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MAGIC III: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS. VOLUME II. USER'S MANUAL

Stephen Jordan, et al

Bell Aerospace Company

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MAGIC III: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

STEPHEN JORDAN

JAMES R. BATT

BELL AEROSPACE COMPANY

TECHNICAL REPORT AFFDL-TR-72-42, VOLUME II

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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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MAGIC III: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

STEPHEN JORDAN
JAMES R. BATT

IIa

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.

The authors wish to express appreciation to colleagues in the Advanced Structural Design Technology Section of the Structural Systems Department for their individually significant, and collectively indispensible, contributions to this effort.

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This technical report has been reviewed and is approved.

FRANCIS J. JANIK, Jr.
Chief, Theoretical
Mechanics Branch
Structures Division

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 band-width 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 symmetric 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.

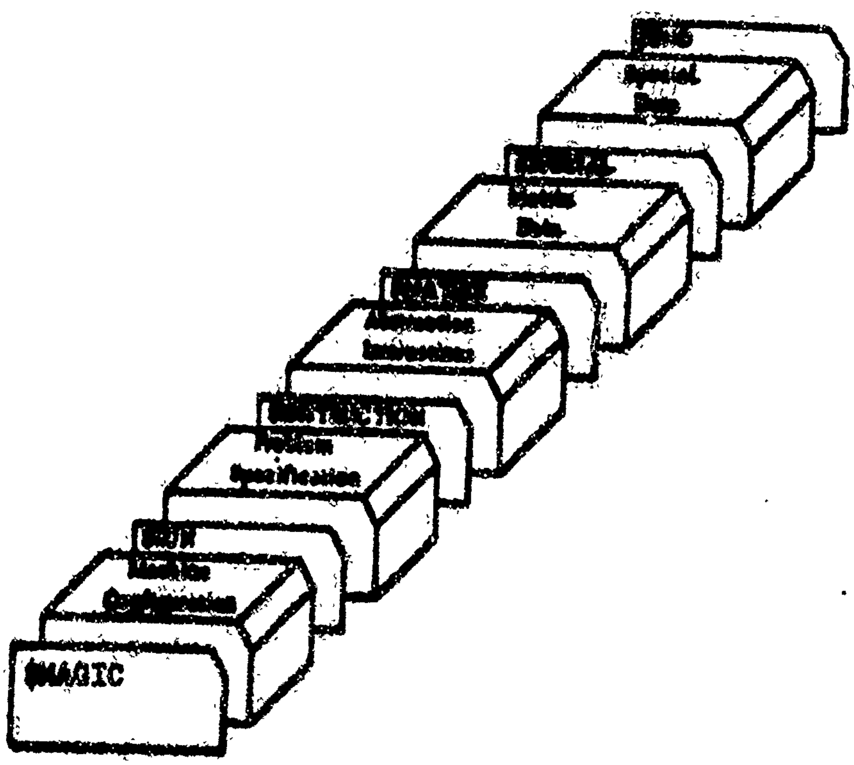
B. System Input Data

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:

$$c = \pm a \quad .Op. \quad \pm b$$

where a and b are known matrix names, c is the name of the matrix to be computed, Op is the operation to be performed in computing c from a and b and the positive signs of a and 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. <u>Solution of Equations by Cholesky Triangularization</u>

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. <u>Computation of Triangularized Matrix</u>

Statements are of the form:

T = A.TRIA.

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

c. <u>Computation of Linear Equation Solution when Triangularized Matrix is Known</u> (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

$$A_0 + A_1x + A_2x^2 = 0$$

which may be processed iteratively to approximate x as follows:

$$x_{i+1} = -A_1^{-1}(A_0 + A_2x_i^2)$$

The appropriate abstraction instruction sequence using REPEAT is as follows.

```
1    7
$INSTRUCTION
     A1INV   = -A1     .INVERS.
     X  /1/  = A1INV  .MULT.    AO
     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/  = AO      .ADD.    AX2/1/
     X  /2/  = A1INV  .MULT.    AAX/1/
     PRINT(,,,)X/2/
```

where matrices AO, 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.    AO
     PRINT(,,,)X/1/
     XR /1/  = X   /1/.RENAME.
     X2 /1/  = XR /1/.EMULT.   X  /1/
     AX2/1/  = A2      .MULT.   X2 /1/
     AAX/1/  = AO      .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/  = AO      .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/  = AO      .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.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 $\leq$ 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:

$$c_1, c_2 = a.DJOIN.(j,o)$$

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., $[\underline{c_1} \vdots \underline{c_2}] = a$). 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 CUTTE. (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. USERO4

a. Introduction

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

This .USERO4. 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.

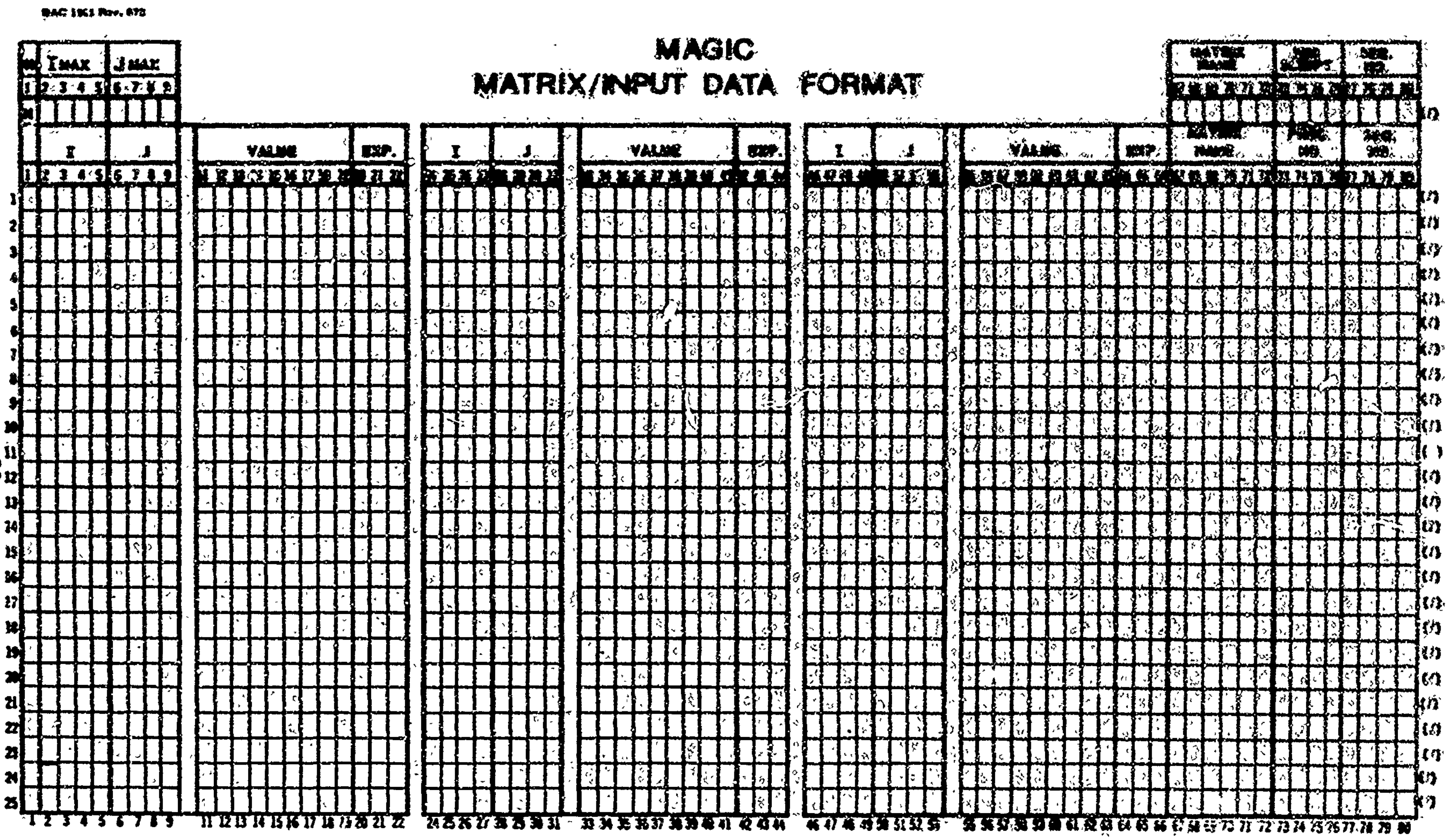


Figure II-1 MAGIC Matrix/Input Data Format

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 wo ng 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 .USERO4.

A complete linearly elastic stress analysis which generates displacements, stresses, forces, and reactions can be obtained by using a .USERO4. 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 .USERO4. instruction follows:

```
CC    CC        CC
1     7         16
$MAGIC
$INSTRUCTION    SOURCE
        ,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC,EM,=,,,.USERO4.
        DISPL,STR,FORCE,REACT=TR,SC,EM,XLD,,,,,.ANALIC.(KALC,NNOM,
        NRSELM)
```

where for the .USERO4. 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	1[illegible]
Triangular Thin Shell	20	6	3[illegible]
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 As[illegible]ct Ratio Quad[illegible]eral Thin She[illegible]	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 .USERO4. 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.

$$\underset{(N\times N)}{[A]}\ \underset{(N\times M)}{[X]} = \underset{(N\times M)}{[B]}$$

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

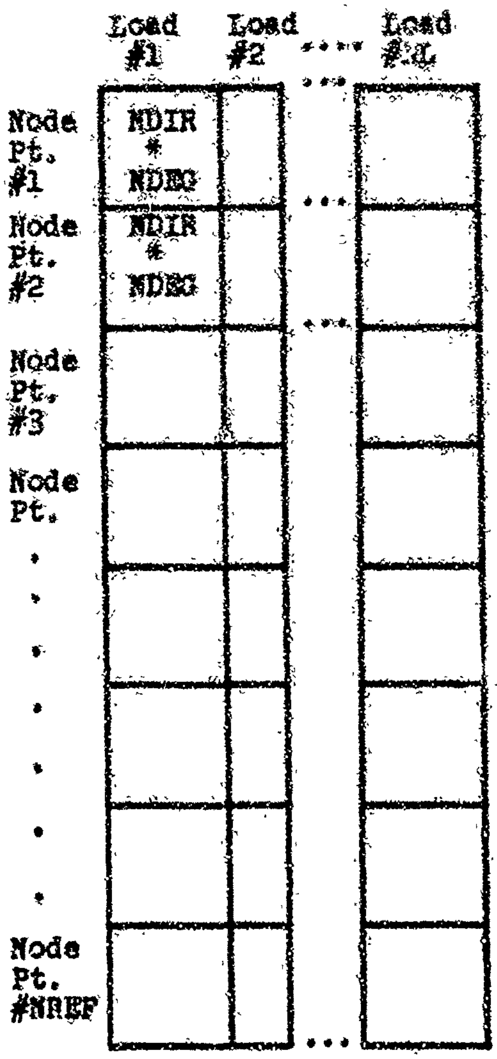
Number of Rows - Number of degrees of freedom in total system

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

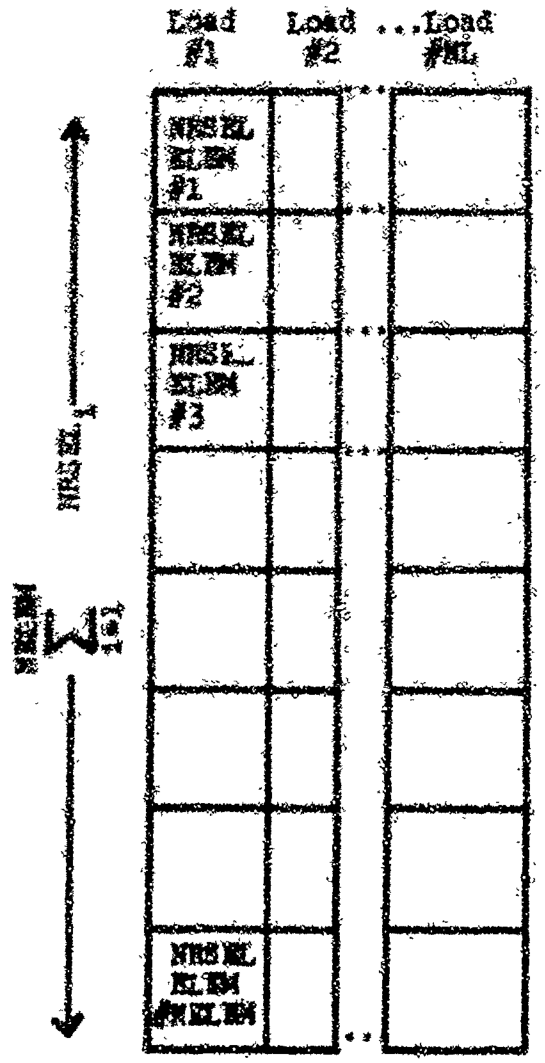
Column records are of the form

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

NREF = number of reference node points

FORMAT OF OUTPUT MATRIX 2 (WTRESS)

Element Stress matrix from ANALIC,



Matrix is of the order

(NTRSEL x NL)

where

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

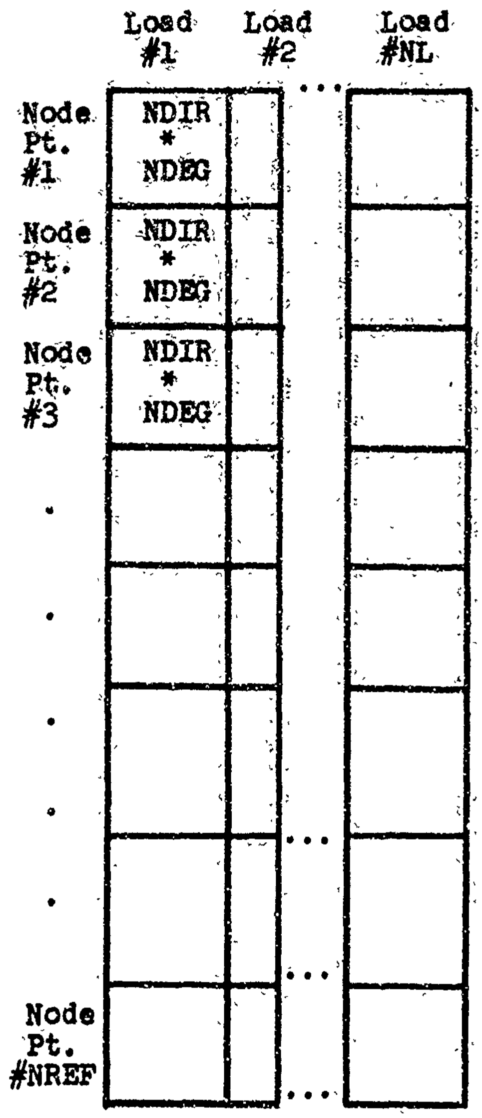
NL = number of load conditions

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

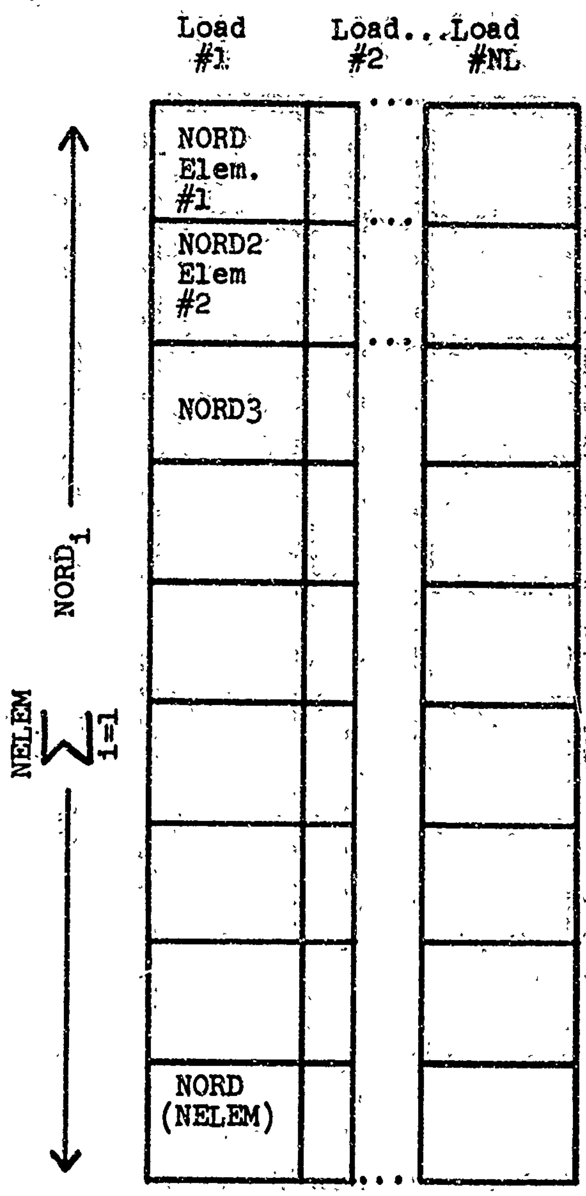
Column records are of the form

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 tc 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

```
      $STATICSA3VN
C     ASSYMMETRIC CROSS SECTION RING ELEMENT AGENDUM
C---- GENERATE MASTER STIFFNESS MATRIX
      ,MAT,,,TR,,REL,FTEL,SEL,STEL,,,SC,EM, = ,,, .USER 4.
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  .MDECD.
      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/
      XO1 /1/  = TR .MULT. XX1 /1/
      ST1 /1/  = EM1 /2/, XO1 /1/ .STRESS. (4,)
      ATT1 /1/ = SA1 /1/ .MULT. XO1 /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/
      XO12  = XX1 /1/  .ADJOIN. XX1 /2/
      ACT12 = ACT1 /1/  .ADJOIN. ACT1 /2/
      IF ( HLC /3/ .NULL. ) GO TO 1020
      ST313 = ST12 .ADJOIN. ST1 /3/
      XO313 = XO12 .ADJOIN. XX1 / 3/
      ACT313 = ACT12  .ADJOIN. ACT1 /3/
      IF ( HLC /4/ .NULL. ) GO TO 1030
      ST414 = ST313 .ADJOIN. ST1 /4/
      XO414 = XO313 .ADJOIN. XX1 /4/
      ACT414 = ACT313 .ADJOIN. ACT1 /4/
      IF ( HLC /5/ .NULL. ) GO TO 1040
      ST515  =  ST414  .ADJOIN. ST1 /5/
      XO515  =  XO414  .ADJOIN. XX1 /5/
      ACT515 = ACT414 .ADJOIN. ACT1 /5/
      IF ( HLC /6/ .NULL. )  GO TO 1050
      ST616 = ST515 .ADJOIN. ST1 /6/
      XO616 = XO515 .ADJOIN. XX1 /6/
      ACT616 = ACT515 .ADJOIN. ACT1 /6/
      IF ( HLC /7/ .NULL. )  GO TO 1060
      ST717  = ST616  .ADJOIN. ST1 /7/
      XO717  = XO616  .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/
      XO818  = XO717  .ADJOIN. XX1 /8/
      ACT818 = ACT717 .ADJOIN. ACT1 /8/
      IF ( HLC /9/ .NULL. )  GO TO 1080
1020 SUMS12, SUMD12, SUMR12 = SC, ST12 , XO12 , ACT12   .HSUM.
      IF ( HLC /3/ .NULL. ) GO TO 1000
1030 SUMS13, SUMD13, SUMR31 = SC, ST313, XO313, ACT313  .HSUM.
      IF ( HLC /4/ .NULL. ) GO TO 1000
1040 SUMS14, SUMD14, SUMR41 = SC, ST414, XO414, ACT414  .HSUM.
      IF ( HLC /5/ .NULL. ) GO TO 1000



1050 SUMS15, SUMD15, SUMR51 = SC, ST515, XO515, ACT515  .HSUM.
      IF ( HLC /6/ .NULL. ) GO TO 1000
1060 SUMS16, SUMD16, SUMR61 = SC, ST616, XO616, ACT616  .HSUM.
      IF ( HLC /7/ .NULL. ) GO TO 1000
1070 SUMS17, SUMD17, SUMR71 = SC, ST717, XO717, ACT717  .HSUM.
      IF ( HLC /8/ .NULL. ) GO TO 1000
1080 SUMS18, SUMD18, SUMR81 = SC, ST818, XO818, ACT818  .HSUM.
1000 CAA = CA .RENAME.
```

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=,,,.USER04. 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) $\begin{bmatrix} TR1 \\ \hline TR12 \end{bmatrix} = [TR]$ 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) [LE1/1/, LE2/1/] = [RE2/1/] 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/ $XX1/1/ = [TR12]^T [X1/1/]$ Forms unordered system of displacements.
17	X01/1/ = TR.MULT.XX1/1/ [X01/1/] = [TR] [XX1/1/] 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/ = [SA1/1/] [X01/1/] 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=GC,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,XO818,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,PTEL,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; 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.
12	SA1=EM1.ASSEM.SC (10) Generate the assembled stiffness matrix SA1 in form of O-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 O-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) [RE1 / RE2] = [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	B1,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) [TR1 / TR12] = [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	X01 = TR.MULT.XX1 [X01] = [TR] [XX1] Forms 0-1 ordered displacement columns in X01.
21	ST1 = EM1, X01.STRESS. (4,) Calculates net element stresses for each element
22	ATT1 = SA1.MULT.X01 ATT1 = [SAI] [X01] 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.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
      GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.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
C
C-----STATICS AGENDUM, WITH CONDENSATION
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        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES



C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
      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)
C
C        REDUCE STIFFNESS MATRIX AND PRINT
C
      KO,K/O = 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
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C-----TRANSFORM EXTERNAL LOADS TO ORDERED SYSTEM, FORM TOTAL LOADS
      LOADO = TR .MULT. LOADS
      TLOAD = FTELS .ADD. LOADO
C-----CONDENSE ASSEMBLED STIFFNESS MATRIX
      TOP,BOT = STIFF .DEJOIN. (SC(6,1),1)
      K11,K12 = TOP .DEJOIN. (SC(6,1),0)
      K12T,K22 = BOT .DEJOIN. (SC(6,1),C)
```

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 = C1 .TRANSP.
      D2T = C2 .TRANSP.
      D12 = C1T .ADJOIN. D2T
      XX  = C12 .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 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.THULT.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.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
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

```
$STABILITY$
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 (I X 1) UNIT AND (I 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.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

      GENERATE STRESSES

30    STRESS = EM,XO .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)
    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

    KINV,DYNAM = STIFF,MASS .CHTRIA.

       FINC 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 [MASS] = [MASSM] + [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: [STIFF][DYNAM] = [MASS] [KINV] = Triangularized stiffness matrix [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 [[DYNAM] - [EVALUE][I]] [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) [TRO / TR12] = [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 [KGEN1] = [EVECT]^T [STIFF] Forms the product of the transpose of the eigenvector matrix and the reduced stiffness matrix.
438	KGEN=KGEN1.MULT.EVECT [KGEN] = [EVECT]^T [STIFF] [EVECT] Forms the generalized stiffness matrix in KGEN by forming the product of KGEN1 and EVECT.
439	MGEN1=EVECT.TMULT.MASS [MGEN1] = [EVECT]^T [MASS] Forms the product of the transpose of the eigenvalue matrix and the reduced mass matrix.
440	MGEN=MGEN1.MULT.EVECT [MGEN] = [EVECT]^T [MASS] [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.

$$\Big[a_0 [M] + [K_f]\Big]^{-1} [M] \{\phi_i\} = \lambda_i \{\phi_i\} \qquad (2)$$

from which the natural frequencies may be recovered as follows:

$$f_{n_i} = \frac{1}{2\pi} \sqrt{\left(\frac{1}{\lambda_i}\right) - a_0} \qquad (3)$$

where a_0 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_0. Problems arise in some cases when diagonal mass matrices are employed whose terms are on the order of 10^{-2} compared to terms on

```
$DYNAMICS$F
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. (I,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_o, so that the matrix product $a_o [M]$ when added to the stiffness matrix will render it non-singular. A large value of a_o 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:

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

It has been found, in general, that when consistent mass matrices are employed in the vibration analysis, a value of $a_o = 1.0$ 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,=,,,.USERO4. 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) $\begin{bmatrix} \text{MSCAL} \\ \text{LMASS} \end{bmatrix} = [\text{M}]$ 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 $[\text{LUMPO}] = [\text{TR}][\text{LMASS}]$ 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) $\begin{bmatrix} \text{LL} \\ \hdashline \text{LUMP} \end{bmatrix} = [\text{LUMPO}]$ 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 [MASS] = [MASSM] + [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) [MASS1] = MSCAL [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 [STIFFM] = [MASS1] + [STIFF] Adds [MASS1] to [STIFF] to form [STIFFM]. This is equivalent to $[a_0 [M] + [K]]$ as described in the writeup.
471	FLEX,DYNAM=STIFFM,MASS.CHTRIA. Solves the following set of equations [STIFFM] [DYNAM] = [MASS] [FLEX] = Triangularized Stiffness Matrix [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 $\left[[DYNAM] - [EVALUE][I]\right][EVECT] = [0]$ 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

----- CYNAMICS 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,
   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.THULT.KR
KGEN = KGEN1.MULT.EVECT
MGEN1 = EVECT.THULT.MR
MGEN = MGEN1.MULT.EVECT

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

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_o, 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.

```
NAMICSCF

---- DYNAMICS 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 TOTAL MASS MATRIX
   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
```

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.

   FINC 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.

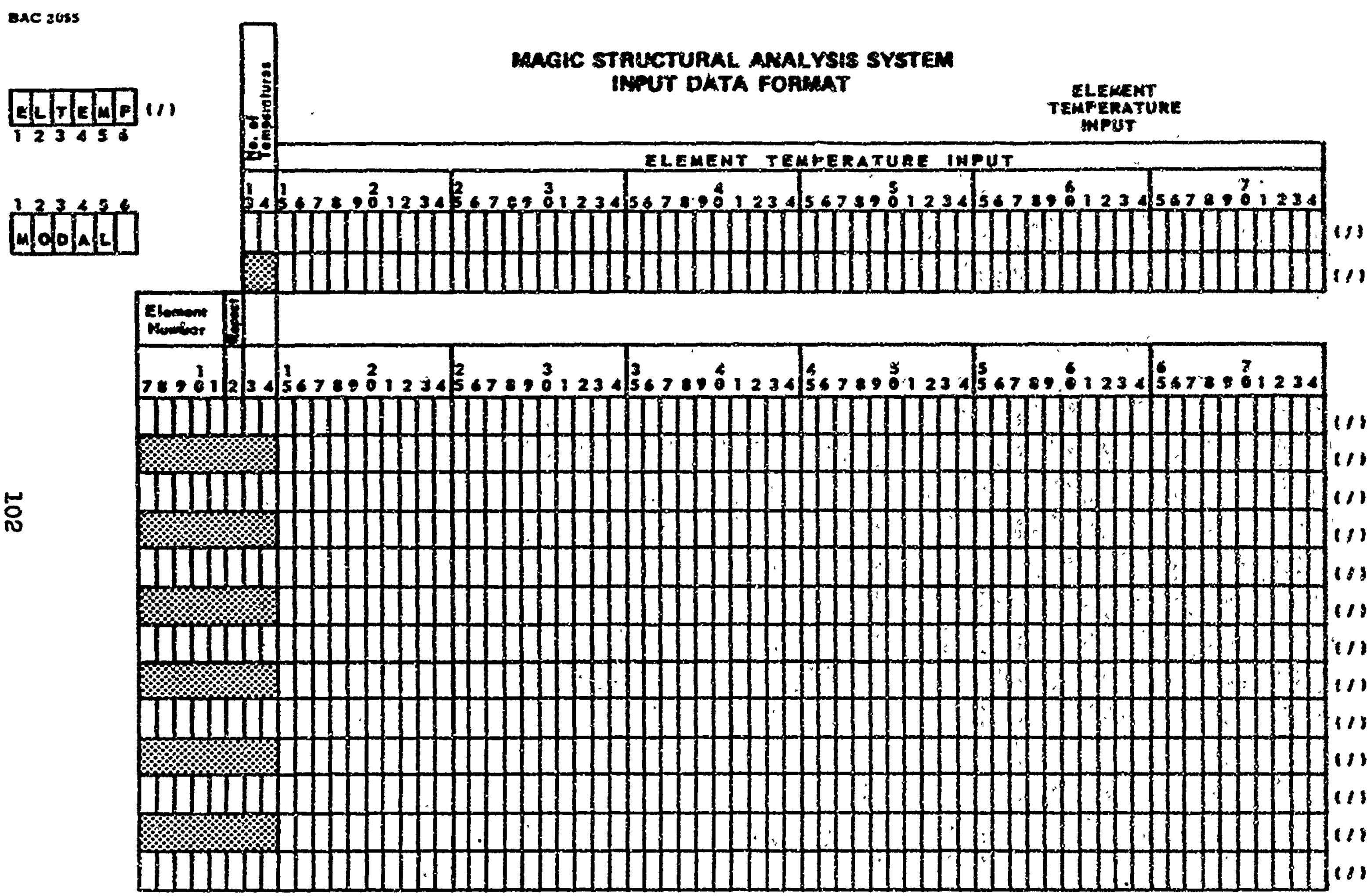


Figure II-13 - Element Temperature Input Data Form

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'

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT PRESSURE INPUT

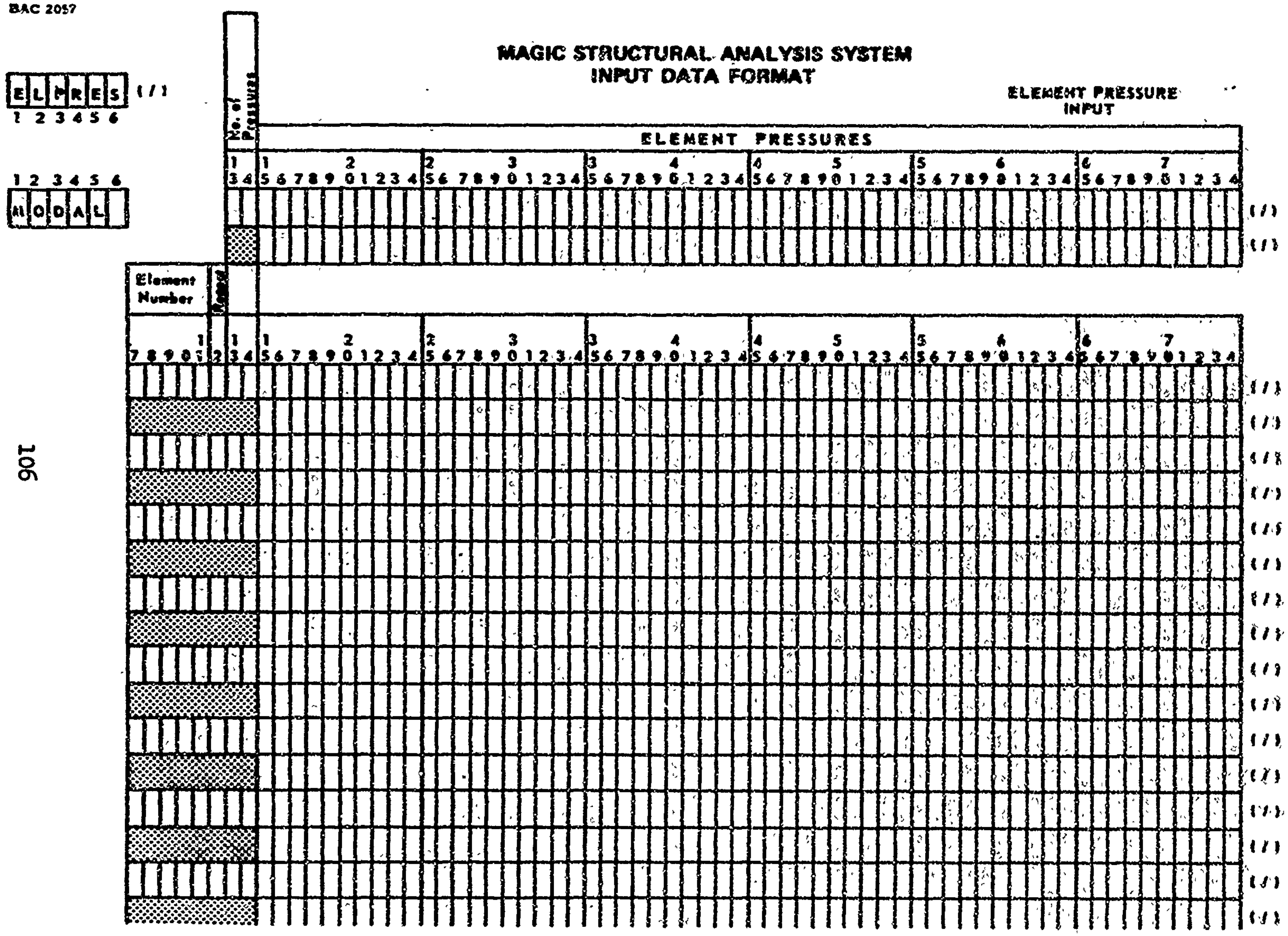

Figure II-14 - Element Pressure Input Data Form must appear in either Column 7 and/or Column 8. No default has been allowed for this card, and its omission is an error.

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.

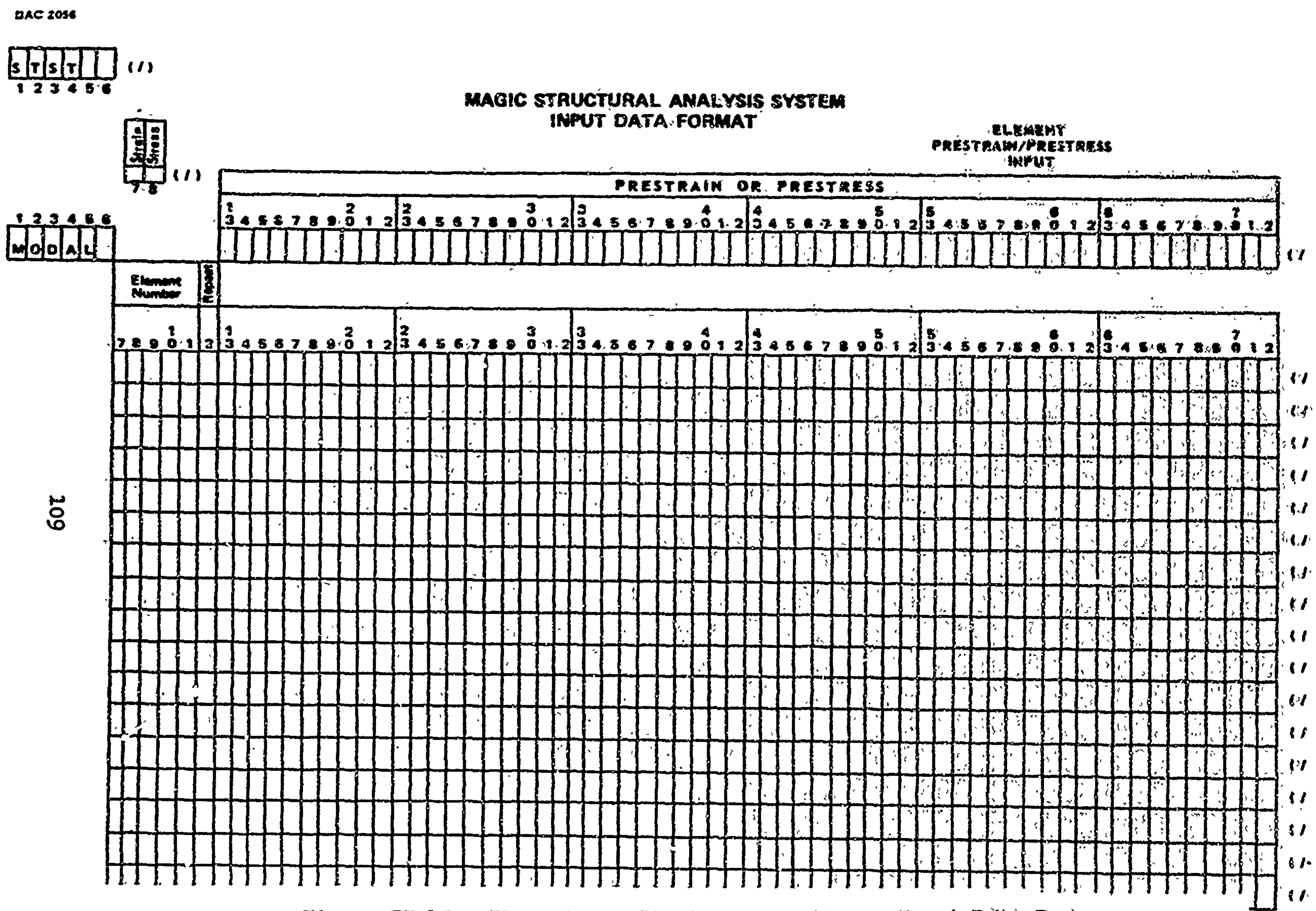

Figure II-15 - Element Pre-Strain or Pre-Stress Input Data Form

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.

BAC 2004

MASS (/)

SCALE (/)

Mass Scalar

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MODAL

Grid Pt. Number

LUMPED MASSES								
M_X	M_Y	M_Z	$M_{\theta X}$	$M_{\theta Y}$	$M_{\theta Z}$	M_1	M_2	M_3

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. <u>Element Control Data Section (Figure II-17)</u>

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.

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

(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.

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

(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: Print	PRINT: Elem. Mat.	PRINT: Full	Number of Input Modes	Suppress Pressure	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	
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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.

SAC 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
13–22	23–32	33–42	43–52	53–62	63–72

Element Number	Repeat	A	B	C	D	E	F	
7–11	12	13–22	23–32	33–42	43–52	53–62	63–72	
								(/)
								(/)
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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 pre-strain 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.

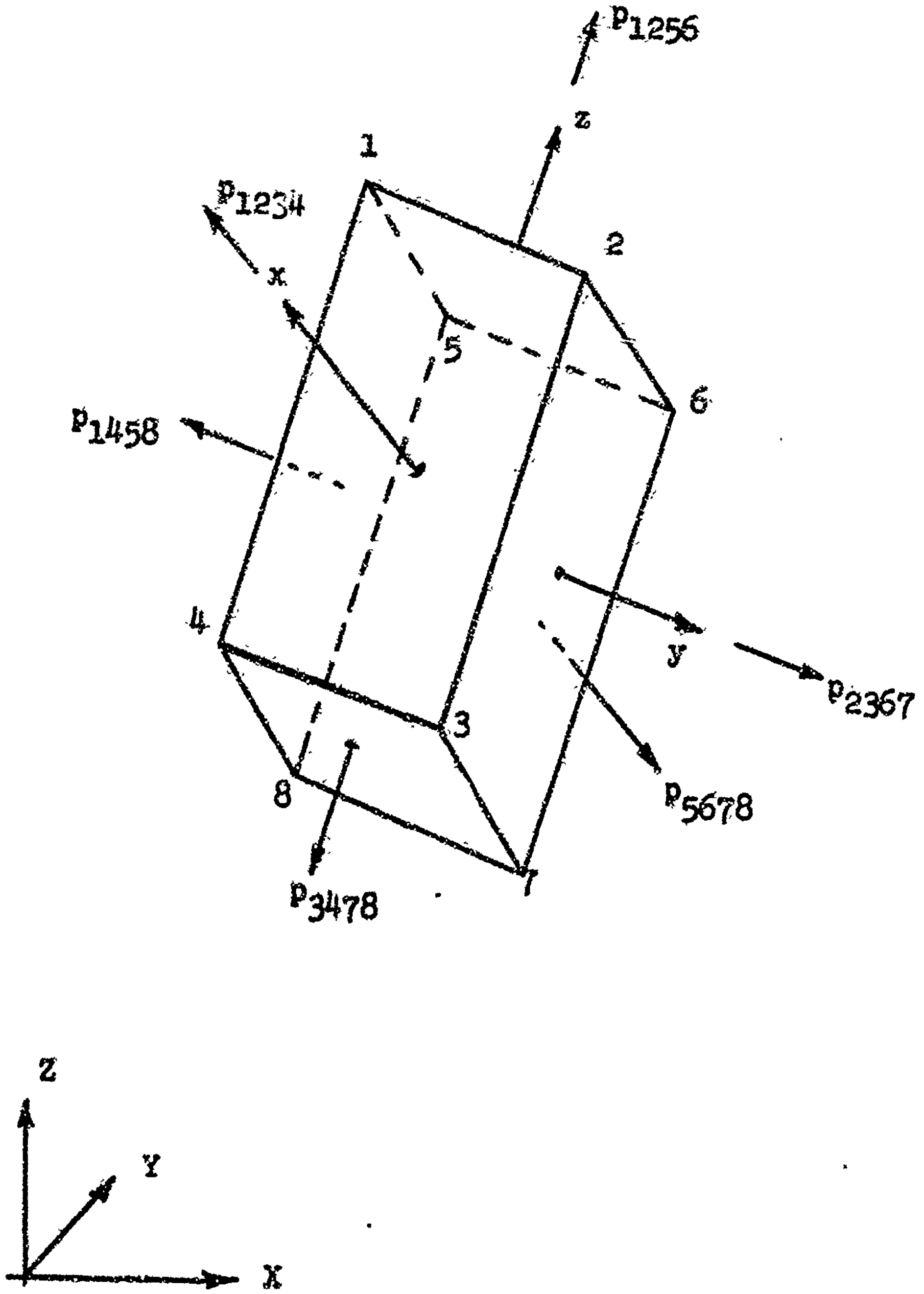


Figure II-19 - Rectangular Prism Element

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.

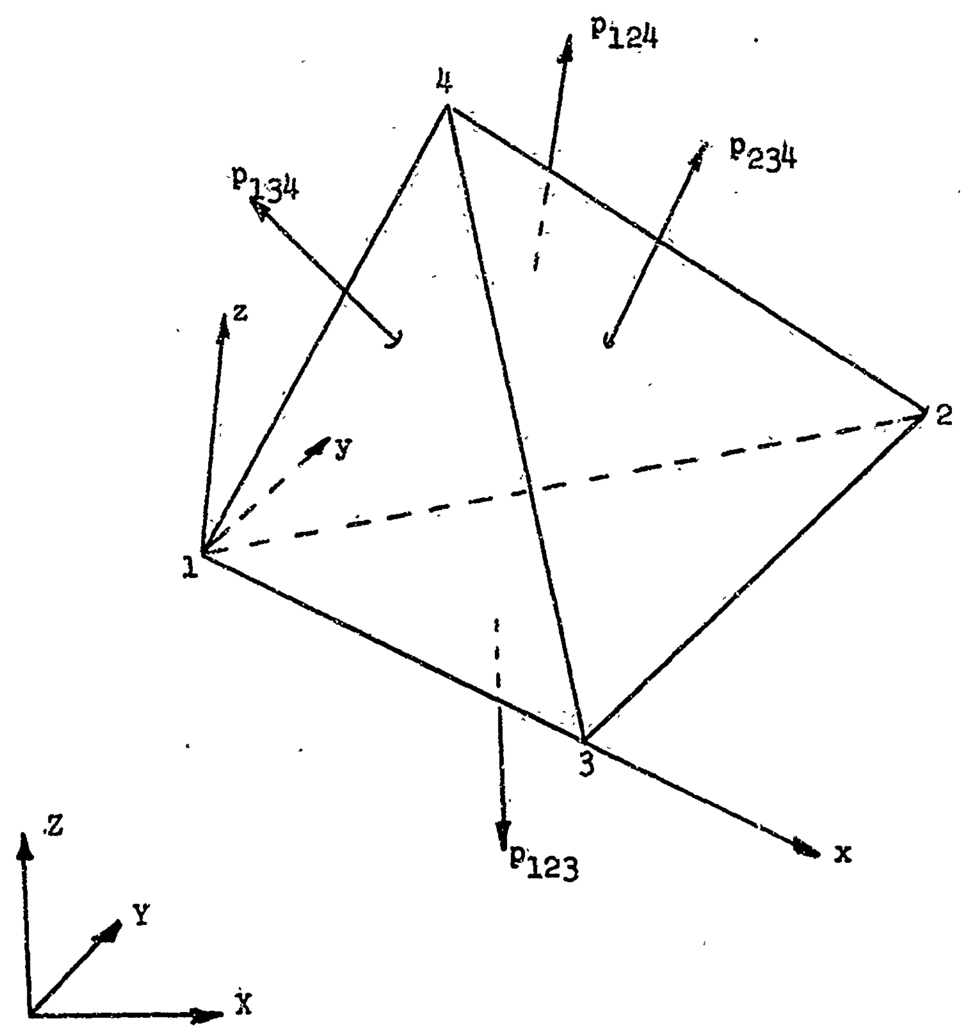


FIGURE II-20 - TETRAHEDRON ELEMENT

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)

Element Number - Cols. 7-10

Refer to Element Control Section.

Plug Number - Cols. 11-12

The triangular prism element is identified as number 51.

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 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).

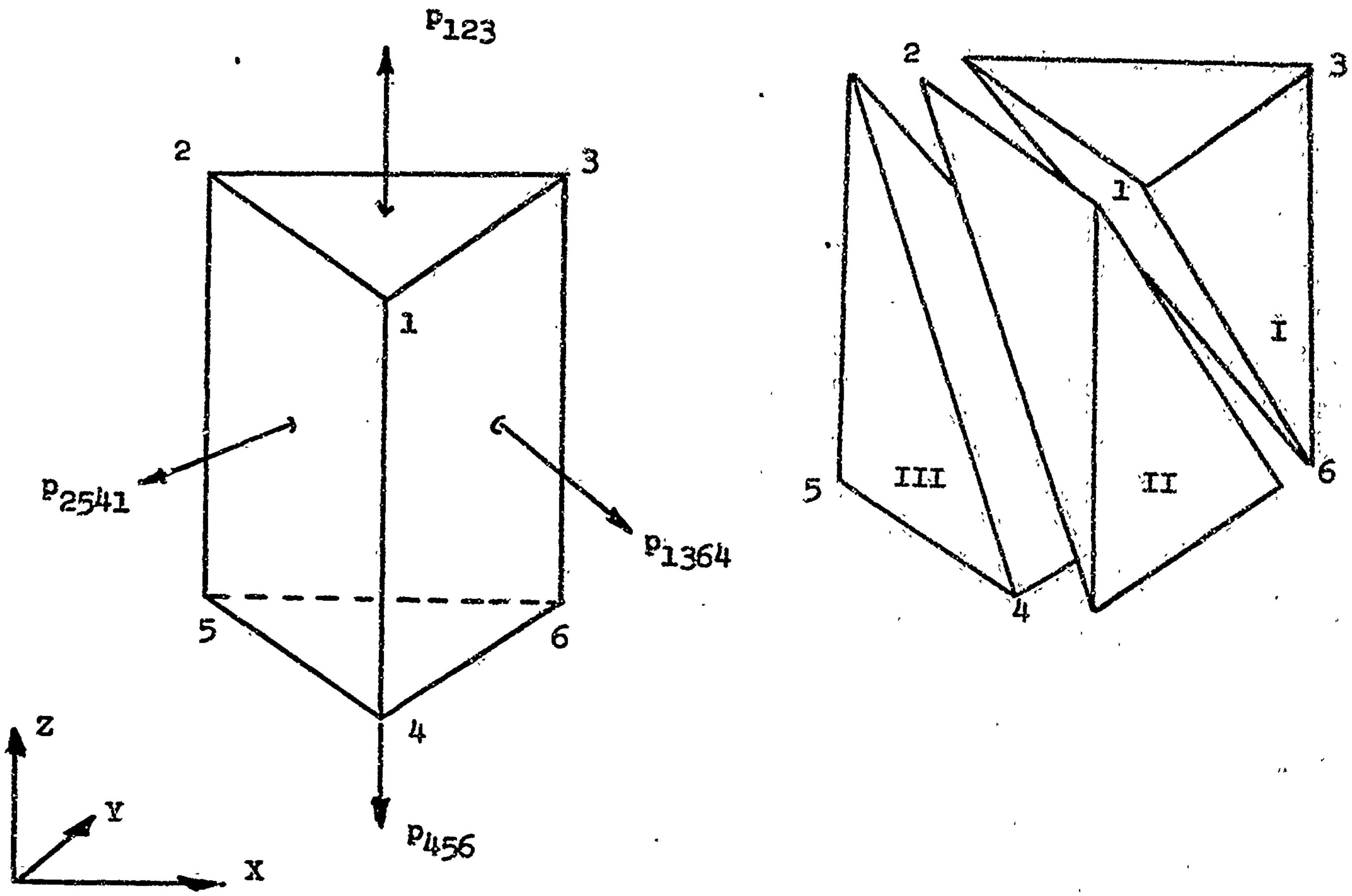


FIGURE II-21 TRIANGULAR PRISM ELEMENT

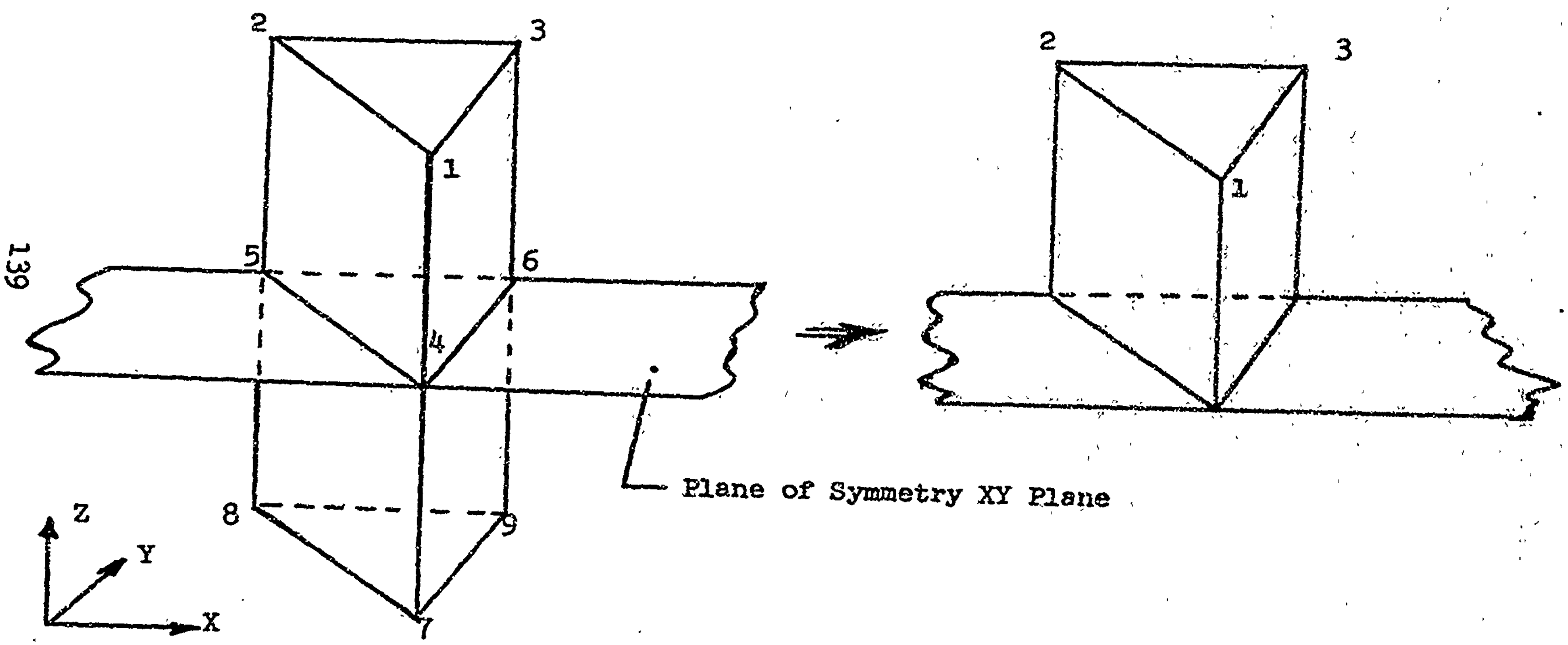


FIGURE II-22 SYMMETRIC TRIANGULAR PRISM ELEMENT

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.

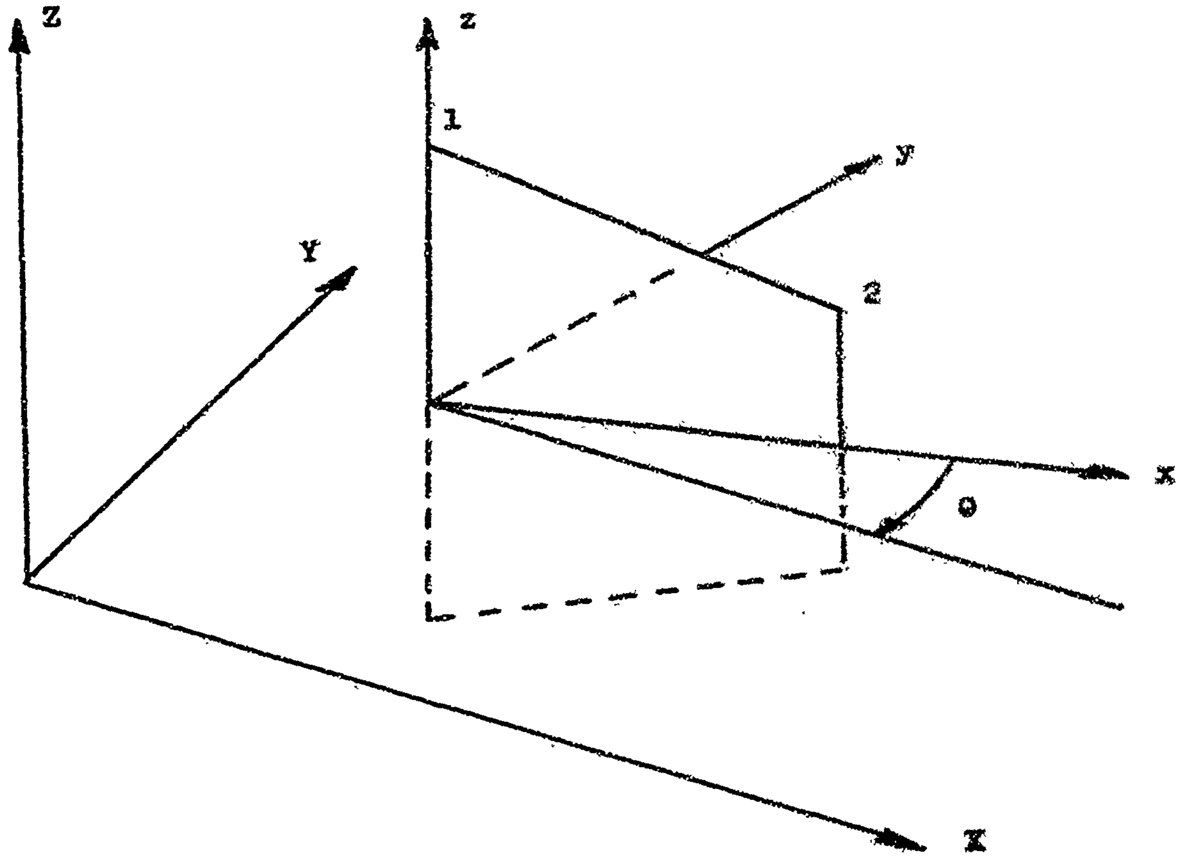


FIGURE II-23 - SYMMETRIC SHEAR WEB ELEMENT

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.

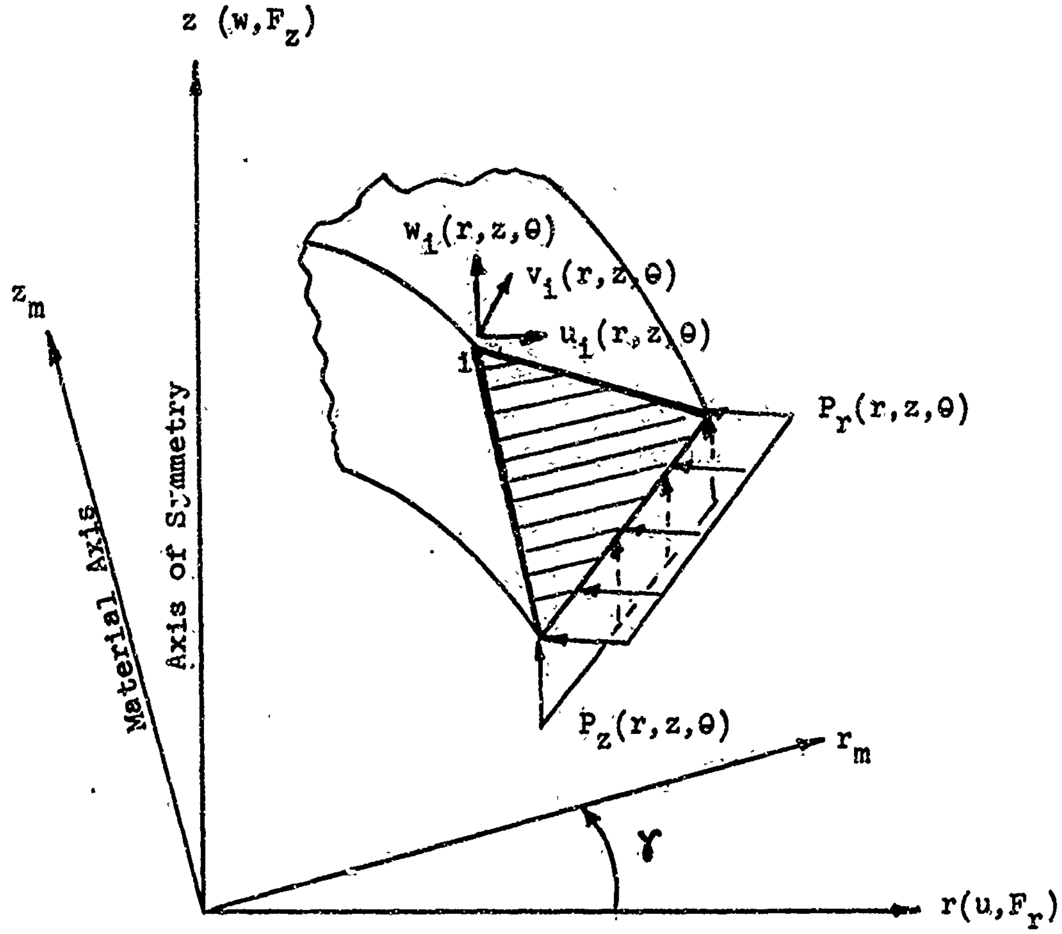


Figure II-24 - Triangular Ring Element (Asymmetric Loading)

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 Cosnθ and Sinnθ.

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 - γ_{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 (γ_{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

$IV \leq FV - RV$

$0 \leq FV - RV$.

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

H	S	D	C		
1	2	3	4	5	6

(/)

REF VALUE	INC. VALUE	FINC. VALUE
7 8 9 10 11	12 13 14 15 16	17 18 19 20 21

(/)

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:

BAC 2050

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)
HARMONIC INCREMENTS

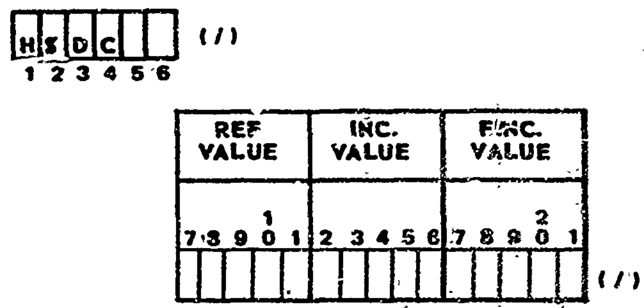


Figure II-25 - Harmonic Stress and Displacement Output Control

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.

BAC 2039 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 7 8 9 2 0 1 2 3 4 5 6	2 7 8 9 0 1 2 3 4 5 6	3 7 8 9 4 0 1 2 3 4 5 6	4 7 8 9 5 0 1 2 3 4 5 6	5 7 8 9 6 0 1 2 3 4 5 6	6 7 8 9 7 0 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)

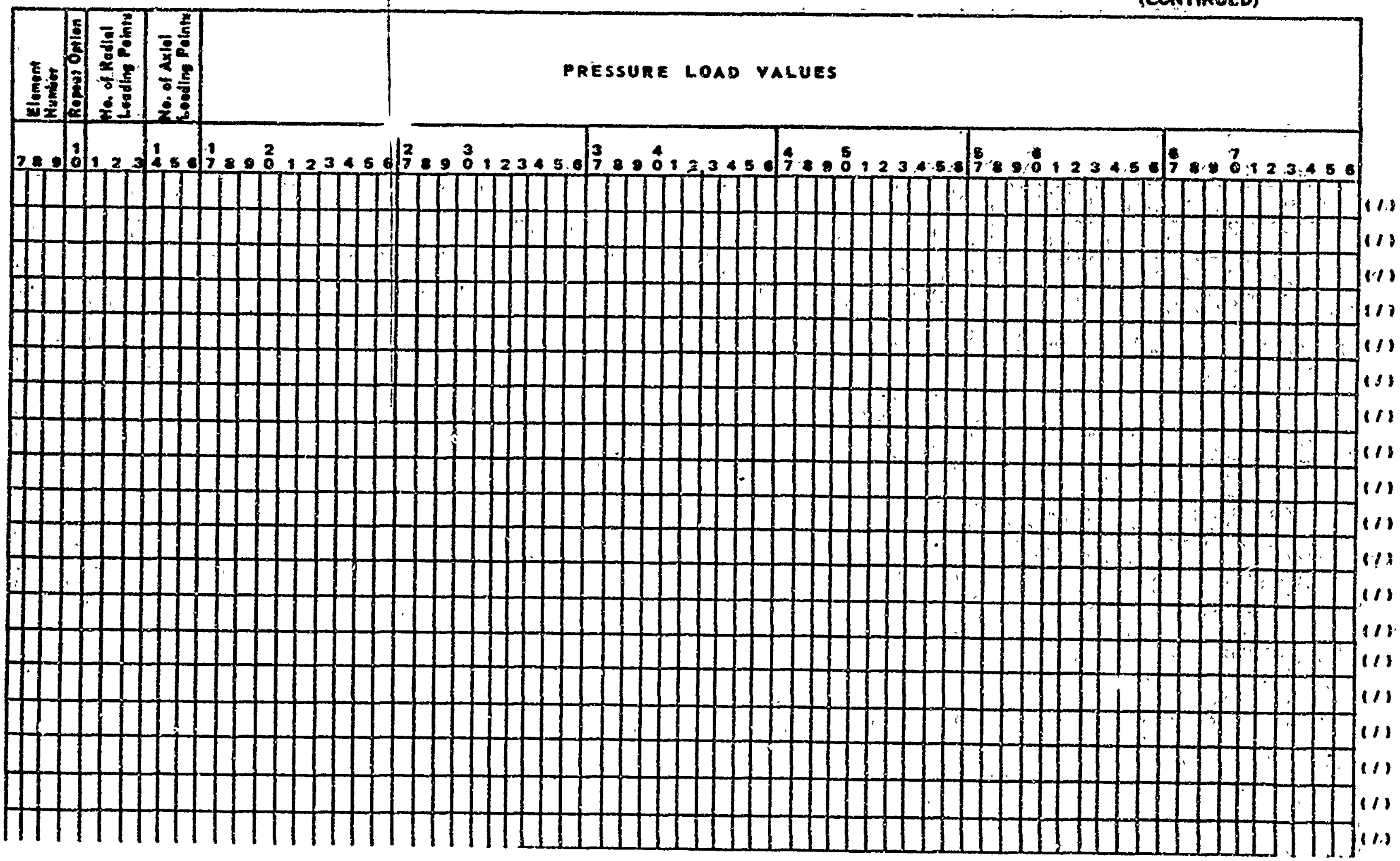


Figure II-26 (Concluded)

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

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)

HARMONIC DEPENDENT ELEMENT THERMAL LOADS

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

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

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	
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

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

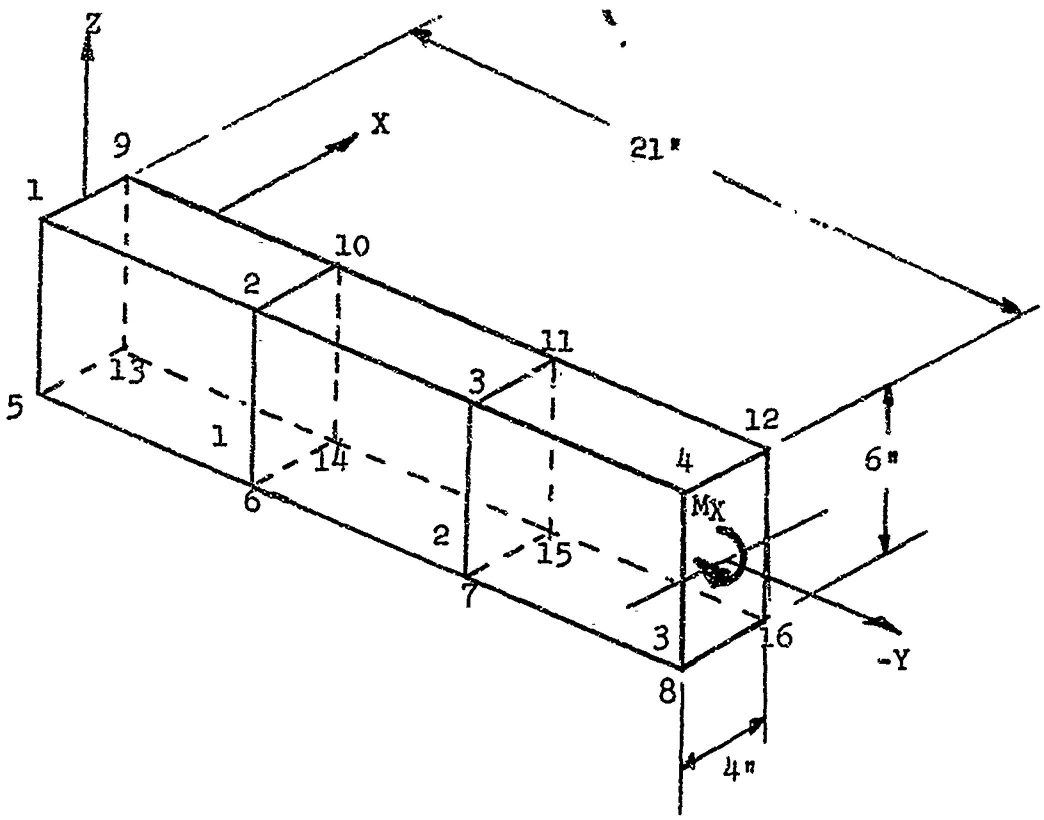
$$\{\Delta\}^T = \lfloor V_2, W_2, V_3, W_3, \ldots\ldots, V_{16}, W_{16} \rfloor$$

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

$\vartheta_{XY} = \vartheta_{YX} = \vartheta_{YZ} = \vartheta_{ZY} = \vartheta_{ZX} = \vartheta_{XZ} = \vartheta = .333$

$\rho = .00073395$ #sec^2/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

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

Columns 1–72	
THREE ELEMENT CANTILEVERED BEAM SUBJECTED TO AN END	(/
MOMENT. RECTANGULAR PRISM ELEMENT IDEN. NO. 52	(/
STATICS ANALYSIS CONCENTRATED LOADS EQUIVELANT TO MOMENT	(/
	(/
	(/
	(/
	(/
	(/
	(/

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

BAC 1616-1

MATER (/)
1 2 3 4 5 6

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	J	BSTEEL	X									1	0	.00073954	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (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-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

	Request	Columns	Entry
		1–6	S Y S T E M (/)
1.	Number of System Grid Points	1–6	16
2.	Number of Input Grid Points	7–12	16
3.	Number of Degrees of Freedom/Grid Point	13–14	3
4.	Number of Load Conditions	15–16	1
5.	Number of Initially Displaced Grid Points	17–22	0
6.	Number of Prescribed Displaced Grid Points	23–28	0
7.	Number of Grid Point Axes Transformation Systems	29–30	0
8.	Number of Elements	31–36	3
9.	Number of Requests and/or Revisions of Material Tape.	37–38	1
10.	Number of Input Boundary Condition Points	39–44	4
11.	T_o For Structure (With Decimal Point)	45–52	0.0 (/)

FIGURE III-B.4 SYSTEM CONTROL INFORMATION - RECTANGULAR 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

Grid Point Number (cols 7–12)	DIRECTIONS: X – R (cols 13–22)	DIRECTIONS: Y – θ (cols 23–32)	DIRECTIONS: Z – Z (cols 33–42)	
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-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 7	8	9	10	11	Repeat 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

LOADS (/)

LCOND [illegible] (/)

Condition Number — Scalar

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

MODAL

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
	0.0	0.0	0.0						

Grid Pt. Number	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
[illegible]	0.0	-66.66667	0.0						
[illegible]									
9	0.0	66.66667	0.0						
[illegible]									

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

BAC 1629

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7-10)	Plug No. (11-12)	Material Number (13-18)	Isotropic Option (19)	Material Temperature (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat. (31)	Print: Full (32)	Number of Identical Nodes (33-34)	No. of Accom. Nodes (35)	Node Points 1 (36-39)	2 (40-43)	3 (44-47)	4 (48-51)	5 (52-55)	6 (56-59)	7 (60-63)	8 (64-67)	9	10	11	12	
1	52	1 1	8			X				8		1	2	4	5	9	10	14	13					(/)
2	52	1 1	8			X				8		2	3	10	11	7	6	14	15					(/)
3	52	1 1	8			X				8		4	12	16	8	5	11	15	7					(/)
																								(/)
																								(/)
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FIGURE III-B.8 ELEMENT CONTROL DATA - RECTANGULAR PRISM ELEMENT, CANTILEVER BEAM

BAC 1528-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

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)
1	2	3	4	5	6	0.0					

Element Number (7–11)	Region (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
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								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

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

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 CONDENSATION                                  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 COLUMN                                   AGEN0377
       C                                                                         AGEN0378
  10         LSCALE,LOADS = XLD .DEJOIN.(1,1)                                    AGEN0379
       C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR                    AGEN0380
  11         FTELS = FTELA.MULT.LSCALE                                           AGEN0381
       C-----TRANSFORM EXTERNAL LOADS TO ORDERED 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

```
          KR2  = K12 .MULT.KR1                                        AGEN0395
          KR =  K11 .ADD. KR2                                         AGEN0396
      C-----SOLVE FOR DISPLACEMENTS D1                                AGEN0397
          TRIA,D1 = KR,P1 .CHTRIA.                                    00004010
      C-----SOLVE FOR DISPLACEMENTS D2                                AGEN0399
          D2 =  KR1 .MULT. D1                                         AGEN0400
      C-----FORM TOTAL DISPLACEMET VECTOR                             AGEN0401
          D1T = D1 .TRANSP.                                           AGEN0402
          D2T = D2 .TRANSP.                                           AGEN0403
          D12 = D1T .ADJOIN. D2T                                      AGEN0404
          XX  = D12 .TRANSP.                                          AGEN0405
      C-----EXPAND DISPLACEMENTS TO TOTAL SYSTEM DEGREES OF           AGEN0406
      C-----FREEDOM AND REARRANGE TO 0-1-2 SYSTEM                     AGEN0407
          TR0,TR12 = TR.DEJOIN.(SC(5,1),1)                            AGEN0408
          X = TR12.TMULT.XX                                           AGEN0409
          XO = TR.MULT.X                                              AGEN0410
      C                                                               AGEN0411
      C      CALCULATE REACTIONS AND INVERSE CHECK                    AGEN0412
      C                                                               AGEN0413
          REACTS = KELA.MULT.XO                                       AGEN0414
          REACTP= REACTS.SUBT.TLOAD                                   AGEN0415
          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 OF FREEDOM                  AGEN0421
      C                                                               AGEN0422
          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,TR )FTELA                   AGEN0423
          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,   )LOADS                   AGEN0424
          GPRINT(2,,,U,V,W,THETAX,THETAY,THETAZ,SC,)X                 AGEN0425
          GPRINT(1,,,FX,FY,FZ,MX,MY,MZ,SC,TR )REACTP                  AGEN0426
          IF (I3.NULL.) GO TO 600                                     AGEN0427
      C                                                               AGEN0428
      C      ELEMENTS HAVE 3 DEGREES OF FREEDOM                       AGEN0429
      C                                                               AGEN0430
       10 GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )FTELA           AGEN0431
          GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,   )LOADS           AGEN0432
          GPRINT(2,,,U,0,W,0,THETAY,0,W0,0,W00,SC, )X                 AGEN0433
          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
      600 STRESP = EM,XO .STRESS. (4,)                                AGEN0438
          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 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
NUMBER OF MATERIAL PROPERTY POINTS. . . . 1
NUMBER OF PLASTIC PROPERTY POINTS 0
MASS DENSITY. 0.73394994E-03

INPUT CODE I

MATERIAL PROPERTIES

YOUNG'S MODULI / POISSON'S RATIOS

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

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 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-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	NC.	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
3	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 LOAD 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

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	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-0.66663599E 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

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	28	-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	-0.288149E 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	0.380845E 08	6	-0.112303E 08	9	-0.819605E 07
		10	0.112303E 08	11	0.929807E 07	12	0.372846E 07	15	-0.136662E 08	16	-0.186423E 07
		17	-0.145016E 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	-0.288149E 07
		17	-0.561516E 07	18	0.667204E 06	21	0.561516E 07	22	-0.101798E 08	23	-0.186423E 07
		24	-0.172445E 08	26	-0.982654E 07	27	-0.196531E 08	29	-0.326240E 07	30	-0.652481E 07
		32	0.326240E 07	33	0.452480E 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	-0.106023E 08	15	-0.902113E 07	16	0.561516E 07	19	-0.330032E 07
		21	-0.136662E 08	22	-0.186423E 07	28	-0.279634E 07	29	-0.559269E 07	32	0.842275E 07
		33	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

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 07	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	-0.288149E 07
		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	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	0.360865E 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 07	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	-0.149967E 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	-0.288149E 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	-0.288149E 07
		7	0.561516E 07	8	-0.101798E 08	10	-0.342890E 08	11	-0.561516E 07	12	-0.101798E 08

FIGURE III-B.17 CONTINUED

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	-0.134662E 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	-0.171443E 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	-0.330033E 07	9	-0.134662E 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	28	-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	-0.134662E 08	8	0.186423E 07	9	-0.330032E 07	11	-0.134662E 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	-0.134662E 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

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	-0.171443E 08	9	-0.186423E 07
		10	-0.288148E 07	11	0.561516E 07	12	0.667204E 06	15	-0.112303E 08	16	-0.165134E 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 09	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	-0.473734E 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

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	-0.361258E 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	-0.361258E 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	8	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	-0.361258E 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	-0.361258E 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

GPRINT OF MATRIX LOADS (ISET 2)

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	0.72126361E-06	-0.43426453E-05	-0.30667666E-05
3	0.57006502E-06	-0.90560117E-05	-0.20699066E-04
4	0.60850269E-06	-0.13695938E-04	-0.47263157E-04
5	0.0	0.0	0.0
6	-0.72112090E-06	0.43425607E-05	-0.30667450E-05
7	-0.56924446E-06	0.90560370E-05	-0.20699066E-04
8	-0.60526717E-06	0.13695391E-04	-0.47243229E-04
9	0.0	0.0	0.0
10	-0.72141148E-06	-0.43426089E-05	-0.30665412E-05
11	-0.56376602E-06	-0.98560678E-05	-0.20698557E-04
12	-0.60667034E-06	-0.13695461E-04	-0.47242473E-04
13	0.0	0.0	0.0
14	0.72156944E-06	0.43426799E-05	-0.30665967E-05
15	0.57872769E-06	0.98564772E-05	-0.20698542E-04
16	0.60934696E-06	0.13695978E-04	-0.47242073E-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	0.53789943E-03	-0.27370453E-02
4	0.74005127E-02	0.38146973E-03	-0.18739700E-02
5	0.28476883E 02	-0.66676398E 02	0.27313232E-02
6	0.84818707E-03	0.32234088E-02	-0.14524460E-02
7	0.63781738E-02	-0.36373133E-02	-0.41780672E-02
8	0.26702881E-02	-0.40283203E-02	-0.41713713E-02
9	0.28478012E 02	0.66677841E 02	0.36719238E-02
10	-0.57220459E-03	-0.57306290E-02	-0.85163116E-03
11	-0.35286878E-02	0.29077530E-02	-0.14371872E-02
12	-0.57754517E-02	0.32806396E-02	-0.48054321E-04
13	-0.28477570E 02	-0.66678787E 02	0.17709732E-02
14	-0.62942505E-03	-0.24747577E-02	-0.23851395E-02
15	-0.79908844E-02	0.32563934E-02	0.51705515E-02
16	-0.59204102E-02	0.22430420E-02	0.33946732E-02

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

STRESSES FOR THE RECTANGULAR PRISM ELEMENT

(STRESSES EVALUATED AT THE ELEMENT CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	52	1 2 6 5 9 10 14 13

APPARENT ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.28610229E-04	0.44822693E-04	0.63896179E-04	-0.28610229E-05	-0.42915344E-03	0.66757202E-05

ELEMENT APPLIED STRESSES

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

NET ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.28610229E-04	0.44822693E-04	0.63896179E-04	-0.28610229E-05	-0.42915344E-03	0.66757202E-05

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

STRESSES FOR THE RECTANGULAR PRISM ELEMENT

(STRESSES EVALUATED AT THE ELEMENT CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	52	1 2 6 5 9 10 14 13

APPARENT ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.286102229E-04	0.448226493E-04	0.638961799E-04	-0.286102229E-05	-0.429153844E-03	0.667572022E-05

ELEMENT APPLIED STRESSES

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

NET ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.286102229E-04	0.448226493E-04	0.638961799E-04	-0.286102229E-05	-0.429153844E-03	0.667572022E-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

MEMBRANE STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
1	0.305175778E-04	-0.305175778E-04	-0.106811152E-03	0.203132631E-03	0.247035532E-04	-0.467300042E-04

ELEMENT APPLIED STRESSES

MEMBRANE STRESSES

STRESS 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

MEMBRANE STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
1	0.305175778E-04	-0.305175778E-04	-0.106811152E-03	0.203132631E-03	0.247035532E-04	-0.467300042E-04

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

STRESSES FOR THE RECTANGULAR PRISM ELEMENT

(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

MEMBRANE STRESSES

STRESS 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	0.20217898E-03	-0.49591064E-04

ELEMENT APPLIED STRESSES

MEMBRANE STRESSES

STRESS 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

MEMBRANE STRESSES

STRESS 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	0.20217890E-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 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 ALPBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	52	1 2 6 5 9 10 14 13

APPARENT ELEMENT FORCES

POINT	FX	FY	FZ
1	-0.28477417E 02	0.66678665E 02	0.32053809E-02
2	-0.59162750E 01	-0.66672806E 02	-0.27088957E-02
3	0.59156494E 01	0.66670883E 02	-0.29954910E-02
4	0.28476898E 02	-0.66676605E 02	0.27619408E-02
5	0.28478012E 02	0.66677841E 02	0.24586650E-02
6	0.59155121E 01	-0.66671478E 02	-0.12664795E-02
7	-0.59147644E 01	0.66672318E 02	-0.33569936E-02
8	-0.28477585E 02	-0.66678818E 02	0.17567607E-02

ELEMENT APPLIED FORCES

POINT	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	FX	FY	FZ
1	-0.28477417E 02	0.66678665E 02	0.32053809E-02
2	-0.59162750E 01	-0.66672806E 02	-0.27088957E-02
3	0.59156494E 01	0.66670883E 02	-0.29954910E-02
4	0.28476898E 02	-0.66676605E 02	0.27619408E-02
5	0.28478012E 02	0.66677841E 02	0.24586650E-02
6	0.59155121E 01	-0.66671478E 02	-0.12664795E-02
7	-0.59147644E 01	0.66672318E 02	-0.33569936E-02
8	-0.28477585E 02	-0.66678818E 02	0.17567607E-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	FORCES FY	FORCES 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	-0.66663549E 02	-0.40828125E-03
5	-0.11745747E 01	0.66663559E 02	-0.40235519E-02
6	-0.59152527E 01	-0.66667511E 02	0.71716309E-03
7	0.59148360E 01	-0.66673813E 02	0.24414063E-03
8	0.11774902E 01	0.66671112E 02	0.73242188E-03

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES 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	FORCES FY	FORCES 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	-0.66663549E 02	-0.40828125E-03
5	-0.11745747E 01	0.66663559E 02	-0.40235519E-02
6	-0.59152527E 01	-0.66667511E 02	0.71716309E-03
7	0.59148360E 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 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	3	52	4 12 16 8 3 11 15 7

APPARENT ELEMENT FORCES

POINT	FX	FY	FZ
1	0.75988770E-02	-0.66667648E 02	-0.12512287E-02
2	-0.39520264E-02	-0.66645237E 02	0.16021729E-02
3	-0.57678223E-02	0.66669312E 02	0.41190730E-02
4	0.18768311E-02	0.66663513E 02	-0.58583750E-02
5	-0.11749878E 01	0.66669052E 02	-0.24414063E-03
6	0.11782227E 01	0.66645889E 02	0.24414063E-03
7	-0.11833191E 01	-0.66668015E 02	0.31633777E-02
8	0.11813965E 01	-0.66666199E 02	-0.26855469E-02

ELEMENT APPLIED FORCES

POINT	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	FX	FY	FZ
1	0.75988770E-02	-0.66667648E 02	-0.12512287E-02
2	-0.39520264E-02	-0.66645237E 02	0.16021729E-02
3	-0.57678223E-02	0.66669312E 02	0.41190730E-02
4	0.18768311E-02	0.66663513E 02	-0.58583750E-02
5	-0.11749878E 01	0.66669052E 02	-0.24414063E-03
6	0.11782227E 01	0.66645889E 02	0.24414063E-03
7	-0.11833191E 01	-0.66668015E 02	0.31633777E-02
8	0.11813965E 01	-0.66666199E 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

$$\{U\}^T = \lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots, U_{16}, V_{16}, W_{16} \rfloor$$

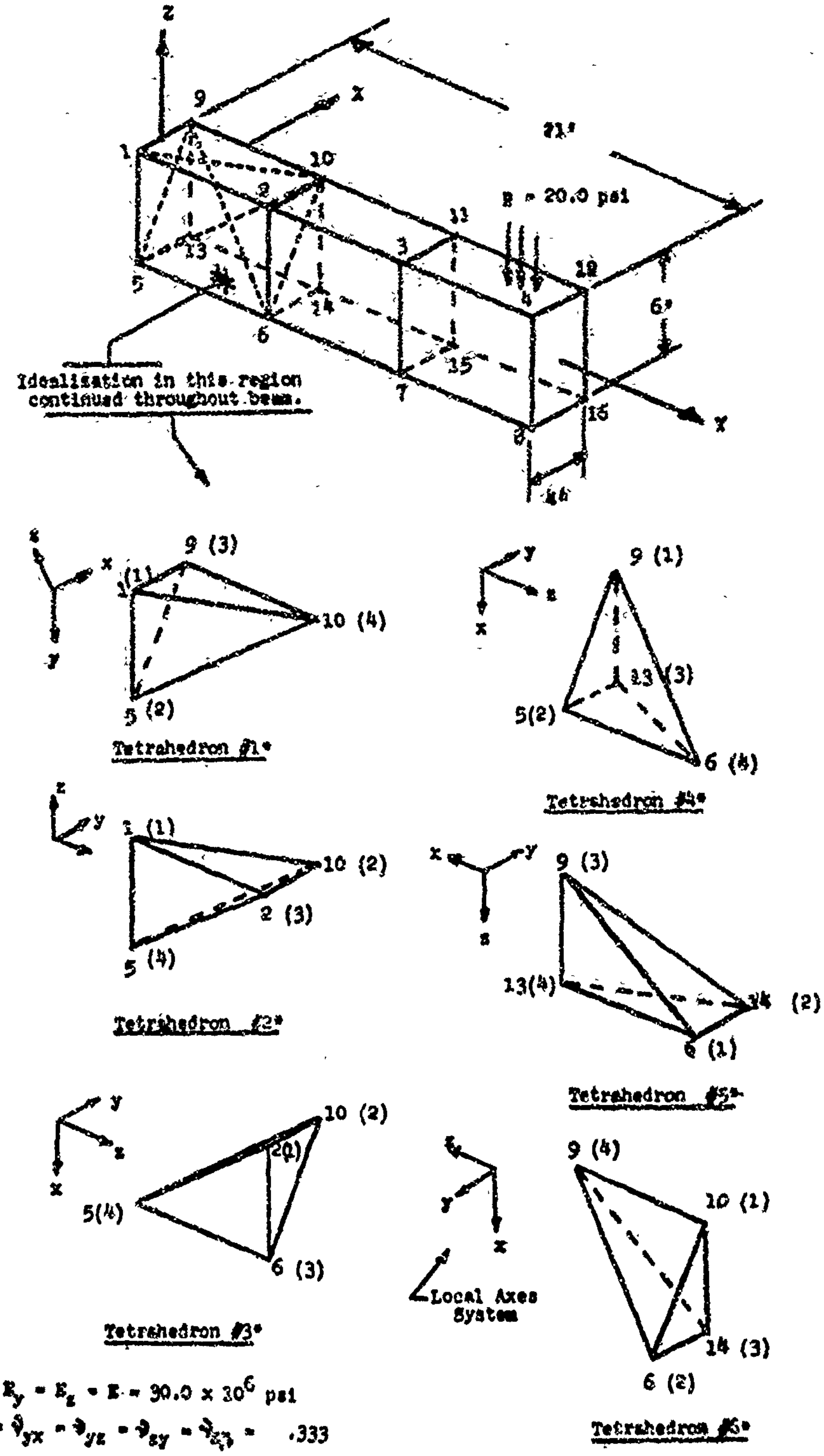
with degrees of freedom U_1, V_1, W_1, U_5, V_5, W_5, U_9, V_9, W_9 and U_{13}, V_{13} W_{13} fixed.

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

$\nu_{xy} = \nu_{yx} = \nu_{yz} = \nu_{zy} = \nu_{zx} = .333$

$\alpha_x = \alpha_y = \alpha_z = 0$, $T_1 = T_2 = T_3 = \dots T_{16}$ 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

SAC 1015

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

2 (/) NUMBER OF TITLE CARDS

FIFTEEN ELEMENT CANTILEVERED BEAM SUBJECTED TO A PRESSURE

LOAD. TETRAHEDRON ELEMENT IDEN. NO. 8G STATICS ANALYSIS.

FIGURE III-C.2 TITLE INFORMATION - TETRAHEDRON ELEMENT, CANTILEVER BEAM

SAC 1618-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

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	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	1	J5	STEEL	X									1	0	.000733456	(/)

MATERIAL PROPERTIES TABLE

Temperature (13–22)	Direction	Youngs Moduli (23–32)	Direction	Poissons Ratios (33–42)	Direction	Coef. of Thermal Expansion (43–52)	Direction	Rigidity Moduli (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

	Request	Columns	Entry
		1 2 3 4 5 6	S Y S T E M (/)
1.	Number of System Grid Points	1–6	16
2.	Number of Input Grid Points	7–12	16
3.	Number of Degrees of Freedom/Grid Point	13–14	3
4.	Number of Load Conditions	15–16	1
5.	Number of Initially Displaced Grid Points	17–22	0
6.	Number of Prescribed Displaced Grid Points	23–28	0
7.	Number of Grid Point Axes Transformation Systems	29–30	0
8.	Number of Elements	31–36	18
9.	Number of Requests and/or Revisions of Material Tape.	37–38	1
10.	Number of Input Boundary Condition Points	39–44	4
11.	T_o For Structure (With Decimal Point)	45–52	0.0 (/)

FIGURE III-C.4 SYSTEM CONTROL INFORMATION -TETRAHEDRON ELEMENT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6
COORD (/)

GRIDPOINT COORDINATE

Grid Point Number (7–12)	X – R (13–22)	Y – θ (23–32)	Z – Z (33–42)	
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-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		O	O	O							(/)
				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	0.0	(/)
	Condition Number	Scalar	

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
MODAL	0.0	0.0	0.0						

Grid Pt. Number

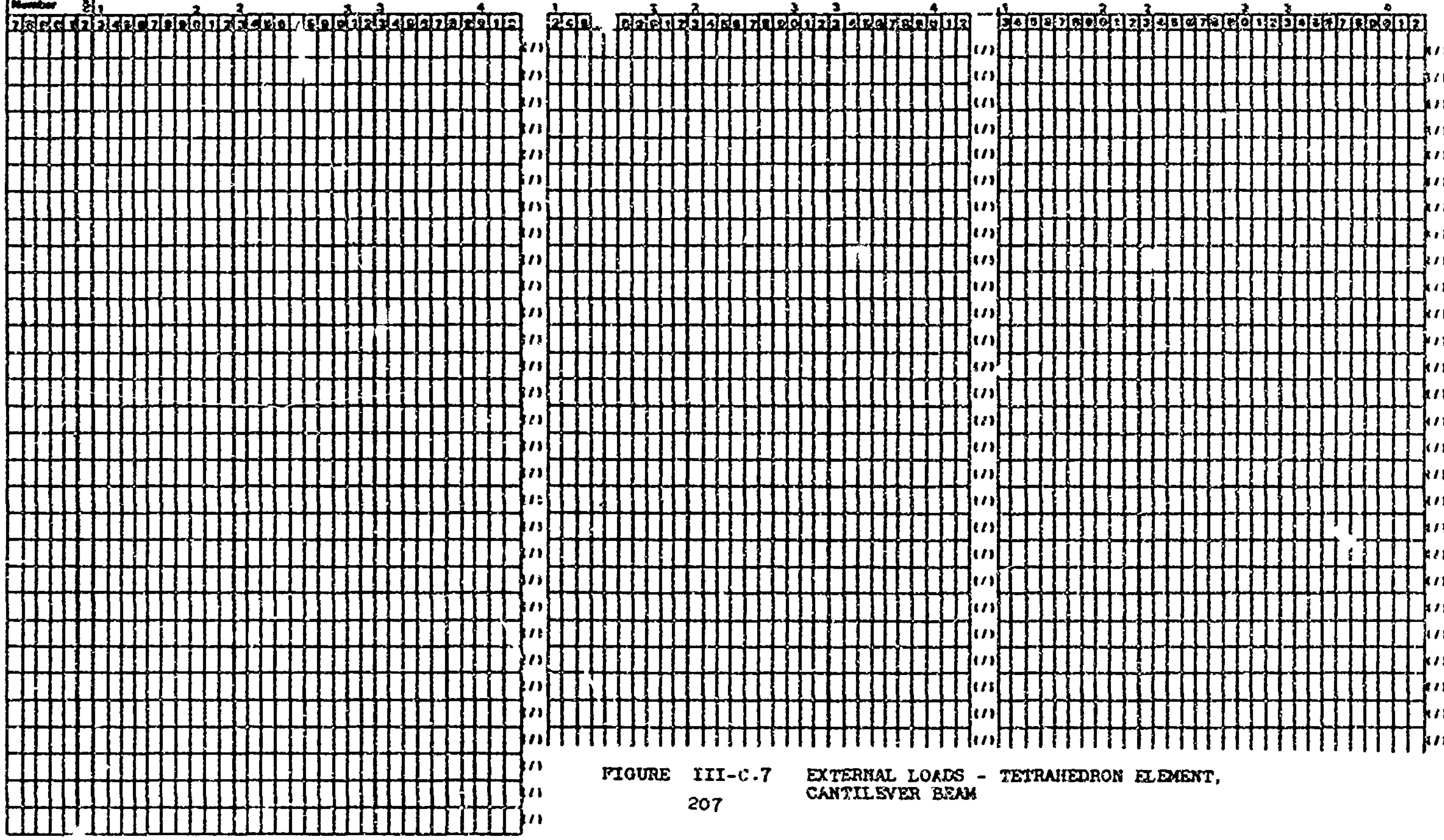


FIGURE III-C.7 EXTERNAL LOADS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7–10)	PLUG NO. (11–12)	MATERIAL NUMBER (13–18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33–34)	No. of Assem. Nodes (35–36)	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
1	50	1	4							4		1	5	9	10								
2	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								
5	50	1	4							4		2	11	3	6								
4	50	1	4							4		3	12	4	7								
3	50	1	4							4		2	10	6	5								
4	50	1	4							4		7	[illegible]	13	6								
5	50	1	4							4		6	14	9	13								
6	50	1	4							4		10	6	14	9								
7	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

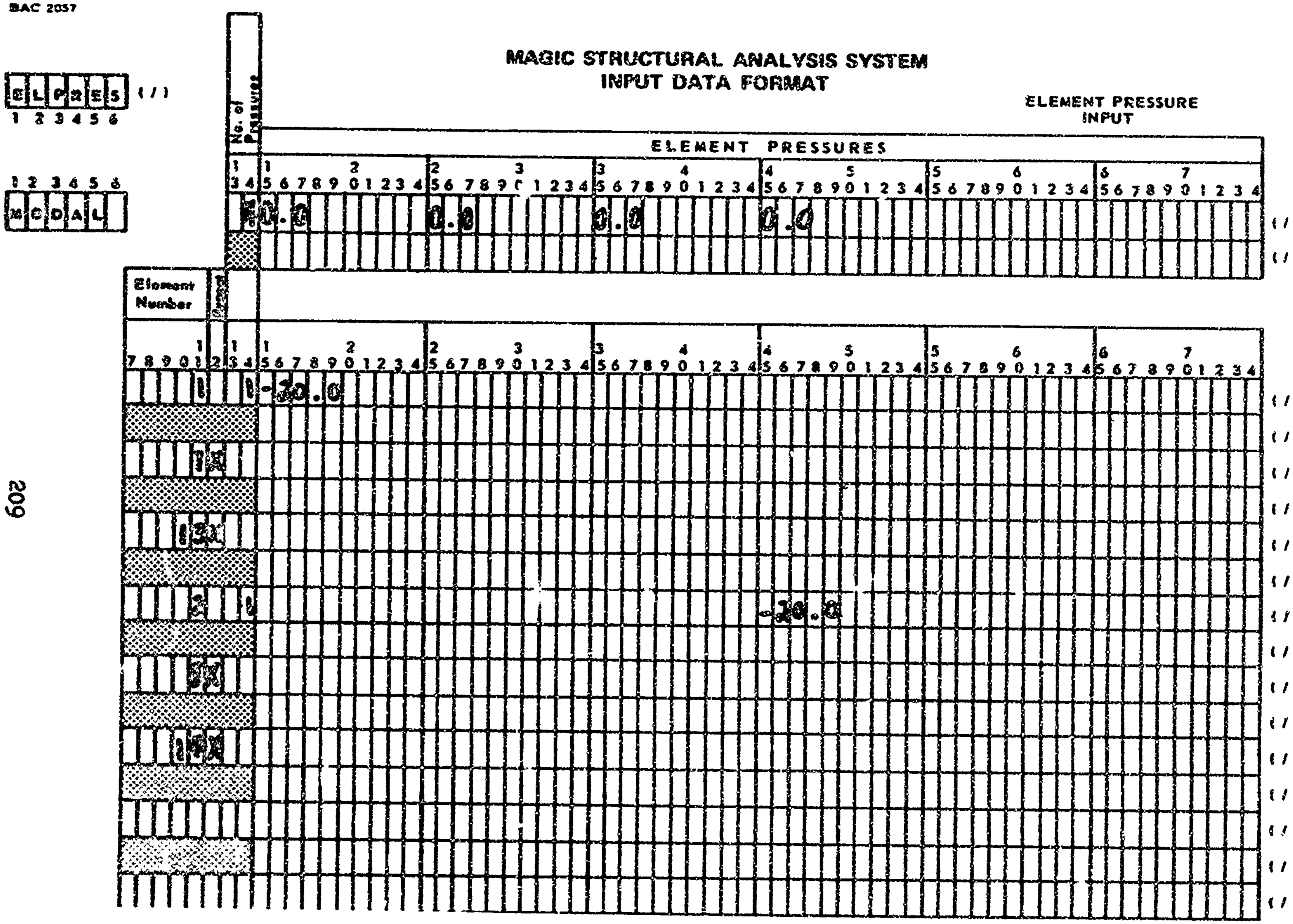


FIGURE III-C.9 ELEMENT PRESSURE INPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

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 INSTRUCTION LISTING          PAGE  1

         TEST MAGIC

SINSTRUCTION   SOURCE                                                   TESTF004

         C----STATICS ADDENDUM WITHOUT PRESCRIBED DISPLACEMENTS               TESTF005
         C                                                                    TESTF006
         C    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * TESTF007
         C                                                                    TESTF008
         C       STATICS INSTRUCTION SEQUENCE                                 TESTF009
         C                                                                    TESTF010
         C    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * TESTF011
         C                                                                    TESTF012
         C       GENERATE ELEMENT MATRICES                                    TESTF013
         C                                                                    TESTF014
   1          ,NLID,,NLD,TR,  ,HEL,FTEL,SEL,STEL,,,SC,EN,  ",,    ,,USER04,   TESTF015
         C                                                                    TESTF016
         C                                                                    TESTF017
         C       FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES                  TESTF018
         C       DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED             TESTF019
         C                                                                    TESTF020
   2          I1 = SC.IDENTC.                                                 TESTF021
   3          I3 = I1.NULL.SC                                                 TESTF022
   4          DIFF = I1 .SMULT. SC(5,1)                                       TESTF023
         C                                                                    TESTF024
         C       ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS          TESTF025
         C                                                                    TESTF026
   5          KELA = EN .ASSEM. SC,(10)                                       TESTF027
   6          FTELA = EN .ASSEM .SC,(40)                                      TESTF028
   7          LSCALE,LOADS = NLD .DEJOIN. (1,1)                               TESTF029
         C                                                                    TESTF030
         C       REDUCE STIFFNESS MATRIX AND PRINT                            TESTF031
         C                                                                    TESTF032
   8          KO,KNO = KELA .DEJOIN.( SC(9,1),1)                              TESTF033
   9          KCO,STIFF = KNO.DEJOIN.( SC(5,1),0)                             TESTF034
  10          PRINT(FORCE,DISP,,) STIFF                                       TESTF035
         C                                                                    TESTF036
         C       FORM REDUCED TOTAL LOAD COLUMN                               TESTF037
         C                                                                    TESTF038
         C       MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR                TESTF039
  11          FTELS = FTELA.MULT.LSCALE                                       TESTF040
         C       TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM           TESTF041
  12          LOADO = TR.MULT.LOADS                                           TESTF042
         C       FORM TOTAL LOAD COLUMNS                                      TESTF043
  13          TLOAD = FTELS.ADD.LOADO                                         TESTF044
  14          TL,TLOADR = TLOAD.DEJOIN.( 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 AND INVERSE CHECK                        TESTF054
```

FIGURE III-C.11 MAGIC ABSTRACTION INSTRUCTION LISTING - TETRAHEDRON ELEMENT, CANTILEVER BEAM

TEST MAGIC

```
C                                                                          TESTF055
      REACTS = KELA.MULT.XD                                                TESTF056
      REACTP= REACTS.SUBT.TLOAD                                            TESTF057
      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
      \PRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,TR )FTELA                            TESTF065
      \PRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,    )LCADS                           TESTF066
      \PRINT(2,,,U,V,W,THETAX,THETAY,THETAZ,SC,)X                          TESTF067
      \PRINT(1,,,FX,FY,FZ,MX,MY,MZ,SC,TR )REACTP                           TESTF068
      IF (IX.NULL.) GO TO 600                                              TESTF069
C                                                                          TESTF070
C        ELEMENTS HAVE 3 DEGREES OF FREEDOM                                TESTF071
C                                                                          TESTF072
   10 \PRINT(4,,,FR,0,FZ,0,MTHETA,0,F1,0,F3,SC,TR )FTELA                   TESTF073
      \PRINT(4,,,FR,0,FZ,0,MTHETA,0,F1,0,F3,SC,   )LCADS                   TESTF074
      \PRINT(2,,,U,0,W,0,THETAY,0,W*,0,W**,SC, )X                          TESTF075
      \PRINT(1,,,FR,0,FZ,0,MTHETA,0,F1,0,F3,SC,TR )REACTP                  TESTF076
C                                                                          TESTF077
C        GENERATE STRESSES AND FORCES                                      TESTF078
C                                                                          TESTF079
  600 STRESP=EM,XD .STRESS.(4,)                                            TESTF080
      FORCEP=EM,XD .FORCE.(4,)                                             TESTF081
```


FIGURE III-C.11 CONCLUDED

```
                    MAGIC - MATRIX ANALYSIS VIA GENERATIVE AND INTERPRETIVE COMPUTATIONS
MAGIC



                         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 ELEMENT CANTILEVEREC BEAM SUBJECTED TO A PRESSURE
LOAD. TETRAHEDRON ELEMENT IDEA. NO.50 STATICS ANALYSIS.
                    REVISIONS OF MATERIAL TAPE

                    ASTERISK (*) PRECEDING 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. . . . . . . . . . . . . . . . . 0.73390094E-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-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.	CJOK	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	5	10	6	9		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	16	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	19		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	21		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

CUTOFF = 0.0 SIZE 36 BY 36

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	1	1	0.2790722E 09	2	0.3369910E 08	3	-0.786124E 08	4	-0.643016E 07	5	-0.112528E 08
		6	-0.1312683E 08	10	-0.2625469E 08	11	0.2243828E 08	12	0.323558E 08	19	-0.235955E 08
		20	-0.3369910E 08	21	0.2625466E 08	22	-0.2030108E 02	23	0.336910E 08	24	0.1312683E 08
DISP	2	1	0.3369102E 08	2	0.1366098E 09	3	0.2246068E 08	4	-0.2243828E 08	5	-0.256021E 08
		6	-0.7381862E 07	10	0.1125208E 08	11	-0.2625658E 08	12	-0.2246048E 08	19	-0.3369108E 08
		20	-0.5907722E 08	21	0.7501078E 07	22	0.3369108E 08	23	-0.653910E 01	24	-0.750107E 07
DISP	3	1	-0.786124E 08	2	0.2246068E 08	3	0.1748068E 09	4	-0.2617798E 08	5	-0.1499888E 08
		6	-0.6430158E 07	10	0.2625668E 08	11	-0.2244078E 08	12	-0.1048498E 09	19	0.3235588E 08
		20	0.1499888E 08	21	-0.5907728E 08	22	0.2617798E 08	23	-0.1495888E 08	24	-0.8586918E 01
DISP	4	1	-0.6430168E 07	2	-0.2243828E 08	3	-0.2617798E 08	4	0.2790728E 09	5	0.3369098E 08
		6	-0.7861248E 08	7	-0.6430178E 07	8	-0.1125208E 08	9	-0.1312838E 08	10	-0.4471498E 08
		11	-0.2243828E 08	12	0.2617798E 08	13	-0.2625658E 08	14	0.2243828E 08	15	0.3235588E 08
		22	-0.2359558E 09	23	-0.3369108E 08	24	0.2625668E 08	25	0.2690838E 01	26	0.3369108E 08
		27	0.1312838E 08								
DISP	5	1	-0.1125288E 08	2	-0.2560218E 08	3	-0.1499888E 08	4	0.3369098E 08	5	0.1366098E 09
		6	0.2246068E 08	7	-0.2243828E 08	8	-0.2560218E 08	9	-0.7501068E 07	10	-0.1125208E 08
		11	0.7883408E 01	12	0.2246068E 08	13	0.1125288E 08	14	-0.2625658E 08	15	-0.2246078E 08
		22	-0.3369098E 08	23	-0.5907728E 08	24	0.7501878E 07	25	0.3369108E 08	26	0.1407908E 01
		27	-0.7381878E 07								
DISP	6	1	-0.1312838E 08	2	-0.7381868E 07	3	-0.6430158E 07	4	-0.7861248E 08	5	0.2246068E 08
		6	0.1748348E 09	7	-0.2617798E 08	8	-0.1499808E 08	9	-0.6430148E 07	10	0.1312838E 08
		11	0.2246068E 08	12	-0.9818478E 01	13	0.2625668E 08	14	-0.2246078E 08	15	-0.1048698E 09
		22	0.3235598E 08	23	0.1499888E 08	24	-0.5907728E 08	25	0.2617798E 08	26	-0.1499888E 08
		27	0.1207028E 02								
DISP	7	4	-0.6430178E 07	5	-0.2243828E 08	6	-0.2617798E 08	7	0.1724838E 05	8	0.3369108E 08
		9	-0.1312838E 08	13	-0.3369108E 01	14	-0.2243828E 08	19	0.2617798E 08	16	-0.6752188E 07
		17	0.2243828E 08	18	0.2617798E 08	25	-0.1499888E 09	26	-0.1125288E 08	27	0.1312838E 08
DISP	8	4	-0.1125288E 08	5	-0.2560218E 08	6	-0.1499888E 08	7	0.3369108E 08	8	0.7381928E 08
		9	-0.1312878E 02	13	-0.1125208E 08	14	-0.1608208E 02	18	0.2246078E 08	16	0.1125288E 08
		17	-0.6752188E 07	18	-0.7501878E 07	25	-0.2243828E 08	26	-0.3938468E 08	27	-0.4197698E-01
DISP	9	4	-0.1312838E 08	5	-0.7381868E 07	6	-0.6430148E 07	7	-0.3738028E 00	8	-0.1338708E 02
		9	0.6777138E 08	15	0.1312838E 08	16	0.2246078E 08	19	-0.1478938E 02	18	0.1312838E 08
		17	-0.1499888E 08	18	-0.3499638E 08	25	0.2617798E 08	26	-0.8378248E-01	27	-0.3938408E 08

FIGURE III-C.17 STIFFNESS MATRIX OUTPUT - TETRAHEDRON ELEMENT, CANTILEVER BEAM

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 0C	5	-0.112528E 08
		6	0.131283E 08	10	0.287932E 09	11	-0.336910E 08	13	-0.128603E 06	14	0.224382E 08
		19	-0.366896E 01	20	0.111054E 08	21	-0.766123E 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	-0.111054E 09	20	-0.147337E 02	21	0.745692E 07
		22	0.224382E 08	23	0.547051E 01	26	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	-0.961847E 01	11	0.224607E 08	12	0.188667E 09	14	-0.750187E 07	15	-0.128603E 08
		19	-0.766123E 08	20	-0.745692E 07	21	-0.368896E 01	22	-0.261779E 08	23	0.149588E 08
		24	0.429969E 01	25	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	1	-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	0.162070E 01
		20	-0.224382E 08	21	-0.261779E 08	22	-0.702849E 01	23	0.111894E 08	24	-0.766123E 08
		25	-0.346539E 01	26	0.112528E 08	27	-0.131283E 08	28	-0.262016E 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	-0.129920E 02
		9	0.224607E 08	10	0.224382E 08	11	-0.513643E 08	12	-0.750187E 07	13	-0.336914E 08
		16	0.188062E 09	15	0.224606E 08	14	0.112528E 08	17	-0.513643E 08	18	-0.149588E 08
		19	-0.112520E 08	20	0.413108E 01	21	-0.149588E 09	22	-0.111054E 08	23	0.702849E 01
		24	0.745692E 07	25	0.224382E 08	26	-0.446945E 01	27	0.750187E 07	28	-0.336910E 08
		29	-0.659910E 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	-0.167051E 02	11	-0.149588E 08	12	-0.128603E 08	13	-0.117142E 01	14	0.224606E 08
		13	0.188667E 09	16	0.669304E 01	17	-0.750187E 07	18	-0.128603E 08	19	-0.131283E 08
		20	-0.750187E 07	21	0.368373E 01	22	-0.766123E 08	23	-0.745692E 07	24	-0.230416E-01
		25	-0.261779E 08	26	0.149588E 08	27	-0.128367E 02	28	0.131283E 08	29	0.750187E 07
		30	-0.859691E 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	0.469304E 01	16	0.178916E 09	17	0.527137E 01	22	-0.346539E 01	23	-0.224382E 08
		24	-0.261779E 08	26	0.111054E 08	27	-0.393062E 08	31	0.269889E 01	32	-0.336910E 08
		33	0.261779E 08	34	-0.157803E 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	-0.111054E 08	31	-0.336910E 08	32	0.140790E 01
		33	0.149588E 08	34	0.112528E 08	35	-0.393048E 08	36	0.837024E-04		

FIGURE III-C.17 CONTINUED

CUTOFF = 0.0 SIZE 36 BY 36

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	18	7	0.261779E 08	8	-0.750187E 07	9	-0.349583E 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	0.419749E-06	36	-0.393848E 08				
DISP	19	1	-0.235959E 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	0.207932E 09
		20	0.336909E 00	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	0.188042E 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	-0.235959E 09	9	-0.336909E 08
		6	0.523558E 08	10	0.195624E 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	0.207932E 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	-0.053910E 01	3	-0.149588E 08	4	-0.336910E 08	5	-0.590772E 08
		6	0.149588E 08	10	0.112528E 08	11	0.347051E 01	12	0.149588E 08	13	0.111854E 08
		14	0.702848E 01	15	-0.745692E 07	16	-0.224382E 08	17	-0.446949E 01	18	-0.750187E 07
		19	-0.224382E 08	20	-0.513643E 08	21	0.750187E 07	22	0.336909E 08	23	0.188042E 09
		24	-0.224606E 08	25	-0.112528E 08	26	-0.112043E 00	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	-0.358691E 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	0.469304E 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	-0.127808E 02		
DISP	25	4	0.209889E 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/

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	-0.120367E 02	16	-0.393062E 08
		22	0.336195E 01	23	0.149588E 08	24	-0.120603E 08	26	-0.224606E 08	27	0.872014E 08
		34	0.261779E 08	35	0.750187E 07	36	-0.349563E 08				
DISP	28	10	-0.235959E 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 07
		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	-0.893910E 01
		15	0.750187E 07	19	-0.112528E 08	20	-0.262565E 08	21	0.224607E 08	28	-0.336910E 08
		29	0.134698E 09	30	-0.224606E 08	31	0.224382E 08	32	-0.254821E 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	-0.104809E 09	28	-0.786220E 08
		29	-0.224606E 08	30	0.176006E 09	31	-0.261779E 08	32	0.149588E 08	33	-0.643015E 07
DISP	31	13	-0.235959E 09	14	0.336910E 08	15	0.262566E 08	16	0.269835E 01	17	-0.336910E 08
		18	0.131283E 08	19	-0.262508E 08	20	0.224382E 08	21	0.261779E 08	22	-0.262563E 08
		23	-0.224382E 08	24	0.523558E 08	28	-0.643016E 07	29	0.224332E 08	30	-0.261779E 08
		31	0.275072E 07	32	-0.336909E 08	33	-0.786124E 08	34	-0.643017E 07	35	0.112528E 08
		36	-0.131283E 08								
DISP	32	13	0.336908E 08	14	-0.590772E 08	15	-0.750187E 07	16	-0.336910E 08	17	0.146790E 08
		18	0.750187E 07	19	0.112528E 08	20	0.624597E 01	21	-0.224606E 08	22	-0.112520E 08
		23	-0.262565E 08	24	0.224606E 08	28	0.112528E 08	29	-0.254821E 08	30	0.149588E 08
		31	-0.336909E 08	32	0.134698E 09	33	-0.224606E 08	34	0.224[illegible] 08	35	-0.256821E 08
		36	0.750186E 07								
DISP	33	13	0.523550E 08	14	-0.149506E 08	15	-0.590772E 08	16	0.261779E 08	17	0.149588E 08
		18	0.120703E 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	0.750128E 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	-0.157383E 09	17	0.112528E 08	18	0.131283E 08	22	-0.341174E 01	23	0.224382E 08
		20	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	36	0.172686E 09	35	-0.336910E 08	34	-0.393062E 08

FIGURE III-C.17 CONTINUED

CUTOFF = 0.0 SIZE 36 BY 36

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	33	16	0.2243[illegible] 00	17	-0.3[illegible] 00	18	0.4197[illegible]-0[illegible]	22	0.1125[illegible] 0[illegible]	23	-0.4470[illegible] 01
		24	-0.[illegible] 00	25	-0.1125[illegible] 0[illegible]	26	-0.[illegible] 07	27	0.75[illegible] 07	31	0.1125[illegible] 00
		32	-0.2348[illegible] 06	33	0.[illegible] 00	34	-0.[illegible] 00	35	0.[illegible] 01	36	0.[illegible] 01
DISP	34	16	0.2417[illegible] 0[illegible]	17	0.[illegible]-0[illegible]	18	-0.[illegible] 00	22	0.1[illegible] 0[illegible]	23	-0.[illegible] 00
		24	-0.1[illegible] 0[illegible]	25	0.1[illegible] 0[illegible]	26	0.[illegible] 0[illegible]	27	-0.[illegible] 0[illegible]	31	-0.[illegible] 00
		32	0.[illegible] 07	33	-0.[illegible] 07	34	-0.[illegible]-0[illegible]	35	0.[illegible] 01	36	0.[illegible] 00

FIGURE III-C.17 CONCLUDED

[illegible]

ROW	FX	FY	FZ
1	0.0	0.0	-0.[illegible]E 03
2	0.0	0.0	-0.[illegible]E 03
3	0.0	0.0	-0.[illegible]E 03
4	0.0	0.0	-0.[illegible]E 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.[illegible]E 02
10	0.0	0.0	-0.[illegible]E 03
11	0.0	0.0	-0.[illegible]E 03
12	0.0	0.0	-0.[illegible]E 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 OPRINT OF MATRIX LOADS - TETRAHEDRON ELEMENT, CANTILEVER BEAM

MATRIX LOADS SIZE 48 BY 1
FULL 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	0.11979872E-04	-0.24304684E-04	-0.51589872E-04
3	0.30256546E-04	-0.33360440E-04	-0.12496015E-03
4	0.50328208E-04	-0.35343779E-04	-0.19549463E-03
5	0.0	0.0	0.0
6	0.91729371E-05	0.15122647E-04	-0.50923308E-04
7	0.27327909E-04	0.20157197E-04	-0.12367318E-03
8	0.47134861E-04	0.20220963E-04	-0.19785648E-03
9	0.0	0.0	0.0
10	0.18939482E-04	-0.15532798E-04	-0.50294457E-04
11	0.29939934E-04	-0.22620060E-04	-0.12696861E-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	-0.50296456E-04
15	0.28405630E-04	0.31450443E-04	-0.12420131E-03
16	0.47979382E-04	0.31560735E-04	-0.19497190E-03

FIGURE III-C.20 DISPLACEMENT MATRIX - TETRAHEDRON ELEMENT, CANTILEVER BEAM

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ
1	-0.34702106E 03	0.15606333E 04	0.10793509E 04
2	-0.17333906E-01	0.14649438E-02	0.25634766E-01
3	-0.46039063E-01	0.32226563E-01	0.57861328E-01
4	-0.25164406E-01	0.48828125E-03	0.20751953E-01
5	0.34203149E 03	-0.15606569E 04	-0.10247501E 03
6	-0.95214844E-02	-0.17822266E-01	0.51269531E-02
7	0.0	-0.19531250E-01	0.35156250E-01
8	0.78125000E-02	-0.78125000E-02	0.15625000E-01
9	0.22293352E 03	0.14398151E 04	-0.96582991E 02
10	0.29296875E-02	0.58593750E-02	0.23925781E-01
11	-0.39062500E-02	0.0	0.95214844E-02
12	0.20507813E-01	-0.63476563E-02	-0.13183594E-01
13	-0.31737466E 03	-0.14398593E 04	0.61949945E 03
14	0.18310547E-01	-0.12207031E-01	-0.10253906E-01
15	0.23437500E-01	-0.12695313E-01	-0.21728516E-01
16	0.39062500E-02	0.26852876E-02	-0.31250000E-01

FIGURE III-C.21 REACTION MATRI - TETRAHEDRON ELEMENT, CANTILEVER EE/μ

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 POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.49789597E 02	0.99728760E 02	0.49789597E 02	-0.17039139E 02	0.85512802E 02	0.0

ELEMENT APPLIED STRESSES

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

NET ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
			MEMBRANE STRESSES			
1	0.49789590E 02	0.99728746E 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

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z (MEMBRANE STRESSES)	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
APPARENT ELEMENT STRESSES						
1	0.28019104E 01	0.31420776E 02	0.80634597E 01	-0.62224417E 01	0.44469430E 02	0.74808377E 00
ELEMENT APPLIED STRESSES						
1	0.0	0.0	0.0	0.0	0.0	0.0
NET ELEMENT STRESSES						
1	0.28019104E 01	0.31420776E 02	0.80634597E 01	-0.62224417E 01	0.44469430E 02	0.74808377E 00

FIGURE III-C.23 STRESS OUTPUT, ELEMENT NO. 7 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

STRESSES FOR THE TETRAHEDRON ELEMENT

(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 POINT	SIGMA-X	SIGMA-Y	SIGMA-Z (MEMBRANE STRESSES)	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
1	0.35231610E 01	0.50445537E 01	-0.13503021E 02	-0.12101746E 00	0.97080841E 01	0.33227539E 00

ELEMENT APPLIED STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z (MEMBRANE STRESSES)	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
1	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z (MEMBRANE STRESSES)	SIGMA-XY	SIGMA-YZ	SIGMA-ZX
1	0.35231610E 01	0.50445537E 01	-0.13503021E 02	-0.12101746E 00	0.97080840E 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	FX	FY	FZ
1	-0.348526406E 03	0.518333329E 03	0.232351306E 03
2	0.0	-0.399959933E 03	-0.232351306E 03
3	0.200837012E 03	0.279640063E 03	0.342091689E 03
4	0.601569595E 02	-0.398914479E 03	-0.342091689E 03

ELEMENT APPLIED FORCES

POINT	FX	FY	FZ
1	0.0	0.0	-0.933332528E 02
2	0.0	0.0	0.0
3	0.0	0.0	-0.933332528E 02
4	0.0	0.0	-0.933332528E 02

NET ELEMENT FORCES

POINT	FX	FY	FZ
1	-0.348526406E 03	0.518333329E 03	0.325684557E 03
2	0.0	-0.399959933E 03	-0.232351306E 03
3	0.200837012E 03	0.279640063E 03	0.435300201E 03
4	0.601569595E 02	-0.398914479E 03	-0.248717777E 03

FIGURE III-C.25 FORCE OUTPUT, ELEMENT NO. 1 - TETRAHEDRON ELEMENT, CANTILEVER BEAM

FORCES FOR THE TETRAHEDRON ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	7	50	2 6 10 11

APPARENT ELEMENT FORCES

POINT	FORCES FX	FY	FZ
1	-0.16121735E 02	0.25107715E 03	0.32393829E 02
2	-0.34907579E 01	-0.20752002E 03	-0.37628891E 02
3	-0.52778320E 01	0.82125488E 02	0.10310089E 03
4	0.24890640E 02	-0.12568311E 03	-0.17787378E 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	-0.16121735E 02	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 03	-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	FX	FORCES FY	FZ
1	0.20361328E 01	0.25122803E 02	-0.10183960E 03
2	-0.24463574E 02	0.84692383E 00	-0.23251953E 01
3	0.23112793E 02	-0.46151123E 02	0.65326843E 02
4	-0.48350154E 00	0.20179199E 02	0.38832031E 02

ELEMENT APPLIED FORCES

POINT	FX	FORCES 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	FX	FORCES 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	-0.48350154E 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 pre-printed 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

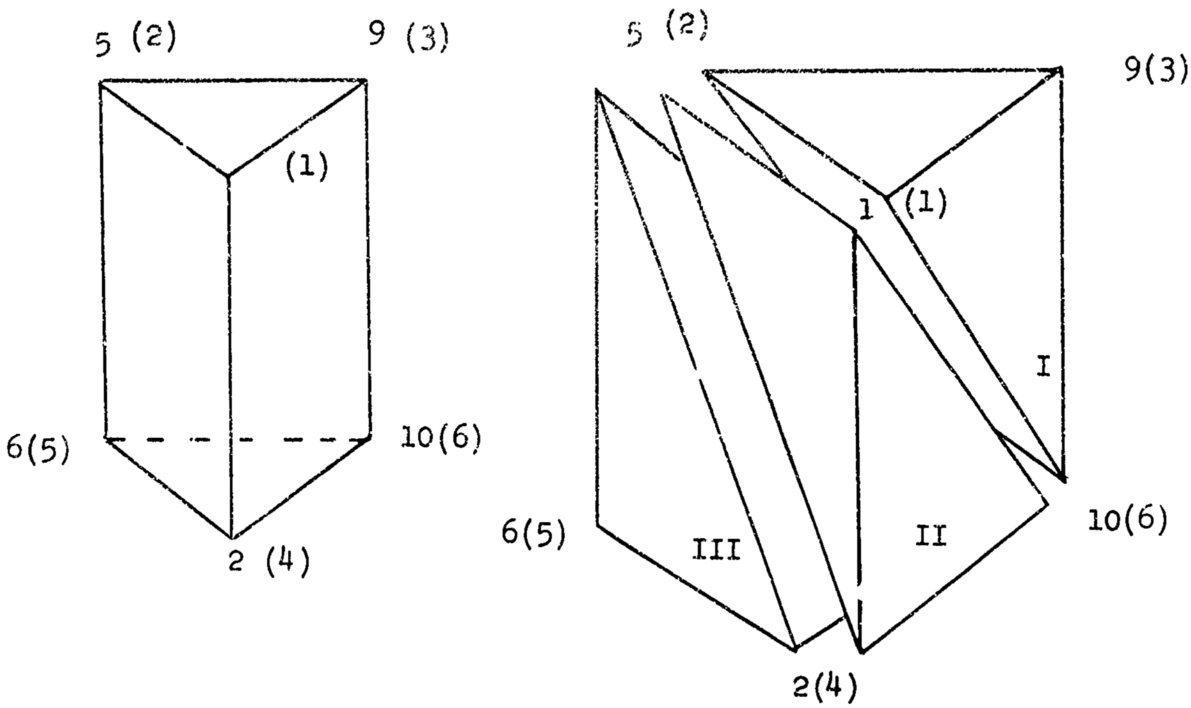
$$\left\{ \Delta^P \right\}^T = \lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots\ldots, U_{16}, V_{16}, W_{16} \rfloor \text{ with}$$

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.

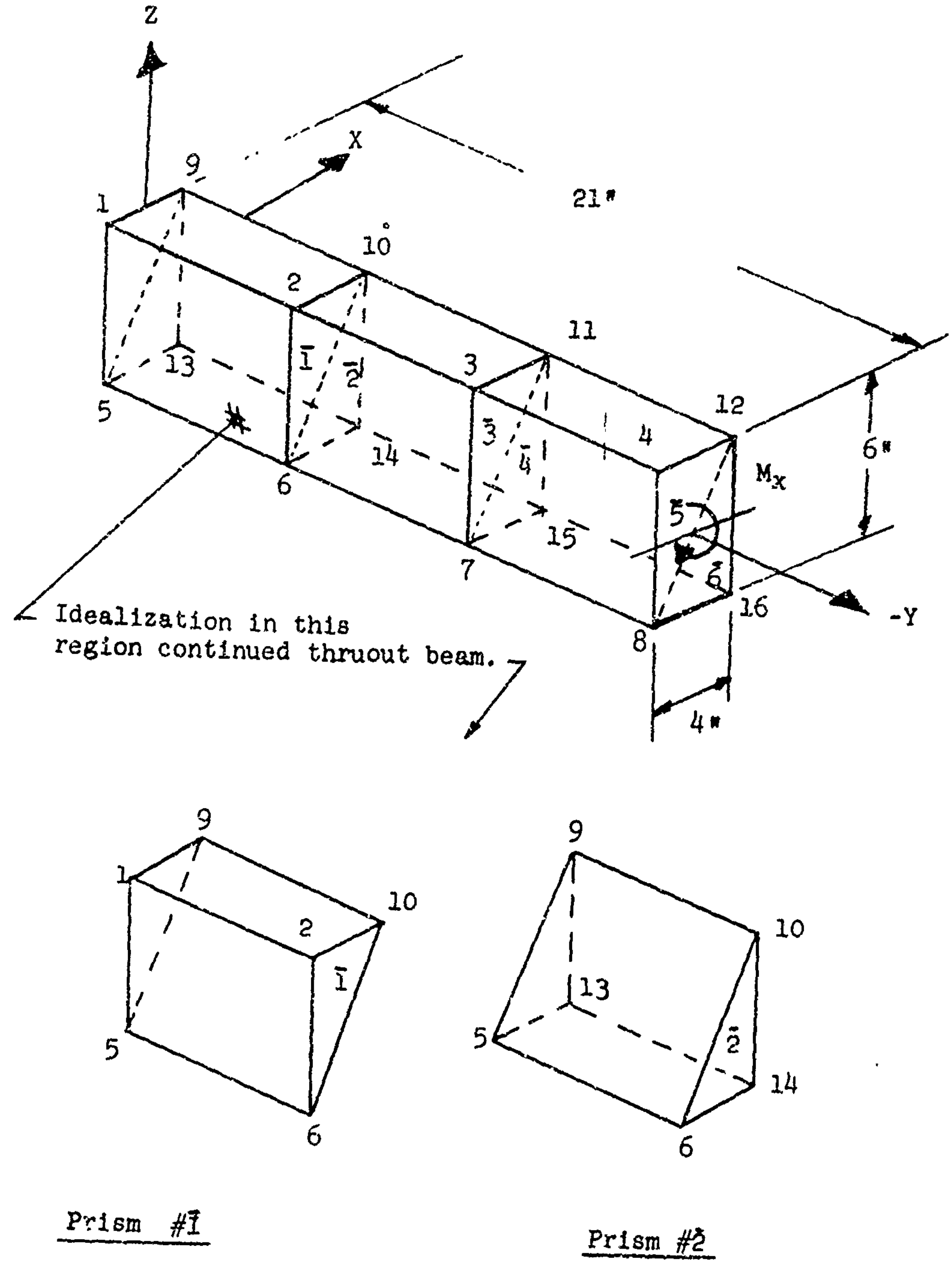
The displacements of the cantilever beam resulting from the above loads are given in Figure III-D.17. It is noted that the displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis. Figure III-D.18 shows the reactions (F_x, F_y, F_z). These are output 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.



$E_x = E_y = E_t = E = 30.0 \times 10^6$ 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

MATER (/)

No. of Requests 1 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	Material Number	Loc. Code	Material Identification	Isotropic	Orthotropic	Plastic	Plastic Orthotropic	Add Plastic	Delete	Print Tape	Print Start Table	Print Start	Number of Start Pts.	Number of Plastic Pts.	Mass Density
1		1	STEEL	X									1		[illegible]

MATERIAL PROPERTIES TABLE

Temperature	Direction	Youngs Moduli	Direction	Poissons Ratios	Direction	Coef. of Thermal Expansion	Direction	Rigidity Moduli
0.0	E_x	[illegible]	ν_{xy}	.[illegible]	α_x	[illegible]	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

Request	Entry	Columns
	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

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

Grid Point Number (cols 7–12)	DIRECTIONS X – R (cols 13–22)	DIRECTIONS Y – θ (cols 23–32)	DIRECTIONS Z – Z (cols 33–42)	
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					[illegible]										
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

GAC 1027

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

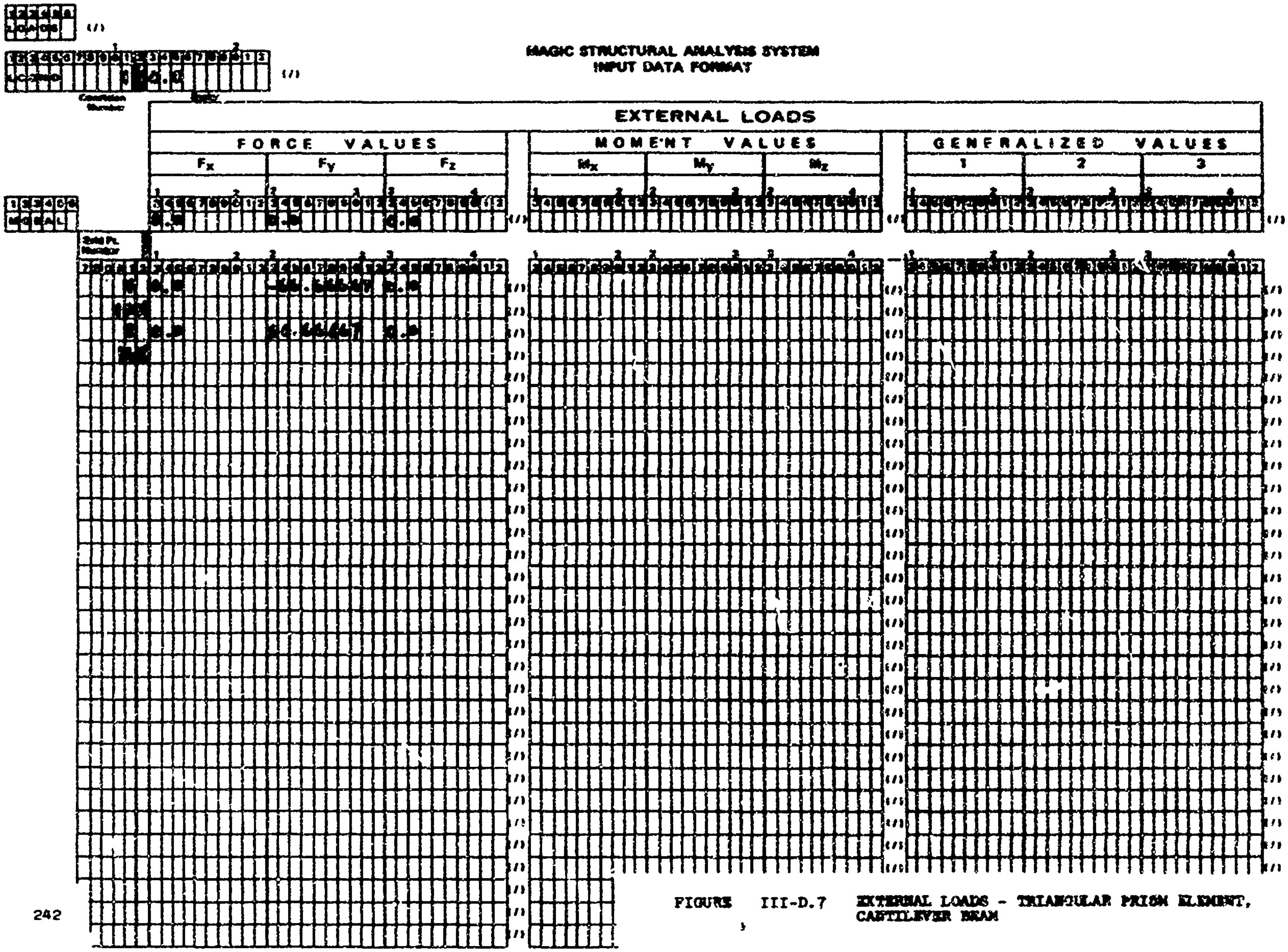


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FIGURE III-D.7 EXTERNAL LOADS - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

ELEM 1 2 3 4 5 6 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7–10)	Plus No. (11–12)	Material Number (13–18)	Interpolation Option (19)	Material Temperature (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Plot (31)	Print: Full (32)	Number of Load Nodes (33–34)	No. of Assem. Nodes (35)	Node Points 1	2	3	4	5	6	7	8	9	10	11	12
1	5	1	6							6		1	5	[illegible]	[illegible]	[illegible]	[illegible]						
2	5 [illegible]	1	6							6		5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
3	5 [illegible]	1	6							6		2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
4	5 [illegible]	1	6							6		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
5	5 [illegible]	1	6							6		3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
6	5 1	1	6							6		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						

FIGURE III-D.8 ELEMENT CONTROL DATA - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

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.  .MEL.FTEL.SEL.STEL...SC.EN.  =..   ..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 = EN .ASSEM. SC,(10)                                    TESTE027
   6          FTELA = EN .ASSEM .SC,(40)                                   TESTE028
   7          LSCALE,LOADS = XLD .DEJOIN. (1,1)                            TESTE029
        C                                                                  TESTE030
        C        REDUCE STIFFNESS MATRIX AND PRINT                         TESTE031
        C                                                                  TESTE032
   8          K0,KN0 = KELA .DEJOIN.( SC(5,1),1)                           TESTE033
   9          KC0,STIFF = KN0.DEJOIN.( SC(5,1),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 COLUMN                                    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          TR0,TR12 = TR.DEJOIN.(SC(5,1),1)                             TESTE050
  17          X = TR12.TMULT.XX                                            TESTE051
  18          XO = 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

TEST MAGIC

```
      C                                                                    TESTE055
19          REACTS = KELA.MULT.XD                                          TESTE056
20          REACTP= REACTS.SUBT.TLOAD                                      TESTE057
21          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
22          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,TR )PTELA                      TESTE065
23          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,    )LOADS                     TESTE066
24          GPRINT(2,,,U,V,W,THETAX,THETAY,THETAZ,SC,)X                    TESTE067
25          GPRINT(1,,,FX,FY,FZ,MX,MY,MZ,SC,TR )REACTP                     TESTE068
26          IF (I3.NULL.) GO TO 600                                        TESTE069
      C                                                                    TESTE070
      C        ELEMENTS HAVE 3 DEGREES OF FREEDOM                          TESTE071
      C                                                                    TESTE072
27     10   GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )PTELA              TESTE073
28          GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,    )LOADS             TESTE074
29          GPRINT(2,,,U,0,W,0,THETAY,0,W0,0,W00,SC, )X                    TESTE075
30          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
31    600   STRESP=EM,XD  .STRESS.(4,)                                     TESTE080
32          FORCEP=EM,XD  .FORCE.(4,)                                      TESTE081
```


FIGURE III-D.10 CONCLUDED

```
SIX ELEMENT CANTILEVER BEAM SUBJECTED TO AN END MOMENT.

TRIANGULAR PRISM ELEMENT ICEN. NO. 51 STATICS ANALYSIS

REVISIONS OF MATERIAL TAPE

ASTERISK (*) PRECEDING 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. . . . . . . . . . . . . . .  0.73394694E-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. 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.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	[illegible]	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	NO.	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 LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 16 ELEMENT LOAD 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

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	0.0	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.

T-ZERO FOR 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	0.136498E 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	-0.643013E 07	10	0.262566E 08	11	-0.224607E 08	12	-0.104869E 09	19	0.923558E 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	0.136498E 09
		6	0.224606E 08	7	-0.224382E 08	8	-0.256821E 08	9	-0.750187E 07	10	-0.112528E 08
		11	0.898236E 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	0.923558E 08	23	0.149588E 08	24	-0.590772E 08	25	0.261779E 08	26	-0.149588E 08
		27	0.245719E 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 03	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	-0.393048E 08	27	-0.534968E 01
DISP	9	4	-0.131283E 08	5	-0.750187E 07	6	-0.643017E 07	7	-0.393062E 08	8	-0.385504E 08
		9	0.607713E 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	-0.393348E 00

FIGURE III-D 15 STIFFNESS MATRIX OUTPUT - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

MATRIX STIFF / 1/

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	-0.212395E 08	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 08	15	0.261779E 08	19	-0.875219E 07	20	-0.336910E 08	21	-0.786123E 08
		22	0.875218E 07	23	0.336910E 08	26	-0.393062E 08	28	-0.244707E 09	29	0.336910E 08
		30	0.916620E 08								
DISP	11	1	0.224382E 08	2	-0.262565E 08	3	-0.224607E 08	4	-0.224382E 08	5	0.888254E 08
		6	0.224607E 08	10	-0.336909E 08	11	0.205567E 09	12	0.673020E 08	13	0.112528E 08
		14	-0.601164E 08	15	-0.336194E 08	19	-0.336910E 08	20	-0.875220E 07	21	-0.224607E 08
		22	0.336910E 08	23	0.875220E 07	26	0.224606E 08	28	0.336910E 08	29	-0.678294E 08
		30	-0.149588E 08								
DISP	12	1	0.523958E 08	2	-0.224606E 08	3	-0.104869E 09	4	0.261779E 08	5	0.224606E 08
		6	-0.114993E 02	10	-0.393062E 08	11	0.673020E 08	12	0.289879E 09	13	0.131283E 08
		14	-0.299625E 08	15	-0.478164E 08	19	-0.786123E 08	20	-0.224606E 08	21	-0.349563E 08
		22	-0.393062E 08	23	0.224606E 08	26	0.349563E 08	28	0.659627E 08	29	-0.790186E 07
		30	-0.940335E 08								
DISP	13	4	-0.262565E 08	5	0.112528E 08	6	0.262566E 08	7	-0.220079E 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	0.224382E 08	18	0.261779E 08
		22	-0.875219E 07	23	-0.336910E 08	24	-0.786123E 08	25	0.875216E 07	24	0.336910E 08
		27	-0.393061E 08	28	0.875218E 07	29	-0.336910E 08	30	-0.131283E 08	31	-0.244767E 09
		32	0.336910E 08	33	0.916619E 08						
DISP	14	4	0.224382E 08	5	-0.262565E 08	6	-0.224606E 08	7	-0.224382E 08	8	-0.860194E 08
		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	0.673019E 08	16	0.112520E 08	17	-0.601164E 08	18	-0.376194E 08
		22	-0.336910E 08	23	-0.875218E 07	24	-0.224606E 08	25	0.336910E 08	26	0.875216E 07
		27	0.224607E 08	28	-0.336910E 08	29	0.675218E 07	30	0.149588E 08	31	0.336910E 08
		32	-0.678254E 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	-0.288879E 01	10	0.261779E 08	11	-0.376194E 08	12	-0.478164E 08	13	-0.393061E 08
		14	0.673019E 08	15	0.298879E 09	16	0.131283E 08	17	-0.299625E 08	18	-0.478164E 08
		22	-0.786123E 08	23	-0.224606E 08	24	-0.360863E 08	25	-0.393061E 08	26	0.224607E 08
		27	0.349562E 08	28	-0.261779E 08	29	0.790186E 07	30	0.349563E 08	31	0.655627E 08
		32	-0.790186E 07	33	-0.940335E 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 09	16	0.109016E 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 08	35	0.224382E 08	36	0.261779E 08				
DISP	17	7	0.224382E 08	8	-0.875218E 07	9	-0.149588E 08	13	0.224380E 08	14	-0.601164E 08
		15	-0.299625E 08	16	0.240977E 02	17	0.885610E 08	18	0.449213E 08	25	-0.224382E 08
		26	-0.875218E 07	27	-0.149568E 08	31	-0.336910E 08	32	0.875216E 07	33	0.149568E 08

FIGURE III-D.15 CONTINUED

MATRIX STIFF / 1/ PAGE 3

CUTOFF = 0.0 SIZE 36 BY 36

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	17	34	0.112520E 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	-0.478164E 08	16	0.281146E 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	-0.239959E 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	0.112520E 08	30	0.262566E 08				
DISP	20	1	-0.336910E 08	2	-0.996772E 08	3	0.149588E 08	10	-0.336910E 08	11	-0.875220E 07
		12	-0.224606E 08	19	0.336909E 08	20	0.180062E 09	21	0.224606E 08	22	-0.112520E 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	-0.990772E 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	-0.239959E 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	-0.112520E 08	22	0.287932E 09
		23	0.336910E 08	24	-0.351425E 01	25	-0.128603E 08	26	-0.224382E 08	27	0.986195E 01
		28	-0.875218E 07	29	-0.112520E 08	30	0.131283E 08	31	-0.175044E 08	32	0.112520E 08
		33	0.262565E 08								
DISP	23	1	0.336910E 08	2	-0.863910E 01	3	-0.149588E 08	4	-0.336910E 08	5	-0.996772E 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	0.180062E 09	24	0.224606E 08	25	-0.112520E 08	26	-0.313643E 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	-0.990772E 08	10	-0.393062E 08	11	0.224606E 08	12	0.349563E 08	13	-0.786123E 08
		14	-0.224606E 08	15	-0.349563E 08	20	-0.750186E 07	21	-0.128603E 08	22	-0.351425E 01
		23	0.224606E 08	24	0.189667E 09	25	0.449504E 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	-0.699125E 08								
DISP	25	4	0.982087E 01	5	0.336910E 08	6	0.261779E 08	7	-0.197203E 09	8	-0.224382E 08
		9	0.261779E 08	13	0.875216E 07	14	0.336910E 08	15	-0.393062E 08	16	-0.875218E 07
		17	-0.224382E 08	18	-0.393062E 08	22	-0.128603E 08	23	-0.112520E 08	24	0.449504E 01
		25	0.187646E 03	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

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	-0.393648E 08
		9	-0.268288E 01	13	0.336910E 08	14	0.875216E 07	15	0.224607E 08	16	-0.112526E 08
		17	-0.875218E 07	18	-0.750186E 07	22	-0.224382E 08	23	-0.513643E 08	24	-0.149588E 08
		25	-0.327137E 01	26	0.108253E 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 08	24	0.261779E 08	28	0.275072E 09	29	-0.336910E 08	30	-0.117918E 09
		31	-0.643817E 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	0.136698E 09	30	0.224607E 08
		31	0.224382E 08	32	-0.256821E 08	33	-0.149588E 08				
DISP	30	10	0.918620E 08	11	-0.149588E 08	12	-0.940335E 08	13	-0.131283E 08	14	0.149588E 08
		15	0.349563E 08	19	0.262566E 08	20	-0.224606E 08	21	-0.699125E 08	22	0.131283E 08
		23	0.224606E 08	24	-0.349543E 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 09	14	0.336910E 08	15	0.655627E 08	16	0.875213E 07	17	-0.336910E 08
		18	-0.261779E 08	22	-0.175044E 08	23	0.224382E 08	24	0.523559E 08	25	-0.875218E 07
		26	-0.224382E 08	27	0.261779E 08	28	-0.643017E 07	29	0.224382E 08	31	0.275072E 09
		32	-0.336909E 08	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	-0.336910E 08	17	0.875218E 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	0.136698E 09	33	0.224606E 08	34	0.224382E 08	35	-0.256821E 08
		36	-0.149588E 08								
DISP	33	13	0.918619E 08	14	-0.149588E 08	15	-0.940335E 08	16	-0.131283E 08	17	0.149598E 08
		18	0.349562E 08	22	0.262565E 08	23	-0.224606E 08	24	-0.699125E 08	25	0.131283E 08
		26	0.224607E 08	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	-0.524610E 01
		27	0.261779E 08	31	-0.643017E 07	32	0.224382E 08	34	0.938340E 08	35	-0.336910E 08
		36	-0.393042E 09								

FIGURE III-D.15 CONTINUED

PATRIX STIFF / 1/ PAGE 5

CUTOFF = 0.0 SIZE 36 BY 36

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	35	16	0.2243432E 08	17	-0.1989826E 08	25	-0.2640996E 01	26	-0.8795218E 07	27	-0.1495808E 08
		31	0.1225258E 07	32	-0.2960821E 08	33	-0.7901467E 07	34	-0.3369210E 08	35	0.9412677E 08
		36	0.2246046E 07								
DISP	34	16	0.2617798E 08	18	-0.3969248E 08	25	0.1318838E 08	26	-0.7701878E 07	27	-0.3495638E 08
		32	-0.1495488E 08	33	-0.6450177E 07	34	-0.3930628E 08	35	0.2214600E 07	36	0.6187888E 08

FIGURE III-D.15 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
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 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	0.51942099E-06	-0.18232240E-05	-0.17246730E-05
3	0.22856448E-05	-0.36443889E-05	-0.67784067E-05
4	0.54131969E-05	-0.54552560E-05	-0.14936100E-04
5	0.0	0.0	0.0
6	0.82286385E-06	0.18807307E-05	-0.26730813E-05
7	0.28037362E-05	0.22812910E-05	-0.67883230E-05
8	0.59999056E-05	0.38794506E-05	-0.16109276E-04
9	0.0	0.0	0.0
10	0.35346599E-06	-0.16807571E-05	-0.16056868E-05
11	0.21245487E-05	-0.22067861E-05	-0.62474273E-05
12	0.51098862E-05	-0.33873048E-05	-0.14538836E-04
13	0.0	0.0	0.0
14	0.93951292E-06	0.18002559E-05	-0.13954290E-05
15	0.29730490E-05	0.35991225E-05	-0.61994055E-05
16	0.64449150E-05	0.62887530E-05	-0.15940849E-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	0.90970963E 02
2	-0.16326904E-02	0.85448219E-03	0.17931480E-02
3	-0.28228760E-02	0.25482178E-02	0.28132437E-02
4	-0.35705564E-02	0.36917578E-04	0.28296875E-02
5	-0.17282297E 02	-0.71576903E 02	-0.97377411E 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	0.36244446E 02
10	0.45776[illegible]7E-03	0.41196730E-03	0.91552734E-04
11	-0.54931641E-03	-0.44086914E-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	-0.23399461E-03
16	0.17089844E-02	-0.97656250E-03	-0.39062500E-02

FIGURE III-D.18 REACTION MATRIX - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

STRESSES FOR THE TRIANGULAR PRISM ELEMENT

(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 5 9 2 6 10

APPARENT ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	SIGMA-YZ	SIGMA-ZX
1	0.34643211E 01	0.69390480E 01	0.34643211E 01	-0.61643881E 00	0.22597046E 01	0.0
2	0.43166508E 01	0.10943444E 02	0.50816183E 01	0.12537174E 01	0.27724876E 01	0.89737320E 00
3	-0.51817627E 01	-0.78914680E 01	-0.46073809E 01	0.76992064E 00	-0.27554349E 01	0.32827568E 00

ELEMENT APPLIED STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	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 POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	SIGMA-YZ	SIGMA-ZX
1	0.34643211E 01	0.69390480E 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	-0.46073809E 01	0.76992064E 00	-0.27554349E 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	5	51	7 15 11 8 16 12

APPARENT ELEMENT STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	SIGMA-YZ	SIGMA-ZX
1	0.49074519E 01	0.79760122E 01	0.38501024E 01	-0.96312809E 00	0.24272919E 01	0.17856338E 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	-0.30460515E 01	-0.79219818E 00

ELEMENT APPLIED STRESSES

STRESS POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	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 POINT	SIGMA-X	SIGMA-Y	SIGMA-Z	SIGMA-XY (MEMBRANE STRESSES)	SIGMA-YZ	SIGMA-ZX
1	0.49074519E 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	-0.30460515E 01	-0.79219318E 00

FIGURE III-D.20 STRESS OUTPUT ELEMENT NO. 6 - TRIANGULAR PRISM ELEMENT, CANTILEVER BEAM

FORCES FOR THE TRIANGULAR PRISM ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	51	1 5 9 2 6 10

APPARENT ELEMENT FORCES

POINT	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	-0.13618750E 02	-0.45930481E 00

ELEMENT APPLIED FORCES

POINT	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	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	-0.13618750E 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 14 12

APPARENT ELEMENT FORCES

POINT	FX	FORCES FY	FZ
1	-0.36415189E 02	-0.17177475E 02	0.53542680E 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	0.23532308E 02	-0.85327148E 00
5	0.97656250E-03	0.66664595E 02	-0.31738281E-02
6	0.19034135E-01	-0.52123230E 02	0.84765156E 01

ELEMENT APPLIED FORCES

POINT	FX	FORCES 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	FX	FORCES FY	FZ
1	-0.36419139E 02	-0.17177475E 02	0.53542680E 01
2	0.35807129E 02	-0.64129868E 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	0.66664595E 02	-0.31738281E-02
6	0.19034195E-01	-0.52123230E 02	0.84765156E 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

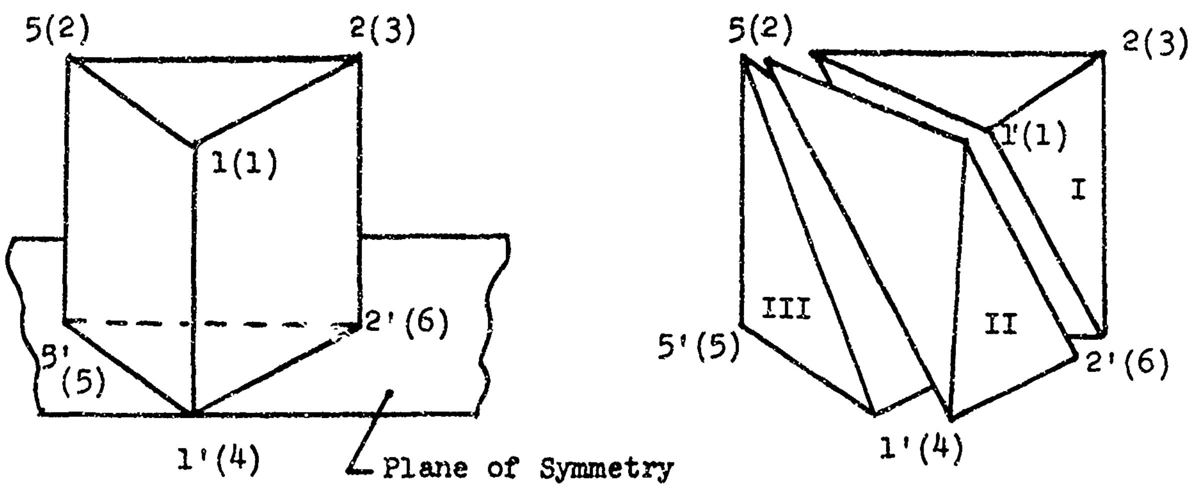
$$\left\{ \Delta^{SP} \right\}^T = \lfloor U_2, V_2, W_2, U_3, V_3, W_3, \ldots U_8, V_8, W_8 \rfloor$$

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.

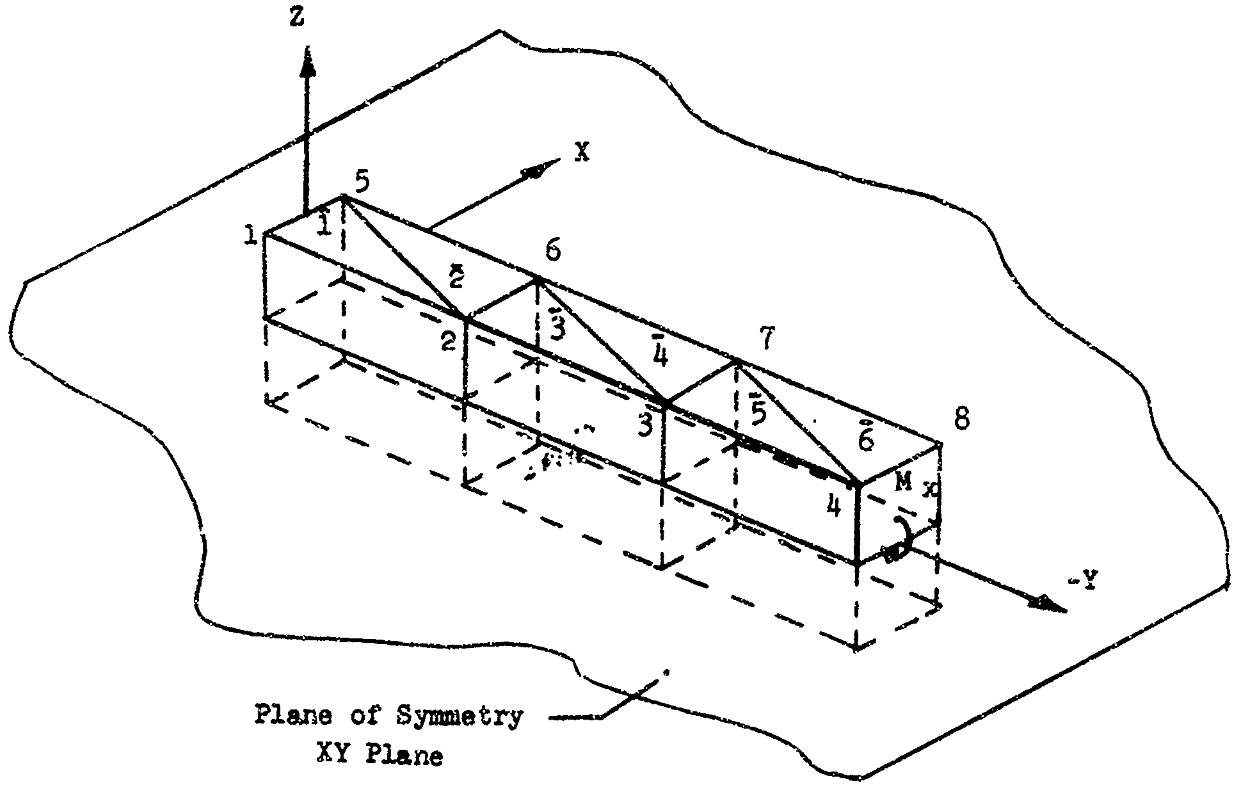
The stresses arising in the structure are displayed in tabular form in Figures III-E.18 and III-E.19 for elements 1 and 6 for example. Stresses are defined at the centroid and are referenced to the global axes for each tetrahedron which makes up a particular symmetric triangular prism element. Three 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

SAC 1916

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 CANTILEVER BEAM SUBJECTED TO AN END MOMENT

SYMMETRIC TRIANGULAR PRISM IDEN. NO. 51

STATICS ANALYSIS CONCENTRATED LOADS EQUIVALENT TO MOMENT.

FIGURE III-E.2 TITLE INFORMATION - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

MATER (/)
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 11 12 13 14 15	16 17	18 – 41	42	43	44	45	46	47	48	49	50	51 52	53 54	55 – 64
	1	J	STEEL	X									1	0	.000733854 (/)

MATERIAL PROPERTIES TABLE

Temperature (cols 3–12)	Direction	Youngs Moduli (cols 23–32)	Direction	Poissons Ratios (cols 33–42)	Direction	Coef. of Thermal Expansion (cols 43–52)	Direction	Rigidity Moduli (cols 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-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

Request	Columns	Entry
	1–6	S Y S T E M (/)
1. Number of System Grid Points	1–6	8
2. Number of Input Grid Points	7–12	8
3. Number of Degrees of Freedom/Grid Point	13–14	3
4. Number of Load Conditions	15–16	1
5. Number of Initially Displaced Grid Points	17–22	0
6. Number of Prescribed Displaced Grid Points	23–28	0
7. Number of Grid Point Axes Transformation Systems	29–30	0
8. Number of Elements	31–36	6
9. Number of Requests and/or Revisions of Material Tape.	37–38	1
10. Number of Input Boundary Condition Points	39–44	2
11. T_o For Structure (With Decimal Point)	45–52	0.0 (/)

FIGURE III-E.4 SYSTEM CONTROL INFORMATION - SYMMETRIC TRIANGULAR PRISM, 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	DIRECTIONS 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	(/)

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

FIGURE III-E.6 BOUNDARY CONDITIONS - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

BAC 1627

LOADS (7)

ICOND	Condition Number	Scale	
ICOND	1	0.0	(7)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
MODAL	0.0	0.0	0.0						

Grid Pt. Number	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
[illegible]	0.0	-66.66667	0.0						
[illegible]									

FIGURE III-E.7 EXTERNAL LOADS - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

ELEM (/)
1 2 3 4 5 6

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7-10)	Plug No. (11-12)	Material Number (13-18)	Interpolate Option (19)	Material Temperature (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat. (31)	Print: Full (32)	Number of Input Nodes (33-34)	No. of A sem. Nodes (35)	Node Points 1 (36-38)	2 (39-41)	3 (42-44)	4 (45-47)	5 (48-50)	6 (51-53)	7 (54-56)	8 (57-59)	9 (60-62)	10 (63-65)	11 (66-68)	12 (69-71)
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									

FIGURE III-E.8 ELEMENT CONTROL DATA - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

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 INSTRUCTION LISTING          PAGE  1
       TEST MAGIC

SINSTRUCTION   SOURCE                                                TESTC004

        C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS            TESTC005
        C                                                                 TESTC006
        C        * * * * * * * * * * * * * * * * * * * * *                TESTC007
        C                                                                 TESTC008
        C        STATICS INSTRUCTION SEQUENCE                             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 FORMAT FOR TYPE OF 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 LOAD COLUMN                           TESTC037
        C                                                                 TESTC038
        C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR            TESTC039
  11          FTELS = FTELA.MULT.LSCALE                                   TESTC040
        C        TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM       TESTC041
  12          LOADC = TR.MULT.LOADS                                       TESTC042
        C        FORM TOTAL LOAD COLUMN                                   TESTC043
  13          TLOAD = FTELS.ADD.LOADC                                     TESTC044
  14          TL.TLOADR = TLOAD.DEJOIN.( 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 REACTIONS AND INVERSE CHECK                    TESTC054
```

FIGURE III-E.10 MAGIC ABSTRACT INSTRUCTION LISTING - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

```
        MAGIC   ABSTRACTION INSTRUCTION LISTING           PAGE  2
      TEST MAGIC

C                                                                  TESTC055
          REACTS = KELA.MULT.XD                                    TESTC056
          REACTP= REACTS.SUBT.ILCAD                                TESTC057
          IF (DIFF.NULL.) GO TO 10                                 TESTC058
C                                                                  TESTC059
C            PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS, TESTC060
C              REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT   TESTC061
C                                                                  TESTC062
C            ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM               TESTC063
C                                                                  TESTC064
          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,TR )FTELA                TESTC065
          GPRINT(4,,,FX,FY,FZ,MX,MY,MZ,SC,    )LCADS               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 OF FREEDOM                    TESTC071
C                                                                  TESTC072
     10   GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )FTELA        TESTC073
          GPRINT(4,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,    )LCADS       TESTC074
          GPRINT(2,,,U,0,W,0,THETAY,0,D4,0,D44,SC, )X              TESTC075
          GPRINT(1,,,FR,0,FZ,0,MBETA,0,F1,0,F3,SC,TR )REACTP       TESTC076
C                                                                  TESTC077
C            GENERATE STRESSES  AND FORCES                         TESTC078
C                                                                  TESTC079
    600   STRESP=EN.XD .STRESS.(4,)                                TESTC080
          FORCEP=EN.XD .FORCE.(4,)                                 TESTC081
```


FIGURE III-2.10 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.

                    REVISION OF MATERIAL TAPE

               ASTERISK (*) PRECEDING 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. . . . . . . . . . . . . . . 0.733900E-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	AC.	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	1	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 DESCRIPTION OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 8

4	0.0	-0.66667E 02	0.0
8	0.0	-0.66667E C2	0.0
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.C
5	0.0	0.0	0.C
6	0.0	0.0	0.0
7	0.0	0.C	0.0

ELEMENT LOAD SCALAR = 0.0

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

24 X 1

0.0	0.C	0.0	0.0	0.0	0.0
0.0	0.C	0.0	0.0	-0.66666592E C2	0.0
0.0	0.C	0.0	0.0	C.0	0.0
0.0	0.C	0.0	0.0	-C.66666592E C2	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 18 BY 18

		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	6	-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	-0.750188E 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	0.750189E 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	0.803033E 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	-0.750188E 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	0.368981E-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	0.783670E 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 08	7	-0.393258E 08	8	-0.168455E 08

FIGURE III-E.14 STIFFNESS MATRIX OUTPUT - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

MATRIX STIFF / 1/ PAG. 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	0.262546E 09	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	0.262546E 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	0.262546E 08
		14	0.280000E 02	15	0.783678E 08	16	0.109418E 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	0.560981E-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	-0.295306E 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)

OFFSET 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	-0.666666992E 01	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	-0.666666992E 02	0.0

FIGURE III-E.15 OFFSET 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	0.16454066E-06	-0.16448810E-05	-0.21[illegible]E-05
3	-0.37[illegible]E-07	-0.34[illegible]E-05	-0.[illegible]E-05
4	-0.29[illegible]E-06	-0.34[illegible]E-05	-0.21[illegible]E-04
5	0.0	0.0	0.0
6	-0.23[illegible]E-06	-0.2[illegible]E-05	-0.2[illegible]E-05
7	-0.4[illegible]E-06	-0.6[illegible]E-05	-0.[illegible]E-05
8	-0.[illegible]E-06	-0.6[illegible]E-05	-0.21[illegible]E-04

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FIGURE III-E.16 DISPLACEMENT MATRIX - SYMMETRIC TRIANGULAR PRISM, CANTILEVER BEAM

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ
1	-0.19958706E 03	0.60087463E 03	0.70000073E 01
2	-0.10810941E-02	0.12207631E-03	0.97903390E-03
3	-0.93076811E-03	0.16021720E-02	0.12287631E-02
4	-0.12287830E-02	0.85449219E-03	0.21972696E-02
5	0.30204147E 02	0.73316477E 02	-0.70104270E 01
6	-0.15258789E-03	0.91552734E-03	-0.23362305E-03
7	-0.57656250E-03	0.72718369E-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(1,2,3,1))
(STRESS POINT TWO EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(4,2,1,4))
(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 3 4 5 6

APPARENT ELEMENT STRESSES

MEMBRANE STRESSES

STRESS 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

MEMBRANE STRESSES

STRESS 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

MEMBRANE STRESSES

STRESS 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

STRESSES FOR THE TRIANGULAR PRISM ELEMENT

(STRESS POINT ONE EQUALS ELEMENT STRESSES AT CENTROID OF TETRAHEDRON WITH NODES(4,2,3,1))
(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

MEMBRANE STRESSES

STRESS 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	-0.66631605E 01	-0.24040375E 01
2	-0.14023790E 01	-0.70013865E 00	-0.70014328E 00	0.34100904E 01	0.26205902E 01	-0.74319458E 00
3	-0.94668394E-06	-0.18962115E-05	-0.94668394E-06	-0.24349734E-07	-0.19261780E 01	-0.27502641E 00

ELEMENT APPLIED STRESSES

MEMBRANE STRESSES

STRESS 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

MEMBRANE STRESSES

STRESS 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	-0.66631605E 01	-0.24040375E 01
2	-0.14023790E 01	-0.70013845E 00	-0.70014328E 00	0.34100904E 01	0.26205902E 01	-0.74319458E 00
3	-0.94668394E-06	-0.18962115E-05	-0.94668394E-06	-0.24349734E-07	-0.19261780E 01	-0.27502641E 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	FX	FORCES 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	0.21602611E 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	FX	FORCES 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	FX	FORCES 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	0.21602611E 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

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 4 8 0 0 0

APPARENT ELEMENT FORCES

POINT	FX	FORCES FY	FZ
1	-0.14008379E 02	0.49647873E 02	-0.11977249E 02
2	-0.18815918E 01	-0.10928375E 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	FX	FORCES 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	FX	FORCES FY	FZ
1	-0.14008379E 02	0.49647873E 02	-0.11977249E 02
2	-0.18815918E 01	-0.10928375E 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.

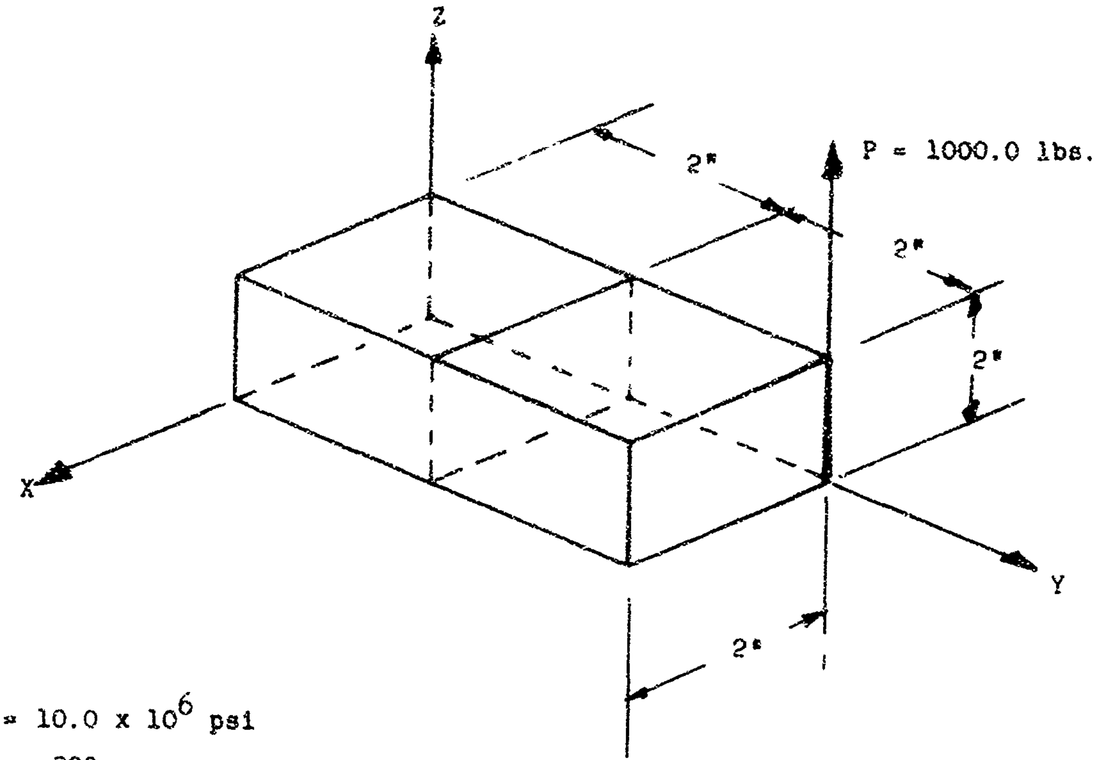
The displacements and reactions of the cantilever beam resulting from the above loads are given in Figure III-F.18. It is noted that the displacements (U, V, W) are output corresponding to node point number and are referenced to the global axes unless otherwise specified. The second portion of Figure 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.



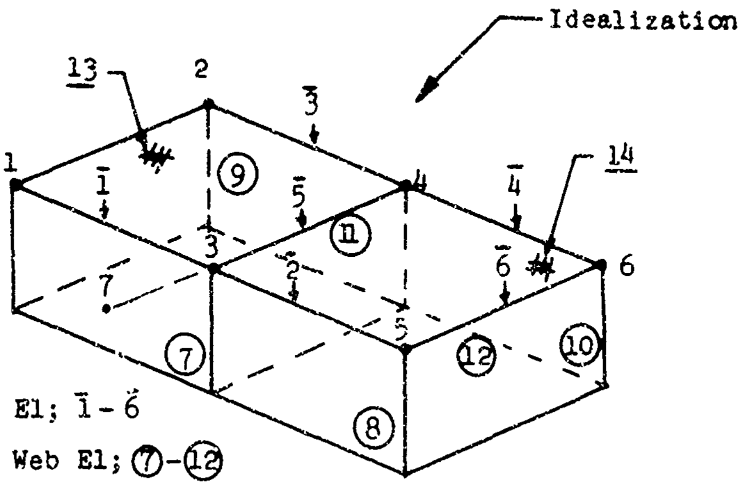
$E = 10.0 \times 10^6$ psi

$\nu = .300$

$E_x = E_y = E_z = 0.0$

$T_1 = T_2 = \cdots = T_6 = 0.0$

P = 1000.0 lbs.



Note:

(1) Axial Force El; $\bar{1} - \bar{6}$

(2) Symm. Shear Web El; ⑦-⑫

(3) Quad. Shear El; 13 - 14

Figure III-F.1 Box Beam With Symmetric Shear Web Element

BAC 1018

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 1619-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

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	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1			7178 ALUMINUM	X									8			(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
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

Item	Request	Entry	Columns
		S Y S T E M (/)	1–6
1.	Number of System Grid Points	7	1–6
2.	Number of Input Grid Points	7	7–12
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	17–22
6.	Number of Prescribed Displaced Grid Points	0	23–28
7.	Number of Grid Point Axes Transformation Systems	0	29–30
8.	Number of Elements	14	31–36
9.	Number of Requests and/or Revisions of Material Tape.	1	37–38
10.	Number of Input Boundary Condition Points	4	39–44
11.	T_o For Structure (With Decimal Point)	0.0 (/)	45–52

FIGURE III-F.4 SYSTEM CONTROL INFORMATION - SYMMETRIC SHEAR WEB CANTILEVERED BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

Grid Point Number (7–12)	DIRECTIONS: X – R (13–22)	DIRECTIONS: Y – Θ (23–32)	DIRECTIONS: Z – Z (33–42)	
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

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 7	8	9	10	11	Repeat 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

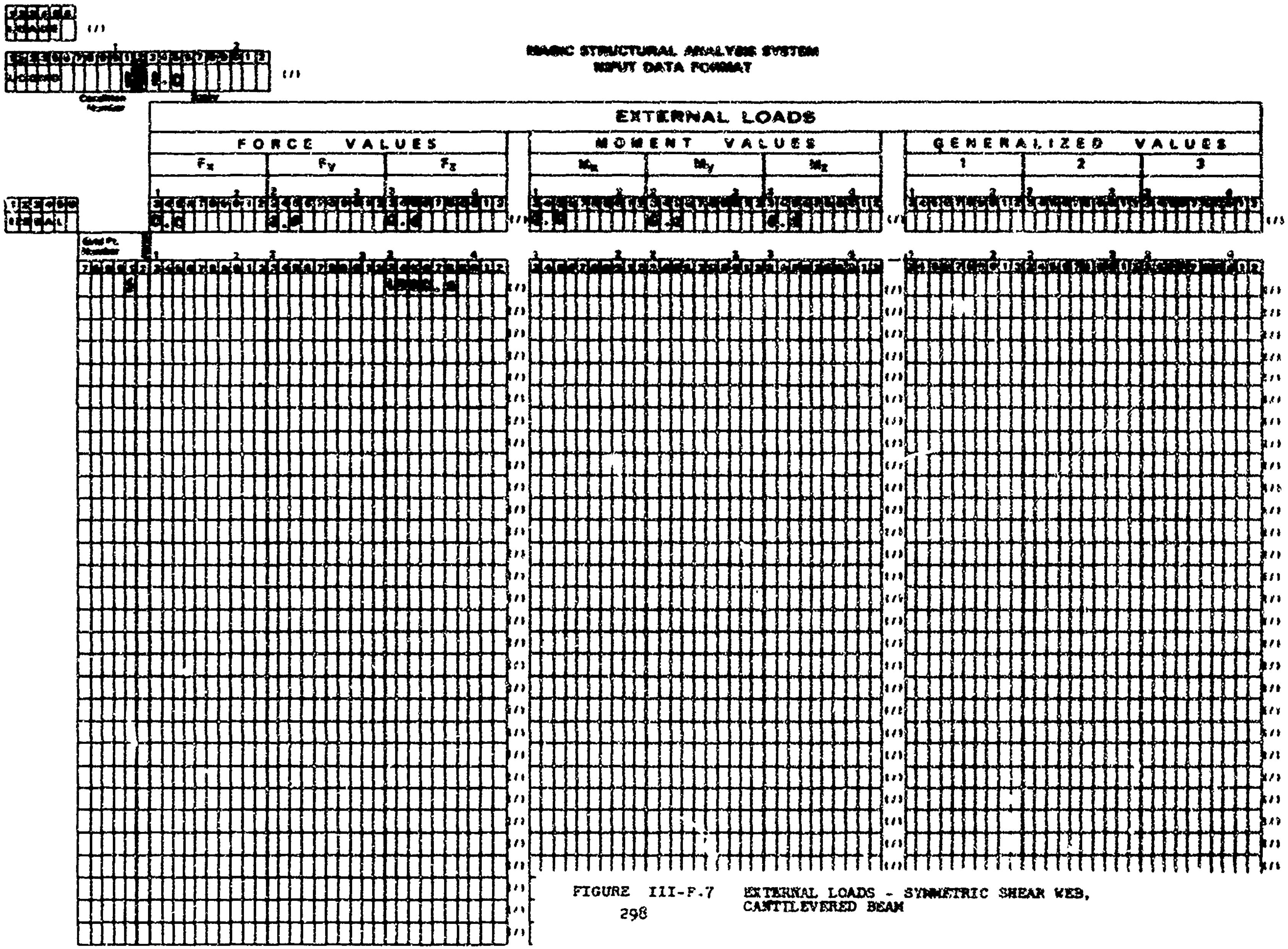


FIGURE III-F.7 EXTERNAL LOADS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

MAC 1020

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number	Plus No.	Material Number	Interpolate Option	Material Temperature	Repeat Elem. Matrices	Elem. Input	Print: Print	Print: Elem. Mat.	Print: Full	Number of Joint Nodes	No. of Assem. Nodes	Node Point 1	Node Point 2	Node Point 3	Node Point 4	Node Point 5	Node Point 6	Node Point 7	Node Point 8	Node Point 9	Node Point 10	Node Point 11	Node Point 12	
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							2		1	5											(/)
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

SAC 1078-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

MODAL

ELEMENT INPUT

Element Number	Repeat	A	B	C	D	E	F	
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

TEST MAGIC

```
       C                                                                  TESTD055
19           REACTS = KELA.MULT.XD                                        TESTD056
20           REACTP= REACTS SUBT.TLCAD                                    TESTD057
21           IF (DIFF.NULL.) GO TO 10                                     TESTD058
       C                                                                  TESTD059
       C        PRINT ELEMENT APPLIED LCADS, EXTERNAL LCADS, 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
22           GPRINT(4,,,FX.FY.FZ.PX.PY.PZ,SC, F )FTELA                    TESTD065
23           GPRINT(4,,,FX.FY.FZ.MX.PY.PZ,SC,    )LCADS                   TESTD066
24           GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X                  TESTD067
25           GPRINT(1,,,FX.FY.FZ.MX.PY.PZ,SC,TF )REACTP                   TESTD068
26           IF (I3.NULL.) GO TO 6CC                                      TESTD069
       C                                                                  TESTD070
       C        ELEMENTS HAVE 3 DEGREES OF FREEDOM                        TESTD071
       C                                                                  TESTD072
27       10  GPRINT(4,,,FR.O.FZ.C.PBETA.C.F1.O.F3,SC,TR )FTELA            TESTD073
28           GPRINT(4,,,FR.O.FZ.O.PBETA.C.F1.O.F3,SC,    )LCADS           TESTD074
29           GPRINT(2,,,U.C.W.C.THETAY.C.W*.O.W**,SC, )X                  TESTD075
30           GPRINT(1,,,FR.O.FZ.O.PBETA.C.F1.O.F3,SC,TR )REACTP           TESTD076
       C                                                                  TESTD077
       C        GENERATE STRESSES  AND FORCES                             TESTD078
       C                                                                  TESTD079
31      600  STRESP=EM,XD .STRESS.(4,)                                    TESTD080
32           FORCEP=EM,XD .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    1
      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

T REF. PCINTS

NO. DIRECTIONS = 3 NC. DEGREES CF FREEDCP = 2

GRIDPCINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z
1	0.20000000E 01	C.0	0.20000000E 01
2	0.0	C.0	0.20000000E 01
3	0.20000000E 01	C.20000000E C1	0.20000000E 01
4	0.0	C.20CC00CCE C1	0.20000000E 01
5	0.20000000E C1	C.40CC00CCE 01	0.20000000E 01
6	0.0	C.40000000E C1	0.20000000E 01
7	0.40C00000E 01	C.2C000000E 01	0.20000000E 01

TEMPERATURES	PRESSURES
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
0.0	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	0.0
0.0	0.0
0.0	0.0
0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES CF FREEDCP						NO. OF ONES	NO. OF TWOS
1	0	C	C	0	0	0	0	0
2	0	C	C	0	0	0	0	0
3	1	1	1	C	0	0	3	C
4	1	1	1	0	0	0	6	C
5	1	1	1	0	0	0	9	0
6	1	1	1	C	0	0	12	0
7	0	C	C	C	0	0	12	0

FIGURE III-F.13 GRIDPOINT DATA AND BOUNDARY CONDITIONS - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

TOTAL NO. ELEMENTS = 14

ELEM	TYPE	MAT.NO.	CODE	TEMP.	ORAT	NO.	GRID POINTS				EXT. GRID PTS	SECTION PROPERTIES			
1	11	77	2	0.0	0	3	1	3	7			0.25000E	00	0.0	0.0
2	11	77	2	0.0	0	3	3	5	7			0.25000E	00	0.0	0.0
3	11	77	2	0.0	0	3	2	4	7			0.25000E	00	0.0	0.0
4	11	77	2	0.0	0	3	4	6	7			0.25000E	00	0.0	0.0
5	11	77	2	0.0	0	3	3	4	7			0.25000E	00	0.0	0.0
6	11	77	2	0.0	0	3	5	6	7			0.25000E	00	0.0	0.0
7	29	77	2	0.0	0	2	1	3				0.50000E-01		0.0	0.0
8	29	77	2	0.0	0	2	3	5				0.50000E-01		0.0	0.0
9	29	77	2	0.0	0	2	2	4				0.50000E-01		0.0	0.0
10	29	77	2	0.0	0	2	4	6				0.50000E-01		0.0	0.0
11	29	77	2	0.0	0	2	3	4				0.50000E-01		0.0	0.0
12	29	77	2	0.0	0	2	5	6				0.50000E-01		0.0	0.0
13	29	77	4	0.0	0	4	1	3	4	2		0.50000E-01		0.0	0.0
14	29	77	4	0.0	0	4	3	5	6	4		0.50000E-01		0.0	0.0

FIGURE III-F.14 FINITE ELEMENT DESCRIPTION - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

EXTERNAL LOAD CONDITIONS 1

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LOAD NO. 1

NUMBER OF LOADED NODES 7 ELEMENT LOAD SCALAR = 0.10000000E 01

6	0.0	0.0	0.10000E 04	0.0	0.0	0.0
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
7	0.0	0.0	0.0	0.0	0.0	0.0

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

42 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	0.10000000E 04	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	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	0.16555939E-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	-0.89491501E-03	0.40009090E-02	0.0	0.0	0.0
6	0.30805506E-02	-0.74508623E-03	0.83991859E-02	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0

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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
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	-0.12718750E-01	0.32043457E-03	0.24414063E-03	0.0	0.0	0.0
6	0.93710938E-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

STRESSES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	11	1 3 7

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS 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 POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS 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 POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS 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                      0.30033616E 04

ELEMENT APPLIED STRESSES
STRESS
POINT                 MEMBRANE SHEAR STRESS
   1                      0.0

NET ELEMENT STRESSES
STRESS
POINT                 MEMBRANE SHEAR STRESS
   1                      0.30033616E 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

FORCES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	11	1 3 7

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	ACRPAL(MZ)
1	0.0	0.81521045E 03	0.0	0.0	0.0	0.0
2	0.0	-0.81521045E 03	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	ACRPAL(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

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	ACRPAL(MZ)
1	0.0	0.81521045E 03	0.0	0.0	0.0	0.0
2	0.0	-0.81521045E 03	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-F.22 FORCE OUTPUT, ELEMENT NO. 1 - SYMMETRIC SHEAR WEB, CANTILEVERED BEAM

FORCES FOR THE SYMMETRIC SHEAR WEB ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	7	29	1 3

APPARENT ELEMENT FORCES

POINT	FX	FORCES FY	FZ
1	0.0	0.15416800E 03	-0.30833594E 03
2	0.0	0.15416800E 03	0.30833594E 03

ELEMENT APPLIED FORCES

POINT	FX	FORCES FY	FZ
1	0.0	0.0	0.0
2	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FX	FORCES 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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

$$\{\Delta\}^T = \lfloor U_1, U_2, V_2, U_3, V_3, U_4, \dots V_{21}, V_{22}, V_{23} \rfloor .$$

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:

$$N_x = \int_z \sigma_x \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_y = \int_z \sigma_y \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_{xy} = \int_z \tau_{xy} \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$M_x = \int_z z\,\sigma_x \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

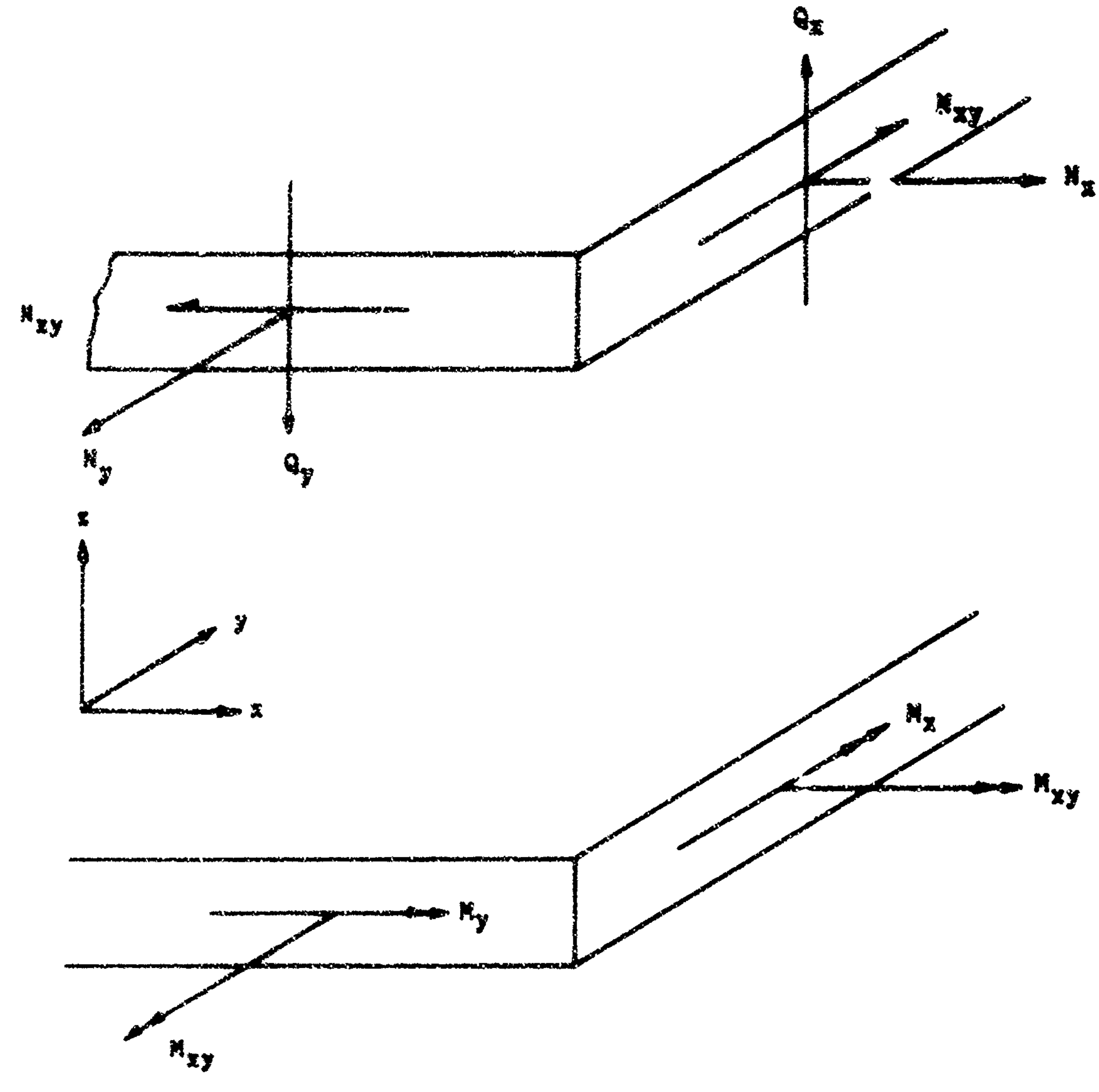
$$M_y = \int_z z\,\sigma_y \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

$$M_{xy} = \int_z z\,\tau_{xy} \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

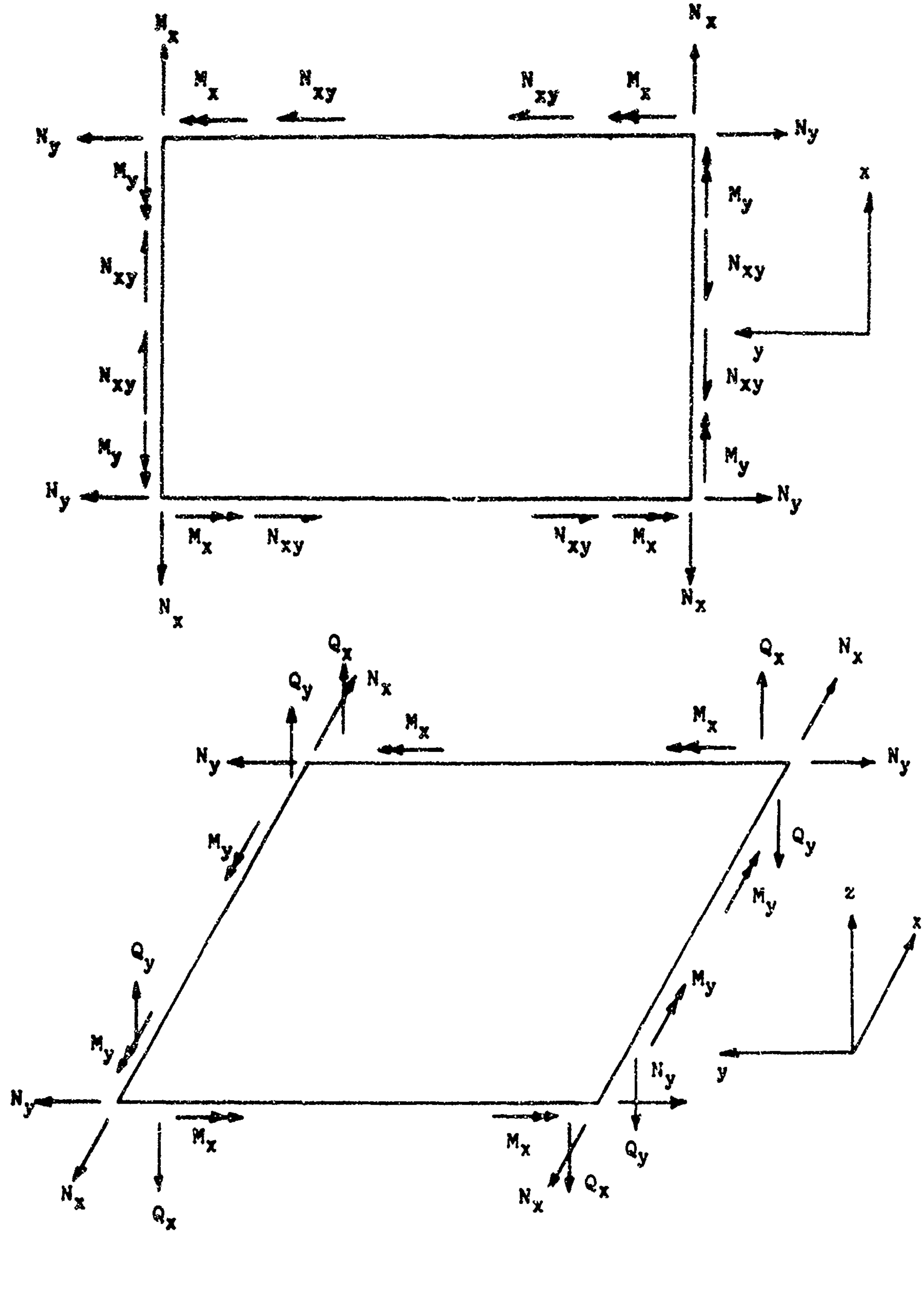
$$Q_x = \int_z z \left(\frac{\partial \sigma_x}{\partial x}\right) dz + \int_z z \left(\frac{\partial \tau_{xy}}{\partial y}\right) dz ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$Q_y = \int_z z \left(\frac{\partial \sigma_y}{\partial y}\right) dz + \int_z z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz ; \text{ units } \frac{\text{force}}{\text{length}}$$

The following sketches show the proper manner in which to interpret the stress resultants.



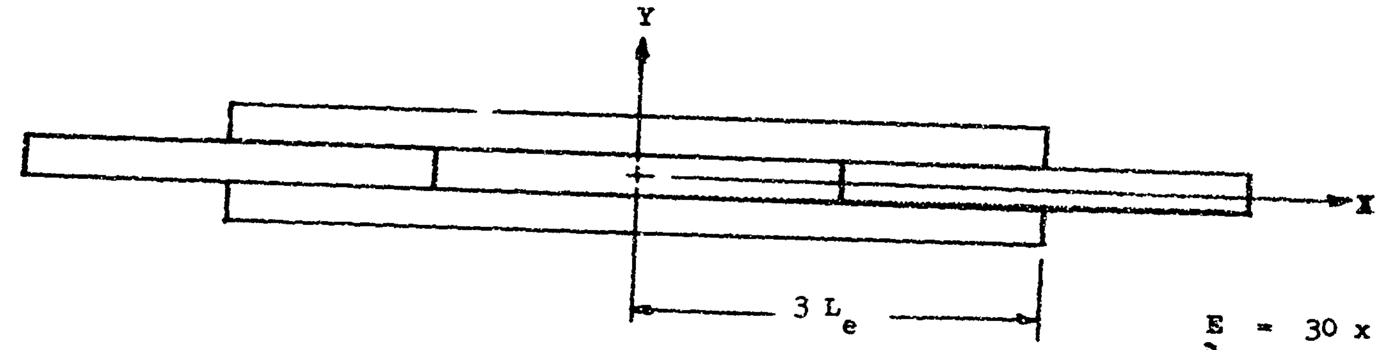
Stress Resultants



N_x
M_x
N_{xy}
N_y
M_y
x
y
Q_x
Q_y
z

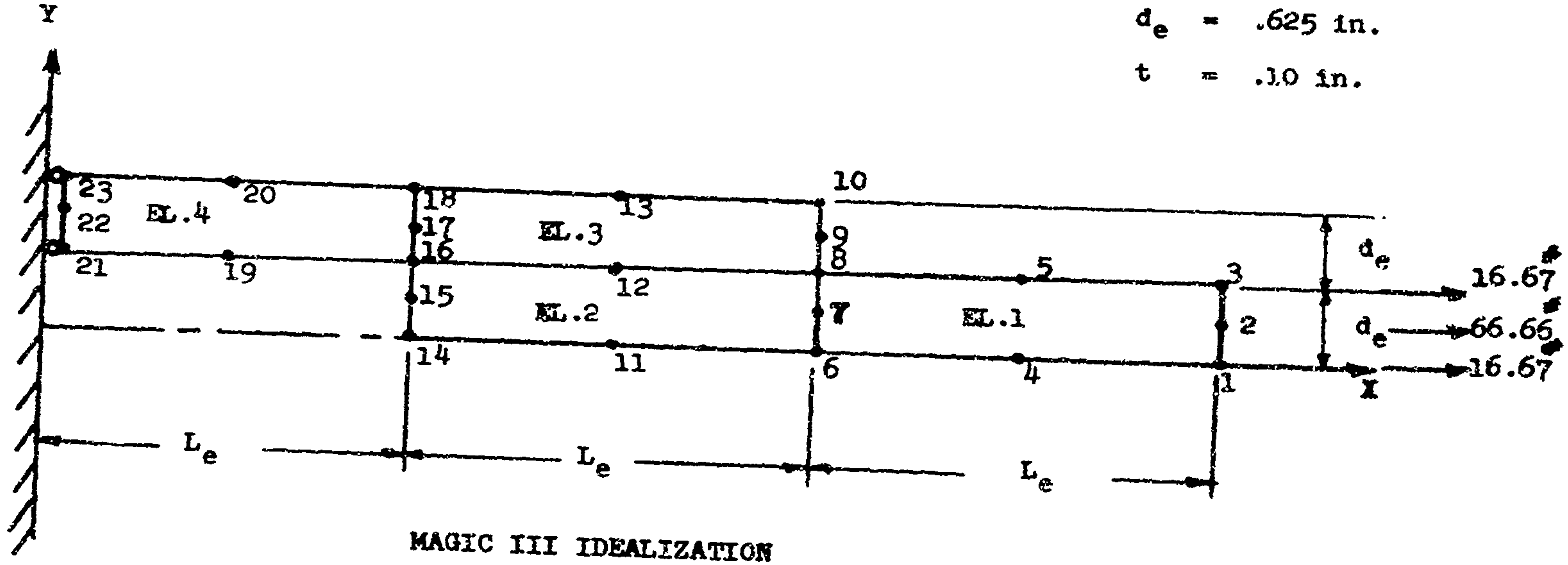
Returning to Figure III-G.20 it is noted that there are five stress points at which the stress resultants are evaluated. These correspond to element grid points 1, 3, 8, and 6. The fifth stress point corresponds to the stresses evaluated at the element centroid. The stresses are in general referenced 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 1616

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

FOUR ELEMENT PLATE SUBJECTED TO A SHEAR LOAD (/)

MODIFIED QUADRILATERAL THIN SHELL ELEMENT IDEN. NO. 58 (/)

ASPECT RATIO 16.0 STATICS ANALYSIS (/)

FIGURE III-G.2 TITLE INFORMATION - LAP JOINT PROBLEM

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 (7–9)	MATERIAL NUMBER (10–15)	Lock Code (16–17)	MATERIAL IDENTIFICATION (18–41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51–52)	Number of Plastic Pts. (53–54)	MASS DENSITY (55–64)	
1	99391	24	STEEL	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
1.0	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

Item	Entry	Columns
	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 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

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

| C | O | O | R | D | |

(/)

GRIDPOINT COORDINATE

Grid Point Number (7–12)	DIRECTIONS X – R (13–22)	DIRECTIONS Y – θ (23–32)	DIRECTIONS Z – Z (33–42)	
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 (7–11)	Repeat (12)	13	14	15	16	17	18	19	20	21	
1		1	0	0	0	0	0				(/)
4	X										(/)
6	X										(/)
11	X										(/)
14	X										(/)
21		0	1	0	0	0	0				(/)
22	X										(/)
23	X										(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)

FIGURE III-G.6 BOUNDARY CONDITIONS - LAP JOINT PROBLEM

BAC 1627

LOADS (/)

LCOND — Condition Number: [illegible] — Factor: 1.0 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MODAL

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F_x	F_y	F_z	MOMENT VALUES M_x	M_y	M_z	GENERALIZED VALUES 1	2	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 XII-G.7 EXTERNAL LOADS - LAP JOINT PROBLEM

BAC 1020

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7–10)	PLUS NO. (11–12)	MATERIAL NUMBER (13–18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT Print (30)	PRINT Elem. Mat. (31)	PRINT Full (32)	Number of Input Nodes (33–34)	No. of Assem. Nodes (35)	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
1	38	9113R8		0.0		X				5		1	3	8	6	2	5	7	4	6	1		
2					X							6	8	16	14	7	12	15	11	6	2		
3					X							8	10	13	14	9	13	17	12	6	1		
4					X							16	18	23	21	17	20	22	19	6	1		

FIGURE III-G.8 ELEMENT CONTROL DATA - LAP JOINT PROBLEM

EAC 1623-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

Columns 1–6	Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL			01.0	0.0	0.0	0.0	0.0	0.0

Element Number (7–11)	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 .SMLLY. 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             XO,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

TEST MAGIC

```
C                                                                       TESTB055
          REACTS = KELA.MULT. XD                                        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 )PTELA                     TESTB065
          GPRINT(4,..FX.FY.FZ.MX.MY.MZ,SC,    )LCADS                    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 )PTELA             TESTB073
          GPRINT(4,..FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LCADS            TESTB074
          GPRINT(2,..U.0.W.0.THETAY.0.W*.0.W**,SC, )X                   TESTB075
          GPRINT(1,..FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP            TESTB076
C                                                                       TESTB077
C            GENERATE STRESSES AND FORCES                               TESTB078
C                                                                       TESTB079
 600      STRESP=EM,XD .STRESS.(4,)                                     TESTB080
          FORCEP=EM,XD .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   99350
    MATERIAL IDENTIFICATION     STEEL                          INPUT CODE   1
      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

 TEMPERATURE                  DIRECTIONS                                          DIRECTIONS
                 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

 TEMPERATURE                  DIRECTIONS                                          DIRECTIONS
                 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 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.30000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.30000000E 02	0.62500000E 00	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
6	0.20000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
8	0.20000000E 02	0.62500000E 00	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
10	0.20000000E 02	0.12500000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
14	0.10000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
16	0.10000000E 02	0.62500000E 00	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
18	0.10000000E 02	0.12500000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
21	0.0	0.62500000E 00	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
23	0.0	0.12500000E 01	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	C.1000E 01	0.0	0.0
2	38	99398	0	0.0	0	8	6	8	10	14	7	12	15	11	6	1	ELEMENT MATRICES REPEATED		
					PRE-STRAIN =		0.0				0.0			0.0		0.0	C.C	0.0	
					PRE-STRESS =		0.0				0.0			0.0		0.0	C.C	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	C.C	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 LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 3   ELEMENT LOAD SCALAR = 0.10000000E 01

1	0.16470E 02	0.0	0.0	0.0	0.0	0.0	
2	0.66660E 02	0.0	0.0	0.0	0.0	0.0	
3	0.10470E 02	0.0	0.0	0.0	0.0	0.0	

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

138 X 1

0.16469990E 02	0.0	0.0	0.0	0.0	0.0
0.66659990E 02	0.0	0.0	0.0	0.0	0.0
0.10469990E 02	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	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	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-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	0.238052E 07	12	0.477058E 08	13	-0.416665E 07				
DISP	2	1	-0.163944E 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	-0.238094E 07	10	0.280000E 02
		11	0.468476E 09	12	0.236092E 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 08
		6	-0.132234E 08	7	0.104762E 08	8	-0.531133E 07	9	0.477059E 08	10	-0.621853E 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	0.385176E 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	0.477059E 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	0.280000E 03	12	-0.327929E 09	13	-0.350000E 02	18	-0.888750E 02	19	-0.666250E 08
		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	0.238052E 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	15	-0.952377E 07	19	0.952376E 07

FIGURE III-G.15 STIFFNESS MATRIX - LAP JOINT PROBLEM

MATRIX STIFF / 1/

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 08	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	0.343233E 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	0.952378E 07	22	-0.308750E 02
		26	-0.238094E 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	0.107897E 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	0.134902E 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	-0.605025E 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	-0.388750E 02	12	-0.400000E 03	13	0.490475E 08
		14	-0.952377E 07	15	-0.289938E 03	16	-0.238094E 07	17	-0.354850E 08	18	0.700000E 01
		19	-0.320000E 02	20	0.565198E 09	22	-0.280676E 09	23	-0.238094E 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	-0.604250E 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	0.262599E 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	0.358126E 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	-0.405625E 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	0.140000E 02	11	0.468476E 09	12	-0.238093E 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	0.938100E 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	-0.238094E 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	0.190000E 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	-0.537626E 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	[illegible]	28	0.656603E 09	29	0.208000E 03	30	-0.327929E 09
		31	-0.350000E 02	32	[illegible]	33	-0.952377E 07	34	-0.606250E 01	35	0.952376E 07
		36	-0.230096E 07	37	0.160000E 02	38	0.230094E 07				
DISP	29	12	0.230092E 07	13	-0.234479E 09	14	0.160000E 02	15	0.468476E 09	16	-0.230095E 07
		17	-0.234479E 09	19	0.952376E 07	20	-0.299125E 03	21	-0.952379E 07	22	0.417188E 03
		26	-0.320000E 02	27	-0.937624E 09	28	0.200000E 03	29	0.187622E 10	30	-0.320000E 02
		31	-0.937624E 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 06	13	-0.416665E 07	14	-0.821883E 08	15	0.230092E 07	16	0.355126E 08
		17	-0.137347E 06	19	-0.132234E 08	20	0.230095E 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	-0.230094E 07	34	0.104762E 08	35	-0.531133E 07
		36	0.416669E 07	37	-0.230095E 07	38	0.137361E 06				
DISP	31	12	-0.416669E 07	13	0.134982E 09	14	0.230094E 07	15	-0.234479E 09	16	0.137361E 06
		17	0.998574E 08	19	0.230095E 07	20	-0.354846E 08	21	0.421243E 07	22	0.345233E 08
		26	0.190000E 02	27	0.328475E 09	28	-0.350000E 02	29	-0.937628E 09	30	-0.190000E 02
		31	0.610351E 09	32	-0.230094E 07	33	-0.354850E 08	34	-0.421243E 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 07	30	-0.132234E 08
		31	-0.230094E 07	32	0.102124E 09	34	-0.966297E 08	35	0.700000E 01	36	-0.421242E 07
		37	0.952376E 07	38	0.230095E 07						
DISP	33	26	0.531132E 07	27	0.345237E 08	28	-0.952377E 07	29	-0.289938E 03	30	-0.230094E 07
		31	-0.354850E 08	33	0.282599E 09	35	-0.280676E 09	36	0.345238E 08	37	-0.299125E 08
		38	-0.354849E 08								
DISP	34	26	-0.132234E 08	27	0.230094E 07	28	-0.606250E 01	29	0.952376E 07	30	0.104762E 08
		31	-0.421242E 07	32	[illegible]	34	0.102124E 09	35	-0.320000E 02	36	-0.230096E 07
		37	-0.952379E 07	38	0.421245E 07						
DISP	35	26	0.230094E 07	27	-0.354851E 08	28	0.952376E 07	29	-0.368750E 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	-0.230096E 07	29	-0.234479E 09	30	0.416663E 07
		31	0.134982E 09	32	-0.421242E 07	33	0.345238E 08	34	-0.230096E 07	35	-0.354853E 08
		36	0.305177E 09	37	-0.468814E 09	38	0.164238E 09				
DISP	37	26	0.230092E 07	27	-0.234479E 09	28	0.160000E 02	29	0.468474E 09	30	-0.230095E 07
		31	-0.234479E 09	32	0.952376E 07	33	-0.299125E 03	34	-0.952379E 07	35	0.417188E 03
		36	-0.468814E 09	37	0.938108E 09	38	-0.468813E 09				
DISP	38	26	-0.416669E 07	27	0.134982E 09	28	0.230094E 07	29	-0.234479E 09	30	0.137361E 06

FIGURE III-G.16 CONTINUED

MATRIX STIFF / 1/

CUTOFF = 0.0 SIZE 38 BY 38

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	38	31	0.998574E 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 CF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.16669958E 02	0.0	0.0	0.0	0.0	0.0
2	0.66659981E 02	0.0	0.0	0.0	0.0	0.0
3	0.16669958E 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 [illegible] 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	-0.47325757E-[illegible]	0.0	0.0	0.0	0.0
3	0.13477041E-03	-0.54440353E-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	0.81462176E-04	-0.38511165E-06	0.0	0.0	0.0	0.0
8	0.81290957E-04	-0.77487406E-06	0.0	0.0	0.0	0.0
9	0.86524303E-04	-0.10398408E-05	0.0	0.0	0.0	0.0
10	0.79940874E-04	-0.13878181E-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	-0.91653559E-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	0.52761654E-04	-0.14030793E-05	0.0	0.0	0.0	0.0
19	0.27219023E-04	-0.54516899E-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	-0.12547585E-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	-0.27252253E 00	-0.10223389E-01	0.0	0.0	0.0	0.0
6	-0.34629154E 00	-0.72069767E 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	-0.23956289E-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	0.4[illegible]60710E-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	-0.70409372E 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

STRESSES FOR THE HIGH ASPECT RATIO QUADRILATERAL ELEMENT

(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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	0.165301E 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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	0.165301E 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

STRESSES FOR THE HIGH ASPECT RATIO QUADRILATERAL ELEMENT

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	38	4 8 16 24 7 12 15 11

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	0.899601E 02	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	0.899601E 02	0.0	0.0	0.0	0.0	0.0

FIGURE III-G.21 STRESS OUTPUT, ELEMENT NO. 2 - LAP JOINT PROBLEM

STRESSES FOR THE HIGH ASPECT RATIO QUADRILATERAL ELEMENT

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	36	8 10 18 16 9 13 17 12

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	-0.490854E 01	0.507861E 02	0.0	0.0	0.0	0.0	0.0
3	0.982681E 02	-0.925603E 01	0.895258E 02	0.0	0.0	0.0	0.0	0.0
4	0.754702E 02	-0.144459E 02	0.631821E 02	0.0	0.0	0.0	0.0	0.0
5	0.816790E 02	0.185908E 01	0.926693E 02	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR 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	-0.490854E 01	0.507861E 02	0.0	0.0	0.0	0.0	0.0
3	0.982681E 02	-0.925603E 01	0.895258E 02	0.0	0.0	0.0	0.0	0.0
4	0.754702E 02	-0.144459E 02	0.631821E 02	0.0	0.0	0.0	0.0	0.0
5	0.816790E 02	0.185908E 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

STRESSES FOR THE HIGH ASPECT RATIO QUADRILATERAL ELEMENT

(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

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	NORMAL(MX)	FLEXURAL MOMENTS NORMAL(MY)	TORQUE(MXY)	NORMAL(QX)	SHEAR 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

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	NORMAL(MX)	FLEXURAL MOMENTS NORMAL(MY)	TORQUE(MXY)	NORMAL(QX)	SHEAR 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 POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	NORMAL(MX)	FLEXURAL MOMENTS NORMAL(MY)	TORQUE(MXY)	NORMAL(QX)	SHEAR 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

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	1	38	1 3 8 6 2 5 7

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.16864990E 02	0.88540430E 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.16864990E 02	0.88540430E 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

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	2	38	6 8 16 14 7 12 15 11

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.533618816E 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	-0.33355539E 01	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.333618816E 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	-0.33355539E 01	0.0	0.0	0.0	0.0

FIGURE III-G.25 FORCE OUTPUT, ELEMENT NO. 2 - 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	3	38	8 10 18 16 9 13 17 12

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.47354660E 02	-0.31523780E 01	0.0	0.0	0.0	0.0
2	0.12687969E 00	-0.31375885E-02	0.0	0.0	0.0	0.0
3	-0.20855637E 02	-0.95370646E 01	0.0	0.0	0.0	0.0
4	0.25125061E 02	0.18111542E 02	0.0	0.0	0.0	0.0
5	-0.29732704E 00	-0.84157214E-02	0.0	0.0	0.0	0.0
6	-0.23437500E-01	-0.21057125E-01	0.0	0.0	0.0	0.0
7	-0.58130890E 02	-0.55389250E 01	0.0	0.0	0.0	0.0
8	0.65273438E 01	0.19206238E 00	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.47354660E 02	-0.31523780E 01	0.0	0.0	0.0	0.0
2	0.12687969E 00	-0.31375885E-02	0.0	0.0	0.0	0.0
3	-0.20855637E 02	-0.95370646E 01	0.0	0.0	0.0	0.0
4	0.25125061E 02	0.18111542E 02	0.0	0.0	0.0	0.0
5	-0.29732704E 00	-0.84157214E-02	0.0	0.0	0.0	0.0
6	-0.23437500E-01	-0.21057125E-01	0.0	0.0	0.0	0.0
7	-0.58130890E 02	-0.55389250E 01	0.0	0.0	0.0	0.0
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	38	16 18 23 21 17 20 22 19

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.21474731E 02	-0.15047119E 02	0.0	0.0	0.0	0.0
2	0.20874446E 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
7	-0.70403564E 02	-0.31596590E-01		0.0	0.0	0.0
8	-0.97656250E-02	-0.19531250E-02		0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS 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 FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.21474731E 02	-0.15047119E 02	0.0	0.0	0.0	0.0
2	0.20874446E 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 ($1 + \cos 2\theta$) 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 ($1 + \cos 2\theta$) variation.

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 samevariation (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)

$$P_{R_1}(\theta) = - \left\{ 100.027 + 98.9766 \cos 2\theta \right\} \quad (1)$$

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.

$$\begin{bmatrix} \sigma_{RR_1}(\theta) \\ \sigma_{ZZ_1}(\theta) \\ \sigma_{\theta\theta_1}(\theta) \\ \sigma_{RZ_1}(\theta) \\ \sigma_{R\theta_1}(\theta) \\ \sigma_{Z\theta_1}(\theta) \end{bmatrix} = \begin{bmatrix} -75.384766 \\ 3.0233459 \\ -163.20439 \\ -7.5593872 \\ 0 \\ 0 \end{bmatrix} + \left[C_2(\theta) \right] \begin{bmatrix} -111.55794 \\ -10.439285 \\ -458.28198 \\ 25.463989 \\ 101.23071 \\ -3.4822311 \end{bmatrix} \quad (2)$$

The matrix $C_2(\theta)$ is the diagonal matrix

$$\lfloor C_2(\theta) \rfloor = \lfloor \cos 2\theta, \cos 2\theta, \cos 2\theta, \cos 2\theta, \sin 2\theta, \sin 2\theta \rfloor . \quad (3)$$

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 $(1 + \cos 2\theta)$ 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

$$\{\sigma\} = \{\sigma_0\} + \sum_m \lceil C_{o_m} \rfloor + \sum_m \lceil \bar{C}_{o_m} \rfloor \{\bar{\sigma}_m\} \tag{4}$$

where the diagonal matrices $\lceil C_{o_m} \rfloor$ and $\lceil \bar{C}_{o_m} \rfloor$ appear as

$$\lceil C_{o_m} \rfloor = \lceil \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta \rfloor \tag{5}$$

and

$$\lceil \bar{C}_{o_m} \rfloor = \lceil \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Sin}\, m\theta,\ \text{Cos}\, m\theta,\ \text{Cos}\, m\theta \rfloor.$$

The net harmonic stress for the A-series, m^{th} harmonic can be expressed as

$$\{\sigma_m\} = [\,E\,]\{\epsilon_m\} - \{SZAEL\ (m)\} \tag{6}$$

where

$$[\,E\,]\{\epsilon_m\} = \underline{\text{harmonic}}\ \text{apparent element stress}, \tag{7}$$

and

$$\{SZAEL\ (m)\} = \text{harmonic element applied stress}. \tag{8}$$

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

$$[E] = \frac{E}{\Delta}\begin{bmatrix} 1-\nu^2 & \nu(1+\nu) & \nu(1+\nu) & 0 & 0 & 0 \\ & (1-\nu^2) & \nu(1+\nu) & 0 & 0 & 0 \\ & & (1-\nu^2) & 0 & 0 & 0 \\ & & & \frac{\Delta}{2(1+\nu)} & 0 & 0 \\ & & & & \frac{\Delta}{2(1+\nu)} & 0 \\ & & & & & \frac{\Delta}{2(1+\nu)} \end{bmatrix} \qquad (12)$$

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

$$E = 30 \times 10^{6} \qquad a)$$
$$\nu = 0.3 \qquad b) \qquad (15)$$
$$\alpha = 6 \times 10^{-6} \qquad c)$$

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).

$$T(0) = 353.526$$
$$T(+2) = 349.965 \qquad (16)$$

The vector $\{SZAEL(m)\}$ for an isotropic material can be expressed as

$$\{SZAEL(m)\} = \begin{bmatrix} \sigma_{pm} \\ \sigma_{pm} \\ \sigma_{pm} \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad (17)$$

where

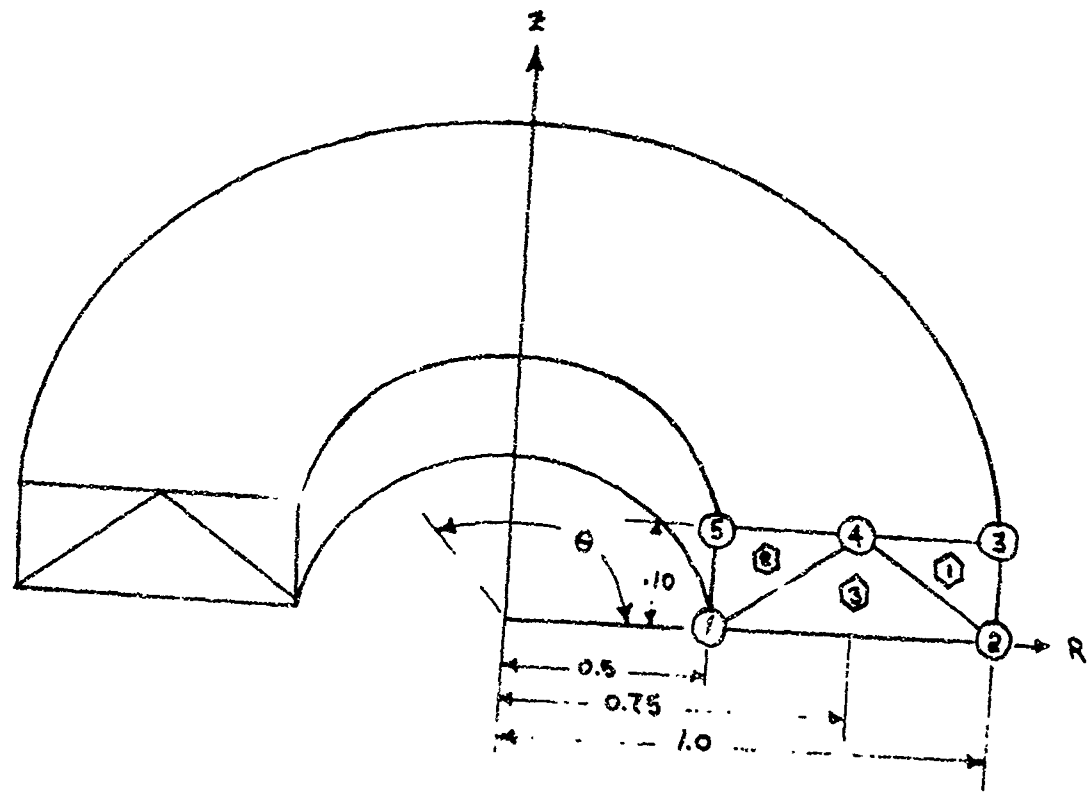
$$\sigma_{pm} = \frac{(1+\nu)^{2}}{1 - 3\nu^{2} - 2\nu^{3}} E \alpha T_{m} \,. \qquad (18)$$

Evaluating Equation III-H.18 for harmonics $m = 0$, $m = +2$ for Element Number 1 of the Thick Walled Disc:

$$\sigma_{p}(0) = .15908656 \text{ E } 06 \qquad a)$$
$$\sigma_{p}(+2) = .15748388 \text{ E } 06 \qquad b) \qquad (19)$$

The quantities $\sigma_{p}(0)$ and $\sigma_{p}(+2)$ 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 1616

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

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: 1 (/) NUMBER OF TITLE CARDS

Columns 1–72:

THICK WALLED DISK SUBJECTED TO NON-AXISYMMETRIC LOADING (/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

FIGURE III-H.2 TITLE INFORMATION, THICK WALLED DISC

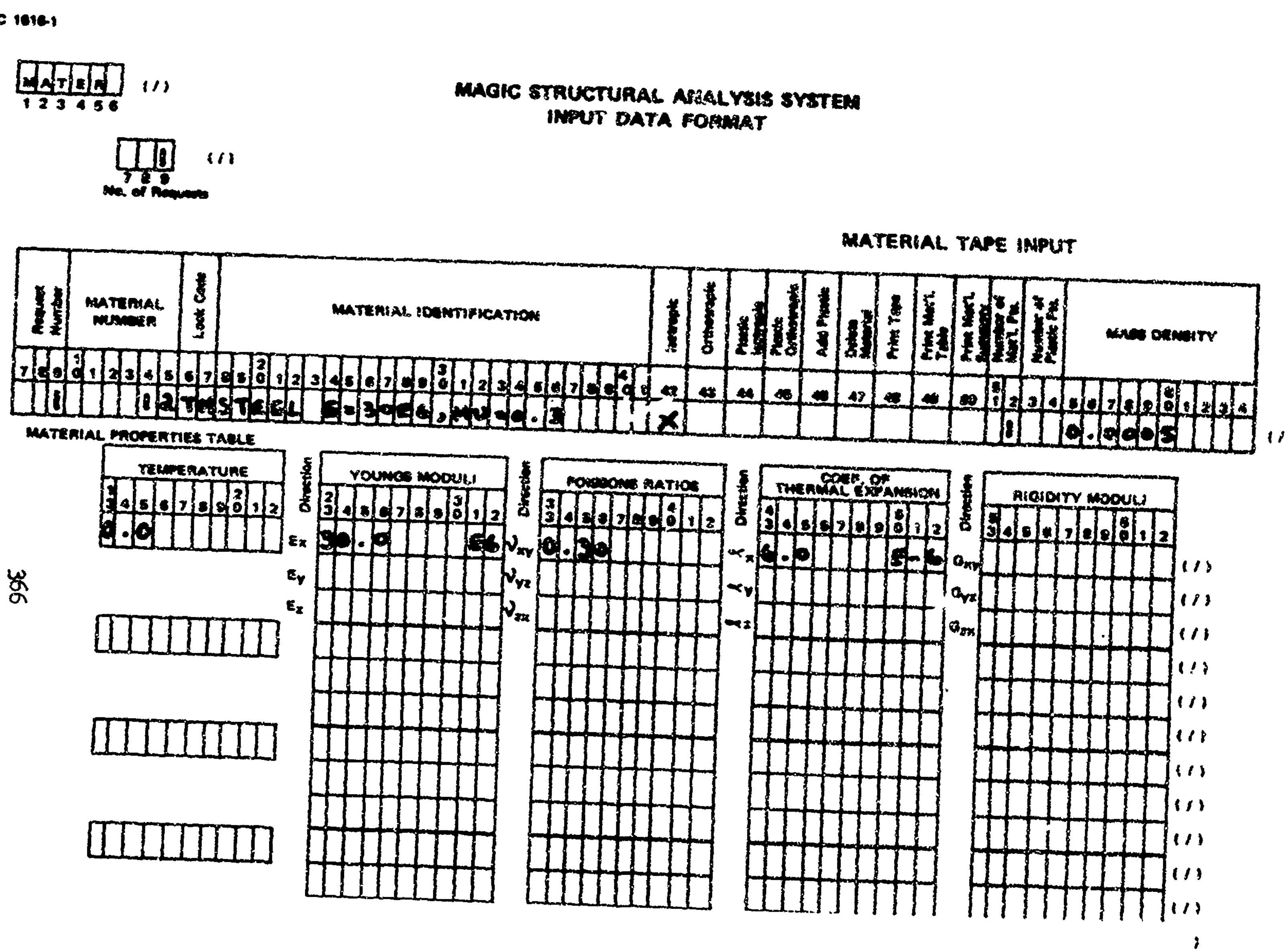


FIGURE III-H.3 MATERIAL TAPE INPUT, THICK WALLED DISC

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

Request	Entry	Columns
	S Y S T E M (/)	1–6
1. Number of System Grid Points	5	1–6
2. Number of Input Grid Points	5	7–12
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	17–22
6. Number of Prescribed Displaced Grid Points	0	23–28
7. Number of Grid Point Axes Transformation Systems	0	29–30
8. Number of Elements	3	31–36
9. Number of Requests and/or Revisions of Material Tape.	1	37–38
10. Number of Input Boundary Condition Points	5	39–44
11. T_o For Structure (With Decimal Point)	0.0 (/)	45–52

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	DIRECTIONS Y – θ	DIRECTIONS Z – Z	
	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

PAC 1626

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7-10)	PLUG NO. (11-12)	MATERIAL NUMBER (13-18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33-34)	No. of Assem. Ligaments (35)	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
1	31	12							X	3		2	3	4										(/)
2	31	12							X	3		1	4	5										(/)
3	31	12							X	3		1	2	4										(/)

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 (7)	(8)	(9)	REPEAT ELEMENT LOADING OPTION (10)	NUMBER OF RADIAL LOADING POINTS (11)	(12)	(13)	NUMBER OF AXIAL LOADING POINTS (14)	(15)	(16)	HARMONIC PRESSURE LOAD VALUES (17)	(27)	(37)	(47)	(57)	(67)
		1			3	6				-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-H.8 HARMONIC PRESSURE LOAD INPUT,
THICK WALLED DISK

BAC 2066

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TRIANGULAR RING ELEMENT (ASYMMETRIC LOADING)
HARMONIC INCREMENTS

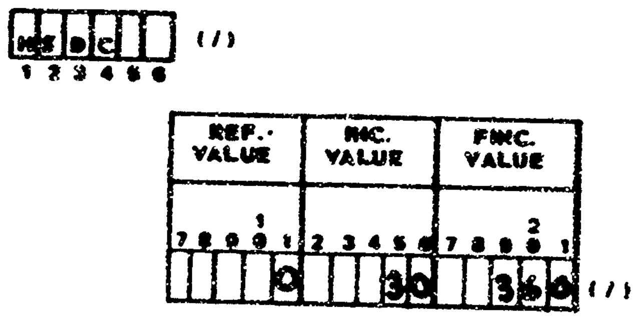


FIGURE III-H.9 DESIGNATION OF STRESS AND DISPLACEMENT OUTPUT LOCATIONS; THICK WALLED DISC

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, NU=0.3 INPUT CODE 1
NUMBER OF MATERIAL PROPERTY POINTS. . . . 1
NUMBER OF PLASTIC PROPERTY POINTS 0
MASS DENSITY. 0.49999965E-03

MATERIAL PROPERTIES

	YOUNG'S MODULI			POISSON'S RATIOS		
TEMPERATURE	DIRECTIONS			DIRECTIONS		
	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		
TEMPERATURE	DIRECTIONS			DIRECTIONS		
	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. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 1

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z
1	0.50000000E 00	0.0	0.0
2	0.10000000E 01	0.0	0.0
3	0.10000000E 01	0.0	0.99999964E-01
4	0.75000000E 00	0.0	0.99999964E-01
5	0.50000000E 00	0.0	0.99999964E-01

TEMPERATURES	PRESSURES
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

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM			NO. OF ONES	NO. OF TWOS
				3	0
1	1	1	1	6	0
2	1	1	1	9	0
3	1	1	1	12	0
4	1	1	1	14	0
5	1	1	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    5    2   3   4

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, NU=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         0.29999999E 00      0.29999999E 00      0.29999999E 00
      TH. EXP. COEF.          0.99999999E-05      0.99999999E-05      0.99999999E-05
      RIGIDITY MODULI         0.11538460E 08      0.11538460E 08      0.11538460E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

INTERNAL INPUT
      NONE


ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   ---------GRID POINTS---------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  31       12    0  0.0          2    5    1   4   5

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, NU=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         0.29999999E 00      0.29999999E 00      0.29999999E 00
      TH. EXP. COEF.          0.99999999E-05      0.99999999E-05      0.99999999E-05
      RIGIDITY MODULI         0.11538460E 08      0.11538460E 08      0.11538460E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

INTERNAL INPUT
      NONE


ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   ---------GRID POINTS---------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  3  31       12    0  0.0          2    5    1   2   6

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . . STEEL - E=30E6, NU=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         0.29999999E 00      0.29999999E 00      0.29999999E 00
      TH. EXP. COEF.          0.99999999E-05      0.99999999E-05      0.99999999E-05
      RIGIDITY MODULI         0.11538460E 08      0.11538460E 08      0.11538460E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

INTERNAL 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 NO	DIRECTION OF LOADING	NUMBER OF LOADING POINTS	NUMBER OF HARMONIC REQUESTS
1	RADIAL	36	2

LOADS

POINT		POINT		POINT	
1	-0.200000E 03	2	-0.193970E 03	3	-0.176400E 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	-0.176400E 03	18	-0.193970E 03
19	-0.200000E 03	20	-0.193970E 03	21	-0.176400E 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	-0.176400E 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 NO	HARMONIC COEFFICIENT	FOURIER COEFFICIENT
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                 0.30483086E 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
 0.49431494E 06     0.42359232E 08

ROW         3
-0.22655770E 07    -0.15103760E 07     0.14599336E 09

ROW         4
-0.40217200E 08     0.23067450E 07    -0.27186706E 06     0.67019424E 08

ROW         5
-0.71400300E 06    -0.41315696E 08    -0.75518770E 07     0.10984190E 07     0.47796564E 08

ROW         6
-0.14348364E 08     0.75518960E 07    -0.14515397E 09     0.43800646E 08     0.15103490E 07     0.15223901E 09

ROW         7
-0.49432019E 06    -0.13181520E 07     0.22655544E 08    -0.22847720E 08    -0.25263960E 07    -0.22655594E 08
 0.21859236E 08

ROW         8
 0.17026160E 07     0.14280020E 07    -0.45311430E 07     0.35151080E 07    -0.58217640E 07     0.45311430E 07
-0.10990400E 06     0.86777290E 07

ROW         9
 0.16614154E 03     0.30207650E 07     0.21969431E 06    -0.16414154E 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 ($n = +2$), ELEMENT No. (1), THICK WALLED DISC

STRESSES FOR THE ASYMMETRIC TRIANGULAR CROSS SECTION RING ELEMENT

(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 POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	-0.753047640E 02	0.302334590E 01	-0.143204390E 03	-0.755938720E 01	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	-0.753047640E 02	0.302334590E 01	-0.143204390E 03	-0.755938720E 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 POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (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 POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (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 (n = +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	0.192116E-04	-0.498264E-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	0.267955E-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 $\theta = 0°$, THICK WALLED DISC

REACTIONS

THETA	GRID POINT	U	V	W
60	1	-0.546215E 00	0.120364E-02	0.732376E-03
60	2	-0.480445E-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	0.518767E-03	-0.106627E-02	-0.488251E-03

FIGURE III-H.18b NODAL CIRCLE REACTIONS AT $\theta = 60°$, THICK WALLED DISC

NET STRESSES FOR THE TRIANGULAR RING ELEMENT

(STRESSES EVALUATED AT ELEMENT CENTROID)

ELEMENT NUMBER	ELEMENT TYPE	CIRCUMFE- RENTIAL	NORMAL RADIAL	NORMAL CIRCUMFERENTIAL	NORMAL AXIAL	SHEAR R-Z	SHEAR R-THETA	SHEAR 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	0.8756806E 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	0.1704743E-02	-0.5864208E-04
1	31	120	-0.1960361E 02	0.8243194E 01	0.6594560E 02	-0.2029187E 02	-0.8766721E 02	0.3015650E 01
1	31	150	-0.1311609E 03	-0.2196036E 01	-0.3923337E 03	0.5171772E 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	0.3015907E 01

FIGURE III-H.19 STRESSES IN ELEMENT NO. (1), THICK WALLED DISC

1	2	3	4
H	T	E	M

(/)

Number of Elements (7–9)	No of Harmonic per Element (10)	No of Harmonic Requests (11)
3	2	2

(/)

Element ID (7–9)	Repeat Element Loading Option (10)	Number of Loading Points (11–13)
1		36

Harmonic Thermal Load Values

17	27	37	47	57	67
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 (7 8 9)	REPEAT ELEMENT LOADING OPTION (10)	NUMBER OF LOADING POINTS (11 12 13)
2		36

HARMONIC THERMAL LOAD VALUES					
17	27	37	47	57	67
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 (7 8 9)	REPEAT ELEMENT LOADING OPTION (10)	NUMBER OF LOADING POINTS (11 12 13)
3		36

HARMONIC THERMAL LOAD VALUES					
17	27	37	47	57	67
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.20b 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     12TM STEEL - E=30E6, NU=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    665.8     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      98.0
                    54.5     25.9       6.6       0.0       6.6      25.6
                    54.5     98.0     127.9     163.5     192.5     211.4
                   218.0    211.4     192.5     163.5     127.9      98.0
                    54.5     25.5       6.6       0.0       6.6      25.9
                    54.5     98.0     127.9     163.5     192.5     211.4
      03   36      976.0    946.6     861.5     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 O A D S (THERMAL)

ELEMENT NO	DIRECTION OF LOADING	NUMBER OF LOADING POINTS	NUMBER OF HARMONIC REQUESTS
1		36	2

LOADS

POINT		POINT		POINT	
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	0.176000E 03	8	0.827000E 02	9	0.213000E 02
10	0.0	11	0.213000E 02	12	0.827000E 02
13	0.176000E 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	0.176000E 03	26	0.827000E 02	27	0.213000E 02
28	0.0	29	0.213000E 02	30	0.827000E 02
31	0.176000E 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 NO	HARMONIC COEFFICIENT	FOURIER COEFFICIENT
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

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.13969919E 06	0.15608494E 06	0.16607738E 06	0.74993750E 04	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.15908656E 06	0.15908656E 06	0.15908656E 06	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	-0.19387379E 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 (α = 0), THICK WALLED DISC

STRESSES FOR THE ASYMMETRIC TRIANGULAR CROSS SECTION RING ELEMENT

(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 POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.12593919E 06	0.15220494E 06	0.11695213E 06	0.13904594E 05	-0.25779180E 04	0.38851470E 04

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	0.15748388E 06	0.15748388E 06	0.15748388E 06	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (RR)	AXIAL (ZZ)	CIRCUMFERENTIAL (THETA-THETA)	SHEAR STRESSES (RZ)	SHEAR STRESSES (R-THETA)	SHEAR STRESSES (Z-THETA)
1	-0.31544688E 05	-0.52789375E 04	-0.40533175E 05	0.13904594E 05	-0.25779180E 04	0.38851470E 04

FIGURE III-H.24 b HARMONIC STRESSES FOR ELEMENT NO. (1), HARMONIC ([illegible] = +2),
THICK WALLED DISC

DISPLACEMENTS

THETA	GRID POINT	U	V	W
0	1	-0.322093E-02	0.0	-0.672427E-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	-0.143497E-01
0	5	0.222443E-02	0.0	0.0

FIGURE III-H.25 a NODAL CIRCLE DISPLACEMENTS AT $\theta = 0°$, THICK WALLED DISC

DISPLACEMENTS

THETA	GRID POINT	U	V	W
60	1	-0.135632E-02	0.116007E-02	-0.142783E-03
60	2	-0.976223E-03	0.656439E-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 $\theta = 60°$, THICK WALLED DISC

NET STRESSES FOR THE TRIANGULAR RING ELEMENT

(STRESSES EVALUATED AT ELEMENT CENTROID)

ELEMENT NUMBER	ELEMENT TYPE	CIRCUMFERENTIAL	NORMAL RADIAL	NORMAL CIRCUMFERENTIAL	NORMAL AXIAL	SHEAR R-Z	SHEAR R-THETA	SHEAR Z-THETA
1	31	0	-0.5003284E 05	-0.8280963E 04	-0.3354094E 05	0.2140397E 05	0.0	0.0
1	31	30	-0.3515900E 05	-0.5641117E 04	-0.1327527E 05	0.1445174E 05	-0.2232539E 04	0.3364424E 04
1	31	60	-0.3615359E 04	-0.3622107E 03	0.2725627E 05	0.5472227E 03	-0.2232558E 04	0.3344659E 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	0.2725740E 05	0.5468047E 03	0.2232513E 04	-0.3364592E 04
1	31	150	-0.3515093E 05	-0.5640961E 04	-0.1327405E 05	0.1445132E 05	0.2232579E 04	-0.3364492E 04
1	31	180	-0.5003206E 05	-0.8280563E 04	-0.3354094E 05	0.2140397E 05	0.8682621E-01	-0.1308547E 00
1	31	210	-0.3516400E 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	0.3344722E 04
1	31	270	0.1215731E 05	0.2277313E 04	0.4752256E 05	-0.6405219E 04	-0.1302389E 00	0.1962013E 00
1	31	300	-0.3613492E 04	-0.3618967E 03	0.2725066E 05	0.5464023E 03	0.2232476E 04	-0.3364526E 04
1	31	330	-0.3515604E 05	-0.5640813E 04	-0.1327290E 05	0.1445993E 05	0.2232621E 04	-0.3364753E 04

FIGURE III-H.26 STRESSES IN ELEMENT NO. (1), THICK WALLED DISC

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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.

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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.

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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 $\left[C\right]$ 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 unreduced 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.

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.

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 Condition Number.

13. Page 140 Item Number 1 under REMEMBER 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

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

(/) NUMBER OF TITLE CARDS

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

(/)

BAC 1616-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

M	A	T	E	R	
1	2	3	4	5	6

(/)

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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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 ________

SAC 1617

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PLASTIC PROPERTIES TABLE

TEMPERATURE												
	N		K		X		Y		Z		(/)
	R		S								(/)

Page ______ of ______

400

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	

Request	Card columns
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 (/)

SAC 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

Operation	Box
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) — columns 1–2

2. Convergence Criteria (Floating Point) (Default Option - 0.001) — columns 3–14

3. Maximum Number of Iterations (Default Option - 500 Iterations) — columns 15–17

4. Debug Iteration Print
   Iteration Print ON = 1
   Iteration Print OFF = 0
   (Default Option - Print OFF) — column 18

5. First Normalizing Element for Print (Default Option - No First Normalization) — columns 19–22

6. Second Normalizing Element for Print (Default Option - No Second Normalization) — columns 23–26

7. Control for Guess Vector Iteration Start
   Column Iteration Start = 0
   Row Iteration Start = 1
   (Default Option - Column Iteration Start) — column 27 (/)

BAC 1822 Rev. 871

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	DIRECTIONS Y – θ	DIRECTIONS 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.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

1	2	3	4	5	6
P	R	E	S	S	

(/)

PRESSURES																													
P1										P2										P3									
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	3	4	5	6
M	O	D	A	L	

Grid Point Number					Repeat	P1										P2										P3										
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	Blank	F_1	F_2	F_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 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	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	
																														(/)

Grid Point Number					Repeat	T_1										T_2										T_3										
7	8	9	10	1	12	13	4	5	6	7	8	9	20	1	2	23	4	5	6	7	8	9	20	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
(continued)

Grid Point Number	Repeat	T_1	T_2	T_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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BAC 1445

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 X	Local Axis Direction Y	Local Axis Direction Z	Plane Definition Grid Point Numbers 1	2	3	Applicable Grid Point Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7–9	10	11	12	13–16	17–20	21–24	25–27	28–30	31–33	34–36	37–39	40–42	43–45	46–48	49–51	52–54	55–57	58–60	61–63	64–66	67–69	(/)
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IF GRAXES INFORMATION MUST BE CONTINUED ON SECOND SHEET,
USER MUST DELETE GRAXES LABEL CARD FROM SECOND SHEET.

Page ______ of ______

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 7	8	9	10	11	Repeat 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 2604

MASS (/)

SCALE (/)

Mass Scaler

MODAL

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LUMPED MASSES

Grid Pt. Number	M_x	M_y	M_z		$M_{\theta x}$	$M_{\theta y}$	$M_{\theta z}$		M_1	M_2	M_3
				(/)				(/)			

BAC 1627 Rev. 3/71

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS

L-COND — Condition Number — Scale — Trans.

NOGEAL

Grid Pt. Number

EXTERNAL LOADS								
FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
F_x	F_y	F_z	M_x	M_y	M_z	1	2	3

BAC 1620 Rev.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number	Plug No.	Material Number	Integration Option	Material Temperature	Repeat Elem. Matrices	Elem. Input	Print: Print	Print: Elem. Mat.	Print: Full	Number of Joint Nodes	Surface Pressure	Node Points: 1	2	3	4	5	6	7	8	9	10	11	12

IF ELEMENT CONTROL DATA MUST BE CONTINUED ON SECOND SHEET, USER MUST DELETE ELEM LABEL CARD FROM SECOND SHEET.

Page ______ of ______

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RAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

MODAL

ELEMENT INPUT

Element Number	Repeat	A	B	C	D	E	F

416

Page ______ of ______

BAC 1629-2

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT
(continued)

Element Number	Repeat	A	B	C	D	E	F	
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	43 4 5 6 7 8 9 50 1 2	53 4 5 6 7 8 9 60 1 2	63 4 5 6 7 8 9 70 1 2	
								(/)
								(/)
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BAC 1530

PRDISP

PCOND

Condition Number

MODAL

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRESCRIBED DISPLACEMENTS

TRANSLATIONS			ROTATIONS			GENERALIZED		
U	V	W	θ_x	θ_y	θ_z	1	2	3

Grid Pt. Number

BAC 1431

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

(/)

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

(/)
(/)
(/)

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

(/)

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

(/)
(/)
(/)

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

(/)

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

(/)
(/)
(/)

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

(/)

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

(/)
(/)
(/)

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

(/)

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

(/)
(/)
(/)

DAC 1211 Rev. 672

MAGIC
MATRIX/INPUT DATA FORMAT

M	IMAX	JMAX	MATRIX NAME	SUBSCRIPT	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	
M						(/)

	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	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																(/)
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22																(/)
23																(/)
24																(/)
25																(/)

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	
3 4	5 6 7 8 9 0 1 2 3 4 ... (columns 15–74)	
		(/)
		(/)

Element Number	Subcase		Temperatures (columns 15–74)	
7 8 9 0 1	2	3 4	5 6 7 8 9 0 1 2 3 4 ...	
				(/)
				(/)
				(/)
				(/)
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				(/)

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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 (columns 13–74, fields 15–24, 25–34, 35–44, 45–54, 55–64, 65–74) | (/)

Element Number (columns 7–11) | Blank (12) | columns 13–14 | fields 15–24, 25–34, 35–44, 45–54, 55–64, 65–74 | (/)

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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

Columns 13–22	Columns 23–32	Columns 33–42	Columns 43–52	Columns 53–62	Columns 63–72

(/)

Element Number (columns 17–21)	Repeat (column 22)	Columns 23–32	Columns 33–42	Columns 43–52	Columns 53–62	Columns 63–72

(/)

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
7 8 9 10 11	12 13 14 15 16	17 18 19 20 21

(/)

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	10	11	
			(/)

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	10	11 12 13	14 15 16	17 – 26	27 – 36	37 – 46	47 – 56	57 – 66	67 – 76	
										(/)
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										(/)

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Page ________ of ________

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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										(/)

BAC 2058 Sht 1

1	2	3	4	5	6
H	T	E	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	10	11

(/)

HARMONIC DEPENDENT ELEMENT THERMAL LOADS

Element Number	Report Opt	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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										(/)
										(/)
										(/)

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BAC 2058 Sht. 2

MAGIC STRUCTURAL ANALYSIS SYSTEM
INFUT 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	17–26	27–36	37–46	47–56	57–66	67–76

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Page ______ of ______