (ZZ)            (THETA-THETA)             (RZ)                (R-THETA)             (Z-THETA)

   1       0.0                 0.0                  0.0                  0.0                  0.0                  0.0

NET ELEMENT STRESSES
STRESS          RADIAL                AXIAL           CIRCUMFERENTIAL                      S H E A R   S T R E S S E S
POINT            (RR)                  (ZZ)            (THETA-THETA)             (RZ)                (R-THETA)             (Z-THETA)

   1      -0.75384766E 02      0.30233459E 01      -0.16320439E 03      -0.75593872E 01       0.0                  0.0
```

FIGURE III-H.16a HARMONIC STRESS COEFFICIENTS FOR ELEMENT NO. (1), HARMONIC (n = 0), THICK WALLED DISC

```
S T R E S S E S   F O R   T H E   A S Y M M E T R I C   T R I A N G U L A R   C R O S S   S E C T I O N   R I N G   E L E M E N T
                                    (STRESSES EVALUATED AT THE ELEMENT CENTROID)

      LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE        ELEMENT GRID POINTS

                 1                     1                 31              2    3    4

APPARENT ELEMENT STRESSES
STRESS        RADIAL            AXIAL          CIRCUMFERENTIAL                   S H E A R   S T R E S S E S
POINT          (RR)              (ZZ)           (THETA-THETA)          (RZ)               (R-THETA)            (Z-THETA)

   1    -0.11155794E 03   -0.10439285E 02   -0.45828198E 03    0.25463989E 02    0.10123071E 03    -0.34822311E 01

ELEMENT APPLIED STRESSES
STRESS        RADIAL            AXIAL          CIRCUMFERENTIAL                   S H E A R   S T R E S S E S
POINT          (RR)              (ZZ)           (THETA-THETA)          (RZ)               (R-THETA)            (Z-THETA)

   1     0.0               0.0               0.0               0.0               0.0               0.0

NET ELEMENT STRESSES
STRESS        RADIAL            AXIAL          CIRCUMFERENTIAL                   S H E A R   S T R E S S E S
POINT          (RR)              (ZZ)           (THETA-THETA)          (RZ)               (R-THETA)            (Z-THETA)

   1    -0.11155794E 03   -0.10439285E 02   -0.45828198E 03    0.25463989E 02    0.10123071E 03    -0.34822311E 01
```

FIGURE III-H.16b HARMONIC STRESS COEFFICIENTS FOR ELEMENT NO. (1), HARMONIC (m = +2), THICK WALLED DISC

```
                         DISPLACEMENTS

THETA   GRID POINT           U                  V                 W

  0        1          -0.296247E-04        0.0             0.544077E-06
  0        2          -0.299754E-04        0.0            -0.498346E-05
  0        3          -0.289156E-04        0.0            -0.419975E-05
  0        4          -0.289300E-04        0.0            -0.193829E-05
  0        5          -0.285588E-04        0.0             0.0
```

FIGURE III-H.17a NODAL CIRCLE DISPLACEMENTS AT $\theta = 0°$, THICK WALLED DISC

```
                         DISPLACEMENTS

THETA   GRID POINT           U                  V                 W

 60        1           0.787113E-05     0.192114E-04     -0.698266E-06
 60        2           0.776971E-05     0.252034E-05     -0.299463E-05
 60        3           0.816699E-05     0.234586E-05     -0.301347E-05
 60        4           0.851580E-05     0.108076E-04     -0.158066E-05
 60        5           0.820817E-05     0.191946E-04      0.0
```

FIGURE III-H.17b NODAL CIRCLE DISPLACEMENTS AT $\theta = 60°$, THICK WALLED DISC

```
                              REACTIONS

THETA    GRID POINT          U                      V                      W

  0          1          0.109502E 01          0.106812E-03          -0.146484E-02
  0          2         -0.137329E-03          0.122070E-03          -0.103474E-02
  0          3         -0.427246E-03         -0.152588E-04          -0.619888E-04
  0          4          0.247955E-04         -0.915527E-04           0.117493E-02
  0          5         -0.991821E-03          0.0                    0.976563E-03
```

FIGURE III-H.18a NODAL CIRCLE REACTIONS AT θ = 0°, THICK WALLED DISC

```
                              REACTIONS

THETA    GRID POINT          U                      V                      W

 60          1         -0.546215E 00          0.120364E-02           0.732376E-03
 60          2         -0.480645E-03          0.137509E 02           0.517336E-03
 60          3          0.946017E-03          0.137500E 02           0.309925E-04
 60          4          0.102042E-03         -0.109588E-02          -0.587427E-03
 60          5          0.519767E-03         -0.106627E-02          -0.488251E-03
```

FIGURE III-H.18b NODAL CIRCLE REACTIONS AT θ = 60°, THICK WALLED DISC

```
                              NET STRESSES FOR THE TRIANGULAR RING ELEMENT

                                  (STRESSES EVALUATED AT ELEMENT CENTROID)

ELEMENT  ELEMENT  CIRCUMFE-       NORMAL          NORMAL             NORMAL           SHEAR            SHEAR             SHEAR
NUMBER    TYPE    RENTIAL         RADIAL      CIRCUMFERENTIAL         AXIAL            R-Z             R-THETA           Z-THETA
   1       31        0       -0.1869427E 03  -0.7415939E 01  -0.6214863E 03   0.1790460E 02   0.0              0.0
   1       31       30       -0.1311643E 03  -0.2196350E 01  -0.3923477E 03   0.5172737E 01   0.8766806E 02  -0.3015690E 01
   1       31       60       -0.1960695E 02   0.8242881E 01   0.6593187E 02  -0.2029111E 02   0.8766896E 02  -0.3015720E 01
   1       31       90        0.3617317E 02   0.1346263E 02   0.2950774E 03  -0.3302338E 02   0.1704763E-02  -0.5864208E-04
   1       31      120       -0.1960361E 02   0.8243194E 01   0.6594560E 02  -0.2029187E 02  -0.8766721E 02   0.3015660E 01
   1       31      150       -0.1311609E 03  -0.2196036E 01  -0.3923337E 03   0.5171972E 01  -0.8766982E 02   0.3015750E 01
   1       31      180       -0.1869427E 03  -0.7415939E 01  -0.6214863E 03   0.1790460E 02  -0.3409527E-02   0.1172842E-03
   1       31      210       -0.1311676E 03  -0.2196654E 01  -0.3923611E 03   0.5173480E 01   0.8766635E 02  -0.3015631E 01
   1       31      240       -0.1961011E 02   0.8242585E 01   0.6591888E 02  -0.2029039E 02   0.8767062E 02  -0.3015778E 01
   1       31      270        0.3617317E 02   0.1346263E 02   0.2950774E 03  -0.3302338E 02   0.5114272E-02  -0.1759257E-03
   1       31      300       -0.1960036E 02   0.8243498E 01   0.6595897E 02  -0.2029262E 02  -0.8766551E 02   0.3015602E 01
   1       31      330       -0.1311578E 03  -0.2195741E 01  -0.3923208E 03   0.5171251E 01  -0.8767146E 02   0.3015807E 01
```

FIGURE III-H.19 STRESSES IN ELEMENT NO. (1), THICK WALLED DISC

1	2	3	4	
H	T	E	M	(/)

NUMBER OF ELEMENTS 7	8	9	NO OF HARMONIC PER ELEMENT 10	NO # HARMONIC REQUESTS 11	
		3	2	2	(/)

ELEMENT ID 7	8	9	REPEAT ELEMENT LOADING OPTION 10	NUMBER OF LOADING POINTS 11	12	13	HARMONIC THERMAL LOAD VALUES 17	27	37	47	57	67	
		1			3	6	707.1	685.8	624.4	530.2	414.9	292.1	(/)
							176.8	82.7	21.3	0.0	21.3	82.7	
							176.8	292.1	414.9	530.2	624.4	685.8	
							707.1	685.8	624.4	530.2	414.9	292.1	
							176.8	82.7	21.3	0.0	21.3	82.7	
							176.8	292.1	414.9	530.2	624.4	685.8	

FIGURE III-H.20a HARMONIC THERMAL LOAD INPUT, THICK WALLED DISK

ELEMENT ID	REPEAT ELEMENT LOADING OPTION	NUMBER OF LOADING POINTS	HARMONIC THERMAL LOAD VALUES						
7 8 9	10	11 12 13	17	27	37	47	57	67	
2		36	218.0	211.4	192.5	163.5	127.9	90.0	(/)
			54.5	25.5	6.6	0.0	6.6	25.0	
			54.5	90.0	127.9	163.5	192.5	211.4	
			218.0	211.4	192.5	163.5	127.9	90.0	
			54.5	25.5	6.6	0.0	6.6	25.0	
			54.5	90.0	127.9	163.5	192.5	211.4	

ELEMENT ID	REPEAT ELEMENT LOADING OPTION	NUMBER OF LOADING POINTS	HARMONIC THERMAL LOAD VALUES						
7 8 9	10	11 12 13	17	27	37	47	57	67	
3		36	976.0	946.0	861.8	732.0	572.8	403.2	(/)
			244.0	114.2	29.4	0.0	29.4	114.2	
			244.0	403.2	572.8	732.0	861.8	946.6	
			976.0	946.6	861.8	732.0	572.8	403.2	
			244.0	114.2	29.4	0.0	29.4	114.2	
			244.0	403.2	572.8	732.0	861.8	946.2	

FIGURE III-H.206 HARMONIC THERMAL LOAD INPUT, THICK WALLED DISK (CONTINUED)

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

REPORT
TITLE
        1
THICK WALLED DISC SUBJECTED TO NCN-AXISYMMETRIC LOADING
SYSTEM
     5     5 3 1     0     0 0     3 1     5  0.0
MATER
        1
        1    121M STEEL - E=30E6, MU=0.3 X         1  0.0005
            0.0       30.0    E60.30      6.00   E-6
COORD
           10.5        0.0          0.0
           201.0       0.0          0.0
           301.0       0.0          0.1
           40.75       0.0          0.1
           500.5       0.0          0.1
BOUNDS
          1 111
          2 111
          3 111
          4 111
          5 11C
ELEM
         131    12             X 3 002003004
         331    12             X 3 001002004
         231    12             X 3 001004005
HTEM
        322
       01  36     707.1   685.8     624.4     530.2     414.9     292.1
                  176.8    82.7      21.3       0.0      21.3      82.7
                  176.8   292.1     414.9     530.2     624.4     685.8
                  707.1   685.8     624.4     530.2     414.9     292.1
                  176.8    82.7      21.3       0.0      21.3      82.7
                  176.8   292.1     414.9     530.2     624.4     685.8
       02  36     218.0   211.4     192.5     163.5     127.9      90.C
                   54.5    25.5       6.6       0.0       6.6      25.C
                   54.5    90.0     127.9     163.5     192.5     211.4
                  218.0   211.4     192.5     163.5     127.9      90.0
                   54.5    25.5       6.6       0.0       6.6      25.5
                   54.5    90.0     127.9     163.5     192.5     211.4
       03  36     976.0   946.6     861.8     732.0     572.8     403.2
                  244.0   114.2      29.4       0.0      29.4     114.2
                  244.0   403.2     572.8     732.0     861.8     946.6
                  976.0   946.6     861.8     732.0     572.8     403.2
                  244.0   114.2      29.4       0.0      29.4     114.2
                  244.0   403.2     572.8     732.0     861.8     946.6

12345678901234567890123456789012345678901234567890123456789012345678901234567890
         1         2         3         4         5         6         7         8
```

FIGURE III-H.21 INPUT - THICK WALLED DISC, NON-AXISYMMETRIC LOADING

```
                                H A R M O N I C   L C A D S (THERMAL )

ELEMENT   DIRECTION OF   NUMBER OF LOADING  NUMBER OF HARMONIC                            LOADS
NO        LOADING              POINTS             REQUESTS       POINT           POINT            POINT
 1                              36                   2               1  0.707100E 03  2  0.685800E 03  3  0.624400E 03
                                                                    4  0.530200E 03  5  0.414900E 03  6  0.292100E 03
                                                                    7  0.176800E 03  8  0.827000E 02  9  0.213000E 02
                                                                   10  0.0          11  0.213000E 02 12  0.827000E 02
                                                                   13  0.176800E 03 14  0.292100E 03 15  0.414900E 03
                                                                   16  0.530200E 03 17  0.624400E 03 18  0.685800E 03
                                                                   19  0.707100E 03 20  0.685800E 03 21  0.624400E 03
                                                                   22  0.530200E 03 23  0.414900E 03 24  0.292100E 03
                                                                   25  0.176800E 03 26  0.827000E 02 27  0.213000E 02
                                                                   28  0.0          29  0.213000E 02 30  0.827000E 02
                                                                   31  0.176800E 03 32  0.292100E 03 33  0.414900E 03
                                                                   34  0.530200E 03 35  0.624400E 03 36  0.685800E 03
```

FIGURE III-H.22 ASYMMETRIC LOAD DATA OUTPUT, THICK WALLED DISC

```
                    R E S U L T   O F   H A R O N I C   A N A L Y S I S

ELEMENT  HARMONIC  CCEFFICIENT      FOURIER  COEFFICIENT
  NO
  1            0.0                          0.353526E 03
               0.200000E 01                 0.349965E 03
```

FIGURE III-H.23 HARMONIC LOAD OUTPUT, THICK WALLED DISC

```
S T R E S S E S   F O R   T H E   A S Y M M E T R I C   T R I A N G U L A R   C R O S S   S E C T I O N   R I N G   E L E M E N T
                                       (STRESSES EVALUATED AT THE ELEMENT CENTROID)

      LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE       ELEMENT GRID POINTS

               1                       1                  31              2    3    4

APPARENT ELEMENT STRESSES                                                              S H E A R   S T R E S S E S
STRESS          RADIAL              AXIAL          CIRCUMFERENTIAL             (RZ)             (R-THETA)              (Z-THETA)
POINT            (RR)               (ZZ)            (THETA-THETA)

    1      0.13969919E C6     0.15608494E C6      0.16607738E 06      0.74993750E 04      0.0                   0.0

ELEMENT APPLIED STRESSES                                                               S H E A R   S T R E S S E S
STRESS          RADIAL              AXIAL          CIRCUMFERENTIAL             (RZ)             (R-THETA)              (Z-THETA)
POINT            (RR)               (ZZ)            (THETA-THETA)

    1      0.15908656E 06     0.15908656E 06      0.15908656E 06      0.0                 0.0                   0.0

NET ELEMENT STRESSES                                                                   S H E A R   S T R E S S E S
STRESS          RADIAL              AXIAL          CIRCUMFERENTIAL             (RZ)             (R-THETA)              (Z-THETA)
POINT            (RR)               (ZZ)            (THETA-THETA)

    1     -0.19387375E 05    -0.30016250E 04      0.69908125E 04      0.74993750E 04      0.0                   0.0
```

FIGURE III-H.24 a HARMONIC STRESSES FOR ELEMENT NO. (1) , HARMONIC ($n = 0$),
THICK WALLED DISC

```
S T R E S S E S   F O R   T H E   A S Y M M E T R I C   T R I A N G U L A R   C R O S S   S E C T I O N   R I N G   E L E M E N T
                                   (STRESSES EVALUATED AT THE ELEMENT CENTROID)

       LOAD CONDITION NUMBER      ELEMENT NUMBER      ELEMENT TYPE        ELEMENT GRID POINTS

                 1                      1                  31               2    3    4

APPARENT ELEMENT STRESSES
STRESS          RADIAL               AXIAL             CIRCUMFERENTIAL                 S H E A R   S T R E S S E S
POINT            (RR)                (ZZ)              (THETA-THETA)          (RZ)              (R-THETA)              (Z-THETA)

   1       0.12593919E 06      0.15220494E C6      0.11695213E 06      0.13904594E 05     -0.25779180E 04     0.38851470E 04

ELEMENT APPLIED STRESSES
STRESS          RADIAL               AXIAL             CIRCUMFERENTIAL                 S H E A R   S T R E S S E S
POINT            (RR)                (ZZ)              (THETA-THETA)          (RZ)              (R-THETA)              (Z-THETA)

   1       0.15748388E 06      0.15748388E 06      0.15748388E 06      0.0                 0.0                 0.0

NET ELEMENT STRESSES
STRESS          RADIAL               AXIAL             CIRCUMFERENTIAL                 S H E A R   S T R E S S E S
POINT            (RR)                (ZZ)              (THETA-THETA)          (RZ)              (R-THETA)              (Z-THETA)

   1      -0.31544688E 05     -0.52789375E C4     -0.40531750E 05      0.13904594E 05     -0.25779180E 04     0.38851470E 04
```

FIGURE III-H.24 b HARMONIC STRESSES FOR ELEMENT NO. (1), HARMONIC (M = +2), THICK WALLED DISC

```
                              DISPLACEMENTS

THETA   GRID POINT            U                    V                   W

  0         1          -0.322093E-02          0.0              -0.672627E-03
  0         2          -0.174501E-02          0.0              -0.281899E-01
  0         3           0.377694E-02          0.0              -0.277109E-01
  0         4           0.304158E-02          0.0              -0.143697E-01
  0         5           0.222443E-02          0.0               0.0
```

FIGURE III-H.25 a NODAL CIRCLE DISPLACEMENTS AT $\theta = 0^\circ$, THICK WALLED DISC

```
                              DISPLACEMENTS

THETA   GRID POINT            U                    V                   W

 60         1          -0.135652E-02      0.116087E-02         -0.142783E-03
 60         2          -0.976223E-03      0.656639E-03         -0.281772E-01
 60         3           0.462233E-02      0.690500E-03         -0.280949E-01
 60         4           0.445186E-02      0.856080E-03         -0.141104E-01
 60         5           0.422915E-02      0.116352E-02          0.0
```

FIGURE III-H.25 b NODAL CIRCLE DISPLACEMENTS AT $\theta = 60^\circ$, THICK WALLED DISC

```
                          NET STRESSES FOR THE TRIANGULAR RING ELEMENT

                               (STRESSES EVALUATED AT ELEMENT CENTROID)

ELEMENT  ELEMENT  CIRCUMFE-      NORMAL          NORMAL           NORMAL          SHEAR           SHEAR            SHEAR
NUMBER    TYPE    RENTIAL        RADIAL       CIRCUMFERENTIAL      AXIAL           R-Z            R-THETA          Z-THETA
   1       31        0      -0.5093206E 05  -0.8280563E 04  -0.3354094E 05   0.2140397E 05   0.0              0.0
   1       31       30      -0.3515988E 05  -0.5641117E 04  -0.1327527E 05   0.1445174E 05  -0.2232535E 04   0.3364624E 04
   1       31       60      -0.3615359E 04  -0.3622107E 03   0.2725627E 05   0.5472227E 03  -0.2232558E 04   0.3364659E 04
   1       31       90       0.1215731E 05   0.2277313E 04   0.4752256E 05  -0.6405219E 04  -0.4341311E-01   0.6542730E-01
   1       31      120      -0.3614414E 04  -0.3620525E 03   0.2725748E 05   0.5468047E 03   0.2232513E 04  -0.3364592E 04
   1       31      150      -0.3515893E 05  -0.5640961E 04  -0.1327405E 05   0.1445132E 05   0.2232579E 04  -0.3364692E 04
   1       31      180      -0.5093206E 05  -0.8280563E 04  -0.3354094E 05   0.2140397E 05   0.8682621E-01  -0.1308547E 00
   1       31      210      -0.3516080E 05  -0.5641273E 04  -0.1327645E 05   0.1445214E 05  -0.2232491E 04   0.3364559E 04
   1       31      240      -0.3616250E 04  -0.3623604E 03   0.2725512E 05   0.5476172E 03  -0.2232600E 04   0.3364722E 04
   1       31      270       0.1215731E 05   0.2277313E 04   0.4752256E 05  -0.6405219E 04  -0.1302389E 00   0.1962813E 00
   1       31      300      -0.3613492E 04  -0.3618987E 03   0.2725866E 05   0.5464023E 03   0.2232470E 04  -0.3364526E 04
   1       31      330      -0.3515804E 05  -0.5640813E 04  -0.1327290E 05   0.1445093E 05   0.2232621E 04  -0.3364755E 04
```

FIGURE III-H.26 STRESSES IN ELEMENT NO. (1), THICK WALLED DISC

LIST OF REFERENCES

1. Mallett, R.H., and Jordan, S., "MAGIC: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual", AFFDL-TR-68-56, Volume I, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, January 1969.

2. Jordan, S., Mallett, R.H., and Maddux, G.E., "MAGIC: An Automated General Purpose System for Structural Analysis: Volume II. User's Manual", AFFDL-TR-68-56, Volume II, Air Force Dynamics Laboratory, Wright-Patterson AFB, Ohio, July, 1969.

3. DeSantis, D., "MAGIC: An Automated General Purpose System for Structural Analysis: Volume III. Programmer's Manual", AFFDL-TR-68-56, Volume III, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, January 1969.

4. Jordan, S., "MAGIC II: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual (Addendum)", AFFDL-TR-71-1, Volume I, Air Force Dynamics Laboratory, Wright-Patterson AFB, Ohio, May 1971.

5. Jordan, S., and Gallo, M., "MAGIC II: An Automated General Purpose System for Structural Analysis: Volume II. User's Manual", AFFDL-TR-71-1, Volume II, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, May 1971.

6. Gallo, A.M., "MAGIC II: An Automated General Purpose System for Structural Analysis: Volume III. Programmer's Manual", AFFDL-TR-71-1, Volume III, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, May 1971.

7. Pickard, J., "FORMAT-FORTRAN Matrix Abstraction Technique: Volume 5, Supplement 1 - Engineering User and Technical Report - Extended", AFFDL-TR-66-207, June 1970.

8. Gallo, A.M., "MAGIC III: An Automated General Purpose System for Structural Analysis: Volume III. Programmer's Manual", AFFDL-TR-72- , Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, April 1972.

9. Batt, J.R. and Jordan, S., "MAGIC III: An Automated General Purpose System for Structural Analysis: Volume I. Engineer's Manual," AFFDL-TR-72-42, June, 1972.

REFERENCES (Continued)

10. Melosh, R. J., and Bamford, R. M., 'Efficient Solution of Load-Deflection Equations,' J.A.S.C.E. (Structures Division) Paper No. 6510, pp 661-676 (1969).

11. Guyan, R. J., "Reduction of Stiffness and Mass Matrices," AIAA Journal, Volume 3, No. 2, February 1965.

12. Rommel, B., "Development of a Pseudo Dynamic Matrix for Free-Free Modes and Frequencies," Private Communication B. Rommel to S. Jordan, June 1963.

13. Zienkiewicz, O. C., "The Finite Element Method in Engineering Science," McGraw Hill - London, 1971.

14. Appa, K., Smith, G.C.C., Hughes, J.T., "Rational Reduction of Large-Scale Eigenvalue Problems", AIAA Journal, Volume 10, Number 7, July, 1972.

APPENDIX A

USER MANUAL UPDATES

The following presents updated User instructions to the MAGIC User's Manual. The updates are referenced to the MAGIC II User's Manual (Reference 5) by page number.

1. Page 36 — The EPRINT abstraction instruction does not have dots around it. It should read EPRINT(a,b,c)D.

2. Page 37 — The following additional options are available for the .ASSEM. structural abstraction instruction:

   d = 1 , to assemble the reduced element stiffness matrices

   d = 2 , to assemble the reduced element mass matrices

   d = 3 , to assemble the reduced element incremental matrices

   d = 4 , to assemble the reduced element applied load matrices

   where for d = 1, 2 and 3 $[C]$ will have the order (N x N) where N = NS x S - (the number of retained degrees of freedom). If d = 4, then C will have the order (N x 1).

$$C = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \quad \text{or} \quad C = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix}$$

3. Page 37 — The GPRINT abstraction instruction does not have dots around it. It should read GPRINT(a,b,c,C1.C2.C3.etc)F,G.

4. Page 38 — Explanation of Matrix E.

   E. This matrix is optional. It may be suppressed if input matrix F is in <u>unreduced</u> form, i.e., contains all system degrees of freedom. If matrix F is reduced, then E must be a transformation matrix (generated from OMP5) used to unreduce F for printing. If a = 3, then this matrix must be present if the eigenvector matrix is reduced, which is usually the case.

APPENDIX A (CONT)

5. Page 103 Item Number 4

4. Number of Load Conditions - (Cols. 15-16)

The number of load conditions is equal to the number of external load conditions that are applied to the system. Note that external loads are not to be confused with element applied loading such as temperature and pressure.

If there are no external loads applied to the system, then the number of load conditions should be set to zero and no LOADS section need be input. An element applied load scalar of 1.0 will automatically be generated.

At the present time, the maximum number of external load conditions allowed is one hundred (100).

6. Page 103 Item Number 6

6. Number of Prescribed Displacement Condition - (Cols. 23-28)

Applied loading may be prescribed in terms of non-zero displacement values. Either one prescribed displacement condition or NL prescribed displacement conditions can be accommodated per execution, where NL is defined in item number (4) above. Therefore, the number of prescribed displacement conditions should be equal only to 1 or NL. If there are no prescribed displacement conditions, then this entry is ignored by the User.

7. Page 105 Item Number 6

This item should read as follows:

6. Number of prescribed displacement conditions.

8. Page 131 Item Number 12

This item should read as follows:

12. Prescribed Displacement Condition Section (Figure II-11)

9. Page 134 Condition Number - (Cols. 7-11)

The condition number is a fixed point number. In the present MAGIC System either 1 or NL prescribed displacement conditions can be accommodated per execution. NL is defined as the total number of loading conditions in a given analysis. If the User specifies NL prescribed displacement conditions then the corresponding prescribed displacement condition will be used with the appropriate external load condition. If you specify 1 prescribed displacement condition, then the same set of values will be generated NL times to be used with each external load condition.

APPENDIX A (CONT.)

10. Page 136 Item Number 5

5. The number of prescribed displacement conditions must be specified on the System Control Information Data Form (Figure II-3). This value is equal to 1 or NL, where NL is defined to be the number of external load conditions.

11. Page 138 Last Paragraph should read as follows:

The first entry on the External Grid Point Loads Form is prelabeled LOADS and requires no information from the User. If there are no External Loads acting on the system, then the User does not have to input a LOADS section. The MAGIC system will automatically generate one zero load condition with an element applied load scalar of 1.0 for the User.

12. Page 138 Delete Item Number 3 under <u>Condition Number</u>.

13. Page 140 Item Number 1 under <u>REMEMBER</u> heading should read:

1. The External Grid Point Loads Section may be omitted if there is no external grid point loads acting on the structure. Enter a zero on the System Control Information Data Form (Figure II-3) if this is the case. An applied element load scalar of 1.0 will automatically be generated for the user.

APPENDIX B

MAGIC INPUT DATA FORMS

This Appendix compiles all the MAGIC structural analysis input data forms. The use of these forms is explained in detail in Reference 5 and this report. They are placed here to serve the User as "tear-outs".

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

R E P O R T (/)

1 2 3 4 5 6

T I T L E (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

7 8 9

(/) NUMBER OF TITLE CARDS

TITLE INFORMATION

1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7 8 9 50 1 2 3 4 5 6 7 8 9 60 1 2 3 4 5 6 7 8 9 70 1 2

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

M	A	T	E	R		(/)
1	2	3	4	5	6	

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

			(/)
7	8	9	

No. of Requests

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
																(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
	E_x		ν_{xy}		α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
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									(/)
									(/)

BAC 1816-2

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL PROPERTIES TABLE
(continued)

TEMPERATURE		YOUNGS MODULI		POISSONS RATIOS		COEF. OF THERMAL EXPANSION		RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
	E_x		ν_{xy}		α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
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Page __________ of __________

BAC 1617

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PLASTIC PROPERTIES TABLE

TEMPERATURE 13 14 15 16 17 18 19 20 21 22		23 24 25 26 27 28 29 30 31 32		33 34 35 36 37 38 39 40 41 42		43 44 45 46 47 48 49 50 51 52		53 54 55 56 57 58 59 60 61 62		63 64 65 66 67 68 69 70 71 72	
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Page ________ of ________

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M 1 2 3 4 5 6	(/)
1. Number of System Grid Points	1 2 3 4 5 6	
2. Number of Input Grid Points	7 8 9 10 11 12	
3. Number of Degrees of Freedom/Grid Point	13 14	
4. Number of Load Conditions	15 16	
5. Number of Initially Displaced Grid Points	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	29 30	
8. Number of Elements	31 32 33 34 35 36	
9. Number of Requests and/or Revisions of Material Tape.	37 38	
10. Number of Input Boundary Condition Points	39 40 41 42 43 44	
11. T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	(/)

BAC 1619

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

CALCULATION CONTROL

C	A	L	C		(/)
1	2	3	4	5	

PLACE 'X' IN BOX OPPOSITE DESIRED OPERATIONS

1.	Revise Material Tape	☐	1	
2.	Inverse Solution	☐	2	
3.	Choleski Decomposition	☐	3	
4.	Linear Function Minimization Solution	☐	4	
5.	Nonlinear Function Minimization Solution	☐	5	
6.	Plastic Analysis	☐	6	
7.	Grid Point Axes Transformation	☐	7	
8.	Stress Calculations	☐	8	
9.	Reactions	☐	9	
10.	Structure Plot	☐	10	
11.	Dynamics Analysis	☐	11	(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRINT OPTIONS

P	R	I	N	T		(/)
1	2	3	4	5	6	

PLACE 'X' IN BOX OPPOSITE DESIRED PRINT

1. Assembly — Stiffness	☐ 1	
2. Inverse — Stiffness	☐ 2	
3. Triangularized — Stiffness	☐ 3	
4. Displacements	☐ 4	
5. Intermediate Function Minimization	☐ 5	(/)

BAC 1621 Rev. 571

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EIGENVALUE INFORMATION

FOR USE IN ALL EIGENVALUE PROBLEMS

D	Y	N	A	M	☐	(/)
1	2	3	4	5	6	

1. Number of Eigenvalues Requested
(Less Than or Equal to 20)
☐☐
1 2

2. Convergence Criteria (Floating Point)
(Default Option - 0.001)
☐☐☐☐☐☐☐☐☐☐☐☐
3 4 5 6 7 8 9 10 11 12 13 14

3. Maximum Number of Iterations
(Default Option - 500 Iterations)
☐☐☐
15 16 17

4. Debug Iteration Print
Iteration Print ON = 1
Iteration Print OFF = 0
(Default Option - Print OFF)
☐
18

5. First Normalizing Element for Print
(Default Option - No First Normalization)
☐☐☐☐
19 20 21 22

6. Second Normalizing Element for Print
(Default Option - No Second Normalization)
☐☐☐☐
23 24 25 26

7. Control for Guess Vector Iteration Start
Column Iteration Start = 0
Row Iteration Start = 1
(Default Option - Column Iteration Start)
☐ (/)
27

BAC 1622 Rev. 571

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
C	O	O	R	D		(/)

GRIDPOINT COORDINATES

			D I R E C T I O N S			
S		Grid Point Number	X – R	Y – Θ	Z – Z	
5	6	7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
	▨					(/)
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If coordinate information must be continued on second sheet, user MUST delete Coord. Label Card from second sheet.

Page ____________ of ____________

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

1	2	3	4	5	6	
P	R	E	S	S		(/)

						PRESSURES																													
						P_1										P_2										P_3									
1	2	3	4	5	6	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
M	O	D	A	L																															

Grid Point Number					Repeat	P_1										P_2										P_3										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES
(continued)

Grid Point Number	Repeat	P 1	P 2	P 3	
7 8 9 10 11	12	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES

1	2	3	4	5	6	
T	E	M	P			(/)

1	2	3	4	5	6
M	O	D	A	L	

TEMPERATURES			
T_1	T_2	T_3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)

Grid Point Number	Repeat	T_1	T_2	T_3	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
					(/)
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Page ____________ of ____________

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES
(continued)

Grid Point Number	Repeat	T_1	T_2	T_3	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
					(/)
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Page ____________ of ____________

BAC 1625

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

G	R	A	X	E	S
1	2	3	4	5	6

(/)

ROTATIONAL TRANSFORMATIONS
(Generate Transformation Matrices)

SYS. NO.	Local Axis Direction			Plane Definition Grid Point Numbers			APPLICABLE GRID POINT NUMBERS															
	X	Y	Z	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10	11	12	13 4 5 6	7 8 9 20	1 2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4 5	6 7 8	9 50 1	2 3 4	5 6 7	8 9 60	1 2 3	4 5 6	7 8 9	
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IF GRAXES INFORMATION MUST BE CONTINUED ON SECOND SHEET,
USER <u>MUST</u> DELETE GRAXES LABEL CARD FROM SECOND SHEET.

Page ________ of ________

BAC 1626-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
									(/)

1	2	3	4	5	6
M	O	D	A	L	

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
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Page ________ of ________

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS
(continued)

INPUT CODE 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

LISTED INPUT

Grid Point Number					Repeat	TRANSLATIONS			ROTATIONS			GENERALIZED			
						U	V	W	θ_x	θ_y	θ_z	1	2	3	
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
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BAC 2064

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
M	A	S	S		

(/)

										1									2		
1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2
S	C	A	L	E						1		Mass Scalar									

(/)

LUMPED MASSES

1	2	3	4	5	6
M	O	D	A	L	

	M_x	M_y	M_z		$M_{\theta x}$	$M_{\theta Y}$	$M_{\theta z}$		M_1	M_2	M_3	
	1 2	2 3	3 4		1 2	2 3	3 4		1 2	2 3	3 4	
	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
				(/)				(/)				(/)

Grid Pt. Number	repeat	M_x	M_y	M_z		$M_{\theta x}$	$M_{\theta Y}$	$M_{\theta z}$		M_1	M_2	M_3	
		1 2	2 3	3 4		1 2	2 3	3 4		1 2	2 3	3 4	
7 8 9 0 1	2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
					(/)				(/)				(/)
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					(/)				(/)				(/)

BAC 1627 Rev. 5/71

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
L	O	A	D	S		(/)

LCOND (/)

Condition Number (columns 7–11) · Scalar (columns 13–22) · Trans (column 24)

MODAL

EXTERNAL LOADS

		FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES			
Grid Pt. Number	repeat	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3	
7–12		13–22	23–32	33–42	13–22	23–32	33–42	13–22	23–32	33–42	(/)

BAC 1628 Rev.

E	L	E	M			
1	2	3	4	5	6	(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT			Number of Input Nodes	Supress Pressure	NODE POINTS												
							Print	Elem. Mat.	Full			1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
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IF ELEMENT CONTROL DATA MUST BE CONTINUED ON SECOND SHEET, USER MUST DELETE ELEM LABEL CARD FROM SECOND SHEET.

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BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

1	2	3	4	5	6
M	O	D	A	L	

	A	B	C	D	E	F
	1 3 4 5 6 7 8 9 0 1 2	2 3 4 5 6 7 8 9 0 1 2	3 3 4 5 6 7 8 9 0 1 2	4 3 4 5 6 7 8 9 0 1 2	5 3 4 5 6 7 8 9 0 1 2	6 3 4 5 6 7 8 9 0 1 2

Element Number	Repeat							
7 8 9 0 1	2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
								(/)
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Page ______ of ______

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT
(continued)

Element Number	Repeat	A	B	C	D	E	F	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	43 44 45 46 47 48 49 50 51 52	53 54 55 56 57 58 59 60 61 62	63 64 65 66 67 68 69 70 71 72	
								(/)
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Page ____________ of ____________

BAC 1630

1	2	3	4	5	6	
P	R	D	I	S	P	(/)

1	2	3	4	5	6	7	8	9	0	1	
P	C	O	N	D							(/)

Condition Number

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRESCRIBED DISPLACEMENTS

1	2	3	4	5	6
M	O	D	A	L	

Grid Pt. Number	repeat	TRANSLATIONS U	TRANSLATIONS V	TRANSLATIONS W		ROTATIONS θ_x	ROTATIONS θ_y	ROTATIONS θ_z		GENERALIZED 1	GENERALIZED 2	GENERALIZED 3	
					(/)				(/)				(/)
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					(/)				(/)				(/)

BAC 1631

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

T	R	A	N	S		
1	2	3	4	5	6	(/)

ROTATIONAL TRANSFORMATIONS
(INPUT MATRICES)

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24	25 26 27	28 29 30	31 32 33	34 35 36	37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	
															(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)
			(/)
			(/)

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24	25 26 27	28 29 30	31 32 33	34 35 36	37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	
															(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)
			(/)
			(/)

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24	25 26 27	28 29 30	31 32 33	34 35 36	37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	
															(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)
			(/)
			(/)

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24	25 26 27	28 29 30	31 32 33	34 35 36	37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	
															(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)
			(/)
			(/)

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10 11 12	13 14 15	16 17 18	19 20 21	22 23 24	25 26 27	28 29 30	31 32 33	34 35 36	37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	
															(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)
			(/)
			(/)

BAC 1911 Rev. 672

MAGIC
MATRIX/INPUT DATA FORMAT

H	IMAX	JMAX
1	2 3 4 5	6 7 8 9
H		

MATRIX NAME	SUB SCRIPT	SEQ. NO.	
67 68 69 70 71 72	73 74 75 76	77 78 79 80	
			(/)

		I	J	VALUE	EXP.	I	J	VALUE	EXP.	I	J	VALUE	EXP.	MATRIX NAME	PROG. NO.	SEQ. NO.	
	1	2 3 4 5	6 7 8 9	11 12 13 14 15 16 17 18 19	20 21 22	24 25 26 27	28 29 30 31	33 34 35 36 37 38 39 40 41	42 43 44	46 47 48 49	50 51 52 53	55 56 57 58 59 60 61 62 63	64 65 66	67 68 69 70 71 72	73 74 75 76	77 78 79 80	
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23																	(/)
24																	(/)
25																	(/)
	1	2 3 4 5	6 7 8 9	11 12 13 14 15 16 17 18 19	20 21 22	24 25 26 27	28 29 30 31	33 34 35 36 37 38 39 40 41	42 43 44	46 47 48 49	50 51 52 53	55 56 57 58 59 60 61 62 63	64 65 66	67 68 69 70 71 72	73 74 75 76	77 78 79 80	

BAC 2055

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E	L	T	E	M	P	(/)
1	2	3	4	5	6	

ELEMENT
TEMPERATURE
INPUT

1	2	3	4	5	6
M	O	D	A	L	

No. of Temperatures	ELEMENT TEMPERATURE INPUT						
13 14	15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34	35 36 37 38 39 40 41 42 43 44	45 46 47 48 49 50 51 52 53 54	55 56 57 58 59 60 61 62 63 64	65 66 67 68 69 70 71 72 73 74	
							(/)
							(/)

Element Number	Repeat									
7 8 9 10 11	12	13 14	15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34	35 36 37 38 39 40 41 42 43 44	45 46 47 48 49 50 51 52 53 54	55 56 57 58 59 60 61 62 63 64	65 66 67 68 69 70 71 72 73 74	
									(/)
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Page ________ of ________

BAC 2057

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESSURE INPUT

E	L	P	R	E	S	
1	2	3	4	5	6	(/)

1	2	3	4	5	6
M	O	D	A	L	

No. of Pressures	ELEMENT PRESSURES						
13 14	15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34	35 36 37 38 39 40 41 42 43 44	45 46 47 48 49 50 51 52 53 54	55 56 57 58 59 60 61 62 63 64	65 66 67 68 69 70 71 72 73 74	
							(/)
							(/)

Element Number	Repeat								
7 8 9 10 11	12	13 14	15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34	35 36 37 38 39 40 41 42 43 44	45 46 47 48 49 50 51 52 53 54	55 56 57 58 59 60 61 62 63 64	65 66 67 68 69 70 71 72 73 74	
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Page ______ of ______

BAC 2056

S	T	S	T			(/)
1	2	3	4	5	6	

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESTRAIN/PRESTRESS INPUT

Strain	Stress	(/)
7	8	

M	O	D	A	L	
1	2	3	4	5	6

PRESTRAIN OR PRESTRESS						
1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2	
						(/)

Element Number 1 7 8 9 0 1	Repeat 2	1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	4 5 3 4 5 6 7 8 9 0 1 2	5 6 3 4 5 6 7 8 9 0 1 2	6 7 3 4 5 6 7 8 9 0 1 2	
								(/)
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								(/)

Page ____________ of ____________

BAC 2060

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)
HARMONIC INCREMENTS

H	S	D	C		
1	2	3	4	5	6

(/)

REF. VALUE					INC. VALUE					FINC. VALUE				
			1										2	
7	8	9	0	1	2	3	4	5	6	7	8	9	0	1

(/)

BAC 2059 Sht. 1

1	2	3	4	5	6	
H	A	R	M			(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)

No. of Loaded Elements	No. Harmonics – Element	No. Harmonics – Output	
7 8 9	1 0	1	
			(/)

HARMONIC DEPENDENT ELEMENT PRESSURE LOADS

Element Number	Repeat Option	No. of Radial Loading Points	No. of Axial Loading Points	PRESSURE LOAD VALUES						
7 8 9	1 0	1 2 3	4 5 6	1 2 7 8 9 0 1 2 3 4 5 6	2 7 8 9 0 1 2 3 4 5 6	3 4 7 8 9 0 1 2 3 4 5 6	4 5 7 8 9 0 1 2 3 4 5 6	5 6 7 8 9 0 1 2 3 4 5 6	6 7 7 8 9 0 1 2 3 4 5 6	
										(/)
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Page ________ of ________

BAC 2059 Sht. 2

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

HARMONIC DEPENDENT ELEMENT PRESSURE LOADS (CONTINUED)

Element Number	Repeat Option	No. of Radial Loading Points	No. of Axial Loading Points	PRESSURE LOAD VALUES						
7 8 9	10	11 12 13	14 15 16	17 18 19 20 21 22 23 24 25 26	27 28 29 30 31 32 33 34 35 36	37 38 39 40 41 42 43 44 45 46	47 48 49 50 51 52 53 54 55 56	57 58 59 60 61 62 63 64 65 66	67 68 69 70 71 72 73 74 75 76	
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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)

HARMONIC DEPENDENT
ELEMENT THERMAL LOADS

No. of Loaded Elements			No. Harmonics–Element	No. Harmonics–Output	
7	8	9	10	11	
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Element Number			Repeat Option	No. of Temperature Points						THERMAL LOAD VALUES						
7	8	9	10	11	12	13	14	15	16	17–26	27–36	37–46	47–56	57–66	67–76	
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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

HARMONIC DEPENDENT ELEMENT THERMAL LOADS (CONTINUED)

Element Number	Repeat Option	No. of Temperature Points		THERMAL LOAD VALUES						
7 8 9	10	11 2 3	4 5 6	17 8 9 20 1 2 3 4 5 6	27 8 9 30 1 2 3 4 5 6	37 8 9 40 1 2 3 4 5 6	47 8 9 50 1 2 3 4 5 6	57 8 9 60 1 2 3 4 5 6	67 8 9 70 1 2 3 4 5 6	
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13. ABSTRACT

An automated general purpose system for analysis is presented. This system identified by the acronym, "MAGIC III" for Matrix Analysis via Generative and Interpretive Computations, is an extension of the structural analysis capability available in the initial MAGIC System. MAGIC III provides a powerful framework for implementation of the finite element analysis technology and provides diversified capability for displacement, stress, vibration, and stability analyses.

Additional elements have been added to the MAGIC element library in this phase of MAGIC development. These are the solid elements; rectangular prism, tetrahedron, triangular prism, symmetric triangular prism, and triangular ring (asymmetrical loading). Also included are the symmetric shear web element and a revised quadrilateral thin shell element. The finite elements listed include matrices for stiffness, mass, prestrain load, thermal load, distributed mechanical load, pressure and stress.

Documentation of the MAGIC III System is presented in three parts; namely, Volume I: Engineer's Manual, Volume II: User's Manual and Volume III: Programmer's Manual.

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