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MAGIC: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

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AIR FORCE SYSTEMS COMMAND
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FOREWORD

This report was prepared by Textron's Bell Aerosystems Company (BAC), Buffalo, New York, under USAF Contract No. AF 33(615)-67-C-1505. The contract was initiated under Project No. 1467, ''Structural Analysis Methods,'' Task No. 146702, ''Thermal Elastic Analysis Methods.'' The program was administered by the Air Force Dynamics Laboratory (AFFDL), Systems Command, Wright-Patterson Air Force Base, Ohio 45433, under the cognizance of Mr. G. E. Maddux, AFFDL Program Manager. The program was carried out by the Structural Systems Department, Bell Aerosystems Company, during the period 15 March 1967 to 15 March 1968 under the direction of Dr. Robert H. Mallett, BAC Program Manager.

This report ''MAGIC: 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 March 1968 for publication as an AFFDL Technical Report.

The numercial results presented in this report were obtained, in part, on the AFFDL tie-in to the Wright-Patterson Air Force Base Electronic Data Processing Center. The utilization of this equipment and the helpful assistance of AFFDL personnel is acknowledged.

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This technical report has been reviewed and is approved.

FRANCIS J. JANIK, JR.
Chief, Theoretical Mechanics Branch
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ABSTRACT

An automated general purpose system for analysis is presented. This system, identified by the acronym "MAGIC" for " Matrix Analysis via Generative and Interpretive Computations'', provides a flexible framework for implementation of the finite element analysis technology. Powerful capabilities for displacement, stress and stability analyses are included in the subject MAGIC System for Structural analysis.

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Six versatile finite elements are incorporated in the finite element library. These are; frame, shear panel, triangular cross-section ring, toroidal thin shell ring, quadrilateral thin shell and triangular thin shell elements. These finite element representations include matrices for stiffness, incremental stiffness, prestrain load, thermal load, distributed mechanical load and stress.

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

Documentation of the MAGIC 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, contains instructions for the preparation of input data and interpretation of output data with examples drawn from the applications presented in Volume I.

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SECTION I

INTRODUCTION

The MAGIC System is made up of three primary functional elements; namely, Preprocessor, Execution and Structural Monitors. The organizational interrelation of these monitors is considered in Volumes I and III of this report (References 1,2). Of interest here are the interfaces of these monitors with the MAGIC System User.

The Preprocessor Monitor relies wholly upon the FORMAT System for its capability. This Monitor has the responsibility for reading and interpreting FORMAT data, setting system parameters, allocating available internal and external storage, and translating the input abstraction instructions into a form useable by the Execution Monitor. Under normal operation of the MAGIC System for structural analysis, User provided data to the Preprocessor Monitor consists of a preset control deck. On the other hand, nonstandard operation of the MAGIC System to perform matrix algebra requires development of a complete problem oriented control deck for the Preprocessor Monitor.

The Execution Monitor carries out instructions passed from the Preprocessor Monitor and has no interfaces with the MAGIC. System User. The primary input data interface resides in the Structural Monitor. Modules underlying the Structural Monitor, read, interpret, and store the structure input, generate the requested matrices and furnish these matrices in a form useable by the Executive Monitor.

Corresponding to the computational flow through the MAGIC System, Section 2 of this report begins with instructions for the specification of data to the Preprocessor Monitor. Then, attention is focused upon the structural data. Preprinted, report form input sheets are described that facilitate the specification of structure data.

Section 3 is devoted to interpretation of the output from the MAGIC System. Output from the Structural Monitor records the input data problem description as well as optional intermediate results. System level matrix output of final results is handled by the FORMAT standard matrix print capability.

Instructions for the interpretation of output data are presented in the context of example problem executions. Each problem is accompanied by a set of the preprinted input sheets described in Section 2.

Functional knowledge of the MAGIC System is gained best by utilization. Therefore, it is recommended that elementary example problems be executed in parallel with study of the MAGIC System documentation.

SECTION II

INPUT TO THE MAGIC SYSTEM

A. INTRODUCTION

The MAGIC System presents two input data interfaces to the Structural Analyst. The first encountered in operation of the MAGIC System is referred to as the System Input Data interface. This input data is generally not problem orientated. Rather, it can be viewed as the system level control setup to accommodate the structural analysis process.

The second input data interface with the User concerns the Structural Input Data. This is problem orientated data which accounts for nearly all the effort expended in conducting structural analyses.

Separate subsections, devoted to instructions for the specification of System Input Data and Structural Input Data, follow. Utilization of the MAGIC System for structural analysis is covered in depth. The reader is referred to Reference 3 for detailed instructions on carrying out general matrix computations.

B. SYSTEM INPUT DATA

System Input Data is given definition most clearly within the context of a general card deck setup. Beginning with the first card and proceeding in the required order, the System Input Data is described using a modified list format.

<u>$FORMAT Card</u>	-	required, format type I
Function	-	indicate beginning of a FORMAT case, select machine configuration
Option	-	STANDARD - use set machine configuration
	-	UPDATE - alter set machine configuration
	-	CHANGE - supply new machine configuration
Default Option	-	STANDARD

The first line of the foregoing description of the FORMAT card indicates that provision of this card is mandatory and that the card format is "type I". The "type I" card format is defined in Table I. A total of four types of card formats are employed for the following cards; namely, types I, II, III and IV. All types are defined in Table I.

The remaining lines of the FORMAT card description do not require clarification in the context of the MAGIC System. The reader is referred to Reference 3 for in-depth discussion.

Beginning at this point with the second card in the System Input Data deck, description of the individual cards is continued.

<u>$RUN Card</u> - required, format type I

Function - control execution of problem

Options - GO - full execution of problem

- NOGO - execution terminated after preprocessor

- LOGIC - listing of preprocessor logic and allocation

- NO LOGIC - no listing of preprocessor logic and allocation

Default Option - GO, NO LOGIC

<u>ANALYSIS Card</u> - Optional, format type II

Function - Supply page header label for FORMAT System output

Text - any alphameric information

Omission Option - header label blank

<u>PROBLEM Card</u> - optional, format type II

Function - supply page header label for matrix print instruction

Text - any alphameric information

Omission Option - header label blank

TABLE I

DEFINITION OF POSSIBLE FORMAT TYPES

FORMAT TYPE I

CARD COLUMN

1	16 72
$ FORMAT	STANDARD
$ RUN	GØ, LØGIC
$ INSTRUCTION	SOURCE
$ MATRIX	LIST, PRINT
$ SPECIAL	LIST
$ END	any Text

FORMAT TYPE II

CARD COLUMN

1 . . . . 7 72

ANALYSIS (any text enclosed in parantheses)

PROBLEM (any text enclosed in parantheses)

TABLE I

CONCLUDED

FORMAT TYPE III

CARD COLUMN

1 . . . . 7 72

INPUT TAPE (name, modifier)

OUTPUT TAPE (name, modifier)

name - 1 to 6 alphameric characters, first of which is alphabetic

modifier - integer number

FORMAT TYPE IV

CARD COLUMN

1 . . . . 7 72

PAGE SIZE (14 * 11)
or
(11 * 8)

<u>INPUT TAPE Card</u>	-	optional, format type III
Function	-	supply name and modifier of master input tape to FORMAT System
Omission	-	FORMAT System assumes there is no master input tape
<u>OUTPUT TAPE Card</u>	-	optional, format type III
Function	-	supply name and modifier of master output tape to FORMAT System
Omission	-	FORMAT System assumes no master output tape will be needed
<u>PAGE SIZE Card</u>	-	optional, format type IV
Function	-	select limits of printing output
Options	-	(14 * 11)
	-	(11 * 8)
	-	(8 * 11)
Default Option	-	(14 * 11)
<u>$INSTRUCTION Card</u>	-	required, format type I
Function	-	indicate beginning of abstraction instructions
	-	indicate location of abstraction instructions
Option	-	SOURCE - abstraction instructions are in card data deck (only option available at this time)

The abstraction instructions specify the built-in operations, matrix and non-matrix, to be executed. Basic preset abstraction instruction sequences are associated with the MAGIC System. Other abstraction sequences can be defined by the User to carry out various computations. A general description of these instructions is given in Reference 3.

$MATRIX Card	-	optional, format type I
Function	-	indicate beginning of card input matrices
Option	-	(LIST - card images of matrix data are printed)
	-	NOLIST - card images of matrix data are not printed
	-	PRINT - matrices are printed after sorting
	-	NOPRINT - matrices are not printed after sorting
Default Option	-	NOLIST, NOPRINT
Omission Option	-	FORMAT System assumes no card input matrices

System level matrices may be introduced via cards using this feature. The MATRIX card indicates the existence of such data. This option is often useful in structural analyses although matrices are conventionally generated internal to the MAGIC System.

$SPECIAL Card	-	optional, format type I
Function	-	indicate beginning of special module data (e.g. - structural system data)
Options	-	(NOLIST - card, images of special data not printed)
	-	(LIST - card images of special data are printed if NOGO specified on RUN card)

All data not expressly defined under the MATRIX option enters via the SPECIAL data feature. For example, all data provided to the Structural System Monitor is introduced under the SPECIAL data card. This data is not processed in any way within the Preprocessor Monitor. It is merely accepted and passed to the interface between the User and the Structural System Monitor.

$END Card - required, format type I

Function - indicate end of a FORMAT II case

The END card completes the presentation of the types of data which make up the System Input Data. Perspective on the System Input Data as a whole is gained by reference to an example. Table II illustrates a typical input data deck for the MAGIC System. Comments are included to make this example self explanatory.

Table III is a listing of MAGIC System abstraction instruction sequences to conclude this subsection on System Input Data. Attention is focused next on the everyday problem of specifying the Structural Input Data which is passed directly to the Structural System Monitor.

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. 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.

TABLE II

TYPICAL INPUT DATA DECK FOR MAGIC SYSTEM

INPUT CARDS	EFFECT
$ FORMAT STANDARD	Signifies beginning of data and instructs FORMAT II System to use standard machine configuration.
$ RUN GO, LOGIC	Full execution and print preprocessor logic.
ANALYSIS (PLUG 2 INSERTION)	FORMAT II System output label will be as indicated.
PROBLEM (ONE ELEMENT - PLUG 2)	Matrix print header label will be as indicated.
PAGE SIZE (14 * 11)	Print output will be arranged for 14" x 11" paper.
INPUT TAPE (LIB1, 011668)	Master input tape exists for the job with given name and modifier.
OUTPUT TAPE (LIB2, 021068)	Master output tape will be needed for the job, give it name LIB1 and modifier 021068.

TABLE II

CONTINUED

INPUT CARDS	EFFECT
$ INSTRUCTION SOURCE	Signifies beginning of abstraction instruction.
C C DISPLACEMENT AND STRESS ANALYSIS C	COMMENTS (will appear in listing, non-executable)
,MATLBB,,LOADS,TR,TA,K,F,S,SO,,=,, MATLBA,.USER04.	Enter Structural Generative System to generate: MATLBB - Revised material library LOADS - system grid point loads TR - boundary condition matrix TA - assembly matrix K - element stiffness matrices F - element generated load matrices S - element stress matrices SO - element thermal stress matrices MATLBA is input material library and will be found on master input tape LIB1

TABLE II

CONTINUED

INPUT CARDS	EFFECT
C C FORM TAR (TRANSFORMATION TO ASS. C AND REDUCE)	COMMENTS
TRT = TR .TRANSP. TAR = TA .TMULT. TRT	Perform $[TAR] = [TA]^T [TR]^T$
C C ASSEMBLE AND REDUCE ELEMENT C STIFFNESS MATRICES	COMMENTS
KTEMP = K .TMULT. TAR STIFF = TAR .TMULT. KTEMP PRINT (FORCE, DISP,,) STIFF	Perform $[STIFF] = [TR] [TA] [K] [TA]^T [TR]^T$ and print STIFF. Since K is symmetric TMULT is equivalent to MULT
C C ASSEMBLE AND REDUCE ELEMENT C APPLIED LOADS	COMMENTS
FTELAR = TAR .TMULT. F PRINT (REDDOF, COND,,) LOADR	Perform $\{LOADR\} = [TR] \{LOADS\}$ and print results.
C C COMBINE ELEMENT AND SYSTEM LOADS C	COMMENTS
TLOAD = FTELAR .ADD. LOADR PRINT (REDDOF, COND,,) TLOAD	Perform $\{TLOAD\} = \{FTELAR\} + \{LOADR\}$ and print results.

TABLE II

CONTINUED

INPUT CARDS	EFFECT
C C SOLVE FOR DISPLACEMENTS C	COMMENTS
DISPR = STIFF .SEQEL. TLOAD PRINT (REDDOF, COND,,) DISPR	Solve $[STIFF]\{DISPR\} = \{TLOAD\}$ for $\{DISPR\}$ and print results.
C C SOLVE FOR ELEMENT STRESSES C	COMMENTS
STREL = S .MULT. TAR STRESF = STREL .MULT. DISPR STRESS = STRESF .SUBT. SO PRINT (NRSEL, COND,,) STRESS	Remove unwanted stresses by performing $[STREL] = [S]\,[TA]^T[TR]^T$ then solve for final stresses by performing $\{STRESS\} = [STREL]\{DISPR\} - \{SO\}$ and print results.
C C SOLVE FOR ELEMENT FORCES C	COMMENTS
FORCEL = KTEMP .MULT. DISPR FORCES = FORCEL .SUBT. F PRINT (D.O.F.,COND,,) FORCES	Perform $\{FORCES\} = [K]\,[TA]^T\,[TR]^T\,\{DISPR\} - \{F\}$ and print results.
C C SOLVE FOR SYSTEM REACTIONS C	COMMENTS

TABLE II

CONCLUDED

INPUT CARDS	EFFECT
REACTN = TA .MULT. FORCES REACT = REACTN .SUBT. LOADS PRINT (D.O.F., COND,,) REACT	Perform {REACT} = [TA] {FORCES} - {LOADS} and print results.
SAVE (LIB2) MATLBB	Place revised material library, MATLBB, on master output tape LIB2
$ SPECIAL (STRUCTURAL INPUT DATA)	Indicates beginning of structural data deck
$ END	Signifies end of case

TABLE III

MAGIC ABSTRACTION INSTRUCTION LISTING

```
INSTRUCTION      SOURCE

C
C       DISPLACEMENT AND STRESS ANALYSIS INSTRUCTION SEQUENCE
C
     MATLBA,LOADS,TR,TA,KEL,FEL,SEL,SZALEL, , , , = .USER04.
C
C       PRINT OUTPUT MATRICES
C
     PRINT (D.O.F.,COND. ,E6,) LOADS
     PRINT (REDDOF,D.O.F.,E6,) TR
     PRINT (NSYS  ,NORSUM,E6,) TA
     PRINT (ROW   ,COL   ,E6,) KEL
     PRINT (ROW   ,COL   ,E6,) FEL
     PRINT (ROW   ,COL   ,E6,) SEL
     PRINT (ROW   ,COL   ,E6,) SZALEL
C
C       FORM TAR MATRIX (ASSEMBLY AND APPLICATION OF
C                        BOUNDARY COND.)
     TRT = TR .TRANSP.
     TAR = TA .TMULT. TRT
C
C       ASSEMBLE AND REDUCE ELEMENT STIFFNESS MATRICES
C
     KTEMP = KEL .TMULT. TAR
     STIFF = TAR .TMULT. KTEMP
     PRINT (FORCE ,DISP. , ,) STIFF
C
C       ASSEMBLE AND REDUCE ELEMENT APPLIED LOADS
C
     FTELAR = TAR .TMULT. FEL
     PRINT (REDDOF,COND. , , ) FTELAR
C
C       APPLY BOUNDARY CONDITIONS TO SYSTEM LOADS
C
     LOADR = TR .MULT. LOADS
     PRINT (REDDOF,COND. , ,) LOADR
C
C       COMBINE ELEMENT AND SYSTEM LOADS
C
     TLOAD = FTELAR .ADD. LOADR
     PRINT (REDDOF,COND. , ,) TLOAD
```

TABLE III

CONCLUDED

INSTRUCTION SOURCE

```
C
C       SOLVE FOR DISPLACEMENTS
C
    DISPR = STIFF .SEQEL. TLOAD
    PRINT (REDDOF,COND. , ,) DISPR
C
C       SOLVE FOR ELEMENT STRESSES
C
    STREL = SEL .MULT. TAR
    STRESF = STREL .MULT. DISPR
    STRESS = STRESF .SUBT. SZALEL
    PRINT (NRSEL ,COND. , , ) STRESS
C
C       SOLVE FOR ELEMENT FORCES
C
    FORCEL = KTEMP .MULT. DISPR
    FORCES = FORCEL .SUBT. FEL
    PRINT (D.O.F.,COND. , ,)FORCES
C
C       SOLVE FOR SYSTEM REACTIONS
C
    REACTN = TA .MULT. FORCES
    REACT = REACTN .SUBT. LOADS
    PRINT (D.O.F.,COND. , , ) REACT
```

(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.

(7) A program option is provided to conduct a read and write of input data with execution suppressed. Output from the data read and write option includes the material properties derived from the Materials Library as well as tables completed by MODAL specification of data. This option is exercised by simply placing the prelabeled input data form designated as CHECK at the end of the input data deck.

The prelabeled input data forms are separable into four main categories; namely, Material Library, Control Data, Problem Data and Data Read and Write.

The Material Library Section is a particularly useful input feature of the MAGIC System. This library is a permanent data set available for interrogation by the system. Additions and/or deletions to the Material Library are executed by the MAGIC System. The updating of the Materials Library may be conducted independently of program execution or as an integrated pre/post execution operation.

A library specification of material may include Elastic Constants, Coefficients of Thermal Expansion and Mass Density. Material anisotropy is assumed as well as temperature dependence. Provision is made for data at up to ten temperature levels. Linear interpolation is employed in interrogation of the material specification.

The number of entries in the Material Library need not be limited, though the time for interrogation is affected by the number of entries. Listings of the complete library or specified portions are conveniently available by program option.

The Control Section provides the User with controls on System parameters. A prelabeled input form is provided. Figure II-3 shows the prelabeled data form which pertains to System Control Information.

The Problem Data Section consists of the following input:

(1) Grid point coordinates

(2) Grid point pressures

(3) Grid point temperatures

(4) Rotational transformations

(5) Boundary conditions

(6) External loads

(7) Prescribed displacements

(8) Element input

The numerical input pertinent to the above problem 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 measureable 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 30 000 000.0 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.

In the Problem Data Section, extensive use can be made of the MODAL and REPEAT options. Identical elements should be grouped in order to maximize the use of REPEAT options. Grid points should be numbered in such a manner that full advantage is taken of stiffness matrix banding.

The Data Read and Write Section is provided to conduct read and write of input data with primary calculations suppressed. This is exercised via the prelabeled input data form designated as CHECK.

It is recommended that this feature be used routinely to minimize execution against incorrect problem specifications. Reduction in costs and frequently, reduction in elapsed calendar time can be expected with disciplined use of this feature.

The input data package has been designed to minimize redundant information. As a consequence, consistency checks do not verify that the same information given at different times is in fact the same. Rather, these checks insure that prespecified types and quantities of data are consistent with the data of reference. For example, the specification of a certain type of analysis implies the need for associated items of data. Messages are printed corresponding to inconsistencies identified and execution is suppressed though complete Read and Write is attempted.

The procedure used in the preparation of the prelabeled data forms will now be explained in detail. The description will proceed by data sections. 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. Title Section (Figure II-1)

A prelabeled input data form is provided for the TITLE Section and is shown in Figure II-1.

The first entry on the form is prelabeled REPORT and requires no information from the User. It is to be noted that this label card designated REPORT must be the first card for all data decks which use these prelabeled input data forms.

The second entry on the form is prelabeled TITLE and also requires no information from the User.

The third entry on the form concerns the Number of Title Cards which are to follow. This information appears in Columns 7-9 and is given in fixed point form.

Alphameric description of the problem is placed on the following cards. The total number of these cards must be equal to the number which appears in Columns 7-9 of the third entry, (Number of Title Cards).

SAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

R E P O R T (/)

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

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

7 8 9
(/) NUMBER OF TITLE CARDS

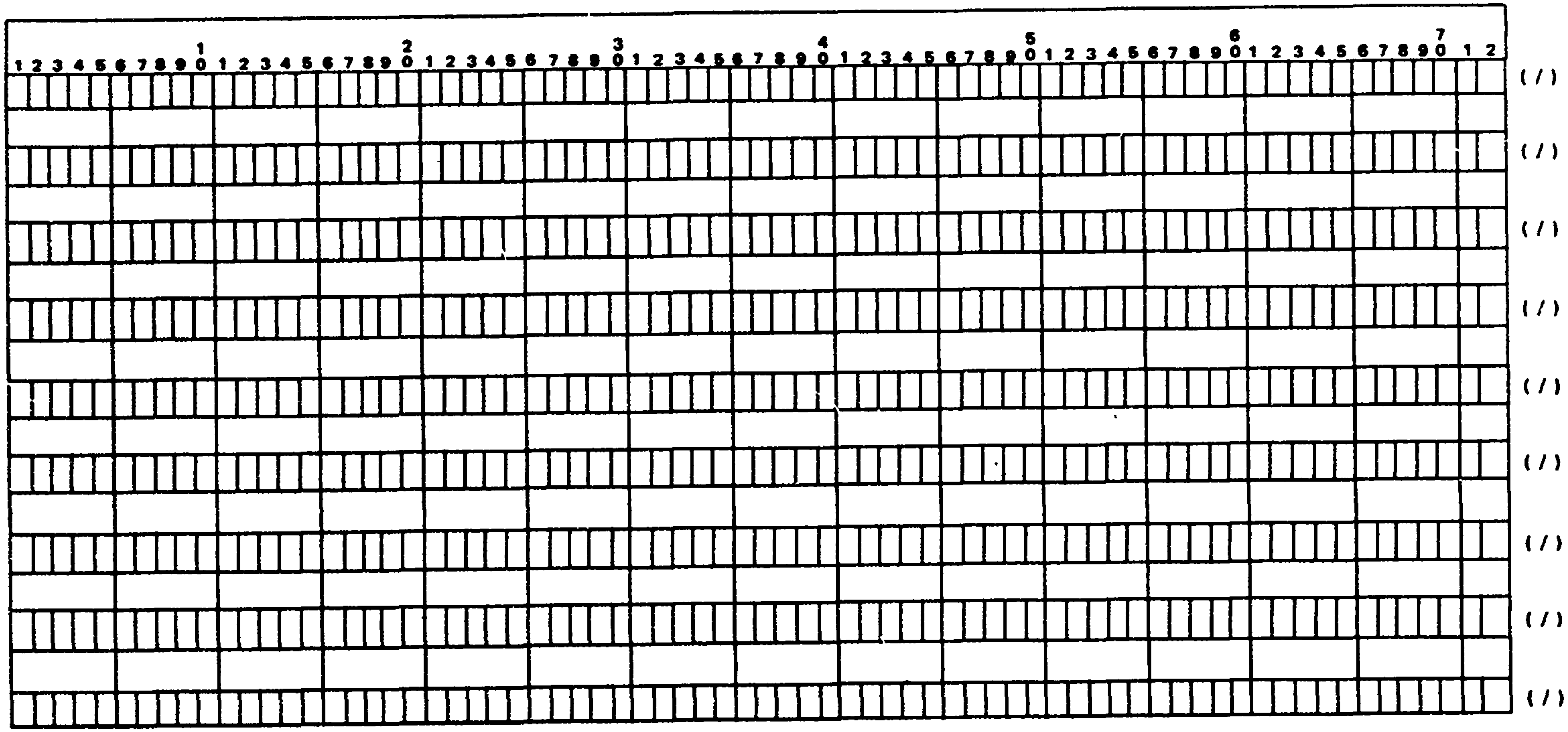


FIGURE II-1 TITLE DATA FORM

3. Material Tape Input Section (Figure II-2)

The Material Tape Input Section is used when a material is to be added, revised or deleted from the material tape. It can also be employed at the User's option to examine the contents of the tape or to obtain a summary of the materials which appear on the tape at the time the request is being made.

The labeled input data from provided for material tape entries, is shown in Figure II-2. The first entry on the form is prelabeled MATER and requires no input from the User.

The second entry on the form concerns the number of requests which are being made against the material tape. This information appears in Columns 7-9 of the second entry, and the User may make as many requests as desired against the material tape.

The third entry in the section contains the following detailed information as shown in the figure.

Request Number - (Cols. 7-9)

The total number of requests which are made against the material tape must be equal to the number of requests specified on the second entry of the form. It should be noted, however, that the first set of material data (Material Properties Table) is input before a second request is made.

Material Number -(Cols. 10-15)

The material number for a material which is to be added to the tape is chosen at the discretion of the User. If a number is chosen that corresponds to the number of a material which already appears on the tape, the new material will not be accepted unless the lock code associated with the new material is exactly the same as the lock code of the material which already appears on the tape. If this is the case the new material will be added to the tape and the material that formerly appeared there will be deleted.

Lock Code - (Cols. 16-17)

A lock code is associated with each material specification. Any User has access to the entire material library but modification of an existing material specification requires a prior knowledge of the lock code. The lock code is not disclosed by displays of the material library. As a consequence revision or deletion of any entry remains under the control of the initiator. The lock code may be any combination of alphameric characters.

Material Identification - (Cols. 18-41)

The material identification is left to the discretion of the analyst.

Material Tape Input - (Cols. 42-50)

The information which appears in those columns is self explanatory. For example, if the material is isotropic, and a print of the material tape is desired, the User simply places an 'X' in Column 42 and in Column 48.

Number of Material Points - (Cols. 51-52)

The number entered in these columns determines the number of material (temperature) points which will appear in the material properties table. At the present time, the number of allowable material points is ≤ 9.

Material Properties Table

All the data input to the Material Properties Table, appears in floating point form. If the material in question is isotropic, only the Modulus of Elasticity, E, Poisson's Ratio, ν_{ij}, and the coefficient of thermal expansion, α , are needed for each temperature point. The value of the modulus of shearing rigidity, G, is calculated by the program.

For an orthotropic material there are three cards required for each temperature point entered. For these cases, the value of, G_{ij} must be entered by the User for each of the x, y, and z directions.

IMPORTANT REMINDERS:

(1) Poisson's Ratio, ν_{ij} is defined as strain induced in the j direction by a stress in the i direction.

(2) For isotropic materials Poisson's ratio, ν_{ij}, must lie between 0.0 and 0.5 ($0.0 \leq \nu_{ij} \leq 0.5$) Violation of this rule causes the material properties matrix [E] to become non-positive definite.

(3) A maximum of nine (9) material (temperature) points may be input per material and a minimum of 1 must appear for a material of constant temperature.

(4) Certain limits on material properties must be observed. These limits are as follows:

(a) Young's Modulus (E) $E > 1.0$

(b) Thermal Coefficient (α) $-1.0 < \alpha < 1.0$

(c) Shear Modulus (G) $G > 1.0$

(5) If it is desired to bypass the internal check of input material properties an asterisk (*) is placed in Column 10, the first column of the material number in the third entry.

(6) The Number of Requests and/or Revisions of Material Tape must be specified on the System Control Information Data Form (Figure II-3).

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

7	8	9

No. of Requests (/)

MATERIAL TAPE INPUT

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

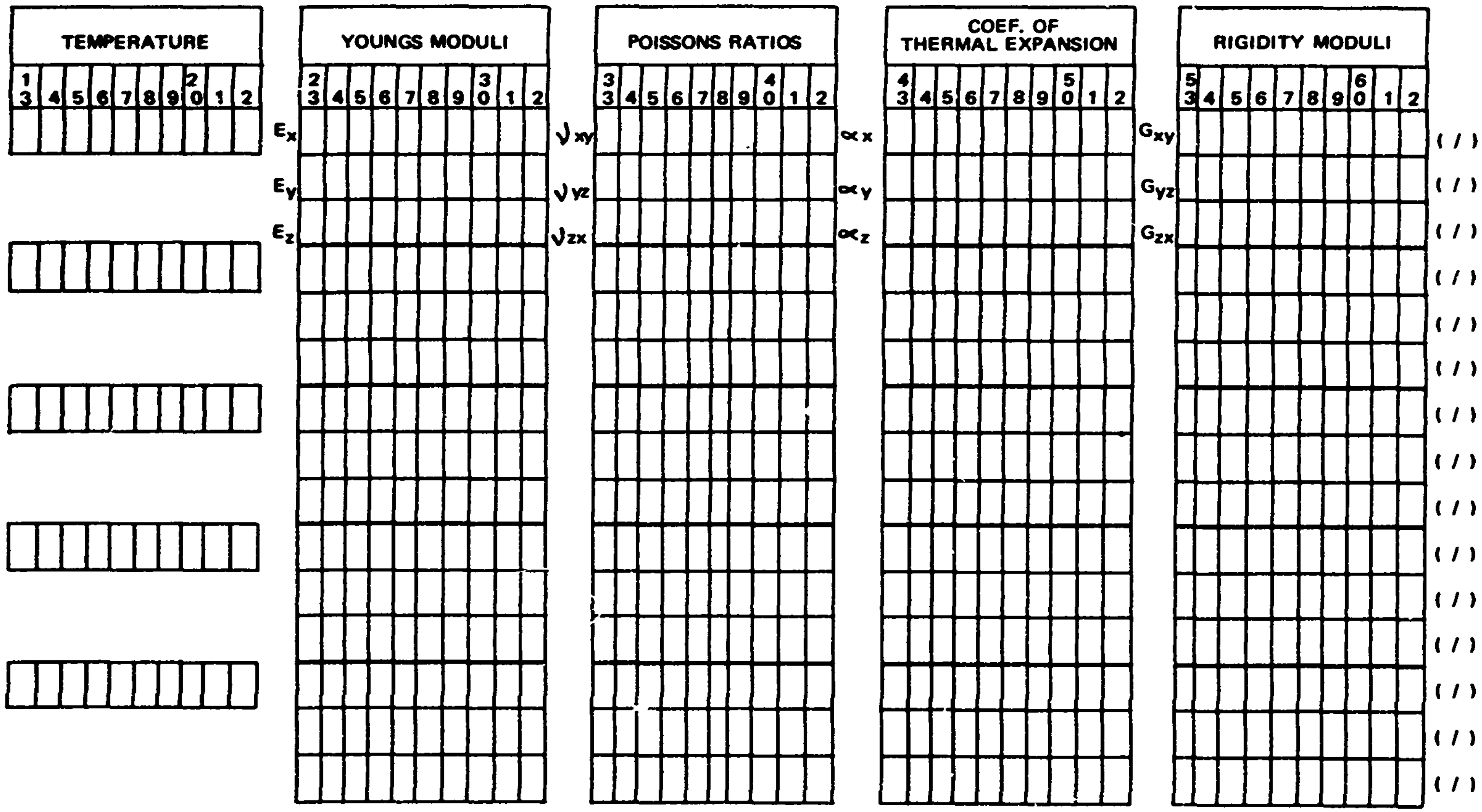
MATERIAL PROPERTIES TABLE

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

FIGURE II-2 MATERIAL TAPE INPUT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL PROPERTIES TABLE
(continued)



Page__________ of __________

FIGURE II-2 CONCLUDED

4. System Control Information Section (Figure II-3)

The prelabeled System Control Information data form is shown in Figure II-3. The first entry on the form is prelabeled SYSTEM, and requires no input from the User.

The second entry on the form contains the eleven (11) items of information defined in the list which follows. All items of information are written in fixed point notation with the exception of Item 11 which is written in floating point form.

(1) Number of System Grid Points - (Cols. 1-6)

The number of System Grid Points is equal to the largest integer number which participates in element connection (assembly). This number is best obtained from a scan of the completed Element Control Data Cards. These will be described in detail in a subsequent data section.

(2) Number of Input Grid Points - (Cols. 7-12)

The number of input grid points is equal to the integer number of grid points for which coordinates are data specified. This number is best obtained from a scan of the completed Grid Point Coordinate Input Section. The number entered is equal to the total number of grid points for which coordinates are specified. (Maximum allowable = 999).

(3) Number of Degree of Freedom/Grid Point - (Cols. 13-14)

The number of degrees of freedom per grid point is dictated by the type of finite elements which are being used for any particular analysis.

(a) Three (3) Degrees of Freedom per Grid Point

Triangular Cross-Section
Ring Element

(b) Six (6) Degrees of Freedom per Grid Point

1 - Frame Element

2 - Quadrilateral Shear Panel Element

3 - Quadrilateral Thin Shell Element

4 - Triangular Thin Shell Element

(c) Nine (9) Degrees of Freedom per Grid Point

Toroidal Thin Shell Ring Element

At the present time, only elements that are characterized by the same number of degrees of freedom per grid point can be used together in any one analysis. For example, the toroidal thin shell ring and frame elements are not compatible.

(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 loadings such as temperature and pressure.

At least one load condition is required for every analysis even if there are no external loads applied to the system. An entry must be made in the External Loads Section even for zero loads.

At the present time, the maximum number of external load conditions allowed is one hundred (100).

(5) Number of Initially Displaced Grid Points - (Cols. 17-22)

Initially displaced grid points are present only if function minimization (or other iterative technique) is employed in the analysis. In the present MAGIC System no provision is made for initially displaced grid points. Therefore, no entries should be made in this location.

(6) Number of Prescribed Displaced Grid Points - (Cols. 23-28)

Applied loading may be prescribed in terms of non-zero displacement values. A single displacement load condition can be accommodated per execution. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero. If there are no prescribed non-zero grid point displacements, this entry is ignored by the User.

(7) Number of Grid Point Axes Transformation Systems - (Cols. 29-30)

The number of grid point axes transformation systems required by the problem is entered in this location. If grid point axes are being used in an analysis, the number of systems employed is best obtained from a scan of the completed Rotational Transformation (GRAXES or TRANS) Sections which will be described in a following section. If there are no grid point axes transformations employed, this entry is ignored by the User.

(8) Number of Elements - (Cols. 31-36)

The total number of elements to be employed in the analysis is entered in this location. The allowable number of elements is governed by the order of the unreduced stiffness matrices for each individual element. The sum of the element stiffness matrix orders must be $\leq$ 2000. For example, the element stiffness matrix for the quadrilateral thin shell element is of the order 48 by 48. Therefore a maximum of 41 quadrilateral thin shell elements can be used in any one analysis because 48 x 41 = 1968 which is less than 2000.

(9) Number of Requests and/or Revisions of Material Tape - (Cols. 37-38)

The total number of requests and/or revisions being made against the material tape for any particular run are entered in this location. This number must be equal to the number which appears on the second entry under Section II, Material Tape Input Section (Figure II-2).

(10) Number of Input Boundary Condition Points (Cols. 39-44)

The Number of Input Boundary Condition Points is equal to the number of exceptions to the MODAL card associated with the Boundary Condition Section. This number is best obtained by scanning the completed Boundary Condition Section and counting the total number of grid points which are entered as Listed Input.

(11) T_o for Structure (With Decimal Point) - (Cols. 45-52)

The number entered in this location is equal to the equilibrium temperature for the structure to be analyzed. If a value is not entered in this location, an ambient temperature of zero degrees will be assumed.

If a thermal stress analysis is being run, then the ambient temperature must be entered if different than zero degrees.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

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

FIGURE II-3 SYSTEM CONTROL INFORMATION DATA FORM

5. Print Control Section (Figure II-4)

The labeled input data form provided for the Print Control Section is shown in Figure II-4.

On this form provision is made for printing the following items:

(1) Assembly - Stiffness - (Col. 1)

(2) Inverse - (Col. 2)

(3) Triangularized - Stiffness - (Col. 3)

(4) Displacements - (Col. 4)

(5) Intermediate Function Minimization (Col. 5)

This section is not applicable in the present MAGIC System. It is included because it is anticipated that these and other options will be provided in this manner in future MAGIC Systems.

It is noted, however, that output from the Structural Monitor records the input data problem description as well as optional intermediate results. These optional intermediate results can be obtained using the element matrix print options which are described in the Element Control Section. It should also be noted that System level matrix output of final results is handled by the FORMAT standard matrix print capability.

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 (/)

FIGURE II-4 PRINT CONTROL DATA FORM

6. Grid Point Coordinate Section (Figure II-5)

The labeled input data form provided for the Grid Point Coordinate Section is shown in Figure II-5. The first entry is prelabeled COORD and requires no input from the User.

The second and following entires contain information pertaining to the grid point numbers and their corresponding coordinates as follows.

Grid Point Number - (Cols. 7-12)

Grid points are entered as fixed point numbers and can be entered in any sequence desired. The maximum number of input grid points allowed is equal to 999. The total number of grid points entered in this section must be called out on the System Control Information Data Form in the entry reserved for the Number of Input Grid Points (Figure II-3).

Grid Point Coordinates - (Cols. 13-42)

Grid point coordinates are entered as floating point numbers. For each grid point number entered, a corresponding set of coordinates must also be entered. In the cartesian system these correspond to X, Y, and Z coordinates while in a cylindrical system, the corresponding coordinates are R, Θ, and Z.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

	DIRECTIONS		
Grid Point Number	X – R	Y – θ	Z – Z
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
			(/)
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			(/)
			(/)
			(/)
			(/)

If coordinate information must be continued on second sheet, user MUST delete Coord. Label Card from second sheet.

FIGURE II-5 GRID POINT COORDINATE DATA FORM

7. Grid Point Pressure Section (Figure II-6)

Pressure loading is considered as element applied loading and is transformed into consistent energy equivalent grid point loads within the MAGIC System. For convenience to the User, the pressures are input at each grid point. In order to accomplish this, a labeled input data form is provided for the Grid Point Pressure Section. This form is shown in Figure II-6.

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 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 first entry on the form is prelabeled PRESS and requires no input from the User. The second entry on the form is the MODAL entry. MODAL is prelabeled in Columns 1-5 of this entry. Columns 13-42 are reserved for input pressures. This MODAL option allows the User to input a pressure value or set of pressure values (depending on the finite element employed) which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards which follow the MODAL entry.

In the present MAGIC System, a maximum of two pressure values may be input per grid point. These pressures (entered in floating point notation) are interpreted according to the element which is being employed in the analysis.

The third and following entries in the section contain information pertaining to the Grid Point Numbers, Repeat Option and corresponding pressure values as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid points are entered as fixed point numbers.

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

(3) Along with each grid point a maximum of two pressure values can be input. The pressure entry is a function of the type of element or elements employed in the analysis (See Element Control Section).

Repeat - (Col. 12)

The repeat option allows the User to repeat re-occurring pressure from grid point to grid point. This is accomplished in the following manner. If pressures at a number of grid points are identical, the User enters the grid point number and associated pressure or pressures for the first grid point at which the pressure or pressures are acting. For the following points with identical pressures, just the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

(1) For a problem with equal pressures at all grid points, only the MODAL entry is required.

(2) The Repeat option can be used effectively for sets of grid points which have identical pressures.

(3) For a problem where pressure loading is not pertinent, the User simply ignores the Grid Point Pressure Section.

(4) Pressures associated with each finite element are completely described in the Element Control Section.

(5) Pressure loadings are element related and are not to be confused with External Loads.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

GRID POINT PRESSURES

1	2	3	4	5	6
M	O	D	A	L	

PRESSURES			
P1	P2	P3	
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	P1	P2	P3	
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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					(/)
					(/)
					(/)
					(/)

FIGURE II-6 GRID POINT PRESSURE DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES
(continued)

Grid Point Number (7 8 9 10 11)	Repeat (12)	P1 (13 4 5 6 7 8 9 20 1 2)	P2 (23 4 5 6 7 8 9 30 1 2)	P3 (33 4 5 6 7 8 9 40 1 2)	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
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					(/)
					(/)
					(/)
					(/)

FIGURE II-6 CONCLUDED

8. Grid Point Temperature Section - (Figure II-7)

Temperature loading 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, the temperature values (or temperature gradients) are input at each grid point. In order to accomplish this, a labeled input data form is provided for the Grid Point Temperature Section. In this section (as in the Grid Point Pressure 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 Grid Point Temperature Section is shown in Figure II-7. The first entry on the form is prelabeled TEMP and requires no input from the User.

The second entry on the form is the MODAL entry. MODAL is prelabeled in Columns 1-5 of this entry. Columns 13-42 are reserved for input temperatures (or temperature gradients). The MODAL option allows the User to input a temperature, or temperature gradient, (depending on the finite element employed) which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards which follow the MODAL entry.

The second and following entries in the section contain information pertaining to the Grid Point Numbers, Repeat Option, and corresponding temperature values (or gradients) as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid points are entered as fixed point numbers.

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

Repeat - (Col. 12)

The repeat option allows the User to repeat reoccurring temperatures (or gradients) from grid point to grid point. This is accomplished in the following manner. If temperatures at a number of grid points are identical, the User enters the grid point number and associated temperature data for the first grid point. For the following points having the same temperature data, just the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

From Figure II-7 it is noted that provision is made for three values of temperature (or temperature gradients) depending on what finite element is being used in the analysis. A complete description of each element along with appropriate instructions for the input of temperatures and temperature gradients will be presented in the Element Control Section.

In the present MAGIC System provision is not made for input into Cols. 33-42 which contain the quantity, T_3. These columns should therefore be ignored by the User.

REMEMBER:

(1) For a problem with equal temperatures at all grid points, only the MODAL entry is required.

(2) The Repeat option can be used effectively for sets of grid points which have the same temperatures.

(3) Remember to specify T_o on the System Control Information Data Form (Figure II-3).

(4) For a problem where temperature loading is not pertinent the User simply ignores the Grid Point Temperature Section.

(5) Temperature loadings are element related and are not to be confused with External Loads.

(6) The temperatures input in the Section must be consistent with the units of the coefficient of thermal expansion, α , which was input in the Material Tape Input Section (Figure II-2).

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES

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

1	2	3	4	5	6
M	O	D	A	L	

TEMPERATURES			
T_1	T_2	T_3	
13 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 11	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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					(/)
					(/)
					(/)
					(/)
					(/)

FIGURE II-7 GRID POINT TEMPERATURE DATA FORM

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 20 1 2	33 4 5 6 7 8 9 40 1 2	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

FIGURE II-7 CONCLUDED

9. <u>Rotational Transformations Section - Input Matrices - (Figure II-8)</u>

In general, a reference axis system is associated with each grid point. This Local System $(\bar{X}, \bar{Y}, \bar{Z})$ may be specified in two ways. Firstly, it can be specified in terms of a 3 x 3 transformation relative to Global Axes (X, Y, Z). Alternatively, axes for a grid point may be specified by a set of coordinate points. The three by three transformation relative to Global Axes is then generated internally and exhibited in the edited display of problem description data. This feature enables treatment of boundary constraints arbitrarily oriented with respect to Global Axes. It also allows displacement output to be displayed in convenient Local Systems (e.g. shell midsurface and normal directions).

This section deals with the case in which the User inputs the three by three transformation matrices relative to Global Axes.

The labeled input data form provided for this section is shown in Figure II-8. The first entry is prelabeled TRANS and requires no input from the User. The second and subsequent entries contain the following items of information.

<u>System Number - (Cols. 7-9)</u>

The System Number is entered as a fixed point number. This number can be from 1 to n where n is the number of Local Systems which are being transformed. The value of n must be called out on the System Control Information Data Form (Figure II-3).

<u>Number of Applicable Grid Points - (Cols. 10-12)</u>

The entry made in this position is equal to the number of grid points which are contained in the Local System being transformed. This number is entered as a fixed point number.

The next entries made by the User pertain to the applicable grid points themselves. The number of grid points entered must be equal to the number which was entered in the Number of Applicable Grid Points Location (Cols. 10-12).

Applicable Grid Points - (Cols. 7-51)

There is provision made for a maximum of 15 applicable grid points per system number in this location. Each grid point is contained in a three column field and is entered as a fixed point number. If more than 15 grid points are applicable to one transformation, the remaining points must be defined under additional systems.

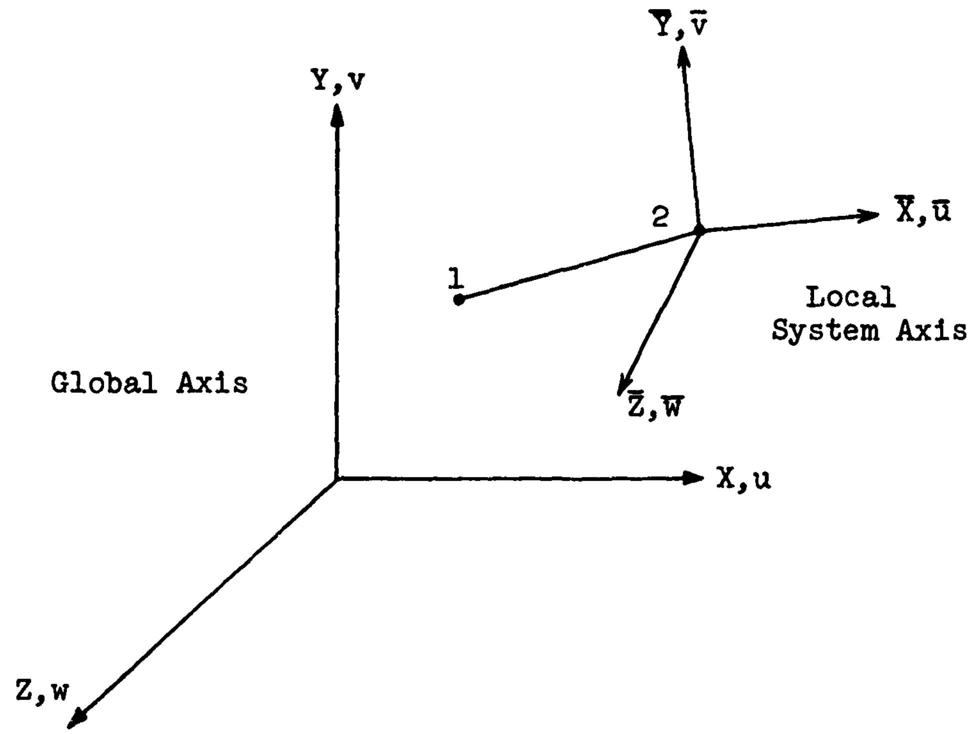
Transformation Matrix

The following entries are the elements of the three by three transformation matrix itself. The transformation matrix is of the form

$$\left\{X_G\right\} = [T] \left\{X_L\right\}$$

where the $\left\{X_G\right\}$ refers to Global (X, Y, Z) coordinate Vector and the $\left\{X_L\right\}$ refers to Local System ($\bar{X}$, $\bar{Y}$, $\bar{Z}$) coordinate Vector. The transformation matrix is of the form:

$$[T] = \begin{bmatrix} \lambda_x & u_x & v_x \\ \lambda_y & u_y & v_y \\ \lambda_z & u_z & v_z \end{bmatrix}$$

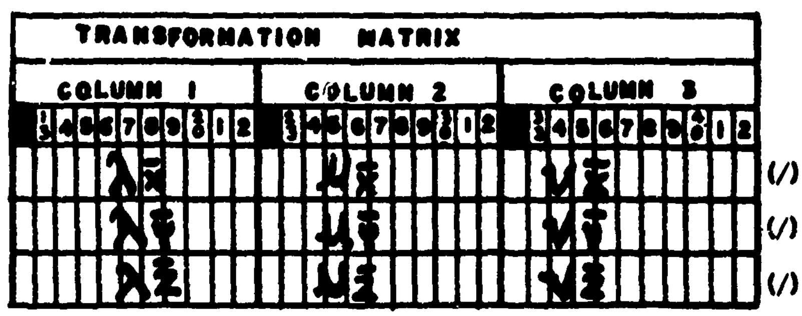


$$\lambda_{\bar{x}} = \text{Cos } \theta_{x\bar{x}} \qquad u_{\bar{x}} = \text{Cos } \theta_{y\bar{x}} \qquad v_{\bar{x}} = \text{Cos } \theta_{z\bar{x}}$$

$$\lambda_{\bar{y}} = \text{Cos } \theta_{x\bar{y}} \qquad u_{\bar{y}} = \text{Cos } \theta_{y\bar{y}} \qquad v_{\bar{y}} = \text{Cos } \theta_{z\bar{y}}$$

$$\lambda_{\bar{z}} = \text{Cos } \theta_{x\bar{z}} \qquad u_{\bar{z}} = \text{Cos } \theta_{y\bar{z}} \qquad v_{\bar{z}} = \text{Cos } \theta_{z\bar{z}}$$

and the input to the prelabeled input data form is as follows:



REMEMBER:

(1) Total number of Systems which are being transformed must be set forth on the Systems Control Information Data Form (Figure II-3).

(2) In this section the transformation matrices are input by the User. In the following section, titled GRAXES the transformation matrices are calculated internally by the MAGIC System.

T	R	A	N	S	
1	2	3	4	5	6

(/)

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
7 8 9	10 1 2	3 4 5	6 7 8	9 20 1	2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4

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
7 8 9	10 1 2	3 4 5	6 7 8	9 20 1	2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4

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
7 8 9	10 1 2	3 4 5	6 7 8	9 20 1	2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4

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
7 8 9	10 1 2	3 4 5	6 7 8	9 20 1	2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4

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
7 8 9	10 1 2	3 4 5	6 7 8	9 20 1	2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4

FIGURE II-8 ROTATIONAL TRANSFORMATION (INPUT MATRICES) DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ROTATIONAL TRANSFORMATIONS
(INPUT MATRICES)

LE GRID POINTS											
	5	6	7	8	9	10	11	12	13	14	15
												(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
			(/)
			(/)
			(/)

LE GRID POINTS											
	5	6	7	8	9	10	11	12	13	14	15
												(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
			(/)
			(/)
			(/)

LE GRID POINTS											
	5	6	7	8	9	10	11	12	13	14	15
												(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
			(/)
			(/)
			(/)

LE GRID POINTS											
	5	6	7	8	9	10	11	12	13	14	15
												(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
			(/)
			(/)
			(/)

LE GRID POINTS											
	5	6	7	8	9	10	11	12	13	14	15
												(/)

TRANSFORMATION MATRIX			
COLUMN 1	COLUMN 2	COLUMN 3	
			(/)
			(/)
			(/)

T MATRICES) DATA FORM

10. Rotational Transformations Section - General Trans. Matrices (Figure II-9)

A reference axis system is normally associated with each grid point. This Local System ($\bar{X},\bar{Y},\bar{Z}$) may be specified in two ways. Firstly, it can be specified in terms of a 3 x 3 transformation relative to Global Axes (X,Y,Z). Alternatively, axes for a grid point may be specified by a set of coordinate points. The three by three transformation relative to Global Axes is then generated internally and exhibited in the edited display of problem description data. This feature enables treatment of boundary constraints arbitrarily oriented with respect to Global Axes. It also allows displacement output to be displayed in convenient Local Systems (e.g. shell midsurface and normal directions).

This section deals with the case in which the transformation matrices are generated internally by the MAGIC System based on instructions supplied by the User.

The labeled input data form provided for this section is shown in Figure II-9. The first entry is prelabeled GRAXES and requires no information from the User. The second and subsequent entries contain the following items of information.

System Number - (Cols. 7-9)

The grid point triad System Number is an integer identification code which enables convenient and explicit reference to particular grid point axes transformations of the form

$$\{X_G\} = [T] \{X_L\}$$

$\{X_G\}$ = Global Coordinate Vector

$\{X_L\}$ = Local System Coordinate Vector

$[T]$ = Transformation Matrix

Local Axis Direction - (Cols. 10-12)

A grid point axis system is described by specifying the identification numbers of two grid points which lie along one axis together with the identification number of a gridpoint, which lies in one of the Local coordinate planes. The integer number '1' is placed in Column 10, 11, or 12, corresponding to the respective definition of the $\bar{X}$, $\bar{Y}$, or $\bar{Z}$ axis by two coordinate points.

Plane Definition Grid Point Numbers - (Cols. 13-24)

The grid point number column 1 and 2 identify the two grid points which lie along an axis of the grid point coordinat system. The positive direction is assumed from 1 toward 2. The coordinate plane (in which the coordinate point associated with the grid-point column labeled 3 resides), depends upon the axis defined by the first two points. The interpretation is as follows:

(1) If points 1 and 2 define the $\bar{X}$-axis then point 3 lies in the $(\bar{X},\bar{Y})$ plane.

(2) If points 1 and 2 define the $\bar{Y}$-axis then point 3 lies in the $(\bar{X},\bar{Y})$ plane.

(3) If points 1 and 2 define the $\bar{Z}$-axis then point 3 lies in the $(\bar{X},\bar{Z})$ plane.

Applicable Grid Point Numbers - (Cols. 25-69)

This data specifies the list of grid points associated with the grid point axis coordinate system identification number. If the list length exceeds the available space on the first line, then the remaining points must be redefined under additional Systems.

REMEMBER:

(1) Total number of Systems which are being transformed must be set forth on the Systems Control Information Data Form (Figure II-3).

(2) In this section the transformation matrices are generated internally by the System. In the preceding section entitled TRANS the transformation matrices were input by the User.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

G	R	A	X	E	S
1	2	3	4	5	6

(/)

ROTATIONAL TRANSFORMATIONS
(Generate Transformation Matrices)

SYS. NO.	Local Axis Direction			Plane Definition Grid Point Numbers			APPLICABLE GRID POINT NUMBERS															
	X	Y	Z	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10	11	12	13 4 5 6	7 8 9 20	1 2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4 5	6 7 8	9 50 1	2 3 4	5 6 7	8 9 60	1 2 3	4 5 6	7 8 9	
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FIGURE II-9 ROTATIONAL TRANSFORMATION (GENERATE TRANS. MATRICES) DATA FORM

11. <u>Boundary Condition Section (Figure II-10)</u>

The labeled input data form provided for the Boundary Condition Section is shown in Figure II-10. Three types of input codes define the types of displacement allowed:

(a) 0 = No displacement allowed,

(b) 1 = Unknown Displacement and

(c) 2 = Known (Prescribed) Displacement.

The input code designated, '2', Known Displacement, pertains to displacement loading. If displacement loading is present in an analysis, the degrees of freedom which have known values of displacement are designated with the input code '2'. A separate prelabeled input data form designated as the prescribed Displacement Section is provided so that the User may input the values of the known (prescribed) displacements associated with these degrees of freedom. This form will be described in detail in the following section.

With regard to the Boundary Condition Section, the User may employ two time saving devices.

(1) MODAL - The MODAL option automates the specification of reoccurring values within a subset of input data. This feature enables data-prescribed initialization of tables. Explicit data requirements are thereby limited to specification of <u>exceptions</u> 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 first entry on the Boundary Condition form is prelabeled BOUND and requires no input from the User. The second entry on the form is the MODAL entry. MODAL is prelabeled in columns 1-5 of this entry. Columns 13-21 are reserved for boundary conditions. The MODAL option allows the User to input a set of boundary conditions which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards (Listed Input) which follow the MODAL entry.

A total of nine degrees of freedom per point is provided for on the prelabeled input forms. Three translation degrees of freedom (u, v, w), three rotations (θ_x, θ_y, θ_z) and three generalized degrees of freedom (1, 2, 3). The total number of degree of freedom entries per point is a function of the plug type being employed in the analysis.

(1) Triangular Cross-Section Ring - Three Degree of Freedom Entries per Point: Corresponding Displacements (u, v, w).

(2) Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements - Six Degree of Freedom Entries per Point: Corresponding Displacements (u, v, w, θ_x, θ_y, θ_z).

(3) Toroidal Thin Shell Ring Element - Nine Degree of Freedom Entries per Point: Corresponding Displacements (u, o, w, o, θ_y, o, u', o, w'').

Following the MODAL entry are the entries pertaining to Listed Input. Included are Grid Point Numbers, Repeat Option and corresponding boundary conditions as follows:

<u>Grid Point Number - (Cols. 7-11)</u>

(1) Grid points are entered as fixed point numbers.

(2) Grid points can be entered in any order.

<u>Repeat - (Col. 12)</u>

The repeat option allows the User to repeat reoccurring boundary conditions, from grid point to grid point. This is accomplished in the following manner. If the boundary conditions at a number of grid points are identical, the User enters the grid point number and associated boundary conditions for the first grid point. For the following points with identical boundary conditions, just the grid point number (Cols. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

(1) The repeat option can be used effectively for sets of grid points which have identical boundary conditions.

(2) The Number of Input Boundary Condition Points must be specified on the System Control Information Data Form (Figure II-3). This value is equal to the number of exceptions to the MODAL card.

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	
															(/)
															(/)
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FIGURE II-10 BOUNDARY CONDITION DATA FORM

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	Θx	Θy	Θz	1	2	3	
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
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FIGURE II-10 CONCLUDED

12. <u>Prescribed Displacement Section (Figure II-11)</u>

Applied loading may be prescribed in terms of non-zero displacement values. A single displacement load condition can be accommodated per execution. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero.

This section is used in conjunction with the Boundary Condition Section when an input code '2' is used in that section. This code designates that the grid point degree of freedom for which '2' is entered has a prescribed displacement. In order to input the actual value for each prescribed displacement, the Prescribed Displacement Data Form is provided and is shown in Figure II-11.

A total of nine possible prescribed displacements per grid point are provided for in the section. These are as follows:

(1) three Translations (u, v, w)

(2) three Rotations (θ_x, θ_y, θ_z) and

(3) three Generalized Displacements (1, 2, 3).

The total number of degree of freedom entries per grid point is a function of the plug type being employed in the analysis.

(1) Triangular Cross-Section Ring - Three Degree of Freedom Entries per Point: Possible Displacements (u, v, w).

(2) Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements - Six Degree of Freedom Entries per Point: Possible Displacements (u, v, w, θ_x, θ_y, θ_z).

(3) Toroidal Thin Shell Ring Element - Nine Degree of Freedom Entries per Point: Possible Displacements (u, o, w, o, θ_y, o, u', o, w").

Where the (u', o, w") correspond to the last three generalized displacements (1, 2, 3) which will be completely described in the Toroidal Ring portion of the Element Control Section.

The applicable values of prescribed displacement 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 zero's. Zero's must be entered in an entry when applicable.

The first entry on the Prescribed Displacement Data Form is prelabeled PRDISP and requires no information from the User. The second entry is prelabeled PCOND in columns 1-5. Columns 7-11 are reserved for the Condition Number.

Condition Number - (Cols. 7-11)

The condition number is a fixed point number. In the present MAGIC System, only one (1) displacement load condition can be accommodated per execution. Therefore, the number '1' is entered in this location.

The next entry on the form is the MODAL entry. This entry allows the User to input a set of prescribed displacements 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 prescribed displacement values which have been discussed previously.

The third and following entries contain information pertaining to the Grid Point Numbers, Repeat Option and prescribed displacement values as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid Points are entered as fixed point numbers.

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

Repeat - (Col. 12)

The repeat option allows the User to repeat values of prescribed displacements from grid point to grid point. This is accomplished in the following manner. If the prescribed displacements at a number of grid points are identical, the User enters the grid point number and associated displacements for the first grid point. For the following points with identical displacements, only the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

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

(2) If the number of degree of freedom entries per grid point is equal to three (3), then only the translation entry (u, v, w) is applicable. The other two entries (Rotations and Generalized) are ignored by the User.

(3) If the number of degree of freedom entries per grid point is equal to six (6) then the translation and rotation entries must be considered. If for instance, at a certain grid point there are prescribed values of translations, but not rotations, zeros must be entered for the rotation values or the rotation entry will be ignored by the Keypunch Operator. This would cause premature termination of the run since six degree of freedom elements require two cards per grid point.

(4) If the number of degree of freedom entries per grid point is equal to nine (9) - (Toroidal Ring Element) then entries for translation, rotation and generalized values of displacement must be entered where applicable. 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 termination of the run.

(5) The Number of Prescribed Displaced Grid Points must be specified on the System Control Information Data Form (Figure II-3). This value is equal to the number of exceptions to the MODAL card.

SUMMARY:

For convenience the last three Reminders are briefly stated as,

(1) Three (3) Degree of Freedom Entries per Grid Point; 1 Prescribed Displacement Card Required per Grid Point.

(2) Six (6) Degree of Freedom Entries per Grid Point; 2 Prescribed Displacement Cards Required per Grid Point.

(3) Nine (9) Degree of Freedom Entries per Grid Point; 3 Prescribed Displacement Cards Required per Grid Point.

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1	2	3	4	5	6
P	R	D	I	S	P

(/)

MAGIC STRUCTURAL A
INPUT DATA

1	2	3	4	5	6	7	8	9	0	1
P	C	O	N	D						

(/)

Condition Number

PRESCRIBED

TRANSLATIONS			ROTA
U	V	W	θ_x

1	2	3	4	5	6
M	O	D	A	L	

Card columns: 13–42 (U, V, W) (/) 43–56 (θ_x …)

Grid Pt. Number | repeat

Card columns: 17–22 (Grid Pt. Number, repeat), 23–42 (U, V, W) (/), 43–56 (θ_x …)

FIGURE II-11 PRESCRIBED DISPLACEMENT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRESCRIBED DISPLACEMENTS

ROTATIONS				GENERALIZED			
θ_x	θ_y	θ_z		1	2	3	
1 … 2	3	4		1 … 2	3	4	
3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	(/)	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	(/)

1 … 2	3	4		1 … 2	3	4	
3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
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13. External Grid Point Load's Section - (Figure II-12)

Concentrated loads are specified by component against grid point number. For convenience the axes of reference may be specified optionally as Global or Local System (grid point) Axes.

The labeled input data format provided for the External Grid Point Loads Section is shown in Figure II-12. A total of nine possible external loads are provided for in this section. These are as follows:

(1) three Forces (F_x, F_y, F_z),

(2) three Moments (M_x, M_y, M_z) and

(3) three Generalized Forces (F_1, F_2, F_3).

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

(1) Triangular Cross-Section Ring - Three Degree of Freedom Entries per Point: Possible External Forces (F_x, F_y, F_z).

(2) Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements - Six Degree of Freedom Entries per Point: Possible External Forces (F_x, F_y, F_z, M_x, M_y, M_z).

(3) Toroidal Thin Shell Ring - Nine Degree of Freedom Entries per Point: Possible External Forces (F_x, 0, F_z, 0, M_y, 0, F_1, 0, F_3). The F_1, 0 and F_3 are a set of generalized forces which will be described in detail in the section dealing with the Toroidal Ring Element.

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

The first entry on the External Grid Point Loads Form is prelabeled LOADS and requires no information from the User. The second entry is prelabeled LCOND in Columns 1-5. The User supplies two items of information for this entry as follows:

Condition Number - (Cols. 7-11)

(1) Each external load condition requires a number.

(2) Each External Load Condition is entered on a Separate labeled input data form.

(3) In every analysis, the User must designate at least one (1) External Load Condition. This applies even when there are no External Loads acting on the system.

(4) The condition number is entered as a fixed point number.

Element Applied Load Scalar - (Cols. 13-22)

The Element Applied Load Scalar (EALS), entered as a floating point number, is a device which enables the User to scale the element applied load up or down by a scalar multiplier. Element applied loading is pressure or thermal loading. The EALS is utilized in the following way.

Total Load = External Grid Point Loads + (EALS) x Element Applied Loads

For multiple load conditions, the EALS is always applied to the original element applied loads. As an example, if for the first loading condition, the EALS = 0.50, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0.5) x Element Applied Loads

If for the second load condition, the EALS = 0.10, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0.1) x Original Element Applied Loads

The next entry on the form is the MODAL entry. This entry allows the User to input a set of External Loads 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 External Load Values which have been discussed previously.

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

<u>Grid Point Number - (Cols. 7-11)</u>

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

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

<u>Repeat - (Col. 12)</u>

The repeat option allows the User to repeat values of external loads from grid point to grid point. This is accomplished in the following manner. If the external loads at a number of grid points are identical, the User enters the grid point number and associated external loads for the first grid point. For the following points having identical loads, only the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

<u>REMEMBER:</u>

(1) The External Grid Point Loads Section must be utilized even if there are no external grid point loads acting on the structure. For this case, only the MODAL Card is required with zero entries in the appropriate locations.

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

(3) External Grid Point Loads are <u>not</u> element related and should not be confused with element applied loads such as pressures and thermal loading.

(4) The number of external load conditions must be specified on the System Control Information Data Form (Figure II-3).

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

(6) If the number of degree of freedom entries per grid point is equal to three (3) then only the force values (F_x, F_y, F_z) are applicable. The other two entries (Moments and Generalized Forces) are ignored by the User.

(7) If the number of degree of freedom entries per grid point is equal to six (6) then the Force and Moment Values must be considered. If for instance, at a certain grid point there are applied forces but no applied moments, zeros must be entered for the Moment 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 External Load cards per grid point.

(8) If the number of degree of freedom entries per grid point is equal to nine (9) then Forces, Moments and Generalized Forces 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.

SUMMARY:

For convenience the last three Reminders are briefly stated as,

(1) Three (3) Degree of Freedom Entries per Grid Point; 1 External Load Card Required per Grid Point.

(2) Six (6) Degree of Freedom Entries per Grid Point; 2 External Load Cards Required per Grid Point.

(3) Nine (9) Degree of Freedom Entries per Grid Point; 3 External Load Cards Required per Grid Point.

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INP

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

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
L C O N D (/)

Condition Number

Scalar

FORCE VALUES

F_x F_y F_z

M

M_x

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

Grid Pt. Number

FIGURE II-12 EXTERNAL GRID POINT LOADS DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

		MOMENT VALUES				GENERALIZED VALUES			
		M_x	M_y	M_z		1	2	3	
1 2	(/)	1 2 3 4 5 6 7 8 9 0 1 2 (13–22)	2 3 3 4 5 6 7 8 9 0 1 2 (23–32)	3 4 3 4 5 6 7 8 9 0 1 2 (33–42)	(/)	1 2 3 4 5 6 7 8 9 0 1 2 (13–22)	2 3 3 4 5 6 7 8 9 0 1 2 (23–32)	3 4 3 4 5 6 7 8 9 0 1 2 (33–42)	(/)
	(/)				(/)				(/)

		Mx	My	Mz		1	2	3	
1 2		1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2		1 2 3 4 5 6 7 8 9 0 1 2	2 3 3 4 5 6 7 8 9 0 1 2	3 4 3 4 5 6 7 8 9 0 1 2	
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14. <u>Element Control Data Section (Figure II-13)</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-13. 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 finite element in the Element Library has an identification number as follows:

(a) Number 11 - Frame Element

(b) Number 25 - Quadrilateral Shear Panel

(c) Number 40 - Triangular Cross-Section Ring

(d) Number 30 - Toroidal Ring Element

(e) Number 21 - Quadrilateral Thin Shell

(f) Number 20 - Triangular Thin Shell

(2) Identification numbers are entered as fixed point numbers.

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.

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 elements contained in the MAGIC System element library require Element Input peculiar to that element. All of the elements available in the MAGIC element library require Element Input with the exception of the Triangular Cross-Section Ring where it depends upon the type of analysis being performed. For elements which require Element Input, an 'X' is placed in Column 29.

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 node points are applicable to the elements in the MAGIC Library.

(1) Frame Element:	3 Node Points
(2) Quadrilateral Shear Panel:	4 Node Points
(3) Toroidal Ring Element:	2 Node Points
(4) Quadrilateral Thin Shell:	8 Node Points
(5) Triangular Thin Shell:	6 Node Points

Number of Assembled Nodes - (Col. 35)

This entry is not used in the present MAGIC System. Therefore, an entry should not be made in this location.

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. The last four locations (9, 10, 11, and 12) apply only to the quadrilateral and triangular thin shell elements. Their use will be fully described in the section which pertains to the quadrilateral and triangular thin shell elements.

REMEMBER:

The total Number of Elements must be called out on the System Control Information Data Form (Figure II-3).

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ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number	Plug No.	Material Number	Interpolate Option	Material Temperature	Repeat Elem. Matrices	Elem. Input	Print: Print	Print: Elem. Mat.	Print: Full	Number of Input Nodes	No. of Accom. Nodes	Node Points 1	2	3	4	5	6	7	8	9	10	11	12
7 8 9 10	1 2	3 4 5 6 7 8	19	20 1 2 3 4 5 6 7	28	29	30	31	32	33 34	35	36 7 8	9 40 1	2 3 4	5 6 7	8 9 50	1 2 3	4 5 6	7 8 9	60 1 2	3 4 5	6 7 8	9 70 1

FIGURE II-13 ELEMENT CONTROL DATA FORM

15. <u>Element Input Section - (Figure II-14)</u>

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 sections.

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

<u>Element Number - (Cols. 7-11)</u>

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

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

Repeat - (Col. 12)

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

REMEMBER:

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

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

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

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

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

1	2	3	4	5	6	A	B	C	D	E	F
M	O	D	A	L		13–22	23–32	33–42	43–52	53–62	63–72

Element Number (7 8 9 10 11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/)
								(/)
								(/)
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								(/)
								(/)
								(/)

FIGURE II-14 ELEMENT INPUT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT
(continued)

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

16. Element Input Description

a. Frame Element (Ident. No. 11)

The frame discrete element is suitable for idealization of all structures which are adequately characterized by "beam theory". The frame element representation is developed in detail in Reference 4, and is shown in Figure II-15.

Geometric specification of the straight slender prismatic frame element is given, in part, by the end point coordinates. A third coordinate point in the element X_g-Y_g positive quadrant is required to specify twist orientation.

The cross-section of the frame element is assumed doubly symmetric with respect to element geometric axes. It is characterized by moments of inertia about the three element axes together with the cross-sectional area.

A linear Hooke's Law is assumed to govern material behavior. Temperature referenced mechanical and physical material properties are selected from the material library.

The frame element representation includes membrane, torsion, and flexure actions. These contributions are uncoupled in consequence of the zero curvature and cross-section symmetry assumptions.

Deformation behavior of the basic frame element is described by the twelve displacement degrees of freedom associated with the two grid points which it connects. Description of stress behavior is accepted as the definition of the twelve forces acting at the two grid point connections.

The following element matrices are provided for the Frame Element in the MAGIC System.

Stiffness

Stress

Distributed Loading

Axial Thermal Load

Incremental Stiffness

Referring to Figure II-15, it is seen that the Frame Element is defined by three node points and that the third point determines the X_g-Y_g plane of the element. This fact is important if distributed loading is present in an analysis. The frame element is provided with a linearly varying pressure load. Provision is made for loading in both the element Y_g and Z_g directions. The Grid Point Pressure Data Form (Figure II-6) is provided for these pressure loadings if they exist. On that form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Frame Element, pressure (distributed Loading) values acting in the element Y_g direction correspond to pressures designated, P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. Pressures acting in the element Z_g direction correspond to pressure designated, P_2 on the Grid Point Pressure Data Form. These pressures are input in columns 23-32. Pressures are defined as positive if acting in the direction of positive element Y_g or Z_g directions.

An axial thermal load vector is also provided for the Frame Element. It is based on the assumption of a uniform temperature over the length of the element. The latter being the average of the two grid point temperatures. The Grid Point Temperature Data Form (Figure II-7) is provided for these temperature values if they exist. In that section provision is made for three possible input temperatures, T_1, T_2, and T_3.

For the Frame Element, the node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that form.

The Element Control Data which is required for the Frame Element is as follows. (See Figure II-13)

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

Refer to Element Control Section.

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

The Frame Element is identified as Number 11.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option-(Col. 19)

If the User exercises this option, the program will average the node point temperatures of the element, and use this temperature when establishing material properties from the material tape. The Frame Element is defined by three node points as explained previously with the third node point establishing the twist orientation of the element. Because of this only the first two node points will participate in the temperature averaging process in general. Therefore a '2' is usually entered for the Frame Element in this column when the Interpolate Option is being exercised.

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 Frame Element always requires Element Input therefore an 'X' is always placed in Column 29 when a Frame Element is being employed.

The following element input is required when using the Frame Element. (Refer to the Element Input Section and the Sample Element Input Data Form, Figure II-14). From the form, it is seen that the Element Input Locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

The Element Input for the Frame Element consists of the following information.

Location A - (Cols. 13-22)

Cross-Section Area, (A)

Location B - (Cols. 23-32)

Area Moment of Inertia, I_{zz} which is defined in the following manner: (See Figure II-15)

$$I_{zz} = \int_A Y^2 \, dA$$

Location C - (Cols. 33-42)

Area moment of inertia, I_{yy} which is defined in the following manner: (See Figure II-15)

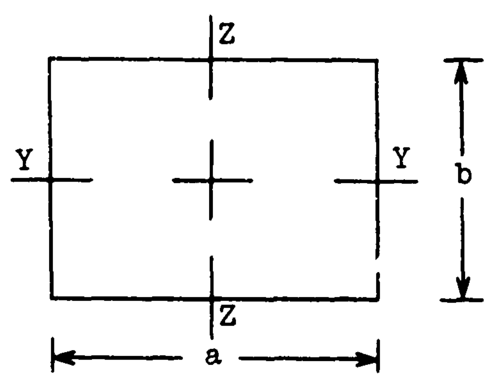
$$I_{yy} = \int_A Z^2 \, dA$$

Location D - (Cols. 43-52)

Torsional Moment of Inertia, J, which for a circular cross-section is equal to:

$$J = I_{zz} + I_{yy}$$

and for a rectangular cross-section.



For $a > b$

can be approximated by:

$$J = ab^3 \left(1/3 - 0.21 \; b/a \left[1 - (1/12)(b^4/a^4) \right] \right)$$

For $a > b$

Location E - (Cols. 53-62)

Eccentricity, ECC - An eccentric connection of a finite element to adjacent elements is effected by a special type of matrix transformation. Eccentricity of an element is specified through the element data and measured with respect to the element geometric axis.

The eccentricity is defined as the distance from the neutral axis of the eccentrically placed frame element to the connection line. The eccentricity is taken to be positive when the direction specified from the eccentric element to the connection line is in the positive local Y direction. (Figure II-15)

It should be noted by the User that if Eccentric Connections are not pertinent in an analysis then this entry is ignored by the User. It should also be noted that the Frame Element degenerates into an Axial Force Member if the only entry made in the Element Input Section is Location A. (Cross-Section Area).

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

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 Frame Element is always defined by 3 input nodes.

Number of Assembled Nodes - (Col. 35)

Not applicable.

Node Points - (Col. 36-71)

The three node points which define each Frame Element are entered in these locations.

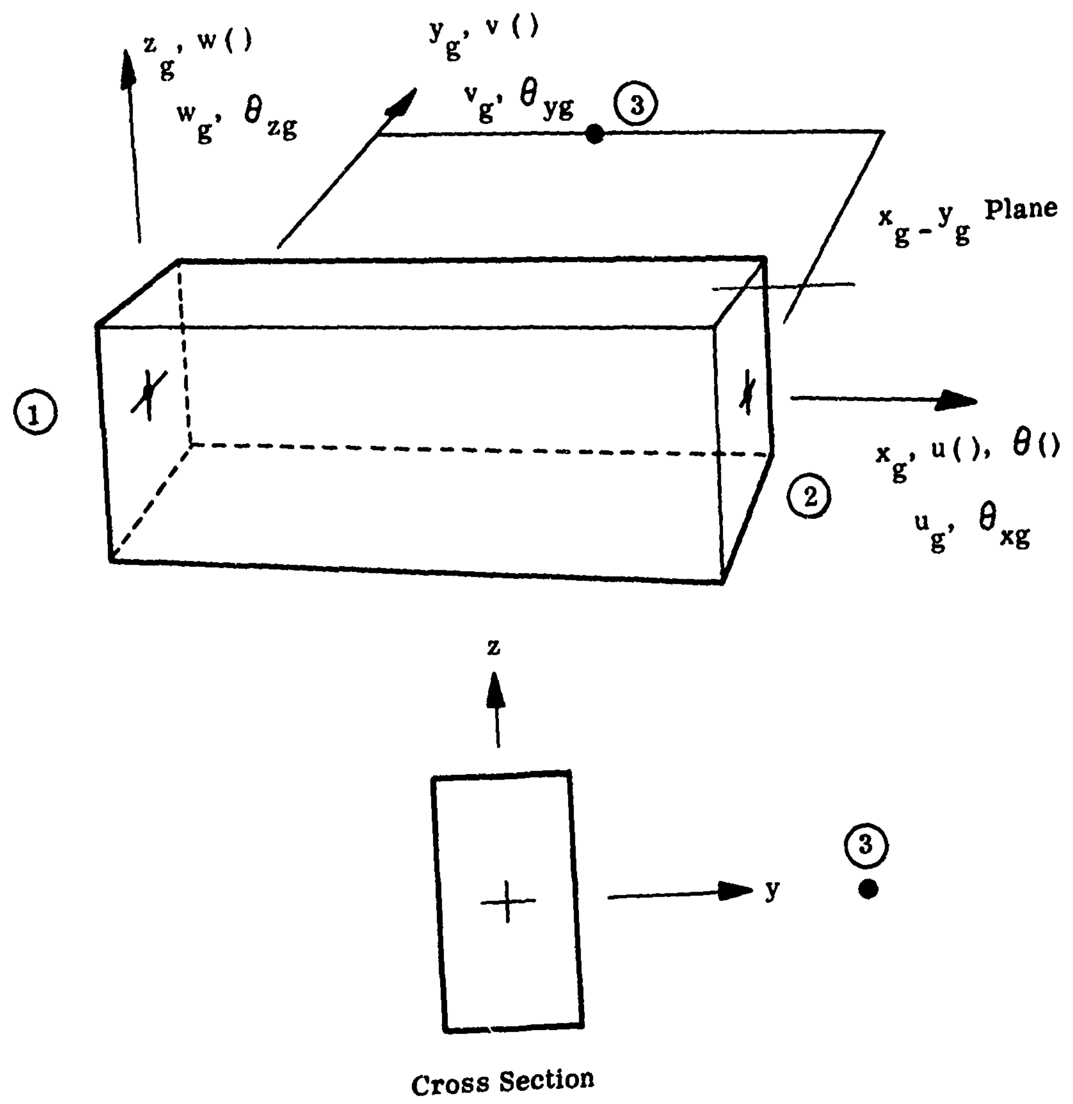


Figure II-15 **Frame Element Representation**

b. Quadrilateral Shear Panel (Ident. No. 25)

The quadrilateral shear panel is appropriate for representation of thin membranes. In order to transmit direct forces it must be used in combination with a truss specialization of the frame element. The shear panel element representation is developed in detail in Reference 5, and is shown in Figure II-16. The general quadrilateral shape of the shear panel is defined by the coordinates of the four corner points. Geometric definition is completed by specification of an effective uniform thickness.

A pure shear stress state is assumed. Stiffness coefficients are generated for corner point displacements under this pure shear assumption.

A deformation behavior of the shear panel discrete element is described by the eight corner point displacement degrees of freedom associated with the four grid points which it connects. Description of stress behavior is accepted as the constant shear stress value.

The following element matrices are provided for the quadrilateral shear panel in the MAGIC System.

Stiffness

Stress

The Element Control Data which is required for the Quadrilateral Shear Panel is as follows. (See Figure II-13)

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Quadrilateral Shear Panel is identified as Number 25.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Quadrilateral Shear Panel is designated by 4 node points. If the User desires to exercise the Temperature Interpolate Option, and average all four (4) of the node point temperatures, an entry is not made in Column 19. If the User only wants to use the first n node points in the averaging process ($n < 4$) then this number, n, is entered and the program will take the first n node points entered in Columns 36-71 and use these in the averaging process, when determining material properties. If the User desires to enter a Material Temperature in Columns 20-27 then a '1' is entered in Column 19 which tells the program to use this Material Temperature when establishing material properties from the tape.

Material Temperature - (Cols. 20-27)

Repeat Element Matrices - (Col. 28)

} Refer to Element Control Section

Element Input - (Col. 29)

The Quadrilateral Shear Panel always requires Element Input. Therefore, an 'X' is always placed in Column 29 when a Quadrilateral Shear Panel is being employed.

The Element Input (Figure II-14) required for the Quadrilateral Shear Panel 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 Panel.

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)

Full Print - (Col. 32)

} Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

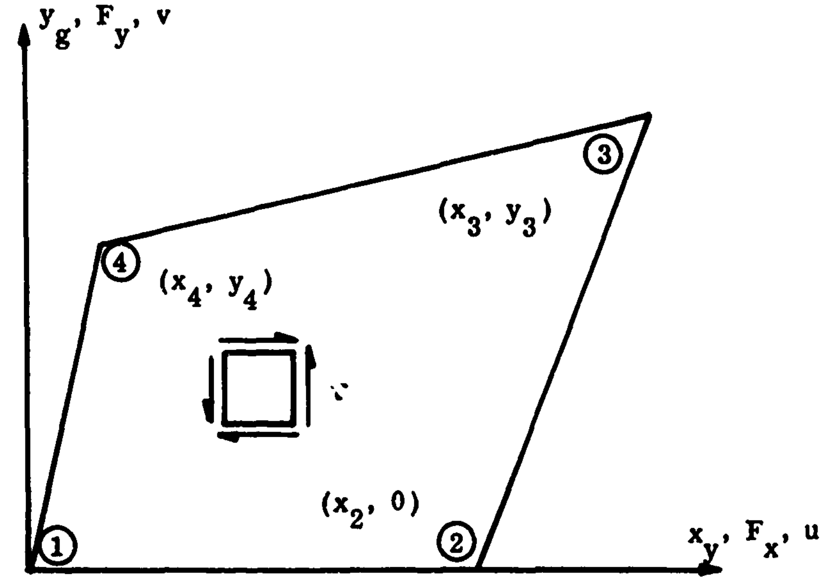
The Quadrilateral Shear Panel is always defined by 4 input nodes.

Number of Assembled Nodes - (Col. 35)

Not applicable.

Node Points - (Cols. 36-71)

The four node points which define each quadrilateral Shear Panel are entered in the first four entries provided in the Node Point Section of the Element Control Data Form.



-ure II-16 Quadrilateral Shear Panel Representation

c. <u>Triangular Cross - Section Ring</u> (Ident. No. 40)

The triangular cross-section ring discrete element, shown in Figure II-17, is suitable for idealization of axisymmetric thick walled structures of arbitrary profile. A detailed development of the element representation is presented in Reference 6.

The ring element representation is written with respect to cylindrical coordinate axes. The configuration of the element is completely defined by specifying radial and axial coordinates of the corner points.

Cylindrical anisotropy is provided for in the mechanical and physical material properties of the ring element. Orientation of orthotropic axes in the (r, z) plane is data specified.

The element designation "ring" implies an axisymmetric geometric configuration. It has been further tacitly assumed that the applied loading is axisymmetric; it follows, as a consequence, that the displacement behavior is also.

A three dimensional axisymmetric stress state is assumed. Linear Polynomial functions are employed for displacement mode shapes leading to constant element strain and stress states.

Element field loads are assumed constant over the cross-section. A linearly varying boundary pressure is included.

Deformation behavior of the ring element is described by the six displacement degrees of freedom associated with the three grid points which it connects. The predicted element stress behavior is constant over the triangular cross-section. Radial, circumferential, and axial stresses are predicted.

The Triangular Ring is numbered in the following manner. Referring to Figure II-17, the element is numbered in a counter-clockwise manner when looking in the positive element Y (θ) direction.

The Triangular Cross-Section Ring Element is provided with a linearly varying pressure load. The pressure is defined as positive when acting <u>into</u> the element (Figure II-17). Provision is made for pressure loading on only <u>one</u> side of the element. This side of the element is always defined by the first two node point numbers which are called out in the Node Point locations of the Element Input Section.

The Grid Point Pressure Data Form (Figure II-6) is provided for entering these pressure loadings if they exist. For the Triangular Ring Element, the input pressures correspond to pressures designated, P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22 of that Form.

A constant prestrain load vector is included in this element representation to accommodate thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures if thermal loading is present. For the Triangular Ring Element, the node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

The Element Control Data which is required for the Triangular Ring Element is as follows: (See Figure II-13).

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

Refer to Element Control Section

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

The Triangular Cross-Section Ring Element is identified as Number 40.

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

Refer to Element Control Section

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

The Triangular Ring Element is designated by 3 node points. If the User desires to exercise the Temperature Interpolate Option and average all three (3) of the node point temperatures, an entry is <u>not</u> made in Column 19. If the User desires to enter a material temperature in Cols. 20-27, a '1' is entered in Column 19.

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 Cross-Section Ring Element only requires Element Input under certain special conditions as follows: Referring to Figure II-17, 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-14) 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-clockwise direction (Figure II-17).

Remember

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

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

<u>Interpolated Input Print - (Col. 30)</u>

<u>Element Matrix Print - (Col. 31)</u>

<u>Full Print (Col. 32)</u>

} Refer to Element Control Section

<u>Number of Input Nodes (Cols. 33-34)</u>

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

<u>Number of Assembled Nodes - (Col. 35)</u>

Not applicable.

<u>Node Points - (Cols. 36-71)</u>

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

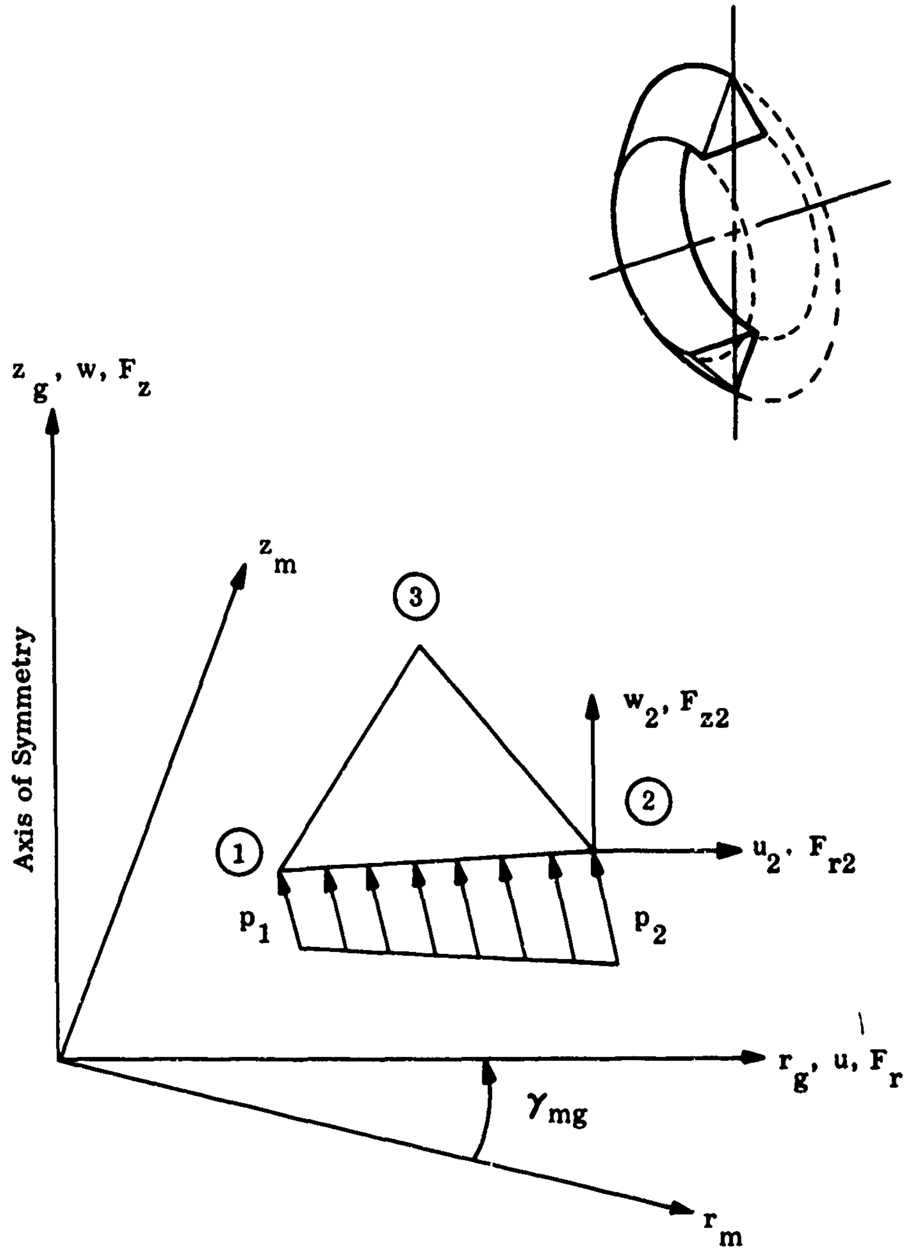


Figure II-17 Triangular Cross Section Ring Element Description

d. Toroidal Thin Shell Ring (Ident. No. 30)

The toroidal thin shell element is recommended for the idealization of axisymmetric structures of arbitrary profile. Performance of the toroidal ring element is outstanding relative to the well known conic ring. The toroidal thin shell ring element representation is developed in detail in Reference 7, and is shown in Figure II-18. The toroidal thin shell ring discrete element is written with respect to a toroidal coordinate system. In general, the cross-section of the toroidal segment is circular. Specialization to conic and cylindrical shapes is automatically accounted for in the MAGIC System. The geometric shape of the element is specified by the coordinates and surface orientation at its edge grid rings. The thickness of the element is assumed constant.

The subject element is written to accommodate orthotropic materials. Axes of orthotropy are assumed to coincide with the principal axes of the element. Material properties are taken to be constant throughout the element. The temperature of reference is the average of the data specified element node point temperatures.

The mathematical model for the toroidal ring embodies coupled representation of membrane and flexure action. A state of plane stress is assumed in formulating the continuum mechanics model. Discretization is effected by the construction of assumed modes for displacement and applied loading functions.

An osculatory axisymmetric polynomial interpolation is taken to represent membrane displacement within the element. Transverse displacement is represented by a hyperosculatory interpolation function. Applied loadings are assumed to be constant over the element.

Deformation behavior of the toroidal ring element is described by the ten displacement degrees of freedom associated with the two grid rings which it connects. These degrees of freedom provide for a relatively high order of variation within the element. In virtue of this, stress resultants are exhibited at the two boundary rings and at the midspan of the element. The toroidal axes provide the frame of reference.

The following element matrices are provided for the Toroidal Thin Shell Ring in the MAGIC System.

Stiffness

Stress

Distributed Loading (Pressure)

Thermal Loading

The Toroidal Ring Element is provided with a linearly varying pressure load.

Provision is made for pressure acting normal to the element. The Grid Point Pressure Data Form (Figure II-6) is provided to accept pressure loadings if they exist. On that Form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Toroidal Ring Element, pressure values correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. Pressures are defined as positive if acting in the positive local element Z direction (see Figure II-18).

A membrane thermal load matrix is also provided for the Toroidal Ring Element. The Grid Point Temperature Data Form (Figure II-7) is provided for the temperature values if they exist. In that section provision is made for three possible input temperatures, T_1, T_2, and T_3.

For the Toroidal Ring Element, the node point temperatures correspond to the temperatures designated T_1 and T_2 on the Grid Point Temperature Data Form. For each gridpoint, the temperature designated as T_1 corresponds to the inner temperature at node point (1) and is input in columns 13-22. The temperature designated as T_2 corresponds to the outer temperature at node point (1) and is input in columns 23-32 of the Grid Point Temperature Data Form. The program then averages the inner and outer temperatures given for each node point and uses this temperature as the representative node point temperature.

The input procedure for the Boundary Condition Section when using the Toroidal Ring merits special comment at this time. Figure II-19 shows a typical Boundary Condition Input Form. For the Toroidal Ring Element, the Boundary Condition Input requires three extra fields giving a total of nine (9). It is important to note, however, that only five (5) of these degrees of freedom exist as shown in the figure.

The first six degrees of freedom may be considered as the degrees of freedom which are considered in the normal manner. These six degrees of freedom may be based on Global coordinates or on element system coordinates. In the element system, X(ξ) is tangential and positive in the direction from element point (1) to element point (2) and Z is normal to the element, with positive Z being defined as though the Global system were rotated about the Y(Θ) axis so as to align with the element X(ξ) axis (see Figure II-18). In order to invoke the element axis option for the Toroidal Ring, a special code is employed which is described subsequently.

The remaining degrees of freedom (w' and w") are always referenced to the element system. Physically w' is difficult to define but can be thought of as the rate of change of arc length (at symmetric boundaries, w' = 0, otherwise w' = 1;) w" is the curvature defined in the element system at the point in question. Restraint (w" = 0), implies that the curvature is zero. No restraint (w" = 1) implies that the curvature is permitted to change. In general, it is recommended that w" = 1 except at symmetric or rigidly fixed boundaries where w" = 0.

The Element Control Data which is required for the Toroidal Thin Shell Ring Element is as follows (see Figure II-13).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Toroidal Ring is identified as Number 30.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Toroidal Ring is designated by 2 node points. If the User desires to exercise the Temperature Interpolate Option a '1' is entered in Column 19.

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 Toroidal Ring Element always requires Element Input, therefore an 'X' is always placed in column 29 when a Toroidal Ring Element is being employed.

The following Element Input is required when using the Toroidal Ring Element (refer to Element Input Section). From the pre-labeled input data form it is seen that the Element Input locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

The Element Input for the Toroidal Ring consists of the following information.

Location A - (Cols. 13-22)

Element Thickness (t)

Location B - (Cols. 23-32)

TCØ - This is a control input which changes the axis of reference from Global to element.

(a) Global - (TCØ = 0.0)

If the User desires to have the displacement behavior referenced to the Global system of reference, then the code 0.0 is entered in this location.

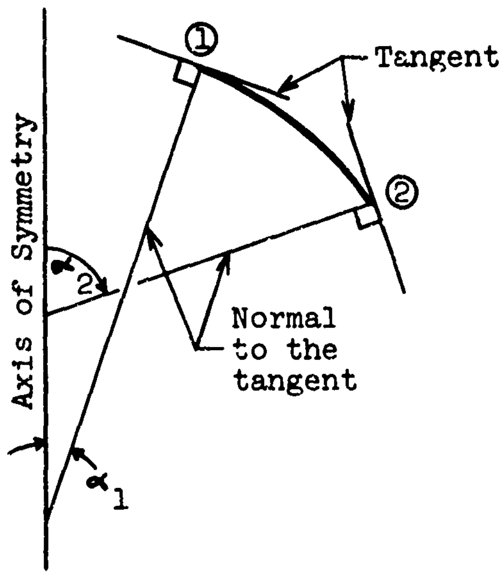
(b) Element - (TCØ = -1.0)

If the User desires to have the displacement behavior referenced to the element system (normal and tangential at point in question) then the code -1.0 is entered in this location. If the code -1.0 is used, then External Loads (if any exist) must be entered in the element system of reference. Provision is made for these External Loads on the External Grid Point Loads Data Form (Figure II-12).

It is important to note that all elements must be referenced to the same system, i.e., in any analysis which involves Toroidal Rings either the Global or element system must be used exclusively, as a frame of reference. There can be no mixing of the systems.

Location C - (Cols. 33-42)

Alpha 1 - (α_1) - Referring to the sketch, α_1 is defined as the angle measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node point ① .



Location D - (Cols. 43-52)

Alpha 2 - (α_2) - Referring to the sketch, α_2 is defined as the angle measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node point ② .

Note that for Conic Ring idealizations, $\alpha_1 \equiv \alpha_2$

The above is the required Element Input for the Toroidal Ring.

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

<u>Interpolated Input Print - (Col. 30)</u>

<u>Element Matrix Print - (Col. 31)</u>

<u>Full Print - (Col. 32)</u>

} Refer to Element Control Section

<u>Number of Input Nodes - (Cols. 33-34)</u>

The Toroidal Thin Shell Element is always defined by 2 node points.

<u>Number of Assembled Nodes - (Col. 35)</u>

Not applicable.

<u>Node Points - (Cols. 36-71)</u>

The two node points which define each Toroidal Thin Shell Ring Element are entered in these locations.

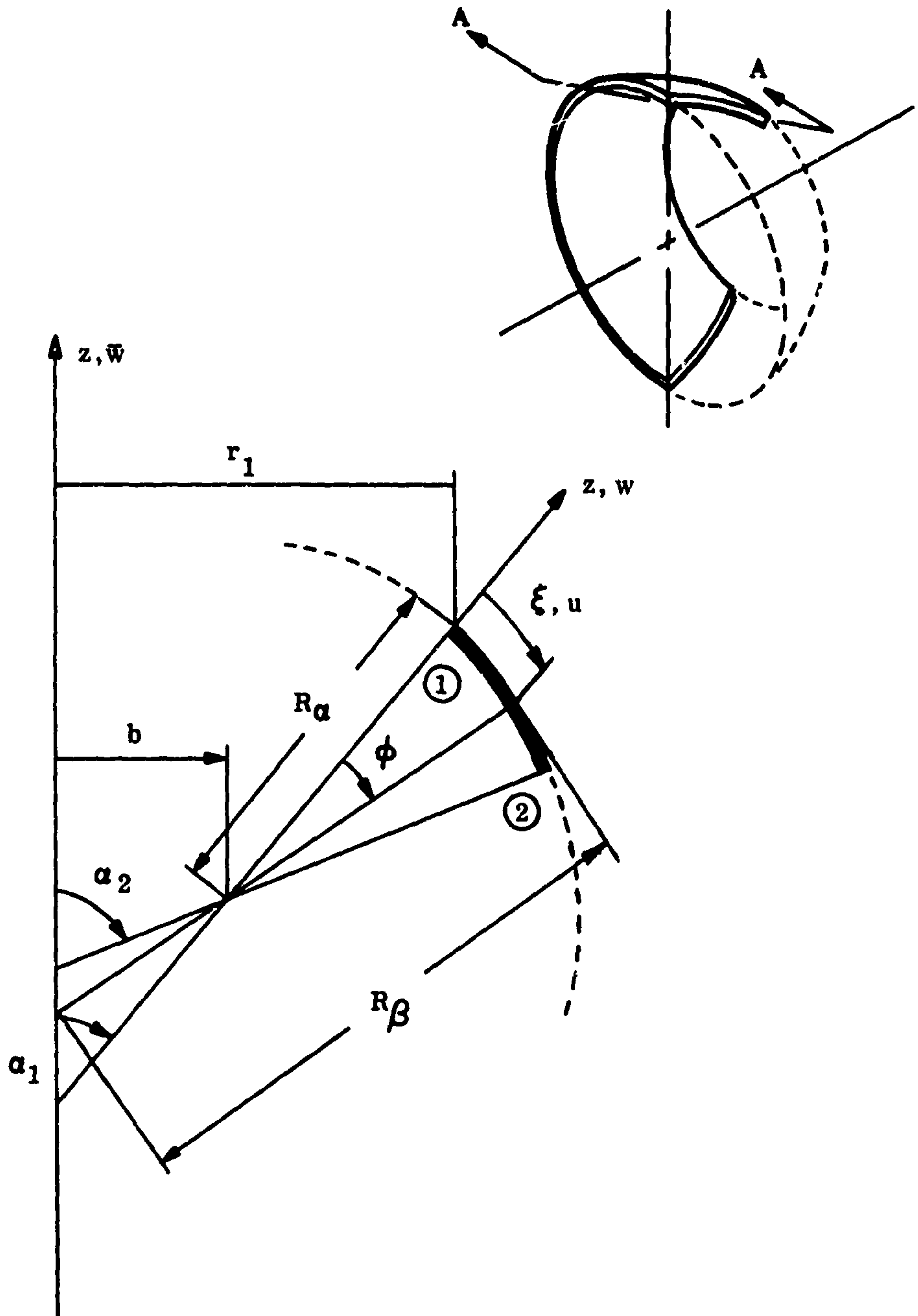


Figure II-18 Toroidal Thin Shell Ring Representation

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	
U	0	W	0	θy	0	U'	0	W''	(/)

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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Figure II-19 BOUNDARY CONDITION INPUT FOR TOROIDAL RING

e. Quadrilateral Thin Shell (Ident. No. 21)

The quadrilateral thin shell element is recommended for use as the basic building block for membranes, plates, and shells. The triangular thin shell element is a compatible companion element useful in regions of irregularity and prominent double curvature. The quadrilateral thin shell element representation is developed in detail in Reference 8, and is shown in Figure II-20.

The shape of the general quadrilateral element is defined by the coordinates of the four corner points. It is a zero curvature element. The plane of the element is determined by its first three corner point coordinates.

The subject element is a thin shell element in that both membrane and flexure action are represented. Referenced to axes in the plane of the element, the membrane and flexure representations are uncoupled. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure effective thicknesses are assumed constant over the plane of the element.

Under normal circumstances, four corner points and four midside points participate in establishing continuous connection of the quadrilateral thin shell element with adjacent elements. Used in this way input data volume is reduced and accuracy is enhanced. An option is provided to suppress the midside nodes individually if associated complexities arise in grid refinement or nonstandard connections with adjacent elements. Invoking this suppression option causes linear variation to be imposed on the specified midside variables.

The quadrilateral thin shell element, is written to accommodate anisotropy of mechanical and physical material properties. Orientation of material axes is data specified. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's law is employed for the equations of state. Three options are provided; namely, conventional plane stress, corrected plane stress, and restricted plane strain.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the subject element are approximated by quadratic polynomials. Transverse displacement is represented by cubic polynomials. A linear variation is provided for midplane and gradient variations in thermal loading. Other element loadings such as pressure are assumed constant over the element. Deformation behavior of the quadrilateral thin shell element is described by the displacement degrees of freedom associated with the gridpoints which it connects.

The variation in strain within the element which is permitted by the assumed displacement functions leads to similar stress variation. Advantage is taken of this by exhibiting predicted stress resultants at the four corners as well as at the center of the element. Inplane and normal direct, shear, and bending stress resultants are included. The display of stresses implies a set of axes of reference. These axes are data specified.

The following element matrices are provided for the Quadrilateral Thin Shell Element in the MAGIC System.

Stiffness

Stress

Thermal Load

Distributed Loading (Pressure)

Referring to Figure II-20, it is seen that in general the Quadrilateral Thin Shell Element is defined by eight node points. There is an option in the program, however, which allows the User to suppress the midside node points individually if desired.

When defining the element, the first four node points determine the corner points of the element. The midside nodes are then numbered with the first entry being that midside node which falls between the first two corner points. Referrring to the figure, the element would be numbered as follows:

1, 2, 3, 4, 5, 6, 7, 8

If it were desired to suppress mid-side node #6, the element would be numbered in the following manner (based on Figure II-20).

1, 2, 3, 4, 5, 0, 7, 8

This suppression causes linear variation to be imposed on the specified midside variables.

The element geometric axes (X_g, Y_g, Figure II-20) have their origin at the intersection of the diagonals of the quadrilateral thin shell element. The positive direction of the X_g axis of the element is defined by the line which connects the origin of the (X_g, Y_g) axis to node point ① of the element as shown in the figure. The ($X_g - Y_g$) plane of the element is determined by the first three corner point coordinates. A material axes (X_m, Y_m) is also provided for this element. The angle (γ_{mg}) between the material and element geometric axes is considered positive when measured in a counter-clockwise direction from X_m to X_g.

With respect to the element geometric axes, the corner grid points include the degrees of freedom u, v, w, θ_x and θ_y. A reduced set of degrees of freedom is associated with the midside grid points; namely, u, v and θ_n (normal slope). In general, transformation to global or grid point axes reference systems tends to fill these sets of degrees of freedom to u, v, w, θ_x, θ_y, θ_z for the corner grid points and to u, v, w, θ_n, 0, 0 (θ_n is not transformed) for the midside grid points. It is for the Analyst to decide, of course, whether or not these additional terms lead to bona-fide degrees of freedom in the assembled structure. The User should also note that on the Boundary Condition Data Form (Figure II-10). Whenever θ_n (θ_{normal}) is being considered, then the proper input code (either 0, 1, or 2) is always entered in the location which is normally reserved for the θ_x entry (Column 16).

The Grid Point Coordinate Data Form (Figure II-5) is provided for input of the coordinates which define the elements. Grid point coordinates for midside nodes are not necessary input since the program calculates these coordinates automatically.

The Quadrilateral Thin Shell Element is provided with a constant normal pressure load. The Grid Point Pressure Data Form (Figure II-6) is provided for this pressure loading if it exists. On that form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Quadrilateral Thin Shell Element the input pressures correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. The pressure is defined as positive when acting in the direction of positive element Z_g direction.

A linear variation is provided for midplane and gradient variations in thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures and/or temperature gradients. For the Quadrilateral Thin Shell Element, the midplane node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

Provision for a temperature gradient through the thickness of the Quadrilateral Thin Shell is also provided. This gradient is defined as positive when the temperature is increasing through the thickness in the positive element Z_g direction. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. The gradient is entered in the following manner.

$$T_2 = \frac{\Delta T}{t}$$

where

ΔT = Change in temperature through the thickness of the element

t = Thickness of element

Note that the sign of T_2 depends upon the direction of the gradient as pointed out above.

The Element Control Data which is required for the Quadrilateral Thin Shell Element is as follows. (See Figure II-13).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Col. 11-12)

The Quadrilateral Thin Shell Element is identified as Number 21.

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 eight node point temperatures of the element and use this average temperature when establishing material properties from the material tape. This means that temperatures for all eight node points (including the mid-side nodes) must be entered on the Grid Point Temperature Data Form (Figure II-7). If the User wishes to employ a specified number of node points, n, in the averaging process ($n < 8$) 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)

Repeat Element Matrices - (Col. 28)

Element Input - (Col. 29)

} Refer to Element Control Section

The Quadrilateral Thin Shell Element always requires Element Input therefore an 'X' is always placed in Column 29 when a Quadrilateral Thin Shell Element is being employed.

The following Element Input is required when using the Quadrilateral Thin Shell Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F, with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness (t_m) -

For the Quadrilateral Thin Shell Element, both membrane and flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thickness. If the User desires to do a membrane problem, the membrane thickness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input.

Location B - (Cols. 23-32)

Flexural Thickness - (t_f) -

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled both can be run consecutively if desired.

Location C - (Cols. 33-42)

Material Axes Angle - (Gamma) -

Since the Quadrilateral Thin Shell 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 material axis (X_m) and the element geometric axis (X_g) with this angle being measured in a counterclockwise direction from the material axis (X_m) to the element geometric axis (X_g). This angle (γ_{mg}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

(a) Corrected Plane Stress (Code 0.0) - The corrected plane stress solution is one in which the stress in the out of plane direction (σ_z) is set equal to zero but the full material properties matrix is used. That is, the effect of transverse properties on the in-plane stresses are included. Such effects are negligible for most practical materials.

(b) Restricted Plane Strain (Code 1.0) - The restricted plane strain solution is one in which the strain in the out of plane direction (ϵ_z), is set equal to zero.

(c) Conventional Plane Stress (Code 2.0) - The conventional plane stress solution is one in which the stress in the out of plane direction (σ_z), is set equal to zero and the effect of transverse properties on the in-plane stresses are not included.

Location E - (Cols. 53-62)

Eccentricity (ECC) -

The eccentricity is defined as the distance measured from the neutral axis of the eccentrically placed element to the midplane of the reference element. The sign of the eccentricity is taken to be positive when the direction specified from the eccentric element to the reference element is in the positive local element direction.

The above is the Element Input required for the Quadrilateral Thin Shell Element. Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)
Element Matrix Print - (Col. 31)
Full Print - (Col. 32)

} Refer to Element Control Section

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

The Quadrilateral Thin Shell Element is always defined by 8 input nodes.

Number of Assembled Nodes - (Col. 35)

Not applicable.

Node Points - (Cols. 36-71)

In general the Quadrilateral Thin Shell Element is defined by 8 node points. The User, however, has the option to suppress the mid-side nodes individually if desired. Referring to Figure II-13, it is seen that 12 locations are set aside for node point entries. The first 8 locations are set aside for the four corner points and four mid-side nodes respectively.

Locations 9 and 10 - (Cols. 60-65)

Most finite elements accommodate anisotropic materials. Axes of reference must be specified for material properties. This is accomplished through specification as element data, of coordinate points defining the material axes. These axes are defined by inputting the applicable set of coordinates in these locations. These coordinates define the X axis for material property definition. This device may also be used effectively to define stress output direction and the same two points used for the reference element can be used for each following element so that the output has a common reference.

Locations 11 and 12-(Cols. 66-71)

A specification of stress values implies a set of reference axes. The axes of reference, are determined with the provision of an element stress matrix. Frequently axes of reference convenient for formulation are not convenient for interpretation of stresses. The problem is resolved by data specification of stress axes. This is accomplished through specification as element data, of coordinate points which define the direction of the (X) stress axis. With this definition the stresses in the other directions retain their proper orientation with respect to this axis.

The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

REMEMBER:

(a) If all four mid-side nodes were suppressed only the first four locations would be needed. If mid-side nodes are suppressed individually then zeros are input in the location pertaining to that particular point.

(b) The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

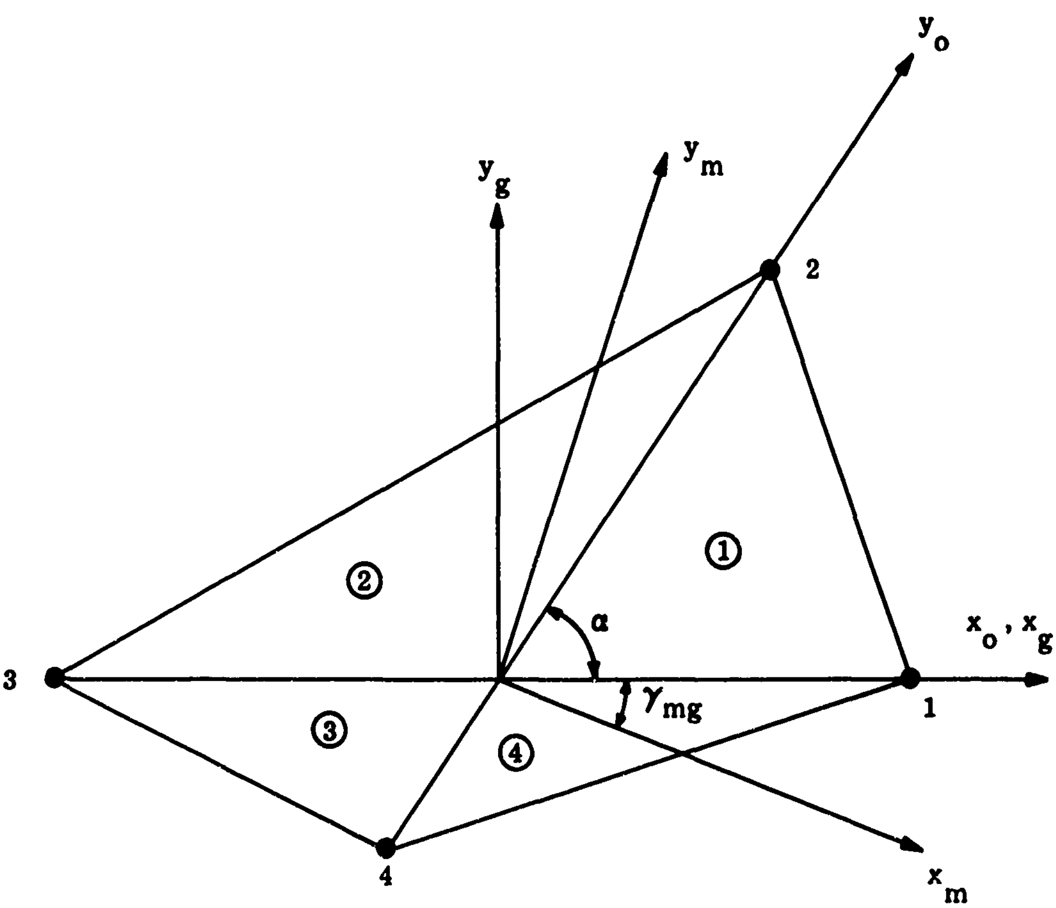

Figure II-20 Quadrilateral Thin Shell Element Representation

f. Triangular Thin Shell (Ident. No. 20)

The Triangular thin shell element is recommended for use as the basic building block for most doubly curved shells. Additionally, it is useful in combination with the quadrilateral thin shell element for dealing with irregular geometries of all membrane, plate, and shell structures. The triangular thin shell element representation is developed in detail in Reference 9, and is shown in Figure II-21.

The shape of the general triangular element is defined by the coordinates of the three corner points. It is a zero curvature element. The plane of the element is determined by the three cornerpoint coordinates.

The subject element is a thin shell element in that both membrane and flexure action are represented. Referenced to axes in the plane of the element, the membrane and flexure representations are uncoupled. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure effective thicknesses are assumed constant over the plane of the element.

Under normal circumstances, three corner points and three midside points participate in establishing continuous connection of the triangular thin shell element with adjacent elements. Used in this way input data volume is reduced and accuracy is enhanced. An option is provided to suppress the midside nodes individually if associated complexities arise in grid refinement or nonstandard connections with adjacent elements. Invoking this suppression option causes linear variation to be imposed on the specified midside variables.

The triangular thin shell element is written to accommodate anisotropy of mechanical and physical material properties. Orientation of material axes is data specified. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's Law is employed for the equations of state. Three options are provided; namely, conventional plane stress, corrected plane stress, and restricted plane strain.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the subject element are approximated by quadratic polynomials. Transverse displacement is represented by cubic polynomials. A linear variation is provided for midplane and gradient variations in thermal loading. Other element loadings such as pressure are assumed constant over the element.

Deformation behavior of the triangular thin shell element is described by the displacement degrees of freedom associated with the grid points which it connects.

The variation in strain within the element which is permitted by the assumed displacement functions leads to similar stress variation. Advantage is taken of this by exhibiting predicted stress resultants at the three corners as well as at the center of the element. Inplane and normal; direct, shear, and bending stress resultants are included. The display of stresses implies a set of axes of reference. These axes are data specified.

The following element matrices are provided for the Triangular Thin Shell Element in the MAGIC System.

Stiffness

Stress

Thermal Load

Distributed Loading (Pressure)

Referring to Figure II-21, it is seen that in general the Triangular Thin Shell Element is defined by six node points. There is an option in the program, however, which allows the User to suppress the midside node points individually if desired.

When defining the element, the first three node points determine the corner points of the element. The midside nodes are then numbered with the first entry being that midside node which falls between the first two corner points. Referring to the figure, the element would be numbered as follows

1, 2, 3, 4, 5, 6

If it were desired to suppress mid-side node #4, the element would be numbered in the following manner (based on Figure II-21)

1, 2, 3, 0, 5. 6

This suppression causes linear variation to be imposed on the specified midside variables.

The element geometric axes (X_g, Y_g, Figure II-21) have their origin at the intersection of the lines which connect the centroid to the vertices. The positive direction of the X_g axis is defined by the line which connects the origin of the (X_g, Y_g) axis to node point ① of the element as shown in the figure. The (X_g-Y_g) plane of the element is determined by the three corner point coordinates. A material axis (X_m, Y_m) is also provided for this element. The angle (γ_{mg}) between the material and element geometric axis is considered positive when measured in a counter-clockwise direction from X_m to X_g.

With respect to the element geometric axes, the corner grid points include the degrees of freedom u, v, w, θ_x and θ_y. A reduced set of degrees of freedom is associated with the midside grid points; namely, u, v and θ_n (normal slope). In general, transformation to global or grid point axes reference systems tends to fill these sets of degrees of freedom to u, v, w, θ_x, θ_y, θ_z for the corner grid points and to u, v, w, θ_n, 0, 0 (θ_n is not transformed) for the midside grid points. It is for the Analyst to decide, of course, whether or not these additional terms lead to bona-fide degrees of freedom in the assembled structure. The User should also note that on the Boundary Condition Data Form (Figure II-10). Whenever θ_n (θ_{normal}) is being considered, then the proper input code (either 0, 1, or 2) is always entered in the location which is normally reserved for the θ_x entry (Column 16).

The Grid Point Coordinate Data Form (Figure II-5) is provided for input of the coordinates which define the elements. Grid point coordinates for mid-side nodes are not necessary input since the program calculates these coordinates automatically.

The Triangular Thin Shell Element is provided with a constant normal pressure load. The Grid Point Pressure Data Form (Figure II-6) is provided for this pressure loading if it exists. On that form provision is made for three possible input pressures per grid point P_1, P_2, and P_3.

For the Trinagular Thin Shell Element the input pressures correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. The pressure is defined as positive when acting in the direction of positive element Z_g direction.

A linear variation is provided for midplane and gradient variations in thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures and/or temperature gradients. For the Triangular Thin Shell Element, the midplane node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

Provision for a temperature gradient through the thickness of the Triangular Thin Shell is also provided. This gradient is defined as positive when the temperature is increasing through the thickness in the positive element Z_g direction. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. The gradient is entered in the following manner.

$$T_2 = \frac{\Delta T}{t}$$

where

ΔT = Change in temperature through the thickness of the element

t = Thickness of element

Note that the sign of T_2 depends upon the direction of the gradient as pointed out above.

The Element Control Data which is required for the Triangular Thin Shell Element is as follows. (See Figure II-13).

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

Refer to Element Control Section

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

The Triangular Thin Shell Element is identified as Number 20.

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

Refer to Element Control Section

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

If the User exercises this option by <u>not</u> making an entry in Column 19, the program will average the <u>six</u> node point temperatures of the element and use this average temperature when establishing material properties from the material tape. This means that temperatures for all six node points (including the mid-side nodes) must be entered on the Grid Point Temperature Data Form (Figure II-7). If the User wishes to employ a specified number of node points, n, in the averaging process ($n<6$) 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.

<u>Material Temperature - (Cols. 20-27)</u>

Refer to Element Control Section

<u>Repeat Element Matrices - (Col. 28)</u>

Refer to Element Control Section

<u>Element Input - (Col. 29)</u>

The Triangular Thin Shell Element <u>always</u> requires Element Input therefore an 'X' is always placed in Column 29 when a Triangular Thin Shell Element is being employed.

The following Element Input is required when using the Triangular Thin Shell Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness (t_m) -

For the Triangular Thin Shell Element, both membrane and flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thickness. If the User desires to do a embrane problem, the membrane thickness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input.

Location B - (Cols. 23-32)

Flexural Thickness (t_f) -

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled both can be run consecutively if desired.

Location C - (Cols. 33-42)

Material Axes Angle - (Gamma) -

Since the Triangular Thin Shell 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 material axis (X_m) and the element geometric axis (X_g) with this angle being measured in a counterclockwise direction from the material axis (X_m) to the element geometric axes (X_g).

This angle (γ_{mg}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

(a) Corrected Plane Stress (Code 0.0) - The corrected plane stress solution is one in which the stress in the out of plane direction (σ_z) is set equal to zero but the full material properties matrix is used. That is, the effect of transverse properties on the in-plane stresses are included. Such effects are negligible for most practical materials.

(b) Restricted Plane Strain (Code 1.0) - The restricted plane strain solution is one in which the strain in the out of plane direction (ϵ_z) is set equal to zero.

(c) Conventional Plane Stress (Code 2.0) - The conventional plane stress solution is one in which the stress in the out of plane direction, (σ_z) is set equal to zero and the effect of transverse properties on the in-plane stresses are not included.

Location E - (Cols. 53-62)

Eccentricity (ECC) -

The eccentricity is defined as the distance measured from the neutral axis of the eccentrically place element to the midplane of the reference element. The sign of the eccentricity is taken to be positive when the direction specified from the eccentric element to the reference element in the positive local element direction.

The above is the Element Input required for the Triangular Thin Shell Element. Returning to the Element Control Data Section, the list of data items continues as follows.

Interpolated Input Print - (Col. 30)

Element Matrix Print - (Col. 31)

Full Print - (Col. 32)

(Refer to Element Control Section)

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

The Triangular Thin Shell Element is always defined by 6 Input Nodes.

Number of Assembled Nodes (Col. 35)

Not applicable.

Node Points - (Cols. 36-71)

In general the Triangular Thin Shell Element is defined by six node points. The User, however, has the option to suppress the mid-side nodes individually if desired. Referring to Figure II-13, it is seen that 12 locations are set aside for node point entries. The first 6 locations are set aside for the three corner points and three-mid-side nodes respectively.

Locations 9 and 10 - (Cols. 60-65)

Most finite elements accommodate anisotropic materials. Axes of reference must be specified for material properties. This is accomplished through specification as element data, of coordinate points defining the material axes. These axes are defined by inputting the applicable set of coordinates in these locations. These coordinates define the X axis for material property definition. This device may also be used effectively to define stress output direction and the same two points used for the reference element can be used for each following element so that the output has a common reference.

Locations 11 and 12 - (Cols. 66-71)

A specification of stress values implies a set of reference axes. The axes of reference are determined with the provision of an element stress matrix. Frequently axes of reference convenient for formulation are not convenient for interpretation of stresses. The problem is resolved by data specification of stress axes. This is accomplished through specification as element data, of coordinate points which define the stress axes. The node points entered in these locations define the direction of the (X) stress axis. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis.

REMEMBER:

(a) If all three mid-side nodes were suppressed only the first three locations would be needed. If mid-side nodes are suppressed individually then zeros are input in the location pertaining to that particular point.

(b) The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

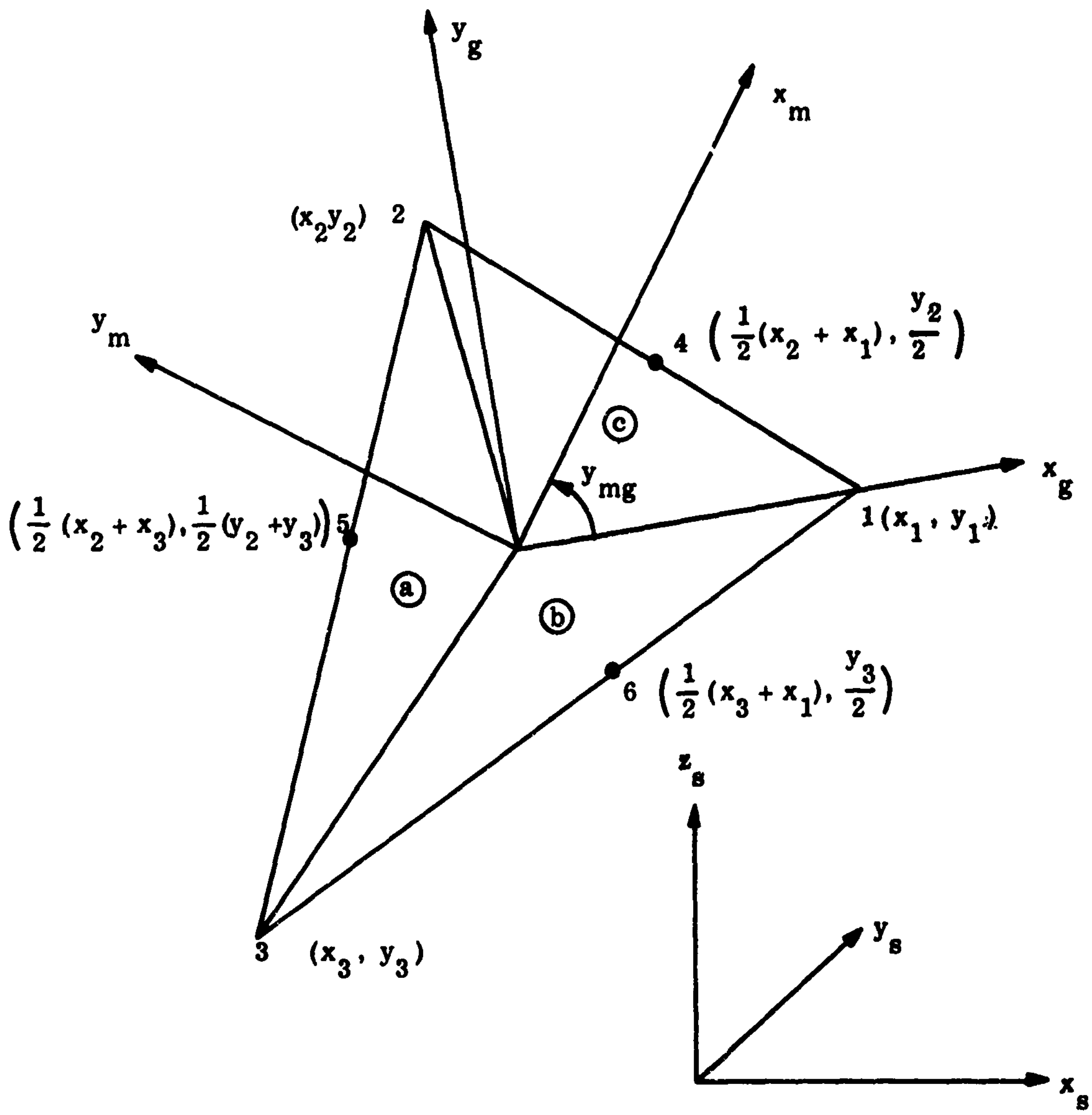

Figure II-21 Triangular Thin Shell Element Representation

17. <u>Check Or End Section (Figure II-22)</u>

The labeled input data form provided for the Check or End Section is shown in Figure II-22.

A program option is provided to conduct a read and write of input data with execution suppressed. Output from the data read and write option includes the material properties derived from the materials library as well as tables completed by MODAL specification of data. It is recommended that this feature be used routinely to minimize execution against incorrect problem specifications. If the User desires to use the CHECK option, he simply scratches out the END designation which appears on the input data form. The keypunch operator will then punch the word CHECK in columns 1-5.

If the User does not want to exercise the CHECK option but wishes to execute the problem, he simply scratches out the CHECK designation which appears on the form. The keypunch operator will then punch the word END in columns 1-3.

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 II-22 CHECK OR END DATA FORM

SECTION III

INPUT AND OUTPUT OF THE MAGIC SYSTEM

A. GENERAL DESCRIPTION

In this section, the proper interpretation of the input supplied to the MAGIC System and the output supplied by the MAGIC System will be provided by reference to specific example problems. These examples will utilize each of the finite elements which make up the library of the MAGIC System.

It is to be noted that output from the Structural Monitor records the input data problem description as well as optional intermediate results. System level matrix output of final results is handled by the FORMAT standard matrix print capability.

B. THREE ELEMENT PORTAL FRAME

A three element portal frame is shown in Figure III-B.1, along with its loading, dimensions and pertinent material properties. The preprinted input data forms associated with this frame are displayed in Figures III-B.2 thru III-B.10.

In Figure III-B.6 (Boundary Condition Section) it is instructive to note the use of the MODAL and Repeat options. There are 2 exceptions to the MODAL Card (Grid points 2 and 3). Grid point 3 has exactly the same boundary conditions as Grid point 2, therefore the Repeat Option is employed by placing an 'X' in Column [illegible] opposite the entry for Grid Point Number 3. Note that the 2 exceptions to the MODAL card are called out on the System Control Information Data Form (Figure III-B.4).

In Figure III-B.7 (External Loads Section) the following information is evident.

(1) One load condition is input.

(2) The External Applied Load Scalar equals 0.0.

(3) Grid point number 2 is loaded with a load in the X direction equal to 550.0. It should be noted that the entry corresponding to External Moments is also filled in even though there are no external moments applied to the system. This is done because the Frame Element requires two external load cards per grid point.

In Figure III-B.9 (Element Input) it is noted that only the MODAL entry is used. This means that all of the Frame Elements used in this analysis have identical Element Input as follows:

Location A - Cross Sectional Area (A) = 18.0 in^2

Location B - Area Moment of Inertia (I_{zz}) = 13.5 in^4

Location C - Area Moment of Inertia (I_{yy}) = 13.5 in^4

Location D - Torsional Moment of Inertia (J) = 27.0 in^4

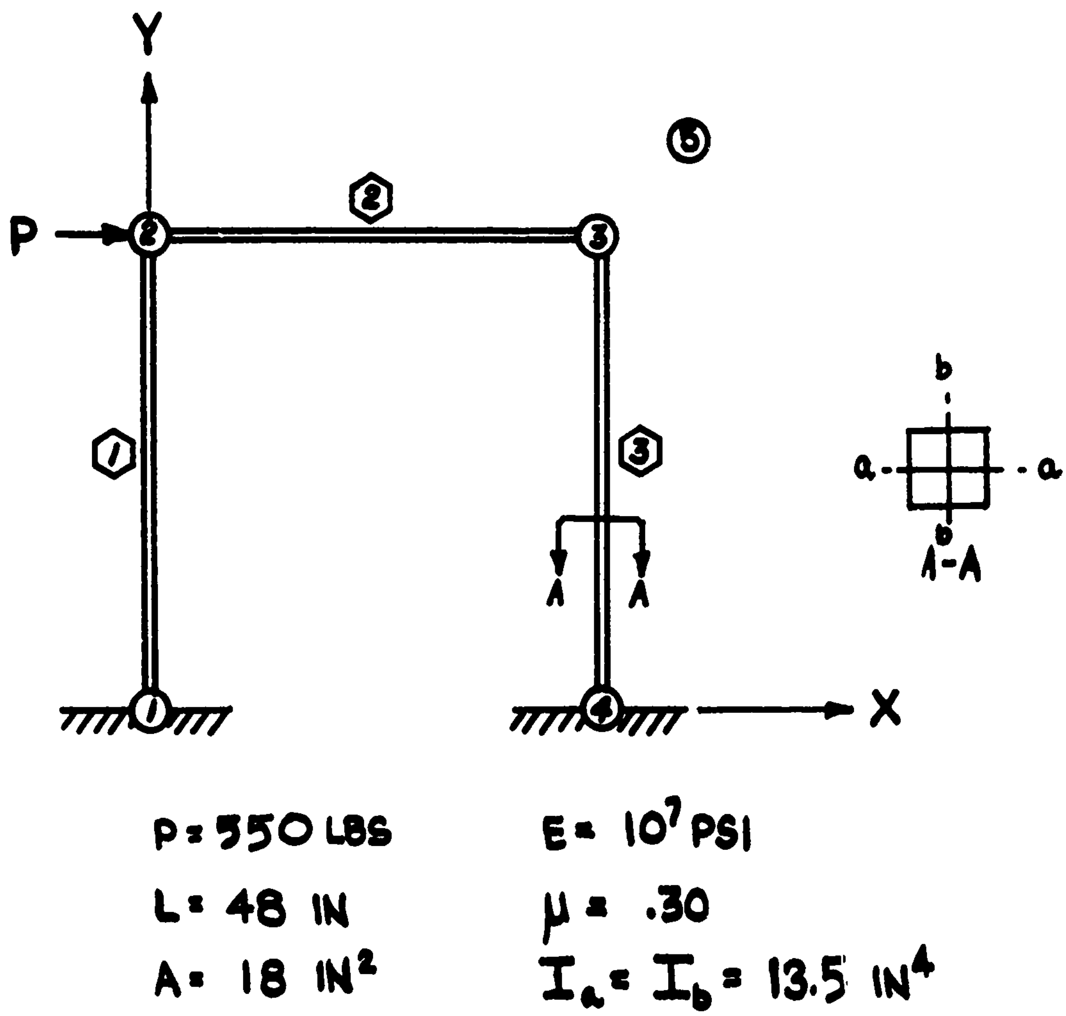

FIGURE III-B.1 - Idealized Three Element Portal Frame

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 PORTAL FRAME SUBJECTED TO A HORIZONTAL LOAD	(/)
THREE FRAME ELEMENTS USED IN THE IDEALIZATION	(/)
REFERENCE- H.C. MARTIN MATRIX METHODS OF STRUCTURAL ANALYSIS, PAGE 209	(/)
	(/)
	(/)
	(/)
	(/)
	(/)
	(/)

FIGURE III-B.2 TITLE INFORMATION, THREE ELEMENT PORTAL FRAME

JAC 1616-1

MATER (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64
1	12	TU	ALUMINUM - E=10E6, MU=0.3	X							X		1	0	0.00026

(/)

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	10.0E06	ν_{xy}	0.3	α_x	12.5E-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, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, R[illegible]GHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Item	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	6	13–14
4.	Number of Load Conditions	1	15–16
5.	Number of Initially Displaced Grid Points		17–22
6.	Number of Prescribed Displaced Grid Points		23–28
7.	Number of Grid Point Axes Transformation Systems		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	2	39–44
11.	T_o For Structure (With Decimal Point)	0.0 (/)	45–52

FIGURE III-B.4 SYSTEM CONTROL INFORMATION, THREE ELEMENT PORTAL FRAME

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	0.0	0.0	0.0	(/)
2	0.0	48.0	0.0	(/)
3	48.0	48.0	0.0	(/)
4	48.0	0.0	0.0	(/)
5	60.0	60.0	0.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
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				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-B.5 GRIDPOINT COORDINATES, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

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

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

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	0	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				2		1	1	0	0	0	1				(/)
				3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-B.6 BOUNDARY CONDITIONS, THREE ELEMENT PORTAL FRAME

BAC 1627

MAGIC STRU
INP

LOADS (/)

LCOND — Condition Number: 1 — Scaler: 0.0 (/)

MODAL

Grid Pt. Number	FORCE VALUES Fx	FORCE VALUES Fy	FORCE VALUES Fz		MO... Mx
2	550.0	0.0	0.0	(/)	

FIGURE III-B.7 EXTERNAL LOADS, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

Z	MOMENT VALUES: Mx	MOMENT VALUES: My	MOMENT VALUES: Mz	GENERALIZED VALUES: 1	GENERALIZED VALUES: 2	GENERALIZED VALUES: 3
0.0	0.0	0.0	0.0			

AME

BAC 1020

E	L	E	M	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 Assem. 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	11					X			X	3		1	2	5										(/)
2	11					X				3		2	3	5										(/)
3	11					X				3		3	4	5										(/)

FIGURE III-B.8 ELEMENT CONTROL DATA, THREE ELEMENT PORTAL FRAME

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Missing Page/s That Are
Unavailable In The
Original Document

OR are
Blank pgs
that have
Been Removed

BEST
AVAILABLE COPY

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

ELEMENT INPUT

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	18.0	13.5	13.5	27.0		

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-B.9 ELEMENT INPUT, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

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

E	N	D	(/)
1	2	3	

Figure III-B.10 End Card, Three Element Portal Frame

The output supplied by the MAGIC System for the three element portal frame is as follows.

Figure III-B.11 shows the matrix abstraction instructions associated with this particular problem. A complete discussion of these abstraction instructions is provided in Section II of this report. Figures III-B.12 thru III-B.14 display the output from the Structural System Monitor. These figures record the input data pertinent to the problem being solved.

Figure III-B.13 displays the coordinate and boundary condition information for this problem. In the Boundary Condition Information Section of the figure, zeros ('0') represent degrees of freedom that are fixed and ones ('1') represent degrees of freedom that have unknown values of displacement. The last column in the section represents the cumulative degree of freedom total.

The finite element information is also shown in Figure III-B. 13. Under the section titled External Input, the first entry printed is the cross-sectional area of Element Number 1 which is equal to 18.0. The second and third entries printed are equal to the moments of inertia Izz and Iyy respectively with numerical values equalling 13.50. The fourth value printed is the Torsional Moment of Inertia, J, which in this case equals 27.00.

Figure III-B.14 displays the External Load Column for this problem. The 30 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-B.13. Note that the external load of 550.0 is applied at node point Number 2 in the positive Global X direction.

System level matrix output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figures III-B.15 thru III-B.17. Figure III-B.15 shows the reduced stiffness matrix for this problem. It is to be noted that only non-zero terms of the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-B. 13. For this case, the ordering of the displacement vector is as follows:

$$\{ q \}^T = \lfloor u_2, v_2, \theta_{z2}, u_3, v_3, \theta_{z3} \rfloor$$

The Reduced Externally Applied Load Vector (LOADR) is presented in Figure III-B.16. The size of this vector is 6 x 1. This is true because there are 6 degrees of freedom in the reduced stiffness matrix. There is one non-zero value shown in this vector. The other eight values of force which make up the vector are equal to zero. From the figure is is seen that the force value presented corresponds to reduced degree of freedom (REDDOF) 1. From the Boundary Condition Information (Figure III-B.13) it is seen that this corresponds to a force in the Global X direction at node point 2 numerically equal to 550.0.

The vector of displacements (DISPR) is again of the order 6 x 1, since there are 6 degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-B.13. The ordering of the displacement vector is as follows:

$$\{ q \}^T = \lfloor u_2, v_2, \theta_{z2}, u_3, v_3, \theta_{z3} \rfloor$$

It is to be noted that the displacements are referenced to the global axis of reference unless otherwise indicated. MATRIX DISPR is interpreted as follows.

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP VALUE
1	2	u	0.0269096
2	2	v	0.0000627872
3	2	θ_z	-0.000338244
4	3	u	0.0268363
5	3	v	-0.0000627872
6	3	θ_z	-0.000336718

The stress matrix is also shown in Figure III-B.16 and is of the order 36 x 1. This is true because each frame element is defined by six forces at each end of the element, giving a total of 12 forces per element. Since 3 frame elements were used in this analysis, the size of the stress vector is 36 x 1. The stress vector is related to element coordinates and for the frame element, description of stress behavior is accepted as the definition of the twelve forces acting at the two grid point connections. The ordering for the stress matrix is as follows: (See Figure III-B.1 for Element Numbering).

MATRIX STRESS

NRSEL	ELEMENT	STRESS(FORCE)	NODE POINT
1	1	Fx = -235.452	1
2	1	Fy = -275.269	1
3	1	Fz = 0.0	1
4	1	Mx = 0.0	1
5	1	My = 0.0	1
6	1	Mz = -7557.77	1
7	1	Fx = 235.452	2
8	1	Fy = 275.269	2
9	1	Fz = 0.0	2
10	1	Mx = 0.0	2
11	1	My = 0.0	2
12	1	Mz = -5655.14	2
13	2	Fx = 274.729	2
14	2	Fy = -235.452	2
15	2	Fz = 0.0	2
16	2	Mx = 0.0	2
17	2	My = 0.0	2
18	2	Mz = -5655.14	2
19	2	Fx = -274.729	3
20	2	Fy = 235.452	3
21	2	Fz = 0.0	3
22	2	Mx = 0.0	3
23	2	My = 0.0	3
24	2	Mz = -5646.56	3
25 (etc.)	3 (etc.)	Fx = 235.452 (etc.)	3 (etc.)

. The vector is read row-wise and note that only non-zero values are printed.

The MATRIX FORCES are presented in Figure III-B.17. These forces are defined with respect to the Global Coordinate System. The Matrix Force vector is a 54 x 1 vector for the following reason. Each frame element is defined by three node points with the third point defining the element Xg-Yg plane. Since there are six forces per point, each element is defined by 18 forces with the last six related to the third node point always being equal to zero. The ordering of the Matrix Forces is as follows:

(See Figure III-B.1 for Element Numbering.)

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	Fx = -275.269	1
2	1	Fy = -235.452	1
3	1	Fz = 0.0	1
4	1	Mx = 0.0	1
5	1	My = 0.0	1
6	1	Mz = 7557.77	1
7	1	Fx = 275.269	2
8	1	Fy = 235.452	2
9	1	Fz = 0.0	2
10	1	Mx = 0.0	2
11	1	My = 0.0	2
12	1	Mz = 5755.14	2
13	1	Fx = 0	5
14	1	Fy = 0	5
15	1	Fz = 0	5
16	1	Mx = 0	5
17	1	My = 0	5
18	1	Mz = 0	5
19	2	Fx = 274.729	2
20	2	Fy = -235.452	2
21	2	Fz = 0.0	2
22	2	Mx = 0.0	2
23	2	My = 0.0	2
24	2	Mz = -5655.14	2
25	2	Fx = -274.729	3
26	2	Fy = 235.452	3
27	2	Fz = 0.0	3
28	2	Mx = 0.0	3
29	2	My = 0.0	3
30	2	Mz = -5646.56	3
31	2	Fx = 0	5
32	2	Fy = 0	5
33	2	Fz = 0	5
34	2	Mx = 0	5
35	2	My = 0	5
36	2	Mz = 0	5
37	3	Fx = 274.732	3
38	3	Fy = -235.452	3
(etc.)	(etc.)	(etc.)	(etc.)

The matrix force vector is read row-wise and only non-zero values of force are printed. Note again that the Element Forces are referenced to the Global Axis unless otherwise indicated.

The final item of information contained in Figure III-B. 17 is the vector of reactions (MATRIX REACT). This vector is a 30 x 1 since there are five node points associated with this problem and six associated degrees of freedom per node-point. The reactions are read row-wise and are interpreted as follows.

MATRIX REACT

D.O.F.	REACTION	NODE POINT
1	P_{RX} = -275.269	1
2	P_{RY} = -235.452	1
3	P_{RZ} = 0	1
4	M_{RX} = 0	1
5	M_{RY} = 0	1
6	M_{RZ} = 7557.77	1
7	———	2
8	———	2
9	———	2
10	———	2
11	———	2
12	———	2
13	———	3
14	———	3
15	———	3
16	———	3
17	———	3
18	———	3
19	P_{RX} = -274.732	4
20	P_{RY} = 235.452	4
21	P_{RX} = 0	4
22	M_{RX} = 0	4
23	M_{RY} = 0	4
24	M_{RZ} = 7540.60	4
25	———	5
26	———	5
27	———	5
28	———	5
29	———	5
30	———	5

FORMAT ABSTRACTION INSTRUCTION LISTING PAGE 1

```
$INSTRUCTION   SOURCE                                                  BELL0000
C                                                                      BELL0010
C      DISPLACEMENT AND STRESS ANALYSIS INSTRUCTION SEQUENCE           BELL0020
C                                                                      BELL0030
 .MATLDA.,LOADS,TR,TA,KEL,FEL,SEL,SZALEL,. = ... .USER04.
C                                                                      BELL0050
C      PRINT OUTPUT MATRICES                                           BELL0060
C                                                                      BELL0070
 PRINT (D.O.F.,COND. ,E6.) LOADS                                       BELL0080
 PRINT (REDDOF,D.O.F.,E6.) TR                                          BELL0090
 PRINT (NSYS  ,NORSUM,E6.) TA                                          BELL0100
 PRINT (ROW   ,COL   ,E6.) KEL                                         BELL0110
 PRINT (ROW   ,COL   ,E6.) FEL                                         BELL0120
 PRINT (ROW   ,COL   ,E6.) SEL                                         BELL0130
 PRINT (ROW   ,COL   ,E6.) SZALEL                                      BELL0140
C                                                                      BELL0150
C      FORM TAR MATRIX (ASSEMBLY AND APPLICATION OF BOUNDARY COND.)    BELL0160
C                                                                      BELL0170
 TRT = TR .TRANSP.                                                     BELL0180
 TAR = TA .TMULT. TRT                                                  BELL0190
C                                                                      BELL0200
C      ASSEMBLE AND REDUCE ELEMENT STIFFNESS MATRICES                  BELL0210
C                                                                      BELL0220
 KTEMP = KEL .TMULT. TAR                                               BELL0230
 STIFF = TAR .TMULT. KTEMP                                             BELL0240
 PRINT (FORCE .DISP. . .) STIFF                                        BELL0250
C                                                                      BELL0260
C      ASSEMBLE AND REDUCE ELEMENT APPLIED LOADS                       BELL0270
C                                                                      BELL0280
 FTELAR = TAR .TMULT. FEL                                              BELL0290
 PRINT (REDDOF,COND. . .) FTELAR                                       BELL0300
C                                                                      BELL0310
C      APPLY BOUNDARY CONDITIONS TO SYSTEM LOADS                       BELL0320
C                                                                      BELL0330
 LOADR = TR .MULT. LOADS                                               BELL0340
 PRINT (REDDOF,COND. . .) LOADR                                        BELL0350
C                                                                      BELL0360
C      COMBINE ELEMENT AND SYSTEM LOADS                                BELL0370
C                                                                      BELL0380
 TLOAD = FTELAR .ADD. LOADR                                            BELL0390
 PRINT (REDDOF,COND. . .) TLOAD                                        BELL0400
C                                                                      BELL0410
C      SOLVE FOR DISPLACEMENTS                                         BELL0420
C                                                                      BELL0430
 DISPR = STIFF .SEQEL. TLOAD                                           BELL0440
 PRINT (REDDOF,COND. . .) DISPR                                        BELL0450
C                                                                      BELL0460
C      SOLVE FOR ELEMENT STRESSES                                      BELL0470
C                                                                      BELL0480
 STREL = SEL .MULT. TAR                                                BELL0490
 STRESF = STREL .MULT. DISPR                                           BELL0500
```

FORMAT ABSTRACTION INSTRUCTION LISTING PAGE 2

```
 STRESS = STRESF .SUBT. SZALEL                                         BELL0510
 PRINT (NRSEL ,COND. . .) STRESS                                       BELL0520
C                                                                      BELL0530
C      SOLVE FOR ELEMENT FORCES                                        BELL0540
C                                                                      BELL0550
 FORCEL = KTEMP .MULT. DISPR                                           BELL0560
 FORCES = FORCEL .SUBT. FEL                                            BELL0570
 PRINT (D.O.F.COND. . .) FORCES                                        BELL0580
C                                                                      BELL0590
C      SOLVE FOR SYSTEM REACTIONS                                      BELL0600
C                                                                      BELL0610
 REACTN = TA .MULT. FORCES                                             BELL0620
 REACT = REACTN .SUBT. LOADS                                           BELL0630
 PRINT (D.O.F.COND. . .) REACT                                         BELL0640
```

FIGURE III-B.11 FORMAT ABSTRACTION INSTRUCTION LISTING

```
THREE ELEMENT PORTAL FRAME SUBJECTED TO A HORIZONTAL LOAD

THREE FRAME ELEMENTS USED IN THE IDEALIZATION

REFERENCE- H.C.MARTIN MATRIX METHODS OF STR. ANALYSIS PAGE 209

                    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    ALUMINUM                        INPUT CODE    I
     NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
     NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
     MASS DENSITY. . . . . . . . . . . . . . .-0.

   MATERIAL PROPERTIES

                     YOUNG'S MODULI                                    POISSON'S RATIOS

                       DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                   XX             YY            ZZ              XY             YZ             ZX
      0.      0.100000E 08   0.100000E 08   0.100000E 08   0.300000E 00   0.300000E 00   0.300000E 00
                THERMAL EXPANSION COEFFICIENTS                        RIGIDITY MODULI

                       DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                   XX             YY            ZZ              XY             YZ             ZX
      0.      0.125000E-04   0.125000E-04   0.125000E-04   0.384615E 07   0.384615E 07   0.384615E 07

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

FIGURE III-B.12 TITLE AND MATERIAL DATA OUTPUT, THREE ELEMENT PORTAL FRAME

```
                                            , 5 REF. POINTS

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

                                            GRIDPOINT DATA
POINT          X                  Y                  Z              TEMPERATURES        PRESTARES
  1       0.                 0.                 0.                  0.                  0.
                                                                    0.                  0.
  2       0.                 0.40000000E 02     0.                  0.                  0.
                                                                    0.                  0.
  3       0.40000000E 02     0.40000000E 02     0.                  0.                  0.
                                                                    0.                  0.
  4       0.40000000E 02     0.                 0.                  0.                  0.
                                                                    0.                  0.
  5       0.60000000E 02     0.60000000E 02     0.                  0.                  0.
                                                                    0.                  0.

                                   BOUNDARY CONDITION INFORMATION
           NODES        DEGREES OF FREEDOM
                    u    v    w    θx   θy   θz   ←cumulative total, degrees of freedom
             1      0    0    0    0    0    0    0
             2      1    1    0    0    0    1    3
             3      1    1    0    0    0    1    6
             4      0    0    0    0    0    0    6
             5      0    0    0    0    0    0    6

                                        TOTAL NO. ELEMENTS =    3

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  11      12    0 -0.            2    3     1   2   3
MATERIAL NUMBER. . . . . . . . .  12
     MATERIAL IDENTIFICATION. . . .  ALUMINUM
     ANALYSIS CAPABILITY. . . . . .       ISOTROPIC
     INPUT PRINT CODE . . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . . -1
INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -      0.
     YOUNG'S MODULI                  0.10000000E 08     0.10000000E 08     0.10000000E 08
     POISSON'S RATIOS                0.30000000E 00     0.30000000E 00     0.30000000E 00


     THERMAL EXPANSION COEFFICIENTS  0.12900000E-04     0.12900000E-04     0.12900000E-04
     RIGIDITY MODULI                 0.38461538E 07     0.38461538E 07     0.38461538E 07
INTERPOLATED PLASTIC PROPERTIES
     NONE
PRE-STRAIN INPUT
     NONE
PRE-STRESS INPUT
     NONE
EXTERNAL INPUT   Area               Izz                 Iyy
        0.10000000E 02     0.13500000E 02     0.13500000E 02     0.27000000E 02     -0.

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  11      12    0  0.            0    3     2   3   5                                   0.1000E 02   0.1350E 02   0.1350E 02
                                                                                             0.2700E 02  -0.
  3  11      12    0  0.            0    3     3   4   5                                   0.1000E 02   0.1350E 02   0.1350E 02
                                                                                             0.2700E 02  -0.
```

FIGURE III-B.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, THREE ELEMENT PORTAL FRAME

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 1 ELEMENT LOAD SCALAR = 0.

2 0.59000E 03 0. 0. 0. 0. 0.

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

30 X 1

0.	0.	0.	0.	0.	0.
0.59000000E 03	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.

FIGURE III-B.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THREE ELEMENT PORTAL FRAME

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 6 BY 6

	FORCE Row	Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}
DISP.	1	1	0.376445E 07	3	0.351562E 06	4	-0.375000E 07				
DISP.	2	2	0.376445E 07	3	0.351562E 06	5	-0.144404E 05	6	0.351562E 06		
DISP.	3	1	0.351562E 06	2	0.351562E 06	3	0.225000E 08	5	-0.351562E 06	6	0.562500E 07
DISP.	4	1	-0.375000E 07	4	0.376445E 07	6	0.351562E 06				
DISP.	5	2	-0.144404E 05	3	-0.351562E 06	5	0.376445E 07	6	-0.351562E 06		
DISP.	6	2	0.351562E 06	3	0.562500E 07	4	0.351562E 06	5	-0.351562E 06	6	0.225000E 08

FIGURE III-B.15 REDUCED STIFFNESS MATRIX OUTPUT, THREE ELEMENT PORTAL FRAME

```
                                              MATRIX  LOADR                                          PAGE    1
                      CUTOFF =    0.                                          SIZE     6  BY      1
         REDDOF                    REDDOF                REDDOF                 REDDOF                 REDDOF
COND.      1   1   0.550000E 03


                                              MATRIX  DISPR                                          PAGE    1
                      CUTOFF =    0.                                          SIZE     6  BY      1
         REDDOF                    REDDOF                REDDOF                 REDDOF                 REDDOF
COND.      1   1   0.269096E-01    2    0.627872E-04    3   -0.338244E-03   4    0.268363E-01    5   -0.627872E-04
               6  -0.336718E-03


                                              MATRIX  STRESS                                         PAGE    1
                      CUTOFF =    0.                                          SIZE    36  BY      1
         NRSEL                     NRSEL                 NRSEL                  NRSEL                  NRSEL
COND.      1   1  -0.235452E 03    2   -0.275269E 03    6   -0.755777E 04   7    0.235452E 03    8    0.275269E 03
              12  -0.565514E 04   13    0.274729E 03   14   -0.235452E 03  18   -0.565514E 04   19   -0.274729E 03
              20   0.235452E 03   24   -0.564656E 04   25    0.235452E 03  26    0.274732E 03   30    0.564656E 04
              31  -0.235452E 03   32   -0.274732E 03   36    0.754060E 04
```

FIGURE III-B.16 LOAD, DISPLACEMENT AND STRESS OUTPUT, THREE ELEMENT PORTAL FRAME

```
                                   MATRIX  FORCES                                            PAGE    1

                   CUTOFF =   0.                                    SIZE    54  BY     1

          D.O.F               D.O.F               D.O.F               D.O.F               D.O.F

COND.    1    1  -0.275269E 03    2  -0.235452E 03    6   0.755777E 04    7   0.275269E 03    8   0.235452E 03
             12   0.565514E 04   19   0.274729E 03   20  -0.235452E 03   24  -0.565514E 04   25  -0.274729E 03
             26   0.235452E 03   30  -0.564656E 04   37   0.274732E 03   38  -0.235452E 03   42   0.564656E 04
             43  -0.274732E 03   44   0.235452E 03   48   0.754060E 04


                                   MATRIX  REACT                                             PAGE    1

                   CUTOFF =   0.                                    SIZE    30  BY     1

          D.O.F               D.O.F               D.O.F               D.O.F               D.O.F

COND.    1    1  -0.275269E 03    2  -0.235452E 03    6   0.755777E 04    7  -0.155640E-02   12  -0.244141E-03
             13   0.288773E-02   14  -0.190735E-05   18  -0.305176E-03   19  -0.274732E 03   20   0.235452E 03
             24   0.754060E 04

$END

         $IBSYS
         $REMOVE        SYSLB2
```

FIGURE III-B.17 FORCE AND REACTION OUTPUT, THREE ELEMENT PORTAL FRAME

C. CANTILEVER BEAM

A cantilever beam is shown in Figure III-C.1 along with its loading, dimensions and pertinent material properties. The beam is idealized using axial force members and a quadrilateral shear panel. The preprinted input data forms associated with this beam are displayed in Figures III-C.2 through III-C.10.

In Figure III-C.6 (Boundary Condition Section) it is interesting to note the use of the MODAL and Repeat options. There are two exceptions to the MODAL card (Grid Points 2 and 3). Grid Point 3 has exactly the same boundary conditions as Grid Point 2, therefore the Repeat option is employed by placing an 'X' in Column 12 opposite the entry for Grid Point 3. Note that the 2 exceptions to the MODAL card are called out on the System Control Information Data Form (Figure III-C.4).

In Figure III-C.7 (External Loads Section) Grid Points 3 and 4 have applied external loading. Note that there are 2 external load cards per grid point.

In Figure III-C.9 (Element Input) the MODAL card is used for Element Numbers 2 and 3. These are the Axial Force Members parallel to the X Axis. For Element Number 1, the Quadrilateral Shear Panel, the thickness of 0.0787 inches is entered in Location A. Finally for Element No. 4 the cross-sectional area of 0.10 sq. inches is entered. The area for Element No. 5 is repeated by simply placing an "X" in the repeat column opposite the entry for Element No. 5.

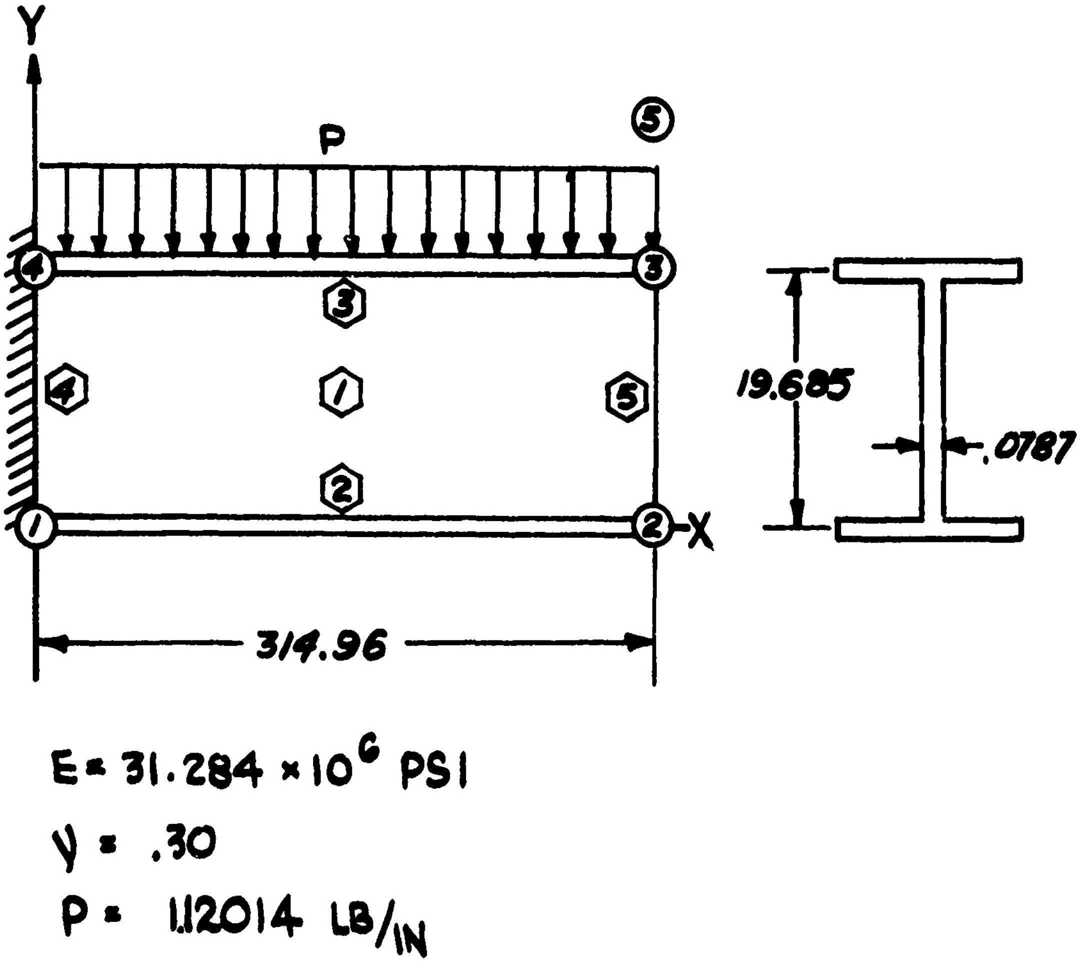

FIGURE III-C.I - Idealized Cantilever Beam

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

5 (/) NUMBER OF TITLE CARDS

```
ØNE ELEMENT CANTILEVER BEAM IDEALIZED U$ING FØUR AXIAL FØRCE         (/)
MEMBER$ AND ØNE QUADRILATERAL $HEAR PANEL REFERENCE: UPPER AND       (/)
LØWER BØUND$ TØ $TRUCTURAL DEFØRMATIØN$ BY DUAL ANALY$I$ IN          (/)
FINITE ELEMENT$ G $ANDER AND B. FRAEIJS DE VEUBEKE AFFDL TR 66 199   (/)
PAGE$ 112-118                                                        (/)
                                                                     (/)
                                                                     (/)
                                                                     (/)
                                                                     (/)
```

FIGURE III-C.2 TITLE INFORMATION, CANTILEVER BEAM

BAC 1616-1

MATER (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number (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	99398	RH	E=3.13E7 MU=0.30	X									1			(/)

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	31.284 E6	ν_{xy}	0.30	α_x	12.5 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, 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 2 3 4 5 6	5
2.	Number of Input Grid Points	7 8 9 10 11 12	5
3.	Number of Degrees of Freedom/Grid Point	13 14	6
4.	Number of Load Conditions	15 16	1
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	5
9.	Number of Requests and/or Revisions of Material Tape.	37 38	1
10.	Number of Input Boundary Condition Points	39 40 41 42 43 44	2
11.	T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	0.0 ( )

FIGURE III-C.4 SYSTEM CONTROL INFORMATION, 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 (7–12)	DIRECTIONS X – R (13–22)	Y – Θ (23–32)	Z – Z (33–42)	
1	0.0	0.0	0.0	(/)
2	314.960	0.0	0.0	(/)
3	314.960	19.6063	0.0	(/)
4	0.0	19.6063	0.0	(/)
5	314.960	25.0	0.0	(/)
				(/)
				(/)
				(/)
				(/)
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				(/)

FIGURE III-C.5 **GRIDPOINT COORDINATES, 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	
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	
				2		1	1	0	0	0	0				(/)
				3	X										(/)
															(/)
															(/)
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FIGURE III.C.6 BOUNDARY CONDITIONS, CANTILEVER BEAM

BAC 1627

MAGIC STR
IN

1	2	3	4	5	6
L	O	A	D	S	

(/)

LCOND — Condition Number: 1 — Scalar: 0.0 (/)

MODAL

Grid Pt. Number	FORCE VALUES Fx	Fy	Fz		M Mx
3	0.0	-176.39965	0.0	(/)	0.0
4	0.0	-176.39965	0.0	(/)	0.0

FIGURE III-C.7 EXTERNAL LOADS, CANTILEVER BEAMS

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

Fz	(/)	MOMENT VALUES Mx	MOMENT VALUES My	MOMENT VALUES Mz	(/)	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3	(/)
4		1 2	2 3	3 4		1 2	2 3	3 4	
8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
	(/)				(/)				(/)

Fz	(/)	Mx	My	Mz	(/)	1	2	3	(/)
4		1 2	2 3	3 4		1 2	2 3	3 4	
8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
	(/)	0.0	0.0	0.0	(/)				(/)
	(/)	0.0	0.0	0.0	(/)				(/)
	(/)				(/)				(/)
	(/)				(/)				(/)
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					(/)				(/)
					(/)				(/)
					(/)				(/)

BAC 1628

ELEM 1 2 3 4 5 6 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT: Print	PRINT: Elem. Mat.	PRINT: Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35	36 37 38 39	40 41 42	43 44 45	46 47 48	49 50 51	52 53 54	55 56 57	58 59 60	61 62 63	64 65 66	67 68 69	70 71	
1	25	99398				X			X	4		1	2	3	4									(/)
2	11	99398				X			X	3		1	2	5										(/)
3	11	99398				X				3		3	4	5										(/)
4	11	99398				X				3		1	4	5										(/)
5	11	99398				X				3		2	3	5										(/)
																								(/)
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FIGURE III-C.8 ELEMENT CONTROL DATA, CANTILEVER BEAM

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Missing Page/s That Are
Unavailable In The
Original Document

OR are
Blank pgs.
that have
Been Removed

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BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

Columns 1–6	A	B	C	D	E	F
MODAL	1.550					

Element Number	Repeat	A	B	C	D	E	F	
1		0.07870						(/)
4		0.10						(/)
5	X							(/)

FIGURE III-C.9 ELEMENT INPUT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

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

E	N	D	(/)
1	2	3	

FIGURE III-C.10 END CARD, CANTILEVER BEAM

The output supplied by the MAGIC System for the cantilever beam is as follows:

Figures III-C.11 thru III-C.14 display the output from the Structural Systems Monitor. These figures display the input data pertinent to the particular problem being solved.

Referring to Figure III-C.1 it is seen that one shear panel and four axial force members are used in this idealization. Element Number 1 represents the shear panel while elements 2, 3, 4, and 5 represent the axial force members. In Figure III-C.13, the external input for element number 1 is equal to 0.07870. This value represents the thickness of the quadrilateral shear panel being employed. For elements 2 and 3 the values of the external input are equal to 1.55 while for elements 4 and 5 the values are equal to 0.10. These values represent the cross-sectional area of the respective axial force members.

Figure III-C.14 displays the transformed external assembled (unreduced) load column for this problem. This vector is read row-wise and is consistent with the ordering of the displacements displayed in the Boundary Condition Section shown in Figure III-C.12. It is seen from this vector that an externally applied load of -176.40 is acting at node point 3 in the negative Y direction and a force of -176.40 is acting at node point 4 also in the negative Y direction.

Figure III-C.15 shows the assembled and reduced stiffness matrix for this problem. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-C.12. For this case, the ordering of the displacement vector is as follows:

$$\{ q \}^T = \lfloor u_2, v_2, u_3, v_3 \rfloor$$

Figure III-C.16 shows the reduced Externally Applied Load Vector (LOADR). This is a 4 x 1 vector with one non-zero value of force displayed. This value corresponds to reduced degree of freedom (REDDOF) 4. From the Boundary Condition Information (Figure III-C.12) it is seen that this corresponds to a force of -176.40 in the negative Y direction at node point 3.

The vector of displacements (DISPR) also shown in Figure III-C.16, is again of the order 4 x 1, since there are 4 degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-C.12 and is as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	2	u	-0.00920315
2	2	v	-0.150560
3	3	u	0.009230315
4	3	v	-0.15113

Note that the displacements are referenced to the global system axis unless otherwise indicated.

The stress matrix is the last item of information shown in Figure III-C.16. This matrix is of the order 49 x 1. This is true for the following reason. The quadrilateral shear panel is described by one constant shear stress value. The axial force members are defined by six forces at each end of the element giving a total of 12 forces per element. Since four axial force members were used in this analysis, their total contribution to the stress vector is 48. Adding the stress contributed by the shear panel the final size of the stress vector is 49 x 1.

The stress vector is related to element coordinates and the value of stress given for the shear panel has units of (force/length). Description of stress behavior for the axial force members is accepted as the definition of the twelve forces acting at the two grid point connections. The ordering of the Stress matrix is as follows: (See Figures III-C.1 for Element Numbering.) Note that only non-zero values of stress are printed.

MATRIX STRESS

NRSEL	ELEMENT	STRESS	FORCE	NODE POINT
1	1	T_{xy} = 144.323	———	——
2	2		F_x = 1416.89	1
8	2		F_x = -1416.89	2
14	3		F_x = -1416.89	3
20	3		F_x = 1416.89	4
38	5		F_x = 88.2002	2
44	5		F_x = -88.2002	3

Note again that stress values are referenced to the element coordinate system.

In Figure III-C.17, the vector of MATRIX FORCES is presented. These forces are defined with respect to the Global Coordinate System. The Matrix Force Vector is a 96 x 1 vector for the following reason. Element Number 1 (Quadrilateral Shear Panel) is defined by 4 node points with six forces per node point. Each axial force member is defined by three node points with the third point defining the element Xg-Yg plane. Since these are six forces per point, each element is defined by 18 forces with the last six for each element related to the third node point always being equal to zero. Since four axial force members were used in this analysis their total contribution is 72 forces. Adding the contribution of the shear panel, the final size of the Matrix Force vector is 96 x 1. The ordering of the Matrix Force vector is as follows: (See Figure III-C.1 for element numbering and note again that only non-zero values of force are printed.)

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	F_X = 1417.89	1
2	1	F_Y = 88.200	1
7	1	F_X = 1416.89	2
8	1	F_Y = -88.200	2
13	1	F_X = -1416.89	3
14	1	F_Y = -88.200	3
19	1	F_X = -1416.89	4
20	1	F_Y = 88.200	4
25	2	F_X = 1416.89	1
31	2	F_X = -1416.89	2
43	3	F_X = 1416.89	3
49	3	F_X = -1416.89	4
80	5	F_Y = 88.2002	2
86	5	F_Y = -88.2002	3

The final item of information contained in Figure II-C.17 is the vector of reactions (MATRIX REACT). This vector is a 30 x 1 since there are five node points associated with this problem and six associated degrees of freedom per node point.

Only non-zero terma sre printed for this vector. The reactions are read row-wise and are interpreted as follows:

MATRIX REACT

D.O.F.	REACTION	NODE POINT
1	P_{RX} = 2833.77	1
2	P_{RY} = 88.200	1
7	-0.0002746 = 0	2
8	0.0002136 = 0	2
13	0.0003509 = 0	3
14	-0.0001469 = 0	3
19	P_{RX} = -2833.77	4
20	P_{RY} = 264.60	4

```
ONE ELEMENT CANTILEVER BEAM IDEALIZED USING FOUR AXIAL FORCE

MEMBERS AND CNE QUADRILATERAL SHEAR PANEL REFERENCE' UPPER AND

LOWER BOUNDS TC STRUCTURAL DEFORMATIONS BY DUAL ANALYSIS IN

FINITE ELEMENTS G.SANDER AND B.FRAEIJS DE VEVBEKE AFFDL TR 66 199

PAGES 112-118

                              REVISIONS OF MATERIAL TAPE

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

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

  REVISION
    MATERIAL NUMBER  99398
    MATERIAL IDENTIFICATION   E=3.13E7 NV=0.30                 INPUT CODE   I
      NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
      NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
      MASS DENSITY. . . . . . . . . . . . . . .-0.

    MATERIAL PROPERTIES
                         YOUNG'S MODULI                                   POISSON'S RATIOS

                           DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                   XX              YY             ZZ              XY              YZ              ZX
    0.       0.312840E 08    0.312840E 08   0.312840E 08    0.300000E 00    0.300000E 00    0.300000E 00
                    THERMAL EXPANSION COEFFICIENTS                          RIGIDITY MODULI

                           DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                   XX              YY             ZZ              XY              YZ              ZX
    0.       0.125000E-04    0.125000E-04   0.125000E-04    0.120323E 08    0.120323E 08    0.120323E 08

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

FIGURE III-C.11 TITLE AND MATERIAL DATA OUTPUT, CANTILEVER BEAM

5 REF. PCINTS

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

GRIDPOINT DATA

POINT	X	Y	Z
1	C.	0.	0.
2	0.31496000E 03	0.	0.
3	0.31496000E 03	0.19606000E C2	0.
4	C.	C.15606CCCE 02	0.
5	0.31496000E 03	C.25C00CCCE C2	0.

TEMPERATURES	PRESSURES
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.
0.	0.

BCUNCARY CONDITION INFORMATION

NCDES	DEGREES OF FREEDCM						
1	0	C	0	0	C	0	0
2	1	1	0	C	C	0	2
3	1	1	0	C	C	0	4
4	0	0	0	0	C	0	4
5	0	0	0	C	C	0	4

FIGURE III-C.12 GRID POINT DATA AND BOUNDARY CONDITION OUTPUT, CANTILEVER BEAM

```
                                   TOTAL NO. ELEMENTS =      5

ELEM TYPE  PAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  25    99390    0 -0.           2    4     1  2  3  4

MATERIAL NUMBER. . . . . . . . . 99390
       MATERIAL IDENTIFICATION. . . .  E=3.12E7 NU=0.30
       ANALYSIS CAPABILITY. . . . . .        ISOTROPIC
       INPUT PRINT CODE . . . . . . .  1
       ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
       TEMPERATURE -        0.
       YOUNG'S MODULI                       0.312040000E 08     0.312040000E 08     0.312040000E 08
       POISSON'S RATIOS                     0.300000000E 00     0.300000000E 00     0.300000000E 00


       THERMAL EXPANSION COEFFICIENTS       0.125000000E-04     0.125000000E-04     0.125000000E-04
       RIGIDITY MODULI                      0.120323077E 08     0.120323077E 08     0.120323077E 08

INTERPOLATED PLASTIC PROPERTIES
       NONE

PRE-STRAIN INPUT
       NONE

PRE-STRESS INPUT
       NONE

EXTERNAL INPUT
           0.787000000E-01    -0.               -0.               -0.               -0.


ELEM TYPE  PAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  11    99390    0 -0.           2    3     1  2  5

MATERIAL NUMBER. . . . . . . . . 99390
       MATERIAL IDENTIFICATION. . . .  E=3.12E7 NU=0.30
       ANALYSIS CAPABILITY. . . . . .        ISOTROPIC
       INPUT PRINT CODE . . . . . . .  1
       ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
       TEMPERATURE -        0.
       YOUNG'S MODULI                       0.312040000E 08     0.312040000E 08     0.312040000E 08
       POISSON'S RATIOS                     0.300000000E 00     0.300000000E 00     0.300000000E 00
       THERMAL EXPANSION COEFFICIENTS       0.125000000E-04     0.125000000E-04     0.125000000E-04
       RIGIDITY MODULI                      0.120323077E 08     0.120323077E 08     0.120323077E 08

INTERPOLATED PLASTIC PROPERTIES
       NONE

PRE-STRAIN INPUT
       NONE

PRE-STRESS INPUT
       NONE

EXTERNAL INPUT
           0.159000000E 01    -0.               -0.               -0.               -0.


ELEM TYPE  PAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  3  11    99390    0  0.           0    3     3  4  5                         0.1590E 01  -0.          -0.
  4  11    99390    0  0.           0    3     1  4  5                         0.1000E 00  -0.          -0.
  5  11    99390    0  0.           0    3     2  3  5                         0.1000E 00  -0.          -0.
```

FIGURE III-C.13 FINITE ELEMENT DESCRIPTION OUTPUT, CANTILEVER BEAM

EXTERNAL LOAD CONDITIONS 1

LOAC NO. 1

NUMBER OF LOACEC NODES 2 ELEMENT LOAD SCALAR = 0.

```
3  0.          -0.17640E C3  0.      0.         0.         0.
4  0.          -0.1764CE 03  0.      0.         0.         0.
```

TRANSFCRMED EXTERNAL ASSEMBLED LOAD COLUMN

30 X 1

0.	0.	0.	0.	0.	0.
0.	C.	0.	0.	0.	0.
0.	-0.17640CCCE C3	0.	0.	0.	0.
0.	-0.17640CC0E C3	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

T-ZERO FOR STRUCTURE = 0.

FIGURE III-C.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, CANTILEVER BEAM

MATRIX STIFF

CUTOFF = C. SIZE 4 BY 4

		FORCE		FORCE		FORCE		FORCE		FORCE
DISP.	1	1	0.395699E 07	2	-0.236736E 06	3	-C.380303E 07	4	-0.236736E 06	
DISP.	2	1	-0.236736E 06	2	0.174300E 05	3	0.236736E 06	4	-0.144827E 06	
DISP.	3	1	-0.380303E 07	2	C.236736E 06	3	0.395699E 07	4	0.236736E 06	
DISP.	4	1	-0.236736E 06	2	-C.144827E 06	3	0.236736E 06	4	0.174300E 06	

FIGURE III-C.15 REDUCED STIFFNESS MATRIX OUTPUT, CANTILEVER BEAM

```
                                        MATRIX  LOADR                                   PAGE   1
                   CUTOFF =   0.                              SIZE    4  BY    1
        REDDOF             REDDOF             REDDOF             REDDOF             REDDOF
COND.     1   4   -0.176400E 03
```

```
                                        MATRIX  DISPR                                   PAGE   1
                   CUTOFF =   0.                              SIZE    4  BY    1
        REDDOF             REDDOF             REDDOF             REDDOF             REDDOF
COND.     1   1   -0.920315E-02   2   -0.150560E 00   3   0.920315E-02   4   -0.151113E 00
```

```
                                        MATRIX  STRESS                                  PAGE   1
                   CUTOFF =   0.                              SIZE   49  BY    1
        NRSEL              NRSEL              NRSEL              NRSEL              NRSEL
COND.     1   1   -0.114323E 03   2    0.141689E 04   8   -0.141689E 04  14   -0.141689E 04  20   0.141689E 04
             38    0.882002E 02  44   -0.882002E 02
```

FIGURE III-C.16 LOAD, DISPLACEMENT AND STRESS OUTPUT, CANTILEVER BEAM

```
                                        MATRIX  FORCES                                              PAGE    1

                       CUTOFF =   C.                                   SIZE    96  BY    1

              D.O.F             D.O.F              D.O.F              D.O.F              D.O.F

COND.     1     1  0.141689E 04    2  0.882000E 02    7  0.141689E 04    8 -0.882000E 02   13 -0.141689E 04
               14 -0.882000E 02   19 -0.141689E 04   20  0.882000E 02   25  0.141689E 04   31 -0.141689E 04
               43  0.141689E 04   49 -0.141689E 04   80  0.882002E 02   86 -0.882002E 02


                                        MATRIX  REACT                                               PAGE    1

                       CUTOFF =   0.                                   SIZE    30  BY    1

              D.O.F             D.O.F              D.O.F              D.O.F              D.O.F

COND.     1     1  0.283377E 04    2  0.882000E 02    7 -0.274658E-03    8  0.213623E-03   13  0.350952E-03
               14 -0.146866E-03   19 -0.283377E 04   20  0.264600E 03

$END

          $IBSYS
          $REMOVE      SYSLB2
```

FIGURE III-C.17 FORCE AND REACTION OUTPUT, CANTILEVER BEAM

D. THICK WALLED DISK

A thick walled disk under the influence of a radially varying thermal loading is shown in Figure III-D.1 along with its dimensions and pertinent material properties. This disk is idealized using triangular cross-section ring elements. The preprinted input data forms associated with this problem are shown in Figures III-D.2 through III-D.10.

In Figure III-D.3 (Material Tape Input Section) note that 2 material (temperature) points are entered for the material in question. A linear interpolation for material properties is performed for temperatures which fall between these two temperature points.

In Figure III-D.6 (Grid Point Temperature Section) it is instructive to note the use of the Repeat Option. Grid point 5 has the same temperature as grid point 1, therefore the Repeat option is employed by placing an 'X' in column 12 opposite the entry for Grid Point Number 5. This same procedure is also used for Grid Points 2 and 3. Note that the Grid Points are not entered sequentially allowing the use of the Repeat option. It should also be noted that the temperature values are entered in Columns 13-22.

In Figure III-D.7 (Boundary Condition Section) it is instructive to note the use of the MODAL option. There is only 1 exception to the MODAL card and this is Grid Point Number 5. This exception must be called out on the System Control Information Data Form (Figure III-D.4).

In Figure III-D.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed, and loads of 0.0 are entered in the locations corresponding to F_x, F_y, and F_z. Note that this is the only entry required (the Moment and Generalized Values are ignored) since the Triangular Cross-Section ring has three degrees of freedom per point thus requiring only one external load card per grid point.

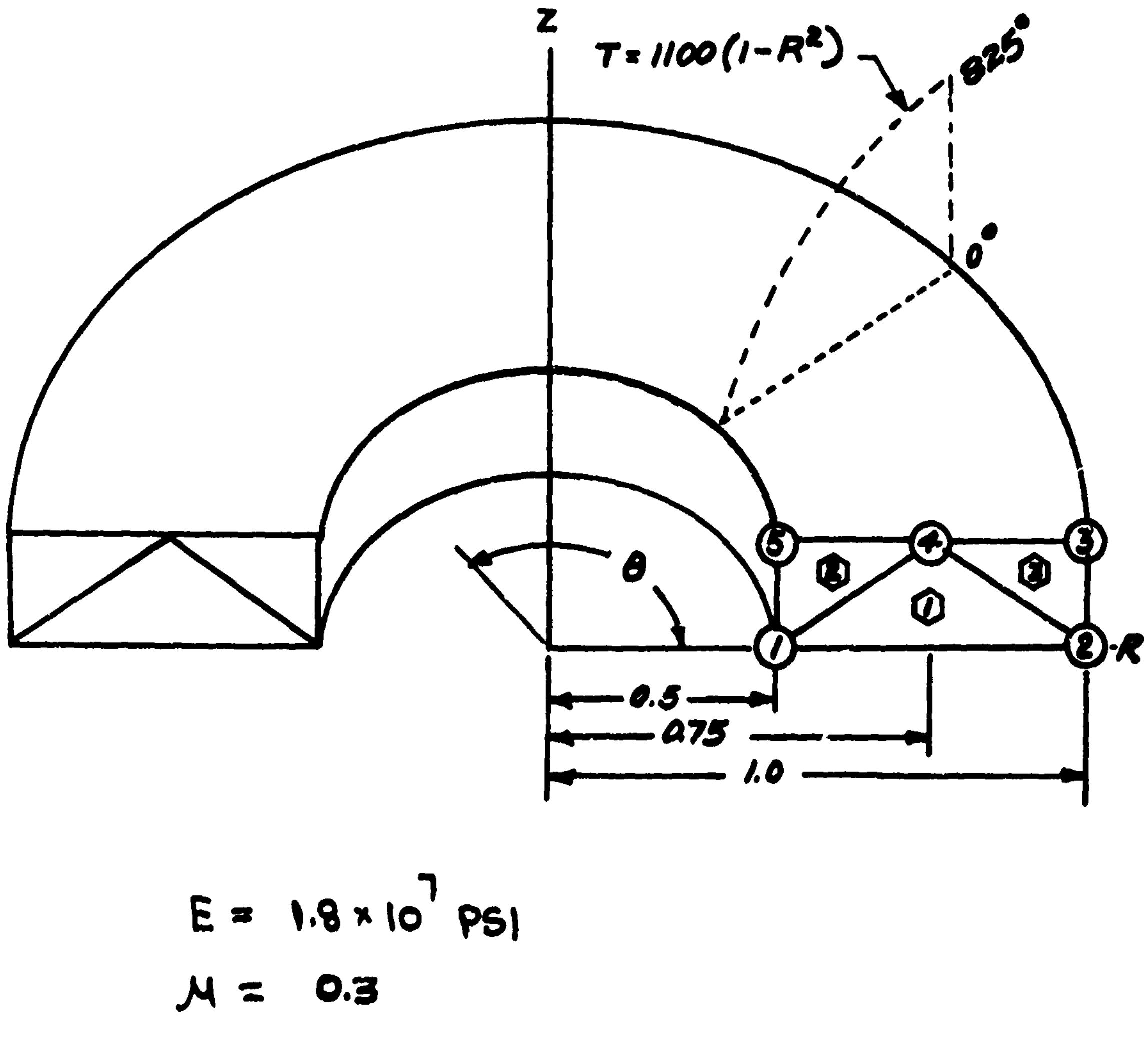


FIGURE III - D.1 - Idealized Thick Walled Disc

BAC 1028

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)	Node Points 1 (36–38)	2 (39–41)	3 (42–44)	4	5	6	7	8	9	10	11	12
1	40	12	3						X	3		1	2	4									
2	40	12	3							3		1	4	5									
3	40	12	3							3		2	3	4									

FIGURE III-D.9 ELEMENT CONTROL DATA, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

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

E	N	D	
1	2	3	(/)

FIGURE III-D.10 END CARD, THICK WALLED DISK

The output supplied by the MAGIC System for the thick walled disk is as follows:

Figures III-D.11 thru III-D.14 display the output from the Structural Systems Monitor. These figures display the input data pertinent to the particular problem being solved.

Figure III-D.12 displays the coordinate and boundary condition information for this problem.

In the Gridpoint Data Section note that node points 1 and 5 have temperature values input of 825.00 while node point 4 has a temperature of 481.25.

In the Boundary Condition Section note that there are three allowable degrees of freedom per point for the triangular ring element as follows:

(u, o, w). The ordering of the reduced displacement vector is as follows:

$$\{q\}^T = \lfloor u_1, w_1, u_2, w_2, u_3, w_3, u_4, w_4, u_5 \rfloor$$

Figure III-D.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since this is a thermal stress problem and thermal loads are element applied loads.

System level output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figure III-D.15 thru III-D.17.

Figure III-D.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is presented row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-D.12. For this case the order of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_1, w_1, u_2, w_2, u_3, w_3, u_4, w_4, u_5 \rfloor$$

Figure III-D.16 displays the thermal stress correction vector SZAEL. This vector is of the order 12 x 1, since four stresses are evaluated at the centroid of each element and three elements were used in this analysis. The stress correction vector is of the following form:

$$\{ SZAEL \} = \Delta T \quad [E] \quad \{ \bar{\alpha} \}$$

where $[E]$ is the material property matrix which has the following form

$$E = \frac{1}{\Delta} \begin{bmatrix} E_r(1 - \nu_{\theta z}\nu_{z\theta}), & E_r(\nu_{\theta r} + \nu_{zr}\nu_{\theta z}), & E_r(\nu_{zr} + \nu_{z\theta}\nu_{\theta r}), & 0 \\ & E_\theta(1 - \nu_{rz}\nu_{zr}) & , E_\theta(\nu_{z\theta} + \nu_{r\theta}\nu_{zr}), & 0 \\ & & E_z(1 - \nu_{r\theta}\nu_{\theta r}) & , 0 \\ \text{Symmetric} & & & \Delta G_{rz} \end{bmatrix}$$

where

$$\Delta = (1 - \nu_{r\theta}\nu_{\theta r} - \nu_{\theta z}\nu_{z\theta} - \nu_{zr}\nu_{rz} - \nu_{r\theta}\nu_{\theta z}\nu_{zr} - \nu_{rz}\nu_{\theta r}\nu_{z\theta})$$

$$\{ \bar{\alpha} \}^T = \lfloor \alpha_r, \alpha_\theta, \alpha_z, 0 \rfloor$$

where α_r, α_θ, and α_z are the coefficients of thermal expansion in the r, θ, and z directions respectively. ΔT is the difference between the centroidal temperature of the element and the equilibrium temperature.

Rewrite the material properties matrix as follows:

$$[E] = \begin{bmatrix} E_{11} & E_{12} & E_{13} & 0 \\ & E_{22} & E_{23} & 0 \\ & & E_{33} & 0 \\ \text{SYMM.} & & & E_{44} \end{bmatrix}$$

Using the above notation the SZAEL vector is read row-wise as follows:

MATRIX SZAEL

ROW	ELEMENT NUMBER	ALGEBRAIC VALUE	NUMERICAL VALUE
1	1	$(E_{11}\alpha_r + E_{12}\alpha_\theta + E_{13}\alpha_z)$	1959.37
2	1	$(E_{12}\alpha_r + E_{22}\alpha_\theta + E_{23}\alpha_z)$	1959.37
3	1	$(E_{13}\alpha_r + E_{23}\alpha_\theta + E_{33}\alpha_z)$	1959.37
5	2	$(E_{11}\alpha_r + E_{12}\alpha_\theta + E_{13}\alpha_z)$	3196.87
6	2	$(E_{12}\alpha_r + E_{22}\alpha_\theta + E_{23}\alpha_z)$	3196.87
7	2	$(E_{13}\alpha_r + E_{23}\alpha_\theta + E_{33}\alpha_z)$	3196.87
9	3	$(E_{11}\alpha_r + E_{12}\alpha_\theta + E_{13}\alpha_z)$	721.875
10	3	$(E_{12}\alpha_r + E_{22}\alpha_\theta + E_{23}\alpha_z)$	721.875
11	3	$(E_{13}\alpha_r + E_{23}\alpha_\theta + E_{33}\alpha_z)$	721.875

The following item of information in the figure is the vector FTELAR (Reduced Element Applied Loads). The size of this vector is 9 x 1. The vector appears as follows and is read row-wise.

MATRIX FTELAR

REDDOF	NODE NUMBER	ELEMENT APPLIED LOAD VALUE
1	1	P_R = -275.380
2	1	P_Z = -2618.81
3	2	P_R = 583.158
4	2	P_Z = -1673.88
5	3	P_R = 226.784
6	3	P_Z = 519.713
7	4	P_R = 583.158
8	4	P_Z = 2308.33
9	5	P_R = -502.164

The last item of information appearing in the figure is the displacement vector (DISPR). This vector is of the order 9 x 1 since there are 9 degrees of freedom remaining after assembly and reduction. The displacement vector is read row-wise and is interpreted as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	1	u	0.00002468
2	1	w	-0.000008658
3	2	u	0.00004296
4	2	w	-0.000004524
5	3	u	0.00004147
6	3	w	-0.000004173
7	4	u	0.00003550
8	4	w	-0.000002076
9	5	u	0.00002274

The stress matrix is shown in Figure III-D.17. This matrix is defined as follows:

$$\sigma = [E]\ \{\epsilon\} - \{SZAEL\}$$

where the thermal stress correction vector SZAEL has been discussed previously. The size of the final stess vector is a 12 x 1. Four stresses are evaluated at the centroid of each element

$$\{\sigma_{ELEM}\} = \lfloor \sigma_r, \sigma_\theta, \sigma_z, \tau_{rz} \rfloor$$

Since there were 3 elements used in this problem the final stress vector is a 12 x 1. The ordering of the stress matrix is as follows: (See Figure III-D.1 for Element Position and Numbering Sequence.)

MATRIX STRESS

NRSEL	ELEMENT	STRESS	NODE POINT
1	1	σ_r = -128.397	Centroid
2	1	σ_θ = 0.004486	Centroid
3	1	σ_z = -9.52805	Centroid
4	1	τ_{rz} = 173.245	Centroid
5	2	σ_r = -568.817	Centroid
6	2	σ_θ = -619.640	Centroid
7	2	σ_z = -76.8477	Centroid
8	2	τ_{rz} = -192.119	Centroid
9	3	σ_r = 346.753	Centroid
10	3	σ_θ = 619.645	Centroid
11	3	σ_z = 64.4932	Centroid
12	3	τ_{rz} = -161.234	Centroid

The second item of information shown in Figure III-D.17 is the element forces (MATRIX FORCES). These forces are defined with respect to the Global Coordinate System. The Matrix Force Vector is a 27 x 1 vector since each triangle has three element forces defined per point (F_R, F_θ, F_Z) with three points per element. Since three triangular ring elements were used in this analysis, the size of the vector is 27 x 1. The ordering of the Matrix Forces is as follows:

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	F_R = -71.7969	1
3	1	F_Z = -35.2073	1
4	1	F_R = -132.303	2
6	1	F_Z = 46.4323	2
7	1	F_R = 204.099	4
9	1	F_Z = -11.2250	4
10	2	F_R = 71.7968	1
12	2	F_Z = 35.2077	1
13	2	F_R = -120.463	4
15	2	F_Z = -35.2076	4
16	2	F_R = 0.000069 = 0	5
18	2	F_Z = -0.0001068 = 0	5
19	3	F_R = -83.6355	4
21	3	F_Z = 46.4321	4
22	3	F_R = 132.302	2
24	3	F_Z = -46.4318	2
25	3	F_R = -0.0000248 = 0	3
27	3	F_Z = -0.000259 = 0	3

The final item of information contained in Figure III-D.17 is the vector of reactions (MATRIX REACT). This vector is a 15 x 1 since there are 5 node points associated with this problem and three associated degrees of freedom per node point. From the figure it is seen that all of the reactions are effectively equal to zero which is mandatory for this type of loading.

THICK WALLED DISK SUBJECTED TO A RADIAL THERMAL GRADIENT 1100(1-R**2)

THREE TRIANGULAR RING ELEMENTS USED IN THE IDEALIZATION

REFERENCE- WANG APPLIED ELASTICITY-PAGE 70(PLANE STRESS FORMULATION)

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    E=1.8E6,MU=0.30                INPUT CODE   I
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  2
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
```

TEMPERATURE	YOUNG'S MODULI DIRECTIONS XX	YY	ZZ	POISSON'S RATIOS DIRECTIONS XY	YZ	ZX
0.	0.180000E 08	0.180000E 08	0.180000E 08	0.300000E 00	0.300000E 00	0.300000E 00
1500.00	0.180000E 08	0.180000E 08	0.180000E 08	0.300000E 00	0.300000E 00	0.300000E 00

TEMPERATURE	THERMAL EXPANSION COEFFICIENTS DIRECTIONS XX	YY	ZZ	RIGIDITY MODULI DIRECTIONS XY	YZ	ZX
0.	0.100000E-05	0.100000E-06	0.100000E-06	0.692308E 07	0.692308E 07	0.692308E 07
1500.00	0.100000E-06	0.100000E-06	0.100000E-06	0.692308E 07	0.692308E 07	0.692308E 07

****

FIGURE III-D.11 TITLE AND MATERIAL DATA OUTPUT, THICK WALLED DISK

5 REF. POINTS

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

GRIDPOINT DATA

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.50000000E 00	0.	0.	0.82500000E 03	0.
				-0.	0.
2	0.10000000E 01	0.	0.	0.	0.
				-0.	0.
3	0.10000000E 01	0.	0.09999999E 00	0.	0.
				-0.	0.
4	0.75000000E 00	0.	0.09999999E 00	0.48125000E 03	0.
				-0.	0.
5	0.50000000E 00	0.	0.09999999E 00	0.82500000E 03	0.
				-0.	0.

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM			
1	1	C	1	2
2	1	C	1	4
3	1	0	1	6
4	1	C	1	8
5	1	0	0	9

FIGURE III-D.12 GRID POINT DATA AND BOUNDARY CONDITION OUTPUT, THICK WALLED DISK

```
                                        TOTAL NO. ELEMENTS =      3

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  40       12    0 -0.             2    3      1   2   4

MATERIAL NUMBER. . . . . . . .      12
     MATERIAL IDENTIFICATION. . . .  E=1.8E6,MU=0.30
     ANALYSIS CAPABILITY. . . . . .       ISCTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1

INTERPCLATEC MATERIAL PROPERTIES
     TEMPERATURE -       0.435416667E 03
     YOUNG'S MODULI                          0.18000000E 08      0.18000000E 08      0.18000000E 08
     POISSON'S RATIOS                        C.30000000E 00      0.30000000E 00      0.30000000E 00


     THERMAL EXPANSION COEFFICIENTS          C.1C000000E-06      0.10000000E-06      0.10000000E-06
     RIGICITY MODULI                         C.69230769E 07      0.69230769E 07      0.69230769E 07

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONF

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
     NONE


ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  40       12    0  0.7104E 03  0     3     1   4   5                                        0.          0.          0.
  3  40       12    0  0.1604E C3  0     3     4   2   3                                        0.          0.          0.
```

FIGURE III-D.13 FINITE ELEMENT DESCRIPTION OUTPUT, THICK WALLED DISK

```
                                   EXTERNAL LOAD CONDITIONS   1

      LOAD NO.   1
        NUMBER OF LOADED NODES     1          ELEMENT LOAD SCALAR =  0.10000000E 01
    1  0.            0.            0.

                              TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN
                                              15 X 1
      0.            0.            0.            0.            0.            0.
      0.            0.            0.            0.            0.            0.
      0.            0.            0.

                                   T-ZERO FOR STRUCTURE =  0.
```

FIGURE III-D.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THICK WALLED DISK

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 9 BY 9

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.622780E 08	2	0.149528E 08	3	0.953554E 07	4	0.135934E 07	7	-0.398539E 08
		8	-0.317180E 08	9	-0.324430E 08						
DISP.	2	1	0.149528E 08	2	0.185641E 09	3	-0.679671E 07	4	0.681031E 08	7	-0.407803E 08
		8	-0.142731E 09	9	0.163121E 08						
DISP.	3	1	0.953554E 07	2	-0.679671E 07	3	0.846207E 08	4	-0.258275E 08	5	-0.485244E 08
		6	-0.172183E 08	7	-0.399857E 08	8	0.498426E 08				
DISP.	4	1	0.135934E 07	2	0.681031E 08	3	-0.258275E 08	4	0.249077E 09	5	-0.326242E 08
		6	-0.174449E 09	7	0.407803E 08	8	-0.142731E 09				
DISP.	5	3	-0.485244E 08	4	-0.326242E 08	5	0.801600E 08	6	0.525613E 08	7	-0.276812E 08
		8	-0.199370E 08								
DISP.	6	3	-0.172183E 08	4	-0.174449E 09	5	0.525613E 08	6	0.182424E 09	7	-0.271869E 08
		8	-0.797481E 07								
DISP.	7	1	-0.398539E 08	2	-0.407803E 08	3	-0.399857E 08	4	0.407803E 08	5	-0.276812E 08
		6	-0.271869E 08	7	0.128392E 09	8	0.543737E 07	9	-0.173996E 08		
DISP.	8	1	-0.317180E 08	2	-0.142731E 09	3	0.498426E 08	4	-0.142731E 09	5	-0.199370E 08
		6	-0.797481E 07	7	0.543737E 07	8	0.298512E 09	9	0.126872E 08		
DISP.	9	1	-0.324430E 08	2	0.163121E 08	7	-0.173996E 08	8	0.126872E 08	9	0.476676E 08

FIGURE III-D.15 REDUCED STIFFNESS MATRIX OUTPUT, THICK WALLED DISK

```
                                   MATRIX  SZALEL                                        PAGE    1
                    CUTOFF =    0.                              SIZE    12  BY     1
            ROW               ROW               ROW               ROW               ROW
COL     1    1   0.195937E 04   2   0.195937E 04   3   0.195937E 04   5   0.319687E 04   6   0.319687E 04
             7   0.319687E 04   9   0.721875E 03  10   0.721875E 03  11   0.721875E 03


                                   MATRIX  FTELAR                                        PAGE    1
                    CUTOFF =    0.                              SIZE     9  BY     1
            REDDOF            REDDOF            REDDOF            REDDOF            REDDOF
COND.   1    1  -0.275380E 03   2  -C.261881E 04   3   0.583158E 03   4  -0.167388E 04   5   0.226784E 03
             6   0.519713E 03   7   0.583158E 03   8   0.230833E 04   9  -0.502164E 03


                                   MATRIX  DISPR                                         PAGE    1
                    CUTOFF =    C.                              SIZE     9  BY     1
            REDDOF            REDDOF            REDDOF            REDDOF            REDDOF
COND.   1    1   0.246797E-04   2  -0.865800E-05   3   0.429634E-04   4  -0.452447E-05   5   0.414731E-04
             6  -0.417267E-05   7   0.354973E-04   8  -0.207600E-05   9   0.227351E-04
```

FIGURE III-D.16 THERMAL STRESS, ELEM. APPLIED LOADS AND DISPLACEMENT OUTPUT, THICK WALLED DISK

```
                                  MATRIX  STRESS                                         PAGE   1

                    CUTOFF =   0.                              SIZE   12  BY    1

              NRSEL              NRSEL              NRSEL              NRSEL              NRSEL

COND.    1   1  -0.128397E 03   2  -0.448608E-02   3  -0.952805E 01   4   0.173249E 03   5  -0.568817E 03
             6  -0.619640E 03   7  -0.768477E 02   8  -0.192119E 03   9   0.346753E 03  10   0.619649E 03
            11   0.644932E 02  12  -0.161234E 03


                                  MATRIX  FORCES                                         PAGE   1

                    CUTOFF =   0.                              SIZE   27  BY    1

              D.O.F              D.O.F              D.O.F              D.O.F              D.O.F

COND.    1   1  -0.717969E 02   3  -0.352073E 02   4  -0.132303E 03   6   0.464323E 02   7   0.204099E 03
             9  -0.112250E 02  10   0.717968E 02  12   0.352077E 02  13  -0.120463E 03  15  -0.352076E 02
            16   0.686646E-04  18  -0.106812E-03  19  -0.836355E 02  21   0.464321E 02  22   0.132302E 03
            24  -0.464318E 02  25  -0.247955E-04  27  -0.259399E-03


                                  MATRIX  REACT                                          PAGE   1

                    CUTOFF =   0.                              SIZE   15  BY    1

              D.O.F              D.O.F              D.O.F              D.O.F              D.O.F

COND.    1   1  -0.534058E-04   3   0.335693E-03   4  -0.217438E-03   6   0.511169E-03   7  -0.247955E-04
             9  -0.259399E-03  10  -0.190735E-05  12  -0.505924E-03  13   0.686646E-04  15  -0.106812E-03

$END

         $IBSYS
         $REMOVE       SYSLB2
         $IBSYS
         $STOP
```

FIGURE III-D.17 STRESS, FORCE AND REACTION OUTPUT, THICK WALLED DISK

E. THIN WALLED CYLINDER, EDGE LOADING

A thin walled cylinder is shown in Figure III-E.1, along with its loading, dimensions, and pertinent material properties. This cylinder is idealized using two toroidal thin shell ring elements. The preprinted input data forms associated with this cylinder are shown in Figures III-E.2 through III-E.10.

In Figure III-E.6 (Boundary Condition Section) the User should note that all nine degrees of freedom are required for the Toroidal Ring Element (u, 0, w, 0, u', 0, w', 0, w").

In Figure III-E.7 (External Loads Section) the following items are evident.

(1) One load condition is entered.

(2) The External Applied Load Scalar is equal to zero.

(3) Grid point number 2 is loaded by the following load in the X(R) direction.

F_R = 188495.4 lbs. This load was determined as follows (From Figure III-E.1).

$$F_R = (1500 \text{ lbs./in.})(2\pi r)$$

$$F_R = (1500)(2)(3.14)(20) = 188,495.4 \text{ lbs.}$$

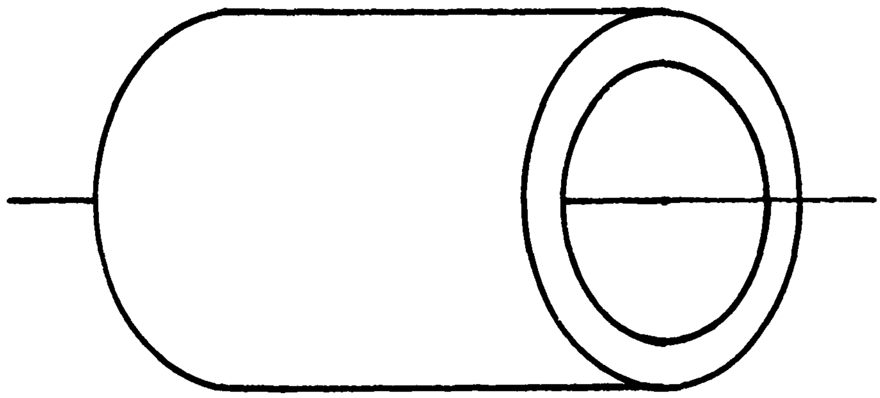
The value which is entered for the applied moment was determined as follows: (From Fiugre III-E.1).

$$M_{y(\Theta)} = (1000 \text{ in.-lb./in.})(2\pi r) = 125,663.6 \text{ in.-lb.}$$

(4) All three entries are filled in for the Toroidal Ring because this element requires <u>three external load cards</u> per grid point.

In Figure III-E.9 (Element Input Section) only the MODAL entry is employed. This means that the two Toroidal Ring elements employed in this analysis have identical Element Input as follows:

Location A - Thickness = 3.0 inches



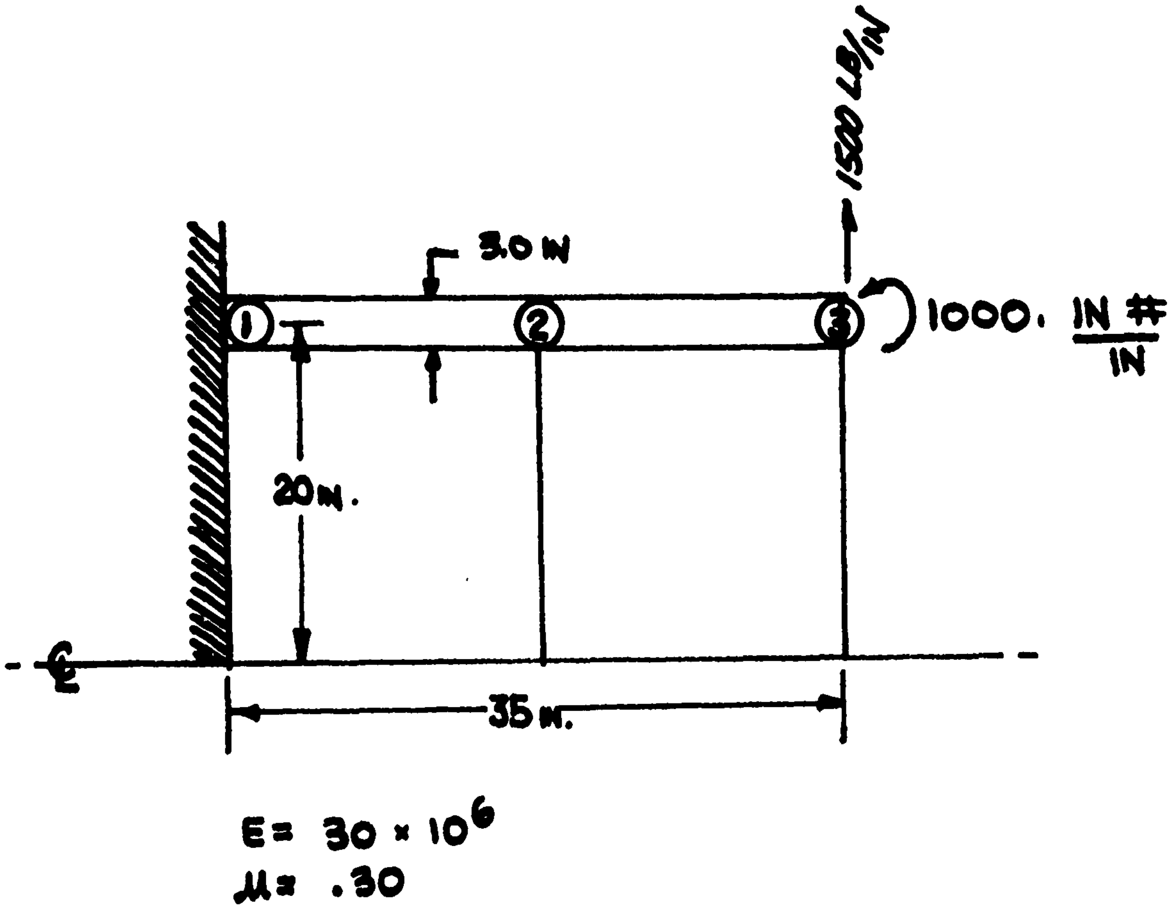


FIGURE III - E.1 - Idealized Thin Walled Cylinder with Edge Load

Location B - TCØ = 0.0 (This code determines the axis of reference for the display of displacement behavior, in this case the axis of reference is global).

Location C - Alpha 1 = 90.0 Degrees

Location D - Alpha 2 = 90.0 Degrees

For a review of the required Element Input for the Toroidal Ring the reader is referred to Section II-C.16.d.

SAC 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

5 (/) NUMBER OF TITLE CARDS

```
CYLINDRICAL SHELL SUBJECTED TO END LOADINGS
TWO TOROIDAL RING ELEMENTS USED IN THE IDEALIZATION
REFERENCE-KLEIN,S. STUDY OF THE MATRIX DISPLACEMENT METHOD APPLIED
TO SHELLS OF REVOLUTION, CONFERENCE ON MATRIX METHODS IN STR.MECH.
WRIGHT PATERSON AFB,1965.
```


FIGURE III-E.2 TITLE INFORMATION, THIN WALLED CYLINDER

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

7	8	9
		1

No. of Requests (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	12	TU	E = 3.0 E6, MU = 0.3	X							X		1	0	0.0002	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	3.0E06	ν_{xy}	0.3	α_x	12.5E-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, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

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

FIGURE III-E.4 SYSTEM CONTROL INFORMATION, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C	O	O	R	D		(/)

GRIDPOINT COORDINATE

	DIRECTIONS			
Grid Point Number	X – R	Y – θ	Z – Z	
7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
1	20.0	0.0	0.0	(/)
2	20.0	0.0	17.5	(/)
3	20.0	0.0	35.0	(/)

FIGURE III-E.5 GRIDPOINT COORDINATES, THIN WALLED CYLINDER

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	0	1	0	1	0	1	0	1	(/)

LISTED INPUT

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

FIGURE III-E.6 BOUNDARY CONDITIONS, THIN WALLED CYLINDER

BAC 1627

MAGIC STRUCT
INPUT

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

Columns 1–12	Condition Number	Scaler	
LCOND	1	1.0	(/)

1–6	
MODAL	

EX

Grid Pt. Number	Repeat	FORCE VALUES Fx	FORCE VALUES Fy	FORCE VALUES Fz		MOM Mx
3		1[illegible]15.4	0.0	0.0	(/)	0.0

FIGURE III-E.7 EXTERNAL LOADS, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

MOMENT VALUES			GENERALIZED VALUES		
M_x	M_y	M_z	1	2	3
0.0	-125663.6	0.0	0.0	0.0	0.0

BAC 1628

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)	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 (36–39)	2 (40–43)	3 (44–47)	4 (48–51)	5 (52–55)	6 (56–59)	7 (60–63)	8 (64–67)	9 (68–71)	10 (72–75)	11 (76–79)	12 (80–83)	
1	30	12				X			X	2		2	1											(/)
2	30	12				X				2		3	2											(/)

FIGURE III-E.8 ELEMENT CONTROL DATA, THIN WALLED CYLINDER

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Missing Page/s That Are
Unavailable In The
Original Document

OR are
Blank pgs.
that have
Been Removed

**BEST
AVAILABLE COPY**

BAC 1628-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

Card (cols 1–6)	A (cols 13–22)	B (cols 23–32)	C (cols 33–42)	D (cols 43–52)	E (cols 53–62)	F (cols 63–72)
MODAL	3.0	0.0	90.0	90.0		

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

FIGURE III-E.9 ELEMENT INPUT, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

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

E	N	D	(/)
1	2	3	

FIGURE III-E.10 END CARD, THIN WALLED CYLINDER

The output supplied by the MAGIC System for the cylindrical shell subjected to edge loading is as follows:

Figures III-E.11 through III-E.15 display the output from the Structural System Monitor. These figures display the input data pertinent to the particular problem being solved.

Figure III-E.12 displays the coordinate and boundary condition information for this problem. In the Boundary Condition Section, note that there are 9 degrees of freedom per point for the toroidal ring element as follows:

$$u,\ o,\ w,\ o,\ u',\ o,\ w',\ o,\ w''$$

The reader is referred to Section II.C-16.d of this report for a complete description of the meaning and significance of the above degrees of freedom.

In Figure III-E.13 the finite element information is displayed. Under the section External Input for Elements 1 and 2 the first entry printed is the element thickness of 3.00. The next entry printed is the control input, TCØ, which defines the axis of reference. In this case TCØ = 0.0 which causes the displacement behavior to be referenced to the Global System Axis. The next two entries printed are the quantities α_1 and α_2 respectively. These are defined as the angles measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node points 1 and 2 respectively. Since this particular problem is a cylinder, $\alpha_1 = \alpha_2 = 90.0$ degrees.

System level matrix output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figures III-E.15 through III-E.17.

Figure III-E.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is presented row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-E.12. For this case the order of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2,\ w_2,\ u_2',\ w_2',\ w_2'',\ u_3,\ w_3,\ u_3',\ w_3',\ w_3 \rfloor$$

The first item of information presented in Figure III-E.16 is the reduced Externally Applied Load Vector (LOADR). The size of this vector is 10 x 1. This is true because there are 10 degrees of freedom in the reduced stiffness matrix. There are two non-zero values of force shown in this vector. These values correspond to reduced degrees of freedom (REDDOF) 6 and 8. From the Boundary Condition Section (Figure III-E.13) it is seen that the first force corresponds to an applied force of 188490.0 acting in the R direction of node point 3 while the second is the applied moment of 125660.0 causing bending about the Y(Θ) axis. The vector of displacements (DISPR) is also presented in Figure III-E.16. This vector is also a 10 x 1 due to the reasons which were previously cited. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-E.13. The ordering of the displacement vector is as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISPL. VALUE
1	2	u	-0.00134100
2	2	w	0.000058635
3	2	u'	-0.000164288
4	2	w'	0.000007016
5	2	w"	0.000030511
6	3	u	0.0245307
7	3	w	-0.000983503
8	3	u'	0.00447184
9	3	w'	-0.000345566
10	3	w"	0.000202298

The next item of information shown in the figure is the vector of element stresses (STRESS). The size of the element stress matrix is 30 x 1. In the toroidal ring element, stresses are evaluated at the two ends of the element as well as at the midspan of the element.

Five values of stress are displayed per point on each element, giving a total of 15 stresses per element. Since there were two elements used in this evaluation, the size of the stress matrix is 30 x 1.

The stress resultants for the toroidal ring are referenced to the element axes. The following are the stress resultants displayed for the toroidal ring element. (See sketches.)

$$T_{\xi} = \int_{z} \sigma_{\xi} \, d\,z \; ; \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

$$T_{\beta} = \int_{z} \sigma_{\beta} \, d\,z \; ; \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

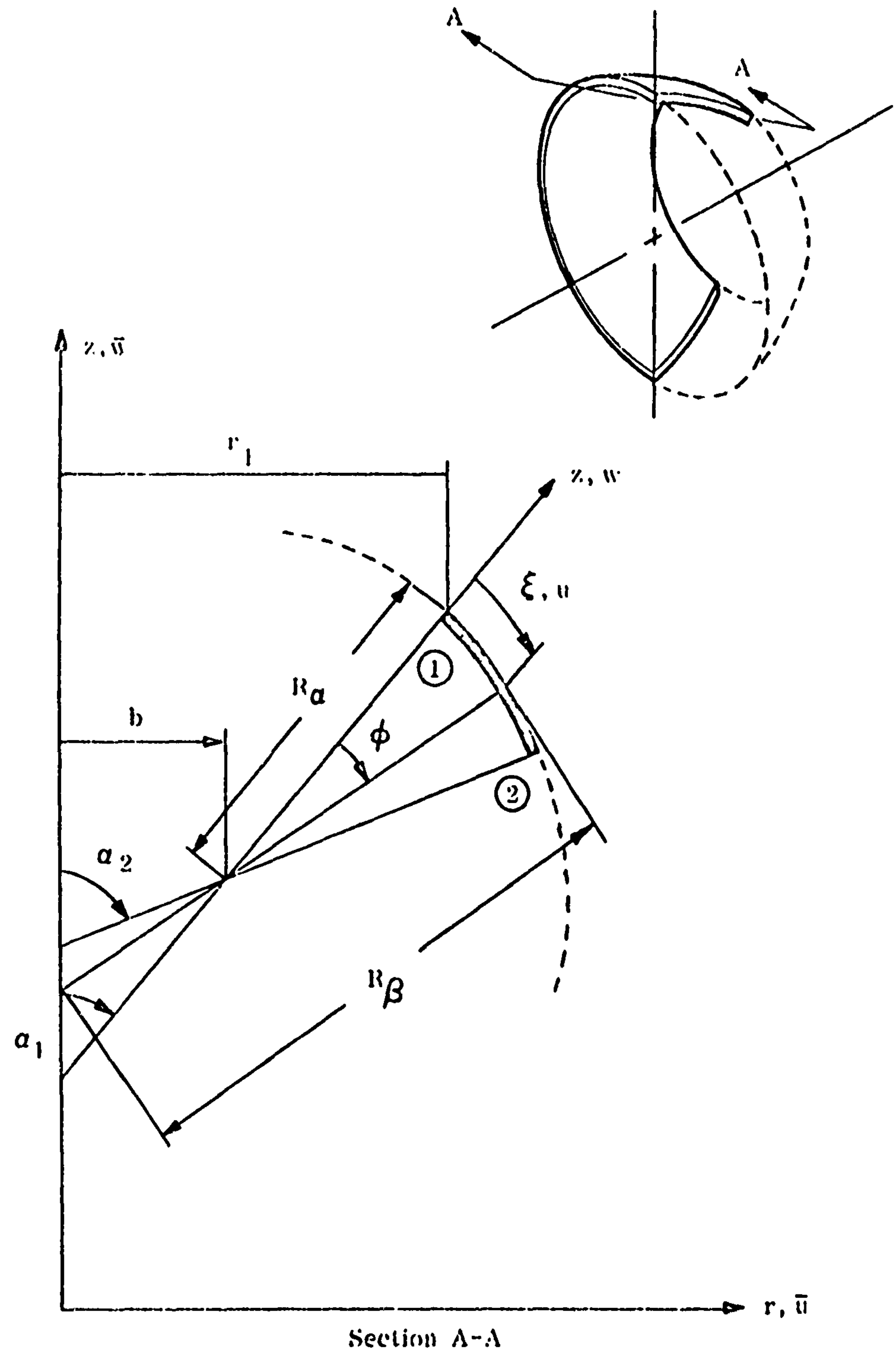
$$M_{\beta} = \int_{z} z \, \sigma_{\xi} \, d\,z \; ; \qquad \text{units, } \frac{(\text{force}) \times (\text{length})}{(\text{length})}$$

$$M_{\xi} = -\int_{z} z \, \sigma_{\beta} \, d\,z \; ; \qquad \text{units, } \frac{(\text{force}) \times (\text{length})}{(\text{length})}$$

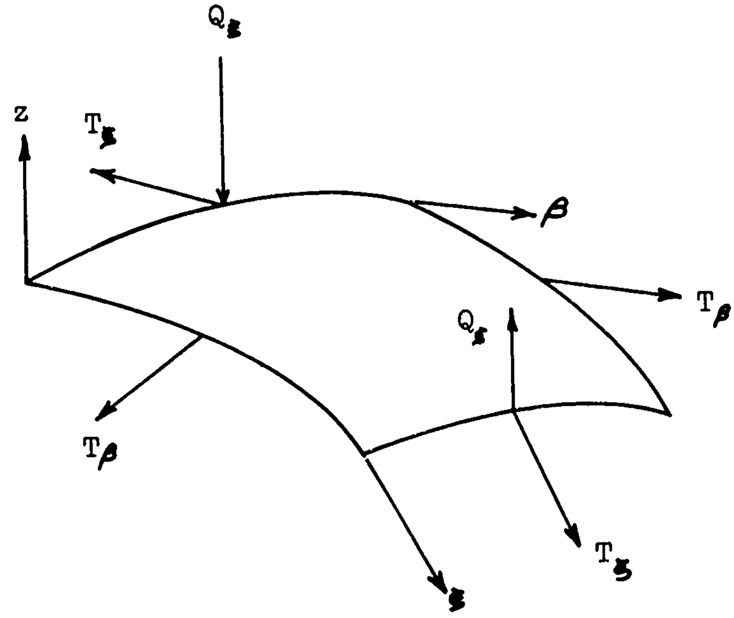
$$Q_{\xi} = \lambda_2 \left[M_{\beta} + M_{\xi} \right] + \frac{\partial M_{\beta}}{\partial \xi} \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

where $\lambda_2 = \frac{1}{B} \frac{\partial B}{\partial \xi}$

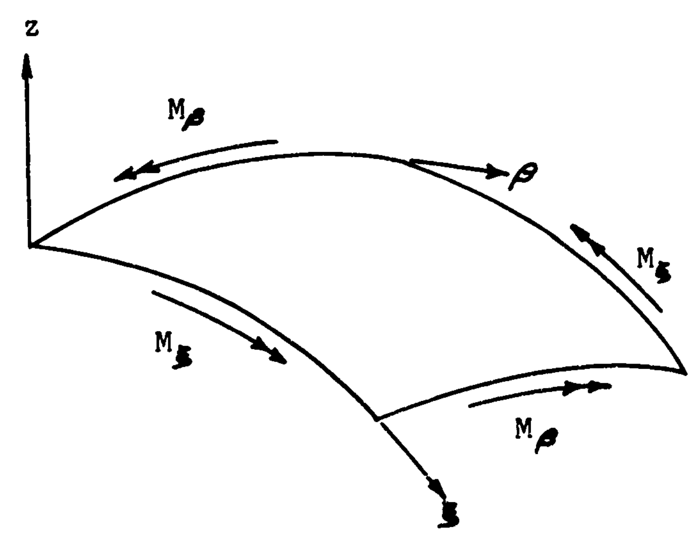
and B is a metric parameter which is explicitly defined in Volume I, Section 7, Equation 180.



Toroidal Thin Shell Ring Representation



Q$_\xi$
z
T$_\xi$
β
T$_\beta$
Q$_\xi$
T$_\beta$
T$_\xi$
ξ



z
M$_\beta$
β
M$_\xi$
M$_\xi$
M$_\beta$
ξ

The ordering of the stress matrix is as follows: (Note that only non-zero terms are displayed.

MATRIX STRESS

NRSEL	ELEMENT	STRESS	NODE POINT
1	1	T_ξ = -129.553	2
2	1	T_β = -642.314	2
3	1	M_β = -226.319	2
4	1	M_ξ = 67.8958	2
5	1	Q_ξ = 148.283	2
6	1	T_ξ = 21.1932	midspan
7	1	T_β = -27.5149	midspan
8	1	M_β = 161.033	midspan
9	1	M_ξ = -48.3098	midspan
10	1	Q_ξ = -23.9065	midspan
11	1	T_ξ = 0.0000039 = 0	1
12	1	T_β = -0.000062 = 0	1
13	1	M_β = -0.0001029 = 0	1
14	1	M_ξ = -0.00000264 = 0	1
15	1	Q_ξ = 22.9380	1

MATRIX STRESS (CONTD)

NRSEL	ELEMENT	STRESS	NODE POINT
16	2	T_ξ = 221.507	3
17	2	T_β = 11105.3	3
18	2	M_β = -1500.56	3
19	2	M_ξ = 450.168	3
20	2	Q_ξ = -922.321	3
21	2	T_ξ = -41.6175	midspan
22	2	T_β = 1.93298	midspan
23	2	M_β = -2515.90	midspan
24	2	M_ξ = 754.770	midspan
25	2	Q_ξ = 381.529	midspan
26	2	T_ξ = -129.552	2
27	2	T_β = -642.311	2
28	2	M_β = -226.319	2
29	2	M_ξ = 67.8961	2
30	2	Q_ξ = -166.911	2

The element forces are presented in Figure III-E.17. The Matrix Force vector is a 36 x 1 vector for the following reason. Each toroidal ring element is defined by two node points. There are nine forces per node point which correspond to the nine displacement degrees of freedom per point., i.e.

$$\{Disp\}^T = \lfloor u, o, w, o, u', o, w', o, w'' \rfloor$$

The interpretation of the forces is dependent upon the code TCØ which was used in the element input section. A code of TCØ = -1.0 references the displacement behavior and the force behavior to the element axes. A code of TCØ = 0.0 (which was used in this particular problem) references the displacement and force behavior to the Global System Axis. The ordering of the force output is as follows:

$$\{Force\}^T = \lfloor F_R, 0, F_z, 0, M_\beta, 0, F_1, 0, F_3 \rfloor$$

where F_R is the force in the system radial direction

F_Z is the force in the system axial direction

M_β is the meriodional moment

F_1 and F_3 are the generalized forces corresponding to the w' and w" respectively

There are a total of 18 forces given per element (9 at each end). Since there are two elements used in this analysis, the vector of Matrix Forces is of the order 36 x 1. The ordering of these MATRIX FORCES is as follows:

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	F_R = -13691.7	2
2	1	———	2
3	1	F_Z = 0.0711212	2
4	1	———	2
5	1	M_β = -9446.86	2
6	1	———	2
7	1	F_1 = -34514.0	2
8	1	———	2
9	1	F_3 = 26589.6	2
10	1	F_R = -1806.08	1
11	1	———	1
12	1	F_Z = -0.0694885	1
13	1	———	1
14	1	M_β = -964.453	1
15	1	———	1
16	1	F_1 = 7841.03	1
17	1	———	1
18	1	F_3 = 8589.15	1

MATRIX FORCES (CONTD)

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
19	2	F_R = 188500.0	3
20	2	———	3
21	2	F_Z = -0.00402832	3
22	2	———	3
23	2	M_β = 125660.0	3
24	2	———	3
25	2	F_1 = 0.0185547	3
26	2	———	3
27	2	F_3 = -0.140625	3
28	2	F_R = 13691.7	2
29	2	———	2
30	2	F_Z = -0.0653076	2
31	2	———	2
32	2	M_β = -9446.86	2
33	2	———	2
34	2	F_1 = 34514.0	2
35	2	———	2
36	2	F_3 = -26589.6	2

Note again that for this particular problem, the forces are referenced to the Global System Axes. If the Code TCØ = -1.0 would have been used the force behavior would have been referenced to the element axis and would have had the following form:

$$\{Force\}^T = \lfloor F_m, o, F_n, o, M_\beta, o, F_1, o, F_3 \rfloor$$

where F_m is the membrance force

F_n is the normal force

M_β is the meriodional moment

F_1 and F_3 are the generalized forces corresponding to the w' and w" respectively.

The final item of information contained in Figure III-E.17 is the vector of reactions (MATRIX REACT). This vector is of the size 27 x 1 since there are three node points associated with this problem and provision for nine associated degrees of freedom per point. The reactions are read row-wise and are interpreted as follows:

MATRIX REACT

D.O.F.	REACTION	NODE POINT
1	P_{RR} = -1806.08	1
2		1
3	P_{RZ} = -0.0694885	1
4		1
5	$M_{R\beta}$ = -964.453	1
6		1
7	F_{R1} = 7841.03	1
8		1
9	F_{R3} = 8589.15	1
(10-27)		(2 and 3)

```
CYLINDRICAL SHELL SUBJECTED TO END LOADINGS

TWO TOROIDAL RING ELEMENTS USED IN THE IDEALIZATION

REFERENCE- KLEIN,S. STUDY OF THE MATRIX DISPLACEMENT METHOD APPLIED

TO SHELLS OF REVOLUTION,CONFERENCE ON MATRIX METHODS IN STR. MECH.

WRIGHT-PATTERSON AFB, 1965

                         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    E= 3.0E6, NU=0.30            INPUT CODE   1
     NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
     NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
     MASS DENSITY. . . . . . . . . . . . . . .-0.

   MATERIAL PROPERTIES

                      YOUNG'S MODULI                              POISSON'S RATIOS

                        DIRECTIONS                                   DIRECTIONS
 TEMPERATURE
                 XX              YY              ZZ              XY              YZ              ZX
    0.      0.300000E 07    0.300000E 07    0.300000E 07    0.300000E 00    0.300000E 00    0.300000E 00
                 THERMAL EXPANSION COEFFICIENTS                     RIGIDITY MODULI

                        DIRECTIONS                                   DIRECTIONS
 TEMPERATURE
                 XX              YY              ZZ              XY              YZ              ZX
    0.      0.125000E-04    0.125000E-04    0.125000E-04    0.115385E 07    0.115385E 07    0.115385E 07

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


FIGURE III-E.11 TITLE AND MATERIAL DATA OUTPUT, THIN WALLED CYLINDER

3 REF. POINTS

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

GRIDPOINT DATA

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.20000000E 02	0.	0.	0. 0.	0. 0.
2	C.20000000E 02	0.	0.17500000E 02	0. 0.	0. 0.
3	C.20000000E 02	0.	0.35000000E 02	0. 0.	0. 0.

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM									
1	0	0	0	0	C	0	0	0	0	0
2	1	0	1	0	1	0	1	0	1	5
3	1	0	1	0	1	0	1	0	1	10

FIGURE III-E.12 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, THIN WALLED CYLINDER

```
                                   TOTAL NO. ELEMENTS =      2

ELEM TYPE  PAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  30       12    0 -0.            2    2      2   1

MATERIAL NUMBER. . . . . . . .    12
     MATERIAL IDENTIFICATION. . . .  E= 3.0E6, MU=0.30
     ANALYSIS CAPABILITY. . . . . .      ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -        0.
     YOUNG'S MODULI                       0.30000000E 07     0.30000000E 07     0.30000000E 07
     POISSON'S RATIOS                     0.30000000E 00     0.30000000E 00     0.30000000E 00
     THERMAL EXPANSION COEFFICIENTS       0.12500000E-04     0.12500000E-04     0.12500000E-04
     RIGIDITY MODULI                      0.11538461E 07     0.11538461E 07     0.11538461E 07

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
            0.30000000E 01     0.                  0.90000000E 02     0.90000000E 02     -0.

ELEM TYPE  PAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  30       12    0  0.            0    2      3   2                            0.3000E 01   0.             0.9000E 02
                                                                                  0.9000E 02  -0.
```

FIGURE III-E.13 FINITE ELEMENT DESCRIPTION OUTPUT, THIN WALLED CYLINDER

```
                         EXTERNAL LOAD CONDITIONS   1

  LOAD NO.   1
    NUMBER OF LOADED NODES    1          ELEMENT LOAD SCALAR =  0.
3  0.18850E 06  0.          0.          0.          0.12566E 06  0.          0.          0.          0.

                  TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN
                                  27 X 1

  0.                  0.                  0.                  0.                  0.                  0.
  0.                  0.                  0.                  0.                  0.                  0.
  0.                  0.                  0.                  0.                  0.                  0.
  0.18850000E 06      0.                  0.                  0.                  0.12566000E 06      0.
  0.                  0.                  0.

                         T-ZERO FOR STRUCTURE = -0.
```

FIGURE III-E.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THIN WALLED CYLINDER

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 10 BY 10

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.485676E 08	2	-0.150000E 02	3	-0.125000E 03	4	0.699091E 08	5	0.214458E 09
		6	0.293304E 07	7	0.932122E 07	8	-0.501150E 07	9	-0.349546E 08	10	0.315374E 08
DISP.	2	1	-0.150000E 02	2	0.170445E 09	3	-0.792303E 08	4	0.450000E 02	5	-0.291000E 03
		6	-0.932120E 07	7	-0.852225E 08	8	0.396151E 08	9	0.124283E 09	10	-0.611702E 08
DISP.	3	1	-0.125000E 03	2	-0.792303E 08	3	0.108418E 10	4	-0.147656E 04	5	-0.241600E 04
		6	0.501169E 07	7	0.396152E 08	8	0.456509E 07	9	-0.129138E 09	10	0.166802E 09
DISP.	4	1	0.699091E 08	2	0.450000E 02	3	-0.147656E 04	4	0.579986E 10	5	-0.118941E 09
		6	-0.349545E 08	7	-0.124283E 09	8	0.129137E 09	9	-0.724983E 09	10	-0.178411E 09
DISP.	5	1	0.214458E 09	2	-0.291000E 03	3	-0.241600E 04	4	-0.118941E 09	5	0.390020E 10
		6	0.315375E 08	7	0.611705E 08	8	-0.166799E 09	9	-0.178415E 09	10	0.692953E 09
DISP.	6	1	0.290304E 07	2	-0.932120E 07	3	0.501169E 07	4	-0.349545E 08	5	0.315375E 08
		6	0.242838E 08	7	0.932120E 07	8	-0.901424E 08	9	0.349546E 08	10	0.107229E 09
DISP.	7	1	0.932122E 07	2	-0.852225E 08	3	0.396152E 08	4	-0.124283E 09	5	0.611705E 08
		6	0.932120E 07	7	0.852225E 08	8	-0.396151E 08	9	-0.124283E 09	10	0.611702E 08
DISP.	8	1	-0.501150E 07	2	0.396151E 08	3	0.456509E 07	4	0.129137E 09	5	-0.166799E 09
		6	-0.901424E 08	7	-0.396151E 08	8	0.542091E 09	9	-0.679777E 07	10	-0.655640E 09
DISP.	9	1	-0.349546E 08	2	0.124283E 09	3	-0.129138E 09	4	-0.724983E 09	5	-0.178415E 09
		6	0.349546E 08	7	-0.124283E 09	8	-0.679777E 07	9	0.289993E 10	10	-0.594693E 08
DISP.	10	1	0.315374E 08	2	-0.611702E 08	3	0.166802E 09	4	-0.178411E 09	5	0.692953E 09
		6	0.107229E 09	7	0.611702E 08	8	-0.655640E 09	9	-0.594693E 08	10	0.195011E 10

FIGURE III-E.15 REDUCED STIFFNESS MATRIX OUTPUT, THIN WALLED CYLINDER

MATRIX LOADR — PAGE 1

CUTOFF = 0. SIZE 10 BY 1

		REDDOF		REDDOF		REDDOF		REDDOF		REDDOF	
COND.	1	6	0.18E500E 06	8	0.125660E 06						

MATRIX DISPR — PAGE 1

CUTOFF = 0. SIZE 10 BY 1

		REDDOF		REDDOF		REDDOF		REDDOF		REDDOF	
COND.	1	1	-0.134100E-02	2	0.586353E-04	3	-0.164288E-03	4	0.701571E-05	5	0.305112E-04
		6	0.245309E-01	7	-0.583503E-03	8	0.447184E-02	9	-0.345566E-03	10	0.202298E-03

MATRIX STRESS — PAGE 1

CUTOFF = 0. SIZE 30 BY 1

		NRSEL		NRSEL		NRSEL		NRSEL		NRSEL	
COND.	1	1	-0.129553E 03	2	-C.642314E 03	3	-C.226319E 03	4	0.678958E 02	5	0.148283E 03
		6	0.211932E 02	7	-0.275149E 02	8	0.161033E 03	9	-0.483098E 02	10	-0.234065E 02
		11	0.391237E-05	12	-0.621506E-04	13	-0.102929E-03	14	-0.264018E-05	15	0.229380E 02
		16	0.221507E 03	17	0.111053E 05	18	-0.150056E 04	19	0.450168E 03	20	-0.922321E 03
		21	-0.416175E 02	22	0.193298E 01	23	-0.251590E 04	24	0.754770E 03	25	0.381529E 03
		26	-0.129552E 03	27	-0.642311E 03	28	-0.226319E 03	29	0.678961E 02	30	-0.166911E 03

FIGURE III-E.16 LOAD, DISPLACEMENT AND STRESS OUTPUT, THIN WALLED CYLINDER

```
                                        MATRIX  FORCES                                              PAGE    1

                     CUTOFF =    0.                                    SIZE    36  BY     1

          D.O.F              D.O.F              D.O.F              D.O.F              D.O.F

COND.    1    1  -0.136917E 05    3   0.711212E-01    5   0.944686E 04    7  -0.345140E 05    9   0.265896E 05
             10  -0.180608E 04   12  -0.654885E-01   14  -0.964453E 03   16   0.784103E 04   18   0.858915E 04
             19   0.188500E 06   21  -0.402832E-02   23   0.125660E 06   25   0.185547E-01   27  -0.140625E 00
             28   0.136917E 05   30  -0.653376E-01   32  -0.944686E 04   34   0.345140E 05   36  -0.265896E 05


                                        MATRIX  REACT                                               PAGE    1

                     CUTOFF =    0.                                    SIZE    27  BY     1

          D.O.F              D.O.F              D.O.F              D.O.F              D.O.F

CCND.    1    1  -0.180608E 04    3  -0.654885E-01    5  -0.964453E 03    7   0.784103E 04    9   0.858915E 04
             10   0.402832E-02   12   0.581360E-02   14   0.610352E-02   16   0.346680E-01   18   0.249023E-01
             19  -0.214844E-01   21  -0.402832E-02   23  -0.390625E-01   25   0.185547E-01   27  -0.140625E 00

$END

         $IESYS
         $REMOVE        SYSLB2
         $IESYS
         $STOP
```

FIGURE III-E.17 FORCE AND REACTION OUTPUT, THIN WALLED CYLINDER

F. SQUARE PLATE - PARABOLIC MEMBRANE LOADING (Quadrilateral Thin Shell Idealization)

An isotropic, square plate under the action of a parabolic membrane loading is shown in Figure III-F.1, along with its dimensions and pertinent material properties. The plate is idealized utilizing one quadrilateral thin shell element.

The preprinted input data forms associated with this example are shown in Figures III-F.2 through III-F.10.

In Figure III-F.5 (Grid Point Coordinate Section) it can be seen that only the grid point coordinates for the four corner points of the element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

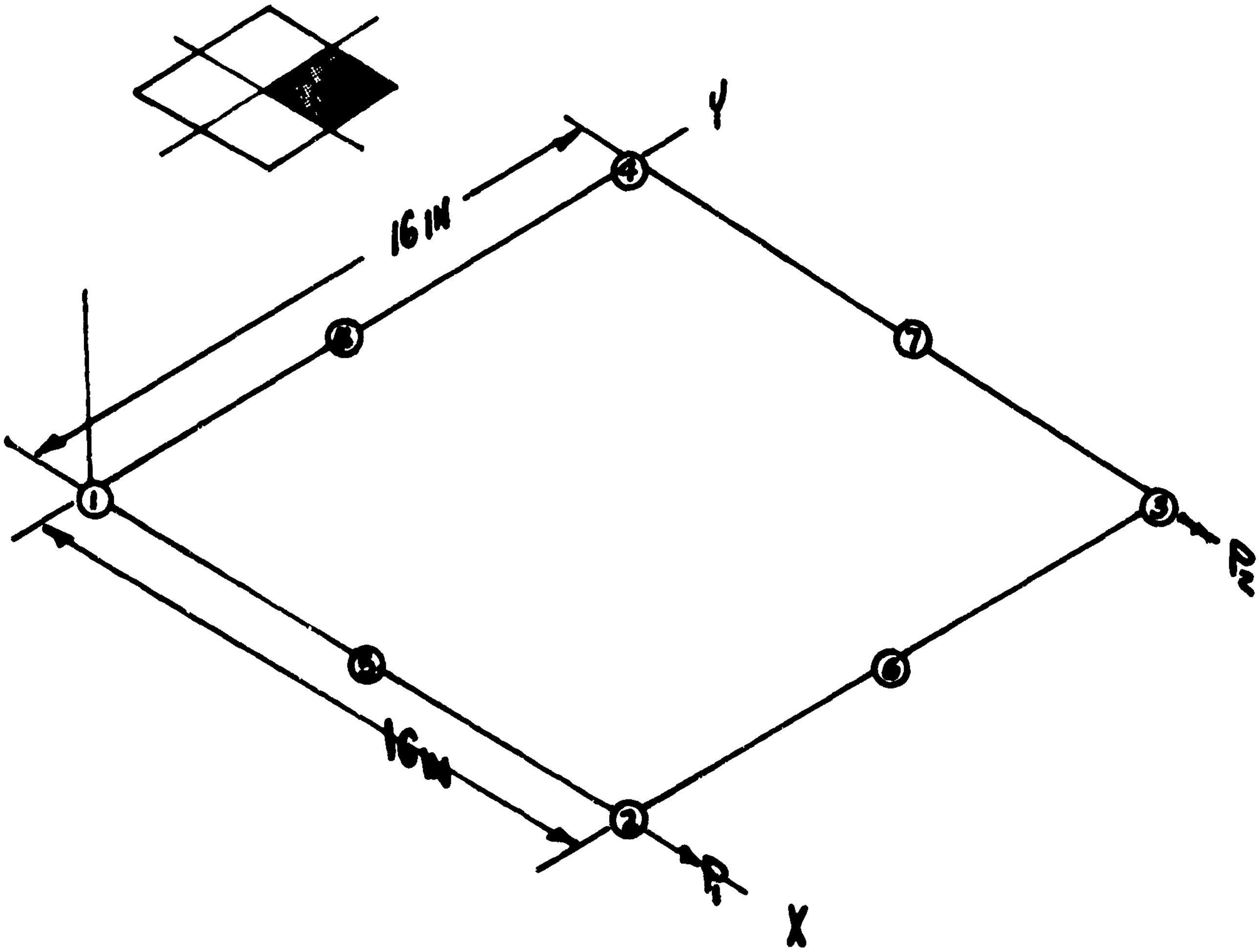
In Figure III-F.6 (Boundary Condition Section) It is instructive to note the extensive use of the Repeat option. Grid point 5 has identical boundary conditions as grid point 2, therefore the Repeat option is exercised by placing an 'X' in column 12 opposite the entry for Grid Point Number 5. The same procedure is also used for Grid Points 3, and 7 as well as for Grid Points 4 and 8. (MODAL entry pertains to Grid Point 1 and to Grid Point 6 which is suppressed).

In Figure III-F.7 (External Loads Section) Grid Points 2 and 3 have applied external loading. Note that there are 2 external load cards per grid point.

In Figure III-F.8 (Element Control Data Section) the following information is of importance.

(1) Mid-point node number 6 is suppressed. The element is therefore numbered 1, 2, 3, 4, 5, 0, 7, 8. These entries are made in the first eight locations of the node point section as shown in Figure III-F.8.

(2) The numbers '1' and '2' are entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points 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 each following element (if they exist) so that the output has a common reference.



$t = 0.10$ INCH $P_1 = 666.67$

$E = 30. \times 10^6$ PSI $P_2 = 400.$

$\mu = .30$

FIGURE III - P.1 - Idealized Square Plate With Parabolic Membrane Loading
(Quadrilateral Thin Shell Idealization)

In Figure III-F.9 (Element Input Section) only one item of information is entered in Location A as follows:

Location A - Membrane Thickness - (t_m) = 0.10

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

6 (/) NUMBER OF TITLE CARDS

Columns 1–72	
QUADRILATERAL SIMPLY SUPPORTED THIN PLATE SUBJECTED TO A SELF-	(/)
EQUILIBRATING PARABOLIC MEMBRANE LOADING- ONE QUADRILATERAL	(/)
THIN SHELL ELEMENT USED IN THE IDEALIZATION, MIDPOINT NODE ON	(/)
THE LOADED SIDE IS SUPPRESSED IN THIS ANALYSIS	(/)
REFERENCE- TIMOSHENKO,S. AND GOODIER, J.N. THEORY OF ELASTICITY SECOND	(/)
EDITION, MC GRAW HILL, NEW YORK, 1951.	(/)
	(/)
	(/)
	(/)

FIGURE III-F.2 TITLE INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

		1
7	8	9

No. of Requests (/)

MATERIAL TAPE INPUT

Request Number (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	12TU		STEEL-E=30.0E6, MU=0.30	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)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	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, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

Item	Request	Columns	Entry
		1 2 3 4 5 6	S Y S T E M (/)
1.	Number of System Grid Points	1 2 3 4 5 6	8
2.	Number of Input Grid Points	7 8 9 10 11 12	4
3.	Number of Degrees of Freedom/Grid Point	13 14	6
4.	Number of Load Conditions	15 16	1
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	1
9.	Number of Requests and/or Revisions of Material Tape.	37 38	1
10.	Number of Input Boundary Condition Points	39 40 41 42 43 44	6
11.	T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	0 . 0 (/)

FIGURE III-F.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – θ	DIRECTIONS Z – Z	
7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
1	0.0	0.0	0.0	(/)
2	16.0	0.0	0.0	(/)
3	16.0	16.0	0.0	(/)
4	0.0	16.0	0.0	(/)

FIGURE III-F.5 GRIDPOINT COORDINATES, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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	
				2		1	0	0	0	0	0				(/)
				5	X										(/)
				3		1	1	0	0	0	0				(/)
				7	X										(/)
				4		0	1	0	0	0	0				(/)
				8	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-F.6 BOUNDARY CONDITIONS, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1627

MAGIC STRUCT
INPUT

1	2	3	4	5	6
L	O	A	D	S	

(/)

Card cols 1–6	Condition Number (cols 7–12)	Scalar (cols 13–22)
LCOND	1	0.0

(/)

1	2	3	4	5	6
M	O	D	A	L	

(/)

EX

Grid Pt. Number	repeat	FORCE VALUES Fx	Fy	Fz		MOM Mx
2		667.67	0.0	0.0	(/)	0.
3		400.00	0.0	0.0	(/)	0.

FIGURE III-F.7 EXTERNAL LOADS, SQUARE PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

MOMENT VALUES			GENERALIZED VALUES		
Mx	My	Mz	1	2	3
0.0	0.0	0.0			
0.0	0.0	0.0			

BAC 1628

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 Assem. 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	21	12				X			X	8		1	2	3	4	5	0	7	8	1	2			(/)
																								(/)
																								(/)
																								(/)
																								(/)
																								(/)
																								(/)
																								(/)
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																								(/)
																								(/)
																								(/)
																								(/)
																								(/)

FIGURE III-F.8 ELEMENT CONTROL DATA, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

MODAL

ELEMENT INPUT

Element Number	Repeat	A	B	C	D	E	F	
1		0.10	0.0	0.0	0.0	0.0		(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

FIGURE III-F.9 ELEMENT INPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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, SQUARE PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the thin square plate subjected to parabolic loading and idealized with one quadrilateral thin shell element is as follows:

Figures III-F.11 thru III-F.13 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

In Figure III-F.12, the finite element information is shown. Under the section titled External Input, the first entry printed has a numerical value of 0.0999999. This value is equal to the membrane thickness of the plate being analyzed.

Figure III-F.13 displays the External Load Column for this problem. The 48 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-F.12. An external load of 667.67 is applied at node point 2 and also a load of 400.0 is applied at node point 3 both in the positive Global X direction.

System level matrix output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figures III-F.14 thru III-F.16. Figure III-F.14 shows the reduced stiffness matrix for this problem. Only non-zero terms in the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-F.12. For this case, the ordering of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2, u_3, v_3, v_4, u_5, u_7, v_7, v_8 \rfloor$$

The reduced externally applied load vector (LOADR) is presented in Figure III-F.15. The size of this vector is 8 x 1. This is true because there are 8 degrees of freedom in the reduced stiffness matrix. There are 2 non-zero values of force shown in this vector. From the figure it is seen that the force values presented correspond to reduced degrees of freedom (REDDOF) 1 and 2. From the Boundary Condition Information (Figure III-F. 12) it is seen that these correspond to forces in the global X direction at node points 2 and 3 having numerical values of 667.67 and 400.0 respectively. The vector of displacements (DISPR) is the next item of information presented in Figure III-F.15. This vector is an 8 x 1 since there are 8 degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-F.12 and is shown as follows:

$$\{ q \}^T = \lfloor u_2, u_3, v_3, v_4, u_5, u_7, v_7, v_8 \rfloor$$

Displacements are referenced to the global axis of reference unless otherwise indicated. The Matrix DISPR is interpreted as follows:

<u>MATRIX DISPR</u>

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	2	u	0.000510389
2	3	u	0.000201391
3	3	v	-0.000021236
4	4	v	-0.000140178
5	5	u	0.000252377
6	7	u	0.000112433
7	7	v	-0.000119797
8	8	v	-0.000091029

The final item of information shown in Figure III-F.15 is the stress matrix (MATRIX STRESS). The stress matrix is of the order 40 x 1 due to the following. Eight Stress resultants are evaluated at each corner point of the element and also at the intersection of the diagonals which connect the opposite corner points of the element. The stress resultants are defined as follows:

$$N_x = \int_x \sigma_x \, d\,z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

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

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

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

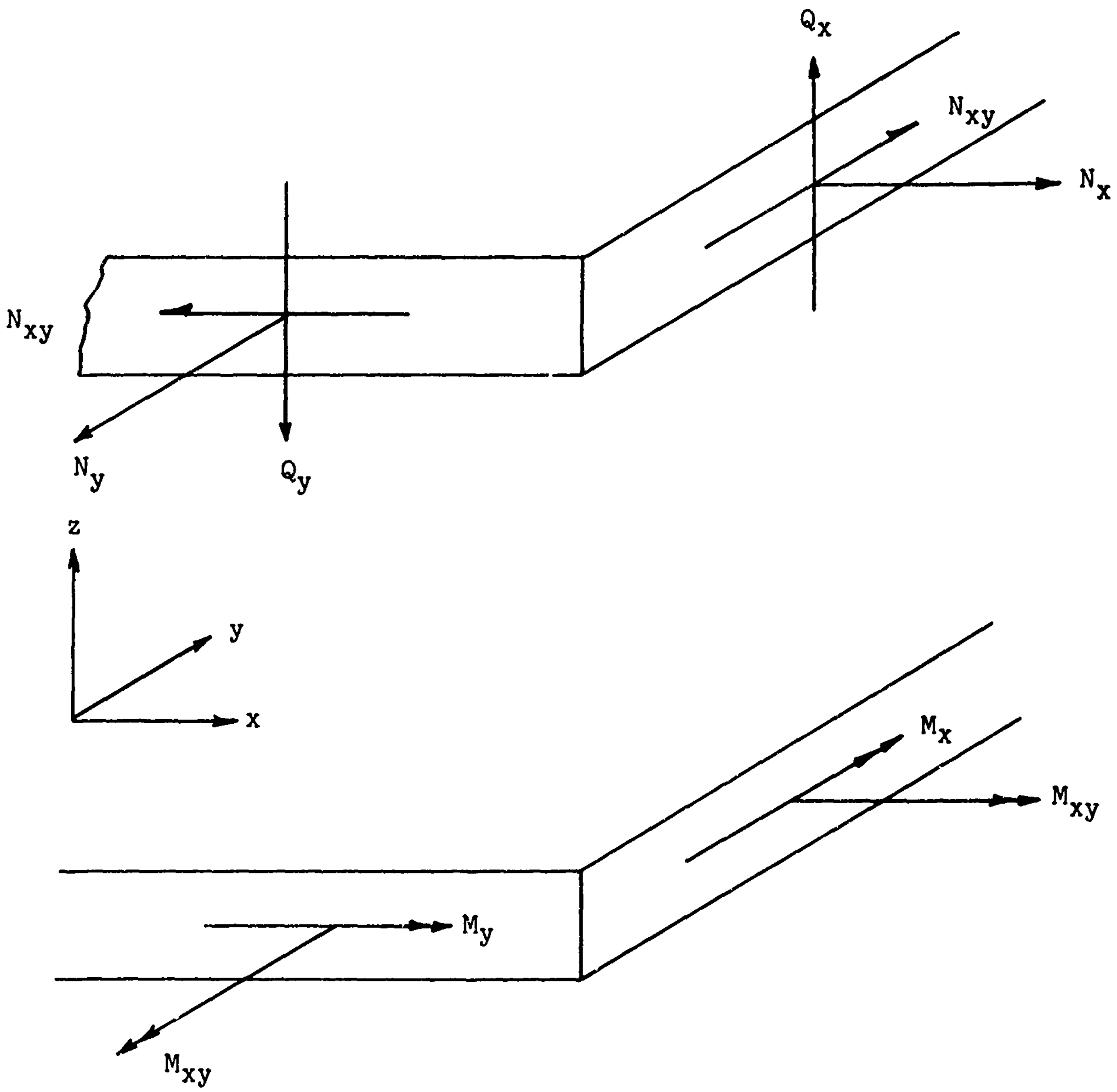
$$M_y = \int_z z\,\sigma_y \, d\,z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

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

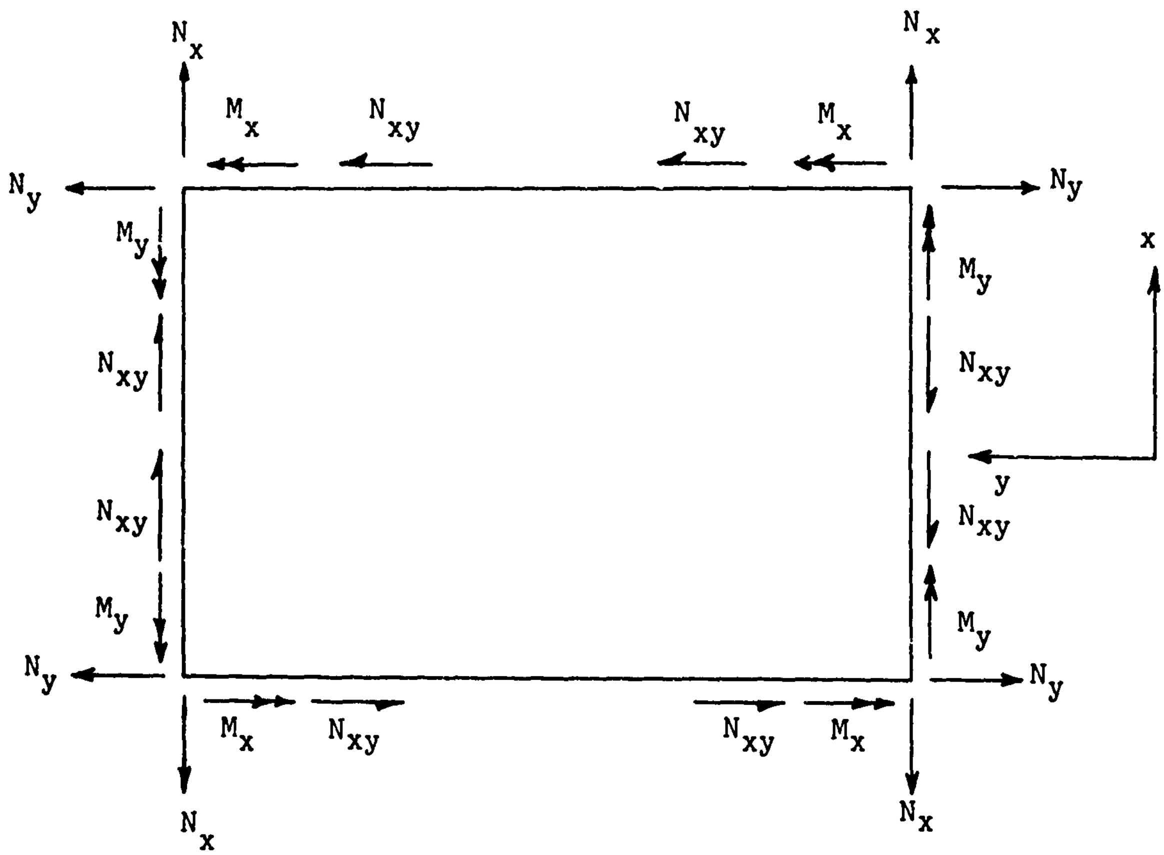
$$Q_x = \int_z z \left(\frac{\partial \sigma_x}{\partial x}\right) d\,z + \int_z z \left(\frac{\partial \tau_{xy}}{\partial y}\right) dz ; \text{ units } \frac{\text{force}}{\text{length}}$$

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

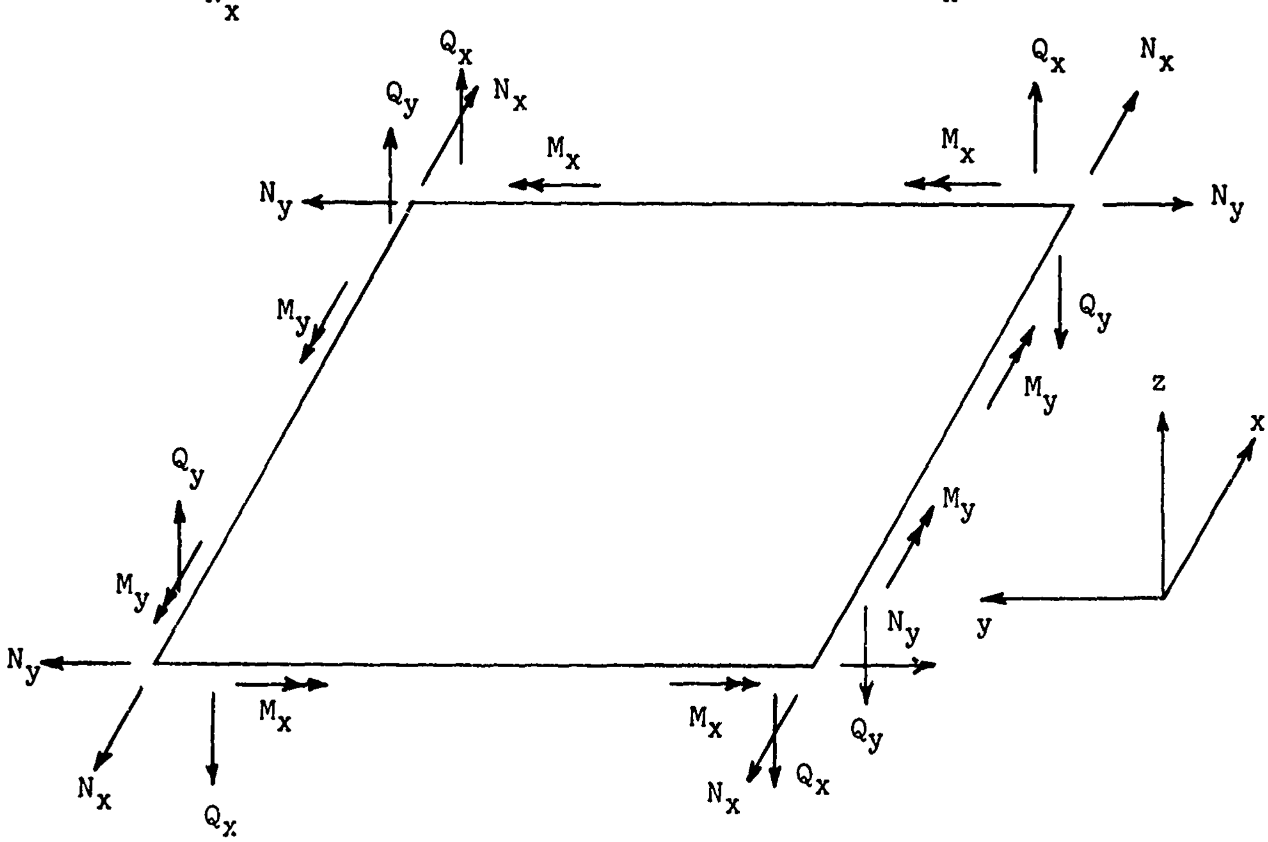
The following sketches show the proper manner in which to interpret the stress resultants.



Stress Resultants



N
x
M
x
N
xy
N
y
M
y
x
y



Q
x
Q
y
N
x
M
x
N
y
M
y
z
x
y

The stress vector is 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 '1' and '2' 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 1 to node point 2.) This axis of reference then becomes the reference axis for the stress output. The ordering of the stress matrix is as follows: (Note that only non-zero terms are printed in the output display.)

MATRIX STRESS

NRSEL	ELEMENT	STRESS RESULTANT	NODE POINT
1	1	N_x = 88.9985	1
2	1	N_y = -15.2888	1
3	1	N_{xy} = -0.00000117	1
9	1	N_x = 106.172	2
10	1	N_y = 27.8697	2
11	1	N_{xy} = -22.2835	2
17	1	N_x = 30.5088	3
18	1	N_y = 5.17088	3
19	1	N_{xy} = -2.41999	3
25	1	N_x = 27.6819	4
26	1	N_y = 3.72625	4
27	1	N_{xy} = -2.69847	4
33	1	N_x = 63.5077	(Int. of Diag.)
34	1	N_y = -10.7390	(Int. of Diag.)
35	1	N_{xy} = -1.73356	(Int. of Diag.)

Figure III-F.16 displays the vector of Matrix Forces. These forces are defined with respect to the Global Coordinate System. The Matrix Force Vector is a 48 x 1 vector for the following reason. The quadrilateral thin shell element is defined by eight node points (4 cornerpoints and 4 mid-side node points). Since there are six forces per node point (F_X, F_Y, F_Z, M_X, M_Y, M_Z) a total of 48 forces per element are defined. The ordering of the Matrix Forces is as follows. (See Figure III-F.1 for the element numbering sequence.)

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	F_X = -225.893	1
2	1	F_Y = 23.6375	1
7	1	F_X = 667.670	2
8	1	F_Y = -141.051	2
13	1	F_X = 400.000	3
14	1	F_Y = 0.00000381 = 0	3
19	1	F_X = -122.911	4
20	1	F_Y = 0.0000305 = 0	4
25	1	F_X = 0.0000591 = 0	5
26	1	F_Y = 117.413	5
37	1	F_X = 0.00000343 = 0	7
38	1	F_Y = -0.00000996 = 0	7
43	1	F_X = -718.866	8
44	1	F_Y = -0.0000153 = 0	8

Note that for this particular problem Mid-Side Node #6 was suppressed.

The final item of information contained in Figure III-F.16 is the vector of reactions (MATRIX REACT). This vector is a 48 x 1 since there are eight node points associated with this problem and six associated degrees of freedom per node point. The reactions are read row-wise and are interpreted as follows: (Note that the reactions are referenced to the Global Coordinate System).

MATRIX REACT

D.O.F.	REACTION	NODE POINT
1	P_{RX} = -225.893	1
2	P_{RY} = 23.6375	1
7	P_{RX} = -0.000069 = 0	2
8	P_{RY} = -141.051	2
13	P_{RX} = -0.000046 = 0	3
14	P_{RY} = -0.000004 = 0	3
19	P_{RX} = -122.911	4
20	P_{RY} = 0.00003 = 0	4
25	P_{RX} = 0.00006 = 0	5
26	P_{RY} = 117.413	5
37	P_{RX} = 0.00003 = 0	7
38	P_{RY} = -0.000009 = 0	7
43	P_{RX} = -718.866	8
44	P_{RY} = 0.00002 = 0	8

```
THIN SQUARE ISOTRCPIC PLATE  SUBJECTED TO A SELF
EQUILIBRATING PARABOLIC MEMBRANE LOADING-ONE QUADRILATERAL
THIN SHELL ELEMENT USED IN THE IDEALIZATION,MIDPOINT NODE  ON
THE LOADED EDGE IS SUPPRESSED IN THIS ANALYSIS
REFERENCE- TIMOSHENKO,S. AND GOODIER,J.N., THEORY OF ELASTICITY,
SECOND EDITION,MCGRAW HILL NEW YORK 1951.
                         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                       INPUT CODE   I
     NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
     NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
     MASS DENSITY. . . . . . . . . . . . . . .-0.

   MATERIAL PROPERTIES

                 YOUNG'S MODULI                                POISSON'S RATIOS

                   DIRECTICNS                                     DIRECTIONS
TEMPERATURE
                XX            YY            ZZ            XY            YZ            ZX
    0.     0.300000E 08  C.300000E 08  0.300000E 08  0.300000E 00  0.300000E 00  0.300000E 00
             THERMAL EXPANSION COEFFICIENTS                    RIGIDITY MODULI

                   DIRECTIGNS                                     DIRECTIONS
TEMPERATURE
                XX            YY            ZZ            XY            YZ            ZX
    0.     -0.           -0.           -0.           0.115385E 08  0.115385E 08  0.115385E 08

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


FIGURE III-F.11 TITLE AND MATERIAL DATA OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

8 REF. POINTS

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

GRIDPOINT DATA

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.	0.	0.	0.	0.
				0.	0.
2	0.16000000E 02	0.	0.	0.	0.
				0.	0.
3	0.16000000E 02	0.16000000E 02	0.	0.	0.
				0.	0.
4	0.	0.16000000E 02	0.	0.	0.
				0.	0.

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						
1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	1
3	1	1	0	0	0	0	3
4	0	1	0	0	0	0	4
5	1	0	0	0	0	0	5
6	0	0	0	0	0	0	5
7	1	1	0	0	0	0	7
8	0	1	0	0	0	0	8

TOTAL NO. ELEMENTS = 1

```
ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  21        12   0 -0.           2    8     1  2  3  4  5  6  7  8       1  2

MATERIAL NUMBER. . . . . . . .  12
     MATERIAL IDENTIFICATION. . . .   STEEL
     ANALYSIS CAPABILITY. . . . . .        ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1


INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -         0.
     YOUNG'S MODULI                       0.30000000E 08    0.30000000E 08    0.30000000E 08
     POISSON'S RATIOS                     0.30000000E 00    0.30000000E 00    0.30000000E 00
     THERMAL EXPANSION COEFFICIENTS      -0.               -0.               -0.
     RIGIDITY MODULI                      0.11538461E 08    0.11538461E 08    0.11538461E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.89999999E 00     0.          0.          0.          0.
```

```
                              EXTERNAL LOAD CONDITIONS    1

LOAD NC.   1
   NUMBER OF LOADED NODES     2          ELEMENT LOAD SCALAR =  0.
2  0.66767E 03  0.            0.         0.            0.            0.
3  0.40000E 03  0.            0.         0.            0.            0.

                         TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                          48 X 1

0.                   0.              0.              0.              0.              0.
0.66767000E 03       0.              0.              0.              0.              0.
0.40000000E 03       0.              0.              0.              0.              0.
0.                   0.              0.              0.              0.              0.
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.
```

FIGURE III-F.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = C. SIZE 8 BY 8

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.293956E 07	2	0.906593E 06	3	-0.412088E 05	4	-0.178571E 06	5	-0.329670E 07
		6	-0.109890E 07	7	0.714286E 06	8	0.585938E-01				
DISP.	2	1	0.906593E 06	2	C.293956E 07	3	0.535714E 06	4	0.137362E 05	5	-0.109890E 07
		6	-0.329670E 07	7	-0.549451E 05	8	C.273438E-01				
DISP.	3	1	-0.412088E 05	2	C.535714E 06	3	0.151099E 07	4	0.384615E 06	5	-0.714286E 06
		6	0.549450E C5	7	-0.115385E 07	8	-0.384615E 06				
DISP.	4	1	-0.178571E 06	2	0.137362E 05	3	0.384615E 06	4	0.296703E 07	5	0.234375E-01
		6	0.659341E 06	7	-0.115385E 07	8	-0.329670E 07				
DISP.	5	1	-0.329670E C7	2	-0.1C9890E 07	3	-0.714286E 06	4	0.234375E-01	5	0.736264E 07
		6	0.142857E 07	7	-C.101563E 00	8	0.142857E 07				
DISP.	6	1	-0.109890E 07	2	-0.329670E 07	3	0.549450E 05	4	0.659341E 06	5	0.142857E 07
		6	0.736264E 07	7	0.156250E 00	8	-0.142857E 07				
DISP.	7	1	0.714286E 06	2	-0.549451E 05	3	-0.115385E 07	4	-0.115385E 07	5	-0.101563E 00
		6	0.156250E 00	7	0.450549E 07	8	0.109375E 00				
DISP.	8	1	0.585938E-01	2	C.273438E-01	3	-0.384615E 06	4	-0.329670E 07	5	0.142857E 07
		6	-0.142857E 07	7	0.1C9375E 00	8	0.736264E 07				

FIGURE III-F.14 REDUCED STIFFNESS MATRIX OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MATRIX LOADR — PAGE 1

CUTOFF = 0. — SIZE 8 BY 1

		REDDOF		REDCOF		REDDOF		REDDOF		REDDOF	
COND.	1	1	0.667670E 03	2	C.4C0000E 03						

MATRIX DISPR — PAGE 1

CUTOFF = C. — SIZE 8 BY 1

		REDCOF		REDDOF		REDDOF		REDOOF		REDDOF	
COND.	1	1	0.510389E-03	2	0.201391E-03	3	-0.212361E-04	4	-0.140178E-03	5	0.252377E-03
		6	0.112433E-03	7	-0.119797E-03	8	-0.910289E-04				

MATRIX STRESS — PAGE 1

CUTOFF = C. — SIZE 40 BY 1

		NRSEL		NRSEL		NRSEL		NRSEL		NRSEL	
COND.	1	1	0.889585E 02	2	-0.152888E 02	3	-0.117351E-05	9	0.106172E 03	10	0.278697E 02
		11	-0.222835E 02	17	0.305088E 02	18	0.517088E 01	19	-0.242999E 01	25	0.476819E 02
		26	0.372625E 01	27	-0.269847E 01	33	0.635077E 02	34	-0.107390E 02	35	-0.173356E 01

FIGURE III-F.15 LOAD, DISPLACEMENT AND STRESS OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

```
                                          MATRIX  FORCES                                       PAGE    1

                        CUTOFF =   0.                                    SIZE    48  BY     1

              D.O.F             D.O.F             D.O.F             D.O.F             D.O.F

COND.     1     1  -0.225893E 03   2   0.236375E 02   7   0.667670E 03   8  -0.141051E 03  13   0.400000E 03
               14   0.381470E-05  19  -0.122911E 03  20   0.305176E-04  25   0.591278E-04  26   0.117413E 03
               37   0.343323E-04  38  -0.995628E-05  43  -0.718866E 03  44  -0.152588E-04


                                          MATRIX  REACT                                        PAGE    1

                        CUTOFF =   0.                                    SIZE    48  BY     1

              D.O.F             D.O.F             D.O.F             D.O.F             D.O.F

COND.     1     1  -0.225893E 03   2   0.236375E 02   7  -0.686646E-04   8  -0.141051E 03  13  -0.457764E-04
               14   0.381470E-05  19  -0.122911E 03  20   0.305176E-04  25   0.591278E-04  26   C.117413E 03
               37   0.343323E-04  38  -C.995628E-05  43  -0.718866E 03  44  -0.152588E-04

$END

          $IBSYS
          $REMOVE          SYSLB2
```

FIGURE III-F.16 FORCE AND REACTION OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

G. SQUARE PLATE - NORMAL PRESSURE LOADING - (Quadrilateral Thin Shell Idealization)

A simply supported isotropic square plate, under the action of normal pressure loading is shown in Figure III-G.1 along with its dimensions and pertinent material properties. This plate is idealized utilizing one quadrilateral thin shell element.

The preprinted input data forms associated with this example are shown in Figures III-G.2 through III-G.11.

In Figure III-G.5 (Gridpoint Coordinate Section) it can be seen that only the gridpoint coordinates for the four corner points of the element are entered. The coordinates associated with mid-point modes are calculated internally by the MAGIC System.

In Figure III-G.6 (Gridpoint Pressure Section) the MODAL entry is used for the input pressure values. This entry means that the normal pressures are acting at every grid point with a value of -1.0 psi. The sign of the pressure is minus since its direction is in the negative element Z_g direction.

In Figure III-G.7 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (see Figure III-G.1). Let us examine the Listed Input (Exceptions to the MODAL Card) first.

(1) Grid Point Number 1 (center of plate) has an unknown displacement in the w direction, all others are zero due to symmetry.

(2) Grid Point Number 2 has an unknown rotation, θ_y. The others are Zero due to the fact that the gridpoint 2 is a point of simple support.

(3) Grid Point Number 3 has all degrees of freedom fixed. This is due to the fact that this is the point where the simple supports meet restricting rotation in the θ_x and θ_y directions.

(4) Grid Point Numbers 5 and 8 are repeated and also have all degrees of freedom fixed. These are midside nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem, u and v are equal to zero. Since Grid Points 5 and 8 lie along symmetric boundaries θ_n equals zero.

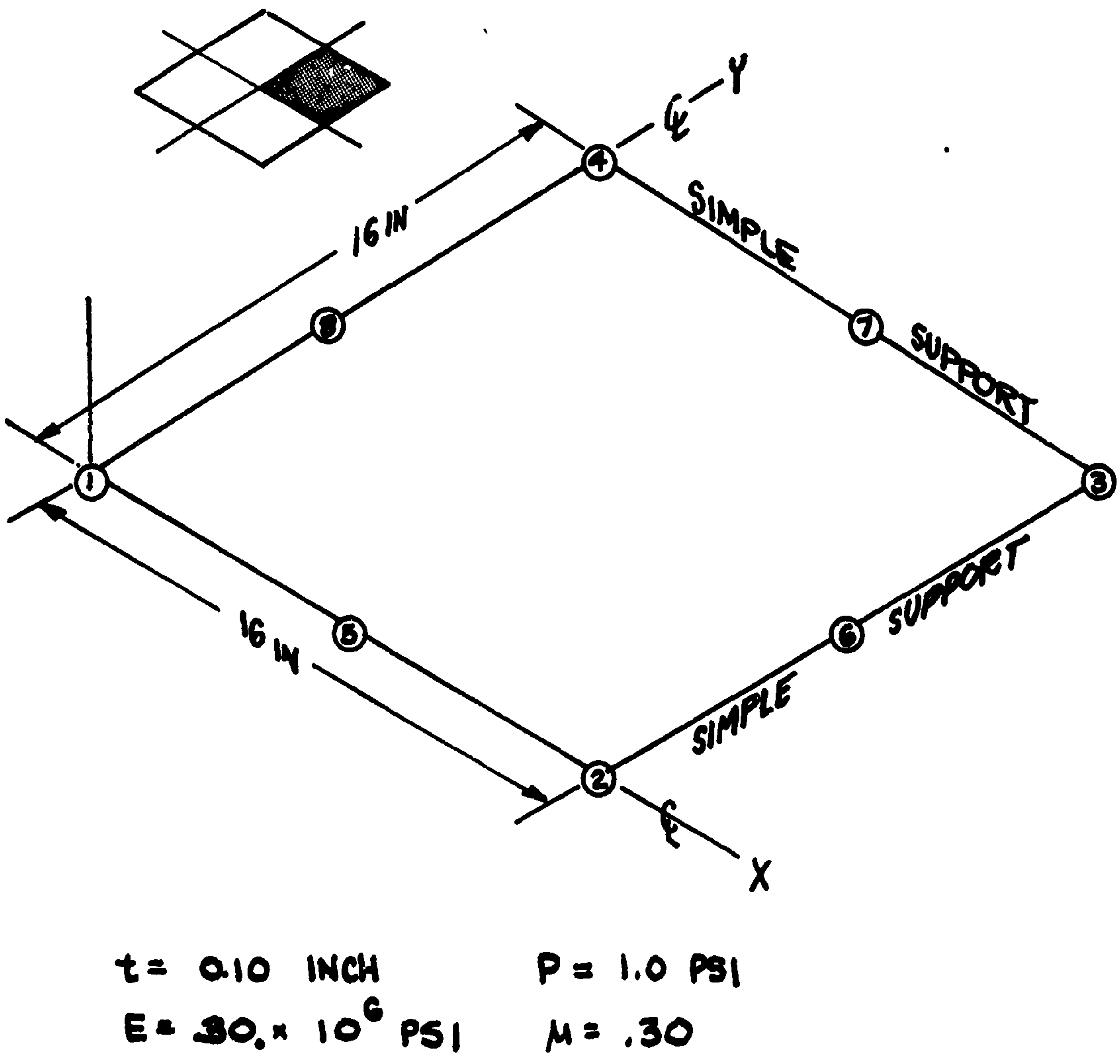


FIGURE III - G.1 - Idealized Simply Supported Plate with Normal Pressure Loading (Quadrilateral Thin Shell Idealization)

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 3, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 4, 6, and 7.

(1) Grid Point Number 4 has an unknown rotation, θ_x. The others are zero since Grid Point 4 is a point of simple support.

(2) Grid Points 6 and 7 are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem, u and v are equal to zero. However, there is an unknown slope θ_n, associated with these grid points. The Code (0, 1, 2) associated with these normal slope values is always entered in the θ_x location for consistency.

In Figure III-G.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed and External Force and Moment values of 0.0 are entered in the appropriate locations. Since the Quadrilateral Thin Shell Element is formulated with six degrees of freedom per point, two external load cards per grid point are required.

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Loads + EALS (Element Applied Loads)

Since the External Loads are equal to zero, and the EALS =

1.0

Total Load = Element Applied Load

These are the correct loads since for this case the Element Applied Loads are equal to the normal pressure loads.

In Figure III-G.9 (Element Control Data Section) the following information is of importance.

(1) The numbers '1' and '2' are entered in locations 11 and 12 of the node point portion of the Element Control Section. These two points define the direction of the (X) stress axis. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis. It should be noted that the stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each following element (if they exist) must be considered separately and node points related to that particular element would be used in determining the stress direction.

In Figure III-G.10 (Element Input Section) only one item of information is entered in Location B as follows:

Location B - Flexural Thickness (t_f) = 0.10

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	
SIMPLY SUPPORTED QUADRILATERAL THIN PLATE SUBJECTED TO A	(/)
UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- ONE QUADRILATERAL	(/)
THIN SHELL ELEMENT USED IN THE IDEALIZATION	(/)
	(/)
	(/)
	(/)
	(/)
	(/)
	(/)

FIGURE III-G.2 TITLE INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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	1Z	TU	STEEL-E=30.0E6, MU=0.30	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)	
0.0	E_x	30.0 E6	ν_{xy}	0 30	α_x	8.50 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, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

		Entry	Columns
		S Y S T E M (/)	1 2 3 4 5 6
1.	Number of System Grid Points	8	1 2 3 4 5 6
2.	Number of Input Grid Points	4	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		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	1	31 32 33 34 35 36
9.	Number of Requests and/or Revisions of Material Tape.	1	37 38
10.	Number of Input Boundary Condition Points	5	39 40 41 42 43 44
11.	T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

FIGURE III-G.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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)	X – R (13–22)	Y – θ (23–32)	Z – Z (33–42)	
1	0.0	0.0	0.0	(/)
2	16.0	0.0	0.0	(/)
3	16.0	16.0	0.0	(/)
4	0.0	16.0	0.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
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				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

FIGURE III-G.5 GRIDPOINT COORDINATES, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

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

1	2	3	4	5	6
M	O	D	A	L	

PRESSURES		
P1 (cols 13–22)	P2 (cols 23–32)	P3 (cols 33–42)
-1.0		

Grid Point Number (cols 7–11)	Repeat (col 12)	P1 (cols 13–22)	P2 (cols 23–32)	P3 (cols 33–42)	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

FIGURE III-G.6 GRIDPOINT PRESSURES, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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	1	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	1	0	0	0				(/)
				2		0	0	0	0	1	0				(/)
				3		0	0	0	0	0	0				(/)
				4											(/)
				5	X										(/)
				8	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-G.7 BOUNDARY CONDITIONS, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1627

MAGIC STRUCTU
INPUT D

1 2 3 4 5 6	
LOADS	(/)

Columns 1–5	Condition Number (columns 6–11)	Scalar (columns 12–22)	
LCOND	1	1.0	(/)

EXT

	FORCE VALUES				MOM
	F_x (columns 13–22)	F_y (columns 23–32)	F_z (columns 33–42)		M_x (columns 13–22)
MODAL	0.0	0.0	0.0	(/)	0.0

Grid Pt. Number (columns 7–11)	repeat (column 12)	F_x (columns 13–22)	F_y (columns 23–32)	F_z (columns 33–42)		M_x (columns 13–22)
					(/)	

FIGURE III-G.8 EXTERNAL LOADS, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

	MOMENT VALUES			GENERALIZED VALUES		
	M_x	M_y	M_z	1	2	3
2	13–22	23–32	33–42	13–22	23–32	33–42
0	0.0	0.0	0.0			

2	13–22	23–32	33–42	13–22	23–32	33–42

B

BAC 1628

ELEM 1 2 3 4 5 6 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT: Print	PRINT: Elem. Mat.	PRINT: Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12	
7 8 9 10	11 12	13 14 15 16 17 18	19	20 21 22 23 24 25 26 27	28	29	30	31	32	33 34	35 36	36 37 38	39 40 41	42 43 44	45 46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61 62	63 64 65	66 67 68	69 70 71	
1	21	12				X			X	8		1	2	3	4	5	6	7	8				12	(/)

FIGURE III-G.9 ELEMENT CONTROL DATA, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

ELEMENT INPUT

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	0.0	0.10	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.10 ELEMENT INPUT, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

CHECK OR END CARD

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

E	N	D	(/)
1	2	3	

FIGURE III-G.11 END CARD, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the simply supported isotopic square plate subjected to a normal pressure load and idealized using one quadrilateral thin shell element is as follows:

Figures III-G.12 through III-G.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

The Gridpoint Data Information is shown in Figure III-G. 13. Note that pressures of -1.0 psi are applied at each gridpoint. The finite element information is also shown in Figure III-G.13. Under the section titled External Input, the second entry has a numerical value of 0.09999999. This value is equal to the flexural thickness of the plate being analyzed.

Figure III-G.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since input pressures are element applied loads.

System level output of final results is handled by the FORMAT standard matrix capability. These results are shown in Figures III-G.15 through III-G.17.

Figure III-G.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is read row-wise and only nonzero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-G.13. For this case the displacement vector is ordered as follows:

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7} \rfloor$$

Where θ_{ni} = normal slope at node point i

Figure III-G.16 displays the vector of Reduced Element Applied Loads (MATRIX FTELAR). The size of this vector is a 5 x 1, since there are five degrees of freedom remaining in the assembled and reduced stiffness matrix. The vector appears as follows and is read row-wise:

MATRIX FTELAR

REDDOF	NODE POINT	ELEMENT APPLIED LOAD VALUE
1	1	F_Z = -64.0000
2	2	M_Y = -102.400
3	4	M_X = -102.400
4	6	M_Y = -136.533
5	7	M_X = -136.533

The vector of displacements (DISPR) is the next item of information presented in Figure III-G.16. This vector is also a 5 x 1 since there are five degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-G.13.

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7} \rfloor$$

The displacements are referred to the global axis of reference unless otherwise indicated.

The MATRIX DISPR is interpreted as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	1	w	-1.55818
2	2	θ_y	-0.163346
3	4	θ_x	-0.163346
4	6	θ_n	-0.117302
5	7	θ_n	-0.117302

The final item of information presented in Figure III-G.16 is the Stress Matrix (MATRIX STRESS). The stress matrix is a 40 x 1 for the following reason. Eight stress resultants are evaluated at each corner point of the quadrilateral and also at the diagonal intersection, giving a total of 40 stress resultants per element.

The stress resultants for the quadrilateral thin shell were explicitly defined in Section III-G (Square Plate-Parabolic Membrane Loading). Sketches were also provided to facilitate proper interpretation of the stress resultants.

The stress vector is 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 '1' and '2' were entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1.

These two points define the x direction of the stress axis (positive x from node point 1 to node point 2). These axes of reference then become the reference stress axis.

The ordering of the stress matrix is as follows:

MATRIX STRESS

NRSEL	ELEMENT	STRESS RESULTANT	NODE POINT
4	1	M_x = -57.5059	1
5	1	M_y = -57.5059	1
6	1	M_{xy} = -0.0000010 = 0	1
7	1	Q_x = -2.86170	1
8	1	Q_y = 3.59377	1
12	1	M_x = -8.28234	2
13	1	M_y = -2.48470	2
14	1	M_{xy} = 2.50353	2
15	1	Q_x = -4.32583	2
16	1	Q_y = 3.59377	2
20	1	M_x = -0.0000007 = 0	3
21	1	M_y = -0.0000019 = 0	3
22	1	M_{xy} = 36.7623	3
23	1	Q_x = -4.32583	3
24	1	Q_y = -3.59377	3
28	1	M_x = -7.13411	4
29	1	M_y = -12.9318	4
30	1	M_{xy} = 0.0000021 = 0	4

MATRIX STRESS

NRSEL	ELEMENT	STRESS RESULTANT	NODE POINT
31	1	Q_x = -2.86170	4
32	1	Q_y = -3.59377	4
36	1	M_x = -34.1365	Int. of Diag.
37	1	M_y = -34.1365	Int. of Diag.
38	1	M_{xy} = 15.4824	Int. of Diag.
39	1	Q_x = -3.59377	Int. of Diag.
40	1	Q_y = -0.00000009=0	Int. of Diag.

Figure III-G.17 presents the vector of element forces. (MATRIX FORCES). These forces are defined with respect to the Global Coordinate System. The Matrix Force vector is a 48 x 1 vector for the following reason. The quadrilateral thin shell element is defined by eight node points (4 corner points and 4 mid-side node points). Since there are six forces per node point (F_X, F_Y, F_Z, M_X, M_Y, M_Z) a total of 48 forces per element are defined. Note that the Mid-side nodes have allowable degrees of freedom equal to u, v, and normal slope (θ_n). Therefore, in a flexure problem, the moment at any mid-side node is associated with the normal slope. The ordering of the Matrix Forces is as follows (See Figure III-G.1 for the element numbering sequence).

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
3	1	F_Z = 0.0000029 = 0	1
4	1	M_X = -136.282	1
5	1	M_Y = 136.282	1
9	1	F_Z = 99.8212	2
10	1	M_X = 252.536	2
11	1	M_Y = 0.0000296 = 0	2
15	1	F_Z = 56.3576	3
16	1	M_X = -190.243	3
17	1	M_Y = 190.243	3
21	1	F_Z = 99.8212	4
22	1	M_X = -0.000033 = 0	4
23	1	M_Y = -252.536	4
28	1	M_N = -376.872	5
34	1	M_N = -0.00000 = 0	6
40	1	M_N = -0.0000134 = 0	7
46	1	M_N = 376.872	8

The final item of information contained in Figure III-G. 17 is the vector of reactions (MATRIX REACT). This vector is a 48 x 1 since there are eight node points associated with this problem and six associated degrees of freedom per node point. The reactions are read row-wise and are interpreted as follows: (Note that the reactions are referenced to the Global Coordinate System.)

MATRIX REACT

D.O.F.	REACTION	NODE POINT
3	P_{RX} = 0.00000 = 0	1
4	M_{RX} = -136.282	1
5	M_{RY} = 136.282	1
9	P_{RZ} = 99.8212	2
10	M_{RX} = 252.536	2
11	M_{RY} = 0.0000296 = 0	2
15	P_{RZ} = 56.3576	3
16	M_{RX} = -190.243	3
17	M_{RY} = 190.243	3
21	P_{RZ} = 99.8212	4
22	M_{RX} = -0.000033 = 0	4
23	M_{RY} = -252.536	4
28	M_{RN} = -376.872	5
34	M_{RN} = -0.0000095 = 0	6
40	M_{RN} = -0.0000134 = 0	7
46	M_{RN} = 376.872	8

```
SIMPLY SUPPORTED ISOTROPIC SQUARE PLATE SUBJECTED TO A
UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- ONE QUADRILATERAL
THIN SHELL ELEMENT USED IN THE IDEALIZATION
                    REVISIONS OF MATERIAL TAPE

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

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

REVISION
  MATERIAL NUMBER      12                              INPUT CODE   I
  MATERIAL IDENTIFICATION     STEEL
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
                        YOUNG'S MODULI                                   POISSON'S RATIOS
                          DIRECTIONS                                       DIRECTIONS
TEMPERATURE                                                    XY               YZ               ZX
                 XX               YY               ZZ    0.300000E 00     0.300000E 00     0.300000E 00
   0.     0.300000E 08     0.300000E 08     0.300000E 08
                                                                          RIGIDITY MODULI
                  THERMAL EXPANSION COEFFICIENTS                            DIRECTIONS
                          DIRECTIONS
TEMPERATURE                                                    XY               YZ               ZX
                 XX               YY               ZZ    0.115385E 08     0.115385E 08     0.115385E 08
   0.      -0.              -0.              -0.

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

FIGURE III-G.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

The final item of information contained in Figure III-G.17 is the vector of reactions (MATRIX REACT). This vector is a 48 x 1 since there are eight node points associated with this problem and six associated degrees of freedom per node point. The reactions are read row-wise and are interpreted as follows: (Note that the reactions are referenced to the Global Coordinate System.)

MATRIX REACT

D.O.F.	REACTION	NODE POINT
3	P_{RX} = 0.00000 = 0	1
4	M_{RX} = -136.282	1
5	M_{RY} = 136.282	1
9	P_{RZ} = 99.8212	2
10	M_{RX} = 252.536	2
11	M_{RY} = 0.0000296 = 0	2
15	P_{RZ} = 56.3576	3
16	M_{RX} = -190.243	3
17	M_{RY} = 190.243	3
21	P_{RZ} = 99.8212	4
22	M_{RX} = -0.000033 = 0	4
23	M_{RY} = -252.536	4
28	M_{RN} = -376.872	5
34	M_{RN} = -0.0000095 = 0	6
40	M_{RN} = -0.0000134 = 0	7
46	M_{RN} = 376.872	8

```
SIMPLY SUPPORTED ISOTROPIC SQUARE PLATE SUBJECTED TO A
UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- ONE QUADRILATERAL
THIN SHELL ELEMENT USED IN THE IDEALIZATION
                         REVISIONS OF MATERIAL TAPE

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

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

REVISION
  MATERIAL NUMBER      12                              INPUT CODE   I
  MATERIAL IDENTIFICATION    STEEL
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
                                                                    POISSON'S RATIOS
                     YOUNG'S MODULI
                                                                       DIRECTIONS
                       DIRECTIONS
TEMPERATURE                                                 XY             YZ             ZX
                 XX             YY             ZZ      0.300000E 00   0.300000E 00   0.300000E 00
   0.      0.300000E 08   0.300000E 08   0.300000E 08
                                                                    RIGIDITY MODULI
             THERMAL EXPANSION COEFFICIENTS
                                                                       DIRECTIONS
                       DIRECTIONS
TEMPERATURE                                                 XY             YZ             ZX
                 XX             YY             ZZ      0.115385E 08   0.115385E 08   0.115385E 08
   0.        -0.            -0.            -0.

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

FIGURE III-G.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

```
                              8 REF. POINTS

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

                              GRIDPOINT DATA

POINT          X                 Y                 Z              TEMPERATURES     PRESSURES
  1      0.                0.                0.                0.               -0.10000000E 01
                                                               0.               -0.
  2      0.14000000E 02    0.                0.                0.               -0.10000000E 01
                                                               0.               -0.
  3      0.14000000E 02    0.14000000E 02    0.                0.               -0.10000000E 01
                                                               0.               -0.
  4      0.                0.14000000E 02    0.                0.               -0.10000000E 01
                                                               0.               -0.

                        BOUNDARY CONDITION INFORMATION

     NODES        DEGREES OF FREEDOM

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

                              TOTAL NO. ELEMENTS =     1

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  21       12    0 -0.          2     8     1  2  3  4  5  6  7  8      -0  -0   1   2

MATERIAL NUMBER. . . . . . . . .   12
     MATERIAL IDENTIFICATION. . . .   STEEL
     ANALYSIS CAPABILITY. . . . . .       ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1


INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -       0.
     YOUNG'S MODULI                       0.30000000E 08     0.30000000E 08     0.30000000E 08
     POISSON'S RATIOS                     0.30000000E 00     0.30000000E 00     0.30000000E 00
     THERMAL EXPANSION COEFFICIENTS     -0.                 -0.                 -0.
     RIGIDITY MODULI                      0.11538461E 08     0.11538461E 08     0.11538461E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.               0.99999999E 00    0.                 0.                 0.
```

FIGURE III-G.13 GRID POINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 8 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.

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.

T-ZERO FOR STRUCTURE = 0.

FIGURE III-G.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 5 BY 5

			FORCE		FORCE		FORCE		FORCE		FORCE
DISP.	1	1	0.128777E 03	2	-0.171703E 03	3	0.171703E 03	4	-0.343407E 03	5	-0.343407E 03
DISP.	2	1	-0.171703E 03	2	0.618132E 04	3	-0.686813E 03	4	-0.549450E 04	5	-0.915751E 03
DISP.	3	1	0.171703E 03	2	-0.686813E 03	3	0.618132E 04	4	0.915751E 03	5	0.549450E 04
DISP.	4	1	-0.343407E 03	2	-0.549450E 04	3	0.915751E 03	4	0.183150E 05	5	-0.366300E 04
DISP.	5	1	-0.343407E 03	2	-0.915751E 03	3	0.549450E 04	4	-0.366300E 04	5	0.183150E 05

MATRIX FTELAR PAGE 1

CUTOFF = 0. SIZE 5 BY 1

			REDDOF		REDDOF		REDDOF		REDDOF		REDDOF
COND.	1	1	-0.640000E 02	2	-0.102400E 03	3	0.102400E 03	4	-0.136533E 03	5	-0.136533E 03

FIGURE III-G.15 REDUCED STIFFNESS MATRIX AND REDUCED ELEMENT APPLIED LOADS, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

```
                                      MATRIX  LOADR                                        PAGE    1
                    CUTOFF =    0.                                 SIZE     5  BY     1
        NULL MATRIX


                                      MATRIX  DISPR                                        PAGE    1
                    CUTOFF =    0.                                 SIZE     5  BY     1
           REDDOF              REDDOF              REDDOF              REDDOF              REDDOF
COND.    1    1  -0.155818E 01    2  -0.163346E 00    3   0.163346E 00    4  -0.117302E 00    5  -0.117302E 00


                                      MATRIX  STRESS                                       PAGE    1
                    CUTOFF =    0.                                 SIZE    40  BY     1
           NRSEL               NRSEL               NRSEL               NRSFL               NRSFL
COND.    1    4  -0.575059E 02    5  -0.575059E 02    6  -0.103504E-05    7  -0.286170E 01    8   0.359377E 01
             12  -0.828234E 01   13  -0.248470E 01   14   0.250353E 01   15  -0.432583E 01   16   0.359377E 01
             20  -0.715256E-06   21  -0.190735E-05   22   0.367623E 02   23  -0.432583E 01   24  -0.359377E 01
             28  -0.713411E 01   29  -0.129318E 02   30   0.212396E-05   31  -0.286170E 01   32  -0.359377E 01
             36  -0.341365E 02   37  -0.341365E 02   38   0.154824E 02   39  -0.359377E 01   40  -0.894070E-07
```

FIGURE III-G.16 LOAD, DISPLACEMENT AND STRESS OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

```
                                    MATRIX  FORCES                                              PAGE    1
                                                                      SIZE    48  BY      1
                      CUTOFF =   0.
            D.O.F              D.O.F              D.O.F              D.O.F              D.O.F
COND.   1     3   0.286102E-05   4  -0.136282E 03   5   0.136282E 03   9   0.998212E 02  10   0.252536E 03
             11   0.295639E-04  15   0.563576E 02  16  -0.190243E 03  17   0.190243E 03  21   0.998212E 02
             22  -0.333786E-04  23  -0.252536E 03  28  -0.376872E 03  34  -0.953674E-05  40  -0.133514E-04
             46   0.376872E 03

                                    MATRIX  REACT                                               PAGE    1
                                                                      SIZE    48  BY      1
                      CUTOFF =   0.
            D.O.F              D.O.F              D.O.F              D.O.F              D.O.F
COND.   1     3   0.286102E-05   4  -0.136282E 03   5   0.136282E 03   9   0.998212E 02  10   0.252536E 03
             11   0.295639E-04  15   0.563576E 02  16  -0.190243E 03  17   0.190243E 03  21   0.998212E 02
             22  -0.333786E-04  23  -0.252536E 03  28  -0.376872E 03  34  -0.953674E-05  40  -0.133514E-04
             46   0.376872E 03

$END

        $IBSYS
        $REMOVE        SYSLB2
        $END
         NOT A BASIC MONITOR CONTROL CARD
        PRESS START TO IGNORE OR
        PROVIDE CLARIFICATION IN CARD READER
        OPER. ACTION PAUSE

        ..CONTINUING

        $IBSYS
        $STOP
```

FIGURE III-G.17 FORCE AND REACTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

H. SQUARE PLATE - PARABOLIC MEMBRANE LOADING (Triangular Thin Shell Idealization)

An isotropic, square plate under the action of a parabolic membrane loading is shown in Figure III-H.1, along with its dimensions and pertinent material properties. The plate is idealized utilizing two triangular thin shell elements.

The preprinted input data forms associated with this example are shown in Figures III-H.2 through III-H.10.

In Figure III-H.5 (Gridpoint Coordinate Section) it can be seen that only the grid point coordinates for the three corner points of each element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

In Figure III-H.6 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (See Figure III-H.1). Remember that in a pure membrane problem, u and v are the only degrees of freedom which are of interest.

Let us examine the Listed Input (Exceptions to the MODAL Card) first.

(1) Grid Point Number 1 (Center of Plate) has all degrees of freedom fixed. This is true because this grid point is at the center of the plate and the plate is loaded by a self-equilibrating parabolic membrane load.

(2) Grid Point Numbers 2 and 5 only have an unknown displacement in the u direction. This is true because these grid points lie along a symmetric boundary defined by the X axis.

(3) Grid Point Numbers 4 and 8 only have an unknown displacement in the v direction. This is true because these grid points lie along a symmetric boundary defined by the Y axis.

(4) Grid Point Number 6 is suppressed, therefore, all associated degrees of freedom are fixed.

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 4, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 3, 7, and 9.

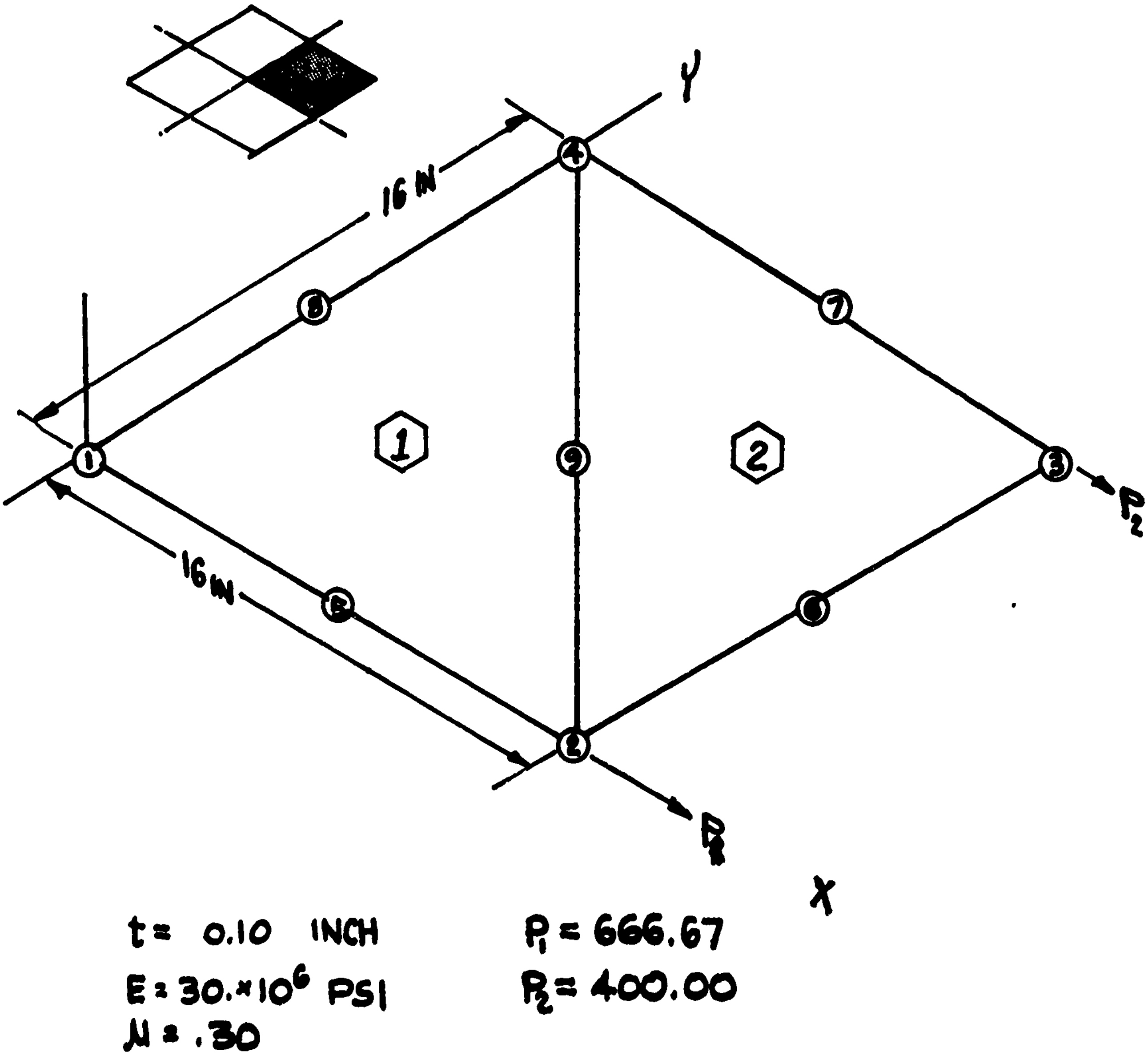


FIGURE III - H.1 - Idealized Square Plate, Parabolic Membrane Loading (Triangular Thin Shell Idealization)

Grid Point Numbers 3, 7, and 9 have unknown displacements both in the u and v directions.

In Figure III-H.7 (External Loads Section) Grid Points 2 and 3 have applied external loading. Note that there are two external load cards per grid point.

In Figure III-H.8 (Element Control Data Section) the following information is of importance.

(1) For element number 2, mid-point node number 6 is suppressed. This element is therefore numbered 2, 3, 4, 0, 7, 9. These entries are made in the first six locations of the node point section as shown in Figure III-H.8.

(2) For element numbers 1 and 2, the numbers '1' and '2' are entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points 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 Element Number 1, can also be used for Element Number 2 as shown in the figure.

In Figure III-H.9 (Element Input Section) only one item of information is entered in Location A of the MODAL section.

Location A - Membrane Thickness (t_m) = 0.10

This MODAL entry signifies that this thickness applies to all elements used in this analysis.

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
6 (/) NUMBER OF TITLE CARDS

SIMPLY SUPPORTED QUADRILATERAL THIN PLATE SUBJECTED TO A SELF- (/)
EQUILIBRATING PARABOLIC MEMBRANE LOADING, TWO TRIANGULAR THIN (/)
SHELL ELEMENTS USED IN THE IDEALIZATION-MID-POINT NODE ON THE (/)
LOADED EDGE IS SUPPRESSED (/)
REFERENCE- TIMOSHENKO, S. AND GOODIER, J.N.-THEORY OF ELASTICITY (/)
SECOND EDITION, MC GRAW HILL, NEW YORK, 1951. (/)
(/)
(/)
(/)

FIGURE III-H.2 TITLE INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1616-1

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

		1	(/)
7	8	9	

No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	1	ZTU	STEEL-E=30.0E6, MU=0.30	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-H.3 MATERIAL TAPE INPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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 2 3 4 5 6	9
2.	Number of Input Grid Points	7 8 9 10 11 12	4
3.	Number of Degrees of Freedom/Grid Point	13 14	6
4.	Number of Load Conditions	15 16	1
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	2
9.	Number of Requests and/or Revisions of Material Tape.	37 38	1
10.	Number of Input Boundary Condition Points	39 40 41 42 43 44	6
11.	T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	0.0 (/)

FIGURE III-H.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – θ	DIRECTIONS Z – Z	
7 8 9 10 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	0.0	0.0	0.0	(/)
2	16.0	0.0	0.0	(/)
3	16.0	16.0	0.0	(/)
4	0.0	16.0	0.0	(/)

FIGURE III-H.5 GRIDPOINT COORDINATES, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

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	8	9	10	11	Repeat 12	13	14	15	16	17	18	19	20	21	
				1		0	0	0	0	0	0				(/)
				2		1	0	0	0	0	0				(/)
				5	X										(/)
				4		0	1	0	0	0	0				(/)
				8	X										(/)
				6		0	0	0	0	0	0				(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-H.6 BOUNDARY CONDITIONS, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1627

MAGIC STRUC
INPU

LOADS (/)

LCOND — Condition Number: 1 — Scalar: 0.0 (/)

MODAL

Grid Pt. Number	FORCE VALUES: F_x	FORCE VALUES: F_y	FORCE VALUES: F_z		MO…: M_x
2	666.67	0.0	0.0	(/)	0.
3	400.00	0.0	0.0	(/)	0.

FIGURE III-H.7 EXTERNAL LOADS, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

(cols 39–42)		MOMENT VALUES Mx (cols 13–22)	MOMENT VALUES My (cols 23–32)	MOMENT VALUES Mz (cols 33–42)		GENERALIZED VALUES 1 (cols 13–22)	GENERALIZED VALUES 2 (cols 23–32)	GENERALIZED VALUES 3 (cols 33–42)	
	(/)				(/)				(/)
0.0	(/)	0.0	0.0	0.0	(/)				(/)
0.0	(/)	0.0	0.0	0.0	(/)				(/)

BAC 1828

ELEM 1 2 3 4 5 6 (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUG NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT: Print	PRINT: Elem. Mat.	PRINT: Full	Number of Input Nodes	No. of Assem. Nodes	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
7–10	11–12	13–18	19	20–27	28	29	30	31	32	33–34	35	36–38	39–41	42–44	45–47	48–50	51–53	54–56	57–59	60–62	63–65	66–68	69–71
1	20	12				X			X	6		1	2	4	5	9	8			1	2		
2	20	12				X				6		2	3	4	0	7	9			1	2		

FIGURE III-H.8 ELEMENT CONTROL DATA, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

. BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)
1 2 3 4 5 6

ELEMENT INPUT

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	0.10	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)	
								(/) (16 blank rows)

FIGURE III-H.9 ELEMENT INPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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-H.10 END CARD, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the thin square plate subjected to parabolic loading and idealized with two triangular thin shell elements is as follows:

Figures III-H.11 thru III-H.13 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

In Figure III-H.12, the finite element information is shown. Under the section titled External Input, the first entry printed has a numerical value of 0.0999999. This value is equal to the membrane thickness of the plate being analyzed.

Figure III-H.13 displays the External Load Column for this problem. The 54 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-H.12. An external load of 667.67 is applied at node point 2 and also a load of 400.0 is applied at node point 3 both in the positive Global X direction.

System level matrix output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figures III-H.14 thru III-H.16. Figure III-H.14 shows the reduced stiffness matrix for this problem. Only non-zero terms in the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-H.12. For this case, the ordering of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2,\ u_3,\ v_3,\ v_4,\ u_5,\ u_7,\ v_7,\ v_8,\ u_9,\ v_9 \rfloor$$

The reduced externally applied load vector (LOADR) is presented in Figure III-H.15. The size of this vector is 10 x 1. This is true because there are 10 degrees of freedom in the reduced stiffness matrix. There are 2 non-zero values of force shown in this vector. From the figure it is seen that the force values presented correspond to reduced degrees of freedom (REDDOF) 1 and 2. From the Boundary Condition Information (Figure III-H.12) it is seen that these correspond to forces in the global X direction at node points 2 and 3 having numerical values of 667.67 and 400.0 respectively. The vector of displacements (DISPR) is the next item of information presented in Figure III-H.15. This vector is a 10 x 1 since there are 10 degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III-H.12 which are as follows:

$$\{q\}^T = \lfloor u_2, u_3, v_3, v_4, u_5, u_7, v_7, v_8, u_9, v_9 \rfloor$$

The displacements are referenced to the global axis of reference unless otherwise indicated. The Matrix DISPR is interpreted as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	2	u	0.000521835
2	3	u	0.000189278
3	3	v	-0.0000131521
4	4	v	-0.000141067
5	5	u	0.000243609
6	7	u	0.000110739
7	7	v	-0.000121466
8	8	v	-0.0000862857
9	9	u	0.000187977
10	9	v	-0.0000796332

The final item of information shown in Figure III-H.15 is the stress matrix (MATRIX STRESS). The stress matrix is of the order 64 x 1 for the following reason. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid, giving a total of 32 stress resultants per element. Since two triangular thin shell elements were employed in this analysis, the size of the stress matrix is 64 x 1.

The stress resultants for the triangular thin shell element are defined as follows.

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

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

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

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

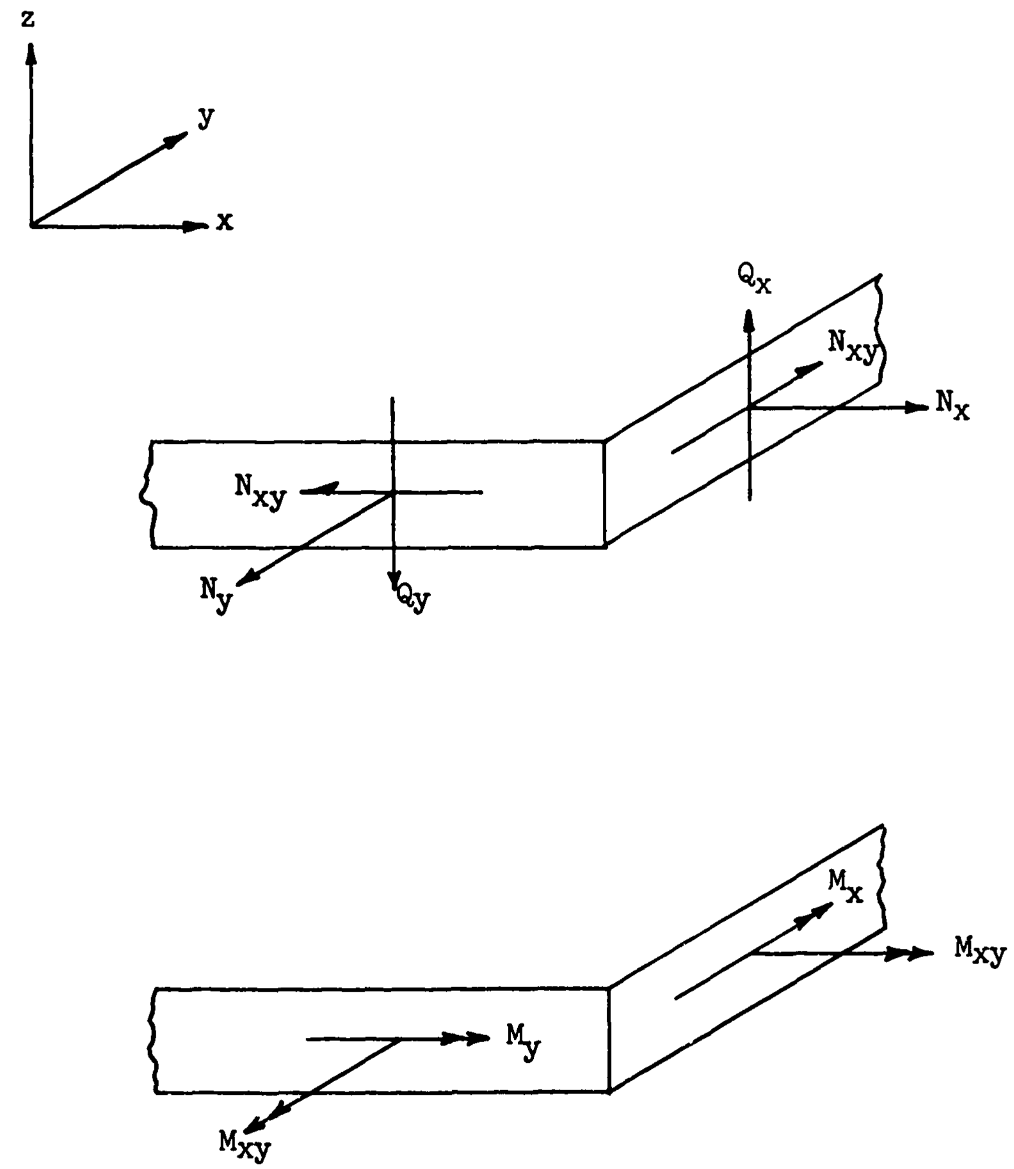
$$M_y = \int_z z \, \sigma_y \, dz \quad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

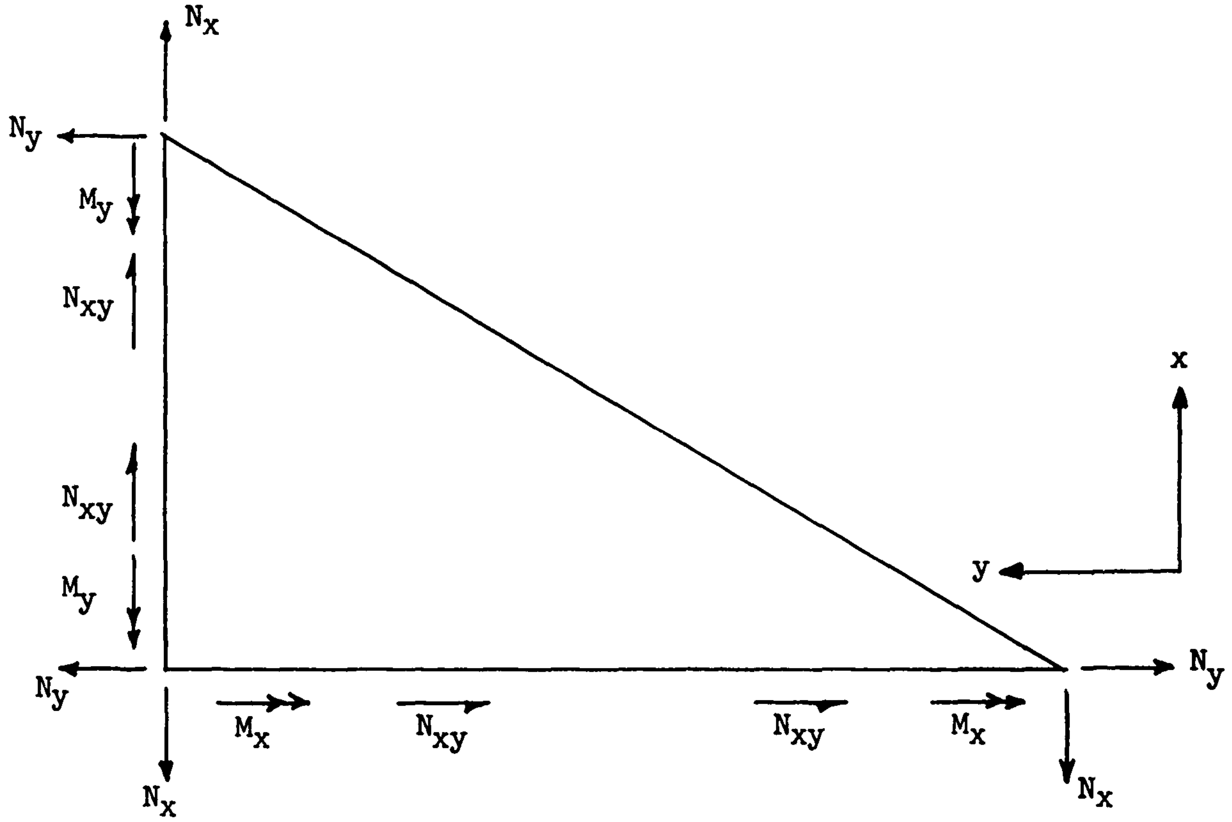
$$M_{xy} = \int_z z \, \tau_{xy} \, dz \quad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

$$Q_x = \int_z z \, \frac{\partial \sigma_x}{\partial x} \, dz + \int_z z \, \frac{\partial \tau_{xy}}{\partial y} \, dz \quad ; \text{ units } \frac{\text{force}}{\text{length}}$$

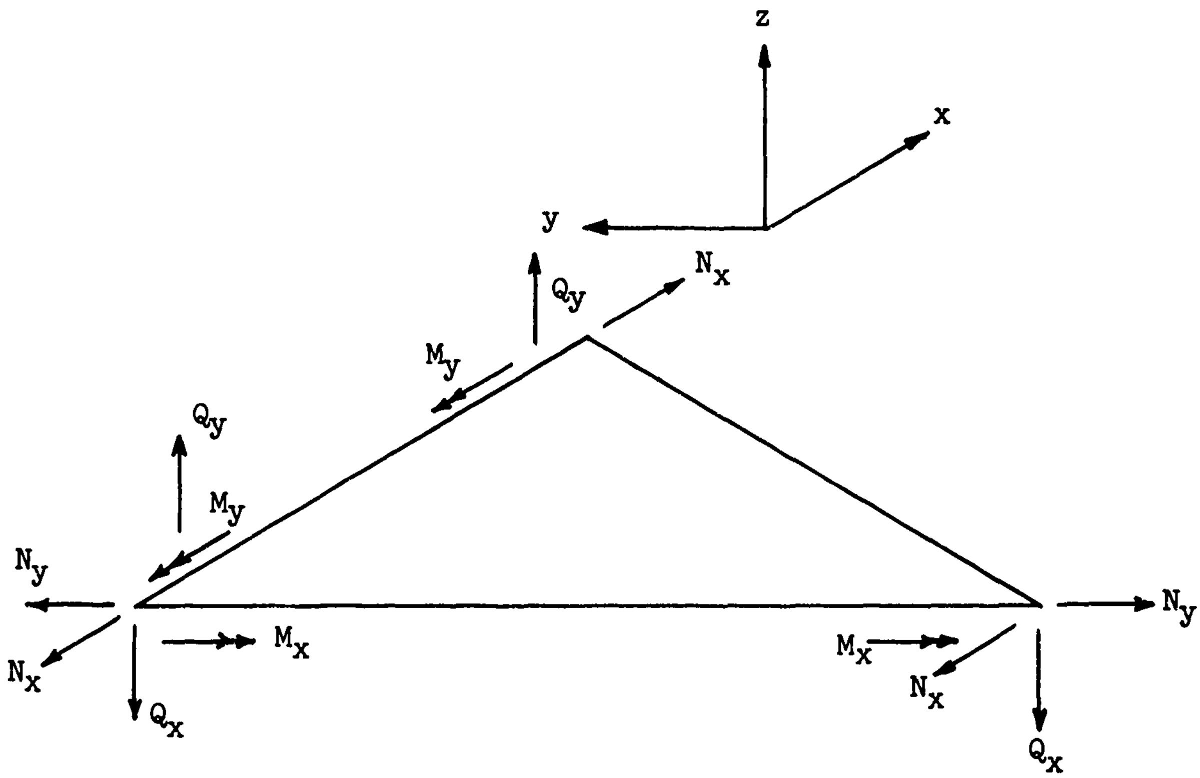
$$Q_y = \int_z z \left(\frac{\partial \sigma_y}{\partial y}\right) dz + \int_z z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz \quad ; \text{ units } \frac{\text{force}}{\text{length}}$$

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





Nx
Ny
My
Nxy
Nxy
My
Ny
Mx
Nxy
Nxy
Mx
Nx
Nx
Ny
x
y



z
x
y
Nx
Qy
My
Qy
My
Ny
Nx
Mx
Qx
Mx
Nx
Qx
Ny

The stress vector is 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 '1' and '2' 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 nodepoint 1 to nodepoint 2). This axis of reference then becomes the reference axis for the stress output.

There is one exception to the usual rules of presenting the stress output for the triangular thin shell element.

> For each triangular element, the centroidal values of the stress resultants for that element are the first to be printed. In the general case the node point stresses are printed and then the centroidal stresses.

The ordering of the stress matrix is as follows:

MATRIX STRESS

NRSEL	ELEMENT		NODE POINT
1	1	N_x = 78.0125	Centroid
2	1	N_y = -53.2127	Centroid
3	1	N_{xy} = -4.70957	Centroid
9	1	N_x = 80.6407	1
10	1	N_y = -14.0719	1
11	1	N_{xy} = -0.0000012 = 0	1
17	1	N_x = 110.817	2
18	1	N_y = -0.02969	2
19	1	N_{xy} = -16.0477	2
25	1	N_x = 42.5797	4
26	1	N_y = -1.86218	4
27	1	N_{xy} = 1.91897	4
33	2	N_x = 55.3213	Centroid
34	2	N_y = 5.32127	Centroid
35	2	N_{xy} = -5.32127	Centroid
41	2	N_x = 98.3029	2
42	2	N_y = 27.0248	2
43	2	N_{xy} = -12.1330	2
49	2	N_x = 24.9175	3
50	2	N_y = 5.00922	3
51	2	N_{xy} = -1.96864	3
57	2	N_x = 42.7434	4
58	2	N_y = -16.0703	4
59	2	N_{xy} = -1.86219	4

Figure III-H.16 displays the vector of Matrix Forces. These forces are defined with respect to the Global Coordinate System. The Matrix Force Vector is a 72 x 1 vector for the following reason. The triangular thin shell element is defined by six node points (3 corner points and 3 mid-side node points). Since there are six forces per node point (F_X, F_Y, F_Z, M_X, M_Y, M_Z) a total of 36 forces per element are defined. Since two elements were utilized in this particular problem, the size of the force vector is 72 x 1. The ordering of the Matrix Forces is as follows: (See Figure III-H.1 for the element numbering sequence).

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
1	1	F_X = -215.042	1
2	1	F_Y = 37.5251	1
7	1	F_X = 295.512	2
8	1	F_Y = -42.7938	2
13	1	F_Y = 5.11725	4
14	1	F_Y = -4.96580	4
19	1	F_X = -0.0000048 = 0	5
20	1	F_Y = 85.4431	9
25	1	F_X = 657.175	9
26	1	F_Y = -75.2086	9
31	1	F_X = 742.763	8
32	1	F_Y = -0.000018 = 0	8
37	2	F_X = 371.158	2
38	2	F_Y = -80.1744	2
43	2	F_X = 400.000	3
44	2	F_Y = -0.0000005 = 0	3
49	2	F_X = -113.983	4
50	2	F_Y = 4.96583	4
61	2	F_X = -0.000008 = 0	7
62	2	F_Y = -0.000015 = 0	7
67	2	F_X = -657.175	9
68	2	F_Y = 75.2086	9

Note that for this particular problem mid-side node #6 was suppressed.

The final item of information contained in Figure III-H.16 is the vector of reactions (MATRIX REACT). This vector is of the size 54 x 1 since there are nine node points associated with this particular problem and six associated degrees of freedom per node point. The reactions are read row-wise and are interpreted as follows: (Note that the reactions are referenced to the Global Coordinate System.)

MATRIX REACT

D.O.F.	REACTION	NODE POINT
1	P_{RX} = 215.042	1
2	P_{RY} = 37.5251	1
7	P_{RX} = -0.000099 = 0	2
8	P_{RY} = -122.968	2
13	P_{RX} = -0.000065 = 0	3
14	P_{RY} = -0.0000005 = 0	3
19	P_{RX} = -108.865	4
20	P_{RY} = 0.000024 = 0	4
25	P_{RX} = -0.000005 = 0	5
26	P_{RY} = 85.4431	5
37	P_{RX} = -0.000008 = 0	7
38	P_{RY} = -0.000015 = 0	7
43	P_{RX} = -742.763	8
44	P_{RY} = -0.0000018 = 0	8
49	P_{RX} = 0.000084 = 0	9
50	P_{RY} = 0.0000076 = 0	9

```
THIN SQUARE ISCTRCFIC PLATE SUBJECTED TO A SELF
EQUILIBRATING PARABOLIC MEMBRANE LOADING-TWO TRIANGULAR
THIN SHELL ELEMENTS USED IN THE IDEALIZATION,MID-POINT NODE ON
THE LOADED EDGE IS SUPPRESSED IN THIS ANALYSIS
REFERENCE-TIMCSHENCO,S.AND GOODIER,J.N.,THEORY OF ELASTICITY,
SECOND EDITION,MCGRAW HILL NEW YORK 1951.

                    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                            INPUT CODE   I
    NUMBER OF MATERIAL PROPERTY POINTS. . . . 1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
                                                                    POISSON'S RATIOS
                        YOUNG'S MODULI
                                                                       DIRECTIONS
                          DIRECTIONS
TEMPERATURE                                                         XY              YZ              ZX
                   XX              YY              ZZ          0.300000E 00    0.300000E 00    0.300000E 00
    0.        0.300000E 08    C.3C0000E 08    0.300000E 08
                                                                    RIGIDITY MODULI
                   THERMAL EXPANSION COEFFICIENTS
                                                                       DIRECTIONS
                          DIRECTIONS
TEMPERATURE                                                         XY              YZ              ZX
                   XX              YY              ZZ          0.115385E 08    0.115385E 08    0.115385E 08
    0.        -0.             -0.             -0.

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

FIGURE III-H.11 TITLE AND MATERIAL DATA OUTPUT,SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                        9 NDF. POINTS

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

                                        GRIDPOINT DATA
POINT          X              Y               Z                 TEMPERATURES        PRESSURES
  1      0.                0.              0.                 0.                  0.
                                                              0.                  0.
  2      0.10000000E 02    0.              0.                 0.                  0.
                                                              0.                  0.
  3      0.10000000E 02    0.10000000E 02  0.                 0.                  0.
                                                              0.                  0.
  4      0.                0.10000000E 02  0.                 0.                  0.
                                                              0.                  0.
                                                              0.                  0.

                                 BOUNDARY CONDITION INFORMATION

     NODES          DEGREES OF FREEDOM
       1        0     0     0     0     0     0     0
       2        1     0     0     0     0     0     1
       3        1     1     0     0     0     0     3
       4        0     1     0     0     0     0     4
       5        1     0     0     0     0     0     5
       6        0     0     0     0     0     0     5
       7        1     1     0     0     0     0     7
       8        0     1     0     0     0     0     8
       9        1     1     0     0     0     0     10

                                        TOTAL NO. ELEMENTS =      2

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  20        12   0 -0.           2    6    1   2   4   5   9   8          1  2
MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . .  STEEL
      ANALYSIS CAPABILITY. . . . . .       ISOTROPIC
      INPUT PRINT CODE . . . . . . .  1

      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        0.
      YOUNG'S MODULI                       0.30000000E 08    0.30000000E 08    0.30000000E 08
      POISSON'S RATIOS                     0.30000000E 00    0.30000000E 00    0.30000000E 00
      THERMAL EXPANSION COEFFICIENTS      -0.               -0.               -0.
      RIGIDITY MODULI                      0.11538461E 08    0.11538461E 08    0.11538461E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          0.99999999E 00      0.              0.              0.              0.

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  20        12   0  0.           0    6    2   3   4   8   7   9          1  2          0.1000E 00   0.            0.
```

FIGURE III-H.12 GRID POINT DATA, [illegible] AND FINITE ELEMENT [illegible] OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                              EXTERNAL LOAD CONDITIONS   1

  LOAD NO.   1

     NUMBER OF LOADEC NODES      2        ELEMENT LOAD SCALAR =  0.
2  0.66667E 03  0.           0.           0.          0.          0.
3  0.4C000E 03  0.           0.           0.          0.          0.

                      TRANSFCRMED EXTERNAL ASSEMBLED LOAD COLUMN

                                        54 X 1
```

0.	0.	0.	0.	0.	0.
0.66667000E 03	0.	0.	0.	0.	0.
C.40000000E 03	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
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.
```

FIGURE III-H.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 10 BY 10

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.293956E 07	2	0.906593E 06	3	-0.219780E 06	4	-0.357143E 06	5	-0.219780E 07
		6	0.100000E 00	7	0.714286E 06	8	0.109375E-01	9	-0.219780E 07	10	0.714285E 06
DISP.	2	1	0.906593E 06	2	0.293956E 07	3	0.714286E 06	4	0.192308E 06	6	-0.219780E 07
		7	-0.549451E 05	9	-0.219780E 07	10	-0.714286E 06				
DISP.	3	1	-0.219780E 06	2	0.714286E 06	3	0.151099E 07	4	0.192308E 06	6	0.549450E 05
		7	-0.769231E 06	9	-0.714286E 06	10	-0.769231E 06				
DISP.	4	1	-0.357143E 06	2	0.192308E 06	3	0.192308E 06	4	0.222527E 07	5	0.265625E-01
		6	-0.769231E 06	7	-0.769231E 06	8	-0.219780E 07	9	0.142857E 07	10	0.109375E 00
DISP.	5	1	-0.219780E 07	4	0.265625E-01	5	0.593406E 07	8	0.142857E 07	9	-0.153846E 07
		10	-0.142857E 07								
DISP.	6	1	0.100000E 00	2	-0.219780E 07	3	0.549450E 05	4	-0.769231E 06	6	0.593407E 07
		7	0.142857E 07	9	-0.153846E 07	10	-0.142857E 07				
DISP.	7	1	0.714286E 06	2	-0.549451E 05	3	-0.769231E 06	4	-0.769231E 06	6	0.142857E 07
		7	0.593407E 07	9	-0.142857E 07	10	-0.439560E 07				
DISP.	8	1	0.109375E-01	4	-0.219780E 07	5	0.142857E 07	8	0.593406E 07	9	-0.142857E 07
		10	-0.153846E 07								
DISP.	9	1	-0.219780E 07	2	-0.219780E 07	3	-0.714286E 06	4	0.142857E 07	5	-0.153846E 07
		6	-0.153846E 07	7	-0.142857E 07	8	-0.142857E 07	9	0.118681E 08	10	0.285714E 07
DISP.	10	1	0.714285E 06	2	-0.714286E 06	3	-0.769231E 06	4	0.109375E 00	5	-0.142857E 07
		6	-0.142857E 07	7	-0.439560E 07	8	-0.153846E 07	9	0.285714E 07	10	0.118681E 08

FIGURE III-H.14 REDUCED STIFFNESS MATRIX OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                        MATRIX  LOADR                                        PAGE    1

                    CUTOFF =   0.                              SIZE    10  BY     1

           REDDOF               REDDOF               REDDOF               REDDOF               REDDOF

COND.    1    1   0.666670E 03    2    0.4C0000E 03


                                        MATRIX  DISPR                                        PAGE    1

                    CUTOFF =   0.                              SIZE    10  BY     1

           REDDOF               REDDCF               REDDOF               REDDOF               REDDOF

COND.    1    1   0.521835E-03    2    0.189278E-03    3   -0.131521E-04    4   -0.141067E-03    5    0.243609E-03
              6   0.110739E-03    7   -0.121446E-03    8   -0.862857E-04    9    0.187977E-03   10   -0.796332E-04


                                        MATRIX  STRESS                                       PAGE    1

                    CUTOFF =   0.                              SIZE    64  BY     1

           NRSEL                NRSEL                NRSEL                NRSEL                NRSEL

COND.    1    1   0.78C125E 02    2   -0.532127E 01    3   -0.470957E 01    9    0.806407E 02   10   -0.140719E 02
             11  -0.115192E-05   17    0.110817E 03   18   -C.296926E-01   19   -0.160477E 02   25    0.425797E C2
             26  -0.186218E 01   27    0.151897E 01   33    0.553213E 02   34    0.532127E 01   35   -0.532127E C1
             41   0.983029E 02   42    C.270248E 02   43   -0.12133QE 02   49    0.249175E 02   50    0.500922E C1
             51  -0.196864E 01   57    C.427434E 02   58   -C.160703E 02   59   -0.186219E 01
```

FIGURE III-H.15 LOAD, DISPLACEMENT AND STRESS OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                        MATRIX  FORCES                                              PAGE    1
                         CUTOFF =   0.                                       SIZE    72  BY     1

             D.O.F                 D.O.F                 D.O.F                 D.O.F                 D.O.F

COND.    1      1  -0.215042E 03     2   0.375251E 02     7   0.295512E 03     8  -0.427938E 02    13   0.511725E 01
               14  -0.496580E 01    19  -0.476837E-05    20   0.854431E 02    25   0.657175E 03    26  -0.752086E 02
               31  -0.742763E 03    32  -0.181198E-04    37   0.371158E 03    38  -0.801744E 02    43   0.400000E 03
               44  -0.476837E-06    49  -0.113983E 03    50   0.496583E 01    61  -0.762939E-05    62  -0.152588E-04
               67  -0.657175E 03    68   0.752086E 02


                                        MATRIX  REACT                                               PAGE    1
                         CUTOFF =   0.                                       SIZE    54  BY     1

             D.O.F                 D.O.F                 D.O.F                 D.O.F                 D.O.F

COND.    1      1  -0.215042E 03     2   0.375251E 02     7  -0.991821E-04     8  -0.122960E 03    13  -0.648499E-04
               14  -0.476837E-06    19  -0.108865E 03    20   0.237226E-04    25  -0.476837E-05    26   0.854431E 02
               37  -0.762939E-05    38  -0.152588E-04    43  -0.742763E 03    44  -0.181198E-04    49   0.839233E-04
               50   0.762939E-05
$END

         $IBSYS
         $REMOVE          SYSLB2
         $IBSYS
         $STOP
```

FIGURE III-H.16 FORCE AND REACTION OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

I. SQUARE PLATE - NORMAL PRESSURE LOADING - (Triangular Thin Shell Idealization)

A simply supported isotropic square plate, under the action of normal pressure loading is shown in Figure III-I.1 along with its dimensions and pertinent material properties. The plate is idealized utilizing two triangular thin shell elements.

The preprinted input data forms associated with this example are shown in Figures III-I.2 through III-I.11.

In Figure III-I.5 (Gridpoint Coordinate Section) it is seen that only the grid points for the three corner points of each element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

In Figure III-I.6 (Grid Point Pressure Section) the MODAL entry is used for the input pressure values.

This entry means that the normal pressures are acting at every grid point with a value of -1.0 psi. The sign of the pressure is minus since its direction is in the negative element Z_g direction.

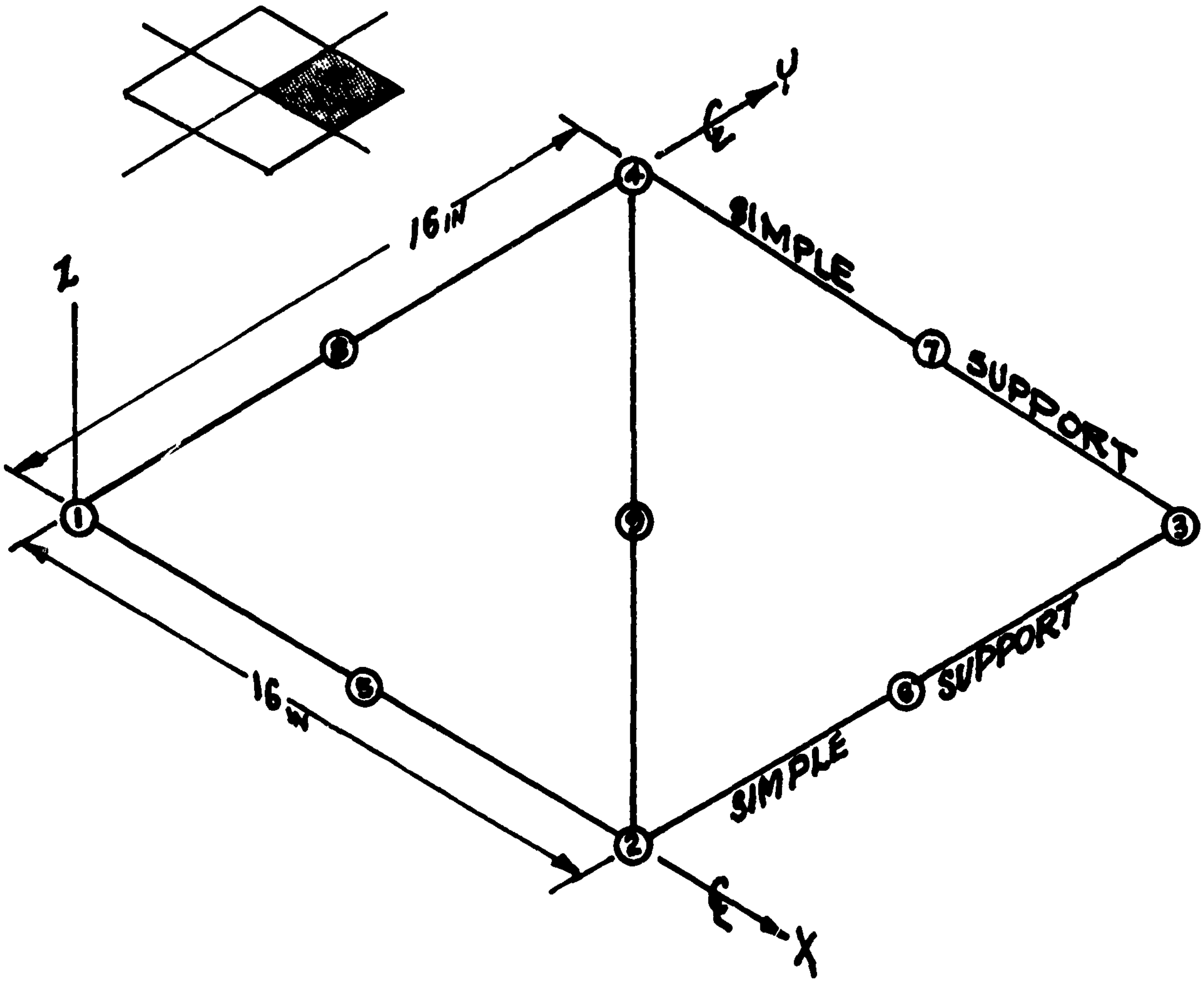
In Figure III-I.7 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (See Figure III-I.1). Let us examine the Listed Input (Exceptions to the MODAL card) first.

(1) Grid Point Number 1 (Center of plate) has an unknown displacement in the w direction, all others are zero due to symmetry.

(2) Grid Point Number 2 has an unknown rotation, θ_y. The others are zero due to the fact that grid point 2 is a point of simple support.

(3) Grid Point Number 3 has all degrees of freedom fixed. This is true because the simple supports meet at this point restricting rotation in the θ_x and θ_y directions.

(4) Grid Point Numbers 5 and 8 are repeated and also have all degrees of freedom fixed. These are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem u and v are equal to zero. Since Grid Points 5 and 8 lie along symmetric boundaries, θ_n equals zero.



$t = 0.10$ INCH $\quad P = 1.0$ PSI

$E = 30. \times 10^6$ PSI $\quad \mu = .30$

FIGURE III - I.1 - Idealized Simply Supported Plate With Normal Pressure Loading (Triangular Thin Shell Idealization of One Quadrant)

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 3, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 4, 6, 7, and 9.

(1) Grid Point Number 4 has an unknown rotation, θ_x. The others are zero since grid point 4 is a point of simple support.

(2) Grid points 6, 7, and 9 are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem u and v are equal to zero. However, there is an unknown normal slope θ_n, associated with these grid points. The code (0, 1, 2) associated with these normal slope values is always entered in the θ_x location for consistency.

In Figure III-I.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed and External Force and Moment values of 0.0 are entered in the appropriate locations. Since the Triangular Thin Shell Element is formulated with six degrees of Freedom per point, two external load cards per grid point are required.

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Loads + EALS (Element Applied Loads)

Since the External Loads are equal to zero and the EALS = 1.0

Total Load = Element Applied Load

These are the correct loads since for this case the Element Applied Loads are equal to the normal pressure loads.

In Figure III-I.9 (Element Control Data Section) the following information is of importance.

(1) The numbers '1' and '2' are entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1. These two points define the direction of the (X) stress axis for Element Number 1. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis.

(2) The numbers '4' and '3' are entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 2. These two points define the direction of the (X) stress axis for Element Number 2.

It should be noted that the stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions then each element must be considered separately. Node points related to each particular element must be used when determining stress directions utilizing locations 11 and 12.

In Figure III-I.10 (Element Input Section) only one item of information is entered in Location B of the MODAL section.

Location B - Flexural Thickness - $(t_f) = 0.10$

This MODAL entry signifies that this thickness applies to all elements used in this analysis.

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

3 (/) NUMBER OF TITLE CARDS

Columns 1–72	
QUADRILATERAL THIN PLATE - SIMPLY SUPPORTED UNDER A UNIFORM	(/)
NORMAL LOADING OF ONE PSI - TWO TRIANGULAR THIN SHELL ELEMENTS	(/)
USED IN THE IDEALIZATION	(/)
	(/)
	(/)
	(/)
	(/)
	(/)
	(/)

FIGURE III-I.2 TITLE INFORMATION, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1616-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

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

		1	(/)
7	8	9	

No. of Requests

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	12	TU	$STEEL-E=30.0E6,MU=0.30	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)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-I.3 MATERIAL TAPE INPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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	9	1 2 3 4 5 6
2. Number of Input Grid Points	4	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		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	2	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	1	37 38
10. Number of Input Boundary Condition Points	5	39 40 41 42 43 44
11. T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

FIGURE III-I.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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)	X – R (13–22)	Y – Θ (23–32)	Z – Z (33–42)	
1	0.0	0.0	0.0	(/)
2	16.0	0.0	0.0	(/)
3	16.0	16.0	0.0	(/)
4	0.0	16.0	0.0	(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)
				(/)

(Column header: DIRECTIONS spans X – R, Y – Θ, Z – Z)

FIGURE III-I.5 GRIDPOINT COORDINATES, SIMPLY SUPPORTED PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

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

1	2	3	4	5	6
M	O	D	A	L	

PRESSURES		
P_1	P_2	P_3
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42
-1.0		

Grid Point Number (7 8 9 10 11)	Repeat (12)	P_1 (13 … 22)	P_2 (23 … 32)	P_3 (33 … 42)	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

FIGURE III-I.6 GRIDPOINT PRESSURES, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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	1	0	0				(/)

LISTED INPUT

Grid Point Number 7	8	9	10	11	Repeat 12	13	14	15	16	17	18	19	20	21	
				1		0	0	1	0	0	0				(/)
				2		0	0	0	0	1	0				(/)
				3		0	0	0	0	0	0				(/)
				5	X										(/)
				8	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-I.7 BOUNDARY CONDITIONS SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1627

MAGIC ST

LOADS (/)

LCOND 1 1.0 (/)

Condition Number | Scalar

	FORCE VALUES			
	Fx	Fy	Fz	Mx
MODAL	0.0	0.0	0.0 (/)	

Grid Pt. Number | repeat

FIGURE III-I.8 EXTERNAL LOADS, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

	MOMENT VALUES			GENERALIZED VALUES		
	M_x	M_y	M_z	1	2	3
4 012	1 3456789 2 012	2 3456789 3 012	3 3456789 4 012	1 3456789 2 012	2 3456789 3 012	3 3456789 4 012
0.0 (/)	0.0	0.0	0.0 (/)			(/)

4 012	1 3456789 2 012	2 3456789 3 012	3 3456789 4 012	1 3456789 2 012	2 3456789 3 012	3 3456789 4 012
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
(/)			(/)			(/)
			(/)			(/)
			(/)			(/)
			(/)			(/)

BAC 1628

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)	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
1	20	12				X			X	6		1	2	4	5	9	8					1	2
2	20	12				X				6		2	3	4	6	7	9					4	3

FIGURE III-I.9 ELEMENT CONTROL DATA, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

1-6	A (13-22)	B (23-32)	C (33-42)	D (43-52)	E (53-62)	F (63-72)
MODAL	0.0	0.10	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-I.10 ELEMENT INPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

CHECK OR END CARD

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

E	N	D	
1	2	3	(/)

FIGURE III-I.11 END CARD, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the simply supported isotopic square plate subjected to a normal pressure load and idealized using two triangular thin shell elements is as follows:

Figures III.I.12 through III.I.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

The Gridpoint Data Information is shown in Figure III.I.13. Note that pressures of -1.0 psi are applied at each grid point. The finite element information is also shown in Figure III.I.13. Under the Section titled External Input, the second entry has a numerical value of 0.09999999. This value is equal to the flexural thickness of the plate being analyzed.

Figure III.I.14 displays the Transformed External Assembled Load column. Note that these loads are all equal to zero since input pressures are element applied loads.

System level output of final results is handled by the FORMAT standard matrix print capability. These results are shown in Figures III.I.15 through III.I.17.

Figure III.I.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is read row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III.I.13. For this case the displacement vector is ordered as follows:

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7}, \theta_{n9} \rfloor$$

Where θ_{ni} = normal slope at node point i

Figure III.I.16 displays the vector of Reduced Element Applied Loads. (MATRIX FTELAR). The size of this vector is a 6 x 1 since there are six degrees of freedom remaining in the assembled and reduced stiffness matrix. The vector appears as follows and is read row-wise:

MATRIX FTELAR

REDDOF	NODE POINT	ELEMENT APPLIED LOAD VALUE
1	1	F_Z = -46.9333
2	2	M_Y = -216.178
3	4	M_X = 216.178
4	6	M_Y = -45.5111
5	7	M_X = -45.5111
6	9	M_N = 0.0000119 = 0

The vector of displacements (DISPR) is the next item of information presented in Figure III.I.16. This vector is also a 6 x 1 since there are six degrees of freedom remaining after assembly and reduction. The ordering of the displacement vector is consistent with that of the boundary conditions shown in Figure III.I.13.

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7}, \theta_{n9} \rfloor$$

The displacements are referenced to the global axis of reference unless otherwise indicated. The MATRIX DISPR is interpreted as follows:

MATRIX DISPR

REDDOF	NODE POINT	D.O.F.	DISP. VALUE
1	1	w	-1.35273
2	2	θ_y	-0.180968
3	4	θ_x	0.180968
4	6	θ_n	-0.105614
5	7	θ_n	-0.105614
6	9	θ_n	-0.100746

The final item of information presented in Figure III.I.16 is the Stress Matrix (MATRIX STRESS). The stress matrix is a 64 x 1 for the following reason. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid, giving a total of 32 stress resultants per element. Since two triangular thin shell elements were employed in this analysis, the size of the stress matrix is 64 x 1.

The stress resultants for the triangular thin shell were explicitly defined in Section III.H (Square Plate - Parabolic Membrane Loading). Sketches were also provided to facilitate proper interpretation of the stress resultants.

The stress vector is 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 '1' and '2' were entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1 and for Element Number 2 the numbers '4' and '3' were entered in locations 11 and 12. These two points define the x direction of the stress axis (Positive x from node point 1 to node point 2 for element No. 1 and positive x from node point 4 to node point 3 for element No. 2). These axes of reference then become the reference stress axes for elements 1 and 2 respectively.

It is to be remembered for the triangular thin shell element that for each elemert, the centroidal value of the stress resultants for that element are the first to be printed. (In the general case the node point stresses are printed and then the centroidal stresses.)

The ordering of the stress matrix is as follows:

MATRIX STRESS

NRSEL	ELEMENTS	STRESS RESULTANT	NODE POINT
4	1	M_x = -39.4002	Centroid
5	1	M_y = -36.0867	Centroid
6	1	M_{xy} = -0.0000038 = 0	Centroid
7	1	Q_x = -6.44949	Centroid
8	1	Q_y = -0.0000025 = 0	Centroid
12	1	M_x = -32.4414	1
13	1	M_y = -32.4414	1
14	1	M_{xy} = 0.0000036 = 0	1
15	1	Q_x = -6.44949	1
16	1	Q_y = -0.0000025 = 0	1
20	1	M_x = -45.0097	2
21	1	M_y = -45.0097	2
22	1	M_{xy} = 1.79741	2
23	1	Q_x = -6.44949	2
24	1	Q_y = -0.00000 = 0	2
28	1	M_x = -11.9934	4
29	1	M_y = -31.8742	4
30	1	M_{xy} = -9.25269	4
31	1	Q_x = -6.44949	4
32	1	Q_y = -0.0000025 = 0	4

MATRIX STRESS (CONTD)

NRSEL	ELEMENTS	STRESS RESULTANT	NODE POINT
36	2	M_x = -24.9945	Centroid
37	2	M_y = 6.98283	Centroid
38	2	M_{xy} = 11.9915	Centroid
39	2	Q_x = 0.817928	Centroid
40	2	Q_y = 1.66367	Centroid
(Etc)	2	(See Figure III-I.16)	2

Figure III.I.17 presents the vector of element forces (MATRIX FORCES). These forces are defined with respect to the Global Coordinate System. The Matrix Force Vector is a 72 x 1 vector for the following reason. The triangular thin shell element is defined by six node points (3 corner points and 3 mid-side node points). Since there are six forces per node point (F_X, F_Y, F_Z, M_X, M_Y, M_Z) a total of 36 forces per element are defined. Note that the mid-side nodes have allowable degrees of freedom equal to u, v, and normal slope (θ_n). Therefore in a flexure problem, the moment at any mid-side node is associated with the normal slope. The ordering of the Matrix Forces is as follows (see Figure III.I.1 for the element numbering sequence).

MATRIX FORCES

D.O.F.	ELEMENT NO.	FORCE	NODE POINT
3	1	F_Z = 0.000018 ≈ 0	1
4	1	M_X = -107.312	1
5	1	M_Y = 107.312	1
9	1	F_Z = 64.0000	2
10	1	M_X = 267.905	2
11	1	M_Y = 110.276	2
15	1	F_Z = 64.0000	4
16		M_X = -110.276	4
17	1	M_Y = -267.905	4
22	1	M_N = -484.202	5
28	1	M_N = -130.888	9
34	1	M_N = 484.202	8
39	2	F_Z = 40.1146	2
40	2	M_X = 114.680	2
41	2	M_Y = -110.275	2
45	2	F_Z = 47.7707	3
46	2	M_X = -173.237	3
(Etc)	(Etc)	(Etc)	(Etc)

The final item of information contained in Figure III.I.17 is the vector of reactions (MATRIX REACT). This vector is a 54 x 1 since there are nine node points associated with this problem and six associated degrees of freedom per node point. The reactions are read row-wise and are interpreted as follows: (Note that the reactions are referenced to the Global Coordinate System.)

MATRIX REACT

D.O.F.	REACTION	NODE POINT
3	P_{RZ} = 0.000018 = 0	1
4	M_{RX} = -107.312	1
5	M_{RY} = 107.312	1
9	P_{RZ} = 104.115	2
10	M_{RX} = 382.585	2
11	M_{RY} = 0.000075 = 0	2
15	P_{RZ} = 47.7707	3
16	M_{RX} = -173.237	3
17	M_{RY} = 173.237	3
21	P_{RZ} = 104.115	4
22	M_{RX} = -0.000031 = 0	4
23	M_{RY} = -382.585	4
28	M_{RN} = -484.202	5
34	M_{RN} = -0.0000024 = 0	6
40	M_{RN} = -0.00061 = 0	7
46	M_{RN} = 484.202	8
52	M_{RN} = 0.000019 = 0	9

```
SIMPLY SUPPORTEC ISCTROPIC SQUARE PLATE SUBJECTED TO A
UNIFORM NORMAL FRESSURE LOAD OF 1 PSI- TWO TRIANGULAR
THIN SHELL ELEMENTS USED IN THE IDEALIZATION
                        REVISIONS OF MATERIAL TAPE

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

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

REVISION
  MATERIAL NUMBER      12                                   INPUT CODE   I
  MATERIAL IDENTIFICATION    STEEL
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
                          YOUNG'S MODULI                                    POISSON'S RATIOS

                            DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                  XX             YY             ZZ                XY             YZ             ZX
    0.      0.300000E 08   0.300000E 08   0.300000E 08      0.300000E 00   0.300000E 00   0.300000E 00
                    THERMAL EXPANSION COEFFICIENTS                          RIGIDITY MODULI

                            DIRECTIONS                                         DIRECTIONS
 TEMPERATURE
                  XX             YY             ZZ                XY             YZ             ZX
    0.      -0.            -0.            -0.               0.115385E 08   0.115385E 08   0.115385E 08

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

FIGURE III-I.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                  9 REF. PCINTS

        NO. DIRECTIONS  =    3      NC. CEGREES OF FREEDOM =   2

                                  GRIDPOINT DATA

POINT          X                 Y                  Z              TEMPERATURES        PRESSURES
  1      C.                0.                0.                    0.              -0.10000000E 01
                                                                   0.              -0.
  2      C.16CC0000E 02    0.                0.                    0.              -0.10000000E 01
                                                                   0.              -0.
  3      C.16C00000E 02    C.16CCCCCCE C2    0.                    0.              -0.10000000E 01
                                                                   0.              -0.
  4      C.                C.16CC00CCE C2    0.                    0.              -0.10000000E 01
                                                                   0.              -0.

                           BCUNCARY CONDITION INFORMATION

        NODES          DEGREES OF FREEDOM

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

                                  TOTAL NO. ELEMENTS =     2

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NC.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  20       12    0 -0.           2    6     1   2   4   5   9   8         -0  -0   1   2

MATERIAL NUMBER. . . . . . . . .   12
      MATERIAL ICENTIFICATION. . . .   STEEL
      ANALYSIS CAPABILITY. . . . . .       ISCTROPIC
      INPUT PRINT CODE . . . . . . . .  1

      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        C.
      YOUNG'S MODULI                        C.30000000E 08     0.30000000E 08     0.30000000E 08
      POISSON'S RATIOS                      C.30000000E 00     0.30000000E 00     0.30000000E 00
      THERMAL EXPANSION COEFFICIENTS      -0.                -0.                -0.
      RIGIDITY MODULI                       C.11538461E 08     0.11538461E 08     0.11538461E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          -0.                 0.C9999999E CC     -0.                -0.                -0.

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  20       12    0  0.           0    6     2   3   4   6   7   9         -0  -0   4   3  -0.          0.1000E 00  -0.
```

FIGURE III-I.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 9 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.

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

54 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.

T-ZERO FOR STRUCTURE = 0.

FIGURE III-I.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 6 BY 6

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.665350E 03	2	-0.123054E 04	3	0.123054E 04	6	-0.404708E 04		
DISP.	2	1	-0.123054E 04	2	0.158730E 05	3	-0.106074E 05	4	-0.120574E 05	5	-0.747863E 04
		6	-0.841794E 04								
DISP.	3	1	0.123C54E 04	2	-0.106074E 05	3	0.158730E 05	4	0.747863E 04	5	0.120574E 05
		6	0.841793E 04								
DISP.	4	2	-0.120574E 05	3	0.747863E 04	4	0.244200E 05	5	-0.122100E 04	6	0.112239E 05
DISP.	5	2	-0.747863E 04	3	0.120574E 05	4	-0.122100E 04	5	0.244200E 05	6	0.112239E 05
DISP.	6	1	-0.404708E 04	2	-0.841794E 04	3	0.841793E 04	4	0.112239E 05	5	0.112239E 05
		6	0.610501E 05								

FIGURE III-I.15 REDUCED STIFFNESS MATRIX OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MATRIX FTELAR PAGE 1

CUTOFF = 0. SIZE 6 BY 1

		REDDOF		REDDOF		REDDOF		REDDOF		REDDOF	
COND.	1	1	-0.469333E 02	2	-0.216178E 03	3	0.216178E 03	4	-0.455111E 02	5	-0.455111E 02
		6	0.119209E-04								

MATRIX DISPR PAGE 1

CUTOFF = 0. SIZE 6 BY 1

		REDDOF		REDDOF		REDDOF		REDDOF		REDDOF	
COND.	1	1	-0.135273E 01	2	-0.180968E 00	3	C.180968E 00	4	-0.105614E 00	5	-0.105614E 00
		6	-0.100746E 00								

MATRIX STRESS PAGE 1

CUTOFF = C. SIZE 64 BY 1

		NRSEL		NRSEL		NRSEL		NRSEL		NRSEL	
COND.	1	4	-0.394002E 02	5	-0.360867E 02	6	-0.382189E-05	7	-0.644949E 01	8	-0.253483E-C5
		12	-0.324414E 02	13	-C.324414E 02	14	C.368322E-05	15	-0.644949E 01	16	-0.253483E-C5
		20	-0.450097E 02	21	-C.450097E 02	22	0.179741E 01	23	-0.644949E 01	24	-0.253483E-C5
		28	-0.119934E 02	29	-0.318742E 02	30	-0.925269E 01	31	-0.644949E 01	32	-0.253483E-C5
		36	-0.249945E 02	37	0.698283E 01	38	-0.119915E 02	39	-0.817920E 00	40	0.166367E 01
		44	-0.237223E 02	45	-0.179944E 02	46	-0.137130E 02	47	-0.817920E 00	48	0.166367E 01
		52	-0.232199E 02	53	0.232199E 02	54	-C.174149E 02	55	-0.817920E 00	56	0.166367E 01
		60	-0.270237E 02	61	0.368096E 01	62	-0.365852E 01	63	-0.817920E 00	64	0.166367E 01

FIGURE III-I.16 LOAD, DISPLACEMENT AND STRESS OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                                   MATRIX  FORCES                                    PAGE    1
                                                                          SIZE    72  BY     1
                               CUTOFF =   0.
                                                                        D.O.F                D.O.F
          D.O.F              D.O.F                  D.O.F
COND.    1   3   0.181198E-04   4  -C.107312E 03   5   0.107312E 03   9   0.640000E 02  10   0.267905E C3
            11   0.110276E 03  15   0.640000E 02  16  -C.110276E 03  17  -0.267905E 03  22  -0.484202E 03
            28  -0.130888E 03  34   C.484202E 03  39   0.401146E 02  40   0.114680E 03  41  -0.110275E 03
            45   0.4777C7E 02  46  -0.173237E 03  47   0.173237E 03  51   0.401147E 02  52   0.110275E 03
            53  -0.114680E 03  58  -0.238419E-05  64  -0.610352E-04  70   0.130888E 03


                                                   MATRIX  REACT                                     PAGE    1
                                                                          SIZE    54  BY     1
                               CUTOFF =   0.
          D.O.F              D.O.F                  D.O.F               D.O.F                D.O.F
COND.    1   3   0.181198E-04   4  -0.107312E 03   5   C.107312E 03   9   0.104115E 03  10   0.382585E 03
            11   0.753403E-04  15   0.477707E 02  16  -0.173237E 03  17   0.173237E 03  21   0.104115E 03
            22  -0.305176E-04  23  -C.382585E 03  28  -0.484202E 03  34  -0.238419E-05  40  -0.610352E-04
            46   0.484202E 03  52   0.190735E-04
END

MRES01  FIRST CARD IS NOT A -$- CONTROL CARC

$END

          $IBSYS
          $REMOVE         SYSLB2
          $IBSYS
          $STOP
```

FIGURE III-I.17 FORCE AND REACTION OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

SECTION IV
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APPENDIX III

TABLE OF ERROR MESSAGES

AN ERROR HAS OCCURRED IN THE USER04 MODULE. FORMAT WILL ATTEMPT TO CONTINUE.

Subroutine: USER04
Explanation: Self explanatory

ASSEMBLY TRANSFORMATION MATRIX SIZE XXXXXX EXCEEDS LIMIT XXXXXX OF FORMAT SYSTEM.

Subroutine: US04A
Explanation: Self explanatory

AVAILABLE SCRATCH DATA SETS XXXX IS LESS THAN THE REQUIRED 4.

Subroutine: US04A
Explanation: The USER04 module requires at least four scratch data sets. The addition of more data sets is required by the program.

DUE TO ABOVE ERROR CONDITION CHECK CARD WILL BE INSERTED. EXECUTION WILL BE SUPPRESSED.

Subroutine: PHASE2
Explanation: Self explanatory

DUE TO ABOVE ERROR MESSAGE THIS SECTION WILL BE OMITTED AND CHECK CARD INSERTED.

Subroutine: PHASE1
Explanation: Self explanatory

DUE TO PREVIOUSLY ENCOUNTERED ERROR CONDITION THIS SECTION IS BEING SKIPPED. PROGRAM WILL FLUSH DATA DECK UNTIL NEXT RECOGNIZABLE INPUT SECTION IS ENCOUNTERED.

Subroutine: PHASE1
Explanation: Self explanatory

DUE TO THE OMISSION OF THIS SECTION THE FOLLOWING SECTIONS MAY BE IGNORED - XXXXXX XXXXXX XXXXXX . . .

Subroutine: PHASE2
Explanation: The final processing of certain sections requires data from other sections which by omission or other input error are not present.

ELEMENT CONTROL ERROR IN SUBROUTINE ELEM
ELEMENT NUMBER XXXXX CALLS PLUG NUMBER XXX. PLUG NUMBER SHOULD BE GREATER THAN ZERO. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: All element type code numbers are greater than zero. Proper element type cannot be selected.

ELEMENT CONTROL ERROR IN SUBROUTINE ELEM
ELEMENT NUMBER XXXXX HAS MATERIAL NUMBER XXXXXX. MATERIAL IDENTIFICATION MUST BE DIFFERENT FROM ZERO. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: Self explanatory

ELEMENT CONTROL ERROR IN SUBROUTINE ELEM
ELEMENT NUMBER XXXXX HAS NUMBER OF INPUT POINTS·= XX. NUMBER OF INPUT POINTS MUST BE POSITIVE. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: Self explanatory

ELEMENT CONTROL ERROR IN SUBROUTINE ELEM
ELEMENT NUMBER XXXXX HAS NUMBER OF GRID POINTS = XXX. NUMBER OF GRID POINTS MUST BE GREATER THAN ZERO AND NO GREATER THAN EIGHT. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: Self explanatory

ELEMENT INPUT ERROR NO. X PLUG NO. XX ELEMENT NO. XXXX
Subroutine: ELPLUG
Explanation: Error number 1 - incorrect plug number (element type code)
Error number 2 - incorrect number of element defining points
Error number 3 - incorrect value for extra element input indicator
Error number 4 - incorrect matrix orders for element (number of degrees of freedom per point incorrect)

ELEMENT GENERATION CORE STORAGE REQUIRED XXXXXX EXCEEDS THAT AVAILABLE XXXXXX TO DISPLACEMENT METHOD MATRIX GENERATOR.
Subroutine: US04A
Explanation: Blank common work area is not large enough for generation of element matrices.

ELEMENT SORT ROUTINE CORE STORAGE REQUIRED XXXXXX EXCEEDS THAT AVAILABLE XXXXXX TO DISPLACEMENT METHOD MATRIX GENERATOR.

Subroutine: US04B

Explanation: Blank common work area is not large enough for output of generated matrices.

ERROR MESSAGE FROM SUBROUTINE MAT
ATTEMPT TO DELETE MATERIAL NUMBER XXXXXX USING LOCK CODE XX. INCORRECT LOCK CODE, REQUEST IGNORED.

Subroutine: FMAT

Explanation: Self explanatory

ERROR MESSAGE FROM SUBROUTINE MAT
ATTEMPT TO DELETE MATERIAL THAT WAS NOT ON MATERIAL TAPE. MATERIAL NUMBER XXXXXX. MATERIAL IDENTIFICATION IS XXXXXXXXXXXXXXXXXXXXXXXXXXXX. INPUT CODE IS XXX. REQUEST IGNORED.

Subroutine: FMAT

Explanation: Self explanatory

ERROR MESSAGE FROM SUBROUTINE MAT
ATTEMPT TO INPUT PLASTIC DATA ONLY FOR MATERIAL WHICH WAS NOT ON TAPE. MATERIAL NUMBER XXXXXX. MATERIAL IDENTIFICATION IS XXXXXXXXXXXXxXXXXXXXXXXX. INPUT CODE IS XXX. REQUEST IGNORED.

Subroutine: FMAT

Explanation: Usage of an input code of "P" requires that the material to be revised already exists in the material library.

ERROR MESSAGE FROM SUBROUTINE MAT
ATTEMPT TO REVISE MATERIAL NUMBER XXXXXX USING LOCK CODE XX. INPUT LOCK CODE DOES NOT MATCH TAPE LOCK CODE FOR THIS MATERIAL. REVISIONS OR DELETIONS NOT ALLOWED WITHOUT PROPER LOCK CODE. EXECUTION TERMINATED.

Subroutine: FMAT

Explanation: Self explanatory

ERROR MESSAGE FROM SUBROUTINE MAT
NUMBER OF REQUESTS RECEIVED IS ZERO.

Subroutine: FMAT

Explanation: Number of requests must not be zero. Value of zero indicates improper operation of program.

ERROR MESSAGE FROM SUBROUTINE MAT
REQUEST FOR PRINT OF MATERIAL THAT WAS NOT ON TAPE. MATERIAL NUMBER XXXXXX. MATERIAL IDENTIFICATION IS XXXXXXXXXXXXXXXXXXXXXXXX. INPUT CODE IS XXX. REQUEST IGNORED.

Subroutine: FMAT
Explanation: Self explanatory

ERROR MESSAGE FROM SUBROUTINE MAT
UNRECOGNIZABLE DATA INPUT CODE. LEGAL CODES ARE PI, PO, I, O, P, OUT, ALL, SEE, SUM. MATERIAL NUMBER XXXXXX. MATERIAL IDENTIFICATION IS XXXXXXXXXXXXXXXXXXXXXXXX. INPUT CODE IS XXX. EXECUTION TERMINATED.

Subroutine: FMAT
Explanation: Self explanatory

ERROR MESSAGE FROM SUBROUTINE MAT
ADDITIONS REQUESTED EXCEED CAPACITY OF MATERIAL TAPE. MAXIMUM NUMBER OF MATERIALS CANNOT EXCEED XXX.

Subroutine: FMAT
Explanation: Self explanatory

FOR I = XX AND N = XX INTEGRAL DOES NOT CONVERGE

Subroutine: PLUG5
Explanation: No convergence has been obtained for the given integral calculated by the Romberg technique in the Toroidal Ring Element.

GRID POINT LOADS MATRIX STORAGE REQUIRED XXXXXX EXCEEDS THAT AVAILABLE XXXXXX TO DISPLACEMENT METHOD MATRIX GENERATOR.

Subroutine: US04A
Explanation: Blank common work area is not large enough for generation of grid point loads matrix.

GRID POINT LOAD MATRIX SIZE XXXXXX EXCEEDS LIMIT XXXXXX OF FORMAT SYSTEM.

Subroutine: US04A
Explanation: Self explanatory

ILLEGAL MODAL CARD ENCOUNTERED. CARD WILL BE IGNORED.

Subroutine: PHASE1
Explanation: A modal card has been found while reading an input section for which no modal card has been defined.

INPUT ERROR IN SUBROUTINE ELEM, AFTER INTERPOLATION
POISSON VALUE EQUALS ±.XXXXXXXXE±XX IN MATERIAL
NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD
BE GREATER THAN -1.0 AND LESS THAN 1.0. EXECUTION
TERMINATED.

Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM, AFTER INTERPOLATION
RIGIDITY VALUE EQUALS ±.XXXXXXXXE±XX IN MATERIAL
NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD
BE GREATER THAN 1.0. EXECUTION TERMINATED.

Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM, AFTER INTERPOLATION
THERMAL COEFFICIENT VALUE EQUALS ±.XXXXXXXXE±XX IN
MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX.
VALUE SHOULD BE GREATER THAN -1.0 AND LESS THAN 1.0.
EXECUTION TERMINATED.

Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM, AFTER INTERPOLATION
VALUE OF YOUNG'S MODULUS EQUALS ±.XXXXXXXX±XX IN
MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX.
VALUE SHOULD BE GREATER THAN 1.0. EXECUTION TERMINATED.

Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM
ELEMENT NODE POINT IS NEGATIVE OR ZERO IN ELEMENT
NUMBER XXXXX.

Subroutine: ELEM
Explanation: No element defining point number may be negative and only mid-points may be zero.

INPUT ERROR IN SUBROUTINE ELEM
ELEMENT NUMBER XXXXXX IS DEFINED BY NODE POINTS FOR
WHICH NO COORDINATES HAVE BEEN INPUT. CALCULATION OF
MATERIAL TEMPERATURE IMPOSSIBLE. EXECUTION TERMINATED.

Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM
MASS DENSITY VALUE EQUALS ±.XXXXXXXXE±XX IN MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD BE GREATER THAN ZERO. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE ELEM
VALUE OF IP = XXX, VALUE OF IPRE = XXX FOR ELEMENT NUMBER ONE. REQUEST TO REPEAT DATA FROM ELEMENT PREVIOUS TO FIRST ELEMENT IS ILLOGICAL. EXECUTION TERMINATED.
Subroutine: ELEM
Explanation: IP and IPRE cannot be negative for first element.

INPUT ERROR IN SUBROUTINE MAT
MASS DENSITY VALUE EQUALS ±.XXXXXXXX±XX IN MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD BE NON-NEGATIVE. EXECUTION TERMINATED.
Subroutine: FMAT
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE MAT
MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. NUMBER OF MATERIAL TEMPERATURE POINTS IS XXX. NUMBER OF PLASTIC TEMPERATURE POINTS IS XXX. NUMBER OF TEMPERATURE POINTS IN EITHER CASE CANNOT EXCEED 9. EXECUTION TERMINATED.
Subroutine: FMAT
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE MAT
POISSON VALUE EQUALS ±.XXXXXXXX±XX IN MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD BE GREATER THAN -1.0 AND LESS THAN 1.0. EXECUTION TERMINATED.
Subroutine: FMAT
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE MAT
RIGIDITY VALUE EQUALS ±.XXXXXXXXE±XX IN MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX. VALUE SHOULD BE GREATER THAN 1.0. EXECUTION TERMINATED.
Subroutine: FMAT
Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE MAT
  THERMAL COEFFICIENT VALUE EQUALS ±.XXXXXXXXE±XX IN
  MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX.
  VALUE SHOULD BE GREATER THAN -1.0 AND LESS THAN 1.0.
  EXECUTION TERMINATED.
        Subroutine: FMAT
        Explanation: Self explanatory

INPUT ERROR IN SUBROUTINE MAT
  VALUE OF YOUNG'S MODULUS EQUALS ±.XXXXXXXXE±XX IN
  MATERIAL NUMBER XXXXXX, XXXXXXXXXXXXXXXXXXXXXXXX.
  VALUE SHOULD BE GREATER THAN 1.0.
        Subroutine: FMAT
        Explanation: Self explanatory

INPUT ERROR   NUMBER OF REFERENCE POINTS INPUT EXCEEDS XXXX.
        Subroutine: INPUT
        Explanation: Program cannot accommodate more than the given number of input points.

INPUT ERROR   NUMBER OF DIRECTIONS OF GRID POINTS NOT
  EQUAL TO NUMBER OF DIRECTIONS OF TRANSFORMATION MATRIX.
  EXECUTION TERMINATED.
        Subroutine: INPUT
        Explanation: Order of grid point axes transformation matrices must be equal to three.

INPUT ROUTINE   CORE STORAGE REQUIRED XXXXXX EXCEEDS THAT
  AVAILABLE XXXXXX TO DISPLACEMENT METHOD MATRIX GENERATOR.
        Subroutine: US04A
        Explanation: Blank common work area is not large enough for processing input.

INTERNAL TAPE ERROR HAS OCCURRED. PROCESSING ABANDONED.
        Subroutine: PHASE2
        Explanation: Report form input preprocessor cannot retrieve information stored on a scratch data set.

LABEL CARD ERROR XXXXXX
        Subroutine: INPUT
        Explanation: Input card read should have been label card. Execution will be terminated.

LOAD CONDITION XXX SUB-LABEL IS INCORRECT. PROGRAM CANNOT DISTINGUISH BETWEEN LOAD CONDITIONS.
Subroutine: PHASE 1
Explanation: Load condition sub-label in report form input is in error.

MAXIMUM NUMBER OF ITERATIONS REACHED IN ROMBERG INTEGRATION ROUTINE.
Subroutine: PLUG5
Explanation: Convergence was not obtained in 15 iterations for an integral in the toroidal thin shell element. Processing will continue, using 15 iteration result.

MAXIMUM NUMBER OF LOAD CONDITIONS ALLOWED IS 100. THIS PROBLEM CONTAINS XXXX.
Subroutine: PHASE 1
Explanation: Self explanatory

MORE THAN ONE OPTION HAS BEEN SELECTED FOR REQUEST NUMBER XXX OF MATERIAL LIBRARY. ONLY THE FIRST SELECTION WILL BE RETAINED.
Subroutine: PHASE 1
Explanation: Self explanatory

NEW MATERIAL TAPE NOT GENERATED. ALL REVISIONS AND/OR DELETIONS REQUESTED BY THIS CASE HAVE BEEN IGNORED.
Subroutine: FMAT
Explanation: Due to a previous error, generation of a new material library has been abandoned. Execution will be terminated.

NO END OR CHECK CARD HAS BEEN FOUND. CHECK CARD WILL BE INSERTED, SUPPRESSING EXECUTION.
Subroutine: PHASE 2
Explanation: Self explanatory

NO OPTION HAS BEEN SELECTED FOR REQUEST NUMBER XXX OF MATERIAL LIBRARY.
Subroutine: PHASE 1
Explanation: Self explanatory

NUMBER OF ELEMENTS READ XXXXX IS GREATER THAN 9999.
NUMBER OF ELEMENTS WILL BE SET AT 9999.

Subroutine: PHASE 2
Explanation: Self explanatory, execution will be suppressed.

NUMBER OF ENTRIES READ FOR THIS SECTION, XXXXX, DOES NOT AGREE WITH NUMBER THAT WAS TO BE READ, XXXXX. ACTUAL NUMBER READ WILL BE USED.

Subroutine: PHASE 2
Explanation: Self explanatory

PLUG7 ERROR - THIRD POINT TO DEFINE PLANE WAS NOT GIVEN - INPUT ERROR.

Subroutine: P7PRT
Explanation: Three element defining points are required for the frame element, the third supplying definition of the plane.

REDUCTION OF TRANSFORMATION MATRICES STORAGE XXXXXX EXCEEDS THAT AVAILABLE TO DISPLACEMENT METHOD MATRIX GENERATOR.

Subroutine: USO4A
Explanation: Blank common work area is not large enough for generation of reduction transformation matrix.

REDUCTION TRANSFORMATION MATRIX SIZE XXXXXX EXCEEDS LIMIT XXXXXX OF FORMAT SYSTEM.

Subroutine: USO4A
Explanation: Self explanatory

REPEAT FOR FIRST POINT IGNORED.

Subroutine: FORMIN
Explanation: Repeat option on table forms of report form input cannot be used for first value entered.

REPORT ROUTINE CORE STORAGE REQUIRED XXXXXX EXCEEDS THAT AVAILABLE XXXXXX TO DISPLACEMENT METHOD MATRIX GENERATOR.

Subroutine: US04A

Explanation: Blank common work area is not large enough for processing report form input data.

STIFFNESS MATRIX SIZE XXXXXX EXCEEDS LIMIT OF FORMAT SYSTEM.

Subroutine: US04A

Explanation: Self explanatory

STRESS MATRIX SIZE XXXXXX EXCEEDS LIMIT XXXXXX OF FORMAT SYSTEM.

Subroutine: US04A

Explanation: Self explanatory

SUBROUTINE MINV HAS DETERMINED ARRAY GAMABQ TO BE SINGULAR, EXECUTION TERMINATED BY SUBROUTINE TRAIC.

Subroutine: TRAIC

Explanation: Transformation matrix to system coordinates in triangular cross-section ring element cannot be inverted, usually because three element defining points do not define a triangle.

SYSTEM INFORMATION CARD MISSING. CANNOT ALLOCATE STORAGE.

Subroutine: CONTRL

Explanation: All input data decks must have SYSTEM section to allocate storage for processing of input.

THE INTEGRAL OF (LN(A+B*X)/X) DX IS NOT ALLOWED FOR A+B*X=0
A = ±.XXXXXXXE±XX B = ±.XXXXXXXE±XX X = ± . XXXXXXXE±XX

Subroutine: F6211

Explanation: Natural log of zero is undefined.

THERE IS A MISTAKE IN THE COORDINATES FOR THIS TRANSFORMATION, WE WILL CALCULATE THE REMAINING IN SPITE OF THIS.

Subroutine: FRED

Explanation: An error has occurred in generating a grid point axes transformation matrix. Execution will continue.

THIS SECTION HAS EITHER BEEN OMITTED OR FLUSHED BY PHASE ONE ERROR. IN EITHER CASE THIS SECTION IS CONSIDERED CRITICAL AND EXECUTION WILL NOT BE ALLOWED.

Subroutine: PHASE 2
Explanation: Self explanatory

THIS SECTION IS TO BE MERGED WITH XXXXXX AND XXXXXX FOR WHICH MODAL CARDS HAVE BEEN ENCOUNTERED FOR BOTH. TWO VALUES CANNOT BE ASSIGNED TO THE SAME POINT. BOTH MODAL CARDS WILL BE IGNORED.

Subroutine: PHASE 2
Explanation: Self explanatory

THIS SECTION IS TO BE MERGED WITH XXXXXX AND XXXXXX FOR WHICH VALUES HAVE BEEN ASSIGNED BY BOTH FOR POINT NUMBER XXXXX. TWO VALUES CANNOT BE ASSIGNED TO THE SAME POINT. NEITHER VALUE WILL BE USED.

Subroutine: PHASE 2
Explanation: Self explanatory

TOROIDAL RING ELEMENT WITH CO-ORDINATES R1 = ± .XXXXXXXXE±XX R2 = ± .XXXXXXXXE±XX Z1 = ± .XXXXXXXXE±XX Z2 = ± .XXXXXXXX±XX IS NOT DIAGONALLY DOMINANT AND SHOULD BE SUBDIVIDED.

Subroutine: PRINT 5
Explanation: Element stiffness matrices must be diagonally dominant.

UNEXPECTED BLANK LABEL CARD ENCOUNTERED.

Subroutine: PHASE 1
Explanation: Card read should have contained an input section label. Input processor will attempt to continue.

UNEXPECTED LABEL CARD READ - POINT XXXXX

Subroutine: FORMIN
Explanation: Input section label card encountered while reading table form input. Point reflects entry now being processed.

UNRECOGNIZABLE INPUT SECTION.

Subroutine: PHASE1

Explanation: Input section label has been read which is undefined in input processor.

VALUE OF SIN (ALPHA) IS ZERO - RUN TERMINATED.

Subroutine: PLUG1

Explanation: Element defining points are in error for Quadrilateral Thin Shell Element.

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13. ABSTRACT

An automated general purpose system for analysis is presented. This system, identified by the acronym "MAGIC" for "Matrix Analysis via Generative and Interpretive Computations," provides a flexible framework for implementation of the finite element analysis technology. Powerful capabilities for displacement, stress and stability analyses are included in the subject MAGIC System for structural analysis.

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Six versatile finite elements are incorporated in the finite element library. These are: frame, shear panel, triangular cross-section ring, toroidal thin shell ring, quadrilateral thin shell and triangular thin shell elements. These finite element representations include matrices for stiffness, incremental stiffness, prestrain load, thermal load, distributed mechanical load and stress.

Documentation of the MAGIC 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 Volume, Volume III, is designed to facilitate implementation, operation, modification, and extension of the MAGIC System.

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