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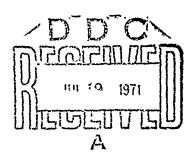
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VOLUME II: USER'S MANUAL

STEPHEN JORDAN A. MICHAEL GALLO BELL AEROSPACE COMPANY

TECHNICAL REPORT AFFDL-TR-71-1, VOLUME II

MAY 1971



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MAGIC II: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

STEPHEN JORDAN A. MICHAEL GALLO

FOREWORD

This report was prepared by Textron's Bell Aerospace Company (BAC), Buffalo, New York under USAF Contract No. F-33615-69-C-1241. This contract is an extension of previous work initiated under Project No. 1467, "Structural Analysis Methods," Task No. 146702, "Thermal Elastic Analysis Methods". The program was administered by the Air Force Flight Dynamics Laboratory (AFFDL), under the cognizance of Mr. G.E. Maddux, AFFDL Program Manager. The program was carried out by the Structural Systems Department, Bell Aerospace Company during the period 2 December 1968 to 2 December 1970 under the direction of Mr. Stephen Jordan, BAC Program Manager.

This report, "MAGIC II: 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 January 1971 for publication as an AFFDL Technical Report.

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

The authors wish to express appreciation also to Miss Beverly J. Dale and Mr. Mark Morgante for the expert computer programming that transformed the analytical development into a practical working tool.

This technical report has been reviewed and is

approved

FRANCIS J. JANUK, JR. Chief, Theoretical Mechaniss Branch Structures Division

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ABSTRACT

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

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Ten versatile finite elements are incorporated in the finite element library. These are frame, shear panel, triangular cross-section ring, trapezoidal cross-section ring (and core), toroidal thin shell ring (and shell cap), quadrilateral thin shell and triangular thin shell elements. Additional elements include a frame element, quadrilateral plate and triangular plate elements which can be used for both stress and stability analysis. The finite elements listed include matrices for stiffness, mass, incremental stiffness, prestrain load, thermal load, distributed mechanical load and stress.

The MAGIC II 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 features. restart options, automated output data reduction and readable output displays.

Documentation of the MAGIC II 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.

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SECTION I

INTRODUCTION

The MAGIC II Systems for Structural Analysis is a logical extension of the original MAGIC System reported in References 1, 2 and 3. All capabilities available from the original MAGIC System have been retained. Extension of the program capability is primarily in the following areas.

- (a) The implementation of four additional finite element representations and their associated element matrices.
- (b) The improvement of output displays to facilitate ease of interpretation by the User.
- (c) The provision of an "Agendum Library" to accommodate the following classes of analyses:
 - (1) Statics
 - (2) Statics with Condensation
 - (3) Statics with Prescribed Displacements
 - (4) Stability
 - (5) Dynamics (Modes and Frequencies)
 - (6) Dynamics (with Condensation)
- (d) The addition of an out-of-core eigenvalue routine for nonsymmetric matrices based on the power method "on the order of" 3000 x 3000.
- (e) The addition of improved and expanded error diagnostics.
- (f) The addition of a prescribed displacement option to accommodate more than one load condition per execution.
- (g) The addition of the capability to accept either rectangular, cylindrical or spherical coordinates as input data.
- (h) The addition of miscellaneous arithmetic modules to the System to support the computational procedures.
- (1) The addition of a new assembly module to increase the permissible assembled system matrix size.

]

Numerous other extensions have been provided with the MAGIC II System. These extensions will be delineated in detail in the Sections to follow.

The MAGIC II 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 4, 5). 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 II of this report begins with a description of the general arrangement of the MAGIC II System and continues with a description of the options available to the user via the available abstraction instructions. Attention is then focused upon the structural data. Preprinted input data sheets are described that facilitate the specification of structural data.

Section III is devoted to interpretation of the output from the MAGIC II System. Print options which provide precise User oriented output are enumerated by reference to specific example problems. These examples utilize each of the finite elements which comprise the MAGIC II System element library.

SECTION II

INPUT TO THE MAGIC II SYSTEM

A. INTRODUCTION

The MAGIC II System presents two input data interfaces to the Structural Analyst. The first encountered is referred to as the System Input Data interface. The System data instructs the program as to what operations should be performed during any execution. These operations may be viewed as the interpretive portion of the MAGIC System. For example, the matrix abstraction instructions which are required to perform a structural analysis are System Input Data. These instructions along with all other System options available to the User will be discussed in detail in the next section.

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

Separate subsections, devoted to instructions for the specification of System and Structural Input Data follow utilization of both types of data is covered in depth. An in depth description of detailed instructions on carrying out general matrix computations is presented in Reference 6. Options frequently used in the MAGIC II System are clearly delineated in the next section.

B. SYSTEM INPUT DATA

1. General Description

The general arrangement of the MAGIC II digital computer program system is shown in Figure II-a The supervisory program consists of the FORMAT control and two monitors; the Preprocessor Monitor, and the Execution Monitor. The main program controls the normal two phase operation by delegating control, in turn, to the two monitors.

The preprocessor Monitor directs the processing of card input data describing the machine configuration, the problem specification, the abstraction instruction sequence and the matrix data.

A standard, modified standard, or totally new machine configuration may be defined for each MAGIC II case.

Subroutines Special Input Data User-Coded Matrix Output & Logic Modules **Execution Monitor** Data Sets Arithmeric R Mcdules Utility Subroutines Printer (Logic) , Logic Allocator Processor Matrix Input Data Matrix Data Preprocessor Monitor Abstraction Instruction Processor Abstraction Instruction Sequence Problem Specification Data Problem Specification Frocessor Utility Subroutine Machine Configuration Configuration Processor Machine 4

Supervisor Control

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MAGIC II - Digital Computer Program Figure II-a

General output format and labeling information, and identifying names of the master input and output data sets (tapes) constitute the problem specification data.

The matrix and pseudo-matrix operations are input in the required sequence of execution in the abstraction instruction sequence. Abstraction instructions are submitted in free form on standard Fortran coding sheets for punched card reproduction.

Card input matrix data are specified on a standard form. Matrices may be of order 3000x30CO, and may contain up to 6000 randomly ordered, single precision real elements, using 45600 words of storage on an IBM 360/65 Digital Computer.

For the general case, preprocessing involves straightforward sequential processing of data by each of the modules under the Preprocessor Monitor. Special preprocessing can be specified by proper use of the control cards described in Section II.B.2.

The final preprocessor operation is to pre-plan the data storage allocation through the problem and to record this program of the "complete problem solution logic" for use by the Execution Monitor.

The Execution Monitor directs the processing of data by the various operational modules according to the program prepared by the Preprocessor Monitor.

The standard matrix operational modules provide for matrix addition, subtraction, multiplication, and transpose multiplication, with optional concurrent scaling, and for matrix scalar multiplication, transposition, adjoining, dejoining, and inversion. Modules for the solution of simultaneous equations by elimination and iterative techniques complete the basic standard matrix operation capability of the system.

The pseudo-matrix operational modules provide for the element by element multiplication of two matrices of identical order, the elements of a matrix to be raised to a scalar power, the extraction of the algebraic maximum and minimum elements of the rows or columns of a matrix (i.e., the envelope of a matrix), the diagonalization of a row or column matrix, the generating of null and identity matrices, and the renaming of a matrix. Included in the classification of pseudo-matrix operational modules is the "Structure Cutter" subroutine which generates a well conditioned solution of "n" linear simultaneous equations in "m" unknowns by Jordanian elimination (where $n \leq m$).

5

Matrices produced as the results of standard and pseudo-matrix operations may be as large as 3000x3000 with no restriction on population density. Storage of matrix data is by column sort, and when individual column population density is less than 50 percent, storage is in compressed format. In compressed format, each nonzero element and its corresponding row location are sequentially stored, and zero elements are omitted. Where feasible, the subroutines operate directly on the compressed data.

MAGIC II includes two subroutines for the calculation of eigenvalues. The first subroutine calculates the specified number of eigenvalues, beginning with the largest, and the corresponding eigenvalues of a matrix, whose maximum order is limited by the working core storage available to the subroutine. Typically, with a 32K storage unit, the matrix may be as large at 160 x 160. This subroutine is written for a real symmetric matrices only. The second subroutine also calculates the specified number of eigenvalues and eigenvectors beginning with the largest eigenvector. However, the real eigenmatrix can be symmetric or nonsymmetric and the only limit on its order is the amount of working storage available to the MAGIC system. For example, with a 32K storage unit, the matrix may be as large as 2000 x 2000.

Up to nine special operational subroutines can be coded by the user and added to the system. The fourth user coded module is the structural generative system of MAGIC and will be described in Section II.B.2.d.

The sequence of operation is controlled by simple abstraction instructions prepared by the user, keypunched, and read directly by the machine. Comments may be included in the abstraction instruction sequence for explanation of the results.

Limited logic is available in the form of a conditional transfer. A matrix may be tested for mullity and, if true, control will be transferred forward to a specified abstraction instruction in the sequence. Conditional transfer is limited to a "skip ahead" in the abstraction instruction sequence.

Matrices can be printed in a standard form, with small number suppression and row-column labeling. The matrix elements are printed as floating point numbers with optional exponent.

The normal printed output for a MAGIC II case includes a listing produced by the preprocessor. The listing unconditionally includes all control and specification data together with the complete abstraction instruction sequence. The listing will also include matrix input data, special input data, and the machine generated "complete problem colution logic" if the appropriate options are chosen in the control data.

6

2. INPUT DATA

a. Organization

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

- (1) Machine configuration data
- (2) Problem specification data
- (3) Abstraction instruction sequence
- (4) Matrix data
- (5) Special data

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

Columns 73 to 80 of all card input data are used for card handling purposes in keeping with normal MAGIC procedure.

b. Control and Specification Data

(1) Control Cards

The general format for control cards is as follows.

Card Column	Contents
~ 1	\$
2-15	Control card name, left justified
16-72	Variable field information (options)

The following are MAGIC control cards for the five sections of input data and the end of input data respectively: \$MAGIC, \$RUN, \$INSTRUCTION, \$MATRIX, \$SPECIAL and \$END.

Summary examples of code for the available control and specification data are shown in Table I.

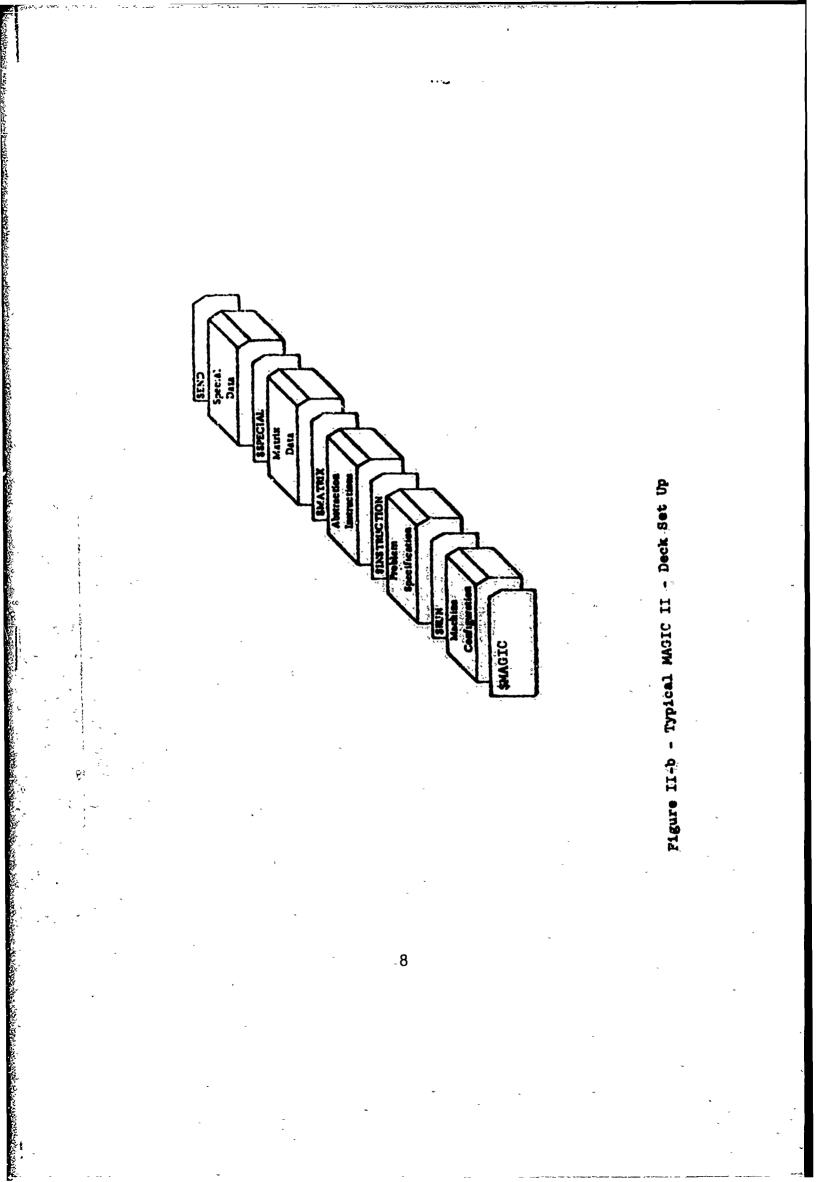


TABLE I

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EXAMPLE CODE FOR CONTROL AND SPECIFICATION DATA

cc16 **CC7** CCI

C (COMMENT)

\$MAGIC

STANDARD

K GO , NOGIC \$RUN

(ANALYSIS IDENTIFICATION) ANALYSIS

PROBLEM IDENTIFICATION) PROBLEM

(NAME, MODIF) INPUT TAPE

OUTPUT TAPE (NAME, MODIF)

(H * M) PAGE SIZE

SOURCE NÖSOURCE \$INSTRUCTION

NOLIST , NOPRINT LIST , PRINT LIST \$MATRIX

\$END

\$SPECIAL

The \$MAGIC card indicates the beginning of a MAGIC case and the options control the machine configuration that is used during the running of the case. The form of the card is:

<u>1</u>	<u>16</u>
\$MAGIC	STANDARD

where the option available to the engineering user is:

STANDARD

- the standard machine configuration is used for this run.

In the implementation of the MAGIC II System at any installation a standard logical machine configuration is compiled into the machine configuration processor module. This logically defines the data processing capability of the computing hardware at the particular installation and may require temporary modification due to day-to-day variations in the machine resources available. To this end options are provided on the MAGIC card to allow such temporary changes by the entry of appropriate machine configuration data cards (Reference 5). Modification of the standard configuration is properly a function of specialists in systems maintenance, and the STANDARD option will always be chosen, therefore, by the engineering user and may be omitted.

The \$RUN card indicates the beginning of the problem specification data and the options control the manner in which the case is executed. The form of the card is:

1

\$RUN

<u>10</u>	, ,
<u>GO</u> ,	NOLOGIC
NOGO,	LOGIC

76

where the execution options are:

GO

the case is executed after it has been preprocessed.

NOGO

it has been preprocessed.

the case is not executed and the run is terminated after all preprocessing is complete.

NOTE:

E: The underlined option is the default option and will be taken if no option is specified.

and the logic options are:

- no listing of the problem solution logic is given.

LOGIC

NOLOGIC

- a listing of the complete problem solution logic is given showing the complete sequence of instructions to be executed and the associated external storage allocation for the case. This is included as part of the preprocessor output.

The \$INSTRUCTION card indicates the beginning of the abstraction instruction sequence and the options define the type of abstraction sequence which is entered. The form of the card is: 1

16

SOURCE **\$INSTRUCTION** NOSOURCE

where the options are:

SQURCE -	the abstraction is card input.	instruction sequence

NOSOURCE - (this option is provided for future development of a method of entry of frequently occurring abstraction sequences.)

The \$MATRIX card indicates the beginning of the matrix data and the options define whether the matrix data is included in the preprocessor output. The form of the card is:

<u>1</u>	<u>16</u>	
\$MATRIX	<u>NOLIST</u> ,	NOPRINT
	LIST ,	PRINT

where the options are:

NOLIST	-	the card images of the matri: are not printed.	k data
LIST		the card images of the matri: are printed as they are read	

NOPRINT	-	the matrix data are not printed
		after sorting.

PRINT - the matrix data are printed after being sorted by row and column.

The \$SPECIAL card indicates the beginning of the special (nonmatrix) data and the options define whether the special data is included in the preprocessor output. The form of the card is:

 $\frac{1}{\text{\$SPECIAL}} \quad \begin{cases} \frac{16}{\text{NOLIST}} \\ \text{LIST} \end{cases}$

where the options are:

NOLIST	•	-	the card data are				special	
list		-	the card	images	of	the	special	đ

- the card images of the special data are printed as they are read. This option applies only when the NOGO option is entered in the \$RUN card.

The \$END card indicates the end of all card input data to a FORMAT case. The form of the card is:

<u>1</u>	<u>16</u>	<u>72</u>
\$END	(any variable text)	

The contents of the \$END card are reproduced as the last line of printed output for a case.

The standard options on the control cards are shown underlined, and these are automatically selected if the option field is blank.

\$MATRIX and \$SPECIAL cards are required if matrix data and special data are submitted, respectively. All other control cards are unconditionally required.

(2) Machine Configuration Data Cards

The machine configuration data cards define the logical machine configuration used during the running of the case if the standard configuration is temporarily modified. No entries are made when the STANDARD option is entered on the \$MAGIC control card.

(3) Problem Specification Data Cards

The problem specification data cards provide general output format and labeling information and identify the master input and output tapes that are used by the problem. The following are problem specification data cards: ANALYSIS, PROBLEM, INPUT TAPE, OUTPUT TAPE, and PAGE SIZE.

The ANALYSIS card provides labeling information for the listing of the abstraction instruction sequence and the listing of the problem solution logic. If the ANALYSIS card is omitted, a totally blank header is used. Only one ANALYSIS card per case is allowed. The form of the card is:

7

ANALYSIS (variable text)

The variable text is printed at the top of each page of the listing of the abstraction instruction sequence, and each page of the problem solution logic if the appropriate option is entered in the \$RUN card. The text should identify the type and origin of the analysis under consideration.

The PROBLEM card provides labeling information for the output from the problem. If the PROBLEM card is omitted a totally blank header is used. Only the PROBLEM card per case is allowed. The form of the card is:

<u>7</u>

1

1

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<u>72</u>

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PROBLEM (variable text)

The variable text is printed at the top of each page which is produced as the results of the abstraction instruction sequence, and each page of matrix and special input data if the appropriate options are entered in the \$MATRIX and the \$SPECIAL and \$RUN control cards respectively. The text should identify the specific problem under consideration.

The INPUT TAPE cards provide identification of the master input tapes used by the problem. If no INPUT TAPE cards are entered, the tapes normally assigned to this function are used as scratch tapes during execution. The form of the card is:

7

1

IMPUT TAPE (name, modif)

where the arguments are:

name

- a six character alphameric name used to identify the master input tape.
- modif an integer number used as a modifier to the name (usually the date).

When master input tapes are used in a MAGIC case, the appropriate instruction for the machine operator to mount tapes must be made external to the normal card input.

The OUTPUT TAPE cards provide identification of the master output tapes used by the problem. If no OUTPUT TAPE cards are entered, the tapes normally assigned to this function are used as scratch tapes during execution. The form of the card is:

<u>7</u>

OUTPUT TAPE (name, modif)

where the arguments are:

1

name - a six character alphameric name used to identify the master output tape. modif - an integer number used as a modifie

 an integer number used as a modifier to the name (usually the date).

When master output tapes are used in a MAGIC case, the appropriate instruction for the machine operator to save tapes must be made external to the normal card input.

The PAGE SIZE card indicates the limit on the size of the printed output which is produced as the results of the abstraction sequence. A standard print format of six lines per inch is used. If the PAGE SIZE card is omitted the standard limits of 14 inches by 11 inches are used. Only one PAGE SIZE card per case is allowed. The form of the card is:

7

1

PAGE SIZE (width * height)

where the arguments are:

Construction of the second of

width

- the width in inches of the printed output.

height

- the height in inches of the printed output.

Allowable page sizes for printed output are 14×11 , 11 $\times 8$ or 8×11 where only the integer part of the width or height dimension need be entered (i.e., 8 for 8.5).

Entry of the nonstandard limits on the PAGE SIZE card should be accompanied by an external instruction to the machine operator of the required output page size.

c. Abstraction Instruction Sequence

(1) General Format

Abstraction instructions are submitted in free form on standard FORTRAN coding sheets, (i.e. blanks are ignored).

The general format for an abstraction instruction is:

Card Column	Contents
1-5	A one to five (1-5) digit statement number.
7-72	An input/output, control or arith- metic statement.

The statement number is a unique index, and is required only for statements to which control can be transferred by a control statement.

Comments may be inserted in the sequence of abstraction instructions. Comments must have a C in card column 1 and any text in card columns 2-72. The only effect of a comment is that the text is printed in the printed listing of the abstraction instruction sequence.

The abstraction instructions are executed in the sequence in which they are submitted. Consequently, any matrix used in an abstraction instruction either must appear as the result of a previous abstraction instruction or must be input by card or tape.

A MAGIC matrix name consists of one to six (1-6) alphameric characters, the first of which must be alphabetic. When the matrix name is interpreted, all non-blank characters are left justified and the remainder of the word is filled with blanks.

A scalar is processed as an element of a matrix and is identified by the matrix name modified by subscripts, which respectively define the row and column location of the scalar in the matrix.

Summary examples of code for the available abstraction instructions are shown in Table II.

(2) Input/Output Statements

Two input/output statements are available: a matrix print statement which is used to print matrices in a standard form and a matrix save statement which is used to save matrices in a standard form on a physical tape for future use.

Matrix Print statements are of the form:

PRINT (a, b, c, d)e

where the arguments are:

- a a six character alphameric name which is printed as a label on the rows of the printed matrices <u>e</u>. The row label is ROW if <u>a</u> is blank.
- b a six character alphameric name which is printed as a label on the columns of the printed matrices e. The column label is COL if <u>b</u> is blank.
- c the element print code Ef or Ff. If the code is Ef, the matrix elements are printed as floating point values with exponent, with f decimal digits to the right of the decimal point. The value of f is an unsigned integer with the limitation 0 f 8. If the code is Ff, the matrix elements are printed as floating point values without exponent, with f decimal digits to the right of the decimal point. If c is blank, the matrix elements are printed by the element print code E6.
- d an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and not to be printed. That is, the matrix element aij is omitted from printing if [aij]<d. If d is blank, zero valued elements are omitted from printing.

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TABLE II EXAMPLE CODE FOR ABSTRACTION INSTRUCTIONS

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	<u>[]</u>	<u> </u>	õ	89	MEB	MEB	AMEE	NAMEB	AMEE		NAME	AMEB		AMEB	± NAMEB,	TRCU	IGEN							B	ធ			etc.
	PRINT (ROWNAM, COLNAM, ELCODE, CUTOFF)	MATNAM, (etc.	IF (MATNAM .NULL.) GO TO STATNO	ADD. ± NAMEB	± NAMEB	± NAMEB	.TMULT. ± NAMEB	+1	+1		.ADJOIN. ± NAMEB		•	.SEQEL. ± NAMEB		NAMEA STRCUT. ± NAMEB,	A.E	. •	•	•	•	•	•	.NULL. NAMEB	. COLREP. NAME	NAMEA DEJOIN.	NAMEA . DEJOIN.	± NAMEAl, (etc.)
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 e - a list of valid matrix names, separated by commas.
 The matrices identified in the list are printed when the matrix print statement is encountered.

Print instructions are executed as they occur in the sequence of abstraction instructions and consequently they should always appear after the generation of the relevant matrices, and immediately after such generation for optimum utilization of terace media during execution.

An example of the standard form of matrix printing J. shown in Section IT.3.b.

Matrix Save statements are of the form:

SAVE (a) b

where the arguments are:

- a a valid tape name that has been declared in the problem specification data.
- b a list of valid matrix names separated by commas.
 The matrices identified in the list are written on tape a as they are generated.

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(3) Control Statements

A single control statement of limited scope is available. This is a conditional transfer statement which is used to "skip ahead" in the abstraction instruction sequence.

Conditional Transfer statements are of the form:

If (a .NULL.) GO TO b

where the arguments are:

a - a valid matrix name

b - the statement number to which control is transferred if matrix a is null. Transfer to b is limited to a "skip ϵ_{need} " in the abstraction instruction sequence.

(4) Arithmetic Statements

The basic form for arithmetic statements is: $c = \pm a$.Op. $\pm b$

where <u>a</u> and <u>b</u> are known matrix names, <u>c</u> is thename of the matrix to be computed, Op is the operation to be performed in computing <u>c</u> from <u>a</u> and <u>b</u> and the positive signs of <u>a</u> and <u>b</u> may be omitted.

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

Matrix Addition statements are of the form:

 $c = \pm a$.ADD. $\pm b$.SCALE. $\pm f(1,j)$

where the signed matrix <u>b</u> is added matrically to the signed matrix <u>a</u>, each element of the matrix sum is multiplied by the signed scalar $\underline{f(1,j)}$, and the matrix of scaled elements is named <u>c</u>.

The abbreviated form is:

 $c = \pm a$.ADD. $\pm b$

where the scale is omitted.

Matrix Subtraction statements are of the form:

 $c = \pm a$ SUBT. $\pm b$ SCALE. $\pm f(i, j)$

where the signed matrix <u>b</u> is subtracted matrically from the signed matrix <u>a</u>, each element of the matrix difference is multiplied by the signed scalar f(1,j) and the matrix of scaled elements is named <u>c</u>.

The abbreviated form is:

 $c = \pm a$.SUBT. $\pm b$

where the scale is omitted.

Matrix Multiplication statements are of the form:

 $c = \pm a$.MULT. $\pm t$.SCALE. $\pm f(i,j)$

where the signed matrix <u>b</u> is pre-multiplied matrically by the signed matrix <u>a</u>, each element of the product matrix is multiplied by the signed scalar <u>f (1,j)</u>, and the matrix of scaled elements is named <u>c</u>.

The abbreviated form is:

 $c = \pm a$.MULT. $\pm b$ 19

where the scale is omitted.

Matrix Transpose-Multiplication statements are of the form:

 $c = \pm a$.TMULT. $\pm b$.SCALE. $\pm f(i,j)$

where the signed matrix <u>b</u> is pre-multiplied matrically by the transpose the signed matrix <u>a</u>, each element of the product matrix is multiplied by the signed scalar $\underline{r(1,j)}$, and the matrix of scaled elements is named <u>c</u>.

The abbreviated form is:

 $c = \pm a$.TMULT. $\pm b$

where the scale is omitted.

Element-by-Element Multiplication statements are of the form:

 $c = \pm a$.EMULT. $\pm b$.SCAIE. $\pm f(i,j)$

where each element of the signed matrix <u>b</u> is multiplied by the corresponding element of the signed matrix <u>a</u>, each element of the matrix of element products is multiplied by the signed scalar $f(\underline{1},\underline{1})$, and the matrix of scaled elements is named <u>c</u>.

The abbreviated form is:

 $c = \pm a$.EMULT. $\pm b$

where the scale is omitted.

Matrix-Scalar Multiplication statements are ci the form:

 $c = \pm a$.SMULT. $\pm b(1, j)$

where each element of the signed matrix <u>a</u> is multiplied by the signed scalar $\underline{b(1,j)}$, and the matrix of scaled elements is named <u>c</u>

Matrix Transposition statements are of the form:

 $c = \pm a$.TRANSP.

where the transpose of the signed matrix a is formed and named matrix c.

Matrix Adjoin statements are of the form:

 $c = \pm a$. ADJOIN. $\pm b$

where the signed matrix <u>b</u> is adjoined to the signed matrix <u>a</u> and the resulting matrix is named <u>c</u> (i.e., <u>c</u> = $\begin{bmatrix} \pm a \\ \pm b \end{bmatrix}$).

Matrix Dejoin statements are of the form:

$$C_1, C_2 = A.DEJOIN.(b,d)$$

 $C_1, C_2 = A.DEJOIN.(B(i,j),d)$

where the matrix $(A(MxN) \text{ is dejoined, columnwise to} form the two matrices <math>C_1$ (MxJ) and C_2 (Mx(N-J)) or dejoined row-wise to form the two matrices C_1 (JxN) and C_2 $(M-J)x_N$ where. $1 \le J \le N$ is the partition number (i.e., $A = \begin{bmatrix} C_1 & \\ & \\ & \\ & \end{bmatrix} \begin{bmatrix} C_2 & \\ & \\ & \\ & \end{bmatrix}$ the following definitions apply:

- b an integer specifying the row or column at which the matrix A is to be partitioned to form C_1 and C_2
- B(i,j) the element b_{ij} of matrix B specifies the row or column at which the matrix A is to be dejoined
 - d = o, for column dejoin
 - = 1, for row dejoin

Matrix Column Repeat statements are of the form:

C = A . COLREP. B

where the column dimension of matrix B specifies the number of times the column matrix A is to be repeated to form the matrix C. If the dimension of A is $(N \times 1)$ and the dimension of B is $(L \times M)$ then the dimension of C will be $(N \times M)$.

Null Matrix statements are of the form:

C = A.NULL.B

Where a null matrix C is formed. C has a row dimension the same as the row dimension of matrix A and C has a column dimension the same as the column dimension of matrix B.

Identity Matrix statements are of the form:

B = A.IDENTC.

where B is an identity matrix having an order the same as the column dimension of matrix A (i.e., if A(MxL) then B(LxL) = I)

and

= A .IDENTR.

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where B is an identity matrix having an order the same as the row dimension of matrix A (i.e., if A(MxL) then B(MxM) = I)

Matrix Power statements are of the form:

 $c = \pm a$.POWER. $\pm b(1, j)$

where the absolute value of each element of the matrix <u>a</u> is raised to the power of the signed scalar $\underline{b(i,j)}$ and the resulting matrix is given the sign of matrix <u>a</u> and named <u>c</u>.

Matrix Inversion statements are of the form:

 $c = \pm a$.INVERS.

where the inverse of the signed matrix \underline{a} is formed by Jordanian elimination, and is named matrix \underline{c} .

This subroutine unconditionally prints pivot element values, with column indices, as special output data.

Solution of Equations by Elimination statements are of the form:

 $c = \pm a$.SEQEL. $\pm b$

where the solution, Y, of the system of "n" linear simultaneous equations in "n" unknowns, $\pm \underline{a} \ \underline{Y} = \pm \underline{b}$, is formed by Jordanian elimination, and the solution matrix is named \underline{c} .

This subroutine unconditionally prints pivot element values, with column indices, as special output data.

Solution of Equations by Iteration statements are of the form: $c = \pm a$.SEQIT. $\pm b$, (d)

where the solution, Y, of the system of "n" linear simultaneous equations in "n" unknowns, $\pm aY = \pm b$, is formed by matrix iteration, and the solution matrix is named c. Execution is terminated when the number of iteration cycles is equal to <u>d</u>. This subroutine requires that the leading diagonal of matrix <u>a</u> dominates.

Eigenvalue - Eigenvector Extraction statements are of the form:

 $c_1, c_2 = \pm a$.EIGEN. (d)

where <u>d</u> eigenvalues and the corresponding eigenvectors are extracted from the signed <u>symmetric</u> matrix <u>a</u> and named matrix <u>c</u>₁ and matrix <u>c</u>₂, respectively. The parameter <u>d</u> is an unsigned integer constant. Matrices <u>c</u>₁ and <u>c</u>₂ are of order (<u>d</u> x 1) and(<u>n</u> x <u>d</u>) respectively with a matrix <u>a</u> of order (<u>n</u> x <u>n</u>).

Eigenvalue - Eigenvector Extraction statements are of the form:

 $C_1, C_2, C_3, C_4 = \Lambda, B$.EIGEN1. (d,e,f,g)

where d eigenvalues and the corresponding eigenvectors are extracted from the eigenmatrix A and named C_1 and C_2 , respectively. With matrix A of order (NxN), matrix C is of order (dxl) and matrix C_2 is of order (Nxd). The following definitions apply:

- A Initial Eigenmatrix (N x N) real, input
- B Input guess for vectors (N x 2) lst column is guess for eigencolumn vector 2nd column is guess for eigenrow vector
- d integer specifying the number of eigenvalues and vectors requested
- e If e = o, then 2nd column of B is not used If e = 1, then 1st column of B is used and must be conveyed eigenvector corresponding to A
- f Integer specifying the number of iterations for each pass. There are 10 passes with the criteria updated each time for each eigenvalue calculation (CRIT = CRIT N + G). Default is 500 iterations.
- g Convergence criteria for eigenvalues and vectors. Default value is .001
- C₁ Output Eigenvalue Matrix (d x 1)
- C₂ Output eigen column. vector matrix (N x d)

C3 - Saved deflated eigen matrix for restart

C4 - Saved vector matrix for restart (N x 2). First column in last iteration of last eigen column vector. Second column is last iteration of last eigen row vector.

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NOTE FOR VECOUT AND MATOUT

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Α.	If the first eigenvector column does not converge, then C4 consists of 1st column - last iteration of the eigenvector (column) vector
	2nd column - not used
	C ₃ consists of the original A eigenmatrix
	Use $e = 0$ for restart with C_3 for A and C_4 for B
В.	If the first eigen (row)vector does not converge or the eigen row root does not correspond to the eigen column root within the specified criteria*, then
	C4 consists of 1st column -converged eigen column vector 2nd column -last iteration of the eigen row vector
	C ₃ consists of the original A eigenmatrix
	Use $e = 1$ for restart with C_3 for A and C_4 for B
	*This case occurs only when there is more than one eigenvalue requested, since eigenrow conver- gence is only required for sweeping the eigenmatrix to prepare it for calculating the next eigenvalue.
C.	If an intermediate or the last eigen (column) vector does not converge, then
	C ₄ consists of 1st column-last iteration of the eigen (column) vector 2nd column-converged eigenrow vector from the previously calcu- lated eigenvalue
	C ₃ consists of the swept eigenmatrix used for calcu- lating the unconverged column vector
	Use $e = 0$ for restart with C_3 for A and C_4 for B

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D. If an intermediate or the last eigen (row) vector does not converge or its root does not converge to the column root, then $\rm C_4$ consists of

lst column - converged eigen column vector
2nd column - last iteration of eigen (row) vector

 C_3 consists of the swept eigenmatrix used for calculating the converged eigen (col) vector

Use e = 1 for restart with C_3 for A and C_4 for B

- E. If the last eigen (column) vector converges, then $C_{\underline{\mu}}$ consists of

 C_3 consists of the swept eigen matrix used for calculating the converged eigen (col) vector Use e = 0 for restart with C_3 for A and C_4 for B

Matrix Envelope statements are of the form:

 $c = \pm a$.ENVROW. or $c = \pm a$.ENVCOL.

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where the algebraic maximum and minimum values in each row (or column) of the signed matrix <u>a</u> are found, and the matrix of the extreme values is named <u>c</u>. The maximum values occupy the first column (or row) of matrix <u>c</u> respectively.

Matrix Diagonalization statements are of the form:

 $c = \pm a$.DIAGON.

where a diagonal matrix is formed from the signed column (or row) matrix a and named c. The elements on the diagonal of c are the corresponding elements of matrix \underline{a} .

Matrix Rename statements are of the form:

 $c = \pm a$.RENAME.

where a copy of the signed matrix \underline{a} is generated and named matrix \underline{c} .

"SER-Coded Subroutine statements have the general form:

 c_1 , (etc.) - $\pm a_1$, (etc.) .USERXX. $\pm b_1$, (etc.)

where computations are performed on the signed matrices \underline{a}_1 , (etc.) and the signed matrices \underline{b}_1 , (etc.) by the subroutine corresponding to the operation .USERXX. and the results are named matrices \underline{c}_1 , (etc.), where $01 \leq xx \leq 09$.

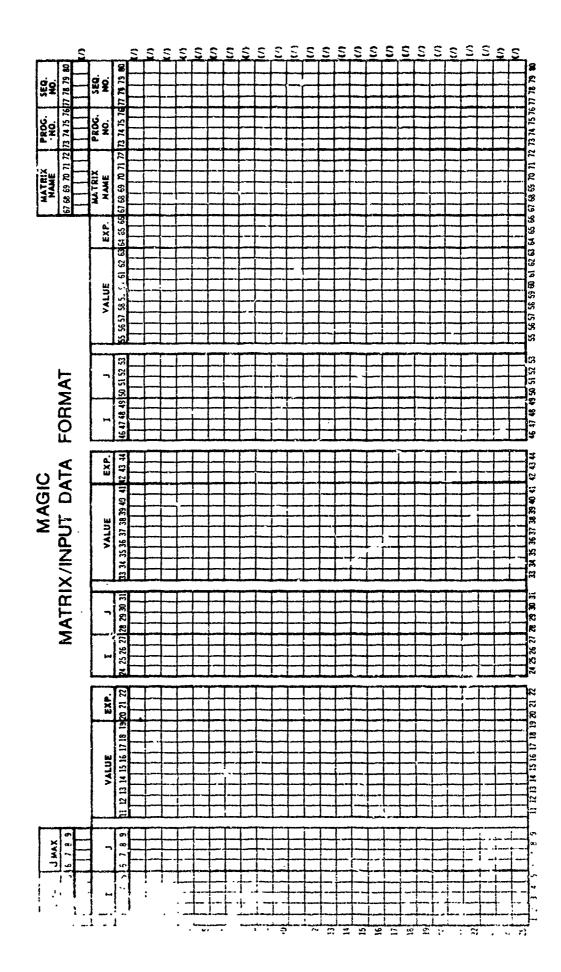
If no output matrices are formed by the subroutine, indication is provided in the statement by an (*) to the left of the equal sign.

(5) Matrix Data

Card input matrix data are specified on the Standard Form shown on the following page.

A matrix header card having an H in card column 1, and containing the matrix name and its row and column dimensions is required for each matrix. The last card after all \$MATRIX data must contain an E in card column 1 with the rest of the card blank.

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



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d. USER04

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

Since the USERO4 instruction plays a very important role in MAGIC II, a detailed analysis follows to aid the user in understanding the flexibility it provides to the total System.

(1) Input and Output Matrix Position Functions

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

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

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

OMP1 OMP2	-	copy of input structure data deck revised material library
•••••		
OMP3	-	interpreted input (structure input
		data as stored after being read
		and interpreted)
OMP4	-	external system grid point loads
Om v		and load scalar matrix
omp5	-	transformation matrix for application
		of boundary conditions
OMP6	-	transformation matrix for assembly
00		of element matrices
		· · · · · · · · · · · · · · · · · · ·
OMP7	-	element stiffness matrices stored
		as one matrix
OMP8	-	element generated load matrices
		stored as one matrix
0,400		
omp9	-	element stress matrices stored as
		one matrix

OMP10	-	element thermal stress matrices stored as one matrix
OMP11	-	element incremental stiffness matrices stored as one matrix
OMP12	-	element mass matrices stored as one matrix
OMP13	-	structural system constants stored as one matrix
OMPLL	-	element matrices in compressed format stored as one matrix
OMP15	-	prescribed displacement matrix

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

IMPL -	structure data deck (this would be a previously generated matrix saved in OMP1)	
IM'? -	interpreted input (this would be a previously generated matrix saved in OMP3 used for restart)	L
IMP3	existing material library (this would be a previously generated matr saved in OMP2)	ix
IMP4 -	displacement or stress matrix to be used for stability analyses (the str matrix must have been generated by the structural abstraction instructi .STRESS.)	

It should be noted that the following matrix positions are called matrices only in the sense that all input and output entities are considered matrices by FORMAT II - OMP1, IMP2, OMP3, OMP14, IMP1, IMP2 and IMP3.

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It is important to note that OMP14 is mutually exclusive with OMP6, OMP7, OMP8, OMP9, OMP10, OMP11, and OMP12. In order to retain compatability with the MAGIC I system and eliminate redundant execution time, the following rules must be observed.

(a) If OMP14 is suppressed then OMP6, OMP7, OMP8, OMP9, OMP10, OMP11, and OMP12 will be generated according to their definition listed previously. If this is the case then it is assumed the user is using MAGIC I abstraction instructions to solve his problem.

(b) If OMP14 is not suppressed then OMF7, OMP8, OMP9, OMP10, OMP11 and OMP12 will serve only as indicators to the .USER04. instruction for generation or non-generation of their respective

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element matrices. Since no matrices will be generated in OMP6 through OMP12 (if OMP14 is not suppressed) they should never be referenced in subsequent abstraction instructions.

(2) Suppression Option

Incorporated into the Structural Generative System is an option to suppress the generation and output of any of the output matrices and also to indicate the absence of any of the input matrices. This option is indicated to the Structural Generative System by the absence of a matrix name in the desired position in the JSER04. instruction. A matrix name is considered to be absent if the matrix position contains all blanks or the character length of the name is zero. For example, an instruction of the form: ,, INTINP, LOADS, TR, TA, KEL, FEL, SEL, SZALEL,,,, = ,,MATLB1, .USER04.; would cause suppression of the copy of the data deck, the revised material library, the element incremental stiffness matrices, the element mass matrices, the structural system constant matrix, the compressed element matrix and the prescribed displacement The instruction also indicates that there is no matrix. input data deck on tape, (directing the Structural Generative System to read data from cards), no interpreted data on tape and no input data deck on tape, (directing the Structural Generative System to read data from cards), no interpreted data on tape and no input displacements or stresses. It should be noted that certain sections of the data deck are necessary for the generation of each of the output matrices and that error checking is done to determine if the required sections are present. Accordingly, error checking is invoked for the input matrix positions to determine if ambiguous or conflicting input indications have been made.

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Use of FORMAT II Data Sets

(1) Master Input and Master Output Use for Material Library

References to the Material Library are indicated by output matrix position two and input matrix position three in the .USERO4. abstraction instruction. Rétention of a newly generated or revised Material Library is governed solely by use of the SAVE abstraction instruction at the discretion of the User. If retention is desired, the matrix name and output matrix position two must appear in a SAVE abstraction instruction, in which case it will be placed on a Master Output tape. If a non-blank matrix name s pears in input matrix position three, the Master Input Tape will be searched for that name.

Usage and generation of the Material Library is controlled by the three legal combinations of suppression of output matrix position two and input matrix position three. If the matrix name in output matrix position two is non-blank, but input matrix position three is suppressed, a new Material Library will be generated and used. If both involved matrix positions are non-blank, the old Material Library will be located on the Master Input tape, will be revised, stored as the matrix named in the specified output position, and then this revised Material Library will be used. If output matrix position two is suppressed and input matrix position three is non-blank, then the named input Material Library will be used: Suppression of both involved matrix positions results in an error condition.

Since the Material Library is stored under a matrix name on Master Output tapes, and also, therefore Master Input tapes, any other matrices may also be saved on the same tape, including other Material Libraries.

(2) Output Matrices

a. Output Matrix Position one (OMP1)

Contents	- Copy of card input data deck
Number of rows	- Set to eighty (80)
Number of columns	- Number of cards in data deck
Column records	- One data card per column
	record, one card column per
	ron

b. Output Matrix Position Iwo (OMP2)

Contents - Material library Number of columns - 306 (maximum number of words possible for one material entry)

Number	of columns	-	Number of mat	terial	tabl	.es in
Column	records	-	library plus One material record.		per	column

c. Output Matrix Position Three (OMP3)

Contents Number of rows	- Interpreted input - Set to number of words in maximum record created
Number of columns Column records	 Number of elements plus four One element input block per record.

d. Output Matrix Position Four (OMP4)

Contents	- External system grid point loads
Number of rows	- Number of degrees of freedom
Number of columns Column records	 in total system plus 1 Number of load conditions The first word is the external load scalar followed by one load condition per column record (use .DEJOIN. to obtain the load scalar).

e. Output Matrix Position Five (OMP5)

- Transformation matrix for
application of boundary conditions
- Number of degrees of freedom in
total system
- Number of degrees of freedom in total system
- (1) for desired degrees of free-
dom - contain a one in the

dom - contain a one in the assigned reduced degree of freedom row

(2) for undesired degrees of freedom - column record is omitted (null column)

f. Output Matrix Position Six (OMP6)

Contents	- Transformation matrix for assembly of element matrices
Number of rows	- Number of degrees of freedom in total system
Number of columns	- Summation of element degrees
Còlumn records	- Contain a one in the assigned degree of freedom row for that summed element degree of freedom

g. Output Matrix Position Seven (OMP?)

	Contents Number of rows Number of columns Column records	 Element stiffness matrices Summation of element degrees of freedom Summation of element degrees of freedom Each record contains a column of an element stiffness matrix
h.	Output Matrix Posi	
	Contents Number of rowr Number of columns	 Element applied load matrices Summation of element degrees of freedom One
	Column record	- Contains all element applied load matrices
i.	Output Matrix Posi	tion Nine (OMP9)
	Contents Number of rows	 Element stress matrices Summation of element stress point and component orders
	Number of columns	- Summation of element degrees
	Column records	- Each record contains a column of an element stress matrix
j.	Output Matrix Posi	tion Ten (OMPlO)
	Contents Number of rows	 Element thermal stress matrices Summation of element stress point and component orders
	Number of columns Column record	
k.	Output Matrix Posi	tion Eleven (CMP11)
	Contents	- Element incremental stiffness matrix
	Number of rows	- Summation of element degrees
	Number of columns	- Summation of element degrees of freedom
	Column records	- Each record contains a column of an element incremental stiffness matrix

33

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1. Output Matrix Position Twelve (OMP12)

Content Number	s of rows	-	Element mass matrices Summation of element degrees of freedom
Number	of columns		Summation of element degrees of freedom
Column	records	-	Each record contains a column of an element mass matrix

Output Matrix Position Thirteen (OMP13)

m.

Personal Construction of the State States and

Contents Number of rows Number of columns	-		
Column record	-	Nineteen structural system constants (for use outside the .USERO4. module)	of

The following is a description of the variables in this matrix:

Word	•, -	-	Number of directions allowed
Word	2	-	Number of types of movement allowed
Word			
			reference node in element connections)
Word	4	-	Order of the reduced system (number of
			l's plus 2's)
Word	5	-	Number of bounded degrees of freedom
	-		(number of 0's)
Word	6	-	Number of unknown degrees of freedom
			(number of l's)
word	7		Number of known degrees of freedom
			(number of 2's)
Word	8	-	Number of O's plus l's
Word			
	-		if word $1 = 3$, equal to one otherwise
Word	10		Order of the total system
Word	11	-	Number of elements
Word	12	-	Number of load conditions
Word	13	-	
Word	21	-	Number of cigenvalues requested
Word	55	-	Eigenvalue/vector convergence criteria
Word	23	~	Maximum number of iterations
Word	24		Control for iteration debug print
Word			
Word	26	-	
Word	27	~	Control for guess vector iteration start

n. Output Matrix Position Fourteen (OMP14)

Contents	- Element matrices in compressed form	l
Number of rows Number of columns Column records	 Varies depending on problem One column for each element Each record contains all element matrices generated by .USER04. instruction in compressed form (to be used by structural modules outside of .USER04.) 	

o. Output Matrix Position Fifteen (OMP15)

		Prescribed displacements			
Number of rows		Number of degrees of freedom in system			
		Number of load conditions			
Column records	-	One prescribed displacement condition per column record			

f.

Structural Abstraction Instructions To Be Used In Conjunction With The .USER04. Instruction

In designing the MAGIC II System for Structural Analysis, provision was made for accommodating new abstraction instructions peculiar to the .USERO4-module. In keeping with the philosophy of generating a highly flexible USER oriented system, specialized instructions were designed for items such as element stress and force determination, element assembly and print controls. These additional USER options provide output capabilities of the MAGIC II System, consistent with input-requirements.

The following abstraction instructions, .STRESS.,.FORCE.,.ASSEM. .EPRINT., and .GPRINT. are to be used in conjunction with the .USER04. abstraction instruction. OMP will be used to represent an output matrix position name and IMP will be used to represent the input matrix position name when referring to the .USER04. instruction.

(1) To compute the net element stress matrix and generate optional engineering print of apparent element stresses, element applied stresses and net element stresses use the .STRESS. abstraction instruction.

C = A, B .STRESS. (d, e)

Where matrix A is OMP14 of the ,.USER04. instruction and Matrix B is a matrix containing the unredued displacement column for each load condition. The output matrix C will contain the net element stresses for each load condition. The following definitions apply:

- đ
- = 0, for no print = 1, for apparent element stress print = 2, for element applied stress print = 3, for net element stress print

 - = 4, for apparent, applied, and net element stress print
- an unsigned floating point number, with or without exponent, boundary matrix element values that are trivial and to be printed as zero. That is, the matrix element $c_{ij} = 0.0 |C_{ij}| \le e$. e If e is suppressed, then the value of e is defaulted to 0.0.

(2) To compute the net element force matrix and generate optional engineering print of apparent element forces, element applied forces and net element forces use the .FORCE. austraction instruction.

> С = A, B .FORCE. (d,e)

Where matrix A is OMP14 of the .USER04. instruction and matrix B is a matrix containing the unreduced displacement column for each load condition. The output matrix C will contain the net element forces for each load condition. The following definitions apply:

- = 0, for no print d
 - 1, for apparent element force print
 2, for element applied force print
 3, for net element force print

 - 4, for apparent, applied, and net element stress pring
- an unsigned floating point number, with or without exponent, bounding matrix element values that are e trivial and to be printed as zero. That is, the matrix element $c_{ij} = 0.0$ if $|C_{ij}| \le e$. If e is suppressed, then the value of a is defaulted to 0.0.

To generate engineering printout of the net element (3) stresses or net element forces use the .EPRINT. abstraction instruction.

.EPRINT. (a, b, c) D

where matrix C is OMP14 rom the .USERO4. instruction and matrix D is either a net element stress matrix generated by a previous .STRESS. abstraction instruction or matrix D is a net element force matrix generated by a previous .FORCE. abstraction instruction. The following definitions apply.

- a. element matrix print code
 a = 1, for net element stress print
 a = 2, for net element force part
- b. an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and to be printed as zero. That is, the matrix element $d_{i,j} = 0.0$ if $|d_{i,j}| \leq b$.

If b is suppressed, then the value of b is defaulted to be 0.0.

- (4) To assemble the element stiffness metrices, element mass matrices, element incremental matrices and element thermal load matrices as output by the .USEH.04. instruction use the .ASSEM. abstraction instruction.
 - C = A .ASSEM. B, (d)

where matrix A is OMP14 and matrix B is OMP13 of the .USER04. instruction, respectively. The output matrix C will be the assembled stiffness, mass, incremental or thermal load matrix depending on the value of d. The following definition applies:

> d = 10, to assemble element stiffness matrix = 20, to assemble element mass matrices = 30, to assemble element incremental matrice = 40, to assemble element applied load matrices

where for d = 10, 20, and 30 and [C] will have an order (NSYS x NSYS) and for d = 40, (NSYS x 1), where NSYS is the total number of system degree degrees of freedom for the structure being analyzed. If we let o's represent retained (or founded) degrees of freedom, 1's represent unknown degrees of freedom, and 2's represent known degrees of freedoms then the matrix C will be ordered as follows:

	• •	C ₀₀	Ĉ _{Ol} Ç _{ll}	C _{Q2}			c ₀ c ₁ c ₂
C	=	C ₁₀	C ₁₁	ClS	or	C ≐	Cl
		C20	°21	с ₁₂ с ₂₂			•°2

(5) To generate engineering printout of reactions, displacements, eigenvalues and eigenvectors, and user matrices use the .GPRINT. abstraction instruction.

.GFRINT. (a,b,c,Cl.CL.C3.C4.C5.C6.C7.C8.C9.C10.C11.C12,D,E)F,G

where the arguments are defined as follows:

a. - print code to select type of print desired
a = 1, for reaction matrix print
a = 2, for displacement matrix print
a = 3, for eigenvalue and eigenvector matrix print

a = 4, for user matrix print

- b. an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and to be printed as zero. That is, the matrix element $f_{ij} = 0.0$ if $|f_{ij}| \le b$. If b is suppressed, then the value of b is defaulted to be 0.0.
- a one to six character alphanumeric name which is printed as a label on the rows of the printed matrix F. If c is suppressed, then the default label is ROW.
- C1 C12 Each C₁ is a one to six character alphanumeric name which is printed as a label on the columns of the printed matrix F. It is possible to suppress any or all of the C₁. For each suppressed C₁ a blank column label will be written over the corresponding column. If a C₁ is suppressed then a

dot (.) must be present to indicate its absence, If all column labels are suppressed, then no dots must be present and data between the last suppressed label and the comma need not be present.

D. This matrix must be OMP13 of the .USER04. instruction.

E. This matrix is optional. It may be suppressed if input matrix F is already in reduced form. If matrix F is unreduced, i.e., contains all system degrees of freedom then E must be a transformation matrix (OMP5) used to reduce matrix F for printing. If a = 3 then this matrix must be present.

F. The matrix to be printed, it can be the reaction, displacement, eigenvector or user matrix.

G. This matrix is input only when a ≈ 3 ; and must contain the eigenvalues corresponding to the eigenvector. Otherwise, it must be omitted and no comma should be present to indicate its absence.

g. Abstraction Instructions For Structural Analyses

The previous sections have detailed the abstraction instructions available to the MAGIC II User.

Instructions of a general nature were discussed; i.e., .ADD., .MULT. etc. as well as instructions pertaining to the .USER04. module such as .STRESS. and .ASSEM.

This section will present the method of using these available instructions to perform structural analyses.

Instructions to perform the following types of analyses are presented.

1. Statics

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

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

(1) Statics Instruction Sequence (STATICS)

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Figure II-c presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis. It is to be noted that the User is not restricted to this particular set of instructions. The flexibility of the System allows the use of additional instructions to accommodate special needs and requirements of the User. As a supplement to the instructions listed in the Figure, Tables III, IV and V are provided. Table III lists definitions of terms used in each abstraction package, while Table IV provides engineering definition for each abstraction instruction which is executed by the System. In addition, Table V provides Matrix Definition for all matrices used in the STATICS Instruction Sequence.

C S	0000001
	0000002
STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS	000003
-	000004
* * * * * * * * * * * * * * * *	* * * * * * * *0000005
	00000060
STATICS INSTRUCTION SEQUENCE	0000007
	0000008
* * * * * * * * * * * * * * * *	* * * * * * * * 0000099
	0000010
JENERATE ELEMENT MATRICES	00000110
, ML LS, XLD, TR . , KEL , FTEL, SEL, STEL,, SC .EN, =,,	+ .USER04. 0000013 0000014
	0000015
FURM (1 X 3) UNIT AND (1 X 1) NULL MATRICES	0000016 SEC 0000017
DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS U	SEL 000017
	0000019
$II = SC \cdot IDENTC \cdot$	0000020
13 = ILONULLOSC	0000020
DIFF = 11 . SMULT. SC (9.1)	0000022
ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED	0000023 0000024
	0000025
KELA = EM .A SSE 4. SC . (10)	0000026
FTELA = EH .ASSEN . SC , (40)	0000023
LSCALE ;LOADS = XLD . DEJOIN. (1, 1)	0000028
AND A TREFATOR NA THE VAND AND THE	.0000022
REDUCE STIFFNE'SS MATRIX AND PRINT	0000030
A ANALY MELLA DE LOTA À COLOR À L. CA	0000031
KCHKNO = KELA .DÊJOIN.Î SC(5,1).1).	2000032
KCC, STIFF = KNOODEJOIN. (. SC (5+1)+0)	0000033
PRINT(FURCE, DISP,) STIFF	0000034
	0000035
FIRM REDUCED TOTAL LOAD COLUMN	0000036
THE PLANE PLEASE MORE OF TRADE TO MEAN CRAFT	A
MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCAUA	0000038
FTELS = FTELA MULTOUSCALE	
TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED	0000040
LUADO = TR. MULT. LOAD'S	000,0041
FURN TOTAL LOAD CCLUMNS	0000042
TLUAU # FTELS.ADD.LUADG	0000043
TL ; TLDADK = TLDAD, DE JOING (SC (5,11) 11)	000.0044
CHANG THE IN COLACEMENTS	0000045
SALVE FOR DI-SPLACEMENTS	0000046
NU SCHTER RARI TI MAD	000,0047
XX = STIFF SEQEL TLOADR	0000048
TRC, TR 12 - TR .DE JUI N. (SC (5 .1) .1)	0000049
X = TRAZOTMULTOXX	0000050
ND = TR MUTOR	0000051
ALL ALLEN TE ACAT TICA & AND INVEDCE CHERK	0000052
CALCULATE REACTIONS AND INVERSE CHECK	0000953
	000005
REACTS = KELA-MULT-XO	-0000055
REACTP = REACTS. SUBT. TA DAD	0000056
IF OIFFONULLOF GU TO LO	0000051
PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS,	
REACTIONS AND INVERSE CHECK IN ENGINEERING	
Figure II-c STATICS Agendum Without Pre	scribed Displacements
41	
	•

L		00000600
C	ELEMENTS HAVE 1 OR 2 DEGREES CF FREEDCM	00000610
C _		00000620
	GPKINT(4,FX.FY.FZ.HX.MY.MZ.SC.TR) FTELA	00000630
	GPR'INT(4,,,FX.FY.FZ.MX.MY.MZ.SC,)LOADS	00000640
	GPR INT (2, , , U. V. W. THE TAX. THE TAY. THE TAZ, SC, IX	00000650
	GPP INT(L,,,FX,FY,FZ,MX,MY,HZ,SC,TP) REACTP	00000660
	IF (13-NULL-) GU TU 6CO	00000670
Ċ,		00000680
G	ELFMENTS HAVE 3 DEGREES OF FREEDCH	00000690
J.		00000700
10-	GPR IN T(*4,,,FR.O.FZ.CO. MBETÀ. O.FL.O.F3,SC.TR) FT ELA	00000710
	GPR INTI 4, , , FR. O.F Z. O. MBETA. O. FJ. O. F3, SC. LECADS	00000720
<i></i>	GPF IN I (2; + U. O. W. O. THE TAY. O. W. O. W. SC. IX	00000730
÷	GPR INT(1,,,FK.O.FZ.O.MBETA.O.F1.O.F3,SC.TR IREACT P	00000740
C	na series de la construction de la La construction de la construction d	00000750
`С	GENERATE STRESSES AND FORCES	00000760
્ટ્ર કપ્ઉ		00000770
500	STRESP=EM+XO +STRESS+(4+)	00000780
· · · · · · · · · · · · · · · · · · ·	FURCEP =EM , XO . FURCE . (4.)	00000790

C C C

Figure II-c STATICS Agendym (Concluded)

TABLE III

PRELIMINARY DEFINITIONS

Unordered System	-	The arrangement of the assembled system according to the boundary table and grid points. Points which are free, fixed or displaced are intermixed.
0's	-	Points which have a 0 boundary

- condition. No displacements are allowed at these points.
- Points which have a 1 boundary condition. Displacements are allowed at these points.
 - Points which have prescribed displacements on them.
 - System where all 0's are placed first and all 1's after them. The ASSEM abstraction instruction generates matrices in this form. All processing by the abstraction sequences uses this form with the exception of the print routines. The system can be written as:

K00	K ₀₁	x ⁰	 P.0.
- K ₁₀	ĸ	X ₁	P ₁

Note that this system is the 0-1-2 ordered system with no 2's.

The order of the assembled unreduced system, i.e., the number of 0's + 1's + 2's.

The order of the reduced system (i.e., the number of 1's plus the number of 2's.

NŞYŞ

1's

2's

. .

4

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0-1 Ordered System

NMDB

TABLE III

(CONCLUDED)

problem.

NMDBO

Number of 0's in the system.

Number of 1's in the system.

Number of 2's in the system.

Number of load conditions in the

NMDB1

NMDB2

NL

0-1-2 Ordered System

System where all 0's are placed first, all 1's next, and finally all 2's are last. The ASSEM instruction generates matrices in this form. All processing by the abstraction instructions uses this form with the exception of the print routine. The system for the statics problem can be written as

	ĸ _{oo}	K _{QÍ}	K ₀₂		x _o		P ₀
4	к ₁₀	K ₁₁	K ₁₂		x ₁	*	P ₁
	^{. K} 20	K ₂₁	K ₂₂	2	; X ₂		P ₂

Note that this reduces to the 0-1 ordered system when NMDB2 = 0.

Reduced System

NL48

NELEM

NVALUE

0-1-2 ordered system or 0-1 ordered system with 01s removed.

Product of the number of degrees of freedom for the element (maximum is 48) and the number of 1 ading conditions.

Number of elements used in idealization

Number of eigenvalues and eigenvectors desired.

TABLE IV

STATICS INSTRUCTION SEQUENCE (Step by Step Description)

Statement Number

1

2

3

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and a second start is the second start of the

Instruction and Explanation

,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC,EM, =,,MATL,.USER04.

Generates element matrices required for the statics problem. Note that names must be included for KEL, FTEL, SEL, STEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated by the module and placed in the EM array. MATL is an optional material library maintained by the user.

I1=SC.IDENTC.

Forms a $l \ge l$ identity matrix in II. This corresponds to a scalar value of 1.0 which is used in multiplication later to form the print control matrix DIFF.

I3=I1.NULL.SC

Forms a 1 x 1 null matrix which is used to generate unconditional 'GO TO' statements needed below.

DIFF=I1.SMULT.SC(9, 1) [DIFF]=[11]*SC(9, 1)

Forms the print control matrix which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is not zero, the system and elements have 1 or 2 degrees of freedom per grid point.

TABLE IV

(Continued)

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Statement Number	Instruction and Explanation
5	KELA=EM.ASSEM.SC, (10)
	Forms the assembled stiffness matrix KELA in the 0-1 ordered system from the element stiffness matrices stored in EM as columns. SC contains system constants required by the .ASSEM. routine.
6	FTELA=EM.ASSEM.SC, (40)
	Forms the assembled element applied load column in the 0-1 ordered system from the element applied load columns stored in EM as columns.
7	LSCALE,LOADS=XLD.DEJOIN.(1,1)
	$\begin{bmatrix} LSCALE \\ LOADS \end{bmatrix} = \begin{bmatrix} xLD \end{bmatrix}$
· _	The load scalars LSCALE and the external load columns LOADS are dejoined from the XLD matrix. The XLD matrix consists of the external columns with the corresponding load scalar as the first row.
8	KO,KNO=KELA:DEJOIN.(SC(5,1),1)
	[KO] = [KELA]
•	The NMDB rows of KELA which correspond to the 1.15 are formed in KNO.
., ⁹	KCO, STIFF=KNO.DEJOIN. (SC(5,1),0) [KCO;STIFF] = [KNO]
	The (NMDB x NMDB) reduced stiffness matrix is formed in STIFF. Matrix STIFF is analogous to partition K_{11} in the definition
	of the 0-1 ordered system.
10	PRINT(FORCE, DISP,) STIFF

PRINT(FORCE, DISP,,) STIFF Prints the reduced stiffness matrix.

TABLE IV

(Continued)

Statement Number	Instruction and Explanation
11	FTELS=FTELA.MULT.LSCALE [FTELS] = [FTELA] [LSCALE]
	Forms NL element applied load columns by multiplying the element applied load column by the corresponding load scalar.
12	LOADO=TR.MULT.LOADS [LOADO] = [TR] [LOADS]
	Forms the transformed 0-1 assembled external load columns from the unordered LOADS.
13	TLOAD=FTELS.ADD.LOADO [TLOAD] = [FTELS] + [LOADO]
-	Forms the total load column TLOAD = (scalar) * FTEL + LOADO in the 0-1 assembled system.
14	TL,TLOADR=TLOAD.DEJOIN.(SC(5,1),1)
-	Forms the reduced total load column TLOADR which reflects only freepoints. TLOADR is analogous to partition P2 in the definition
	of the 0-1 ordered system.
15	XX=STIFF.SEQEL.TLOADR [STIFF] [XX] = [TLOADR]
	Solves for the displacements in the reduced system XX by using Jordan elimination process to solve the system of simultaneous equations.
-	

47

E

Statement Number	Instruction and Explanation
16	TRO,TR12=TR.DEJOIN.(SC(5,1),1) $\begin{bmatrix} TRO \\ TRI2 \end{bmatrix} = [TR]$
	Forms matrix TR12 which when transposed will map the reduced system of XX into the full unordered system of displacements X.
17	$X=TR12.TMULT.XX$ $X = [TR12]^{T}[XX]$
	Forms unordered system of displacements used for printout in X.
18	XO=TR.MULT.X [XO] = [TR] [X]
	Forms 0-1 ordered displacement columns in XO.
-19	RËACTS=KELA.MULT.XO [RËACTS]: = [KËLA] [XO]
	Forms: product of assembled ordered stiffness matrix KELA and assembled ordered displacement columns XO.
⁻ 20	REACTP=REACTS.SUET.TLOAD [REACTP] = [KELA] [XO] - [TLOAD]
	Forms reactions and inverse check in REACTP.
21	IF (DIFF.NULL.) GO TO
	Test print control for number of degrees of freedom per grid point.

TABLE IV (Concluded)

Statement Number	Instruction and Explanation
22 23 24 25 26	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,) X GPRINT(1,,,FX.FY.FZ.MX.MY.MZ.SC,TR) REACTP IF(I3.NULL.) GO TO 600
	Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.
27 1 28 29 30	0 GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR) FTELA GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,) LOADS GPRINT(2,,,V.0.W.0.THETAY.0.W#.0.W##,SC,) X GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR)REACTP
	Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 3 degrees of freedon per grid point.
31	600 STRESP=EM, XO. STRESS.(4,)
	Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
32	FORCEP=EM, XO.FORCE.(4,)
	Calculates and prints net element forces for each élément and éach load condition. The force computation is based on displacements.
	,

-			
		-	
	-		
-		ÚTABLE V	Δ
	-	MATRIX DEFINITION	DEFINITIONS FOR STATICS
	Matrix	order	Definition
	MLIB	(NY X T+SYSN)	Revised Material Library Unordered external load columns with
•	TR TR	(NSYS X NSYS)	Transformation matrix from unordered assembled system into assembled 0-1-2 system
`.	KEL Fyel		Elèment stiffness matrices generation control Element applied load columns generation control
50	SEL . centre		Element stress matrices generation control Thermai stress columns generation control
· · · · · · · · · · · · · · · · · · ·	SC	(12 X 1)	System constants Contatns all element matrices generated Stored as columns
	kela Ptela		
· · · · · · · · · · · · · · · · · · ·	LSCALE Loads I1	SYS	Unordered external load columns Scalar#Value +1
· · · · · · · · · · · · · · · · · · ·	Ľ3	(т х т)	

r Control – Nur erre versate - De en Miche Brennerne bewerten en 1990 and itterates Control Control (1997), det

TABLE V, Contd.

Definition

Matrix		Order	lei		1	
AIID	J	н	×	г	~	SCALAR#U
КО	J	NMDBO	×	X NSYS	~	First NN
KNO	Ū	NMCB	×	X NSYS	~	Batřom N
KCO	C	NMDB	×	X NMDBO	~	First NN
STIFF	C	NMDB	×	X NMDB	~	Reduced
FTELS	Ĵ	SYSN	×	X NL	~	Assemble * Load S
LOADO	C	NSYS	×	X NL	~	Assemble
TLOAD	C	SYSN	k	NL	~	Assemble
TL	C	NMDEO	×	NL	~	First NN
TLOADR	Ξ	NMDB	×	X NL	~	Reduced

•.•

CALAR*IJSEd to control print format irst NMDBO rows of KELA ottom NMDB rows of KELA irst NMDBO columns of KNO educed stiffness matrix ssembled 0-1 element applied load column Load Scalar, for each load condition ssembled 0-1 external load columns ssembled 0-1 total load columns drst NMDBO rows of TLOAD educed total load columns

Matrix	0	Order		Definitions
XX	eidmn)	X NL	-	Reduced displacement columns
TRO	(NMDBO-	X NSYS	~	First NMDBO rows of TR
TR12	(NMDB	X NSYS	~	Transpose of matrix which maps reduced system into unreduced/unordered system
×	(NSYS	X NL V	~	Unordered assembled displacement columns
XO	(NSYS	X NL	~	Ordered 0-1 assembled displacement columns
REACTS	(NŠYS	X NL	~	Product of assembled stiffness matrix and displacement columns (ordered)
REACTP	SYSN)	X NL	~	Reactions based on first load condition
STRESP	(NL48	X NELEM	•	Element stress matrices stored for each load condition as columns
FORCEP	8 h IN)	X NELEM	~	Element force matrices stored for each load condition as columns
SYSN				Order of assembled system
NL				Number of loading conditions
NMDBO	-			Number of 0's in system, (.e., number of points bounded out)
NMDB				Number of 1's in system, (i.e., number of free points)
NL48	•			Product of the number of degrees of freedom for the element (maximum 1s 48) and the number of loading conditions
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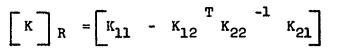
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(2) Statics Instruction Sequence With Condensation (STATICSC)

Figure II-d presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with condensation. The condensation (reduction) technique is that of Guyan (Reference 7). With the use of this option, the User is provided the flexibility to perform a static analysis utilizing a rational condensation procedure. The only basic difference in abstraction instructions between using the statics with condensation option and the standard statics option is the additional instructions required to form the condensed stiffness matrix, i.e.,



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These differences can be clearly noted upon comparison of STATICS (Figure II-c) with STATICSC (Figure II-d).

\$STATIC SC	00003460
C	00003470
CSTATICS AGENDUM, WITH CONDENSATION	00003480
C	00003490
Č + + + + + + + + + + + + + + + + + + +	* *00003500
Č	· 00003510
C STATICS INSTRUCTION SEQUENCE	00003520
C	00003530
č	* *00003540
(00003550
C GENERATE ELEMENT MATRICES	00003560
C	00003570
•MLIH, •XLD, TK, •KEL+FTLL+SFL+STEL++SC+EF+ =++ ••US ER04•	00003580
C	00003590
C FORM (A X 1) UNIT AND (1 X 1) NULL PATRICES	00003600
C CETERMINE PRINT FORMAT FOR TYPE OF ELEPENTS USED	00003610
$I1 = SC \cdot IDENTC \cdot$	00003620
$13 = 11 \cdot \text{NULL} \cdot \text{SC}$	00003630
$\Theta_{1}FF = 11 + SMULT + SC(9+1)$	00003640
C	00003650
C ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LCACS	00003660
C ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LCADS	00003670
KELA = LM CASSEM. SC. (10)	00003680
FTELA = EM .ASSEM .SC, (40)	00003690
Ċ	00003700
C REDUCE STIFFNESS MATRIX AND PRINT	00603710
C REDUCE STIFFNESS MATRIX AND PRINT	00003720
$KC_{0}KNG = KFLA_{0}UEJOIN_{0} (SC(5_{1})_{1})$	00003730
KCC, STIFF = KNO.DEJUIN. (SC(5,1),0)	00003740
PRINT(FORCE, DISP,) STIFF	0000 3750
	00003760
C FORM REDUCED TOTAL LOAD COLUMN	00003770
C	00003780
LSCALE.LOADS = XLD .DEJOIN. (1.1)	00003790
C MULTIPLY ELEMENT APPLIED LOADS BY LCAD SCALAR	0000 3800
FTELS = FTELA.MULT.LSCALE	00003810
CCONDENSE ASSEMBLED STIFFNESS MATRIX	00003820
TUP, BOT = STIFF .DE JGIN. (SC (6 .1).1)	00003830
$K_{11}, K_{12} = TOP = DEJOIN (SC(6+1), 0)$	00003840
K) 27, K22 = BUT .DEJOIN. (SC (6,1),0)	00003950
	00003860
CCUNDENSE EXTERNAL LOAD COLUMNS	00003870
PU.P12 = LUAUS .DEJOIN. (SC(5,1),1)	00003880
P1, P2 = P12 .DEJOIN. (SC (6,1),1)	00003890
C	00003900
CFORM (K11 - K12+K22(INVS)+K12T)	00003910
	00003920
$KL2I = -K22 \cdot INVERS \cdot$	0000 3930
$KPI = K221 \bullet MULT \bullet KL2T$	0000 3940
KR2 = K12 . MULT. KR1	00003950
$KR = K11 \cdot ADD \cdot KR2$	00003960
CSQLVE FOR DISPLACEMENTS D1	00003970
$01 = KR \cdot SEQFL \cdot P1$	00003980
CSOLVE FOR DISPLACEMENTS D2	00003990
$D2 = KR1 \cdot MULT \cdot D1$	00004000

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. . Figure II-d Statics Agendum With Condensation

C----FORM TOTAL DISPLACEMET VECTOR 00004010 DIT = D1 .TRANSP. 00004020 D2T = D2 .TRANSP. 00004030 D12 = DIT .ADJOIN. D2T 00004040 XX = D12 .TRANSP. 00004050 C-----EXPAND DISPLACEMENTS TO TOTAL SYSTEM DEGREES OF C----FREEDUM AND FEARRANGE TO U-1-2 SYSTEM 00004060 00004070 $TK0, TK'2 = TR \cdot DEJOIN \cdot (SC(5,1), 1)$ 00004080 X = TR12. THULT. XX 00004090 XU = TR.MULT.X 00004100 С 00004110 Ç. CALCULATE REACTIONS AND INVERSE CHECK 00004120 C 00004130 00004140 PEACTS = KELA.MULT.XO ł REACTP = REACTS. SUBT. TLOAD 00004150 00004160 IF (DIFF.NULL.) GO TO 10 00004170 C. 00004180 PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS, Ċ 00004190 REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT С 00004200 С С ELEMENTS HAVE 1 OR 2 DEGREES CF FREEDOM 00004210 00004220 С 00004230 G: INT(4,,,FX.FY.FZ.MX.MY.MZ.SC.TR) FTELA 00004240 GPR INT (4,,,FX.FY.FZ.MX.MY.MZ.SC, JLOADS GPR IN TI 2, ... U. V. W. THE TAX. THE TAY. THETAL.SC. X 00004250 00004260 GPR IN F(1,++FXoFYoFZoHXoHYoH7+SC,TR) REACTE 00004270 IF (IJ.NULL.) GO TO 600 00004280 С С ELEMENTS HAVE 3 DEGREES OF FREEDCH 00004290 00004300 С 00004310 10 GPR INT 1 4+++FR+0+FZ+0+MBETA+0+F1+0+F3+SC+TR) FTELA 00004320 GPR INT (4, +, FR. O. FZ. O. MBETA. O. F1. O. F3, SC, ILCADS 00004330 UPR INT (2, , , U. O. N. O. THE TAY' O. W. O. W. SC, IX GPR INTI 1, , , FR. O. FZ. O. MBETA. O. F1. O. F3, SC, TR JREACT P 00004340 00004350 C С GENERATE STRESSES AND FORCES 00004360 00004370 C. 00004380 STRESP = EN+XU . STRESS. 14.1 60 C, FORCEP = EM, XD .FORCE. (4,) 00004390

Figure II-d Statics Agendum With Condensation (Concluded)

(3) Statics Instruction Sequence with Prescribed Displacements (STATICS2)

Figure II-e presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with prescribed displacements. With the use of this option, applied loading may be prescribed in terms of non-zero displacement values. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero. A specialized pre-printed input data form is provided for input of prescribed displacements. This form will be discussed in detail in the Structural Input Data Section.

Tables VI and VII are provided as supplements to Figure II-e. Table VI provides engineering definition for each abstraction instruction listed in Figure II-e; while Table VII provides matrix definition for all matrices used in the STATICS2 Abstraction Instruction Sequence.

SSTATICS2	00000800
G	00000810
CSTATICS AGENDUM WITH PRESCRIBED DISPLACEMENTS	00000820
C	00000830
C STATICS INSTRUCTION SEQUENCE	00000840
C	00000850
C GENERATE ELEMENT MATRICES	00000860
, ML IB, , XLD, TP, , KEL, FTEL, SEL, STEL, , SC, EM, PD=, , , US ER04.	00000870
C	00000880
C FORM (1 X 1) UNIT AND () X 1) NULL PATRICES	00000890
C FORM (1 X 1) UNIT AND () X 1) NULL MATRICES C CETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED C	00000900
	00000910
I) = SC.IDENTC.	00000920
13 = 11 NULL SC	00000930
$DIFF = [1 \circ SPULT \circ SC (9,1)]$	00000940
	00000950
C ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LCACS C	
	00000970
KELA = EM +455EH+ SC+(10)	00000980
FTELA = EM .A SSEM . SC . (40)	00000990
LSCALE, LOADS = XLU . DE JOI N. (1,1)	00001000
C	00001010
C REDUCE STIFFNESS MATRIX AND PRINT	00001020
	00001030
K (,KNO = KELA .DE JOIN. (SC (5,1),1)	00001040
KCC, STIFF = KNO, DEJOIN, (SC(5,1), 0)	00001050
PR INT(FORCE, DISP,) STIFF	00001060
	00001070
C MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR	00001080
FTELS * FTELA-MULT-LSCALE	00001090
C TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM	00001100
LGACO = TR. MULT. LOADS	00001110
C FORM TOTAL LOAD COLUMNS	00001120
TLJAD = FTELS-ADD-LOADO	00001130
TL, TLUADR = TLUAD, DE JUÌN, (SC $(5,1),1$)	00001140
	00001150
C SOLVE FOR DISPLACEMENTS	00001160
C PRESCRIBED DISPLACEMENTS ARE PRESENT	00001170
C PRESCRIDED DISPERCEMENTS ARE PRESENT	00001180-
U C	

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Figure II-e Statics Agendum With Prescribed Displacements

· C 00001190 $K_{1}K_{2} = STIFF \cdot DEJUIN \cdot (SC(6,1),1)$ 00001200 $K_{11}, K_{12} = K_{1}, DEJOIN, (SC(6,1), 0)$ 00001210 PDU = TP.MULT.PD 00001220 PR+122 = $POO \rightarrow DEJOIN \circ (SC(8,1),1)$ 00001230 K3 = K12.MULT.D2 00001240 $P_{1}, P_{2} = TLOADR \cdot DE JUIN \cdot (SC (6,1),1)$ 00001250 $K4 = P1 \cdot SUBT \cdot K3$ 00001260 X1 = K11.SEQEL.K4 00001270 XIT = XI.TRANSP. 00001289 X2T = D2.TRANSP. 00001290 XIZI = X1T.ADJUIN.X2T NOT REPRODUCIBLE 00001300 XCT = XIT.NULL.KCC 00001310 XT = XCT.ADJUIN.X12T 00001320 $XU = XT_{\bullet}TFANSP_{\bullet}$ 00001330 X = TR . TMUL T. XO 00001340 CALCULATE AND PRINT REACTIONS £. 00001350 C 00001360 PEACTT = KELA.MULT.XO 00001370 KEACT = REACTT. SUBT. TLOAD 00001380 C 00001390 ĉ ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM 00001400 C 00001410 C PRINT ELEMENT APPLIED LOADS AND EXTERNAL LCADS 00001420 PRINT ASSEMBLED DESPLACEMENT COLUMN C 00001430 С 00001440 IF (DIFF.NULL.) GO TG 10 00001450 GPR INT (4, , , FX.FY.FZ. MX. MY. MZ.SC.TR) FTELA 00001460 GPR INTEL 4, , , FX. FY. FZ. MX. MY. PZ, SC. ILGADS 00001470 GPR INT (2, , , U. V. W. THE TAX. THE TAY. THE TAZ, SC.)X 00001480 GPR INT(1,,,FX.FY.FZ.MX.MY.HZ,SC.TR IREACT 00001490 IF (12.NULL.) GD TO 60 00001500 С 00001510 ELEMENTS HAVE 3 DEGREES OF FREEDOM Ç, 00001520 ٢, 00001530 10 GPF INT(4,,,FR.O.FZ.O.MBETA.O.F1.C.F3,SC,TR JFTELA 00001540 GPRINT(4,,,FF.O.FZ.O.MBETA.O.FI.O.F3,SC.)LCADS 00001550 GPP IN T (2, , , U. C. W. C. THE TAY. O. W. O. W. +, SC,) X 00001560 GPP INT(1, , , FR. U.FZ. O. MBETA. O. F1. G. F3, SC, TR JREACT 00001570 С 00001580 С 00001590 GENERATE STRESSES AND FORCES C 00001600 50 STRESS = EM, XO . STRESS. (4,) 00001610 00001620 FURCE = EM, XU .FORCE. (4,)

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Figure II-e Statics Agendum With Prescribed Displacements (Continued)

TABLE VI

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STATICS WITH PRESCRIBED DISPLACEMENTS INSTRUCTION SEQUENCE (Step by Step Description)

Statement Number	Instruction and Explanation
1	,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC, EM,PD=,,MATL,.USER04.
	Generate the element matrices needed for the statics problem with prescribed dis- placements. The names KEL, FTEL, SEL, STEL must be present to cause these matrices to he generated in EM. MATL is an optional material library maintained by the user.
2	<pre>I1=FTEL.IDENTC. [I1] = {1.0}</pre>
	Forms a ($l \times l$) identity matrix in I1. The value of $l.J$ will be used to form the print control matrix DIFF.
3	I3=I1.NULL.FTEL [I3] = {0.0}
	Forms a (1 x 1) null matrix in 13 which is used to generate an unconditional GO TO when used in an 'IF' instruction.
4	DIFF=I1.SMULT.SC(9, 1) DIFF = {1.0} * {SC(9,1)}
-	Forms the print control matrix DIFF which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is non-zero, the elements and system have 1 or 2 degrees of freedom per grid point.

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Statement Number	Instruction and Explanation
5	KELA=EM.ASSEM.SC,(10)
	Forms the 0-1-2 ordered assembled stiffness matrix KELA from the element stiffness matrices stored as columns in EM. SC contains system constants required by the ASSEM, routine.
6	FTELA=EM.ASSEM.SC,(40)
	Forms the 0-1-2 ordered assembled element applied load columns from the element applied load columns stored in EM.
7	LSCALE,LOADS=XLD.DEJOIN.(1,1)
	$\begin{bmatrix} LSCALE \\ LOADS \end{bmatrix} = [XLD]$
	The load scalars LSCALE and the external load columns LOADS are dejoined from the XLD matrix. XLD consists of the NL external load columns with the corresponding load scalar as the first row.
8.	KO, KNO=KELA.DEJOIN.(SC(5,1),1) $ \begin{bmatrix} KO \\ KNO \end{bmatrix} = \begin{bmatrix} KELA \end{bmatrix} $
	The NMDB rows of KELA which correspond to 1's and 2's are formed in KNO.
9	KCO,STIFF=KNO.DEJOIN.(SC(5,1),0) [KCO;STIFF] = [KNO]
	The (NMDB x NMDE) reduced stiffness matrix is formed in STIFF. This matrix corresponds to the $\begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$ partitions in the definition of the 0-1-2 ordered system.

Statement Number	Instruction and Explanation
10	PRINT(FORCE, DISP,,) STIFF
	Prints the reduced stiffness matrix.
11	FTELS=FTELA.MULT.LSCALE
	[FTELS] = [FTELA] [LSCALE]
	Forms NL element applied load columns FTELS by multiplying the element applied load columns FTELA by the corresponding load scalar LSCALE.
12	LOADO=TR.MULT.LOADS
	[LOADO] = [TR] [LOADS]
	Transforms the unordered total load columns LOADS into the 0-1-2 ordered assembled load columns LOADO.
13	TLOAD=FTELS.ADD.LOADO
	[TLOAD] = [FTELA] [LSCALE] + [LOADO]
	Forms the NL total load column in the 0-1-2 ordered assembled system by adding the external load columns and a scalar times the element applied load column.
14	TL, TLOADR=TLOAD.DEJOIN.(SC(8,1),1) $\begin{bmatrix} TL\\ TLOAD \end{bmatrix} = [TLOAD]$
	Forms the reduced total load column TLOADR which reflects 1's and 2's. P2 is analogous to the P2 partition in the definition of the 0-1-2 ordered system.
15	K1,K2=STIFF.DEJOIN.(SC(6,1),1) $\begin{bmatrix} K1\\ R2 \end{bmatrix} = [STIFF]$
	Forms the NMDB1 rows of STIFF which corresponds to 1's in K1. K1 corresponds to partitions $[K_{11}, K_{12}]$ in the definition of the 0-1-2 ordered system.
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Statement Number	Instruction and Explanation
16	K11,K12=K1.DEJOIN.(SC(6,1),0) [K11;K12] = [K1]
	Forms the submatrices K11 and K12 which correspond to the partitions with the same names in the definition of the 0-1-2 ordered system.
17	PDO=TR.MULT.PD [PDO] = [TR] [PD]
	Transforms the unordered prescribed dis- placement columns PD into the 0-1-2 ordered assembled prescribed displacement columns PDO.
18	$PR, D2=PDO. DEJOIN.(SC(8,1),1)$ $\left[-\frac{PR}{D2}-\right] = \left[PDO\right]$
	Forms the NMDB2 rows of PDO which correspond to the 2's in D2. D2 corresponds to partition X2 in the definition of the 0-1-2 ordered system.
19	K3=K12.MULT.D2 [K3] = [K12] [D2]
	Forms the product of the K12 matrix and the D2 displacement columns in matrix K3.
20	P1, P2=TLOADR.DEJOIN.(SC(6,1),1) $\begin{bmatrix} P1 \\ P2 \end{bmatrix} = [TLOADR]$
	Forms matrices Pl and P2 which correspond to the loads for 1's and 2's respectively.
	- -

Statement Number	Instruction and Explanation
21	K4=P1.SUBT.K3 [K4] = [P1] - [K12] [D2]
	Forms the new reduced total load columns in K4. This represents the elimination of the prescribed displacements from the problem.
22	$X_1 = K_{11}.SEQEL.K4$ [K11] [X1] = [K4]
	Solves for the unknown displacements 1's using a Jordan elimination scheme to solve the reduced system of simultaneous equations.
23	X1T=X1.TRANSP. $[X1T] = [X1]^{T'}$
	Form the transpose of the displacement columns X1 in X1T.
24	$X2T=D2.TRANSP.$ $[X2T] = [D2]^{T}$
	Form the transpose of the prescribed displacement columns (2's) in X2T.
25	$X12T=X1T.ADJOIN.X2T$ $[X_2T] = [X1T] [22T]$
	Form the transpose of the displacement columns corresponding to 1's and 2's in X12T.
26	XOT=X1T.NULL.KCO Form a null Matrix which represents the displacements for fixed points. (ie.,
•	no displacements for fixed points. (ie., no displacements are allowed for 0's). XT=XOT.ADJOIN.X12T
-1	[XT] = [XOT] [X12T] Form the transpose of the C-1-2 ordered
	assembled displacement columns in XT.

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Statement Number	Instruction and Explanation
28	XO=XT.TRANSP. $[XO] = [XT]^{T}$
	Form the 0-1-2 ordered assembled displacement columns in XO.
29	$X = TR.TMULT.XO$ $X = [TR]^{T}[XO]$
	Form the unordered displacement columns in X which will be used for printout.
30	REACTT=KELA.MULT.XO [REACTT] = [KELA] [XO]
	Forms the product of the 0-1-2 assembled stiffness matrix KELA and the 0-1-2 assembled ordered displacement columns XO.
31	REACT=REACTT.SUBT.TLOAD [REACT] = [KELA] [XO] - [TLOAD]
	Forms the reactions and inverse check in REACT.
32	IF(DIFF.NULL.) GO TO 10 Test print control for number of degrees of freedom per grid point.
33 34 35 36 37	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS GPRINT(2,,U.V.W.THETAX.THETAY.THETAZ,SC,) X GPRINT(1,,,FX.FY.FZ.MX.MY.MZ.SC,TR) REACT IF(13.NULL.) GO TO 600
	Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.

TABLE VI (Concluded)

Statement Number	Instruction and Explanation
38 39 40 41	GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR)FTELA GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,)LOADS GPRINT(2,,,V.O.W.O.THETAY,O.W*.O.W**,SC,) X GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR)REACT
	Print out element applied loads, external loads, displacements, and reactions in e engineering format for elements with 3 degrees of freedom per grid point.
42	600 STRESS=EM, XO. STRESS. (4,)
٠	Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
43	FORCE=EM,XO.FORCE.(4,)
	Calculates and prints net element forces for each element and each load condition. The force computations is based on displacements.

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TABLE VII

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MATRIX DEFINITIONS FOR STATICS WITH PRESCRIBED DISPLACEMENTS

Definition	Revised material library Unordered external load columns with load scalara as first row Transformation matrix from unordered assembled system into assembled 0-1-2 system	Element stiffness matrices generation control Element applied load columns generation control Element stress matrices generation control Thermal stress columns generation control	System constants Contains all element matrices generated Stored as columns	Unordered preşcribed displacement columns Assembled C-1~2 stiffness matrix Assembled O-i-2 element applied load column	Unordered external load columns
Order	(SYSN X RYSH) (NSYS X NSYS)		(IX 2T)	(T X SAS) (NSYS X NSYS) (NSYS X L)	(TN X I)
Matrix	MLIP XLD TR	KEL FTEL STEL STEL	SC EM	PD Kela Ftela	LSCALE

Matrix	0	Order		Definition
LOADS	(NSYS	X NL		Unordered external load columns
	I)	X 1	~	Scalar*Value+1
13	(1	X 1	~	Scalar*Value 0
DIFF	r)	X 1	~	Scalar*Used to control print format
	(NMDBO	X NSYS	~	First NMDBO rows of KELA
KNO	(NMDB	X NSYS	~	Bottom NMDB rows of KELA
IFF	(NMDB	X NMDB	~	Reduced 1-2 stiffness matrix
FTELS	(NSYS	X NL	~	Assembled 0-1-2 element applied load column*Load Scalar, for each load conditioned
LOADO	(NSYS	X NL	~	Assembled 0-1-2 external load columns
DAD	(NSYS	X NL	~	Assembled 0-1-2 total load columns
ТГ .	(NMDBO	X NL	^	First NMDBO rows of TLOAD
TLOADO	(NMDB	X NL	~	Reduced 1-2 total load columns
	LEINN)	X NMDB		First NMDB1 rows of STIFF
	(NMDB2	X NMDB	~	Last NMDB2 rows of STIFF
Kll	LADMN)	X NMDB1		Upper left corner partition of STIFF
Q	LEDMN)	X NMDB2	~	Upper right corner partition of STIFF
PDO	(NSYS	X NI,	<u> </u>	Assembled 0-1-2 prescribed displacement columns
PR	(NMDBO	X NL		First NMDBO rows of PDO
D2	(NMDB2	X NL		Prescribed displacements corresponding

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Element stress matrices stored for each load condition as columns Reactions based on first load condition Element force matrices stored for each Transposed 0-1-2 displacement columns Product of 0-1-2 assembled stiffness Load columns for reduced prescribed displacement system Transposed 1-2 displacement columns Displacements corresponding to 1's Load columns corresponding to l's Load columns corresponding to 2's Null matrix corresponding to 0's matrix and displacement columns Product of matrices Kl2 and D2 Unordered displacement columns load condition as columns 0-1-2 displacement columns Definition Matrix X1 transpose Matrix D2 transpose displacements X NELEM X NMDB2 X NMDBO X NELEM X NMDB1 X NMDB X NSYS X NL R Order × NMDB2 IECIMN **LEIGMN** INMDB1 NMDB1 (NSYS NL48 NSYS NSYS NL48 (NSYS NL NL NL NL NL REACTT Matrix STRESS FORCE REACT X12T עז דוד X2T XOT Ę Š 50 K3 ¥Ч Ч

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TABLE VII (Concluded)

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(4) Stability Analysis Instruction Sequence (STABILITY)

Figure II-f presents the suggested set of abstraction instructions for use in performing elastic instability analyses. The abstraction instructions presented in Figure II-f are given engineering definition in Tables VIII and IX.

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

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

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

The derivations of these elements are presented in detail in the Engineer's Manual, Volume I. In addition, the Element Input Section o. this manual provides additional description for the proper usage of these elements within the MAGIC II System.

STABLL ITY 00001630 C 00001640 C----STABILITY AGENDUM ANALYSIS 00001650 C 00001660 STABILITY ANALYSIS INSTRUCTION SEQUENCE С 00001670 С 00001680 C. GENERATE ELEMENT MATRICES 00001690 Ĉ 00001700 , ML IB, INTP, XLD, TP, ... KEL .FTEL, SEL, STEL, , , SC, EM, =, , + USER04. 00001710 C 00001720 ſ FIRM (1 X 3) UNIT AND (1 X 1) NULL MATRICES 00001730 £ CETERMINE PRINT FORMAT FUR TYPE OF ELEMENTS USED 00001740 C 00001750 $11 = 5C \cdot IDENTC \cdot$ 00001760 13 = 11.NULL.SC 00001770 DIFF = I1 . SMULT. SC (9.1) 00001780 í, 00001790 5 ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LCACS 00001800 r 00001910 STIFF = FM .ASSEM. SC. (1) 00001820 FTFLA = EM .ASSEM . SC. (40) 00001830 LSCALE, LOADS = XL3 .DEJOIN. (1,1) PRINT(FORCE, DISP,,) STIFF 00001840 00001850 C 00001860 С MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR 00001870 FTELS = FTELA.MULT.LSCALE 00001980 C TRANSFORM EXTERNAL LUADS TO 0-1-2 ASSEMBLED SYSTEM 00001890 LUADO = TR. MULT. LOADS 00001900 FURM TOTAL LOAD COLUMNS C 00001910 TLOAD = FTELS.ADD.LOADC 00001920 FORM REDUCED TUTAL LOAD COLUMN С 00001930 TL, TLUADR = TLOAD. DEJUIN. (SC (5,1),1) 00001940 ί 00001950 NOT REPRODUCIBLE С PRINT FLEXIBILITY MATRIX 00001960 C 00001970 FLEX = STIFF. INVERS. 00001980 PRINT (DISP, FORCE, .) FLEX 00001990 С 00002000 C SOLVE FOR DISPLACEMENTS 00002010 C. 00002020 XK= FLEX.MULT.TLUADR 00002030 TRC, TR12 = TR.DEJOIN.(SC(5,1),1)00002040 X = TR 12. THUL T. XR 00002050 XO = TR.MULT.X 00002060 IF (DIFF.NULL.) GO TC 10 00002070 C, 00002080

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Figure II-f Stabili

(presidentes)

Stability Agendum

C	PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS	00002090
C		00002100
Ċ	ELEMENTS HAVE 1 OF 2 DEGREES OF FREEDOM	00002110
ç		00002120
-	GPR INT(4,,,FX.FY.FZ.MX.MY.MZ.SC,TR)FTELA	00002130
	GPP INT (4, , , FX.FY.FZ. MX. MY. MZ, SC,)LOADS	00002140
	GPF INT (2, , , U. V. W. THE TAX. THE TAY. THE TAZ, SC.) X	00002150
	IF (1 ² •NULL•) 57 TO 60	00002160
С		00002170
Č	ELEMENTS HAVE 3 JEGREES OF FREEDOM	00002180
Ç		00002190
10	GPR IN T (4, , , FF + 0 + F 2+ 0+ MBE TA+ 0+ F 1+ 0+ F 3 + SC + TR) F T E LA	00002200
	GPR IN T (4, , , FR . U. F Z. C. MBE TA. O. F1. O. F3, SC,) LCADS	00002210
	GPR INT (2, , , U. G. W. C. THE TAY. O. W*. O. W**, SC,) X	00002220
C		00002230
С	GENEPATE STRESSES	00002240
С		00002250
60	STRESS = FM,XU .STRESS. (4,)	00002260
С		00002270
С	GENERATE ELEMENT INCREMENTAL STIFFNESS MATRIX	00002280
C		00002290
	,,,,,,,,,,NEL,, ,EL,=,INTP, ,STRESS.USER04.	00002300
C		00002310
C.	ASSEMBLE AND REDUCE INCREMENTAL MATRIX	00002320
С		00002330
	INCR = EL .ASSEM. SC. (3)	00002340
	PRINT(,,,) INCR	00002350
C		00002360
ιc	CREATE INPUT EIGENVALUE MATRIX	00002370
ι C	CREATE THE OF EIGENANEDE PATRIA	00002380
C	EIG = FLEX.MULT.INCR	00002390
	PRINT (+++) EIG	00002400
c		00002410
Ċ	CALCULATE AND PRINT E-VALUES, E-VECTORS, FREQUENCIES	00002420
C C C	ARCOLAT, MAD TREAT C TREALOTE TEATENDER AND THE	00002430
ι.	EVALUE, EVECTR., = EIG, .EIGEN1. SC	00002440
	GPR IN T (3+ 9+ + SC + TR 12) E VEC TR + E VALUE	00002450
	·/····································	

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Figure II-f - Stability Agendum (continued)

TABLE VIII

STABILITY INSTRUCTION SEQUENCE (Step by Step Description)

Statement Number

4

Instruction and Explanation

1 ,MLIB, INTP, XLD, TR, , KEL, FTEL, SEL, STEL, ,, SC, EM, =, , MATL, .USER04. Generates element matrices required for the statics problem. Note that names must be included for KEL, FTEL, SEL, STEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated by the module and placed in the EM array. MATL is an optional material library maintained by the user. 2 I1=FTEL.IDENTC. Forms a 1 x 1 identity matrix in I1. This corresponds to a scalar value of 1.0 which is used in multiplication later to form the print control matrix DIFF. I3=I1.NULL.FTEL 3

Forms a 1 x 1 null mc fix which is used to generate unconditional 'GO TO' statements needed below.

DIFF=I1.SMULT.SC(9,1) [DIFF] = [I1] * SC(9,1)

> Forms the print control matrix which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is not zero, the system and elements have 1 or 2 degrees of freedom per grid point.

Statement Number

Instruction and Explanation

5

STIFF=EM.ASSEM.SC, (1)

Forms the assembled stiffness matrix STIFF in the (NMDBxNMDB) reduced system from the element stiffness matrices stored in EM as columns. SC contains system constants required by the.ASSEM.routine.

6

FTELA=EM.ASSEM.SC, (40)

Forms the assembled element applied load column in the O-1 ordered system from the element applied load columns stored in EM as columns.

7

LSCALE, LOADS=XLD.DEJOIN.(1,1)

LSCALE	=	XLD
LOADS		

The load scalars LSCALE and the external load columns LOADS are dejointed from the XLD matrix. The XLD matrix consists of the external columns with the corresponding load scalar as the first row.

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Statement Number	Instruction and Explanation
8	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
9	FTELS=FTELA.MULT.LSCALE [FTELS] = [FTELA] [LSCALE]
	Forms NL element applied load columns by multiplying the element applied load column by the load scalar.
10	LOADO=TR.MULT.LOADS [LOADO] = [TR] [LOADS]
	Forms the transformed C-1 assembled external load columns from the unordered LOADS.
11	TLOAD=FTELS.ADD.LOADS [TLOAD] = [FTELS] + [LOADS]
	Forms the total load column TLOAD = (scalar) * FTEL + LOADO in the 0-1 assembled system.
12	TL, TLOADR=TLOAD.DEJOIN.(SC(5,1),1) $\begin{bmatrix} -TL \\ TLOADR \end{bmatrix} = \begin{bmatrix} TLOAD \end{bmatrix}$
	Forms the reduced total load column TLOADR which reflects only free points. TLOADR is analogous to partition P ₂ in the definition of the 0-1 ordered system.

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Statement Number	Instruction and Explanation					
13	FLEX=STIFF.INVERS. [FLEX] = [STIFF] ⁻¹					
	Forms the inverse of the reduced suiffness matrix in KINV.					
14	PRINT(DISP,FORCE,,) FLEX Print inverse of stiffness matrix (flexibility matrix).					
15	XR=FLEX,MULT.TLOADR [XR] = [STIFF] ⁻¹ [TLOADR]					
	Form reduced displacement column in XR by forming the product of the flexibility matrix and the reduced total load columns.					
16	TR0,TR12=TR.DEJOIN.(SC(5,1,1) $\begin{bmatrix} TR0 \\ TR12 \end{bmatrix} = [TR]$					
	Forms matrix TR12 which when transposed will map the reduced system of displacements XR into the full unordered system of displacements X.					
17	$X = TR12.TMULT.XR$ $[X] = [TR12]^{T}[XR]$					
	Forms the unordered system of displacement used for print out in X.					
18	XO=TR.MULT.X [XO] = [TR] [X]					
	Forms the 0-1 ordered system of displacements in XO.					

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Statement Number	Instruction and Explanation
19	IF(DIFF.NULL.) GO TO 1C
	Test print control for number of degrees of freedom per grid point.
20 21 22 23	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,) X IF(I3.NULL.) GO TO 60
	Print out element applied loads, external loads, and displacements, in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.
24 25 26	GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR)FTELA GPRINT(4,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,)LOADS GPRINT(2,,,V.0.W.0.THETAY.0.W*.0.W**,SC,)X
	Print out element applied loads, external loads, and displacements, in engineering format for elements with 3 degrees of freedom per grid point.
27	STRESS=EM,XO.STRESS.(4,)
	Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
28	<pre>,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,</pre>
	Generates the element incremental stiffness matrices based on the interpreted input generated by the first USER04 instruction and the STRESS matrix.
29	INCR =EL.ASSEM.SC,(3)
	Assembles the (NMDBxNMDB) reduced incremental stiffness matrix INCR. The element incremental stiffness matrices are stored in EL.

TABLE VIII (Concluded)

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Statement Number	Instruction and Explanation
30	PRINT(,,,) INCR Prints the reduced incremental stiffness matrix.
31	EIG=FLEX.MULT.INCR $[EIC] = [STIFF]^{-1} [INCR]$ Forms the product of the inverse of the reduced stiffness matrix and the reduced incremental stiffness matrix.
32	PRINT(,,,)EIG Prints the e.genvalue matrix.
33	EVALUE, EVECTR, ,=EIG, .EIGEN1.SC $\begin{bmatrix} [EIG] - [EVALUE] & [I] \end{bmatrix} \begin{bmatrix} EVECTR \end{bmatrix} = 0$ Solves for the requested eigenvalues and eigenvectors of the EIG matrix using the power method. The eigenvalues are stored in the column matrix EVALUE and the eigenvectors are stored as columns in the EVECTR matrix. The frequencies and mode shapes are printed out along with the eigenvalues and eigenvectors.
34	GPRINT(3,,,,SC,TR12)EVECTR,EVALUE Prints the eigenvalue column and the eigenvector matrix in engineering format.

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TABLE IX MATRIX DEFINITION FOR STADILITY		Derinition	Revised material library	Interpreted input deck	Unordered external load columns with load scalars as first row	Transformation matrix from unordered assembled system into assembled O-1 system	Element stiffness matrices generation control	Element applied load columns generation control	Element stress matrices generation control	Thermal stress columns generation control	System constants	Contains all element matrices generated	Stored as columns	Assembled O-1 element applied load column	Load scalars for each load condition	Unordered external load columns
	Order			(IN X T+SASN)	(SY2N X NSY2)					(I X Z)			(I X SASN)	(T X NF)	(TN X SASN)	
		Matrix	MLIB	INTP	Q.IX	TR	KEI, 82	FTEL	SEL	STEL	SC	ME		FTELA	LSCALE	LOADS

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INDLE IN, (COUCH)	Definition	Scalar*Value+1	Scalar*Value O	Scalar*Used to control print format	Reduced 1-2 stiffness matrix	Assembled O-l element applied load column* load scalar, for each load condition	Assembled O-l external load columns	Assembled 0-1 total load columns	First NMDBO rows of TLOAD	Reduced total load columns	Inverse of reduced stiffness matrix	Reduced displacement columns	First NMDBC rows of TR	Transpose of matrix which maps reduced system into unreduced/unordered system	Unordered assembled displacement columns	Ordered O-1 assembled displacement columns	Element stress matrices stored for each load condition as columins	
VT JUCKI	Order	(1X1)	(T X T)	(T X T)	(NMDB X NMDB)	(IN X SASN)	(TN X SASN)	(IN X SXSN)	(NINDBO X NL)	(NMDB X N ^T)	(AUMD X NMDB)	(IN X EQUIN)	(NMDBO X NSYS)	(NATE X NSYS)	(IN X SASN)		×	
	Matrix	11		L L L F F F	ATTC.	FTELS	T OB DO	TT OAD		0000 THE OPDO	HT.RX	XB	Cam	TR12	\$	v ×	AU STRESS	

TABLE IX, (Contd)

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TABLE IX , (Contd.)

(5) Dynamics Analysis Instruction Sequence (DYNAMICS)

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

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

Tables X and XI are provided as a supplement to Figure II-g. These tables provide engineering and matrix definition for each abstraction instruction listed in Figure II-g.

It should be noted, and emphasized, that this set of example abstraction instructions which have been presented serve only to provide the User with a guide for usage of abstractions for a particular type of analyses. The User, at his option, can modify any set of abstractions to fit his particular need. As an example, the User may have a problem which requires "non-structural" masses to be added to the structural mass matrix which is assembled by the System.

If this is the case, the assembled mass matrix is modified by adding the non-structural mass matrix with an available .ADD. instruction and the analysis then proceeds in the usual manner. In general, the non-structural mass matrix would be supplied to the program as input data thru the \$ matrix option which has been explained previously.

SUYNAMICS	00002460
	00002470
C PYNAMICS AGENDUM ANALYSIS	00002460
	00002490
C BYNAMICS ANALYSIS INSTRUCTION SEQUENCE	00002500
C CENERATE ELEMENT MATRICES	00002510
C CENERATE ELEMENT MATRICES	00002520
ſ	00002530
•ML 13 • • • TR • • KEL • • • • MEL • SC • EM • = • • • • • USER04 •	00002540
(00002550
C ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX	00002560
ſ	00002570
STIFF = FM ASSEM SC (1)	00002580
$MASS = EM \bullet ASSEM \bullet SC \bullet (2)$	00002590
(00002600
C PRINT STIFFNESS MATRIX AND MASS MATRIX	00202610
L	00002620
PRINT(F)PCE+EISP++) STIFF	00092630
C. C	00002640
PRINT(FUFCE, ACCEL, +) MASS	00002650
(, , , , , , , , , , , , , , , , , , ,	00002660
PRINT(FURCE, ACCEL,) MASS GUNERATE DYNAMICS MATRIX KINV = STIFF.INVERS. DYNAM = KINV.MULT.MASS NOT REPRODUCIBLE	00002670
REPRO	00002680
KINV = STIFF.INVERS.	00002690
CYNAM = KINV. MULT. MASS	00002700
(00002710
C FIND E-VALUES, E-VECTORS, NORMAL MODES,	00002720
C. FREQUENCIES AND PRINT	00002730
	00002740
EVALUE, FVECT = DYNAM, .EIGENI. SC	00002750
	00002760
$TRC, TV12 = TR \cdot DEJOIN \cdot (SC(5,1),1)$	00002770
GPR INT (3, , , , SC, TR12) E VEC T, E VALUE	00002780
	00002790
GENERATE STIFFNESS AND GENERALIZED MASS	00002800
C MATRICES AND PRINT	00002810
C TATRICES AND PRINT	00002820
	00002830
KGEN1 = EVECT.TMULT.STIFF	00002830
KGEN = KGEN1.MULT.EVECT	00002850
MGEN1 = EVECT.TMULT.MASS	00002850
MGEN = MGEN1.MULT.EVECT	00002880
<pre>PFINT(+++) MGEN+KGEN+KINV+DYNAM</pre>	00002010

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Figure II-g Dynamics Agendum Analysis Sequence

TABLE X DYNAMICS INSTRUCTION SEQUENCE (Step by Step Description)

Statement Number	Instruction and Explanation
1	.MLIB,,,,,KEL,,,,,MEL,SC,EM,=,,MATL,.USERO4. Generates the element stiffness matrices KEL and element mass matrices MEL needed for the dynamics problem. Note that names must be present for KEL and MEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated and placed in the EM array. MATL is an optional material library maintained by the user.
2	STIFF=EM.ASSEM.SC,(1) Forms the assembled stiffness matrix STIFF from the element stiffness matrices stored in EM. SC contains system constants required by the .ASSEM. routine.
3	MASS=EM.ASSEM.SC,(2) Forms the (NMDBxNMDB) reduced mass matrix in MASS from the element mass matrices stored in EM. System information required by .ASSEM. is input in SC.
4	PRINT(FORCE, DISP, ,) STIFF Prints the reduced stiffness matrix.
5	PRINT(DISP,FORCE,,) MASS Prints the reduced mass matrix.
6	KINV=STIFF.INVERS. $[KINV] = [STIFF]^{-1}$ The inverse of the reduced stiffness matrix is formed in KINV.
7	DYNAM=KINV.MULT.MASS $[DYNAM] = [STIFF]^{-1} [MASS]$ Forms the product of the inverse of the reduced stiffness matrix KINV and the reduced mass matrix MASS in the dynamics matrix DYNAM.

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TABLE X (Continued)

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Statement Number	Instruction and Explanation
8	EVALUE,EVNCTR,,=DYNAM,.EIGEN1.SC solve [[DYNAM] - [EVALUE][I]] [EVECTR] = [0]
	Computes the required eigenvalues and corresponding eigenvectors of the dynamics matrix using the power method. The eigen- values are stored in the column matrix EVALUE and the corresponding eigenvectors are stored as columns in EVECTR. The frequencies and mode shapes are also printed out.
9	KGEN1=EVECT.TMULT.STIFF [KGEN1] = [EVECT] ^T [STIFF]
	Forms the product of the transpose of the eigenvector matrix and the reduced stiffness matrix.
10	KGEN=KGEN1.MULT.EVECT [KGEN] = [EVECT] ^T [STIFF] [EVECT]
	Forms the generalized stiffness matrix in KGEN by forming the product of KGEN1 and EVECT.
11	MGEN1=EVECT.TMULT.MASS [MGEN1] = [EVECT] ^T [MASS]
	Forms the product of the transpose of the eigenvalue matrix and the reduced mass matrix.
12	MGEN=MGEN1.MULT.EVECT [MGEN] = [EVECT] ^T [MASS] [EVECT]
	Forms the generalized mass matrix in MGEN by forming the product of MGEN1 and EVECT.

TABLE X (Concluded)

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Statement Number	Instruction and Explanation
13	PRINT(,,,)MGEN,KGEN,KINV,DYNAM
	Print the generalized stiffness matrix, generalized mass matrix, inverse of the stiffness matrix and the dynamics matrix.
14	TR0,TR12 = TR.DEJOIN.(SC(5,1),1) [TR0] = [TR]
	Forms the matrix TR12 which will be used by the GPRINT instruction.
15	GPRINT(3,,,SC,TR12)EVECT,EVALUE
	Print the eigenvalue column and the eigenvector matrix in engineering format.

E N N N	Eigenvectors of dynamics matrix stored as columns Product of E-value matrix and stiffness matrix Generalized stiffness matrix Product of E-value matrix and mass matrix Generalized mass matrix
TABLE XI TABLE XI MATRIX DEFINITIONS FOR DYNAMICS INSTRUCTION SEQUENCE MAL Definition ALIB Definition MEL Definition ALIB Definition MEL Definition ALUE Definition MEL Dynamics matrix MEL COLUMDS ALUE NMDB O Dynamics matrix	EVECT(NMDB X NVALUE)KGEN1(NVALUE X NMDB)KGEN(NVALUE X NVALUE)MGEN1(NVALUE X NMDB)MGEN1(NVALUE X NMDB)MGEN1(NVALUE X NVALUE)

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TARLE XI

(6) Dynamics Instruction Sequence With Condensation (DYNAMICSC)

Figure 1I-h presents the suggested set of abstraction instructions for use in the performance of a vibration analysis utilizing condensation. The condensation technique utilized is that of Guyan (Reference 7).

The use of this technique allows degrees of freedom considered to be superflous to be eliminated through a condensation transformation. This technique yields a eigenvalue problem which is much reduced in size.

Degrees of freedom that are to be eliminated in a particular analyses are designated by the number '2' in the Bondary Condition Section which will be discussed in detail in the next section.

Given below is a detailed algebraic statement of the condensation procedure which is performed using the Instructions of Figure II-h.

The equations of motion which govern dynamic response of structural systems can be written in matrix notation as follows:

$$\begin{bmatrix} M_2 \end{bmatrix} \left\{ \ddot{\tilde{o}}_2 \right\} + \begin{bmatrix} K_2 \end{bmatrix} \left\{ \delta_2 \right\} = \{F\}$$
(A)

The corresponding strain and kinetic energy functionals for this equation can be written as follows:

$$\mathbf{P}_{U} = 1/2 \left[\mathbf{\delta}_{2} \right] \left[\mathbf{K}_{2} \right] \left\{ \hat{\mathbf{\delta}}_{2} \right\}$$
(B)

for the strain energy and

$$\boldsymbol{\Phi}_{\mathbf{K}} = 1/2 \left[\dot{\boldsymbol{\delta}}_{2} \right] \left[\mathbf{M}_{2} \right] \left\{ \dot{\boldsymbol{\delta}}_{2} \right\}$$
(C)

The assumption made in applying this technique is that the complete set of gridpoint displacement degrees of freedom $\{\delta_2\}$

are not essential to the objective structural dynamics analyses. For example, the gridpoints in the finite element model may have been dictated by the natural breakdown of the structure into components, or the intended use of the model for stress analyses.

The complete set of substructure gridpoint displacement degrees of freedom is partitioned to reflect the division into essential $\{ \boldsymbol{\theta}_{2a} \}$ and superfluous $\{ \boldsymbol{\theta}_{2b} \}$ subsets. Partitioning of the displacement set implies a corresponding partitioning of the total potential energy as

$$\Phi_{\mathbf{p}} = \frac{1}{2} \left[\left[\boldsymbol{\delta}_{2\mathbf{a}} \right], \left[\boldsymbol{\delta}_{2\mathbf{b}} \right] \right] \left\{ \left[\begin{array}{c} \kappa_{2\mathbf{a}\mathbf{a}} \right], \left[\begin{array}{c} \kappa_{2\mathbf{a}\mathbf{b}} \right], \left[\begin{array}{c} \kappa_{2\mathbf{b}\mathbf{b}} \right] \right] \left\{ \begin{array}{c} \boldsymbol{\delta}_{2\mathbf{a}} \\ \boldsymbol{\delta}_{2\mathbf{b}} \end{array} \right\} \right\},$$

$$\left[\left[\begin{array}{c} \boldsymbol{\delta}_{2\mathbf{a}} \right], \left[\begin{array}{c} \boldsymbol{\delta}_{2\mathbf{b}} \right], \left[\begin{array}{c} \kappa_{2\mathbf{b}\mathbf{b}} \right], \left[\begin{array}{c} \kappa_{2\mathbf{b}\mathbf{b}} \right], \left[\begin{array}{c} \kappa_{2\mathbf{b}\mathbf{b}} \right], \left[\begin{array}{c} \boldsymbol{\delta}_{2\mathbf{a}} \\ \boldsymbol{\delta}_{2\mathbf{b}} \end{array} \right] \right\} \right\},$$

$$(1)$$

By definition, the $\{\delta_{2b}\}$ are superfluous to the objective structural dynamics analyses. This being the case, they are condensed from the model via the static principle of potential energy. This principle yields a matrix equation governing static behavior, i.e.,

$$\begin{bmatrix} \begin{bmatrix} K_{2aa} \end{bmatrix} & \begin{bmatrix} K_{2ab} \end{bmatrix} \\ \hline \begin{bmatrix} K_{2ab} \end{bmatrix} & \begin{bmatrix} K_{2bb} \end{bmatrix} \end{bmatrix} \begin{cases} \{ \boldsymbol{\vartheta}_{2a} \} \\ \{ \boldsymbol{\vartheta}_{2b} \} \end{cases} = \begin{cases} \{ \boldsymbol{P}_{2a} \} \\ \{ \boldsymbol{P}_{2b} \} \end{cases}$$
(2)

Solution of this relation for the superflous degrees of freedom in terms of the essential degrees of freedom produces a condensing transformation relation of the form

$$\left\{\boldsymbol{\vartheta}_{2}\right\} = \left\{\boldsymbol{\varUpsilon}_{3}\right\} + \left[\boldsymbol{\Gamma}_{3}\right] \left\{\boldsymbol{\vartheta}_{3}\right\} \tag{3}$$

where

$$\left\{\boldsymbol{\vartheta}_{3}\right\} = \left\{\boldsymbol{\vartheta}_{2\mathbf{k}}\right\} \tag{4}$$

$$\begin{bmatrix} \Gamma_{3} \end{bmatrix} = \begin{bmatrix} - & \begin{bmatrix} I & J \\ - & \begin{bmatrix} K_{2bb} \end{bmatrix}^{-1} \begin{bmatrix} K_{2ab} \end{bmatrix} \end{bmatrix}$$
(5)
$$\{ \mathcal{T}_{3} \} = \begin{cases} - & \begin{bmatrix} 0 \\ - & \begin{bmatrix} K_{2bb} \end{bmatrix}^{-1} \begin{bmatrix} P_{2b} \end{bmatrix} \end{cases}.$$

Introducing the condensation transformation of Equation 3 into the energy functions of Equation 1 references these functions to essential degrees of freedom. For example, application to the strain energy Equation B yields

$$\boldsymbol{\Phi}_{\mathbf{U}} = \frac{1}{2} \left[\boldsymbol{\mathcal{B}}_{3} \right] \left[\boldsymbol{\kappa}_{3} \right] \left\{ \boldsymbol{\vartheta}_{3} \right\}$$
(7)

where

$$\begin{bmatrix} \kappa_3 \end{bmatrix} = \begin{bmatrix} \Gamma_3 \end{bmatrix}^T \begin{bmatrix} \kappa_2 \end{bmatrix} \begin{bmatrix} \Gamma_3 \end{bmatrix}. \tag{8}$$

The other energy functions are similarly transformed as follows:

$$\mathbf{\Phi}_{\mathbf{K}} = 1/2 \begin{bmatrix} \dot{\boldsymbol{\delta}}_3 \end{bmatrix} \begin{bmatrix} \mathbf{M}_3 \end{bmatrix} \{ \dot{\boldsymbol{\delta}}_3 \}$$
(9)

where

$$\begin{bmatrix} M_3 \end{bmatrix} = \begin{bmatrix} \Gamma_3 \end{bmatrix}^T \begin{bmatrix} M_2 \end{bmatrix} \begin{bmatrix} \Gamma_3 \end{bmatrix}$$
(10)

The introduction of this condensation transformation to the set of stiffness and mass matrices can substantially reduce the order of the matrices involved in the determination of modes and frequencies.

```
00002880
$ DYNAM LC SC
                                                                                      00002890
U---- CYNAMICS AGENDUM, WITH CONDENSATION
                                                                                      00002900
                                                                                      00002910
(
C---- OYNAHICS AGENDUM ANALYSIS
                                                                                      00002920
                                                                                      00002930
          CYNAMICS ANALYSIS INSTRUCTION SECUENCE
                                                                                      00002940
                                                                                      00002950
1
r
           CENFRATE ELEMENT MATRICES
                                                                                      00002960
                                                                                      00002970
Ł
       + ML 18+++ TR++KFL+++++MEL+SC+EM+ = +++ +USER04+
                                                                                      00002980
                                                                                      00002990
C
           ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX
                                                                                      00003000
C.
                                                                                      00003010
٢
       STIFF = EM .ASSEM. SC. (1)
                                                                                      00003020
       MASS = EM .ASSEM. SC. (2)
                                                                                      00003030
                                                                                      00003040
C.
                                                                                      00003050
           DELMIT STIFFNESS MATRIX AND MASS MATRIX
(
       PP DAT(FORCE +DISP + +) STIFF
                                                                                      00093069
Ċ
                                                                                      00003070
       PRINT(FORCE, ACCEL,,) MASS
                                                                                      00003080
Ç
                                                                                      00003090
           GENERATE DYNAMICS MATRIX
                                                                                      00003100
ć
                                                                                      00003110
ſ
       T(P_{F}B)T = STIFF \bullet DEJOIN \bullet (SC(6+1)+1)
                                                                                      00003120
       K_{11}K_{2} = TOP \cdot DEJOIN \cdot (SC(6,1),0)

K_{12}T_{1}K_{22} = BOT \cdot DEJOIN \cdot (SC(6,1),0)
                                                                                      00003130
                                                                                      00003140
       K221 = -K22 .INVERS.
                                                                                      00003150
       KR1 = K221 .MULT. K12T
                                                                                      00003160

      KP?
      = K12 .MULT. KRI

      KK
      = K11 .ADD. KR2

      IDENT
      = K11 .IDENTR.

                                                                                      00003170
                                                                                      00003180
                                                                                      00003190
       KELT = KRI .TRANSP.
                                                                                      00003200
                                                                                      00003210
       GAM1 = IDENT .ADJOIN. KRIT
                                                                                      00003220
       GAM
              = GAMT .TRANSP.
       MR 1
            = GAMT .MULT. MASS
                                                                                      00003230
       MR = MR1 . MULT. GAM
                                                                                       00003240
       KHI = KR .INVEPS.
                                                                                       00003250
                                                                                       00003260
       DYNAM = KRI .MULT. MR
С
                                                                                      00003270
                                                                                      00003280
           FIND E-VALLES, E-VECTORS, NORMAL MODES,
С
                                                                                       00003290
           FREQUENCIES AND PRINT
C
                                                                                       00003300
C
       FVALUE, EVECT .. = DYNAM, .EIGENI. SC
                                                                                       00003310
С
                                                                                       00003320
       TRC1, TR2 = TR .DEJOIN. (SC(8,1),1)
                                                                                      00003330
       TRC_{TR1} = TRC1 \cdot DEJOIN \cdot (SC(5+1)+1)
                                                                                       00003340
                                                                                       00003350
       GPP INT (3,,,,SC,TRI) EVECT, EVALUE
                                                                                       00003369
C
           GENERATE STIFFNESS AND GENERALIZED MASS
                                                                                       00003370
C
           MATRICES AND PRINT
                                                                                       00003380
C
C
                                                                                       00003390
       KOFML = EVECT. THUL F. KR
                                                                                       00003400
       KGEN = KGEN1.MULT.EVECT
                                                                                       00003410
       MGEN1 = CVECT. THULT. MR
                                                                                       00003420
                                                                                       00003430
        MGEN = MGEN1.MULT.EVECT
                                                                                       0000 3440
r
                                                                                       00003450
       PRINT(,,,) MGEN, KGEN, DYNAM, KR, MR
```

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Figure II-E Dynamic Agendum With Condensation

h. Agendum Level Abstraction Instructions

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

Subroutine AGENDM controls the selection from the Agendum library of the abstraction instruction sequence requested on the \$INSTRUCTION card. At present, this subroutine has the capability to select six Agendums, STATICS, STATICS, STATICS, DYNAMICS, DYNAMICSC and STABILITY. The programming procedure utilized to add additional options to the library is dis.ussed in Appendix IX, Section III of the Programmer's Manual (Volume III).

The following examples are provided to explain typical usage of the Agendum Library.

The most important points to note from these examples are that an Agendum for any particular run may be modified by addition of additional instructions which are input by the User. However, these additional instructions can only be added to the end of any particular Agendum at the present time.

Examples of Agendum Usage

cc1 cc7 cc16

(a) \$MAGIC \$RUN GO \$INSTRUCTION STATICS \$SPECIAL [Report Form Input Deck for .USER04. Instruction] \$END

(b) \$MAGIC

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.
- (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.

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The Material Library Section is a particularly useful input feature of the MAGIC System. This library is a permanent date set available for interrogation by the system. Additions a d/or deletions to the Material Library are executed by the MARC System. The updating of the Material 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 Cystem parameters. Aprelabeled input form is provided. Figure TI-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

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- (7) Prescribed displacements
- (¹⁴) Element input
- (9) Dynamics information

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 sotation is applicable, for example, to measurable quantities such as loads, coordinates, etc. The fixed point notation is limited to whole numbers or integers such as grid point numbers.

In floating point notation, a number may be written in either the conventional manner or as a factor of 10^{n} ; for example, the number 30 000 000 = 30 x 10^{6} can be written as either 30 000 000 or 30.0 Mb. 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. <u>Title Section</u> (Figure II-1)

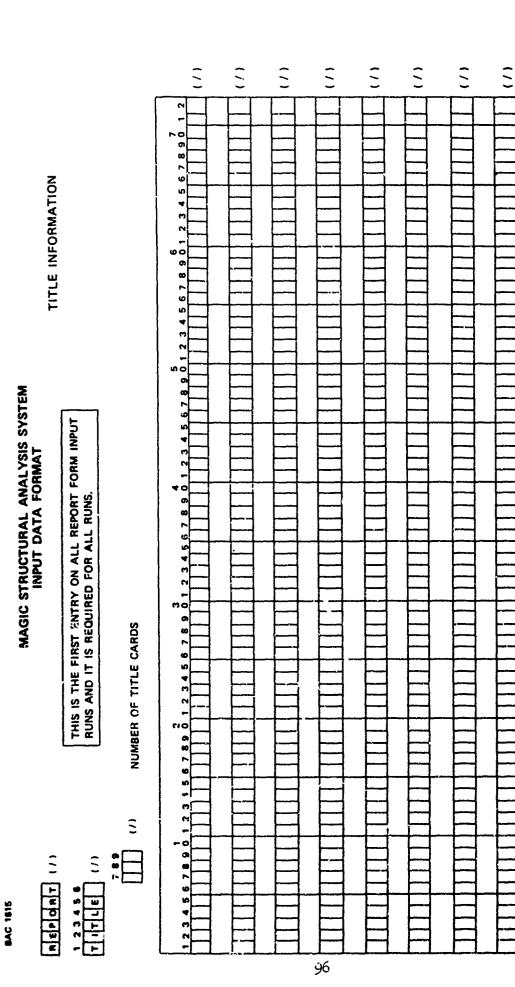
A prelabeled input data form is provided for the TITLE Section and is shown in Figure II-1.

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.

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FIGURE II-1 TITLE DATA FORM

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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).

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 form 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 vaterial 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. The material number can be any combination of alphameric characters.

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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. 13-41)

The material identification is left to the discretion of the User. It serves only to provide the analyst with a means of identifying the material and is not interrogated by the program.

Material Tape Input - (Cols. 42-55)

The information in columns 42 through 50 is mutually exclusive, that is, the User should enter no more than one 'X' in columns 42-50. If the User enters more than one 'X' in columns 42-50, then only the first choice will be retained and the others will be ignored by the program. An 'X' in any of columns 42 through 46 will indicate that a material is to be added or revised. Whenever this is the case, a summary of the material tape will be printed and the material table for the new or revised material will be displayed. When an 'X' is placed in column 47, the specified material will be deleted from the material tape ind a summary of the new tape will be printed. Columns 48 through 50 are used to interrogate the tape to ascertain what it contains. If an 'X' is placed in column 48, 49 or 50, the existing material tape will be printed with no update of the material tape taking place.

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, \mathbf{V}_{ij} , and the coefficient of thermal expansion, $\boldsymbol{\prec}$, 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 r_{ij} must be entered by the User for each of the x, y, and z directions.

IMPORTANT REMINDERS:

- (1) Poisson's Ratio, v_{ij} is defined as strain induced in the j direction by a stress in the i direction.
- (2) For <u>isotropic</u> materials Pcisson's ratic, V_{ij} , must lie between 0.0 and 0.5 ($0.0 \le V_{ij} \le 0.5$). 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 ($\boldsymbol{\vartriangleleft}$)	-1.0 L X L 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).

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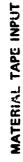
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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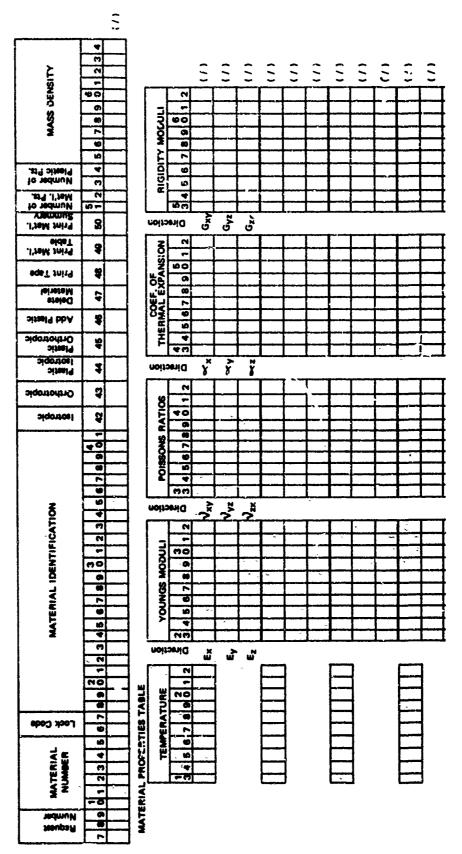


FIGURE II-2 MATERIAL TAPE INPUT DATA FORM

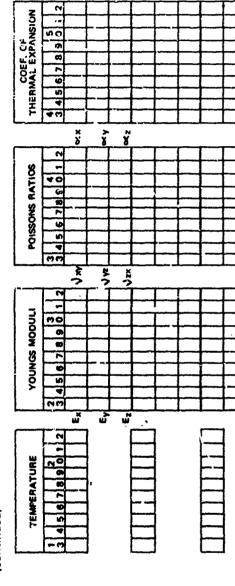
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FIGURE II-2 CONCLUDED

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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 'tems 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. 1-5)

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
 - 1 Triangular Cross-Section Ring Element

2 - Trapezoidal Cross-Section Ring (And Core) Elément

- (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
 - 5 Incremental Frame Element
 - 6-Quadrilateral Plate Element
 - 7 Triangular Plate 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)

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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 t experature 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 Foints - (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 init ally displaced grid points. Therefore, no entries should be made in this location.

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

Applied loadings may be prescribed in terms of non-zero displacement values either one displacement load condition or the NL displacement load conditions can be accommodated per execution. NL is defined as the total number of external load conditions in any given analysis. 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) <u>Number of Grid Point Axes Transformation Systems</u> - (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 equal to 3000.

(9) <u>Number of Requests and/or Revisions of Material Tape-</u> (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 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.

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

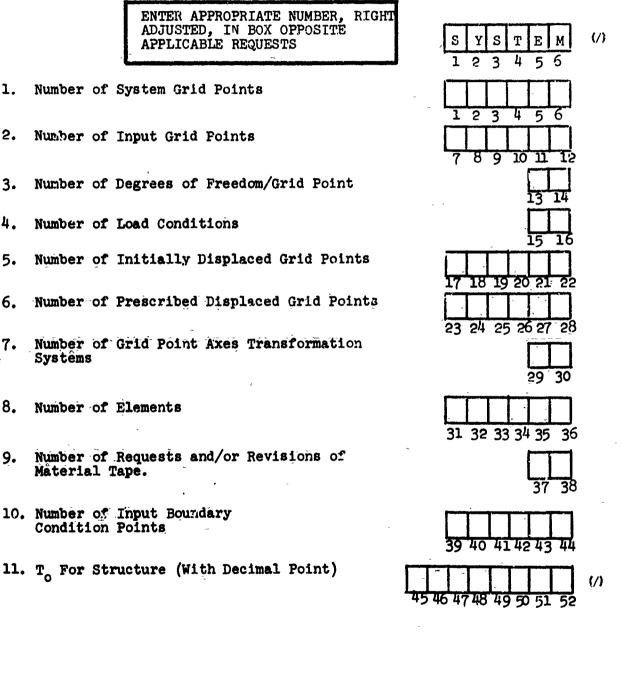


FIGURE II-3 SYSTEM CONTROL INFORMATION DATA FORM 105

1.

2.

3.

4.

5.

6.

7.

8.

9.

5. Print Control Section (Figure II-4)

The labeled input data form provided for the Frint 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. ¹/_c)
- (5) Intermediate Function Minimization (Col. 5)

This section is not applicable in the present MAGIC System. It is included because it is onticipated that these and other options will be provided in $\frac{1}{10}$ manner in future MAGIC Systems. The present print control options reside in the abstraction instruction capability associated with the System.

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.

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 entries contain information pertaining to the grid point numbers and their corresponding coordinates as follows.

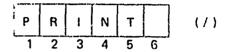
Coordinate System Definition - (Col. 5)

For each grid point entered in the grid point coordinate section, the code corresponding to the coordinate system employed for a particular grid point should be entered. An R in Column 5 indicates that the coordinates for that particular grid point are entered in a Cartesian system. A C indicates entry in a cylindrical system and an S in column 5 indicates an entry in a spherical system. If column 5 is left blank then the program assumes that grid point data is input in the Cartesian system.

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MAGIC STRUCTURAL ANALYSIS SYSTEM. INPUT DATA FORMAT

PRINT OPTIONS



PLACE 'X' IN BOX OPPOSITE DESIRED PRINT

1. Assembly - Stiffness

2. Inverse – Stiffness

3. Triangularized - Stiffness

- 4. Displacements
- 5. Intermediate Function Minimization

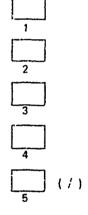


FIGURE II-4 PRINT CONTROL DATA FORM

It is possible to mix coordinate systems since the program converts all coordinates to the Cartesian system before beginning an analysis. It should also be noted that the output such as displacements, and element forces will be referenced to a Cartesian global system even though the input cocrdinates may be in a different system. If the User desires output in a system other than the Cartesian global, the Grid Point Axes Transformation Section should be consulted.

Grid Point Number - (Cols. 7-12)

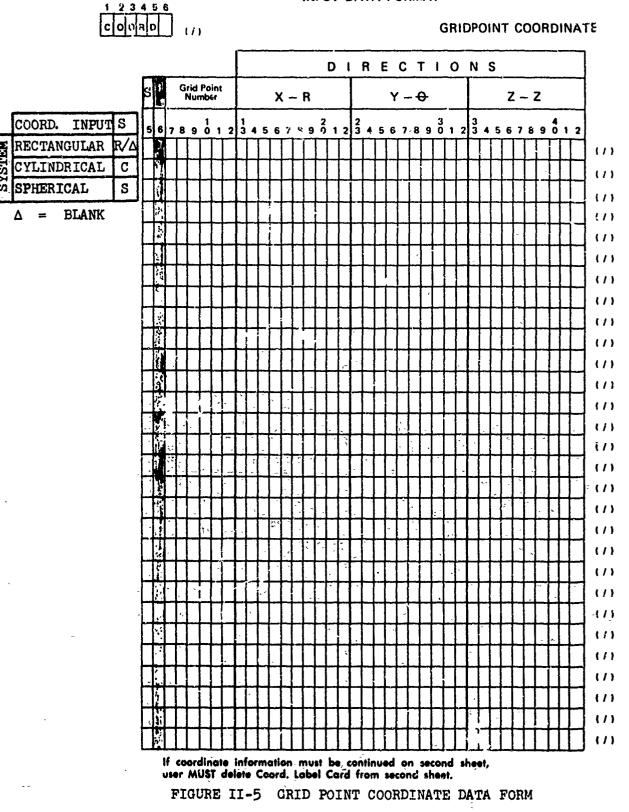
Grid points are entered as fixed point numbers and can be entered in any sequence desired. The maximum number of input grid points allowed is equal to 999. The total number of grid points entered in this section must be called out on the System Control Information Data Form in the entry reserved for 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. BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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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 accompliant this, a labeled input data form is provided for the Grid Point Pressure Section. This form is shown in Figure 11-6.

In this section the User may employ two time saving devices.

- (1) <u>MODAL</u> 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) <u>REPEAT</u> 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 iollow the MODAL entry.

In the present MAGIC System, a maximum of three 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 three 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 reoccurring 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.

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

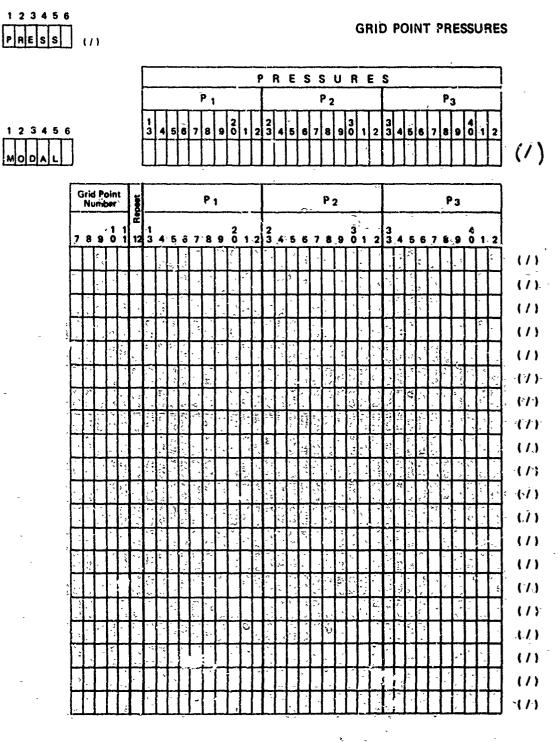


FIGURE II-6 GRID POINT PRESSURE DATA FORM

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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GRID POINT PRESSURES (continued)

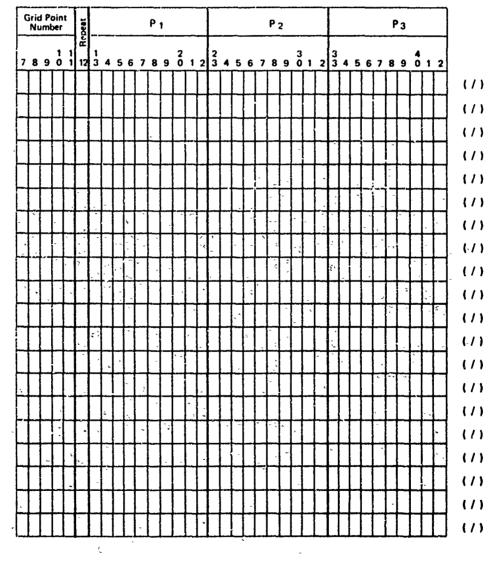


FIGURE II-6 CONCLUDED

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.

REMEMBER:

Sale and

- (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 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 TEMPERATE SES

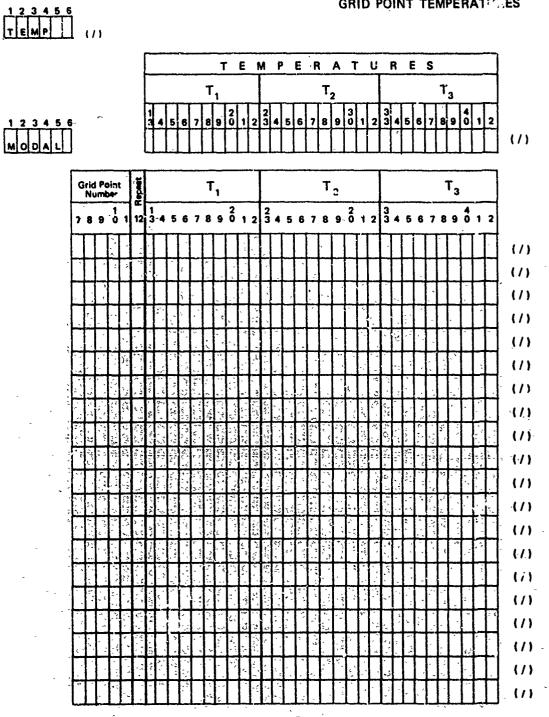


FIGURE 11-7 GRID POINT TEMPERATURE DATA FORM 116

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

GRID POINT TEMPERATURES (continued)

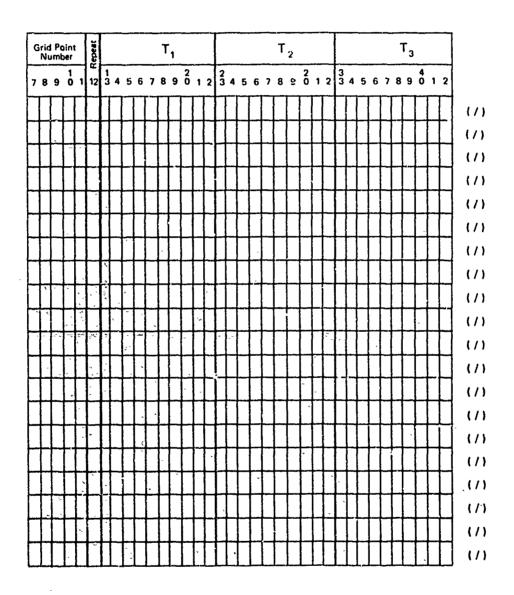


FIGURE II-7 CONCLUDED 117

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

In general, a reference axis system is associated with each grid point. This Local System (X, Y, 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-8a. The first entry is prelabeled TRANS and requires no input from the User. The second and subsequent entries contain the following items of information.

System Number - (Cols. 7-9)

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).

Number of Applicable Grid Points - (Cols. 10-12)

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).

11.8

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

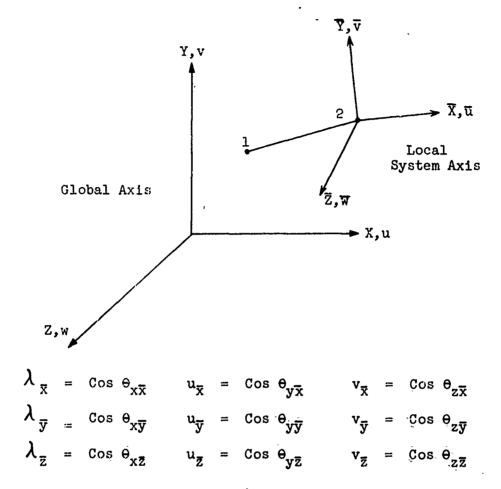
Service - Automatic - Automatic

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

$$\left\{X_{G}\right\} = \left[T\right] \left\{X_{L}\right\}$$

where the $\{X_{C}\}$ refers to Global (X, Y, Z) coordinate Vector and the $\{X_{L}\}$ refers to Local System $(\overline{X}, \overline{Y}, \overline{Z})$ coordinate Vector. The transformation matrix is of the form:

$$\begin{bmatrix} \mathbf{T} \end{bmatrix} = \begin{bmatrix} \lambda_{\mathbf{x}} & \mathbf{u}_{\mathbf{x}} & \mathbf{v}_{\mathbf{x}} \\ \lambda_{\mathbf{y}} & \mathbf{u}_{\mathbf{y}} & \mathbf{v}_{\mathbf{y}} \\ \lambda_{\mathbf{z}} & \mathbf{u}_{\mathbf{z}} & \mathbf{v}_{\mathbf{z}} \end{bmatrix}$$



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

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REMEMBER:

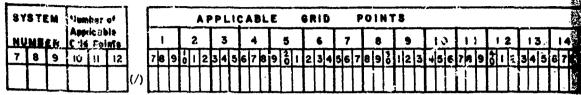
(1) Total number of Systems which are being transformed must be set forth on the Systems Control Information Data Form (Figure II-3). A CONTRACTOR

(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.

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MAGIC STRUCTURAL ANALYSIS SYSTEM





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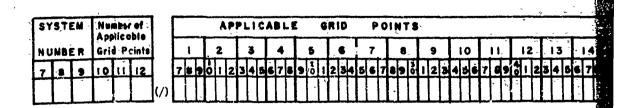
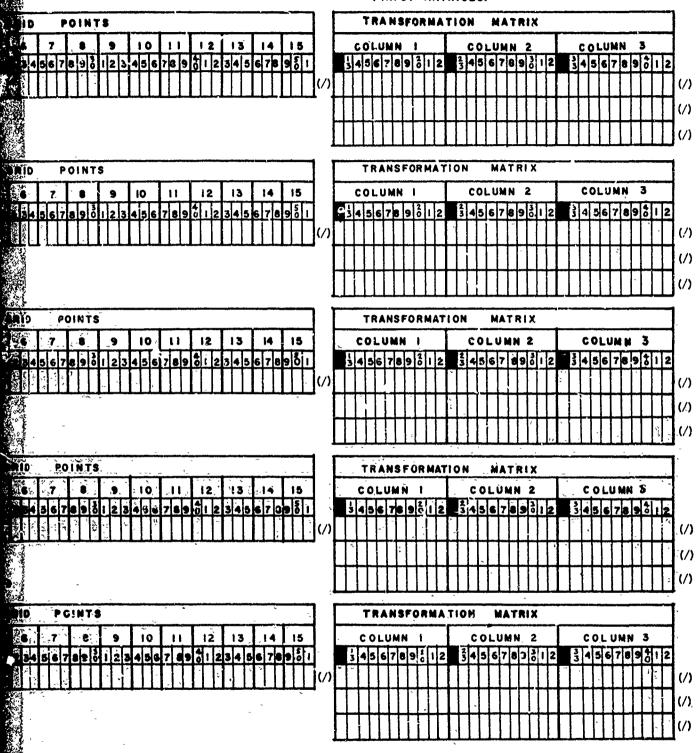


FIGURE II-Sa ROTATIONAL TRANSFORMATION (INPUT MATRICES) DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM

ROTATIONAL TRANSFORMATIONS (INPUT MATRICES)



RICES) DATA FORM

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9.b. <u>Retational Transformations Section - General Trans.</u> <u>Matrices (Figure II-8b)</u>

A reference axis system is normally associated with each grid point. This Local System (X, Y, 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 A exhibited 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 lebeled input data form provided for this section is shown in Figure II-8b. 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 énables convenient and explicit référence to particular grid point axes transformations of the form

$$X_{G} = [T] \{X_{L}\}$$

Global Coordinate Vector

= 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 coerdinate planes. The integer number '1' is placed in Column 10, 11, or 12, corresponding to the respective definition of the X, \overline{Y} , or \overline{Z} axis by two coerdinate 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 coordinate system. The positive direction is assumed from 1 toward 2. The coordinate plane (in which the coordinate point associated with the gridpoint 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 \overline{X} -axis then point 3 lies in the $(\overline{X},\overline{Y})$ plane.
- (2) If points 1 and 2 define the \overline{Y} -axis then point 3 lies in the $(\overline{X}, \overline{Y})$ plane.
- (3) If points 1 and 2 define the \overline{Z} -axis then point 3 lies in the $(\overline{X},\overline{Z})$ 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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ROTATIONAL TRANSFORMATIONS (Generate Transformation Matrices)

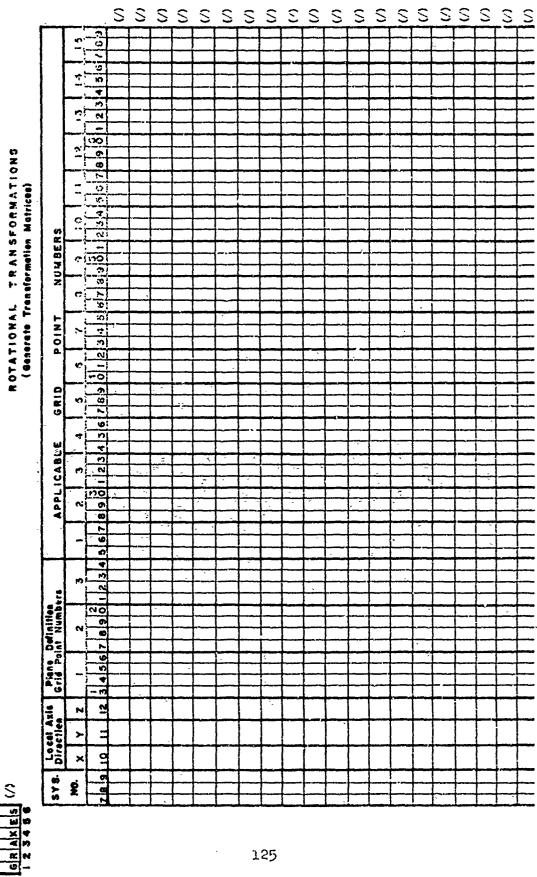


FIGURE II-8b ROTAFI CVAL TRANSFORMATION (GENERATE TRANS. MATRICES) DATA FORM

10. Dynamics Section (Figure II-9)

The labeled input data form provided for the calculation of eigenvalues and eigenvectors using the .EIGEN 1. abstruction instruction is shown in Figure II-9. The first entry on the form is prelabeled DYNAM and requires no input from the User.

The second entry on the form contains the seven (7) items of information defined in the list which follows. All items of information are entered in fixed point notation, with the exception of Item 2 (Convergence Criteria).

(1)Number of Eigenvalues Requested - (Cols. 1-2)

> The number of eigenvalues desired for a particular analyses is entered in this location. The maximum number of eigenvalues requested for any particular run is equal to twenty (20).

(2)Convergence Criteria - (Cols. 3-14)

The convergence criteria desired for each eigenvector is entered in Columns 3-14. The default option is 0.CCl. The program will automatically perform a maxi-mum of 500 iterations (unless otherwise specified in The columns of the third of the trainer of the second sec Item (3) below) with this criteria trying to obtain convergence. If convergence isn't obtained in 500 iterations, the criteria is automatically relaxed to 0.002 and the procedure is repeated. This procedure will be performed a maximum of ten times until the final criteria is 0.01. If convergence hasn't been obtained at this level the program will automatically terminate with exploratory diagnostic messages.

(3) Maximum Number of Iterations - (Cols. 15-17)

> The desired maximum number of iterations per convergence criteria for each mode is entered in Columns 15 thru 17. If an entry is not made in this location, the default will be 500 iterations.

(4) Debug Iteration Print (Col. 18)

> If the User desires a print out of each iteration step, in the analysis sequence a 'l' is entered in Column 18. If iteration print is not desired, Column 18 is left blank or a zero is entered.

(5) First Normalizing Element for Print (Cols. 19-22)

It the User desires eigenvector normalization, on some value other than the largest the option in Cols. 19-22 is used. If this option is to be used, the reduced degree-of-freedom on which the normalization is desired is entered.

(6) Second Normalizing Element for Print (Cols. 23-26)

L' the User desires a second normalization on another degree-of-freedom, then the reduced degree-of-freedom c: which this normalization is desired is entered in Columns 23-26.

It is to be noted that whether options (5), or (5) and (5) are activated or not, the User still obtains a print of the eigenvector normalized on the largest value contained in that vector.

(7) Control for Guess Vector Iteration Start (Col. 27)

Two types of iteration are available in the .EIGEN1. Instruction Package. Column or row iteration can be performed. If the User desires a row iteration start, a 'l' is entered in Column 27. The normal procedure is to utilize Column iterations. For this option a zero is entered in Column 27 or it is left blank.

It is to be noted that the DYNAM Section is utilized to interrogate the .EIGEN1. abstraction for both vibration and stability analyses. In stability analyses, usually only the first buckling mode is of interest while in vibration analyses the first five or maybe ten modes are of interest depending on the problem being analyzed.

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

DYNAMICS INFORMATION

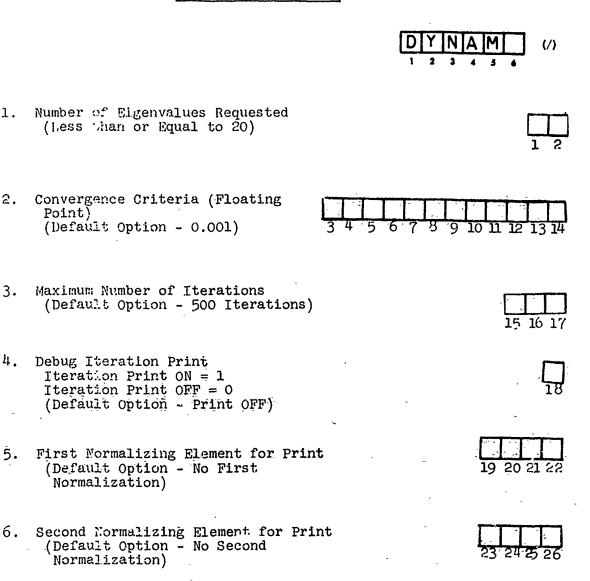
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Control for Guess Vector Iteration Start 7. Column Iteration Start = 0Row Iteration Start = 1 (Default Option - Column Iteration Start)

Figure II-9 Dynamics Control Information Data Form

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11. Boundary Condition Section (Figure II-10)

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:

- 1. Statics
 - (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 prelabelled 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.

- . 2. Statics With Condensation
 - (a) 0 = No displacement allowed,
 - (b) 1 = Unknown Displacement and
 - (c) 2 = Displacement Degree of Freedom to be Condensed (Eliminated) From the Stiffness Matrix Which Define the System.

The input code designated '2' pertains to a degree-offreedom that is to be condensed from the system. This procedure is used in conjunction with the abstraction instructions designated as STATICSC which were described in detail previously.

- 3. Dynamics With Condensation
 - (a) 0 = No displacement allowed,
 - (b) 1 = Unknown displacement and
 - (c) 2 = Displacement degree-of-freedom to be condensed (eliminated) from the stiffness and mass matrices which define the system.

The input code designated '2' pertains to a degree-of freedom that is to be condensed from both the stiffness and mass matrices which define the system. This procedure is used in conjunction with the abstraction instructions designated as DYNAMICSC which were described in detail previously.

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 has been provided 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 type being employed in the analysis.

- (1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree of Freedom Entries per point: Corresponding Displacements (u, v, w).
- (2) Frame Element Incremental Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate Elements - Six Degree of Freedom Entries per Point: Corresponding Displacements (\hat{u} , v, w, $\theta_{\hat{x}}$, θ_{v} , θ_{z}).
- (3) Toroidal Thin Shell Ring Element Nine Degree of Freedom Entries per Point: Corresponding Displacements (u, o, w, o, θ_v , o, u', o, w").

Following the MCDAL entry are the entries pertaining to Listed Input. Included are Grid Point Numbers, Repeat Option and corresponding boundary conditions 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 order.

Eepeat - (Col. 12)

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.

12. Prescribed Displacement Section (Figure II-11)

Applied loading may be prescribed in terms of non-zero displacement values. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero.

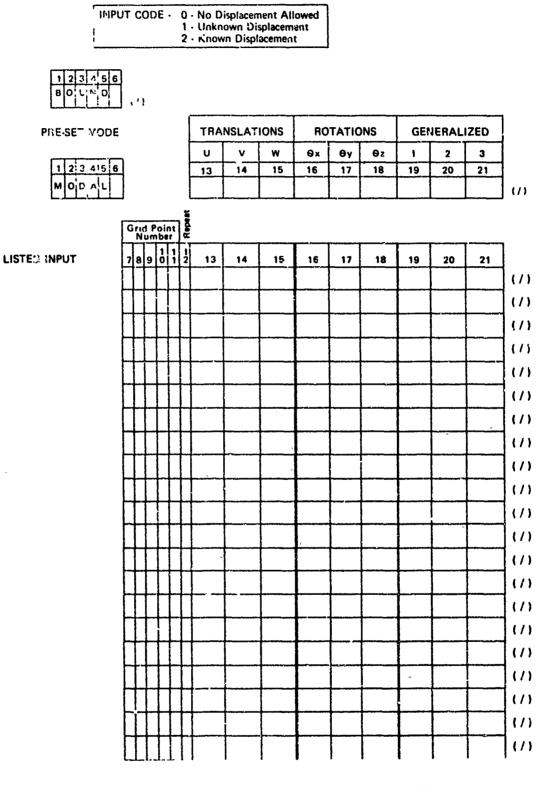
This section is used in conjunction with the Boundary Condition Section when an input code '2' is used in that section in a STATICS Analysis. This code designates that the grid point degree of freedom for which '2' is entered has a prescribed displacement. In order to input the actual value for each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

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS



"IGURE II-10 BOUNDARY CONDITION DATA FORM 132 BAC 1626-2

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS (continued)

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	2	- Known Displacem	ent		
	2	TRANSLATION	S ROTATIO		NERALIZED
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FIGURE II-10 CONCLUDED

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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 $(\theta_x, \theta_y, \theta_z)$ and
- (3) three Generalized Displacements (1, 2, 3).

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

- Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree-of-Freedom Entries per Point: Possible Displacements (u,v,w).
- (2) Frame Element, Incremental Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate 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: Possible Displacements $(u, o, w, c, \theta_y, o, u', o, w'')$.

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 <u>must</u> 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)

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The condition number is a fixed point number. In the present MAGIC System either 1 or NL displacement load condition can be accommodated per execution. NL is defined as the total number of loading conditions in a given analysis.

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:

Crid 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, the only grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered. No additional cards are needed for repeated grid points.

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, except for repeated grid points.

- (¹) 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 <u>must still</u> 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 11-3). This value is equal to the number of <u>exceptions</u> to the MODAL card.

SUMMARY:

For convenience the last three Reminders are briefly stated as,

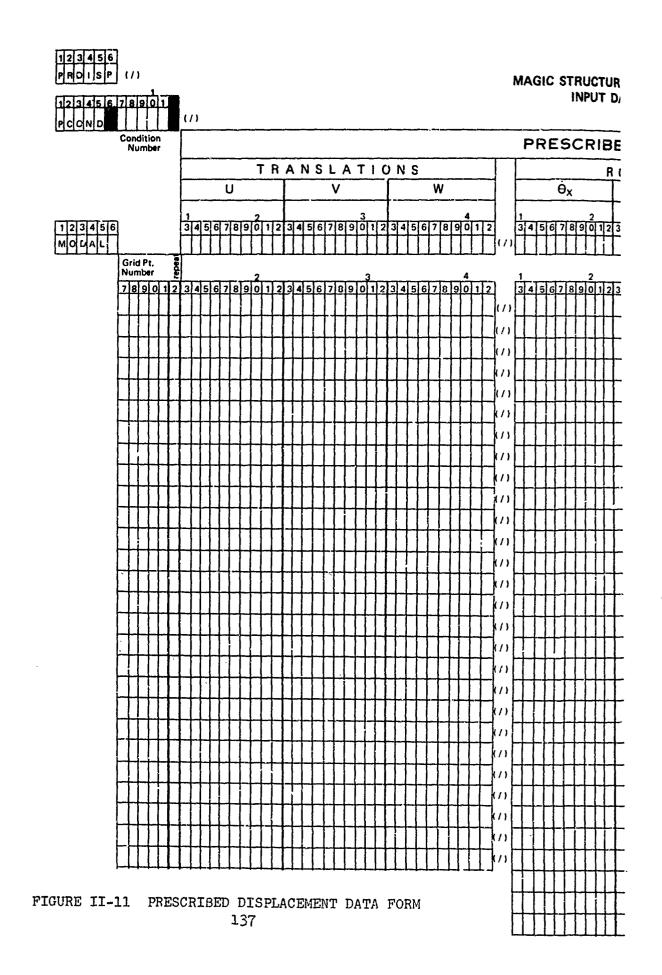
- Three (3) Degree of Freedom Entries per Grid Point; 1 Prescribed Displacement Card Required per Grid Point.
- Six (6) Degree of Freedom Entries per Grid Point; 2 Prescribed Displacement Cards Required per Grid Point.
- (3) Nine (9) Degree of Freedom Entries per Grid Point; 3 Prescribed Displacement Cards Required per Grid Point.
- (4) Repeated grid points require only one card.

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 cptionally 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_v, M_z) and
- (3) three Generalized Forces (F_1, F_2, F_3) .



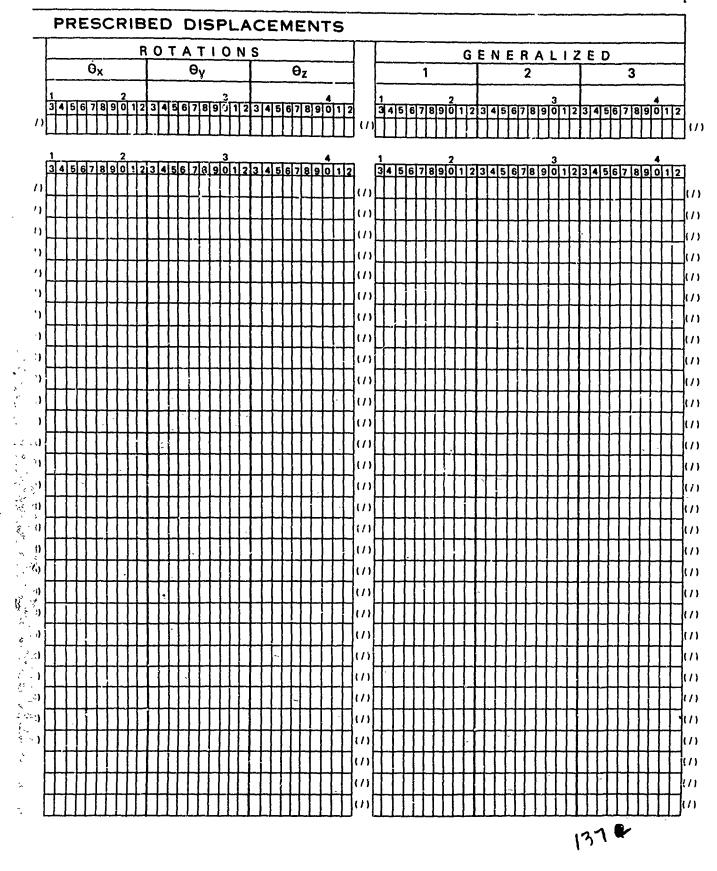
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Element Applied Load Scalar - (Cols. 13-22)

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

External Loads Transformation - (Col. 24)

For User convenience an option has been provided to allow external loads to be input by specifying the axes of reference as either Global or Local System (grid point) Axes.

If Graxes are not employed in an analysis the loads are assumed to be in the Global System and Column 24 is left blank.

If GRAXES are employed (See Sections 9 and 10, Figures II-8 and II-9) the following applies:

- (a) If a 'l' is entered in Column 24, the loads will not be transformed, which indicates that the loads have been entered with reference to the gridpoint axes system.
- (b) If Column 24 is left blank the loads will be transformed utilizing the grid point axes transformation. This indicates that the program assumes that the loads are entered with respect to the Global System of reference.

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

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

- (1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree-of-freedom entries per point: Possible External Forces (F_x, F_y, F_z) .
- (2) Frame Element, Incremental Frame Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate 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 Legree of Freedom Entries per Point: Possible External Forces (F, 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.

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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

External Loads Transformation - (Col. 24)

For User convenience an option has been provided to allow external loads to be input by specifying the axes of reference as either Global or Local System (grid point) Axes.

If Graxes are not employed in an analysis the loads are assumed to be in the Global System and Column 24 is left blank.

If GRAXES are employed (See Sections 9 and 10, Figures II-8 and II-9) the following applies:

- (a) If a 'l' is entered in Column 24, the loads will not be transformed, which indicates that the loads have been entered with reference to the gridpoint axes system.
- (b) If Column 24 is left blank the loads will be transformed utilizing the grid point axes transformation. This indicates that the program assumes that the loads are entered with respect to the Global System of reference.

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 Loais, as follows:

Grid Point Number - (Cols. 7-11)

- (1) Grid Point Numbers are entered as fixed point numbers.
- (?) Grid Point Numbers can be entered in any sequence desired.

Repeat - (Col. 12)

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.

REMEMBER:

- (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 not 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.

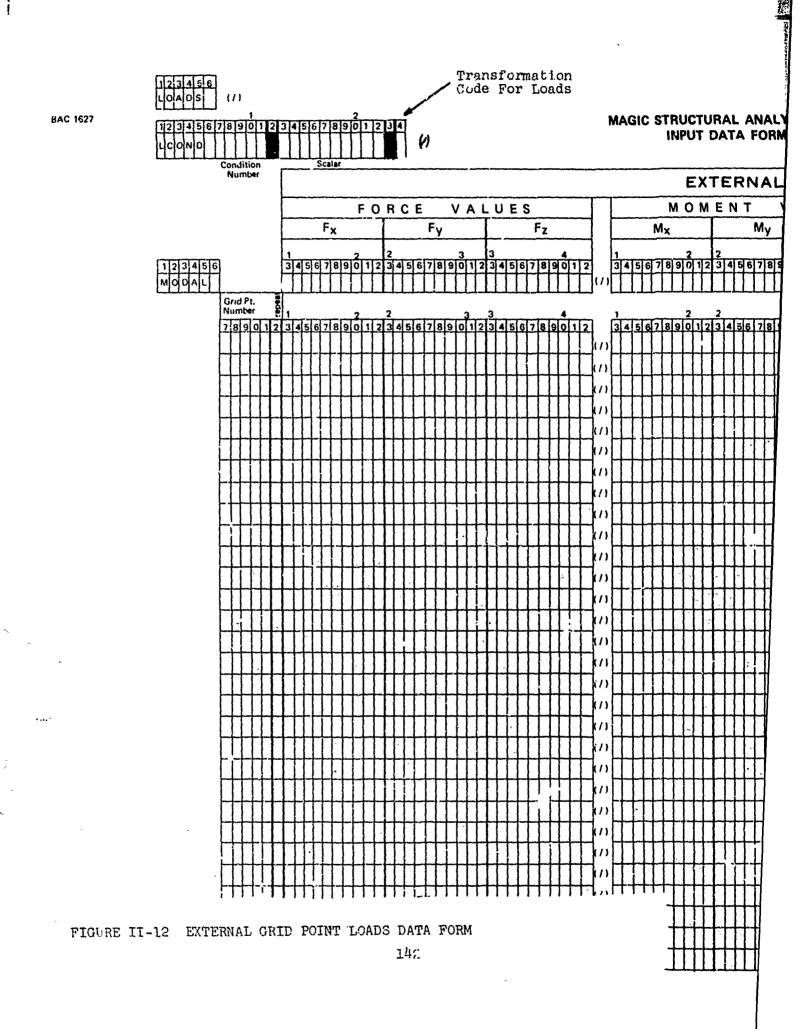
- (7) If the number of degree of freedom entries per grid point is equal to six (6) then the Force and Moment Values must be considered. If for instance, at a certain grid point there are applied forces but no applied moments, zeros must be entered for the Moment values or this entry will be ignored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

(9) Repeated grid points require only one card. SUMMARY:

For convenience the last four Reminders are briefly stated as,

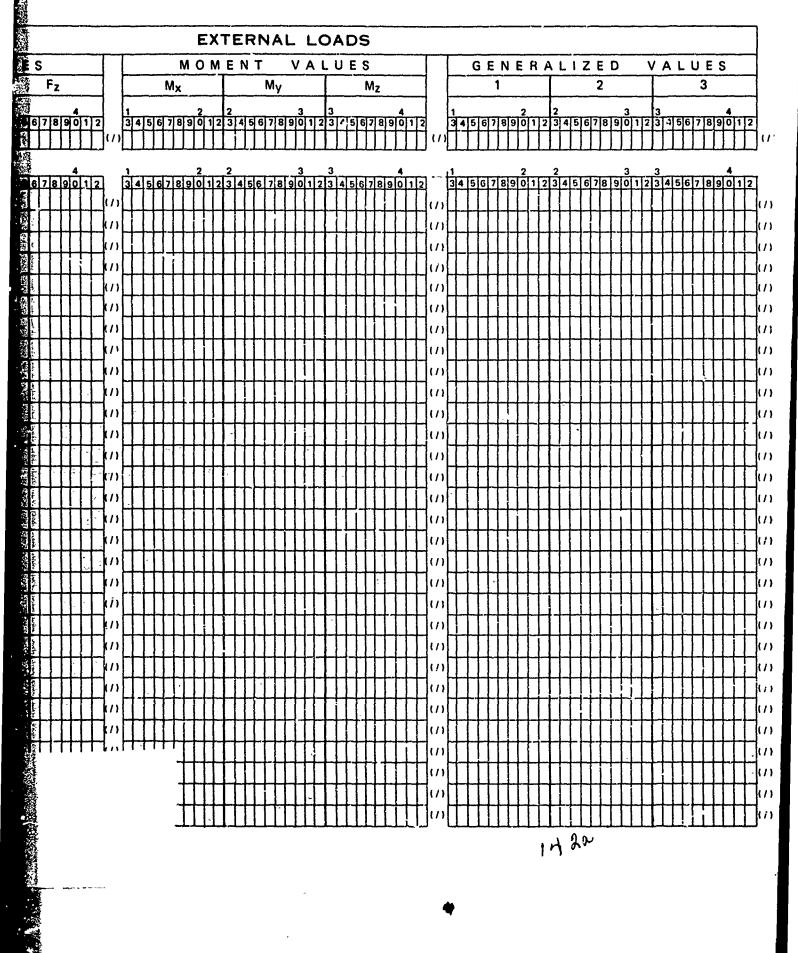
- (1) Three (3) Degree of Freedom Entries per Grid Foint; 1 External Load Card Required per Grid Point.
- (2) Six (6) Degree of Freedom Entries per Grid Point; 2 External Load Cards Required per Grid Point.
- (3) Nine (9) Degree of Freedom Entries per Grid Point;
 3 External Load Cards Required per Grid Point.
- (4) Repeated grid points require only one card.

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT



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14. Element Control Data Section (Figure II-13)

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.

Element Number - (Cols. 7-10)

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

Plug Number - (Cols. 11-12)

- (1) Each finite element in the Element Library has an identification number as follows:
 - (a) Number 11 Frame Element
 - (b) Number 13 Incremental Frame Element
 - (c) Number 25 Quadrilateral Shear Panel
 - (d) Number 40 Triangular Cross-Section Ring
 - (e) Number 41 Trapezoidal Cross-Section Ring (Core)
 - (f) Number 21 Quadrilateral Thin Shell
 - (g) Number 20 Triangular Thin Shell
 - (h) Number 28 Quadrilateral Plate
 - (i) Number 27 Triangular Plate
 - (j) Number 30 Toroidal Ring
- (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. The material number must appear exactly as it was in Cols. 10-15 of the MATER section.

Temperature Interpolate Option - (Col. 19)

The Temperature Interpolate Option is exercised in the following manner:

- (1) If an entry is <u>not</u> 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 'l' 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 exclution 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.

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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 MAGTC element library require Element Input with the exception of the Triangular and Trapezoidal Cross-Section Ring Elements 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) Incremental Frame Element:	3	Node	Points
(3) Quadrilateral Shear Panel:	4	Node	Points
(4) Triangular Cross-Section Ring:	3	Node	Points
(5) Trapezoidal Cross-Section Ring (Core):	4	Node	Points
(6) Quadrilateral Thin Shell:	8	Node	Points
(7) Triangular Thin Shell:	6	Node	Points
(8) Quadrilateral Plate:	4	Noie	Points
(9) Triangular Plate:	3	Node	Points
(10) Toroidal Ring:	2	Node	Points
Pressure Suppression Option - (Col. 35)			

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

Node Points - (Cols. 36-71)

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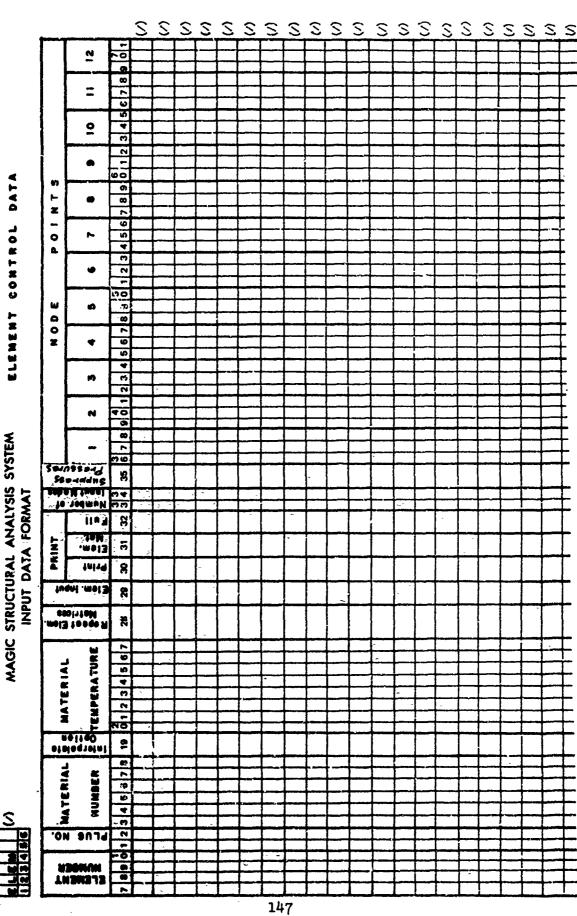


FIGURE II-13 ELEMENT CONTROL DATA FORM

15. Element Input Section - (Figure II-14)

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 clement related and will be explained in cetail 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.:

Element Number - (Cols. 7-11)

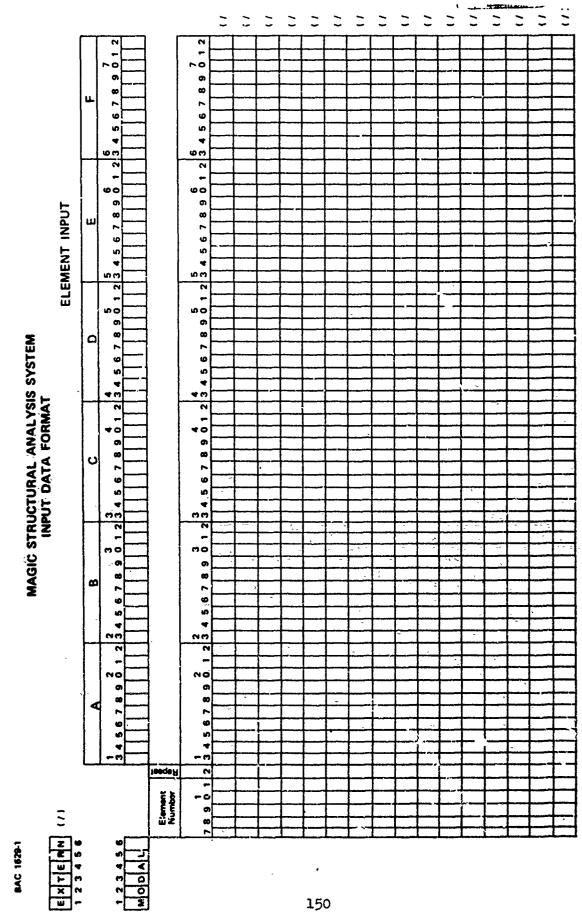
- (1) Element numbers are entered as fixed point numbers.
- (2) Element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

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

REMEMBER:

- (1) For a problem with identical Element Input for every element only the MODAL entry is required.
- (2) The repeat option can be used effectively for sets of elements that have the same Element Input.
- (3) The type of element input required for an element is a function of element type. This element input will be completely described in the following sections.



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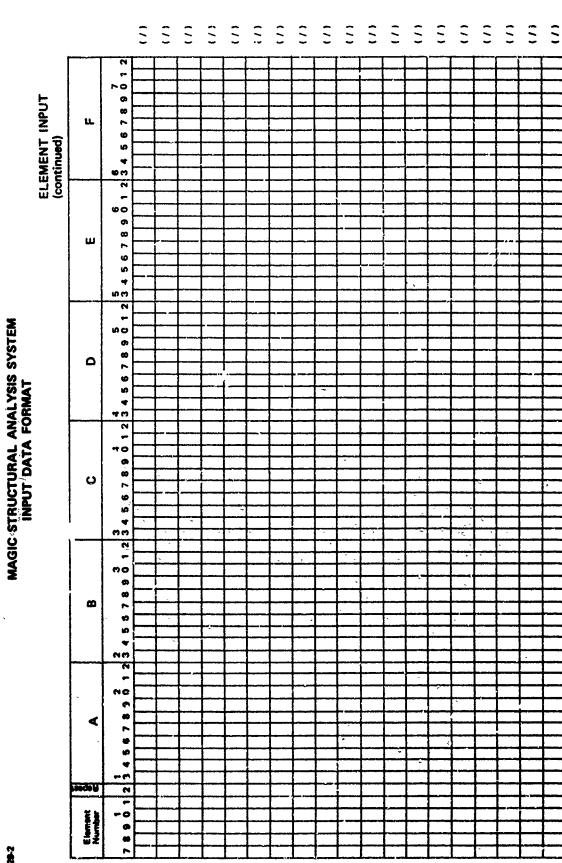
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FIGURE II-14 ELEMENT INPUT DATA FORM



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FIGURE II-14 CONCLUDED

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10. Element Input Description

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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 heference 8, 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 $g^g g$ 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 crosssection symmetry assumptions.

Deformation behavior of the basic rrame 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.

Ltiffness Stress Distributed Loading Axial Thermal Load Incremental Stiffness Consistent Mass

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 direction correspond to pressures designated, P₁ on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. Pressures acting in the element Z direction correspond to pressure designated, P₂ 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)

Element Number - (Cols. 7-10)

Refer to Element Control Section.

Plug Number - (Cols. 11-12)

The Frame Element is identified as Number 11.

Material Number - (Cols. 13-18)

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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 <u>always</u> 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)

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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)

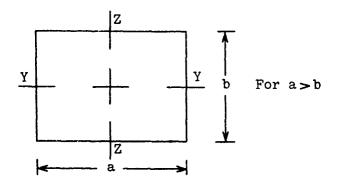
$$I_{yy} = \int_A Z^2 dA$$

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.



can be approximated by:

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

For $a > b$

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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 <u>from</u> the neutral axis of the eccentrically placed frame element <u>to</u> 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)

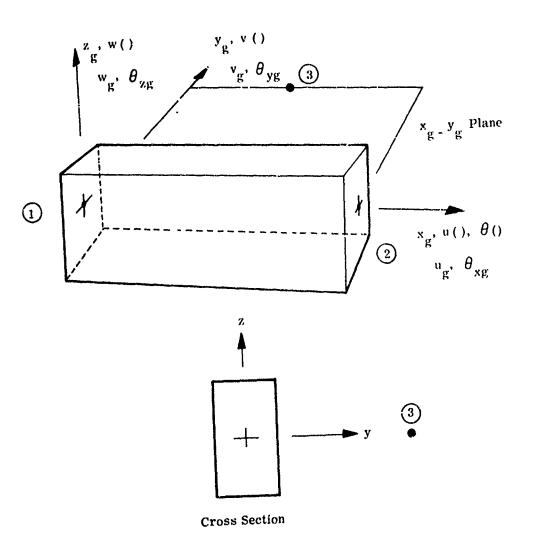
The Frame Element is always defined by 3 input nodes.

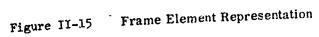
Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Col. 36-71)

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





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 9, and is shear 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 <u>not</u> 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 35-71 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)	Refer to
Repeat Element Matrices - (Ccl. 28)	Element Control Section

Element Input - (Col. 29)

The Quadrilateral Shear Panel <u>always</u> 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 anel.

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

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)	Refer to
Full Print - (Col. 32)	Element Control Section

Number of Input Nodes (Cols. 33-34)

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

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

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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.

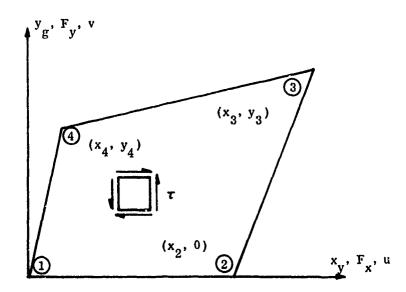


Figure II-1' Quadrilateral Shear Panel Representation

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c. Triangular Cross Section Ring (Ident. No. 40)

The triangular cross-section ring discrete element, shown in Figure [1-17, is suitable for idealization of axisymmetric thick walled structures of arbitrary profile. A detailed development of the element representation is presented in seference 10.

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

Cylindrical anisotropy is provided for in the mechanical and physical material properties of the ring element. Frientation 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 crosssection. Radial, circumferential, and axial stresses are predicted.

The 'friangular 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 following element matrices are provided for the Triangular Cross-Section Ring in the MAGIC System.

Stiffness Stress Thermal Load Distributed Loading (Pressure) Consistent Mass

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.

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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, P₁ on the Grid Point Pressure Data Form. These pressure values are input in Columns 12-22 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).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

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

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

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.

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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 - \aleph_{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 or 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 (X_{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 <u>not</u> 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:

Interpolated Input Print - (Col. 30) Element Matrix Print - (Col. 31) Full Print (Col. 32) Number of Input Nodes (Cols. 33-34)

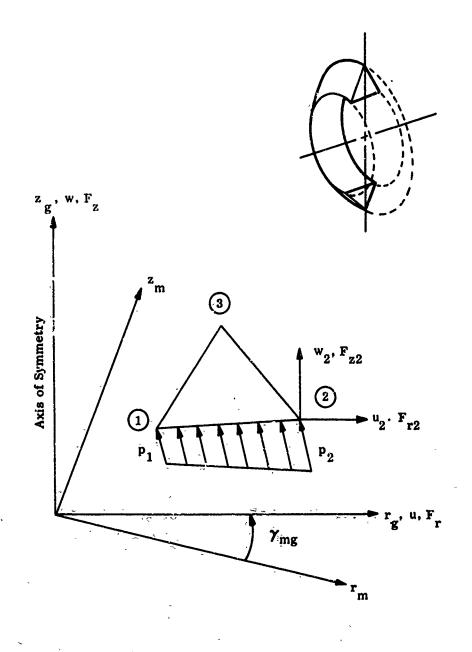
The Triangular Cross-Section Ring Element is always defined by 3 input nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

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.





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

The toroidal thin shell element is recommended for the idealization or 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 11, 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 sutomatically 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 représented 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 Thermal Load Distributed Loading (Pressure) Consistent Mass

The Toroidal King 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 P₁ on the Grid Point Pressure Data Form. These pressure ¹ 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, $X(\xi)$ 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(0) axis so as to align with the element $X(\xi)$ 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 (u' and w") are always referenced to the element system. Physically u'. is difficult to define but can be thought of as the rate of change of arc length (at symmetric boundaries, u' = 0, otherwise u' = 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)

and a state of the
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 besignated 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 <u>always</u> requires Element Input, therefore an 'X' is always placed in column 29 when a Toroidal Ring Element is being employed.

The following Lement Input is required when using the Toroidal Ring Element (refer to Element Input Section). From the prelabeled 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.

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

Location A - (Cols. 13-22)

Element Thickness (t)

Location $B \rightarrow (Cols, 23-32)$

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

(a) Global - $(TC\emptyset = 0.0)$

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.

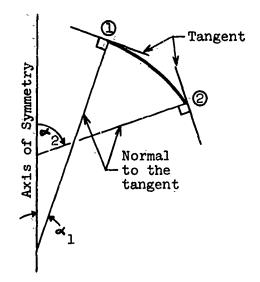
(b) Element - $(TC\emptyset = -1.0)$

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) <u>must</u> 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 <u>all</u> 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. <u>There can be</u> 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)



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Location D - (Cols. 43-52)

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Alpha 2 - (α_{Ξ}) - Referring to the sketch, α_{Ξ} 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 (Ξ) .

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:

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)

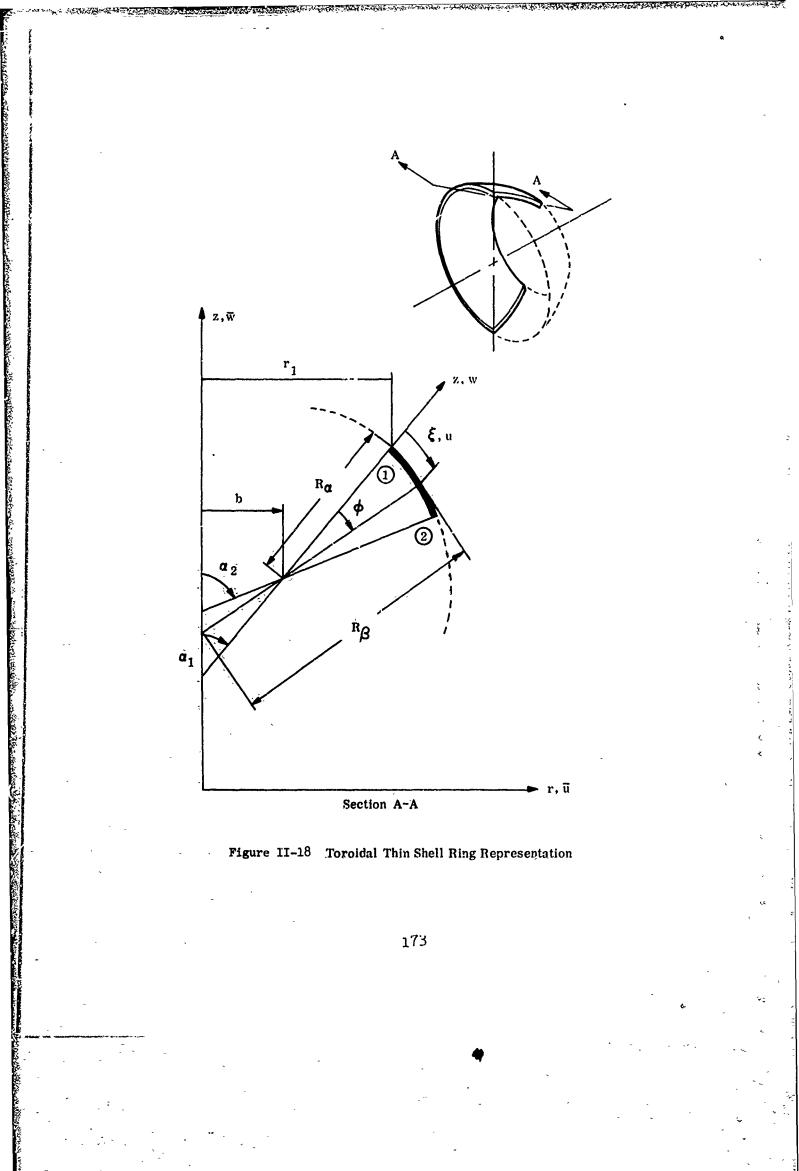
The Toroidal Thin Shell Element is always defined by 2 node points.

Pressure Suppression Option (Col. 35)

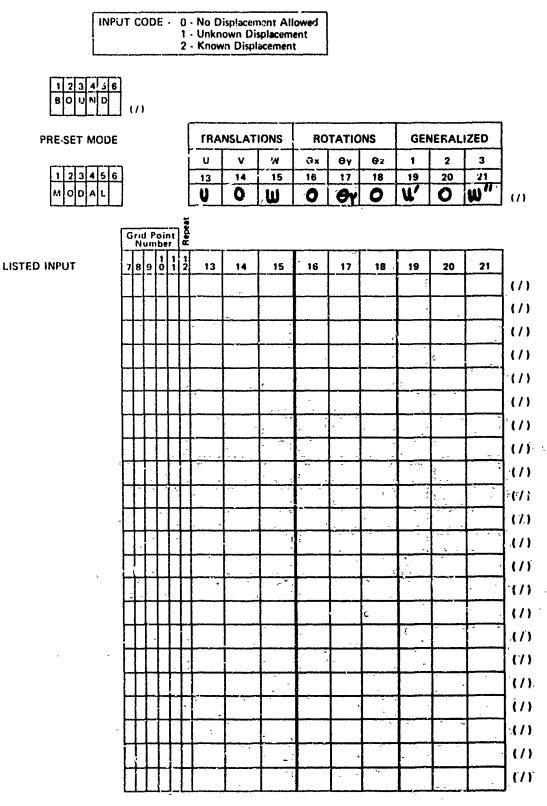
Refer to Element Control Section.

Node Points - (Cols. 36-71)

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



BOUNDARY CONDITIONS



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Figure II-19 BOUNDARY CONDITION INPUT FOR TOROIDAL, RING

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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 dcuble curvature. The quadrilateral thin shell element representation is developed in detail in Reference 12 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.

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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 Inermal Load Distributed Loading (Pressure) Mass

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. Referring * , the figure, the element would be numbered as follows:

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

1.76

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 (\aleph_{mg}) between the material and element geometric axes is considered positive wher 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_1 (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 bonafide 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 miaplane 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.

$$I_2^{-} = \frac{\Delta T}{t^{-1}}$$

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 - (Colo. 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 <u>eight</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 eight node points (including the mid-side nodes) <u>must</u> 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 'l' is entered in this location the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Cols. 20-27)	Refer to
Repeat Element Matrices - (Col. 28)	Element Control
Element Input - (Col. 29)	Section

The Quadrilateral Thin Shell Element <u>always</u> 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.

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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 thick-ness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input. Note also that mass matrix generation is based on the element membrane thickness. 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, provi-sion 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 $(X_{\tilde{m}})$ and the element geometric axis (X_g) with this angle being measured in a counter-clockwise direction from the material axis (X_m) to the element geometric axis (X_g) . This angle (χ_{mg}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

- (a) <u>Corrected Plane Stress</u> (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 ic, the effect of transverse properties on the in-plane stresses are included. Such effects are negligible for most practical materials.
- (b) <u>Restricted Plane Strain (Code 1.0)</u> -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) <u>Conventional Plane Stress</u> (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) -

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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)	Re El Co Se
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.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

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 midside nodes individually if desired. Referring to Figure II-13, it is seen that 12 locations are set aside for node point entries. The first 3 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 ll 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.

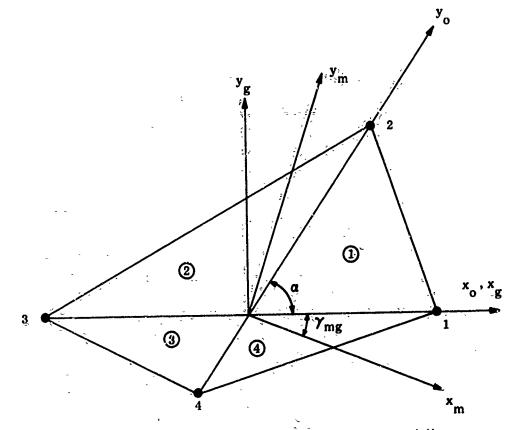


Figure II-20 Quadrilateral Thin Shell Element Representation

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 13, 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, c. ventional 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) Mass

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 axis is defined by the line which connects the origin g of the (X_g, Y_g) axis to node point Oof 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 (\bigvee_{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 Foint 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

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 direction. If temperature gradients through the thick-

ness 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

= 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).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Col. 11-12)

and a second
The Triangular Thin Shell Element is identified as Number 20.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

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.

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 Thin Shell Element always requires Element Input therefore an $1X^{\frac{1}{2}}$ 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 membrane problem, the membrane thickness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input. Note also that mass matrix generation for this element is based on the element membrane thickness.

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 anisctropy 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 (\mathcal{X}_{mr}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

- (a) <u>Corrected Plane Stress</u> (Code 0.0) -The corrected plane stress .olution 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) <u>Restricted Plane Strain</u> (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) <u>Conventional Plane Stress</u> (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.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

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.

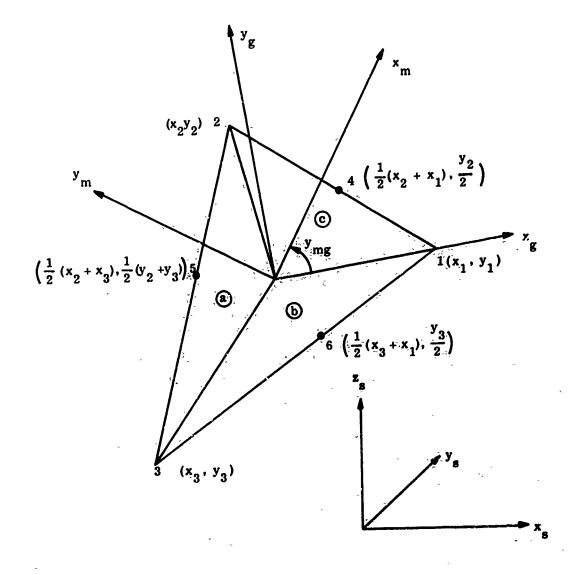
Location: 11 and 12 - (Cold. 66-71)

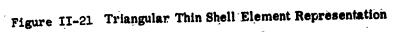
A specification of stress values implies a set of reference axes. The axes of reference are determined with the provision of an element stress matrix. Frequently axes of reference convenient for formulation are not convenient for interpretation of stresses. The problem is resolved by data specification 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.

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- (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 ll 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.





g. Trapezoidal Cross-Section Ring (Core) (Ident. No. 41)

The trapezoidal cross-section ring discrete element, shown in Figure II-22a provides a powerful tool for the analysis of thick walled and solid axisymmetric structures of finite length and arbitrary profile. It may be used alone or if the problem dictates a highly irregular grid work it may be combined with the well known triangular ring element which is described in Reference For the analysis of solid structures, it can be combined with a core discrete element (Figure II-22a) which is a specialization of the trapezoidal ring. A detailed development of the Trapezoidal Ring (and Core) Discrete Elements is presented in Reference 14.

The trapezoidal 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 four 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 axisymmetric.

A three dimensional axisymmetric stress state is assumed. Polynomial functions are employed for displacement mode shapes. A linearly varying thermal load is also provided for this element.

Deformation behavior of the trapezoidal ring is described by the eight displacement degrees of freedom associated with the four grid points which it connects. Element stress behavior is described by the state of stress predicted at the four corner points and at the center of the element. Radial, circumferential and axial stresses are predicted.

The following element matrices are provided for the Trapezoidal Cross-Section Ring (Core) Element representation in the MAGIC System

> Stiffness Stress Thermal Load Distributed Loading (Pressure) Consistent Mass

The trapezoidal cross-section ring element is numbered in the following manner. Referring to Figure II 22-(a), the element is numbered in a counter-clockwise manner when looking in the positive element Y (Θ) direction. The element numbering must begin at the lower left hand corner of the element (i) in Figure 11-22a). The line connecting grid points (1) and) and the line connecting grid points (3) and (4) must both) e parallel to the r-axis. This means that the Z coordinate for rid point (1) is equal to the Z coordinate for grid point (2). nis is also true for grid points (3) and (4).

When the core element specialization of the trapezoidal ring is used, the r coordinate associated with grid points (1) and (4) is always equal to zero.

The Trapezoidal Cross-Section Ring Element is provided with a linearly varying pressure load whose positive definition is shown in Figure II-22(a). Provision is made for pressure loading on all four sides of the element.

The Grid Point Pressure Data Form (Figure II-6) is provided for entering these pressure loadings if they exist. For the Trapezoidal Cross-Section Ring Element, the input pressures correspond to the pressures designated P_1 and P_2 on the Grid Point Pressure Data Form. The pressures P_1 correspond to radial pressure acting on the element and are entered in Columns 13-22. The pressures P_2 correspond to axial pressure acting on the element and are entered in columns 23-32.

A linearly varying thermal load vector is included in this element representation to accommodate thermal loading. The Crid Point Temperature Data Form (Figure II=7) is provided to input node point temperatures if thermal loading is present. For the Trapezoidal Ring Element, the node point temperatures correspond to the temperature designated T₁ 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 Trapezoidal 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 Trapezoidal Cross-Section Ring (Core) Element is identified as Number 41.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Trapezoidal Ring Element 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 desires to enter a material temperature in Cols. 20-27, a 'l' 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 Trapezoidal Cross-Section Ring Element only requires Element Input under certain special conditions as follows: Referring to Figure 11-22, 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 Trapezoidal Cross-Section Ring consists of the following:

Location A - (Cols. 13-22)

Material Axes Angle (Gamma - \mathcal{V}_{mg})

Since the Trapezoidal 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 (\mathcal{Y}_{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-22(a).

Remember

Element Input is not required for the Trapezoidal 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:

Interpolated Input Print - (Col. 30)

Element Matrix Print - (Col. 31)

Refer to Element Control Section

Full Print (Col. 32)

Number of Input Nodes (Cols. 33-34)

The Trapezoidal Cross-Section Ring (Core) Element is always defined by 4 input nodes.

Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

Node Points - (Cols. 36-71)

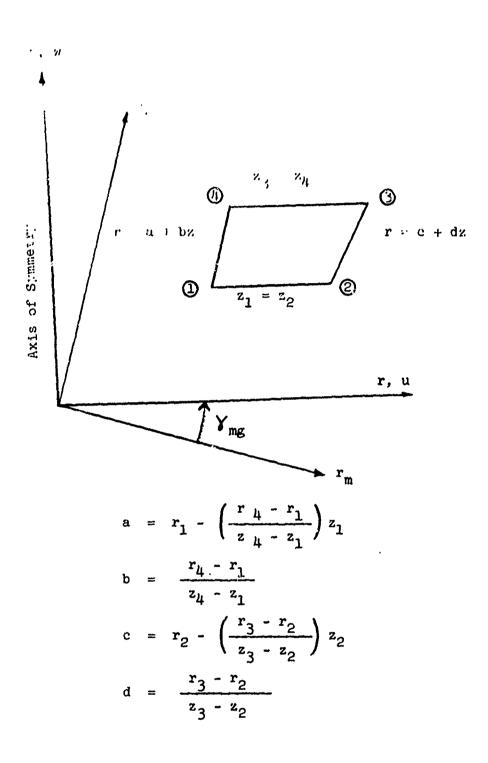
The four node points which define each Trapezoidal Ring are entered in the first four entries provided in the Node Point Section of the Element Control Data Form.

When using the Core Element specialization of the Trapezoidal Ring, the following guidelines are supplied:

- (a) The radii of node points (1) and (4) for any particular Core Element must always be equal to zero (Grid Point Coordinate Section, Figure II-5).
- (b) The radial displacement, u, at node points
 (1) and (4) must always be set equal to zero for any particular Core Element (Boundary Condition Section, Figure II-10).

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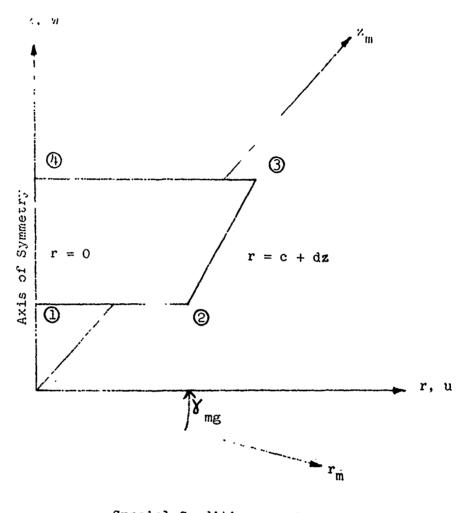


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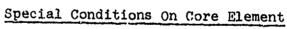
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Figure II-22(a) - Trapezoidal Cross-Section Ring Element Description

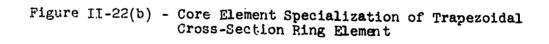


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(a) $r_1 \equiv r_4 \equiv 0$ (b) $u_1 \equiv u_4 \equiv 0$



h. Quadrilateral Plate (Ident. No. 28)

The quadrilateral plate element is recommended for use as the basic building block for membranes, plates and shells when performing an elastic stability analysis. The triangular plate element (Ident. No. 27) is a companion element useful in regions of irregularity and double curvature. The quadrilateral plate element is developed in detail in References 4 and 15 and is shown in Figure 11-23.

The shape of the general quadrilateral plate 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.

Membrane and flexure action are uncoupled for this element. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure thicknesses are assumed constant over the plane of the element.

Four corner points participate in establishing continuous connection of the quadrilateral plate element with adjacent elements.

A quadrilateral plate element is written to accommodate anisotropy of mechanical and physical properties. 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. The conventional plane stress option is provided for this element.

The element formulation is discretized by the construction of mode shapes. Membrane stresses within the element are approximated by the following polynomials

 $\sigma_{\overline{x}} = a_1 + a_2 y$ $\sigma_{\overline{y}} = a_3 + a_4 x$ $\sigma_{\overline{x}y} = a_5$

Transverse displacement is represented by cubic polynomials.

Element stresses for the quadrilateral plate are predicted at the center of the element. Inplane and normal direct, shear and bending stress results are included. The display of stresses implies a set of reference axes. These axes are data specified.

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

Stiffness Stress Thermal Load Incremental Stiffness

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 mid-plane (membrane) variations in thermal loading, the temperature input correspond to the temperatures designated T_1 , on the Grid Point Temperature Data Form. These temperatures are input in Columns 13-22 of that form.

For flexural action, the gradient through the thickness is assumed constant. 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. Thermal moments which arise from the gradients are then automatically defined by the System by prorating the distributed edge moments to the corners.

In the performance of elastic stability analyses using this element, the set of abstraction instructions as outlined in Section II.g.4 of this volume should be utilized. Consistent "initial stress" incremental stiffness matrices are generated using the membrane stress results (σ_x , σ_y , σ_{xy}) from the quadrilateral element in conjunction with the assumed transversedisplacement functions of the element, i.e.,

 $U = \frac{1}{2} \iint N_{x} \left(\frac{\partial w}{\partial x}\right)^{2} + N_{y} \left(\frac{\partial w}{\partial y}\right)^{2} + 2N_{xy} \left(\frac{\partial w}{\partial x} - \frac{\partial w}{\partial y}\right) \int x \partial y$

The Element Control Data which is required for the Quadrilateral Plate Element is as follows: (See Figure II-13)

Element Number -(Cols. 7-10)

Refer to Element Control Section.

Plug Number - (Cols. 11-12)

The Quadrilateral Plate Element is identified as as Number 28.

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 four node point temperatures of the element and use this average temperature when establishing material properties from the material tape. If the User wishes to employ a specified number of node points, n, in the averaging process (1 < n < 4) then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Col. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

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The Quadrilateral Plate Element always requires element input, therefore, an 'X' is always placed in Column 29 when a quadrilateral plate element is employed.

The following Element Input is required when using the Quadrilateral Plate 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 Plate 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 thicknesses.

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. In performing an elastic stability (buckling) analyses both the membrane and flexure thickness are needed.

5.16.1

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

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)

Refer to Element Control Section

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

The Quadrilateral Plate Element is always defined by 4 input nodes.

Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

Node Points - (Cols. 36-71)

The Quadrilateral Plate Element is defined by 4 node points. Note that the first two node points called out for the element determine the positive local 'X' axis for stress output with the local 'Y' axis at the right angles pointing in the direction of the third note point.

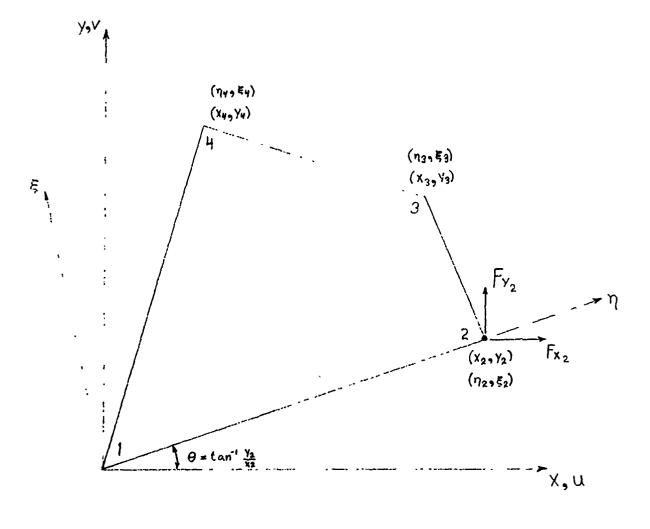


FIGURE 11-23 QUADRILATERAL PLATE ELEMENT REPRESENTATION

i. Triangular Plate (Ident. No. 27)

The triangular plate element is recommended for use as the basic building block for most doubly curved shells when performing an elastic stability analysis. Additionally, it is useful in combination with the quadrilateral plate element (Ident. No. 28) for dealing with irregular geometries of membrane, plate and shell structures when performing buckling analyses. The triangular plate element is developed in detail in References 4 and 15 and is shown in Figure II-24.

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

Membrane and flexure action are uncoupled for this element. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure thicknesses are assumed constant over the plane of the element.

Three corner points participate in establishing continuous connection of the triangular plate element with adjacent elements.

The triangular plate element, is written to accommodate anisotropy of mechanical and physical properties. 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. The conventional plane stress option is provided for this element.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the element are approximated by linear mode shapes leading to constant membrane stress behavior within the element. Transverse displacement is represented by cubic polynomials.

Element stresses for the triangular plate are predicted at the center of the element. Inplane and normal direct, shear and bending stress results are included. The display of stresses implies a set of reference axes. These axes are data specified.

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

> Stiffness Stress Thermal Load Incremental Stiffness

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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 mid-plane (membrane) variations in thermal loading, the temperature input correspond to the temperatures designated T_1 , on the Grid Point Temperature Data Form. These temperatures are input in Columns 13-22 of that form.

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For flexural action, the gradient through the thickness is assumed constant. 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. Thermal moments which arise from the gradients are then automatically defined by the System by promating the distributed edge moments to the corners.

In the performance of elastic stability analyses using this element, the set of abstraction instructions as outined in Section II.g.4 of this volume should be utilized. Consistent "initial stress" incremental stiffness matrices are generated using the membrane stress results ($\sigma_x, \sigma_y, \sigma_{xy}$) from the triangular element in conjunction with the assumed transverse-displacement functions of the element, i.e.,

 $U = \frac{1}{2} \iint N_{x} \left(\frac{d w}{d x}\right)^{2} + N_{y} \left(\frac{d w}{d y}\right)^{2} + 2N_{xy} \left(\frac{d w}{d x} - \frac{d w}{d y}\right)^{2} dx dy$

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

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Triangular Plate Element is identified as Number 27.

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 three node point temperatures of the element and use this average temperature when establishing material properties from the material tape. If the User wishes to employ a specified number of node points, n, in the averaging process $(1 \le n \le 3)$ then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Triangular Plate Element always requires Element Input; therefore, an "X" is always placed in Column 29 when a triangular plate element is employed.

The following Element Input is required when using the Triangular Plate 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 Plate 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 thicknesses.

Location B - (Cols. 23-32)

Flexural Thickness - (t_r)

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. In performing an elastic stability (buckling) analyses both the membrane and flexure thickness are needed.

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

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)

Refer to Element Control Section

Full Print - (Col. 32)

Refer to Element Control Section

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

The Triangular Plate Element is always defined by 3 input nodes.

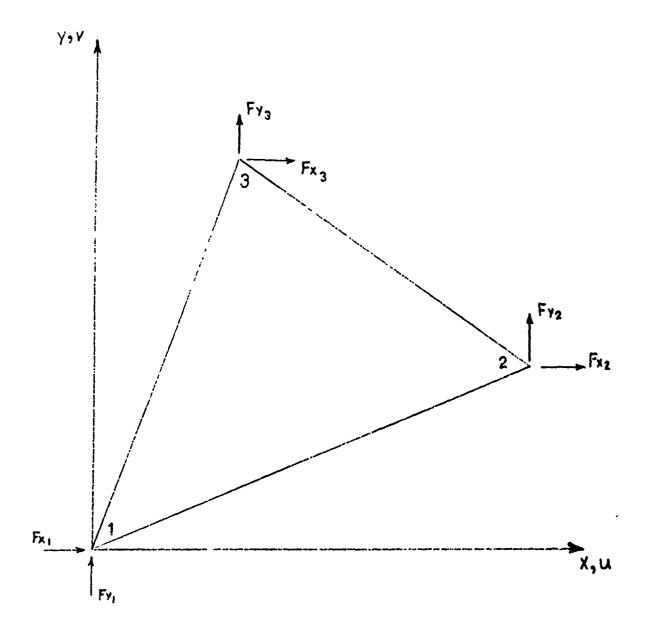
Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

Node Points - (Cols. 36-71)

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The Triangular Plate Element is defined by 3 node points. Note that the first two node points called out for the element determine the positive local "X" axis for stress output with the local "Y" axes at right angles pointing in the direction of the third node point.



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FIGURE 11-24 TRIANGULAR PLATE ELEMENT REPRESENTATION

j. Incremental Frame (Ident. No. 13)

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The formulation of the "incremental frame element" which has been incorporated into the MAGIC II System is essentially identical to the Frame Element (Ident. No. 11) described in Section II.16.a of this Manual (Pages 75-80). The representation for this element is developed in detail in Reference 8, and is shown in Figure II-15.

All element matrices available to Element Id. No. 11, are available to this element as well, i.e., Stiffness, Stress. Distributed Loading, Axial Thermal Load and Consistent Mass.

The addition of this element is primarily intended to serve the purpose of providing a companion frame element to the quadrilateral and triangular plate elements (Idents. No's. 28 and 27) which have been added to MAGIC II.

The use of this element in conjunction with the newly added quadrilateral and triangular plate elements provides a powerful capability for linear eigenvalue stability analyses of stiffened shell structures.

The incremental stiffness matrix employed for this element is derived in detail in Volume I: The Engineer's Manual, Section III.E.II (Reference 4).

All input data required for this element is identical to that required for the original Frame Element (Ident. No. 11). Therefore, in the interest of conciseness, the reader is referred to pages 75 thru 80 of this document for detailed element input description.

17. Check Or End Section (Figure II-22)

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The labeled input data form provided for the Check or End Section is shown in Figure II-25.

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 propertie: derived from the materials library as well as table, completed by MODAL specification of data. It is new mmended 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

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FIGURE 11-25 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 the finite element representations which make up the element library of the MAGIC System.

B. THREE ELEMENT PORTAL FRAME

AND A DESCRIPTION OF A

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 TII-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 12 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

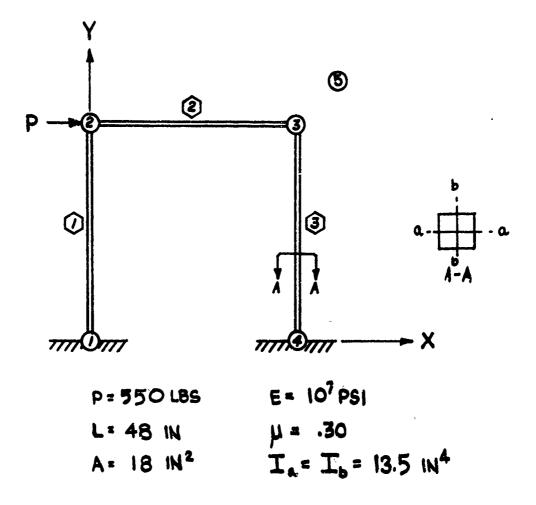


FIGURE III-B.1 - Idealized Three Element Portal Frame

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 $\langle \rangle$ 3 3 ()3 3 (/) 2 4 5 6 7 8 9 0 209 TITLE INFORMATION **PAGE** ო 6 0 1 2 OF STRUCTURAL AMLYSIS 23456789012345678961234567896123456789612345678961234567896123456789 MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT USED EN THE EDEALDENTION THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS. REFERENCET H.C. MARTEN MATELX METHODA NUMBER OF TITLE CARDS THEES REAME ELEMENTS 3 ~ 2 2 1 2 3 4 5 6 T (T) REPORT (/) BAC 1615

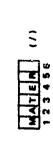
TITLE INFORMATION, THREE ELEMENT PORTAL FRAME FIGURE III-B.2

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT



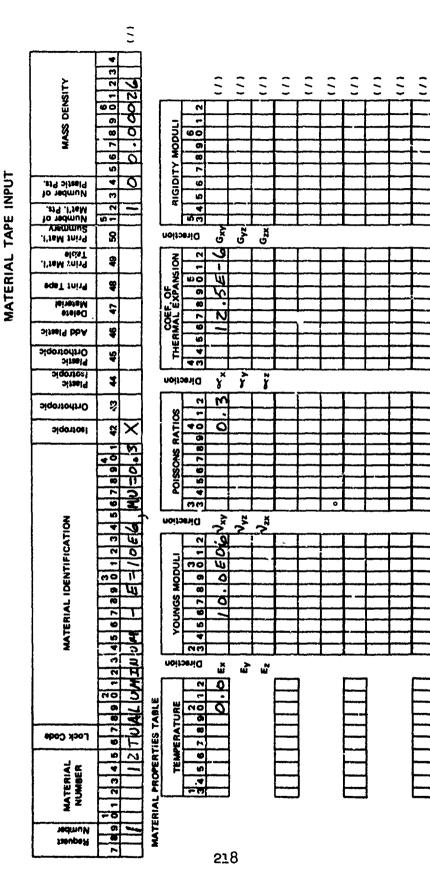


FIGURE III-B.3 MATERIAL TAPE INPUT, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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4 3 5 2 1. Number of System Grid Points ù 1 2 3 5 2. Number of Input Grid Points 8 9 10 ш Number of Degrees of Freedom/Grid Point 3. 14 13 4. Number of Lcad Conditions ٦۶ 5. Number of Initially Displaced Grid Points 18 19 20 21 6. Number of Prescribed Displaced Grid Points 23 24 25 26 27 28 Number of Grid Point Axes Transformation 7. Systems 29 8. Number of Elements 31 32 33 34 35 Number of Requests and/or Revisions of 9. Material Tape. 10. Number of Input Boundary Condition Points <u>39</u> 40 414243 11. T For Structure (With Decimal Point) D ٥ 5 46 47 48 49 50 51 52

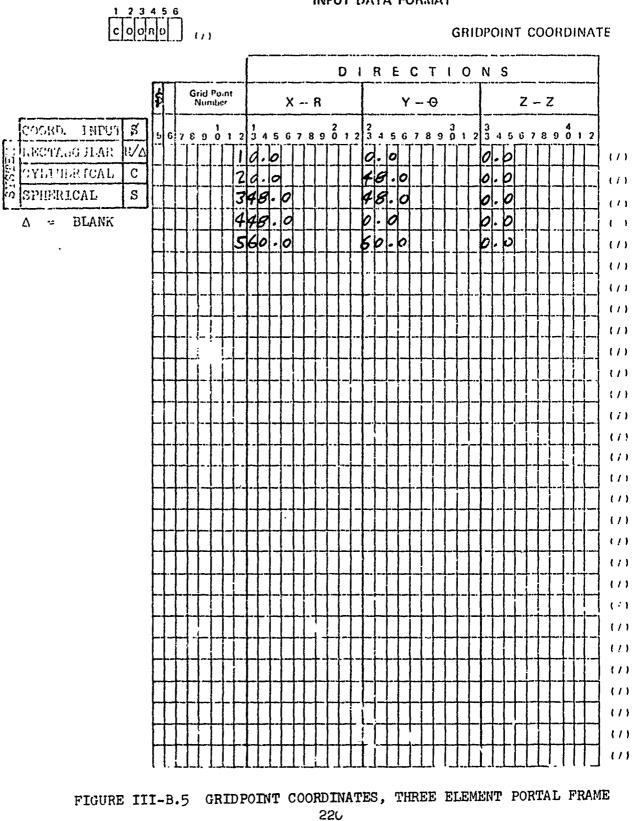
FIGURE III-B.4 SYSTEM CONTROL INFORMATION, THREE ELEMENT PORTAL FRAME 219

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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BAC 1626-1

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CO

ODE	0 · No Displacement Allowed
	1 - Unknown Displacement
	2 · Known Displacement

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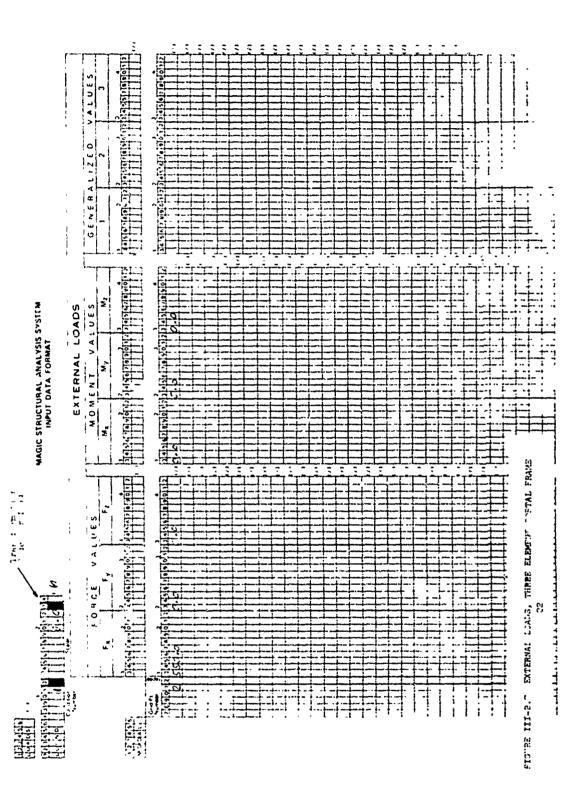
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FIGURE III-B.6 BOUNDARY CONDITIONS, THREE ELEMENT PORTAL FRAME 221



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FIGURE III-B.8 ELEMENT CONTROL DATA, THREE ELEMENT PORTAL FRAME 223

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BAC 1628

(:)3 ()()(/) 3 3 (()()()(3 (\mathbf{z}) 456789012 3 ~0 σ 60 ш 4567 1 2 6 <u>6</u> 1 2 4 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 5 0 ဖဝ 456789 ELEMENT INPUT ш აი 89012 MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT 0 2 3 4 5 6 7 8 2 7 . D 67890123456739012 2 40 S, œ υ 6 7 1/3.5 ŝ 4 **~**~ 1 2 m 0 σ 80 8 2 4 5 6 7 3,5 3 4 S N 0 ę ٠ ~0 00 8 ŋ 4 5 6 7 8 4 1 3 4 5 6 7 8 30. c Repeat :4 78901 Element Number (\cdot) E X T E R N 1 2 3 4 5 6 123456 BAC 1(-29-1 MODAL 224

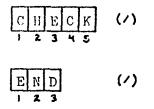


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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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

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

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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 ITI-B.14 display the output from the Structural System Monitor. These figures record the input data pertinent to the problem being solved.

Figure 111-B 13 displays the coordinate and boundary condition information for this problem. In the Boundary Condition Information Section of the figure, zeros ('0') represents 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 Tzz and Tyy respertively 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 30×1 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.

MAGIC System out ut of final results is displayed in Figures III-B.15 thru III-B.22. 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:

$$\left\{q\right\}^{\mathrm{T}} = \left[\frac{u_2}{v_2}, \frac{v_2}{v_2}, \frac{\theta_{z2}}{v_2}, \frac{u_3}{v_3}, \frac{\theta_{z3}}{v_3}\right]$$

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is presented in Figure III-B.16. From the figure, it is observed that the force value presented corresponds to a force (Fx) in the Global X direction at node point 2 numerically equal to 550.0. The portal frame displacements resulting from the Force (Fx) of 550.0 at node point 2 are also shown in Figure III-B.16. It is noted that the displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure 111-B.16 are the Reactions for the problem in question. It is noted that the Reactions $(F_X, F_Y, F_Z, M_X, M_Y, M_Z)$ are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Stresses for the three element portal frame are given in Figures III-B.17 thru III-B.19. Stresses are referenced to element coordinates, and for the frame element, description of stress behavior is accepted as the definition of the twelve forces $(F_{\chi}, F_{\gamma}, F_{Z},$

 M_X , M_Y , M_Z) acting at the two grid point connections. (See Figure III-B.1 for Element Numbering.) In Figure III-B.17, Stresses (Element Forces Referenced To Element Axes) for Element No. 1 are presented. Stress Points 1 and 2 correspond to Element Grid Foints 1 and 2 for this particular element. (Note that the third grid point, in this case grid point 5, is only used to define the plane of the element. Figures III-B.18 and III-B.19 present stresses for element numbers 2 and 3 respectively.

Element forces for the three element portal frame are displayed in Figures III-B.20 thru III-B.22. These forces are defined with respect to the Global Coordinate System.

Figure III-B.20 presents the element forces $(F_X, F_Y, F_Z, M_X, M_Y, M_Z)$ for Element No. 1. Points 1, 2 and 3 correspond to Element Grid Points 1, 2, and 5 respectively for this particular element. Note that the third grid point, in this case grid point 5, is only used to define the plane of the element and therefore there are no element forces evaluated at this particular point, i.e., Point 3 in Figure III-B.20. Figures JII-B.21 and III-B.22 present forces for element numbers 2 and 3 respectively.

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MAGIC ABSTRACTION INSTRUCTION LISTING

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	C	CALCULATE REACTIONS AND INVERSE CHECK	0000052
	C		
19		REACTS = KELA.MULT.KU	0000054
29		REACTP = REACTS.SUBT.TLOAD	0000055
21		IF (DIFF.NULL.) GO TO 10	0000056
	C		0000057
	C	PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,	0000058
	C	PEACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT	0000059
	C		0000060
	С С С	ELEMENTS HAVE 1 DR 2 DEGREES OF FREEDOM	0000061
	C		0000062
22		GPKINT(4,,,+X.FY.FZ.MX.MY.NZ,SC,TR)FTELA	0000063
23		GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,)LOADS	0000064
24		GPR LNT(2, , , U.V. h. THE TAX. THE TAY. THETAZ, SC.) X	0000065
25		GPRINT(1,,,FX.FY.FZ.HX.MY.NZ,SC,TR) REACTP	0000066
26		IF (13-NULL-) GU TO 600	0000067
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	C C C	ELEMENTS HAVE 3 DEGREES OF FREEDOM	0000069
	ċ		0000070
27	10	GPRINTI4,,,FR.G.FZ.U.MBETA.G.FI.U.F3,SC,TR JFTELA	0000071
28		GPR INT(4,,,FR. G.FZ.O.MBETA.O.F1.O.F3,SC.)LOADS	0000072
29		GPR INT (2,,,,U.O.W.G. THE TA Y.O. W+.O.W++,SC, 3X	0000073
30		GPRINTLL,,,FR. U.FZ. U. MBETA. Q.FL. O.F3,SC,TR)REACTP	0000074
~	C		0000075
	C C C	GENERATE STRESSES AND FORCES	0000076
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31	600	STRESP =EM,XO . STRESS.(4,)	0000078
32	200	$FURCEP = EM \cdot XO \cdot FURCE \cdot (4 \cdot)$	0000679
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FIGURE 111-B.11 FORMAT ABSTRACTION INSTRUCTION LISTING (CONT)

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

2X 0.3044156 07 2X 0.300000E 00 POISSON'S RATIOS 72 0.384615€ 07 Y2 0.300006 00 AIGIDITY NODULI DIR ECTIONS DIR ECTIONS XY 0.384615E 07 XY 0.30000E 00 22 0.129000E-04 22 0.100000E 08 THERMAL EXPANSION COEFFICIENTS 77 0.125800E-04 YY 0.100000E 08 VOUNS'S MOULE DIRECTIONS DIRECTIONS XX 0.100000E 08 8, 125009E-04 NATERIAL PROPERTIES TENPERATURE TENPERATURE å • 230

INPUT CODE

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REFERENCE- N.C.RARTIN MATRIX METHODS OF STR. AMALYSIS PAGE 209

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1	0.9	Q.C	C.O	G.U	J.Q
				C.O	0.0
				Ç.U	0.0
2	0.0	C.480000 GUE 02	U.9	C.C	G .C
				C.0	C.C
				0.0	a.c
3	C.48CUUCGOE 02	G.480000CCE 02	U. 0	0.0	0.0
				G.U	6.0
				G.0	C.C
4	0.46006060E 02	C. C	0+0	C.O	D+G
				Q.0	U. C
				G.O	6.6
5	C.6CLOOGCUE 02	C. 400000 CUE 02	0.0	9.0	0.0
				0 . 0	0.0
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GRIDPCINT DATA

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FIGURE 111-B.13 GRIDPOINT DATA, BOULAY COMPACT. AND AN IN DESCRIPTION OF CUTPUT, THREE ELEMENT PORTAL FRAME

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ELEMENT LOAD SLALAR = 0. 0. • 2 0,59000E 03 0. LOAD NG.

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

30 X L	 •		
	0.55000006 03		

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

		FORCE	· · · · · · · · · · · · · · · · · · ·			6 0.5429 00E 8 7			6 0.2250000 08
	6 BY 6		11.		0.3515626 04	-0.351542E 06		-0.351562E 06	-0-3515626 04
	312E	FORCE		1	•	¥.	4	07	5 5
21175			⁴ 11	-0.375000E	-0°144484E 05	0°723900E	0. 351542E 00	0.376445E 07	9.351562E 06
MATRIX STIFF		EINCE	.10J	•	•	•	•	•	•
-			I. K ₁₁	3 0.351542E 04 4 -0.375000E 07	0.351942E 06	0.351342E 04	0.376465E 07	-0.3515626 06	0.542500£ 07
	ġ ,	SARCE	20		•	~	•	•	M
	CUTOF		Row Col. N.	1 1 0.376435 07	2 9,374456 07	0.351542E 06	-0.375006 07	-0.1464046 05	9.3323426 06
			1 03	┝	~	-	-	~	N
			log E	┠	~	•	4	•	٠
					-210	.9210	. * 10	.4210	-7110

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

FX	FY	52	XW		RY	74
0.0	0.0	2•0	Ú • Ú	0 • 0		J. C
0.550000006 03	0.0	0.0	1°(.
0.6	0.0	0°0	0 • C	C. C		0•0
0.0	0.0	0.0	о. ИОТ	C • C		0•0
0.0	•••	0.0	3 3 1 <i>K</i> L.	;		3. 0
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		30 X I		E,		
=	>	3	THETAX		THE TAY	THETAZ
0.0	9- 6	a*c	? * 0	C• J		0.0
L_2691003E-01	U. 42788444E-U4	5.C	0• 3	0*)		-9. 33824937E-33
0.26836831E-01	-0.627884446-04	3.6	c* 0	C + C		-0. 336 72420E-03
0.0	0.0	0-0	0• 0	C • O		0.0
 0	0.0	0.0	0 • J	2.2		۰
۰ ۰	NEACTI CW	S AND INVERSE CHE	REACTIONS AND INVERSE CHECK FOR LUAD CONDITION	1 NO		
	ţ	Z	HX HX		*	ZW
FX -	-0.23545453E 03	0 • C	0 • Ú	0°0		0. 75579531£ 34
	-0-19216426E-03	0°C	9*6) • J		0. 488 28125E -02
	n. 335493365-U3	0.0	0° 0	C. C		-0. 78) 25090E-32
	0. 23545653E 03		?. ?	ن• ر. ۲		4C 318170467
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STRESSES FOR THE FRAME LLEMENT

ELEMENT GRIC PUINTS

ELEMENT TYPE

ELENENT NÜMBER

LOAC CONDITION NUMBER

	NORMAL(M2) -0. 75579609E 04 -0. 56552773E 04	MURMAL(N2) 0.0 0.0	MORMAL(M2) -0.75579609E 04 -0.55552773E 04
	FLEXURAL MUMENTS NURMAL(MY) U.C U.C	FLEXURAL MOMENTS Nurmal(MV) 0.0 U.0	FLEXURAL NOMENTS NORMAL(NY: 0.0
1 2 5	Т ВАQUELHX) 0.0	TORQUELNX) 0.0 0.0	rorquelmx) 0.0
11	SHEAR(F2)	SHEAR(F2) 0.0 0.0	SHEAR(FZ) 0.0
1	FORCES SHEAR (FV) -6.2752756 E (3) 0.27527563E (3)	FURCE'S SHEARGE VI	FONCE S SHEAR (FV) -6. 27527563E 03 6. 27527563E 03
_ m	APPARENT BLEMENT STRESSES Stress Point Axtalifx3 1 -0.22545653E G3 2 0.23545653E G3	ELEMENY APPLIED STRESSES Stress Applied Stresses Point Axialifx) 1 0.0 2 0.0	NET ELENENT STRESSES - STRESS AX (AL(FX) PUINT -0.22949653 C3 2 0.22949653 C3
	APPARENT Stress Point 2	ELENENT STRESS POINT 1 2	NET ELE Stress Point 2

FIGURE III-B.17 STRESS GUTPUT, FLEMENT NO. 1, THREE ELEMENT PORTAL FRAME

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STRESSES FOR THE FLAFT ELERENT

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		NORMAL(MZ)	-U. 565525UUE 04 -Q. 56466719E 04	NORMAL(NZ) 0.0 0.0	NPRMAL(NZ) -4.56552500E 64 - 7.55666719E 04
11 IN I S		FL EXURAL MIMENTS NUKHAL(MY)	30 20	FLEXURAL MOMENTS NURMALINY) 0.5 U.P	FLEXURAL MOMENTS NORMALGNYA 0.0 0.0
EL EMENT GRIC PUINTS	5) M	r ORQUELMX)	5°5 5°5	TORQUELMX) 0.0 0.0	TONQUELNX) 0.0 0.0
ELEMENT TYPE	11	SHEAR(FZ)	C•0	SHEAR(F2) 0.0 0.0	SHEAR(F2) 0.0
ELEMENT AUNGER	8	FONCES SHEAR (FY)	-0.235456886 03 0.235456886 03	FORCES SHEAR (FY) 9.0	FORCE S
LOAD COMDITION NUMBER	1	APPARENT ELEMENT STRESSES Stress Point axial(fx)	0.27448750E (6) -3.27448750E 03	ELEMENT APPLIED STRESSES STRESS AKIAL(FX) POINT AKIAL(FX) 2 0.0	NEF & EMENT STRESSES STRESS AX (AL (FX) PUINT 0.27408750E 03 2 -0.27408750E 03
-		APPARENT STRESS POINT	~ ~	ELENENT STRESS POINT 1 2	NET ELEN STRESS PULNT 1 2

FIGURE III-B.18 STRESS OUTPUT, ELEMENT NO. 2, THKEE ELEMENT PORTAL FRAME

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	NORHAL (M.2) 0. 5446797E 04 0. 75407394E 04	MORMAL(N2) 0.0 0.0	NURRAL(N2) 0. 5446797E 04 0. 75407344E 04
0 [MT 5	FLEXUMAL MUMENTS Normal(NY) C+O G+C	FLEXURAL NUMENTS Normal(NY) 0.0	FLEXUMAL MOMENTS Normal(NY) 0.0 0.0
elenent Gric Puints 3 4 5	ronquernx) 0.0	TORULEI MX)	TONQUE(MK) 0.0
ELEMENT TYPE 11	SHEAR(FZ) 0.0	SHEAN(FZ) 0.0	SHE AR (FZ) 0.0
ELENENT ALMER 3	FONCE S SHEAR (FV) 0.274737556 (G)	FORCE S SHEAR (F-Y) 0.0	FORCE S SHEAR (FY) 9.27473 755E 03
LOAC CONDITION NUMBER 1	APPARENT ELENENT STRESSES STRESS POINT AXIALIFX) 1 0.23949653E 03 2 -0.23949653E 03		NET, ELEMENT STRESSES STAESS AXIAL(FX) POINT AXIAL(FX) 1 0.22343453E 03 2 -0.2334453E 03
5	APPARENT STRESS POINT 2	EL CH CHIT A STRESS" POINT	NET, EL GNI STAESS POINT' 1' 2

FIGURE III-B.19 STRESS OUTPUT, ELEMENT NO. 3, THREE ELEMENT PORTAL FRAME

			NOR NAL (NZ)	G. 7557 95 1E 04 0. 56552578E 04 9. 0	NORMALE PZ)	000	NDRMAL (N2)	6. 75579531E 64 0. 56552570E 64 0.0
	UINT S		FLEXURAL NUMENTS NUGMALLNY	5 ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° °	FLEXURAL MUMENTS NJKMAL(NY)	300 000	FLEXURAL MUMENTS Normal (MY)	000
FRAME LUEME	the Meni GRIC PUINTS	4	f undu et mx)	003 003	T UKQUEL MX)	0,34 0,00 0,00	TORQUE(M.)	000
т 7 Т	ELEMENT TYPE	- 77	SH& A6(F2)	000 000	SHËAR(FZ)	7.70 ·	SHEAR(FZ)	9•9 9•0
	ELENENT NUMER		FONCES SHEAR (FY)	-0.23545453E Q3 0.23545453E Q3 U.O	FONCE S SNEAR (FV)	000 ••••	FONCE S SHEAR (FY)	-0.23545453E 03 0.23545453E 03 0.0
	LOAD CONDITION NUMBER	H	APPARENT ELEMENT FONCES PUINT AX IAL (FX)	-0.275.753% 03 0.275.753% 03 0.0	ELEMENT APPLIED FONCES POINT APPLIED FONCES AXIAL(FX)	0 U U 0 U D	NET ELEMENT FONCES PUINT AKTAL(FX)	-0.275275395 63 C.275275395 63 C.C
			APPARENT PUENT		EL EN ENT A POINT	-4 (N M)	NET ELENE POINT	

FIGURE III-B.20 FORCE OUTPUT, ELEMENT NO. 1, THREE ELEMENT PORTAL FRAME

1 1 ж С 4 FLACES

NoT REPRODUCIBLE

	NJHMAL(M2) -U. 26522293E 34 -J. 56468641E 04 ''	NORKAL(P.2)
2. IA 13	FLEXUMAL MUMMAS Rummal(PV) N+C C+C C+C	FL EXUMAL MUMENTS NURMAL(MY)
tlevent Gallar, INTS 2 a 5	T UKQUELMX) 0.5 0.5 0.0	1 OR QUE E M X)
ELÉMLAT TYPE 11	SHE AV (F23 6.1 0.1	SHŁAP(FZ).
LLENENT ALMUER 2	FUNCE S SHEAR(FY) -6.23345668E J3 11.23545683E J3	FUKCE S SHEAR (FY)
LAAD CUNUITIUN NUMBER 1	APPARENT ELEMENT FUNCES POINT AXIAL(FX) 1 U.27448754E (3 2 -C.27448754E (3 3 0.02	
-	APPAR LNT POINT 1 2 3	EL LM ENT

NORMAL (MZ)	-0.56557504£ 04 -4.5646641£ 44 6.0
FLEXURAL MOMENTS MIXMA1 (MY)	11 C J • • • • • • • •
	د. د و د د و د م
FORCES	SHEANILTT -L.235454604E 13 C.23345683E 13 5.0
NET ELMENT FUNCES PUINT	AX IAL(FX) 12796687506 53 -0.2796887505 53 0.0
NET ELENI PUINT	

330 730

003 9**3**7

FIGURE III-B.21 PARTE AUTPUT, ELEMENT R. 2, THREE PARTER LANE FRAME

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NGXMALEP2) 3. 56466641E (4 3. 73497137E 04 3.0	MURPAL(#2)
HLEXLAL MUMENTS "HIMMAL(MY) ""	FLEXUMAL MUMENTS MUMMALLMUMENTS
TUN4026MX 8 13.65 1.01 1.00	TABOULT NY 1
SHE AN(FL) trop 2011	
FURCE S SHEAK (F V) -L. 23545653E C3 (.23545653E C3	FUNCE S
6 7	
	FURCES SHEAK(FY) SHEAR(FL) TUKUUE(MX) HLEXUAL MUMENTS SHEAK(FY) SHEAR(FL) TUKUUE(MX) 'VIKMAL(MY) (3 ==2,23545653E 03 0.00 (-200 0.00 0.00 (-23545653E 03 0.00 (-200 0.00 0.00 0.00

MURPAL (# 2) 31 31 31	MDRMAL(MZ) U. 5046001E 04 U. 51401187E 04 U. 5
	FLEXURAL MUMENTS Nurmai (ny) V.Ú V.Ú V.C
T0RQUE4 4X)	ТОКЦИЕТИХ) С.0 3.0 3.0
SHEAR(F2) 0 11.0	SHEAR(F2) 6.0 0.0 0.0
FURLE S SHEANLEV) Col Col Col	FUKLES SHEAN (FY) -C.233595653E U3 5.233595653E U3 5.23595653E U3
LLENENT APPLIEU FONCES Point Axialitx) 1 5.C 2 7.G 3 1.C	NET ELEMENT FORCES POINT AXIAL(FX) 1 1.02141273.4 43 2 -6.2747373.4 43 3 40.4
LLEMENT A POINT 1 3 3	NËT ELEM POJNT 2 3

HI JURE III-B.22 FARE ATPRT. ELEMENT RA. 5. HIREE ELEMENT PRAF

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 proprinted 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 crosssectional 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.

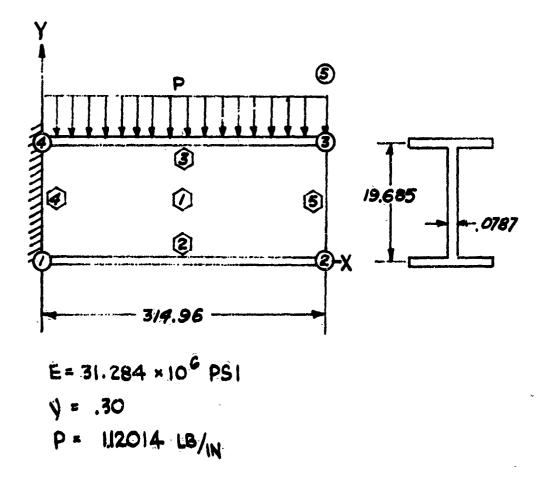


FIGURE III-C.1 - Idealized Cantilever Beam

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REPORT (/)

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

PORT FORM INPUT

MAGIC STRUCTURAL ANALYSIS SYSTEM

TITLE INFORMATION

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FIGURE III-C.2 TITLE INFORMATION, CANTILEVER BEAM

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MAGIC STRUCTURAL ANALYSIS SYSTEM

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MATERIAL, TAPE INPUT

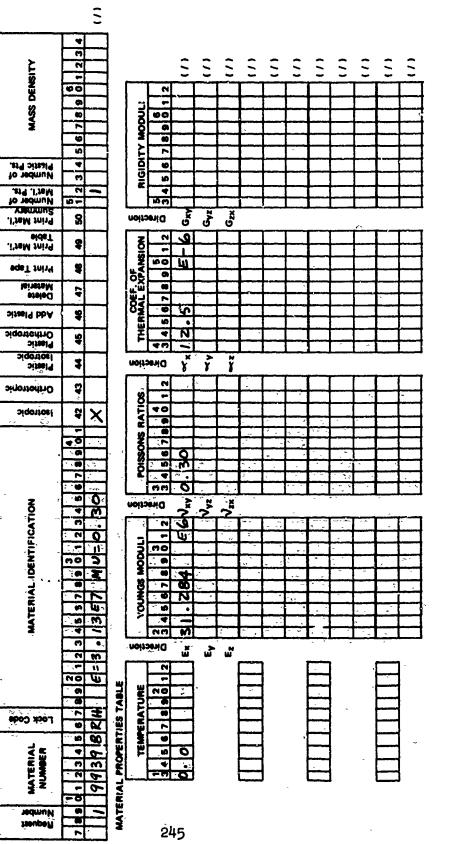


FIGURE III-C.3 MATERIAL TAPE INPUT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

- 1. Number of System Grid Points
- 2. Number of Input Grid Points
- 3. Number of Degrees of Freedom/Grid Point
- 4. Number of Load Conditions
- 5. Number of Initially Displaced Grid Points
- 6. Number of Prescribed Displaced Grid Points
- 7. Number of Grid Point Axes Transformation Systems
- 8. Number of Elements
- 9. Number of Requests and/or Revisions of Material Tape.
- 10. Number of Input Boundary Condition Points
- 11. To For Structure (With Decimal Point)

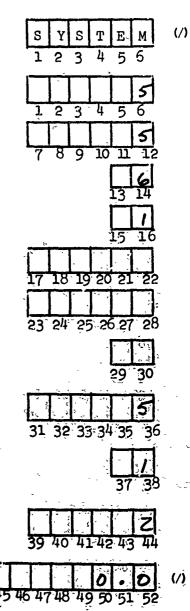
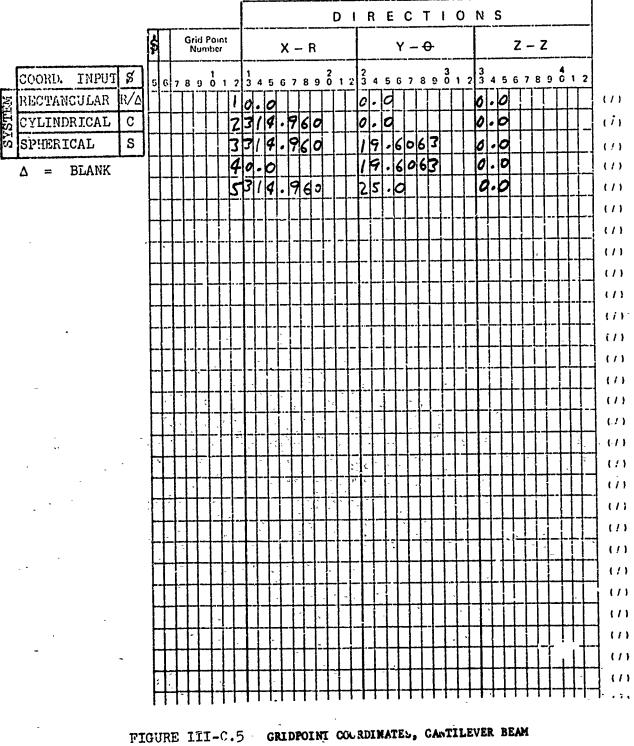


FIGURE III-C.4 SYSTEM CONTROL INFORMATION; CANTILEVER BEAM 246

MAGIC STRUCTURAL ANALYSIS SYSTEM

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

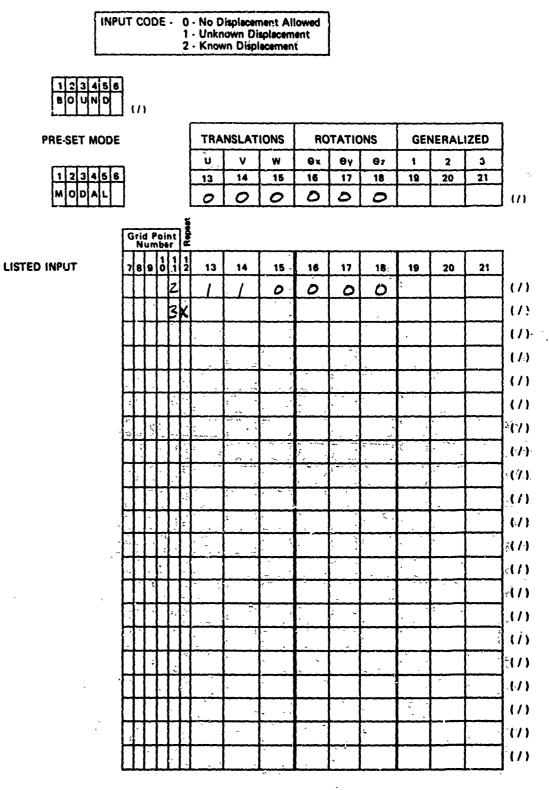
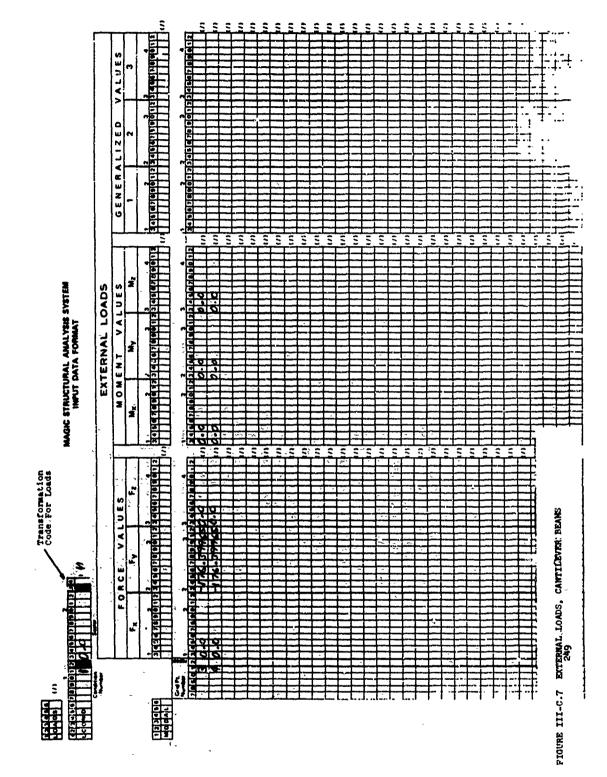


FIGURE III.C.6 BOUNDARY CONDITIONS, CANTILEVER BEAM

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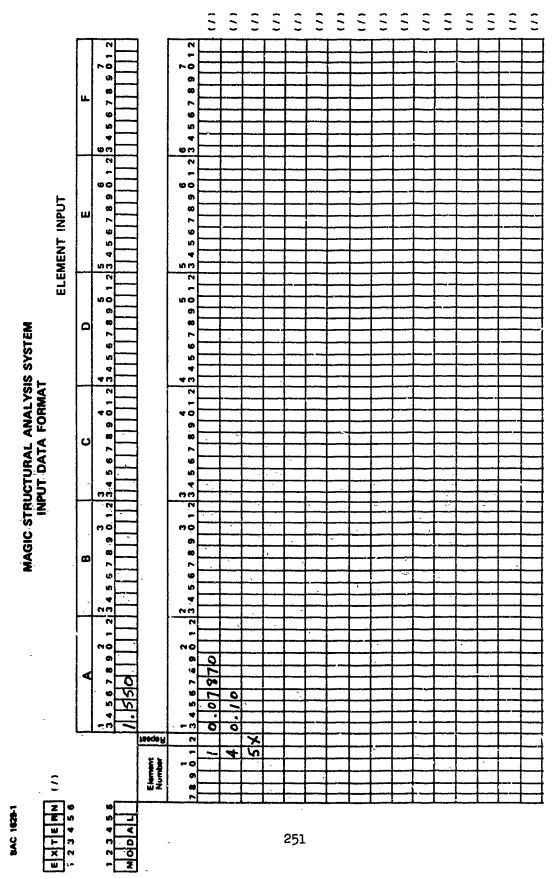
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FIGURE III-C.9 ELEMENT INPUT, CANTILEVER BEAM

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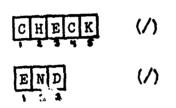


FIGURE III-C.10 END CARD, CANTILEVER BEAM

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

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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 crosssectional 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:

$$\left\{q\right\}^{T} = \left[u_{2}, v_{2}, u_{3}, v_{3}\right]$$

Figure III-C.16 displays External Load, Displacement and Reaction Information.

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is shown first in Figure III-C.16. From the figure, it is observed that the force values presented correspond to forces, Fy, acting in the negative Global Y direction at node points 3 and 4. The magnitude of each force component is equal to -176.40 Note that at node point 4 the degree-of-freedom in which the applied force is acting is bounded out. (See Boundary Condition Information, Figure III-C.12.)

The displacements for this application are also shown in Figure III-C.16. It is noted that the Displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure III-C.16 are the Reactions, $(F_X, F_Y, F_Z, M_X, M_Y, M_Z)$ which are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Stresses for ' e Quadrilateral Shear Panel are shown in Figure III-C.17. The quadrilateral shear panel is described by one constant shear stress value.

Stresses for the Frame Elements (Axial Force Members) are shown in Figures III-C.18 thru III-C.21. Description of stress behavior for the axial force member is accepted as the definition of the twelve forces $(F_X, F_Y, F_Z, M_X, M_Y, M_Z)$ acting at the two grid point connections. (See Figure III-C.1 for Element Numbering.)

Element forces for this application are displayed in Figures III-C.22 thru III-C.26. These forces are defined with respect to the Global Coordinate System. Figure III-C.22 displays the element forces for the Quadrilateral Shear Panel Element. This element is defined by four node points and six forces are associated with each node point. For this application, force points 1, 2, 3, and 4 correspond to element grid points 1, 2, 3, and 4. Figures III-C.23 thru III-C.26 define the element forces for Element Numbers 2 thru 5 respectively. The interpretation of these forces is exactly the same as those in the previous example (Three Element Portal Frame, Figures III-B.20 thru III-B.22).

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FIGURE III-C.14 TRANSFORMED EXTERNAL ASSERTED LOAD COLUMN DUTIUT, CANTILEVER BEAM

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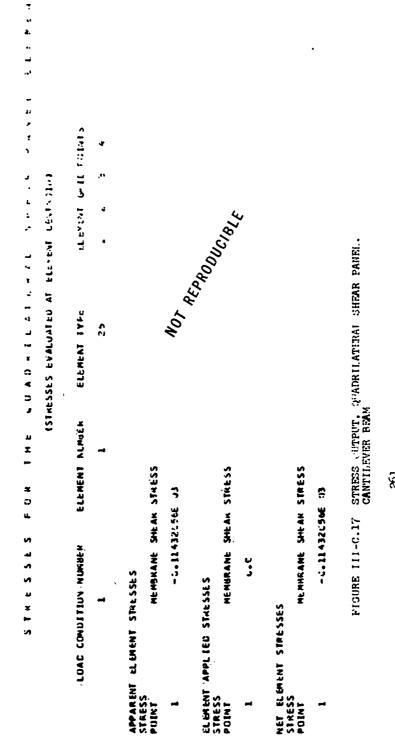
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FIJURE III-C.18 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 1, CANTILEVER BEAM

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FIGURE III-C.19 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 2. CANTLEVER B-AM

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FIGURE III-C.20 STRESS CUTPUT. AXIAL FORCE MEMBER NO. 3, CANTILEVER BEAM

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FIGURE III-C.23 FORCE OUTPUT, AXIAL FORCE MEMBER NO. 1, CANTILEVER BEAM

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FIGURE III-C.26 FORCE WITPUT. ANIAI FURCE MEMBER IN . 4. CAUTILEVER 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.

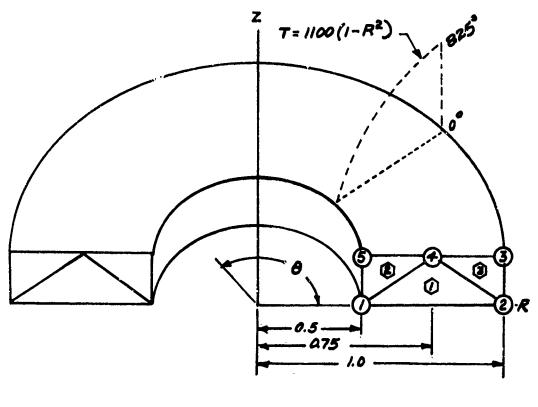
In Figure III-D.3 (Material Tape Input Section) note that 2 material (temperature) points are entered for the material in question. A linear interpolation for material properties is performed for temperatures which fall between these two temperature points.

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.



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FIGURE II1 - D.1 - Idealized Thick Walled Disc

In Figure III-D.9 (Element Control Data Section) it is important to note a number of items.

- (1) The temperature interpolate option (Col. 19) is employed for all three elements. The '3' entered in this location tells the system to average the three node point temperatures for each element and use this average temperature when establishing material properties from the material tape.
- (2) The node point numbering sequence for each element is very important. Note that each element must be numbered in a counter-clockwise manner when looking in the positive element Y (θ) direction (Figure III-D.1).

Element Input is not required for this problem.

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REPORT (/)

TITLE INFORMATION

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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

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FIGURE III-D.2 TITLE INFORMATION, THICK WALLED DISK

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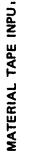
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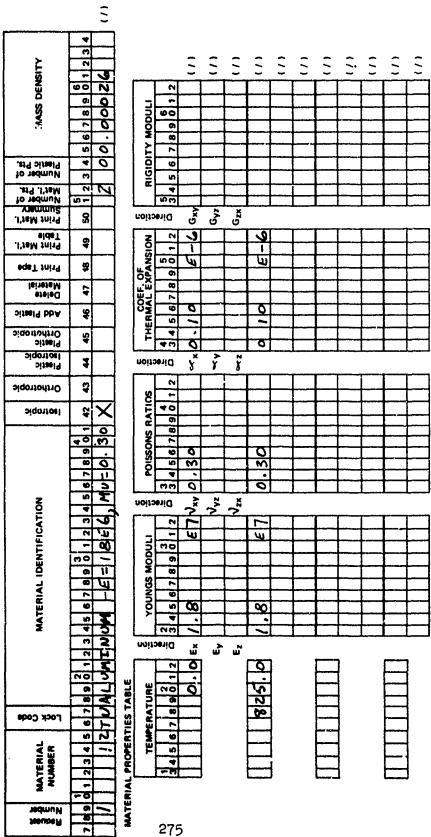


FIGURE III-D.3 MATERIAL TAPE INPUT, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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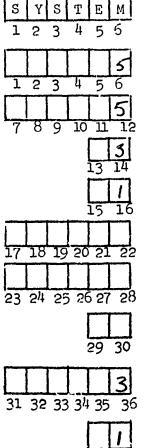
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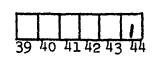
SYSTEM CONTROL INFORMATION

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2.	Number of Input Grid Points	
3.	Number of Degrees of Freedom/Grid Point	
4.	Number of Load Conditions	
5.	Number of Initially Displaced Grid Points	
6,	Number of Prescribed Displaced Grid Points	
7.	Number of Grid Point Axes Transformation ~vstems	
8.	Number of Elements	
9.	Number of Requests and/or Revisions of Material Tape.	
10.	Number of Input Boundary Condition Points	
11.	T _o For Structure (With Decimal Point)	

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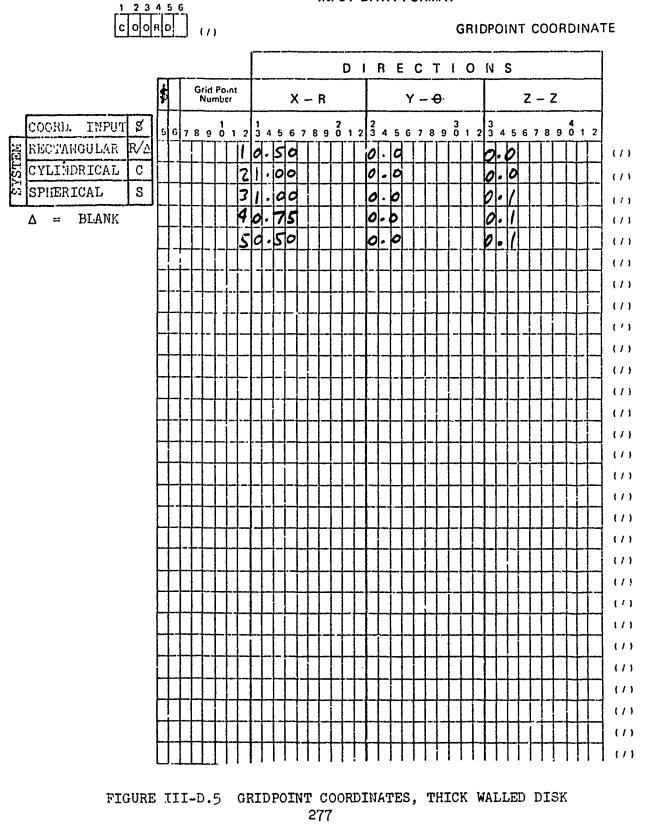
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FIGURE III-D.4 SYSTEM CONTROL INFORMATION, THICK WALLED DISK 276

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT



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CENERAL CONSTRUCTION OF STREET DOCUMENT

MAGIC STRUCTURAL ANALYSIS SYSTEM

GRID POINT TEMPERATURES

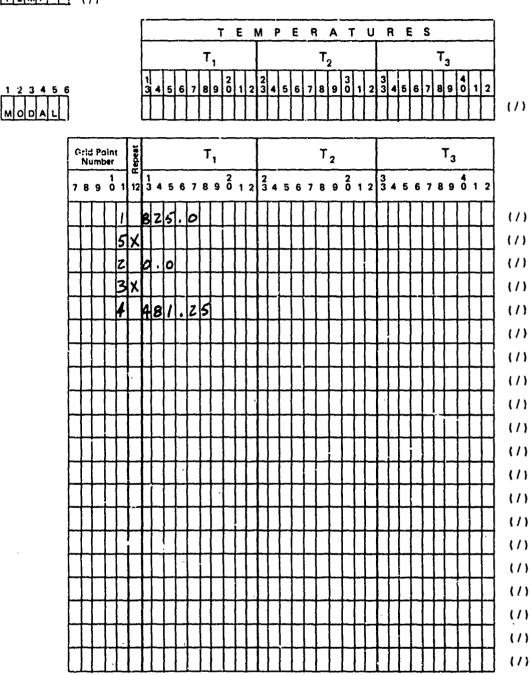


FIGURE III.D.6 GRIDPOINT TEMPERATURES, THICK WALLED DISK 278

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

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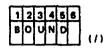
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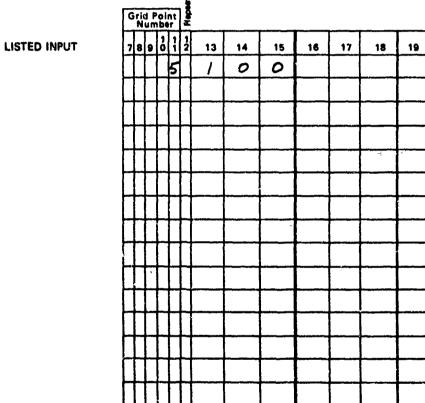


FIGURE III-D.7 BOUNDARY CONDITIONS, THICK WALLED DISK 279

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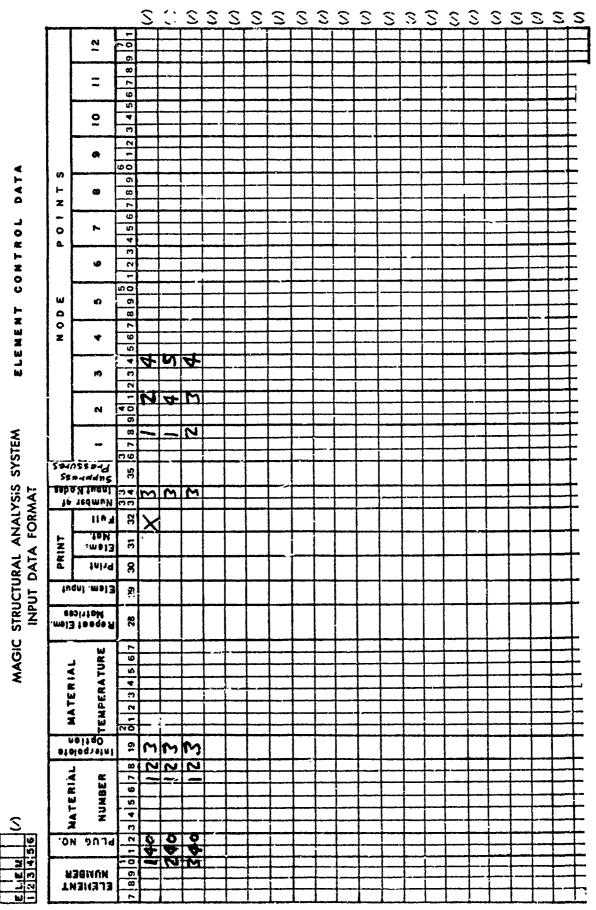
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FIGURE III-D.S EXTERNAL LOADS.	ERNAL LOAES. THICK WALLED DISK 280		
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ELEMENT 281 DATA, THICK WALLED DISK FIGURE III-D.9

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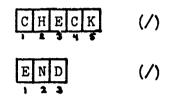
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

CHECK OR END CARD



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FIGURE 111-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:

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

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.

MAGIC System output of final results is shown in Figure III-D.15 thru III-D.22.

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:

 $\{q\}^{T} = [u_1, w_1, u_2, w_2, u_3, w_3, u_4, u_5]$

The thermal load vector (GPRINT OF MATTIX FTELA) is displayed in Figure III-D.16. These forces are generated at the element level and are output with respect to node point number.

The displacements of the thick walled disk which result from the imposed temperature distribution are also presented in Figure III-D.16. It is noted that displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure III-D.16 are the Reactions. The reactions are listed corresponding to node point number. Note that for this particular application, the reactions are effectively equal to zero which results from the nature of the thermal loading which is imposed.

Stresses for each Triangular Ring Element are shown in Figures III-D.17 thru III-D.19. All stresses are evaluated at the element centroids.

The stresses for each element are defined as follows:

 $\nabla = [E] \{ \epsilon \} - \{ szael \}$

where from Figure III-D.17:

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[E]{E}	=	Apparent Element Stress
(szael)	=	Element Applied Stress
{ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	=	Net Element Stress

The thermal stress correction vector {SZAEL} for any particular element is defined as follows:

$$\{SZAEL\} - \Delta T [E] \{\vec{a}\}$$

where [${\tt E}$] is the material property matrix which has the following form

$$\mathbf{E} = \frac{1}{\Delta} \begin{bmatrix} \mathbf{E}_{r} (1 - \mathbf{\hat{v}}_{\Theta Z} \mathbf{\hat{v}}_{Z\Theta}), \ \mathbf{E}_{r} (\mathbf{\hat{v}}_{\Theta r} + \mathbf{\hat{v}}_{ZR} \mathbf{\hat{v}}_{\Theta Z}), \ \mathbf{E}_{r} (\mathbf{\hat{v}}_{Zr} + \mathbf{\hat{v}}_{Z\Theta} \mathbf{\hat{v}}_{\Theta r}), \ \mathbf{0} \\\\ \mathbf{E}_{\Theta} (1 - \mathbf{\hat{v}}_{rZ} \mathbf{\hat{v}}_{Zr}), \ \mathbf{E}_{\Theta} (\mathbf{\hat{v}}_{Z\Theta} + \mathbf{\hat{v}}_{r\Theta} \mathbf{\hat{v}}_{Tr}), \ \mathbf{0} \\\\ \mathbf{E}_{E} (1 - \mathbf{\hat{v}}_{r\Theta} \mathbf{\hat{v}}_{\Theta r}), \ \mathbf{0} \\\\ \mathbf{Symmetrie} \\ \Delta \mathbf{G}_{rv} \end{bmatrix}$$

where

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$$\Delta = (1 - \dot{\gamma}_{\theta} \,\vartheta_{\theta r} - \vartheta_{\theta z} \vartheta_{z \theta} - \vartheta_{z r} \vartheta_{r z} - \vartheta_{r \theta} \vartheta_{\theta z} \vartheta_{z r} - \vartheta_{r z} \vartheta_{\theta r} \vartheta_{z \theta})$$

$$\{ \overline{\alpha} \}^{T} \quad [\alpha_{r}, \alpha_{\theta}, \alpha_{r}, 0]$$

where α_r , α_{θ} , and α_z are the coefficients of thermal expansion in the r, e, 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:

$$\begin{bmatrix} E \end{bmatrix} \begin{bmatrix} E_{11} & E_{12} & E_{13} & 0 \\ & E_{02} & E_{23} & 0 \\ & & E_{33} & 0 \\ & & & E_{LR} \end{bmatrix}$$

Using this notation, the SZAEL vector (Element Applied Stresses) for Element No. 1 is interpreted as follows:

ELEMENT NUMBER	ALGEBRAIC VALUE	NUMERICAL VALUE
1 (5 r)	$(E_{11} \sim r + E_{12} \sim r + E_{13} \sim z)$	1959.37
l (σ ∂)	$(E_{12} \sim r + E_{22} \sim r + E_{23} \sim z)$	1959.37
1 (5 2)	$(E_{13} \sim r + E_{23} \sim e + E_{33} \sim z)$	1959.37

The stresses for Element Numbers 2 and 3 (Figures III-D.18 and 19) are presented in exactly the same manner as in Figure III-D.17.

Element forces for this application are presented in Figures III-D.20 thru III-D.22. These forces are defined with respect to the Global Coordinate System. Each Triangular Ring Element has three element forces defined per grid point (F_r, F_e, F_z) . For Element No. 1 (Figure III-D.20) Force points 1, 2 and 3 correspond to node points 1, 2 and 4 respectively. Forces for Element Numbers 2 and 3 are defined in an analogous manner (Figures III-D.21 and 22).

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

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 FIGURE ILL-D.12 BRIDPOINT DATA ALD BAUNDARY C NDITFON UPDT, THICH WALL 283

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

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

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FIGURE 111-D.15 REDUCED STIFFNESS MATRIX OUTPUT, THICK WALLED DISK

FIGURE III-D.16 ELEMENT APPLIED LOADS, DISPLACEMENT & REATTINE VUTPUT, THICK WHILED IV 1011

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(51	ELEMERT ALMEEN	-4	CIRCUMFERENTIAL (SIGMA-THETA)	1. 19591 765E 04	CIAL U NF EREATIAL (SIGMA-THETA)	0.15593711E L4	LINCUMEERENTIAL (SIGMA-THETA)	-i.20019531E Lu
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			APPARENT STKESS POENT	7	EL CH ENT STRESS PO INT	-	NET EL LM STRESS POINT	м

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FLUCKE INT-D.17 STRESS OUTPUT, ENERT NO. 1, THECK WALLED DISK

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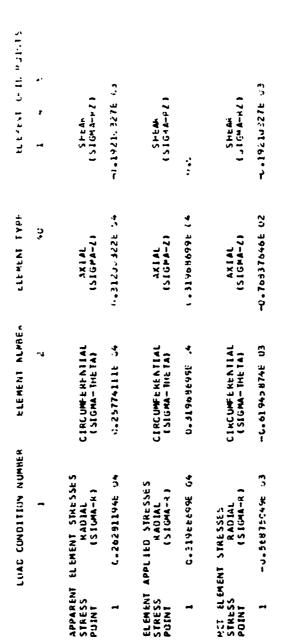


FIGURE 111-D.18 STRESS OUTUT, ELEMENT NO. 2, THICK WALLED DICK

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ELEMENT TYPE	54	AKIAL (516MA-2)	/3637573E v3	4X14L [51644-2]	u•72187354£ ∵3	AX ; AL (SEGPA-2)	1,.545J2197E u2
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2		APPARENT STRESS PUINT	T	EL EN LNT STRESS POINT		NET EL EF Stress Puint	1

FIGURE III-D.19 STRENS CUTPUT, ELEMENT N. 3, THICK WALLED DICK

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ELEMENT ALMBEN 2	CIKCUM-ERENTIAL (F-THETA) ((((C.I.K.L.UMFERE.N.I.A.L (+-THETA) 6. J (CINCUM ENENTIAL (1- THETA) ((
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FIGHRE III-D.E.		-:	ELEMENT FORLES NT RAJIAL NT (FR)	-t.1845£402E (.3 (.18458666E :2 (.22678323E .3	APPLIED FUNCES RADIAL (FR)	-L.27263244E 13 L.25676584E 13 C.22676584E 13	EL EMENT FORCES KADIAL (Fr)	LOAD CONVITION NUMBER
	F AGE OUTPUT. ELEN-W	6 . C	CIRCUMFERENTIAL (F-THÊTA)		CIRCUNFERENTIAL (F-THETA)		C[xCufferen]IAL (F- THE]A)	ELEMENT NUMBER
	F ROE OUTPUT, ELEMPUT GO. 3, THICK WALLED DIE	J.46437.122E 32 -1.46437.122E 32 -1.976562501E-03	AXIAL (F2)	0.51971216E 03 0.51971216E 03	AX10L (+2)		3X1AL (f2)	SLEMENT TYPE

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E. THIN WALLED CYLINDER, EDGE LOADING

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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 $(u, 0, w, 0, \Theta y, 0, u', 0, w'')$.

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).

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

 $F_{\rm R} = (1500)(2)(3.14)(20) = 188,495.4$ lbs.

The value which is entered for the applied moment was determined as follows: (From Fiugre III-E.1).

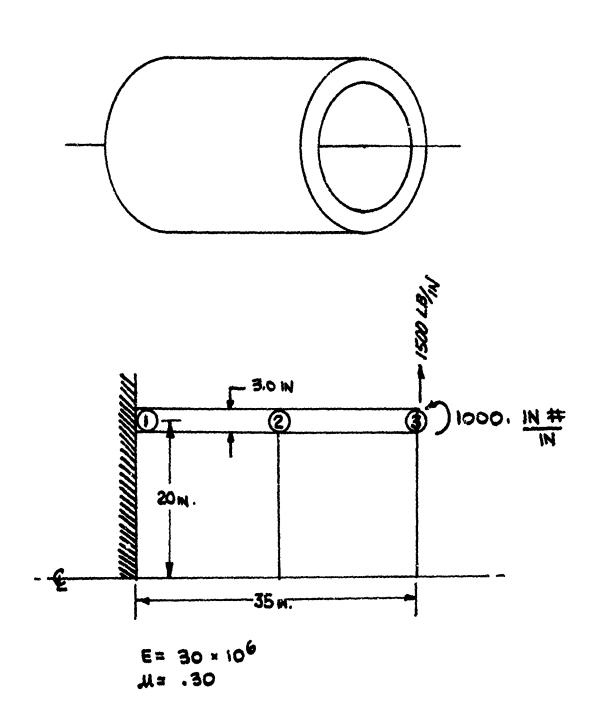
 $M_{y(0)} = (1000 \text{ in.-lb./in.})(2\pi r) = 125,663.6 \text{ in.-lb.}$

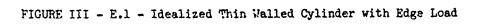
(4) All three entries are filled in for the Toroidal Ring because this element requires three external load cards per grid point.

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

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Location B - TCM = 0.0 (This code determines the axis of reference for the display of displacement behavior, in this case the axis of reference is plobal). Location C - Alpha 1 = 90.0 Lerrees Location D - Alpha 2 = 90.0 begrees For a review of the required Element Input for the Toroidal Ring the reader is referred to Section U-0.16.4.

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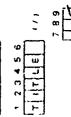
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ALEPORT



MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

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FIGURE III-E.2 TITLE INFORMATION, THIN WALLED CYLINDER

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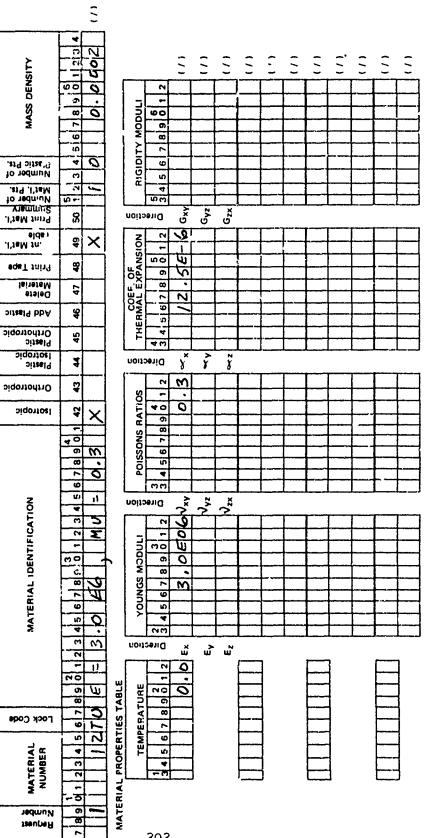
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT MATERIAL TAPE INPUT



THIN WALLED CYLINDER FIGURE III-E.3 MATERIAL TAPE INPUT,

BAC 1018

MAGIC STRUCTURAL ANALYSIS SYSTEM

SYSTEM CONTROL INFORMATION

		<u> </u>
	ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS	SYSTEM (/) 123456
1.	Number of System Grid Points	1 2 3 4 5 6
2.	Number of Input Grid Points	
3.	Number of Degrees of Freedom/Grid Point	[9] 13 14
4.	Number of Load Conditions	
5.	Number of Initially Displaced Grid Points	
б.	Number of Prescribed Displaced Grid Points	23 24 25 26 27 28
7.	Number of Grid Point Axes Transformation Systems	
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)	0 0 (/) 45 46 47 48 49 50 51 52

FIGURE III-E.4 SYSTEM CONTROL INFORMATION, THIN WALLED CYLINDER 304

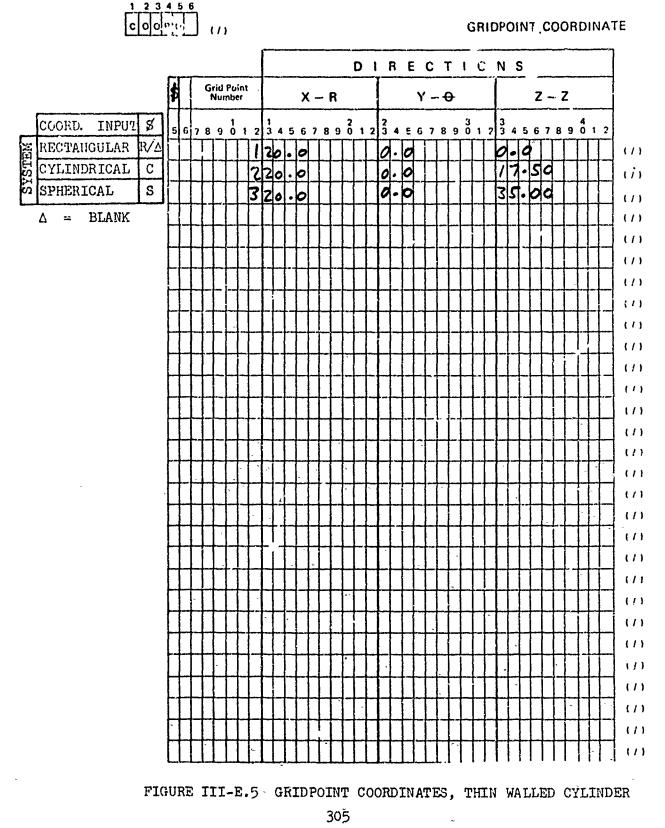
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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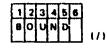


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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - Nr Displacement Allowed
	1 - Unknown Displacement
	2 - Known Displacement



PRE-SET MODE



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FIGURE III-E.6 BOUNDARY CONDITIONS, THIN WALLED CYLINDER 306

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MAGIC STRUCTURAL ANALYSIS SYSTEM

ELEMENT CONTROL DATA

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FIGURE ILI-E.8 ELEMENT CONTROL DATA, THIN WALLED CYLINDER 308

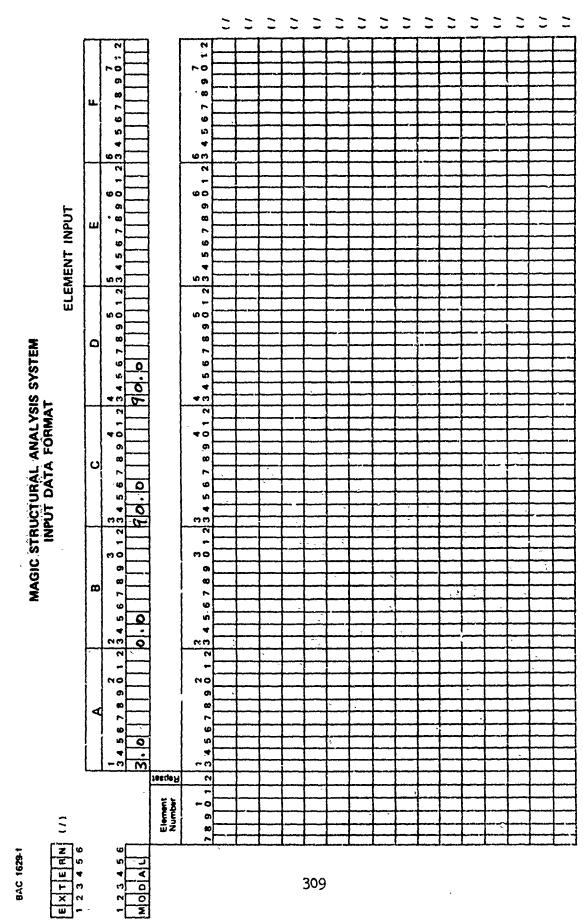


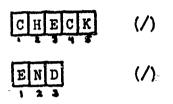
FIGURE III-E.S. ELEMENT INPUT, THIN WALLED CYLINDER

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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_{s} o, w_{s} o, Θy_{s} o, u^{t} , o, w^{t}

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.

MAGIC System output of final results is shown in Figures III-E.15 through III-E.

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:

 $\{q\}^{T} = [u_{2}, w_{2}, u_{2}', w_{2}', w_{2}'', u_{3}, w_{5}, u_{5}', w_{5}]$

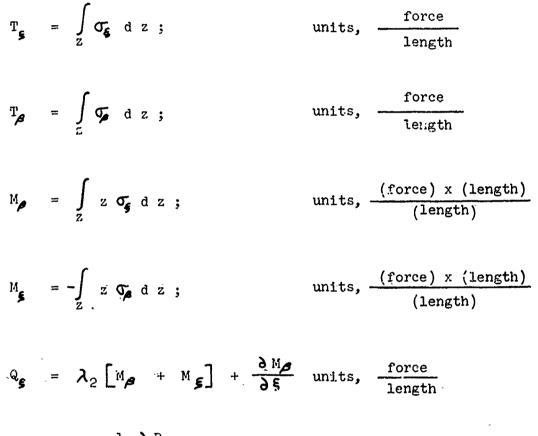
The externally applied loads for this application (GPRINT OF MATRIX LOADS) are presented in Figure III-E.16. The loads are listed against node point number. From the listed loads, it is seen that the first non-zero force corresponds to an applied force of 188500.0 acting in the R direction at node point 3, while the second is the applied moment of 125660.0 causing bending about the Y (Θ) ax's (MBETA). Note that the generalized forces (F_1 , 0, and F_3) are all equal to 0.0.

Figure III-E.17 presents the displacements for this application. These displacements are output referenced to node point number and the Global Axis of Reference. (Unless otherwise indicated by the code $TC \not = -1.0$ in the Element Input Section.)

The Reactions are presented in Figure III-E.18. Note that they are listed according to node point number and have components (F_R , 0, F_Z , 0, M_B , 0, F_1 , 0, F_3).

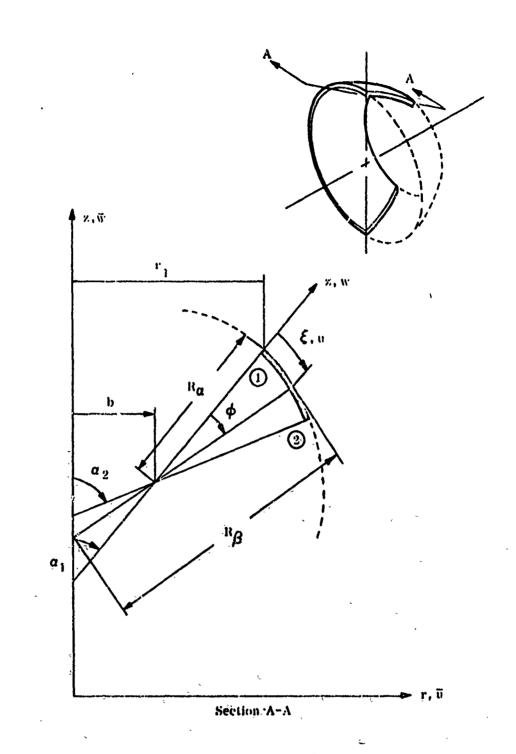
Figures III-E.19 and III-E.20 present the stresses for Toroidal Thin Shell Elements (1) and (2) respectively. In the toroidal ring element, stresses are evaluated at the two ends of the element as well as at the midspan of the element. Referring to Figure III-E.19, note that Stress Point 1 corresponds to Element Grid Point No. 2 while Stress Point 2 corresponds to Grid Point No. 1. Stress Point 3 corresponds to the element midspan position. Five values of stress are displayed per point on each element, giving a total of 15 stresses per element.

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.)



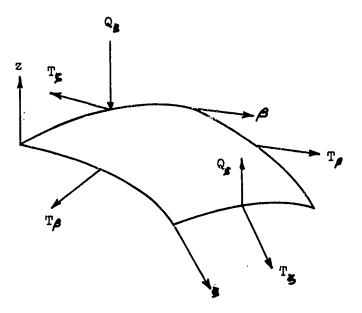
where $\lambda_2 = \frac{1}{B} \frac{\partial B}{\partial \xi}$

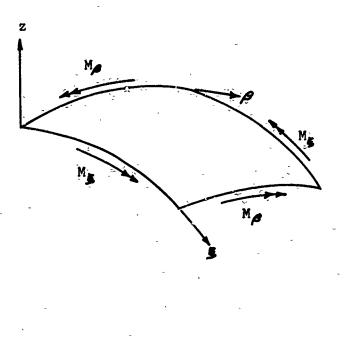
and B is a metric parameter which is explicitly defined in Volume I, Section 7, Equation 180.



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Toroidal Thin Shell Ring Representation







The element forces are presented in Figures III-E.21 and III-E.22.

Nine forces are defined per node point which correspond to the nine displacement degrees of freedom per point, i.e.,

 ${Disp}^{T} = [u, o, w, o, \theta_{y}, o, u', o, w']$

The interpretation of the forces is dependent upon the code $TC\emptyset$ which was used in the element input section. A code of $TC\emptyset = -1.0$ references the displacement behavior and the force behavior to the element axes. A code of $TC\emptyset = 0.0$ (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:

$$\{Force\}^{T} = [F_{R}, 0, F_{Z}, 0, M_{g}, 0, F_{1}, 0, F_{3}]$$

where

 F_p is the force in the system radial direction

 $\mathbf{F}_{\mathbf{T}}$ is the force in the system axial direction

- $M_{\ensuremath{\mathcal{A}}}$ is the meriodicnal moment
- F_1 and F_3 are the generalized forces corresponding to the u' and w" respectively

Note again that for this particular problem, the forces are referenced to the Global System Axes. If the Code $TC\emptyset = -1.0$ would have been used the force behavior would have been referenced to the element axis and would have had the following form:

$$\left\{ \text{Force} \right\}^{T} = \left[F_{m}, 0, F_{n}, 0, M, 0, F_{1}, 0, F_{3} \right]$$

where

- F_m is the membrane force
- F_n is the normal force

Mg is the meriodional moment

 F_1 and F_3 are the generalized forces corresponding to the u' and w' respectively.

From Figure III-E.21 (Element No. 1) note that Force Point 1 corresponds to Grid Point (2) and Force Point 2 corresponds to Grid Point (1). In Figure III-E.22 (Element No. 2) Force Point 1 corresponds to Grid Point (3) and Force Point 2 corresponds to Grid Point (2).

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GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, THIN WALLED GYLINDER

FIGURE III-E.12

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FIGURE III-E.14 TRANSFORMED EXTERNAL ASSEMPLED LCAP COLUMN OUTPUT, THIN WALLED CYLINDER

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FIGURE III-E.19 REPUED TIFFUED WARTY OUTPUT, THIN WALLED CYLINDER

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FIGURE III-F.17 DISPLACEMENT OUTPUT, THIN WALLED CYLINDER

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FIGURE ILL-E.19 STRESS OUTPUT, ELEMENT NO. 1. THIN WALLED CYLINDER

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FIGURE III-E.20 STRESS OUTPUT, ELEMENT NO. 2 THIN WALLED CYLINDER FORCES F'CR THE TCRCICAL THIN SHELL ALEVENT

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r ékent 201NT	R.ENENT APPLIED FONCES POINT RADIAL (FR)	S FOACES CERCUM, CERCUM,	(2:3) 17 EX:3	RACIAL	MOMENTS MER ICIONAL (M-BET A)	AKTAL	GENERA (F1) (Direct strain)	GENERALIZED FORCES (F2) forces (AIM) (F2) (1	FORCES (F3) (CURVATURE)
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FIGURE III-E.21 FORCE OUTPUT, ELEMENT NO. 1, THIN WALLED CYLINDER

0.2083646 05

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-0.210850E 05 0.519657E 04

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0.198204E 05 0.194660E 04

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LOAD CONDITION NUMBER LIEMENT NUMBER ELEMENT TYPE

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	11 2ED (F2)	000	ALI 2ED (F2)	00	ALT ZED (F2)	
	GENERA (F1) (DIFECT STRAIN)	C. 3164C6E G0 C. 210678E O5	GENERA (DIRECT STRAIN)	9 9 9 0	GENER (F1) (DIRECT STRAIN)	C.3164C6E 00 0.210278E 05
ev.	.AX 1 AL	0 0 0 0	AX [AL	00	AX IAL	000
30	MEMENTS MEMELDIDNAL (M-BETA)	-0.125659E 06 -0.198205E 05	MOMENTS MERICIONAL (M-BETA)	00	MCMENTS MERICIONAL (M-BETA)	-0.1982056 06 -0.1982056 05
	RACIAL	3 C • 0	RACI'AL	0.00	RADIAL	
2	A%I AL (F2)	0.142334E 00 -0.295483E 01	AXI AL (F 2)	00 00 00	AX14L (F2)	0.142334E 00 -0.295483E 01
	S FORCES CIRCUM.	00	S FORCE S CIRCUM.	00	FORCES CERCUN-	00
*	APPARENT ELEMENT FORCES Point Radial (f f and (C.e1865006 C6 0.1237886 05	ELEMENT APPLIED FORCES POINT RADIAL AGIAL	0°)	NET ELEMENT FORCES Point Radial (fr)	C.188900E 06 C.123780E C5
	app aren Point	- ~	EL EMENT POINT	pa N	NET ELE Point	 N

FIGURE III-E.22 FORCE OUTPUT, ELEMENT NO. 2, 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.

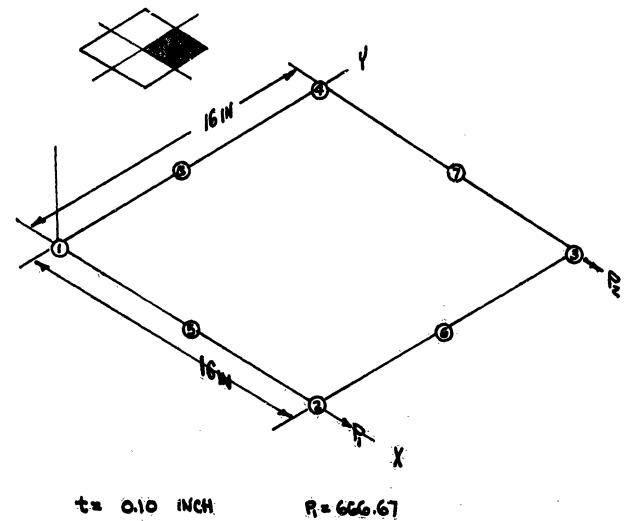
In Figure III-F.6 (Boundary Condition Section) It is instructive to note the extensive use of the Repeat option. Grid point 5 has identical boundary conditions as grid point 2, therefore the Repeat option is exercised by placing an 'X' in column 12 opposite the entry for Grid Point Number 5. The same 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.

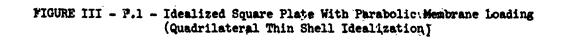
In Figure III-F.8 (Element Control Data Section) the following information is of importance.

- 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 'l' 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.

329



E= 30.× 106 PS1 P= 400. M= .30



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

REPORT (/)

TITLE INFORMATION

MAGIC STRUCTURAL ANALYSIS SYSTEM

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

NUMBER OF TITLE CARDS

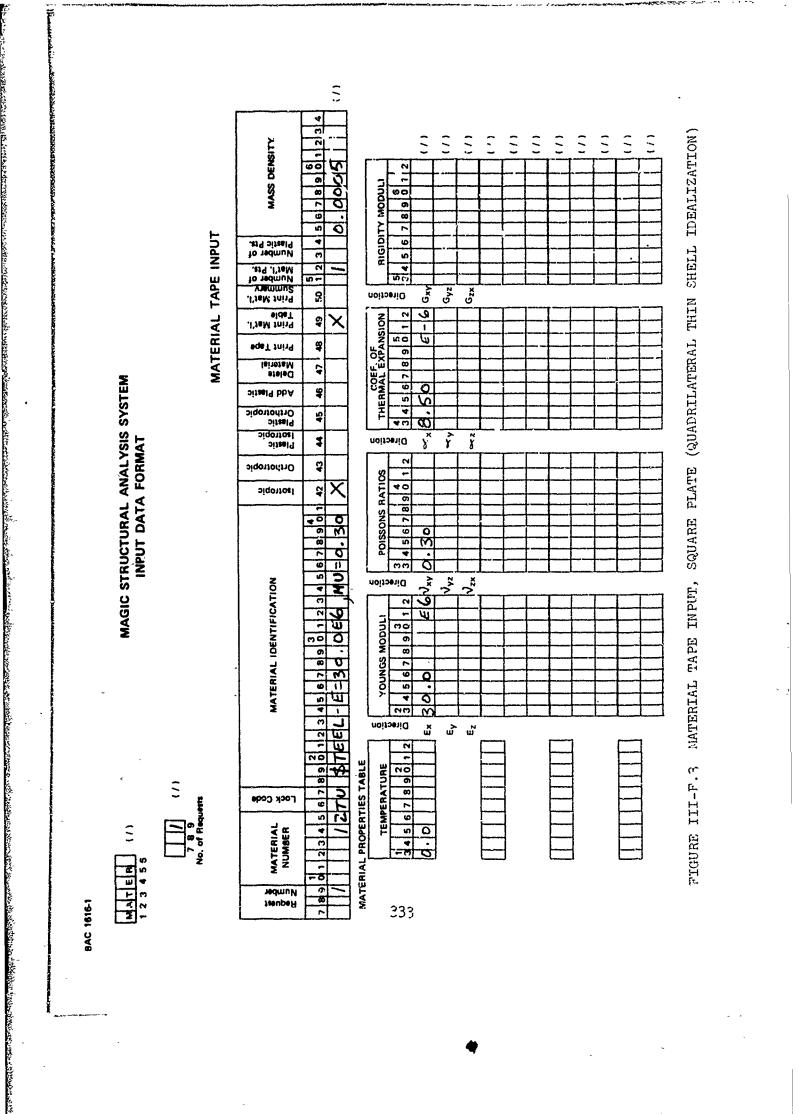
: 2 2 2 2) 2 2 67890 AND SHADTER J.N. THEDRY HIT ELAKITACITY SECAND s 4 123456789012345678921234567893 6440 RELLATERAL 410 PLY 40 P PORTED 1741 M PLATE 30 12345678901234567890123 6440 RELLATERAL 410 M PLY 40 P PORTED 1741 M PLATE 30 123456760 70 A A VELE 2 Equellerrered Paraboultic Membrand Landender OWE OUNDERLATERAL MIDPOINT NODE LOADED SITDET IS SUPPLESSED IN THIS ANALYSIS ELEMENT USED IN THE IDEALIZATION 1991 NEW YORK TTING HENKO 31. SRAW HILL J THEW BARELL DEFERENCE et the way THE

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TITLE INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

FIGURE III-F.2

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

5 Л 6 Number of System Grid Points 1. 2. Number of Input Grid Points 9 10 8 12 Number of Degrees of Freedom/Grid Point 3. Number of Load Conditions 4. Number of Initially Displaced Grid Points 5. 18 19 20 21 22 Number of Prescribed Displaced Grid Points 6. 23 24 25 26 27 28 Number of Grid Point Axes Transformation 7. Systems 30 Number of Elements 8. 31 32 33 34 35 Number of Requests and/or Revisions of 9. Material Tape. ŧ. 10. Number of Input Boundary Condition Points 42 11. To For Structure (With Decimal Point) ()46 47 48 49 50 51

FIGURE III-F.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) 334 BAC 1622

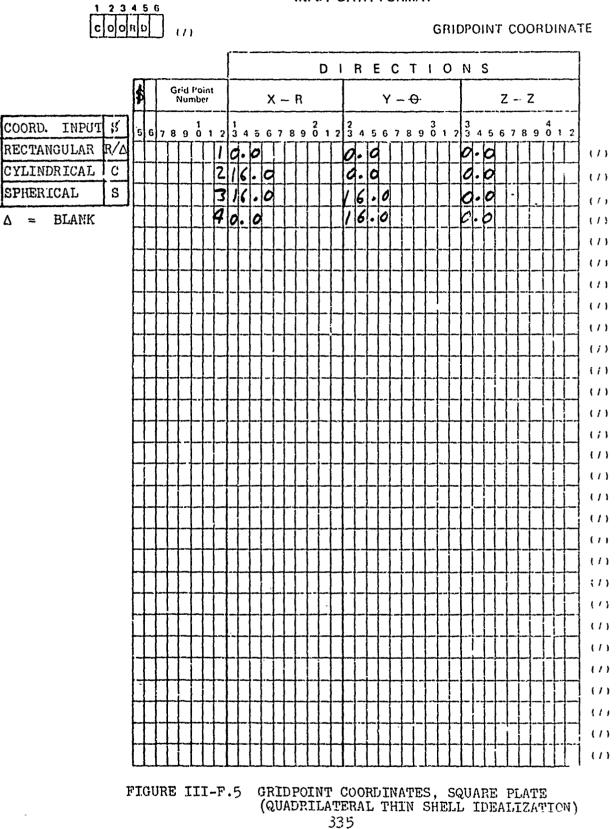
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FIGURE III-F.6 BOUNDARY CONDITIONS, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) 336

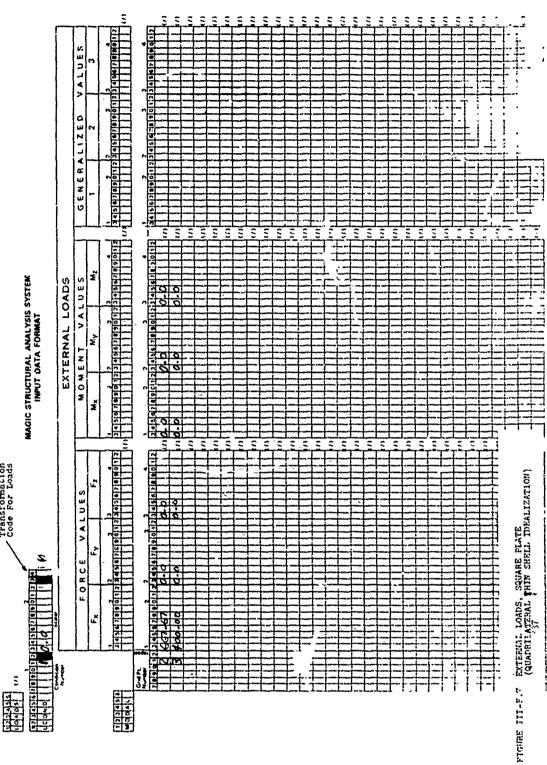
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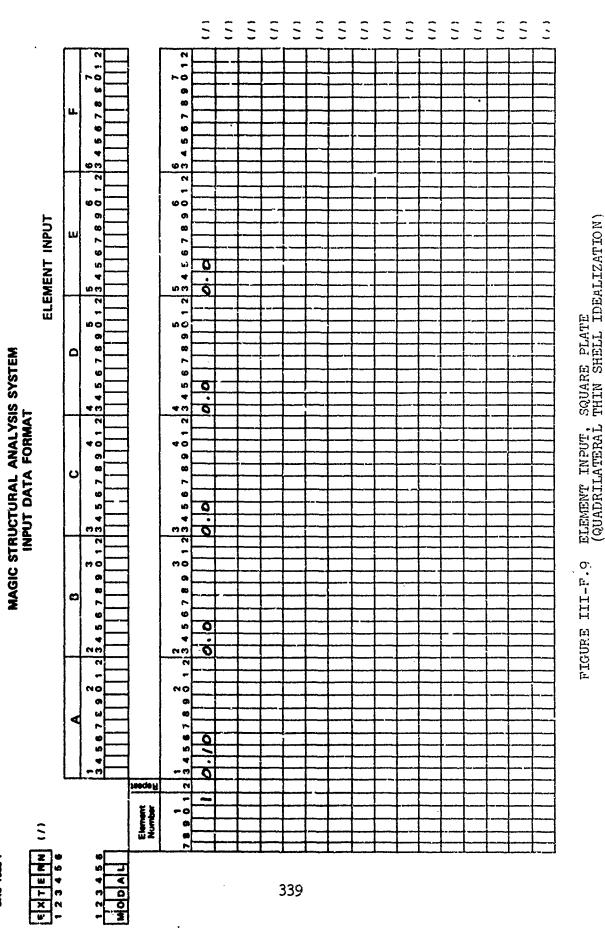
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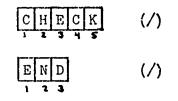
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FIGURE III-F.10	END CARD, SQUARE PLATE	
	QUADRILATERAL THIN SHELL	IDEALIZATION)

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:

At 10.000

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 0.03939999. 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 note point 3, both in the positive Global X direction

MAGIC System output of final results is shown in Figures III-F.14 thru III-F.19. 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:

$$\{q\}^{T} = [u_{2}, u_{3}, v_{3}, v_{4}, u_{5}, u_{7}, v_{7}, v_{8}]$$

The externally applied loads for this application (GPRINT OF MATRIX LOADS) are presented in Figure III-F.15. The loads are listed against node point number. It is to be noted that node points 2 and 3 have forces (F_x) equal in numerical value to 667.67 and 400.0 respectively. Both of these forces are acting in the positive Global X direction.

Figure III-F.16 presents the displacements for this application. These displacements are output referenced to node point number and the Global Axis of reference.

The Reactions are presented in Figure III-F.17. Note that they are listed according to node point number and have components R_{χ} and R_{γ} .

Figure III-F.18 presents the stresses for the Quadrilateral Thin Shell Element. 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:

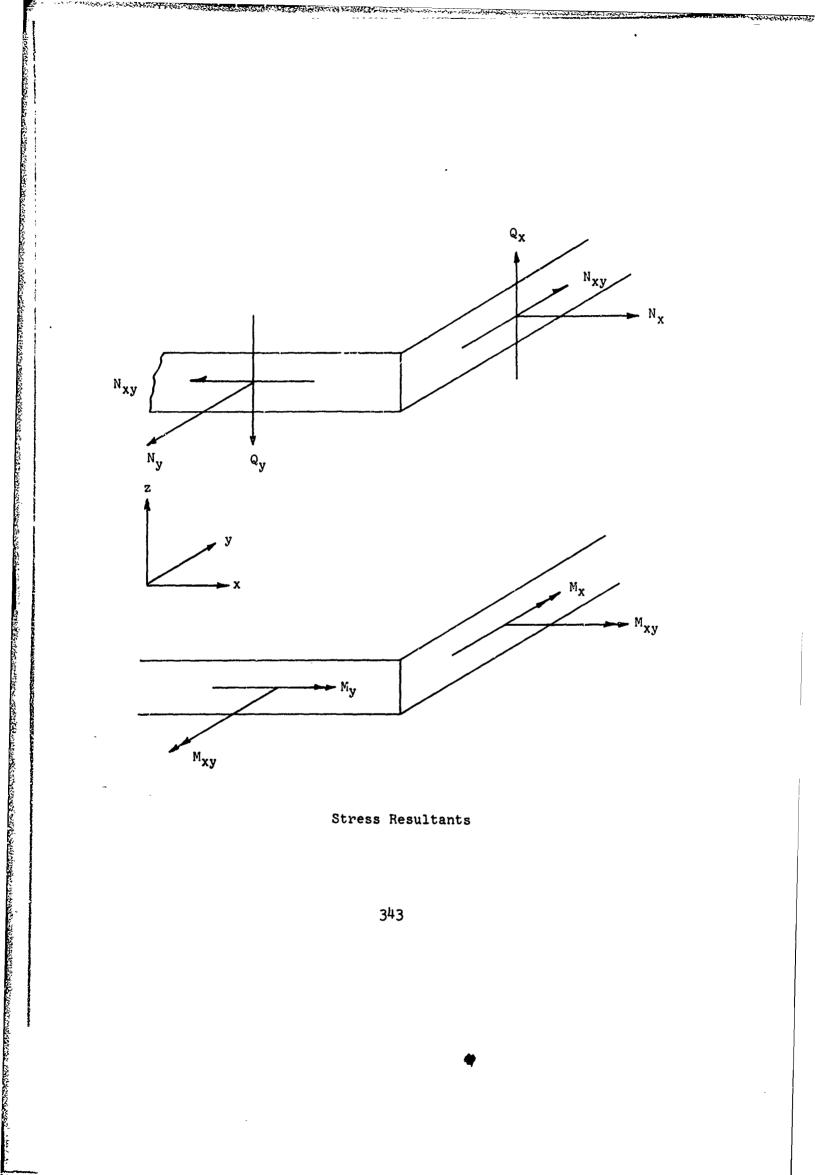
N _x	$= \int_{X} \sigma_{x} dz$; units -	force length
N Y	$= \int_{z} \sigma_{y} dz$; units .	force length
^N xy	$= \int_{z} \boldsymbol{\mathcal{T}}_{xy} dz$; units a	force length
M _x	$= \int_{z} z \sigma_{X} dz$; units	force x length length
My	$= \int_{z} z \sigma_{y} d z$; units	force x length length
M _{xy}	$= \int_{z} z \mathcal{T}_{xy} dz$; units	force x length length
Q _x	$= \int_{z} z \left(\frac{\partial \sigma_{x}}{\partial x}\right) dz + \int_{z} z \left(\frac{\partial \mathcal{L}_{xy}}{\partial y}\right) dz$; units	force length
حرب	$= \int_{z} z \left(\frac{\partial \sigma_{y}}{\partial y}\right) dz + \int_{z} z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz$; units -	force length

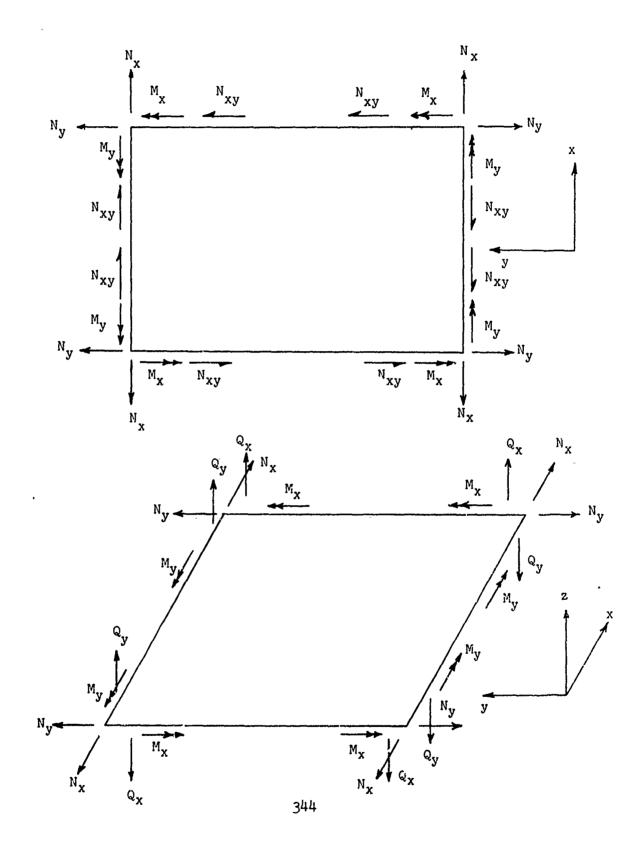
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The following sketches show the proper manner in which to interpret the stress resultants.





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Returning to Figure III-F.18, it is noted that there are five stress points at which the stress resultants are evaluated. These correspond to element grid points 1, 2, 3, and 4. The fifth stress point corresponds to the stresses evaluated at the element centroid. The stresses are in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements, however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '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 element forces for the Quadrilateral Thin Shell Element are displayed in Figure III-F.19. The forces $(F_X, F_Y, F_Z, M_X, M_Y, M_Z)$ are defined with respect to the Global Coordinate System. The forces are defined at eight points on the element. The first four points are corner points (Element Grid Points 1, 2, 3, and 4), and the last four points are mid-points (Element Grid Points 5, 0, 7, 8). Note that one of the mid-side nodes was suppressed in this analysis, corresponding to would-be grid point 6; therefore, there are no element forces evaluated at this particular point.

FIGURS III-F.II TITLE AND MATERIAL DATA OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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REVISIONS OF NATERIAL TAPE

REFERENCE- TIPOSHENKO,S. AND GOODIER,J.N., THEORY OF ELASTICITY,

SECOND EDITION, MCGAAN MILL NEW YORK 1951.

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BOUNDARY CONDITION INFORMATION

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GRIDPOINT DATA, BOUNDARY CONDITION AND FIMITE ELEMENT DESCRIPTION CUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) (CCNTINUED) FIGURE III-F.12

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FIGURE III-F.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SQUARE PLATE (QUARALATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.14 REPUCED STIFFNESS MATRIX OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.15 LOAD OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.16 DISPLACEMENT OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.17 REACTION OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.18 STRESS OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-F.19 ELEMENT FORCE OUTPUT, SQUARE PLATE (QUADRILATERAL THEIL SHELL DEA TATION)

G. SQUARE PLATE - NORMAL PRESSURE LOADING - (Quadrilateral Thin Shell Idealization)

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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.

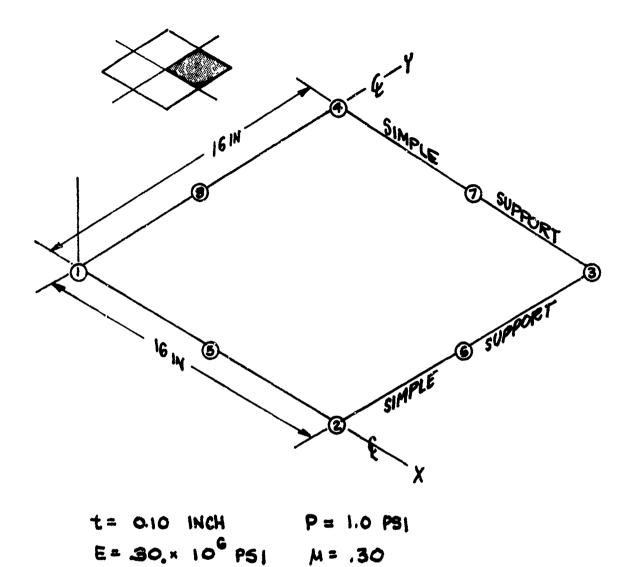
The preprinted input data forms associated with this example are shown in Figures III-G.2 through III-G.11.

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,ⁿu and v are equal to zero. Since Grid Points 5 and 8 lie along symmetric boundaries θ_n equals zero.



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FIGURE III - G.1 - Idealized Simply Supported Plate with Normal Pressure Loading (Quadrilateral Thin Shell Idealization)

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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 <u>Listed Input</u>, 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 , associated with these grid points. The Code (0, 1, 2) associated with these normal slope values is always entered in the θ_r 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 'l' and '2' are entered in locations ll 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 oriertation with respect to this axis. It should be noted that the stress axis determination is element related and therefore if locations ll 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 $(t_f) = 0.10$

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FIGURE III-G.2 TITLE INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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

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TITLE INFORMATION

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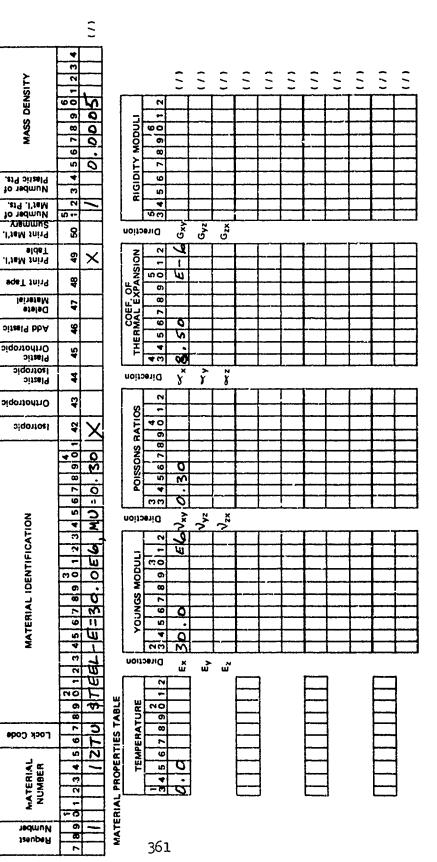
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT







MATERIAL TAPE INPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) FIGURE III-G.3

MAGIC STRUCTURAL ANALYSIS SYSTEM

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Number of Degrees of Freedom/Grid Point	13 14
Number of Load Conditions	15 16
Number of Initially Displaced Grid Points	
Number of Prescribed Displaced Grid Points	23 24 25 26 27 28
Number of Grid Point Axes Transformation Systems	
Number of Elements	31 32 33 34 35 36
Number of Requests and/or Revisions of Material Tape.	37 38
Number of Input Boundary Condition Points	3 9 40 41 42 43 44
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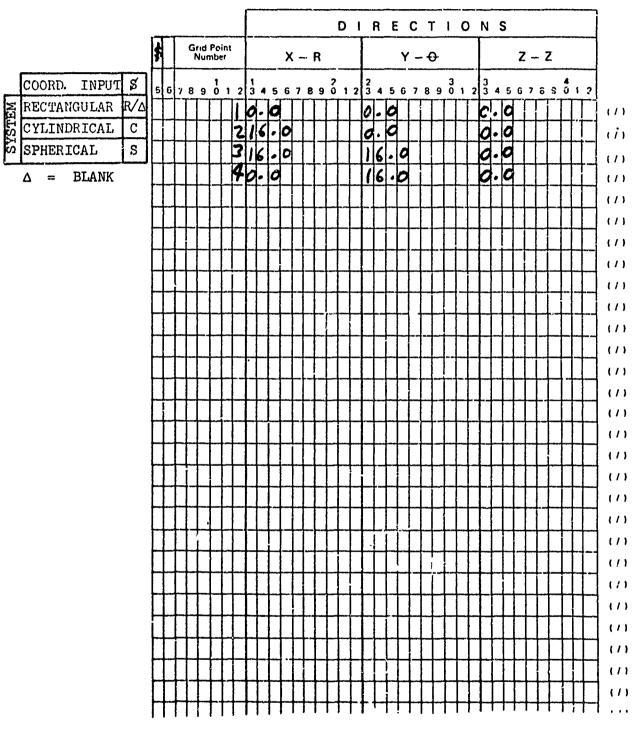
FIGURE III-G.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL, IDEALIZATION) 362

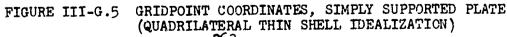
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT



GRIDPOINT COORDINATE





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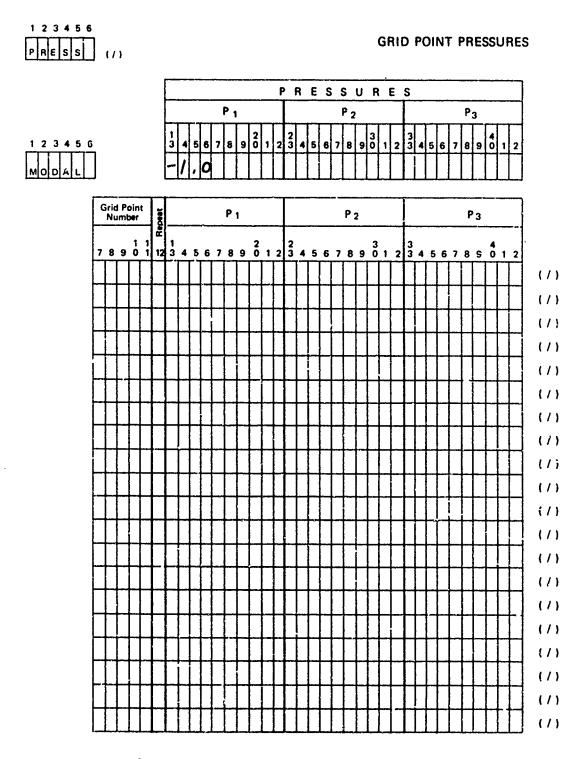


FIGURE III-G.6 GRIDPOINT PRESSURES, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN, SHELL IDEALIZATION)

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

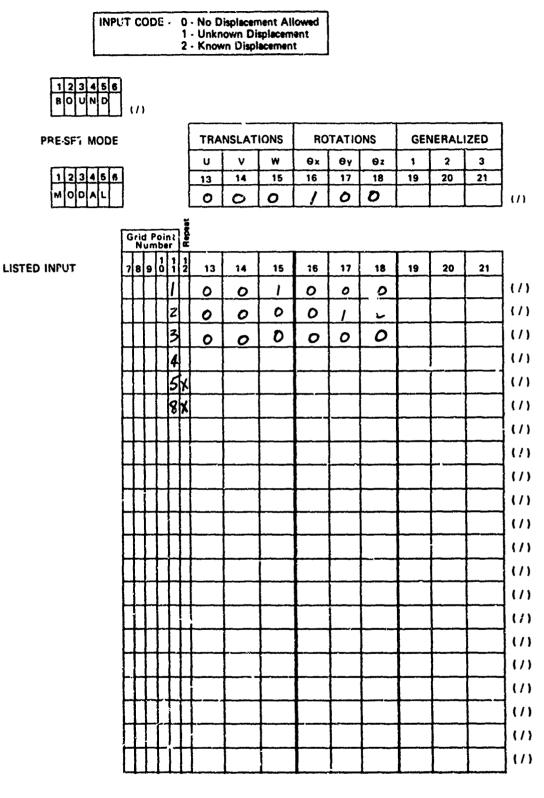


FIGURE III-G.7 BOUNDARY CONDITIONS, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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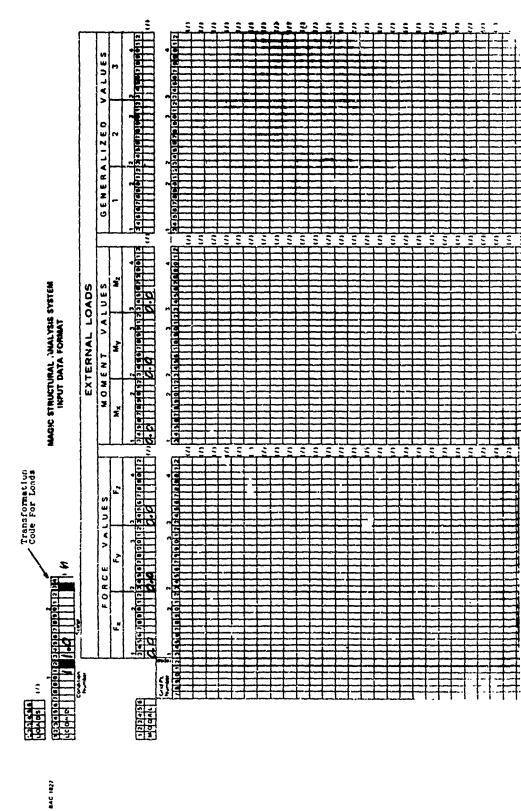
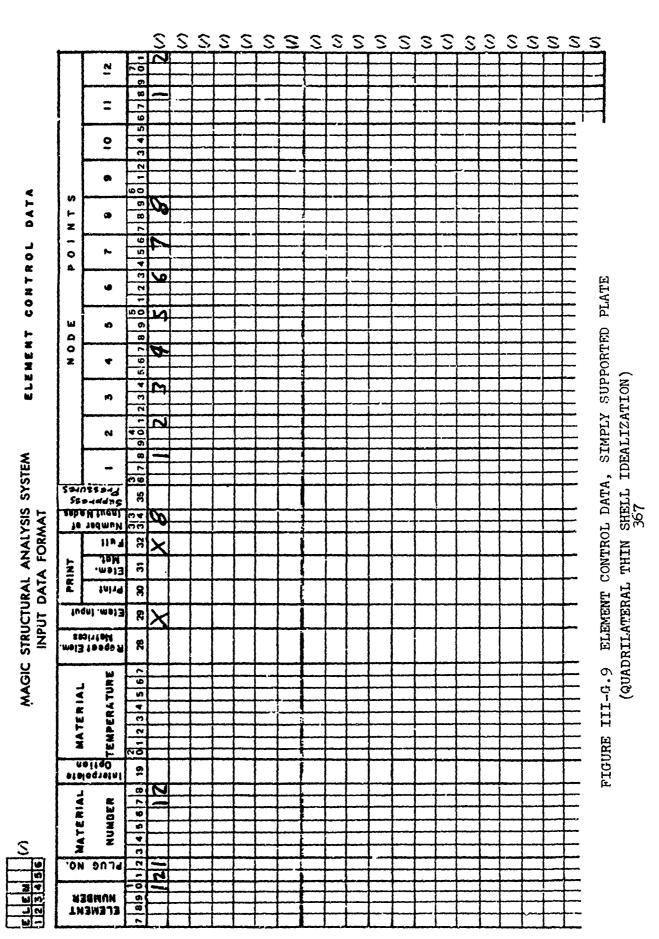


FIGURE III-G.9 EXTERNAL LOADS, SIMPLE SUPPORTED PLATE (QUADRILATERAL THIN SWELL IDEALIZATION) 366

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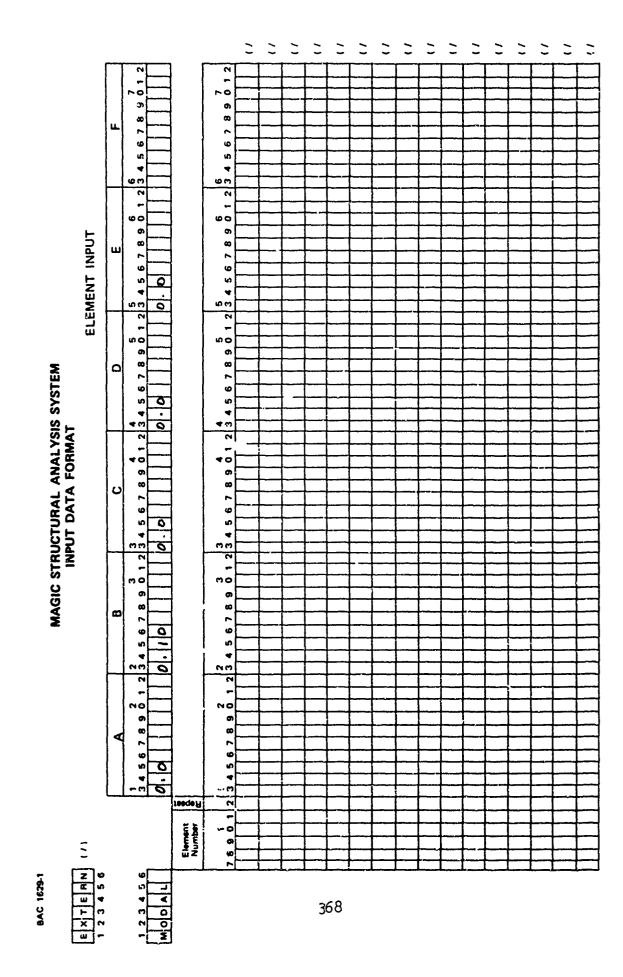
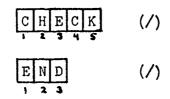


FIGURE III-G.10 ELEMENT INPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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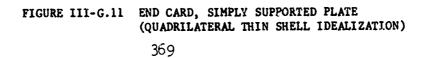


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The output supplied by the MAGIC System for the simply supported isotropic square plate subjected to a normal pressure load and idealized using one quadrilateral thin shell element is as follows:

Figures III-G.12 thru III-G.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

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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.

MAGIC System level output of final results is shown in Figures III-G.15 thru III-G.20.

Figure III-G.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-G.13. For this case the displacement vector is ordered as follows:

$$\{q\}^{T} = [w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7}]$$

Where θ_{ni} = normal slope at node point i

Figure III-G.16 displays the Element Applied Loads (GPRINT OF MATRIX FTELA). Note that the components of load which arise from the uniform normal pressure are output against node point number. It is also to be noted that all membrane components of load(F_X and F_Y) are equal to zero. This arises

since membrane and bending action are uncoupled and the only forces generated by the work equivalent normal pressure loads are F_Z , M_X and M_Y .

The displacements for this application are presented in Figure III-G.17. Note that rows 6 and 7 correspond to midside grid points 6 and 7. The THETAX values of -0.11730331 correspond to the normal slopes at these mid-points. This is true since mid-side nodes have only U, V, and Θ_n degrees of freedom. In addition, the displacements are referenced to the Global Axis unless otherwise indicated.

Figure III-G.18 displays the reactions for this application. These reactions are listed against grid point number and are referenced to the Global Coordinate System.

Stress resultants for the Quadrilateral Thin Shell Element are shown in Figure III-G.19. Eight stress resultants are evaluated at each corner point of the quadrilateral and also at the diagonal intersection, yielding 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.

Note that the stresses are evaluated at five stress points 1 thru 5. The first four correspond to the four corner points of the element (Node points 1 thru 4) while the fifth point corresponds to the element centroid.

Element forces for the quadrilateral thin shell element are presented in Figure III-G.20. These forces are defined with respect to the Global Coordinate System. The element forces are evaluated at eight points. The first four points (1 thru 4) and the last four points are mid-points (node points 5 thru 8). Note that the mid-side nodes have allowable degrees-of-freedom equal to U, V and normal slope (θ_n) .

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FIGURE III-G.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-G.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE FULMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) (CONTINUED) 9°0 0.10 0

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FIGURE III-G.14 TRANSPORMED EXTERNAL ASSEMBLED LARD COLUMY OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDE&LIZATION)

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FIGURE III43.15 REDUCED STIPPNESS MATRIX SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-G.16 ELEMENT APPLIED LOAD GUTPUT, SIMPLY SUPPORTED PLADE (QUADRILATERAL THIN SHELL IDEALIZATION)

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FIGURE III-G.17 DISPLACEMENT OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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JURE III-G.18 REACTION OUTPUT, SIMPLY SUPPORTED FLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

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-0.63999947E 02 0.35820992E 02 0.35821274E 02 0.0 0.0 0.0 0.0	FZ -0.63999934E 02 -0.63999954E 02 -0.63999954E 02 -0.63999924E 02 0.0 0.0
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ELEMENT FORCE OUTPUT. SIMPLY SUPPORTED P'ATS (QUADRILATERAL THIN SHELL IDEALLEATION) FIGURE III-G.20

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H. SQUARE PLATE - PARABOLIC MEMBRANE LOADING (Triangular Thin Shell Idealization)

An isotropic, square plate under the acticA 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 wich 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 <u>Listed</u> 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 <u>Listed Input</u>, the MODAL entry pertains to Grid Point Numbers 3, 7, and 9.

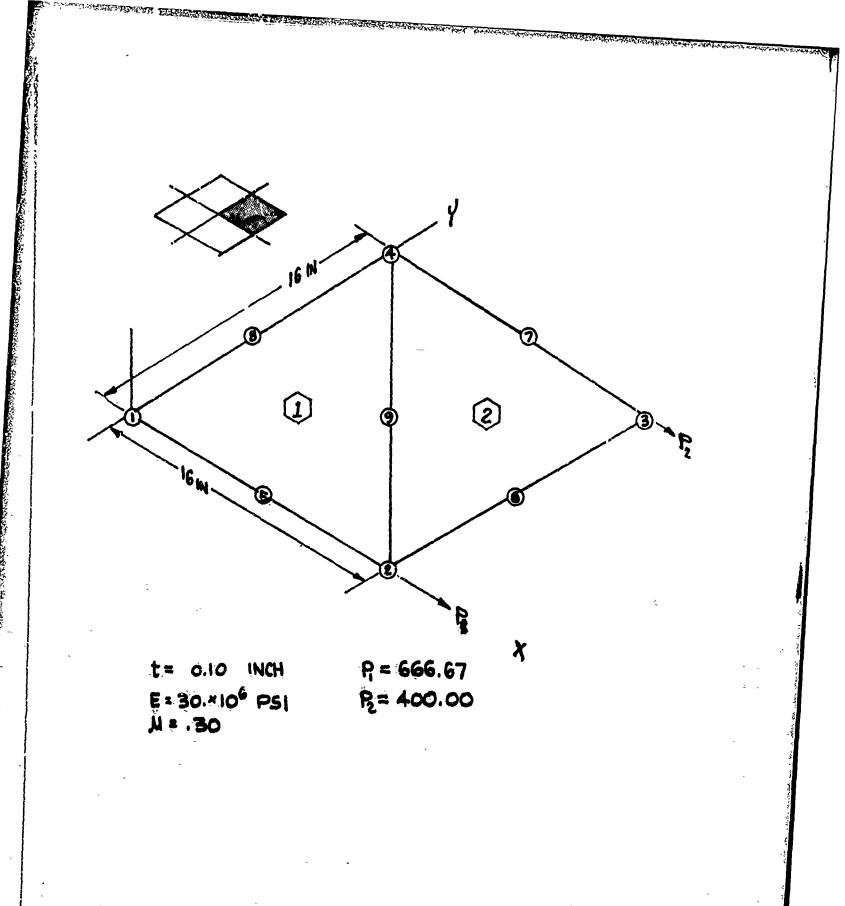


FIGURE III. - H.1 - Idealized Square Plate, Parabolic Membrane Loading (Triangular Thin Shell Idealization)

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.

- 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.

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TITLE INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION) FIGURE III-H.2

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TITLE INFORMATION

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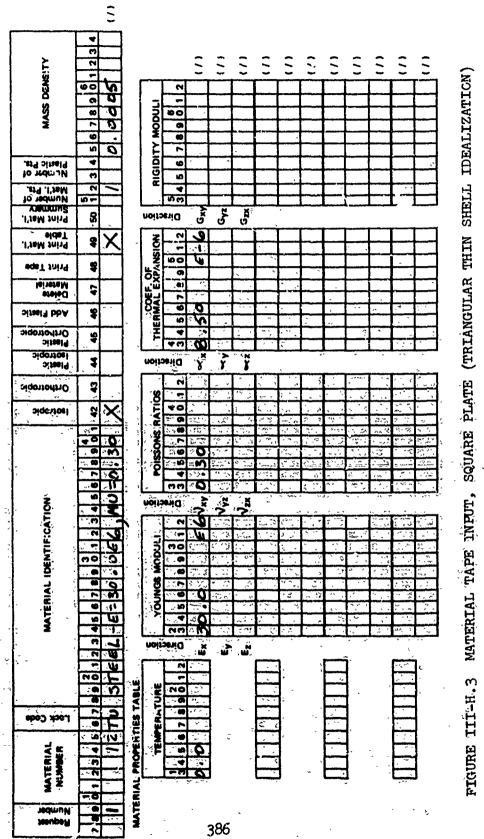
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

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

1. Number of System Grid Points

2. Number of Input Grid Points

3. Number of Degrees of Freedom/Grid Point

4. Number of Load Conditions

5. Number of Initially Displaced Grid Points

6. Number of Prescribed Displaced Grid Points

7. Number of Grid Point Axes Transformation Systems

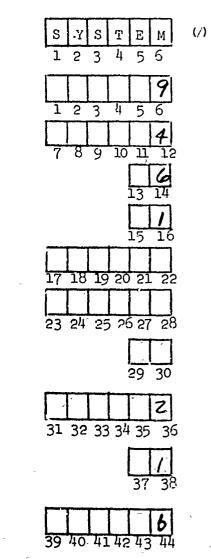
8. Number of Elements

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9. Number of Requests and/or Revisions of Material Tape.

10. Number of Input Boundary Condition Points

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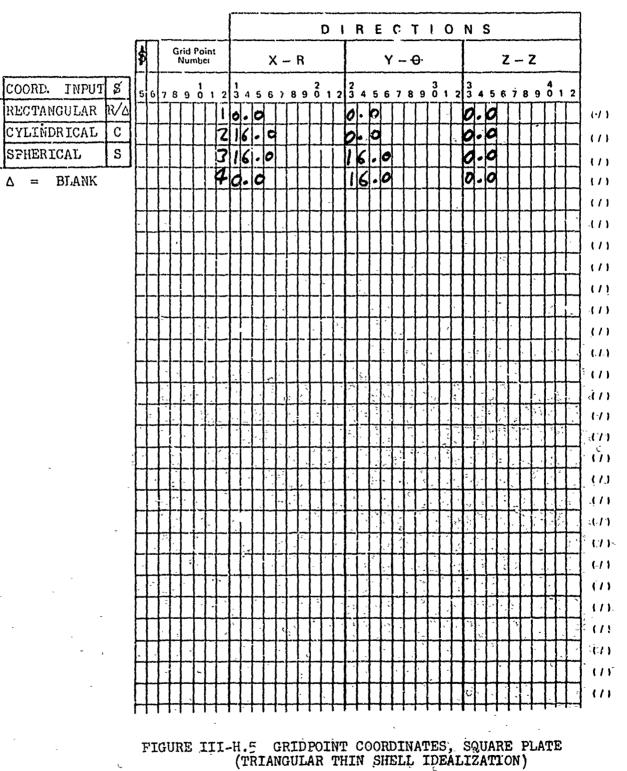
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FIGURE III-H.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION) 387 BAC 1622



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GRIDPOINT COORDINATE



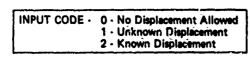
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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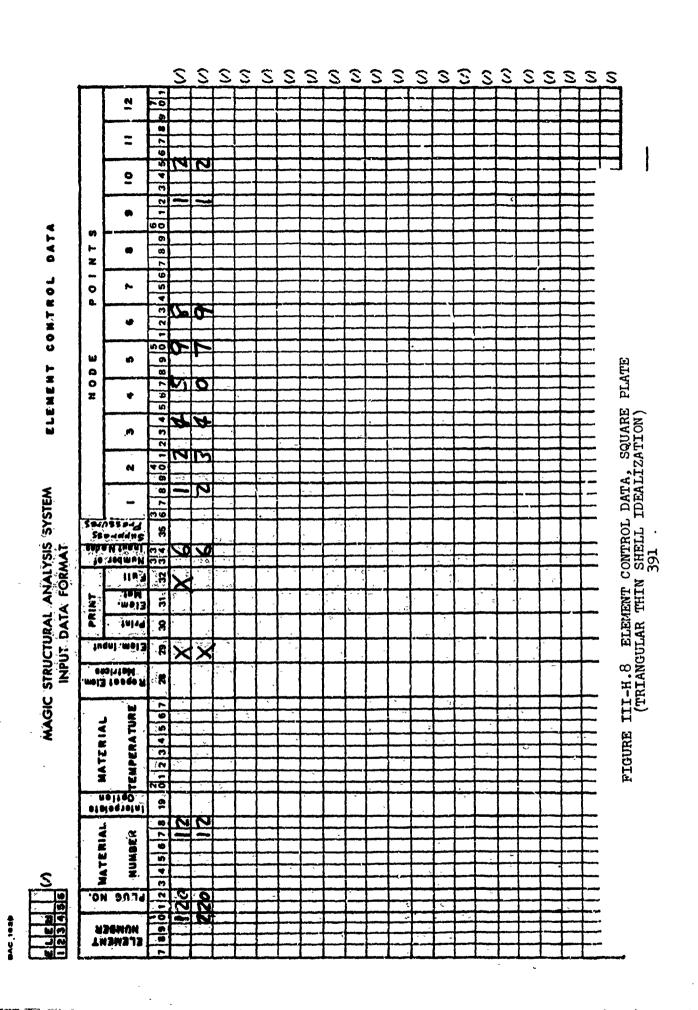
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FIGURE III-H.6 BOUNDARY CONDITIONS, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION) 389

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-H-7 EXTERNAL LOADS, SQUARE PLATE			
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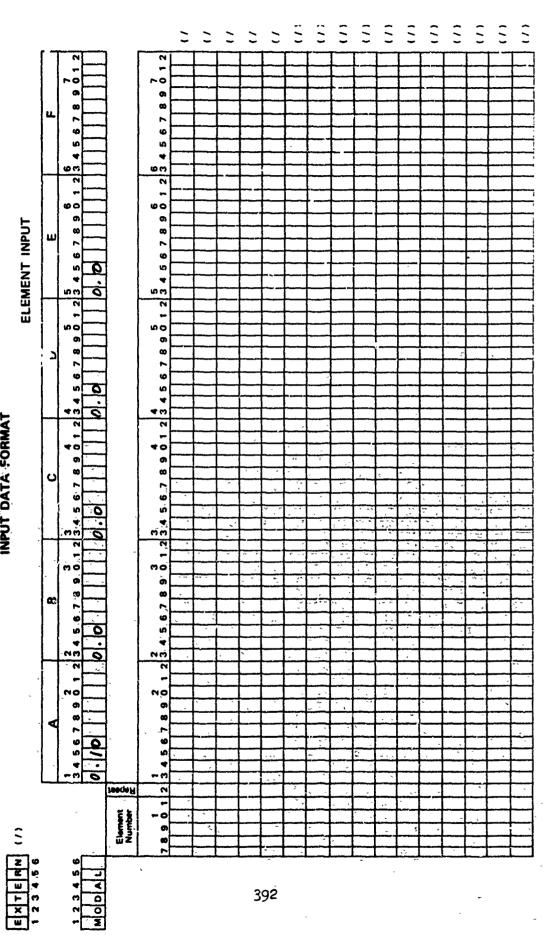
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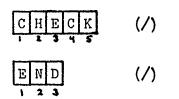
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ELEMENT INPUT, SQUÀRE PLATE (TRIANGULAR THIN SHELL IDEALIZATION) FIGURE III-H.9

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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FIGURE 111-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.

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In Figure III-H.12, the finite element information is shown. Under the section titled External Input, the first. entry printed has a numberical 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 at a load of 400.0 is applied at node point 3 both in the positive Global X direction.

MAGIC System level output of final results is shown in Figures III-H.14 thru III-H.21. 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:

$$\{q\}^{T} = [u_{2}, u_{3}, v_{3}, v_{4}, u_{5}, u_{7}, v_{8}, u_{9}, v_{9}]$$

Figure III-H.15 displays the externally applied loads for this application (GPRINT OF MATRIX LCADS). These loads $(F_X, F_Y, F_Z, N_X, M_Y, M_Z)$ are referenced to the Global Axis and are output against node point number. From the figure, it is seen that node points 2 and 3 are loaded by Forces, F_X , equal to 666.67 and 400.0 respectively. It is also to be noted that these forces are acting in the positive Global X direction.

Displacements are presented in Figure III-H.16. Displacements are output against node point number and are referenced to the Global Axis unless otherwise indicated.

Reactions are presented in Figure III-H.17. There are only two components of Reaction at any grid point (F_X and F_Y) since only membrane loading is involved and there is no coupling between membrane and bending action.

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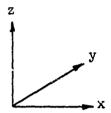
Stress resultants for the Triangular Thin Shell Element are presented in Figures III-H.18 and III-H.19. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid yielding a total of thirty-two stress resultants per element.

The stress resultants for the triangular thin shell element are defined as follows:



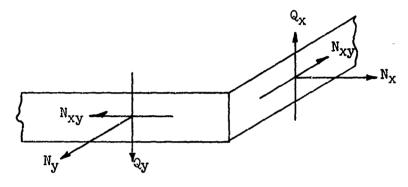
$$\begin{split} & \mathsf{N}_{\mathbf{x}} = \int_{\mathbf{z}} \mathbf{G}_{\mathbf{x}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force}}{\text{length}} \\ & \mathsf{N}_{\mathbf{y}} = \int_{\mathbf{z}}^{-} \mathbf{G}_{\mathbf{y}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{N}_{\mathbf{xy}} = \int_{\mathbf{z}}^{-} \mathbf{C}_{\mathbf{xy}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{M}_{\mathbf{x}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \mathbf{G}_{\mathbf{x}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{M}_{\mathbf{x}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \mathbf{G}_{\mathbf{y}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{M}_{\mathbf{xy}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \mathbf{G}_{\mathbf{y}}^{-} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{M}_{\mathbf{xy}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \frac{\mathbf{\partial} \mathbf{G}_{\mathbf{x}}}{\mathbf{\partial} \mathbf{x}} \, \mathrm{dz} + \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \frac{\mathbf{\partial} \mathbf{f}_{\mathbf{xyy}}}{\mathbf{\partial} \mathbf{y}^{-}} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{Q}_{\mathbf{x}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \frac{\mathbf{\partial} \mathbf{G}_{\mathbf{x}}}{\mathbf{\partial} \mathbf{x}} \, \mathrm{dz} + \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \frac{\mathbf{\partial} \mathbf{f}_{\mathbf{xyy}}}{\mathbf{\partial} \mathbf{y}^{-}} \, \mathrm{dz} & ; \text{ units } \frac{\text{force } \mathbf{x} \text{ length}}{\text{length}} \\ & \mathsf{Q}_{\mathbf{y}} = \int_{\mathbf{z}}^{-} \mathbf{z}^{-} \frac{\mathbf{\partial} \mathbf{G}_{\mathbf{y}}}{\mathbf{\partial} \mathbf{y}} \, \mathrm{dz} + \int_{\mathbf{z}}^{-} \mathbf{z}^{-} (\frac{\mathbf{\partial} \mathbf{f}_{\mathbf{xyy}}}{\mathbf{\partial} \mathbf{z}} & ; \text{ units } \frac{\text{force } \mathbf{z} \text{ length}}{\text{length}} \\ \end{array} \right$$

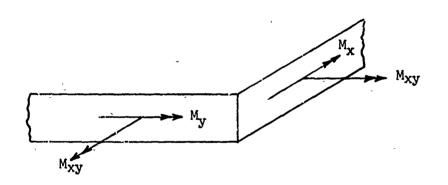
The following sketches show the proper manner in which to interpret the stress resultants.



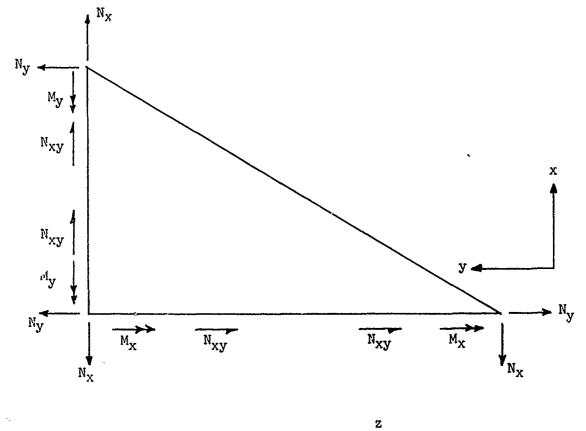
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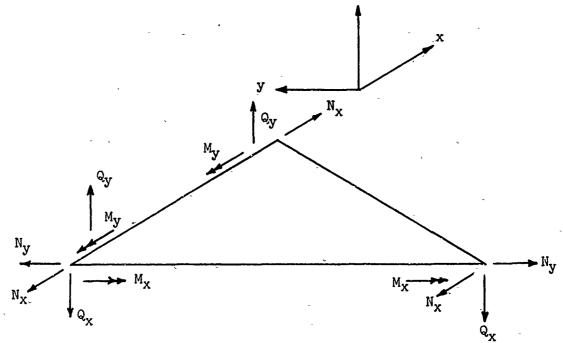


Figure III-H.18 presents the stress resultants for Element Number 1. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 1, 2, and 4 respectively.

Figure III-H.19 presents the stress resultants for Element Number 2. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 2, 3, and 4 respectively.

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.

There is one exception to the usual rules of presenting the stress output for the triangular thin shell element.

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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.

Figures III-H.20 and III-H.21 present the element forces for the two triangular thin shell elements used in this application. The 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. In Figure III-H.20, Force Points 1 thru 3 correspond to element corner points 1, 2, and 4. Force points 4 thru 6 correspond to element mid-points 5, 9 and 8. The forces for Element No. 2, shown in Figure III-H.21 are interpreted in an analogous manner to those for Element No. 1. It is to be noted that the element forces are referenced to the Global Axis unless otherwise indicated.

FIGURE III-H.11 TITLE AND MATERIAL DATA OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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THE LOADED EDGE IS SUPPRESSED IN THES AMALYSIS

REFERENCE-TINCSNENCO,5.AND GOODIER, J.N., THEORY OF ELASTICITY,

SECOND EDITION MCGRAM MILL NEW YORK 1951.

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FIGURE III-11.1 TRANSPORMED EXTERNAL ASSEMBLED LOAD . OLUMN OUTPHT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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FIGUAE III-H.14 REDUCED STIPPNESS MATRIX OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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FIGURE III-H.15 LOAD OUTPUT, SQUARE FLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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FIGURE III-H.17 REACTION OUTPUT, SQUARE FLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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FIGURE III-H.18 STRESS OUTPUT (ELEMENT NO. 1), SQUARE PLATE (TRIANGULAR THIN SHELL: IDEALIZATION) 408

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FIGURE III-H.19 STRESS OUTPUT (ELEMENT NO. 2), SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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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 FiguresIII-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 <u>Listed Input</u> (Exception: 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 y 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_{χ} 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.

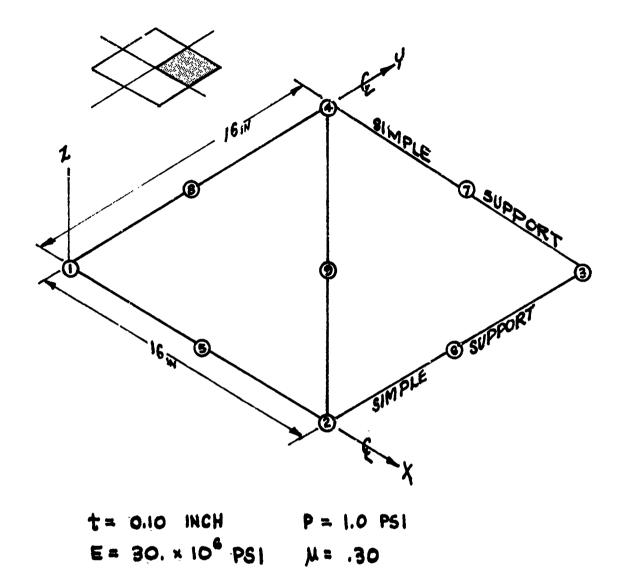


FIGURE III - I.1 - Idealized Simply Supported Plate With Normal Pressure Loading (Triangular Thin Shell Idealization of One Quadrant)

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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 <u>Listed Input</u>, 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 , associated with these grid points. The codeⁿ(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 'l' and '2' are entered in locations ll and l2 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 ll and l2 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 <u>must</u> be considered separately. Node points related to each particular element <u>must</u> 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.

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REPORT (/)



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NUMBER OF TITLE CARDS

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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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

TITLE INFORMATION

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TITLE INFORMATION, SIMPLY SUFPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION) FIGURE III-I.2

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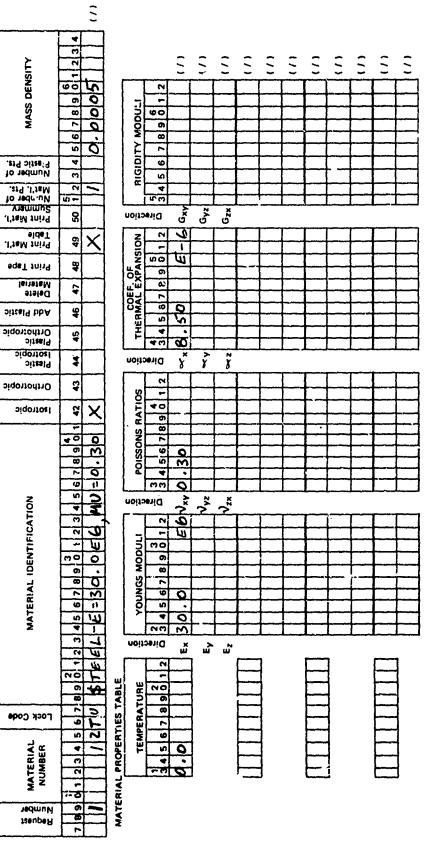
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MATERIAL TAPE INPUT



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FIGURE III-I.3 . MATERIAL TAPE INPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

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MAGIC STRUCTURAL ANALYSIS SYSTEM

SYSTEM CONTROL INFORMATION

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î,	Number of Degrees of Freedom/Grid Point	13 14
4.	Number of Load Conditions	
5.	Number of Initially Displaced Grid Points	17 18 19 20 21 22
б.	Number of Frescribed 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 3 ⁴ 35 36
9.	Number of Requests and/or Revisions of Matorial Tape.	<u> </u> 37 38
10.	Number of Input Boundary Condition Points	39 40 41 42 43 44
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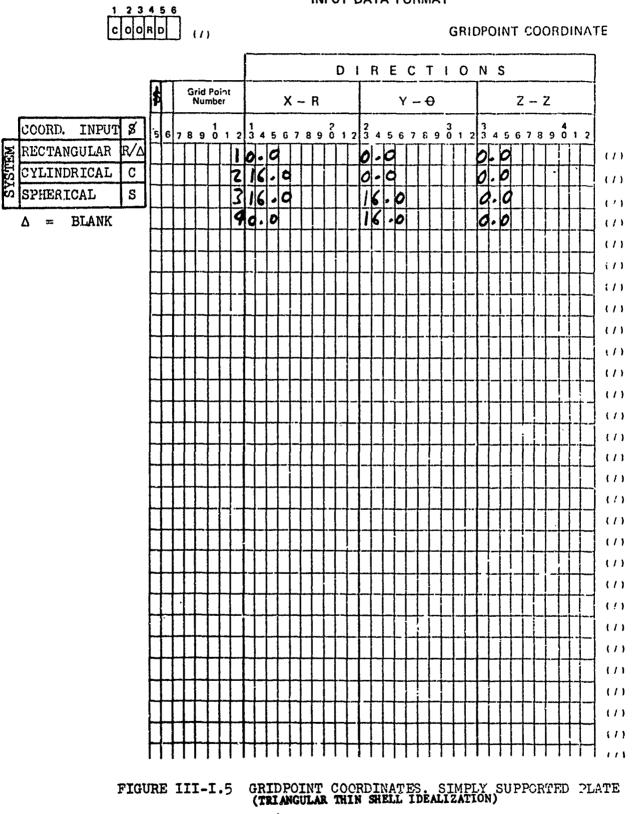
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FIGURE III-I.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (TRIANGULAP THIN SHELL IDEALIZATION) 418

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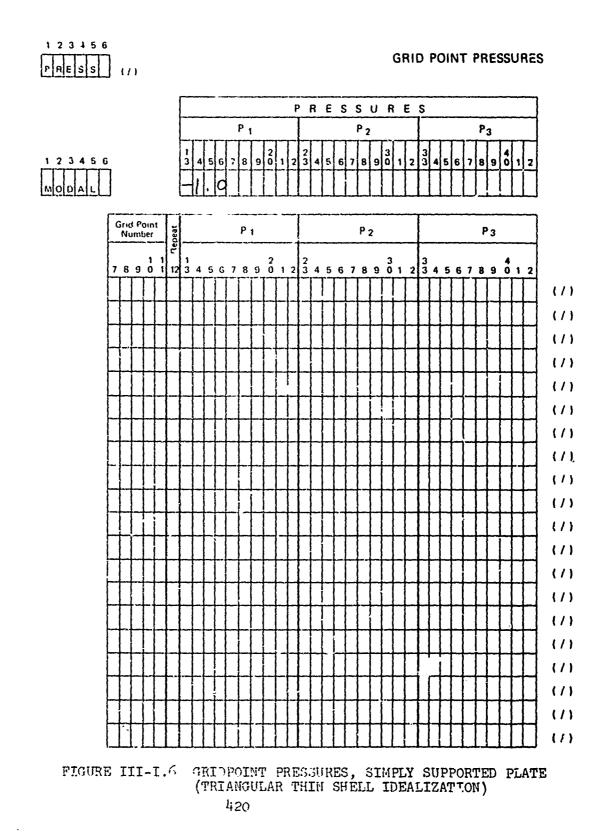


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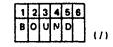
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

BOUNDARY CONDITIONS

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



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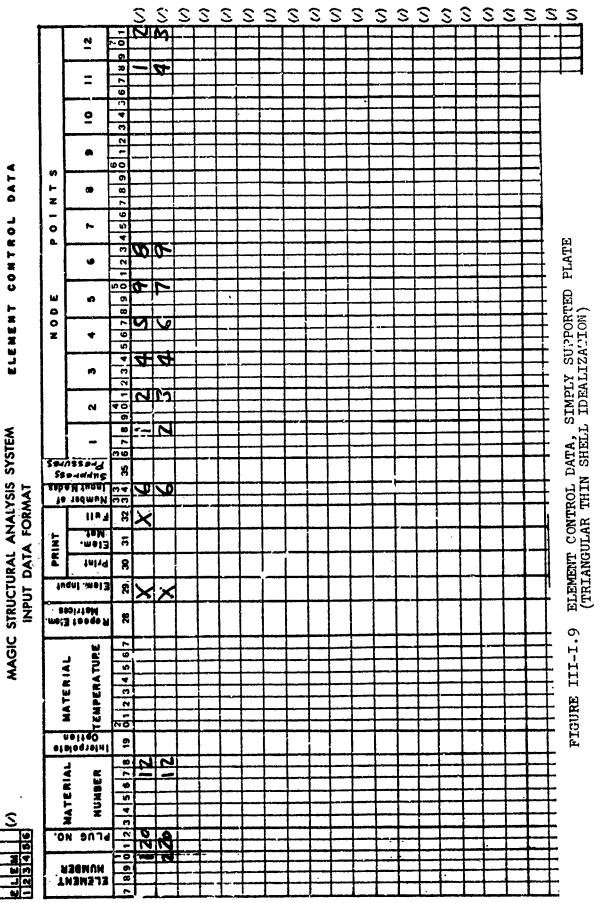
FIGURE III-I.7 BOUNDARY CONDITIONS SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION) 421

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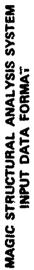


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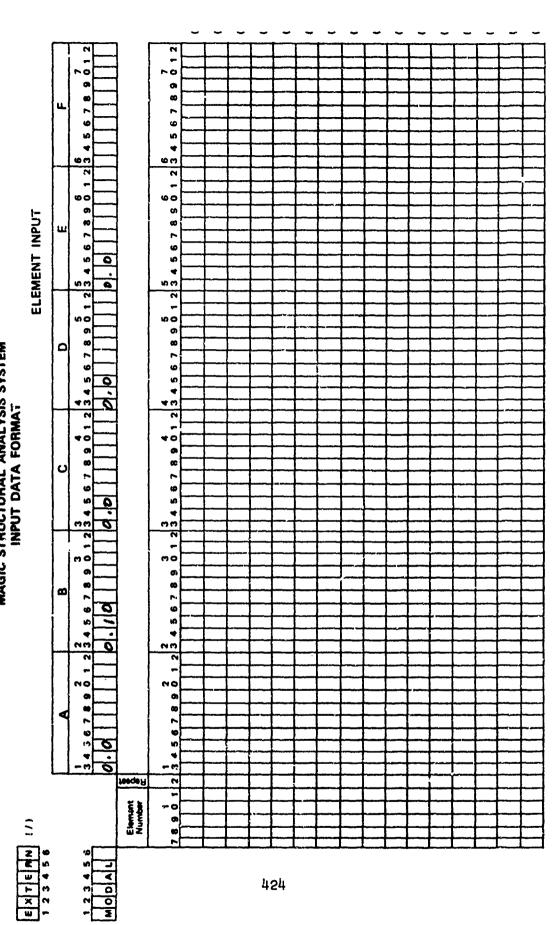
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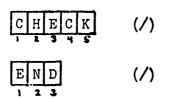


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ELEMENT INFUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION) FIGURE III-I.10

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

CHECK OR END CARD



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FIGURE III-I.11 END CARD, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the simply supported isotropic 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 Grid Point 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.

MAGIC System output of final results is shown in Figures III-I.15 thru III-I.22.

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:

$$q^{2} = [w_{1}, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7}, \theta_{n9}]$$

Where

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= normal slope at node point i

Figure II-I.16 displays the element applied loads (GPRINT OF MATRIX FTELA) which arise from the normal pressure loading of one psi. The loads are output against grid point number and note that grid points 5 thru 9 are associated with mid-side nodes. This being the case, the load (M_X) associated with these node points corresponds to the normal slope degree-of-freedom (Θ_n) .

Displacements are presented in Figure III-I.17. Displacements are output against node point number and are referenced to the Global Axis unless otherwise indicated.

Reactions are presented in Figure III-I.18. The reactions are output against node point number and are referenced to the Global Axis.

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Stress resultants for the Triangular Thin Shell Element are presented in Figures III-I.19 and III-I.20. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid, yielding a total of 32 stress resultants per element.

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 number 1 and positive X from node point 4 to node point 3 for element number 2). These axes of reference then become the reference stress axes for elements 1 and 2 respectively.

Figure III-I.19 presents the stress resultants for Element No. 1. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 1, 2 and 4 respectively.

Figure III-I.20 presents the stress resultants for Element No. 2. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 2, 3, and 4 respectively.

It is to be remembered for the triangular thin shell element that for each element, 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.)

Figures III-I.21 and III-I.22 present the element forces for the two triangular thin shell elements used in this application. These forces are defined with respect to the Global Coordinate System. In Figure III-I.21, Force Points 1 thru 3 correspond to element corner points 1, 2 and 4. Force points 4 thru 6 correspond to element mid-points 5, 9 and 8. Note that the mid-side nodes have allowable degrees-of-freedom equal to U, V, and normal slope (Θ_n) . Therefore, in a flexture problem, the moment at any mid-side node is associated with the normal slope.

The forces for Element No. 2, shown in Figure III-I.22, are interpreted in an analogous manner to those for Element No. 1.

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FIGURE III-I.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SIMPLY SUPFORMED PLATE

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ELEMENT APPLIED LOAD OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEAL "ZATION)

FIGURE III-I.16

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F1	J. 13885498E-02	u.1U411229E 03	J.47772751E 02	J.10411420E 03	0.0	0.0	0.0	0.6	0.0	FIGURES III-I.18 REACTION OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)
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EGUALS ELEMENT S	ELEMENT TYPE	20	NORMAL (MX)				-0.119942F 02		NDRMAL (MX)	•	0.0	0.0	0.0		MORMAL (MX)		-0.394007E 02 -0.324411E 02 -0.450118E 02 -0.4119942E 02	STRESS OUTPUT (ELEMENT NO. 1), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALLIZATION)
(STRESS PLINT CNE	ELEMENT NUMBER	I	RESULTANTS SHEAR(MXY)	(0.0		0		RE SLL TANTS SHEAR (NXY)	0		0.0	0-0		RE SULTANTS SHE AR (NXY)	•		FIGURE III-1,19
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			APPARE Stress Point						518ESS P01N1				•	NET EL	LNIO	-	• n n 4	

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	U 7	NTS TORQUE(MXY)	-0.1199196 02 -0.1371446 02 -0.1741536 02 -0.3659046 01	NTS TORQUE(NXY)	0000	NTS TORQUĒ(MXY)	-0.11991% 02 -0.13714% 02 -0.17415% 02 -0.3459066 0
	n	FLEMJRAL MOMENTS NCRMALINY) TI	0.6983395 01 -0.1799465 02 0.2322025 02 0.3681795 01	FLEAURAR MOMENTS MCRMAbiny] Ti	0000	FL EAURAA, MONENTS MORMAAG NY 3 7	0.498399E 01 -0.179944E 02 0.232202E 02 0.368179E 01
ELEMENT TYPE	50	NORMAL (MX)	-0.249948E 02 -0.237233E 02 -0.232203E 02 -0.270230E 02	(XH) TENNON	0000 0000	NDRMAL (HX)	-0.2312336E 02 -0.2312335E 02 -0.2332203E 02 -0.270230E 02
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FIGURE III-I.20 STRESS OUTPUT (ELEMENT NO. 2), SIMPLY SUPPORTED PLATE (TRIANGULAR TH'N SHILL IDEALIZATION)

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-0.4031005E 02 0.23465317E 02 0.23466446E 02 0.0 0.0	FZ -0.44933273E 02 -0.40533127E 02 -0.40533112E 02 0.0 0.0	F2 0.13085496E-02 0.439999557E 02 0.0 0.0
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PLATE FORCE OUTPUT (ELEMENT NO. 1), SIMPLY SUPPORTED (TRIANGULAR THIN SHELL IDEALLIZATION) III-I.21 FIGURE

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ELEMENT TYPE 20	2 8556 00 9516 00 7746 00		1736 02 1516 02 1966 02		245 02 7516 02 1166 02
ELENE	F2 -0.41944825E 0.83959961E -0.41838074E	5 6 6 6 6 6 6 6 6 7	-0.405331736 -0.469331516 -0.469331516 0.0 0.0 0.0	2	0.40113724E 0.47772751E 0.40114716E 0.0 0.0 0.0
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FORCE OUTPUT (ELEMENT NO. 2), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

FIGURE III-I.22

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### J. THICK WALLED DISK - THERMAL LOAD (Trapezoidal Cross-Section Ring Idealization)

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

In Figure 11I-J.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-J.6 (Grid Point Temperature Section) if is instructive to note the use of the Repeat Option. Grid Point 12 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 12. This same procedure is also used for Grid Points 2, 3, 4, and 5. 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.

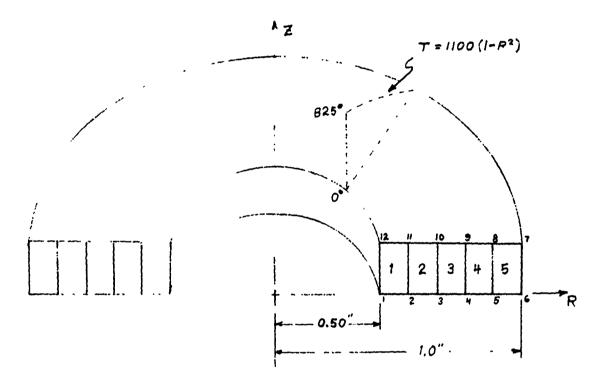
In Figure III-J.7 (Boundary Condition Section) it is instructive to note the use of the MODAL option. There is only 1 exception to the MODAL card and this is Grid Point Number 12. This exception must be called out on the System Control Information Data Form (Figure III-J.4).

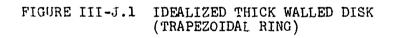
In Figure III-J.8 (External Loads Section) the following information is evident.

- (1) One load condition is input.
- (2) The External Applied Load Scalar equals 1.0.
- (3) At Grid Point (1) 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 Trapezoidal Cross-section ring has three degrees of freedom per point thus requiring only one external load card per grid point.

 $E = 1.8 \times 10^7 PSI$  M = 0.30 $\propto = 0.10 \times 10^{-6}$ 





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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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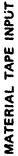
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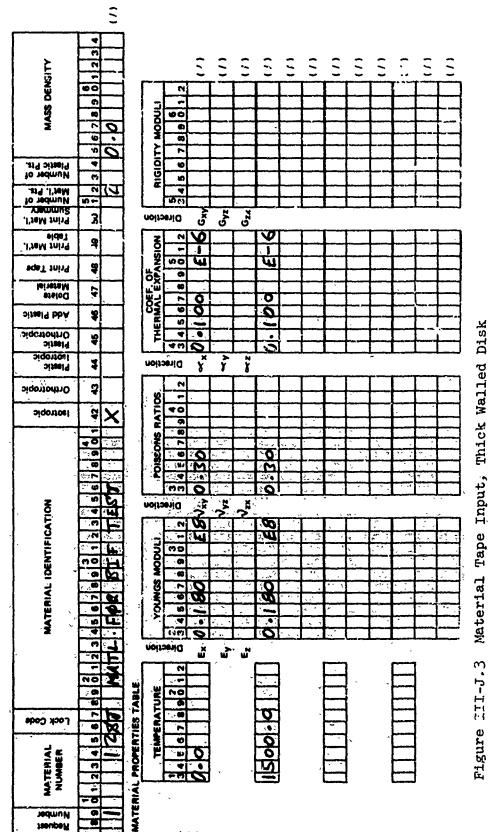


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MAGIC.STRUCTURAL ANALYSIS SYSTEM





# MAGIC STRUCTURAL ANALYSIS SYSTEM

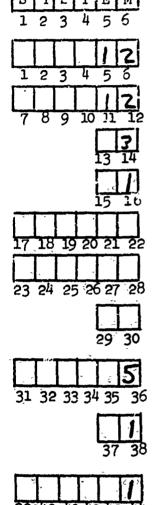
### SYSTEM CONTROL INFORMATION

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

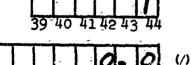
1. Number of System Grid Points

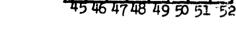
- 2. Number of Input Grid Points
- 3. Number of Degrees of Freedom/Grid Point
- 4. Number of Load Conditions
- 5. Number of Initially Displaced Grid Points
- 6. Number of Prescribed Displaced Grid Points
- 7. Number of Grid Point Axes Transformation Systems
- 8. Number of Elements
- 9. Number of Requests and/or Revisions of Material Tape.
- 10. Number of Input Boundary Condition Points

11. T_o For Structure (With Decimal Point)



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Figure III-J.4 System Control Information, Thick Walled Disk

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## MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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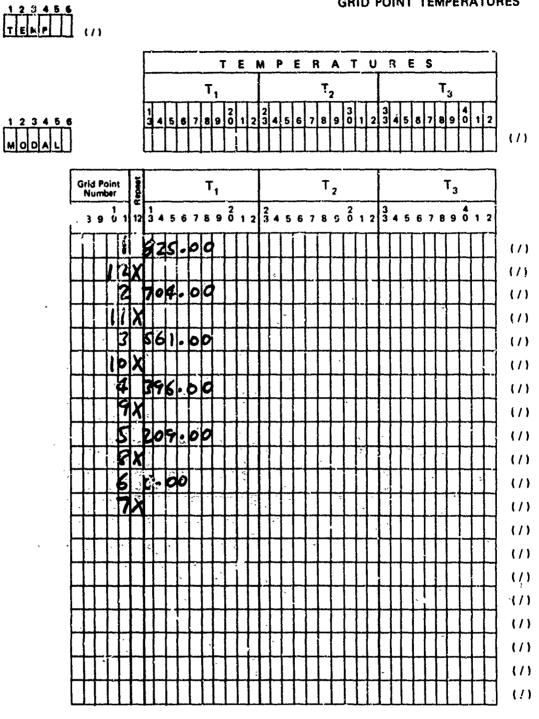
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### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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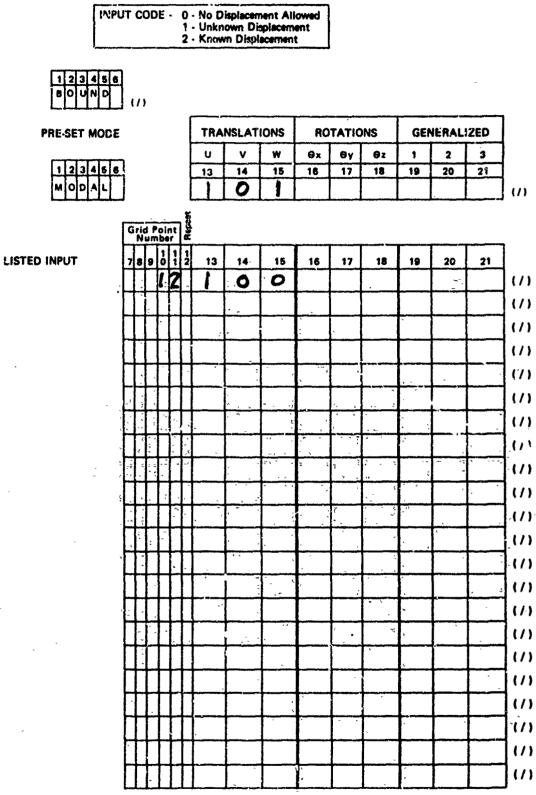
Figure III-J.6 Gridpoint Temperatures, Thick Walled Disk

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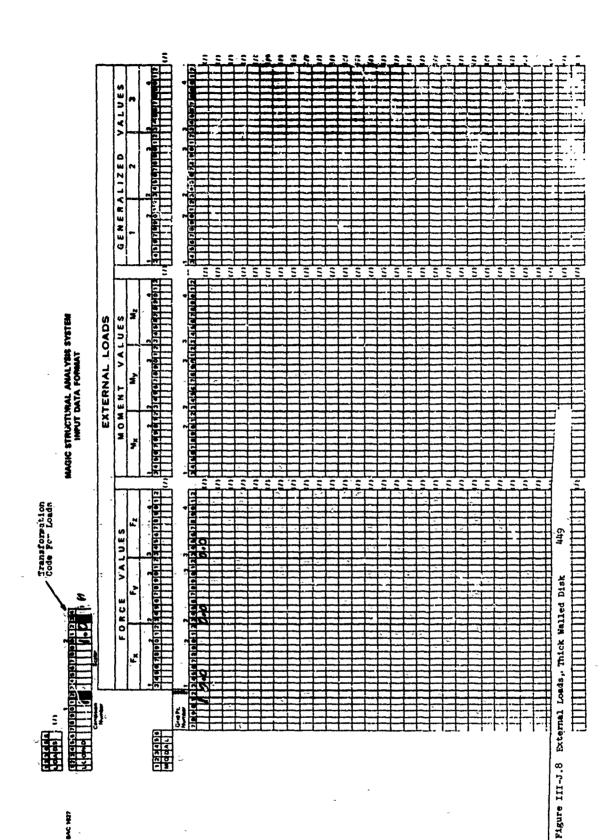
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Figure III-J.7 Boundary Conditions, Thick Walled Disk 448

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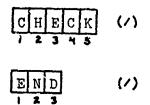
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Figure III-J.10 End Card, Thick Walled Disk

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Load + EALS (Element Applied Load) 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 thermal loads.

In Figure III-J.9 (Element Control Data Section) it is important to note a number of items.

- (1) The temperature interpolate option (Col. 19) is employed for all five elements. The '4' entered in this location tells the system to average the four node point temperature for each element and use this average temperature when establishing material properties from the material tape.
- (2) The node point numbering sequence for each element is very important. Note that each element must be numbered in a counterclockwise manner when looking in the positive element Y ( $\Theta$ ) direction (Figure III-J.1).

Note also that element numbering always begins at the lower left hand corner of the element. Element Input is not required for this problem.

The output supplied by the MAGIC II System for this application is as follows:

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

Figure III-J.12 displays the coordinate information for this application, along with corresponding grid point temperature values.

Figure III-J.13 displays the Boundary Condition and Finite -Element Description Output. Note that for this particular application there are twenty-three degrees-of-freedom remaining in the reduced displacement vector (Total Number of Ones).

Figure III-J.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. and a second state of the second second

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MAGIC System output of final results is presented in Figures III-J.15 thru III-J.22.

Figure III-J.15 displays the assembled and reduced stiffness matrix (MATRIX STIFF) of order 23x23. The stiffness matrix is presented row-wise and only non-zero terms are displayed.

The thermal load vector (GPRINT OF MATRIX FTELA) is displayed in Figure III-J.16. These forces are generated at the element level and are output with respect to node point number.

The displacements of the thick walled disk which result from the imposed temperature distribution are shown in Figure III-J.17. It is noted that displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Figure III-J.18 displays the reactions. The reactions are listed according to node point number. For this particular application, the reactions are effectively equal to zero which results from the self-equilibrating nature of the thermal loading which is imposed.

Stresses for selected Trapezoidal Ring Elements are presented in Figures III-J.19 and III-J.20. Stresses for Element No. 1 are presented in III-J.19 and stresses for Element No. 5 are presented in Figure III-J.20.

Stresses are evaluated at the four corner points of each element and at the element centroid. In Figure III-J.19, Stress Points: 1, 2, 3, and 4 correspond to Element Grid Points (1), (2), (1), and (12) respectively. Stress point 5 corresponds to the element centroidal stress.

> The stresses for each element are defined as follows:  $\{\sigma\} = [E] \{ \epsilon \} - \frac{1}{32AEL} \}$

where from Figures III-J.19 and III-J.20;

 $\begin{bmatrix} E \end{bmatrix} \{ \epsilon \} = \text{Apparent Element Stress} \\ \{ \text{SZAEL} \} = \text{Element Applied Stress} \\ \{ \sigma \} = \text{Net Element Stress} \end{bmatrix}$ 

Note that Radial, Circumferential, Axial and Shear Stresses are presented for each element.

Element forces for selected Trapezoidal Ring Elements are presented in Figures III-J.21 and III-J.22. Forces for Element No. 1 are presented in III-J.21 and forces for Element No. 5 are presented in III-J.22. These forces are defined with respect to the Global Coordinate System. Each Trapezoidal Ring Element has three element forces defined per grid point ( $F_R$ ,  $F_G$ ,  $F_Z$ ). For Element No. 1 (Figure III-J.21) Force Points 1, 2, 3, and 4 correspond to Element Grid Points (**D**, **2**, (**D**), and (**D**) respectively. Forces for Element No. 5 (Figure III-J.22) are defined in an

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FIGURE III-J.11 TITLE AND GRIDPOINT DATA OUTPUT, THICK WALLED DISK

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FIGURE III-J.12 MATERIAL DATA OUTPUT, THICK WALLED DISK

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FIGURE: III-J.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUIN CUTPUT, THICK WALLED DISK

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

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			4510	4510	4510	- 51 G	4510	4510	• • 0 1 2 •	4510	-510	4510

FIGURE III-J.15 REDUCED STIFFNESS MATRIX OUTPUT, THICK WALLED DISK (CONTINUED)

				GORINT CF MATHIX FTELA	(; 13)
NON		FX	<b>A</b> 1	2	
		-0.53753735E 03	0*0	0.51483906F 04	
	N	0.11248315E 03	0•0	0.42485C00E 04	
	<b>6</b> 1	0.15291504E 03	0*0	0.75037930E 04	
×	4	0.19956128E 03	0•0	0.11934789E 05	
	ŝ	0. 25245166E 03	0•0	0.17709328E 05	
	~IJ	0.14280440E 03	0•0	-0.50899023E 05	
÷	~	0.14281168E 03	0•0	0 <b>*50899023E</b> 05	
	•	0. 25243875E 03	0.0	-0.17709328E 05	
	S.	0.19957178E 03	0*0	-0 <b>.11934789</b> £ 05	
	10	0.15291235E 03	0•0	-0.75037930E 04	
-	11	0.11248Å42E 03	0•0	-0.42485000E 04	
-	12	-0,53753955E 03	0*0	-0 <b>.5146</b> 3906E 04	
		FIGURE III-J.16	ELEMENT APPLIED LOADS OUTPUT, THICK MALLED DISK	LOADS OUTPUT, K	
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FIGURE III-J.J.7 DISPLACEMENT OUTPUT, THICK WALLED DISK

REACTIONS AND INVERSE CHECK FOR LIAM FUNCTION

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**(STRESS PCINT FLVE EQUALS ELEMENT STRESSES EVALUATED AT LLEAGUT JEW** 

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ELEMENT GRIF PUTS

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		CAO COMPITION NUMBER	ELEMENT NUPGER	ELEPENT TYPE	ELENENT GRIFP'
NT B. ENENT STRESSES         CIMCUMERENTIAL (SIGMA-2)         AXIAL (SIGMA-2)         SHEAR (SIGMA-2)           0.3310198E         0.3310198E         0.41231641         (SIGMA-2)         (SIGMA-R)           0.3310198E         0.3310198E         0.41231641         (SIGMA-R)         (SIGMA-R)           0.3310198E         0.3310198E         0.41231641         (SIGMA-R)         (SIGMA-R)           0.3310198E         0.3310198E         0.000547176         0.000547176         0.000547176           0.3310198E         0.3310198E         0.000547176         0.0005472176         0.0005472176           0.3310199E         0.000533316         0.000547216         0.0005472176         0.0005472176           0.331019912         0.000533316         0.00056         0.000566         0.0005472176         0.0005472176           11         ANU IAL         (SIGMA-THETA)         (SIGMA-THETA)         (SIGMA-R)         0.2233510746         0.0005676           0.331019912         0.311019912         0.00011         (SIGMA-R)         (SIGMA-R)         0.01101997676         0.00057756           0.31101912         (SIGMA-R)         0.3110199766         0.000         0.01101997676         0.000           0.31101412         (SIGMA-R)         0.31101997766         0.000			1	14	~
0.3310198E       0.3105468TE       04       0.41231641E       04       0.40052754E       0         0.33252996E       0.33252996E       04       0.35275005E       04       0.36275056       0       0.600547217E       0         0.33255299E       04       0.3325590E       04       0.35275005E       04       0.35275005E       0       0.76177002E       0       77002E       0       77017E       0       77017E       0       0       76177002E       0       77017E       0       0       23145776E       0       0.23351077E       0       0       23145776E       0       0.2331477002E       0       0.2331477002E       0       0       231477002E       0       0       23147702E       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0	APP ARENT STR ESS		CINCUMERENTIAL (SIGNÁ-THETA)	AXIAL (5 1644-2 )	SHEAR { 5 ] GMA-R 2 ]
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L         CI NCUMFERENTIAL         AXI AL         SHEAR           R         CI NCUMFERENTIAL         ISI GMA-ZI         SHEAR           R         CS         -Q. 60704835E         O3         0.4106650E         O3         0.40627754E           R         CS         -Q. 60704835E         O3         0.4106650E         O3         0.40622754E           R         CS         -Q. 60704835E         O3         0.4106650E         O3         0.60647217E           R         CS         -Q. 60704835E         O3         0.4562455E         O3         0.60647217F           R         O3         -Q. 32316455E         O3         0.4562455E         O3         0.676177520E           R         O3         0.4552336575E         O3         0.222351074E         0.76177002E           R         O3         0.4022336575E         O3         0.223351074E	HNMAN		0.371.249746 04 0.316.79974E 04 0.316.79974E 04 0.311.24974E 04 0.34402478E 04		
-6.20229907E 63 -0.6070483E 03 0.4106650E 03 0.6082274E 0.15729244E 03 -0.51799029E 03 0.45626245E 03 0.80647217E 0.15729244E 03 -0.51799029E 03 0.45626245E 03 0.80647217E 0.55431689E 02 -0.763756 03 0.33696338E 03 -0.76177002E -0.27635499E 03 -0.46620630E 03 0.40223657E 03 0.22351074E	NET (B.E STRESS POINT	ENENT «STRESSES RADIAL . (SIGNA-R)	CI ACUMFERENTIAL (SIGMA-THETA):	AXIAL (5 1644-2)	-
			-0. 607048835.03 -0.17999295.03 -0.323144555.03 -0.778670415.03 -0.466206305.03	0.4104450E 03 0.45636245E 03 0.39475220E 03 0.33696338E 03 0.402234575 03	

FIGURE III-J.19 STRESS OUTPUT, ELEMENT NO. 1, THICK WALLED DISK 464 STRESSES FORTHETPAPEZOIOALRING FLEWENT (STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT ELEMENT CENTROIC)

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ELEMENT GAIL PLINTS no S ŝ ELEPENT TYPE 4 ELEMENT NUMBER 5 LOAD CONDITION NUMBER

SHEAR (SIGHA-RZ)	0.13514331E C3 0.135510181E C3 -0.13397217E C3 -0.13397066E C3 0.58496094E C0	SHEAR (SIGHA-RZ)	00000	SHEAR (SICHA-RZ)	0.13514331E C3 0.13510181E 03 -0.13397217E C3 -0.13393066E 03 0.58496094E 00
AX1AL 15 16MA-2 )	0.63413989E (\3 -0.34974707E (\3 -0.38659302E (\3 0.32865930776E (\3 0.12169897E (\3 0.12169897E (\3	AXIAL (S IGNA-Z )	0.9404927E 03 0.0 0.0 0.94049927E 03 0.47024951E 03	AKI AL (S 16HA-2 )	-0.30435938E 03 -0.34974707E 03 -0.38659302E 03 -0.34729150E 03 -0.34855054E 03
CI NC UNFERENTIAL SIGNA-THETAL	0.12415693E 04 0.73967285E 03 0.43377612E 03 0.611461545E 04 0.94283496E 03	CI ACUMERENTIAL SIGNATTNETAL	0. %0.49927E 03 0.0 0.02 0.4049527E:03 0.4702495JE 03	CIRCURFERENTAL L'SLGNA-THETA)	0.34007607E03 0.73967289503 0.45377612603 0.20345527603 0.472549545603
ELEMENT STRESSES Radíal (Sigma-r)	0.417934776103 0.234204106 03 0.157245436 03 0.638926516 03 0.434527596 03	APPL IED 'STRESSES (SICHALL (SICHALL)	0.4404V927E 03 0.0 0.0 0.94049927E 03 0.47024951E 03	IENT STRESSES RADIAL (SIGNAFR)	- 0.240542505 03 0.235;204105 03 0.197265635 03 -0.301572755 03 -0.331219245 02
APP ARENT STA ESS POINT	щ N M 4 N	E, ENENT STRESS POINT	4N449	NET & EMENT STA ESS POINT	

FIGURE III-J.20 STRESS OUTPUT, ELEMENT NO. 5, THICK WALLED DISK

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EL ÉMEAT GAIN HUINIS 27 3 14 FIGURE III-J.21 FORCE OUTPUT, ELEMENT NO. 1, THICK WALLED DISK -0.51483320E 04 -0.64733438E 04 0.64771133E 04 -0.51491094E 04 0.51483946E 04 -0.63343944E 04 0.63343944E 04 -0.51483904E 04 -0.58593750E-01 -0.13894531E 03 0.13971484E 03 -0.71675000E 03 ELEPENT TYPE ų. AXEAL (FZ) AXIAL (FZ) AXIAL (F2) ELEMENT NUMBER CINCUMFERENTIAL (F-THETA) CIRCUMFEPENTIAL (F-THETA) CLACUMFERENTIAL (F-THETA) -0000 0000 LOAD CONDITION NUMBER -0.53739063E 03 C.630812500:03 0.63102344E 03 -0.53769922E 03 -0.53753723E 03 0.64561548E 03 0.64561743E 03 -0.53753955E 03 0.14472852 00 -0.144025795 02 -0.145939945 02 -0.15966797 00 . APPARENT ELEMENT FORCES Point Radial (Fr) T APPL JED FORCES RADIAL (FR) -NET GLENENT FORCES POINT RADIAL (FR) R CHENT POINT N m w

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	ADA'D CONDITION NUMBER	NUMBER	ELEMFAT NUMBEG	ELEMENT TYPE	FLC*5VT GALM - 1415
	1		ir.	4 <b>4</b>	a L + 1
APPAREN T POINT	T ELEMENT FORCES Radial (Fr)		CI ACUM€F&FATI A2 (F~THE TA)	4X1 AL	
	-0.112557795 0.142364795 0.143155596 0.14315556205	8888		0.5041504E 05 -0.50895316E 05 C.50859648E 05 -0.50831561E 05	
element Point	ELEMENT APPLIEU FORCES Point Applieu forces (fr)		CIRCUMFE4ENTIAL (F±THETA)	AX1.AL 6 F2`)	
N M 4	- 0.1280 3101E 0.14280440E 0.142811695 0.14281318930	88.88	-0000 6760	0.50623250F 05 -0.50899023E 05 0.505399223E 05 -0.50623250F 05	
NET ELE POINT	NET ELEMENT FORCES Point Radial (FP)		CI RCUMFERENTIAL (F-THETA)	AX I AL ( FZ }	
e1 N M 4	0,15433212E - ),43965149E 2,34191565E 3,14442001E	<b>8</b> 883	0,0 0 0 0 0 0 0	0.2245591E 03 -0.22296875E 00 0.62500000E 00 -0.20371094E 03	
\$ BNC					

FIGURE III-J.22 FORCE OUTPUT, ELEMENT NO. 5, THICK WALLED DISA

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### K. SQUARE PLATE - CRITICAL BUCKLING LOAD (Quadrilateral Plate Idealization)

A simply supported square plate, under the action of uniform axial compressive loading is shown in Figure I.I.-K.1 along with its dimensions and pertinent material properties. A linear eigenvalue stability analysis is performed in this analysis. One quadrant of the plate is analyzed (using 16 elements) and an alternate analytical solution is provided in Reference 17.

The preprinted input data forms associated with this application are displayed in Figures III-K.2 thru III-K.11.

In Figure III-K.6 (Boundary Condition Section) it is instructive to note the use of the MODAL and Repeat options. There are 16 exceptions to the MODAL card as seen from the Figure.

In Figure III-K.7, DYNAM Section, note that two eigenvalues are requested. These two eigenvalues correspond to the first and second buckling modes respectively.

In Figure III-K.10 (Element Input) it is noted that only the MODAL entry is used. This means that all the quadrilateral plate elements used in this analysis have identical element input as follows:

> Location A - Membrane Thickness (tm) = 0.10 in. Location B - Flexure Thickness (tf) = 0.10 in.

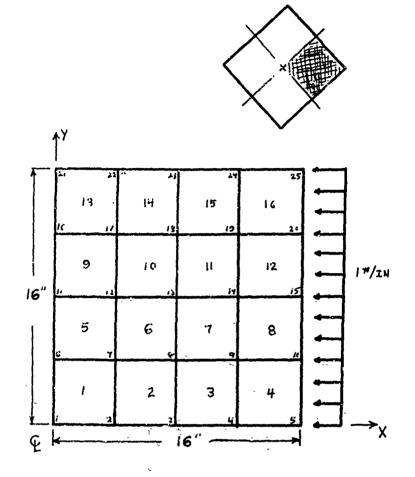
The output supplied by the MAGIC System for this analysis is as follows:

Figure III-K.12 shows the matrix abstraction instructions associated with this particular problem. Note that the STABILITY Agendum was utilized. A full discussion of these instructions is presented on pages 69 thru 80 of this report.

Figures III-K.13 thru III-K.17 display selected output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

Selected MAGIC System output of final results is displayed in Figures III-K.38 thru III-K.22.

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is presented in Figure III-K.18. From the figure it is observed that Grid Points 5, 10, 15, 20 and 25 are loaded in the negative Global 'X' direction.



$$E = 30 \times 10^{6} \text{ psi}$$
  

$$t = 0.10 \text{ in}$$
  

$$v = 0.30$$
  

$$(N_{x})_{CR} = \frac{4}{p^{2}} (\text{Reference 17})$$

FIGURE III-K.1 IDEALIZED SIMPLY SUPPORTED PLATE, CRITICAL BUCKLING LOAD

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and a state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the

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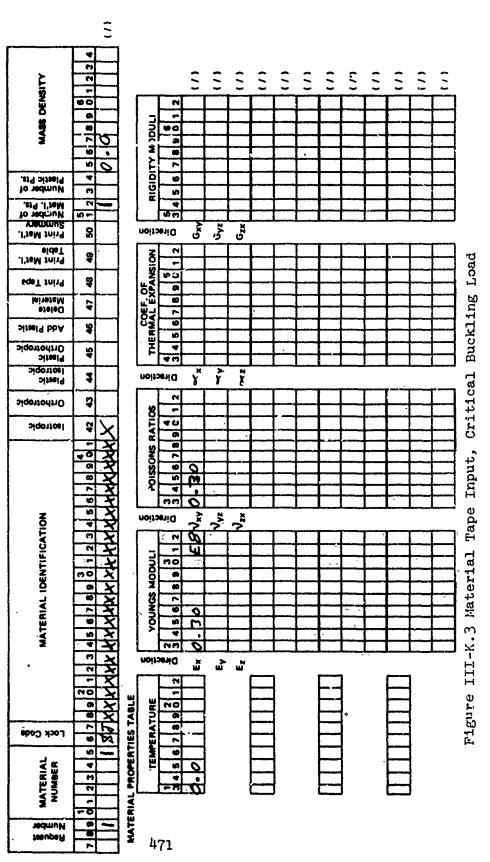
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### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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Figure III-K.4 System Control Information, Critical Buckling Load

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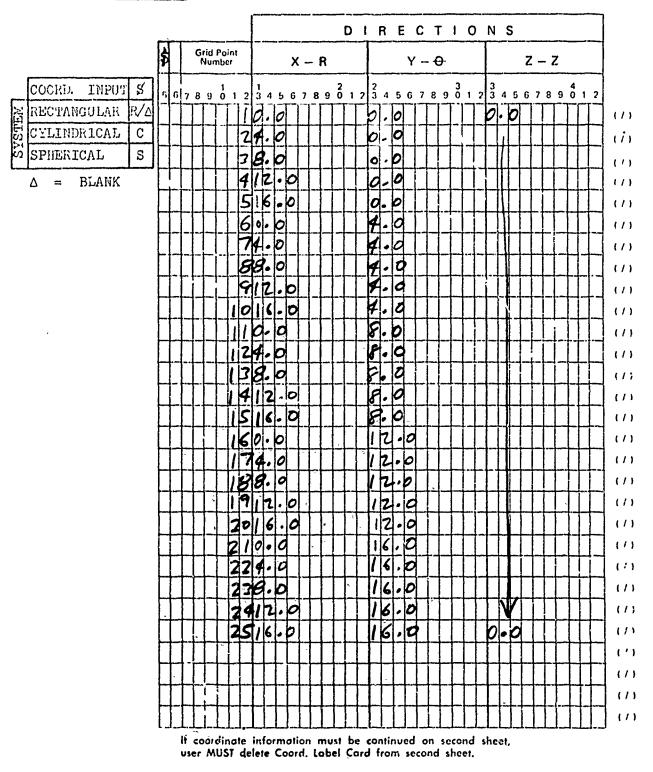
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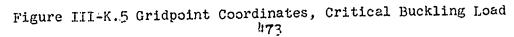
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### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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GRIDPOINT COORDINATE





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### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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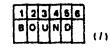
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Figure 111-K.6 Boundary Conditions, Critical Buckling Load With

### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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- 2. Convergence Criteria (Floating Point) (Default Option - 0.001)
- 3. Maximum Number of Iterations (Default Option - 500 Iterations)
- 4. Debug Tteration Print Iteration Print ON = 1 Iteration Print OFF = 0 (Default Option - Print OFF)
- 5. First Normallaing Element, for Print (DeFault Option - No First Hormalization)
- 6. Second Normalizing Element for Print (Default Option ~ No Second Normalization)
- 7. Control for Guess Vector Iteration Start Column Iteration Start - 0 Row Iteration Start - 1 (Default Option - Column Iteration Start)

Figure III-K.7 Dynamics Information, Critical Buckling Load

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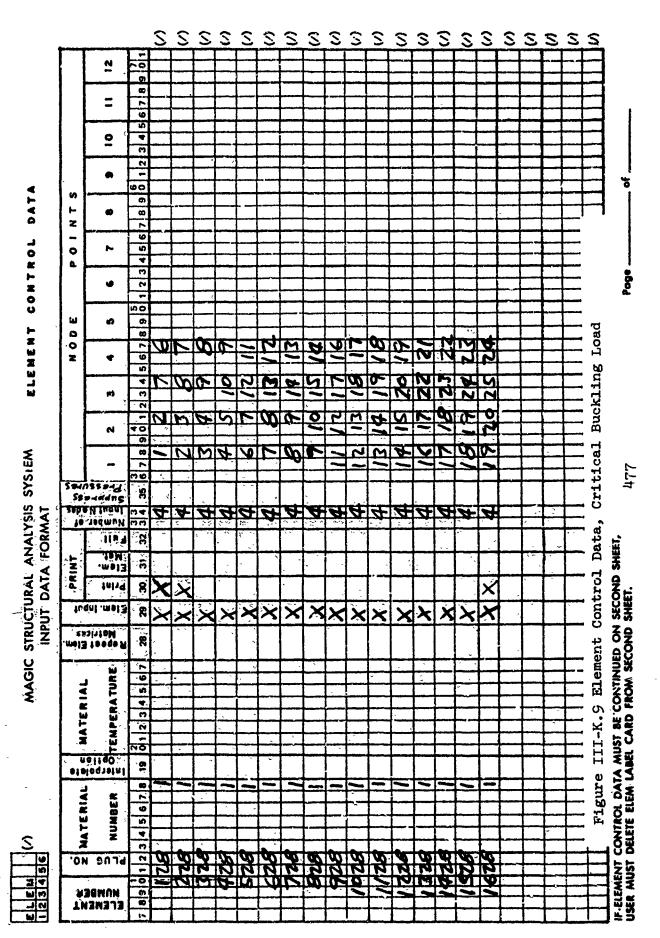
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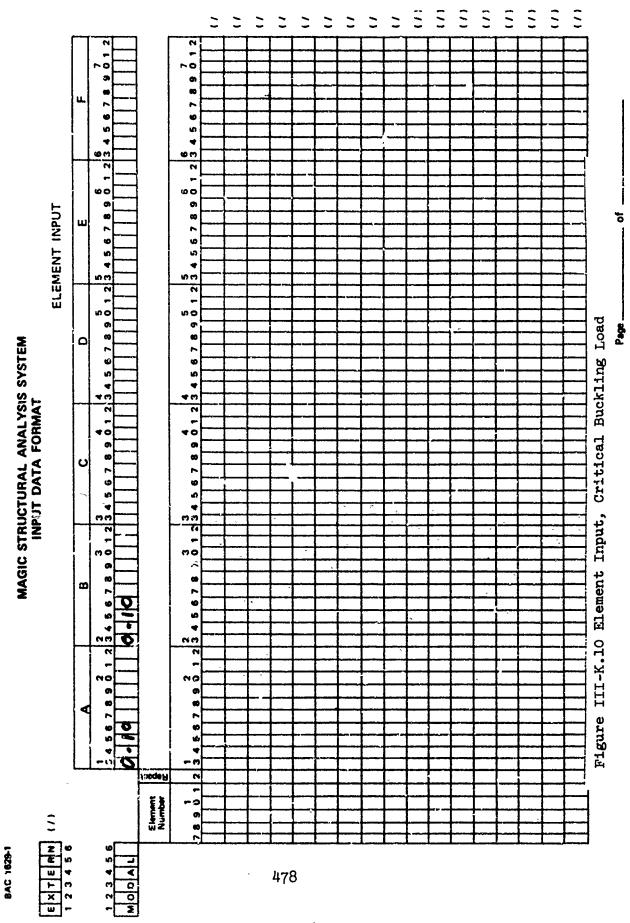
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Figure .II-K.8 External Low



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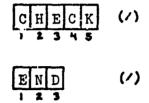


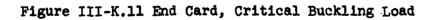
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## MAGIC STRUCTURAL ANALYSIS SYSTEM INFUT DATA FORMAT

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The displacements resulting from the applied loading are displayed in Figure III-K.19.

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It is noted that the displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point numbers and are referenced to the global axis unless otherwise specified.

Stresses for selected quadrilateral plate elements are presented in Figures III-K.20 and III-K.21. Stresses for Element No. 1 are presented in Figure III-K.20. Centroidal stresses are output at STRESS POINT 1.

The lowest buckling load and associated node shape is presented in Figure III-K.22.

In Figure III-K.22, the interpretation of the predicted result for Eigenvalue 1 is as follows:

The relation governing the prediction of stability is as follows:

$$[K]^{-1} [N] \{ d \} = \left( \frac{P}{P_{cr}} \right) \{ d \}$$

[K] -1 = Inverse, Asserbled and Reduced Stiffness Matrix

[N] = Assembled and Reduced Incremental Matrix

= Applied Load Level

Extracting the largest eigenvalue from the above relation yields the lowest buckling load.

For this application

P

$$\frac{\bar{P}}{P_{cr}}$$
 = Eigenvalue 1 = 0.95970668 E-2

Therefore  $P_{cr} = \frac{1}{0.95970068 \text{ E-2}} = 104.20 \text{ lb/in.}$ 

From Reference 17, the critical buckling load for this application is given as 105.91 lb/in. The error between the finite element solution and the alternate analytical rolution is less than two percent for this idealization.

### MAGIC ABSTRACTION INSTRUCTION LISTING

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PAGE 1

### MAGIC ABSTRACTION INSTRUCTION LISTING

23 GPR INT(4,,,FX.FY.FZ.MX.MY.MZ,SC, ) LCAOS 22 GPR INTI 2, , , U. V. W. THETAX. THETAY. THETAZ, SC. ) X 23 IF (13.NULL.) GO TO 60 с с ELEMENTS HAVE 3 DEGREES CF FREEDOM C . 4 ; ) GPRINT(4, ,, FR. C.FZ. O. MBETA. O.FI.O.FJ, SC.TR JFTELA 25 GPR INT(4, ++FR. 0.FZ. 0. MBETA. 0. F1.0. F3+SC, ILCADS GPR INTI 2, , , U. O. W. O. THE TAY. O. H+. O. H++, SC. . . ) X ĉ C GENERA TE STRESSES €, 2.7 6.) STRESS = EM. XO . STRESS. (4.) C r GENERATE FLEMENT INCREPENTAL STIFFNESS PATRIX C ,STRESS.USER04. ť ſ ASSEMBLE AND REDUCE INCREMENTAL MATRIX Ç :5 INCR = PL .ASSEM. SC. (3) 30 PFINT(,,,) INCR С С CREATE INPUT EIGENVALUE MATRIX **(**. FIG = FLEX.MULT.INCR 71 32 PRINT (.... FIG L ĉ CALCULATE AND PRINT E-VALUES, E-VECTORS, FREQUENCIES ſ EVALUE, EVECTRO, = EIG. .EIGENL. SC GPRINT(3,,,,SC,TR22) EVECTR, EVALUE 33 34

FIGURE III-K.12 MAGIC ABSTRACTION INSTRUCTION LISTING FOR STABILITY (CONTINUED)

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FIGURE III-K.13 TITLE AND MATERIAL DATA OUTPUT, CRITICAL BUCKLING LOAD

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•	0.12000006	8	0•0	0*0		0.0
		!			0.0	0.0
4		1	•		0	0.00
n	0*100000E	20	0•0	0•0		
					0	0.0
•	0.0		0.4000000E 01	0.0	0.0	0.0
					0	0.0
r		2				
•		\$		~		0.0
					0	0.0
•	0. 101000005	<b>0</b>	0.4000000E 01	0.0	0*0	0*0
					0.0	0.0
(		1		•	0	0.0
P	0-12000006 0	20	0* 40000000F 0T	0•0		
10	0.110000006 0	62	0.4000000E 01	0-0	0.0	0.0
					0"0	0.0
				,	0.0	0
11	0.0		0. 80000000E 01	0•0	0.0	0•0
		5	0. 8000000E 61	0-0		
4		6			0	0.0
					0.0	0.0
13	0.80000000	10	0. 8000000E 01	0*0	0*0	0.0
					0.0	0•0
					0.0	0.0
**	0.1200000E 0	3	0. 8900000E 01	0.0	0	0.0
					0.0	0.0
					0.00	50
51	0.14000006	80	0.40000006 01	0*0		0 0 0 0
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•					0	0.0
				mtd amtwiddooc		•
	97.4	FIGURE III-K.14		GRIDPOINT COORDINATE DATA OUTPUT,	A OUTPUT, CRITICAL BUCALING	BUCALITS LOAD

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0000		000	000	000		¢ • • • • • •	000	0000
•	•	•	•	•	•	•	•	
0*0	0*0	0*0	0*0	0•0	0•0	0-0	0*0	0.0
50	05	03	5	05	8	05	20	8
0 <b>•12005000E</b> 32	0+12000000E 02	0+12000060E 02	0.1200000E 02	0+16000006 02	0•1+00000E 02	0 <b>•1•00</b> 0006 02	0+14000000E 02	0+1 <b>+000</b> 00E 02
0.120	0-120	0•120	0-120	0-163	0-1+0	0-140	0-140	0-160
10	10	02	03		10	10	8	62
0•4000000	0+ 80000000 08	0+7.20000005 02	0+1+0000006 02		0.4000000	0- 00000000 01	0 <b>-12000</b> 000	0.1600000E 02
0• +00	0• 800	0+7.20	0•140	0•0	0• 400	008 *0	0-120	0c100
11	10	19	20	21	22	23	24	52

FIGURE III-K.14 GRIDPOINT COORDINATE DATA OUTPUT, CRITICAL BUCKLING LOAD (CONTINUED)

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NODE S	~~~************************************

BOUNDARY CONDIT CON INFERMAT SCH

FIGURE III-K.15 BOUNDARY CONDITION OUTFUT, CRITICAL BUCKLING LOAD

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C•0 10-349666666 *0 EXTERVAL INPUT 0.9999944E-01

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6710 POINTS 6 5 19 9 6 5 10 9 6 7 12 11 7 8 13 12 9 10 15 14 13 18 17 13 18 17 13 18 17 14 19 19 17 19 23 22 18 19 23 22 18 19 23 22 18 19 23 22 18 19 23 22 18 19 23 22 19 24 23
20000000000000000000000000000000000000
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SECTI ON PROPERTI ES			
EXTRA GRID PTS		0.30000006 08 0.29999956 05 0.0 0.11538468 08	
	X X XXX XXX	0.3000000 00 00 00 0.300 0.2999995 00 0.299 0.0 0.115384495 00 0.115	
PRNT AG. 19 20	1 • • ##################################	RTIES 0 -0.300 0.29999956 00 0.300 0.29999956 00 0.299 0.0115344666 00 0.0115 0.1153	
B.EM TYPE 4AT.MO. CODE TEMP. 14 '28 1 0 0. U	MATERIAL NUMBER,	INTERPOLATED MATERIAL PROPERTIES TEMPERATURE - 0.0 YOUNG'S MODULI 0.3000 POISSON'S RATID 0.2999 TW. EXP. COEF. 0.0153 R IGIDITY NODULI 0.1153	INTERPOLATED PLASTIC PROPERTIES NONE
	MATERI	LNT CR	14101

PRE-STRAIN INPUT NONE

PRE-STRESS INPUT NONE

0 **•**0 0.0 0.0 G. 9999944 E-01 EXTERNAL INPUT 0.59999944E-01

FIGURE III-K.16 FINITE ELEMENT DESCRIPTION OUTPUT, CRITICAL BUCKLING LOAD (CONTINJED)

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# TRANSFERMED EXTERNAL ASSEMBLED LOAD COLUMN

0°0 0°0 0°0				
	0.0	0°0	0 0	0-0
	0*0	0°0	C• D	0*0
0•0	0•0	0•0	0°0.	0-0
0°0	0*0	0•0	€°0	0*0
- C+2000000E 01 0+0	0*0	0•0	0•0	0•0
0•0	0.65	3.0	0•0	0•0
0•0	0•C	0*0	C. O	0-0
0•0	0.0	0•0	0•0	0*0
0*0	0.0	0*0	0° 0	0*0
- C+1000000€ 01 0.0	0=0	0•0	0.0	0*0
0.0	0*0	0•0	0+0	0•0
0*0 C*0	0.0	0*0	0•0	0-0
0•0	0*0	0*0	0•0	0-0
0.0	0*0	0*0	0-0	0.0
- C+4000000E 01 0.0	0*0	0-3	0° 0	0-0
0-0	0*0	0*0	0•0	0-0
0.0	0*0	0*0	0•0	0.0
0.0	0*0	0*0	0=0	0-0
0.0	0-0	0•0	0•0	0-0
- C+40 00000E 01 0+0.	0 e Ŭ	0*0	0•0	0.0
0•0	0.0	0•0	0*0	0*0
0-0	0.0	0•0	0•0	0 • 0
	-			
5•C	0*0	0*0	0°0	0-0
0.0	6.0	0-0	C• O	0*0
- C. 200 00000 01 0. 9	0*0	0•0	0•0	0-0
-	T-ZERO FCR STRUCTURE =	CTURE . 0.0		

FIGURE III-K.17 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, CRITICAL BUCKLING LOAD

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FIGIRE III-K.18 LOAD OUTPUT, CRITICAL BUCKLING LOAD 490

		0*0			•	
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~			0.00	0*0	5	0-0
2 2 2 2 0 0 2 2 2 0 0 2 0 2 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 2 0 0 0 2 0 0 0 2 0 0 0 2 0 0 0 0		f0	9	0•0	0° 0	0.0
5 5 5 5 5 5 5 7 5 7 5 7 5 7 5 7 5 7 5 7		0*0	0°0	0•0	0•0	0.0
5 - <del>0</del> 20 6 0 0		0*0	0°0	0*0	0• 3	0*0
• •	- G, 2000000E 01	C*0	0*0	0•0	0•0	0•0
7 2.0		0*0	0°0	C*0	0•0	0*0
		0-0	0.0	0*0	0°0	0°0
0°0		0*0	<b>0</b> ~0	0°0	0°0	0*0
5		0*0	<b>9</b> °0	0*0	0•0	0*0
10 -0.40	~ <b>0. 4000000E</b> 01	0.0	<b>q</b> 0	0-0	0*0	•••
		0*0	0°0	0*0	0•0	•••
12 9.0		0*0	0-0	0•0	0*0	•••
() () () () () () () () () () () () () (		0*0	<b>9</b> 0	0*0	0 0	0.0
14 0.0		0*0	9	0.0	0 <b>°</b>	0-0
15 -0.40000	000000 00	0*0	<b>q</b> . 0	0•0	0*0	•••
•		0•0	<b>q</b> 0	0*0	0 •0	0-0
17 0.0		0*0	<b>9</b> 0	0 <b>.</b> .0	0*0	0.0
8		0*0	9-0	0.0	0•0	0.0
9-0		0.0	90	0•0	0-0	0-0
20 - 6-40	- 0, 4000000 01	0•0	<b>9</b> 0	0*0	0.0	0*0
21 0-0		0*0	0°0	0•0	0•0	0*0
22 0.0		0-0	9.0	0*0	0•0	0*0
23 0.0		6.0	90	0*0	0•0	0*0
4		0*0	0.0	0•0	0 • 0	0.0
5 -6.26	- C. 20000000 01	0-0	0*0	0*0	0°7	0-0

(SET 1)

GPLINT CF MATRIX LOADS

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0.0
0-0
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0 <b>-36666666</b> 0
0 <b>*39</b> 999333E-06
0 <b>•344454</b> 6
0-36666666
0.4000003E-04
0.79998754E-04
0 <b>° 7999856</b> 3E-06'
6. 79998733E-06
0• 79999234 E-04
0 <b>• 80</b> 000291 E-0 <del>6</del>
0.11999828E-05
0.11999819E-05
0•11999928E-05
0+11 <del>999909E-05</del>
6 <b>•12000</b> 55E05
0-15999794E-05
0°15999767E-05
0•159 <b>9981</b> 3E-05
0*159599226-05
0•1 <b>6000058E-05 0.0</b>
FIGURE III-K.19

		MORMAT ( 97 ) 0.0	NCANAT (QY) 0.0	NOMMAT (QY) 0. 0
E # E # T	a	SHEAR NGRMAL(036 0.0	SHEAR NCRNAL ( 020 0 0.0	SKAR Hormalion 0.0
OUACAILATEPAL PLATE FLEFEAT	ELEMENT GRIP POINTS 1 2 7 C	Trade (MXV) 0.0	TORQUE (MXV) 0. C	TDAQUE (MXY) 0.0
L A T E P A L	EL EYENT 1 2	ABOUT Y-AKIXA A ABOUT Y-AXIS ABOUT Y-AXIS 0.0	FLEXUMAL MOMENTS Arcut X-Akis About Y-Akis 0.0	RLEXUMAL NOMENTS ABCUT X-AXIS ABOUT Y-AXIS 0.0 0.0
0 4 7 4 1 4	ELEPENT TYPE 28	R. 1.0	ARCUT X-MIS	ABCUT X-AK IS 0.0
33 2 2 3 4 3 3 4 3 3 4 3 4 3 4 3 4 3 4 3	ELEPENT NJØBFR 1	SIGNA-Y 0.953674E-00	signa-Y 0.0	51 6MA-Y 0. 9535 74 E-06
S T R E S S E S	LOAD CONDITION NUMBER ELEM	APPARENT ELEMENT STRESSES Stress stand stresses Point stand stresses 1 -C.999903 Cl -0,524521C-05	ELEMENT APPLIED STRESSES STRESS BEMA-X BEMANE STRESSES POINT SIGMA-X 0.0	NET BLENENT STRESSES STRESS STRESS POINT SIGNA-X POINT SIGNA-X POINT -C.995582E C1 -0.524521E-05

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FIGURE III-K.20 STRESS OUTPUT, ELEMENT NO. 1, CRITICAL BUCKLING LOAD

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		NCRMAT (91) 0.0	NORMAT (QY) 0.0	NGRMAT (QY) 0.0
Е <b>Р</b> Е <b>Р Т</b>		SHEAR NCRMAILOXD 0.0	SHEAR NGRMAL(QX) 0.0	SHEAR NORMALSOX
F C R T H E QUADFILATES AL PLATI FLEPENT	ELFNENT CATL PATINTS	T0k045 (MXY) 0. C	10kQUE (₩XY) 0.0	T0RQ UE ( MXY) 0.0
ATE°AL	EL FYEN T 1º ZC	XURAL 434ENTS Agout Y-Axis 0.0	XURAL HOMENTS About Y-axis 0.0	XURAL MOMENTS Abdut Y-Axis 0.0
3 N A G F 1 i	EL EPENT TYPE 28	RL EXURAL ЧЭЧЕМТS ABCUT X-AXIS A60UT Y-AXIS 0.0	FLEXUMAL MOMENTS About X-axis About Y-axis 0.0	RLEXURAL MOMENTS About X-Axis About Y-Axis 0.0
<b>г</b> са тне	ELEMENT NUMBER 16	SIGMA-Y -0.667572E-05	S SIG#A-Y 0.0	516MA-Y -0.667572E-35
8 1 8 0 5 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 8 0 1 1 8 0 1 1 8 0 1 1 1 1	LOAD CONDITION NUMBER ELE	APPARENT ELEMENT STRESSES STRESS MEMBRANF STRESSES POINT SIGMA-X SIGMA-XY 1 -C.LOGODGE 02 -0.133514E-04	RLEMENT APPLIED STRESSES STRESS MEMDRANE STRESSES PDINT SIGNA-X SIGNA-XY 1 C+0 0+0	NET ELEMENT STRESSES STRESS POINT SIGMA-X SIGMA-XY 1 -0.100000E 02 -0.133514E-04

FIGURE III-K.21 STRESS OUTPUT, ELEMENT NO. 16, CRITICAI BICKLING LOAD

FIGURE III-K.22 LOWEST BUCKLING LOAD AND ASSOCIATED MODE SHAPE OUTPUT, CRITICAL BUCKLING LOAD

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FREQUENCY = 1 / SQUARE ROOT OF EIGENVALUE 0.10207770E 02 RADIANS/SECOND 0.10206166E 01 CYCLES/SECOND

SQUARE RUCT OF EIGENVALUE 0.97964585E-01

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2	0•0	0•0	0 <b>*923903</b> 94E 00	0•0	C. 37567206E-01	0•0
m	0•0	0°0	0.70716709E 0G	0•0	0 <b>.</b> 6942784 8E - 0E	0-0
•	0•0	0•0	0.33274390E 0C	0-0	0. 90 72911 7E-01	0-0
'n	0•0	0•0	0*0	C*0	0.59212481E-7	0°0
ų	0	0•0	0 <b>-9238787</b> 3E 00	-0-37571540E-Cl	0•0	0-0
٢	0•0	0•0	0.853576185 00	-0 <b>-34717385E-01</b>	0• 34 707099E-0I	0•0
•	0•0	0•0	0°92333668E 00	-0 • 265 725C5E- 01	0 <b>• 641 42 704E - 01</b>	0-0
¢	0•0	0•0	0.35361383E 00	-0 <b>-1</b> 43818826-01	0 <b>.</b> 83 822 90 <del>6E - 0</del>	0*0
10	0•0	0•0	0*0	0•0	0. 90 73 704 5E - 0	0-0
11	0•0	0•0	0.70710731E 00	-0.69434285E-01	0.0	0-0
13	0-0	0•0	0*65329999E 00	-0+641 50 6 51F-01	0.26563372E-CE	0-0
13	0*0	0•0	0.50004792E 00	-0.49101762E-01	0* 49 092 <b>69 16 - 01</b>	0.0
•	0•0	0*0	J.27064437E 00	-0.26575428E-01	0 <b>. 641 5563 (E - C</b>	0-0
19	0•0	0*0	0•0	0.0	0. 6944781 5E-01	0*0
16	0*0	0*0	0.38268602E 00	-0.90721011E-01	0.0	J•0
17	0*0	0•0	0.35356706E 00	-0.83817720E-01	0•14376041E-CE	0.0
18	0• 0	0*0	0.27042678E 00	~0 • 64155579E-01	0.26568733E-0	0•0
•1	0 0	0•0	0 <b>.14647228E 00</b>	-0.34723230E-C1	0+ 34 721 073E-0	0-0
20	0 <b>•</b> 0	0*0	0•0	0•0	0. 37584987E-0L	0-0
21	0.0	0*0	0*0	-0-98156149f-01	0•0	0-0
22	0.0	0*0	0 • 0	-0.40724651E- C1	0•0	0-0
23	0.0	0•0	0*0	-0.69442153E-01	0° C	0•0
24	0.0	0*0	0*0	-0.375843C9E-61	0.0	0•0
25	0 0	0*0	<b>0°</b> 0	0*0	0• 0	0-0
		FIGURE III-K.22	OWEST BUCKLING LOAD HAPE OUTPUT, CRITIC	LOWEST BUCKLING LOAD AND ASSOCIATED MODE SHAPE OUTPUT, CRITICAL BUCKLING LOAD (COUT)	(Q2 .11.	

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L. PORTAL FRAME (Vibration Analysis with Condensation)

A portal frame is shown in Figure III-L.1 along with its dimensions and pertinent material properties. This example demonstrates the use of the DYNAMICSC Abstraction Instructions. A mode and frequency analysis is performed using the technique of condensation (Guyan reduction).

The preprinted input data forms associated with this example are displayed in Figures III-L.2 thru III-L.11.

In Figure III-L.3, Material Tape Input Section, note that the mass density value is entered in columns 55 thru 64. This is a required entry in vibration analyses as this value is used in generating consistent mass matrices at the element level.

In Figure III-L.6, Boundary Condition Section, note that certain degrees-of-freedom at selected grid points are eliminated (condensed) by means of Guyan reduction. For example, at Grid Point Number 2, the V and the  $\Theta_Z$  degree-of-freedom are eliminated. This is accomplished by entering the integer '2' opposite Grid Point Number 2 in the locations corresponding to V and  $\Theta_Z$ . As further examples, the  $\Theta_Z$  degree of freedom is eliminated (condensed) at Grid Points (3), (4) and (5) respectively.

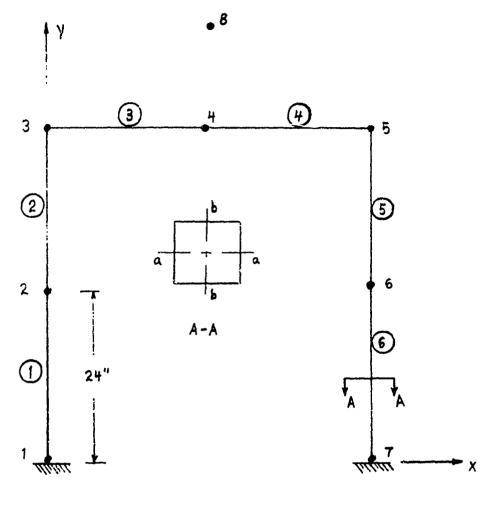
In the DYNAM Section (Figure III-L.7) note that the first five eigenvalues and eigenvectors are requested for this analysis.

In Figure III-L.10 (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) =  $18.0 \text{ in}^2$ Location B - Area Moment of Inertia ( $I_{zz}$ ) =  $13.5 \text{ in}^4$ Location C - Area Moment of Inertia ( $I_{yy}$ ) =  $13.5 \text{ in}^4$ Location D - Torsional Moment of Inertia (J) =  $27.0 \text{ in}^4$

The output supplied by the MAGIC System for the portal frame vibration analysis is as follows.

Figure III-L.12 shows the matrix abstraction instructions (DYNAMICSC) associated with this particular problem. A complete discussion of these instructions is provided on pages 87 thru 90 of this report.



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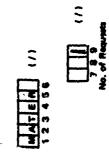
FIGURE TII-L.1 IDEALIZED PORTAL FRAME (VIBRATION ANALYSIS WITH CONDENSATION)

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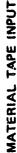
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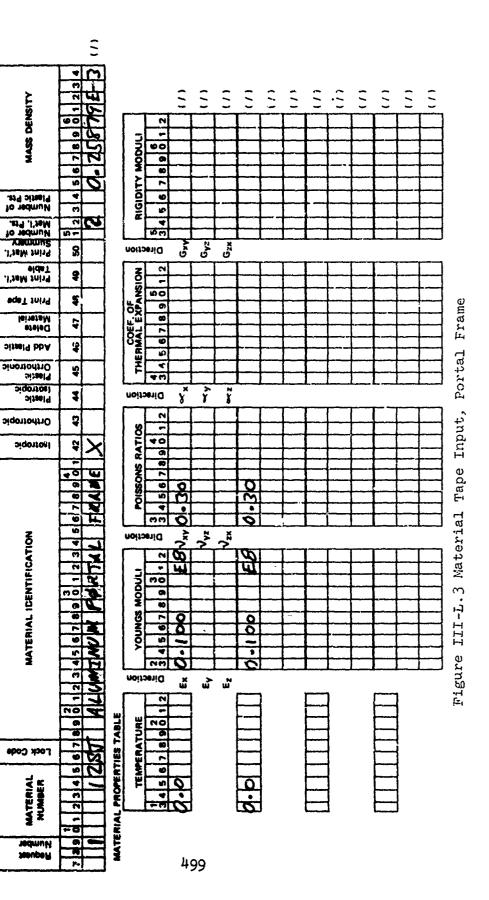




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### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

### SYSTEM CONTROL INFORMATION

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

1. Number of System Grid Points

2. Number of Input Grid Points

3. Number of Degrees of Freedom/Grid Point

4. Number of Load Conditions

5. Number of Initially Displaced Grid Points

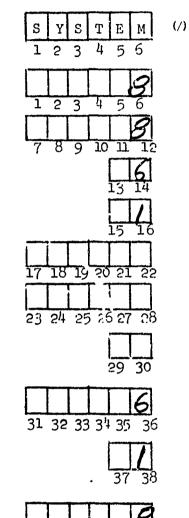
6. Number of Prescribed Displaced Grid Points

7. Number of Grid Point Axes Transformation Systems

8. Number of Elements

- Number of Requests and/or Revisions of Material Tape.
- 10. Number of Input Boundary Condition Points

11. T_o For Structure (With Decimal Point)



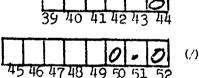
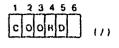


Figure III-L.4 System Control Information, Portal Frame

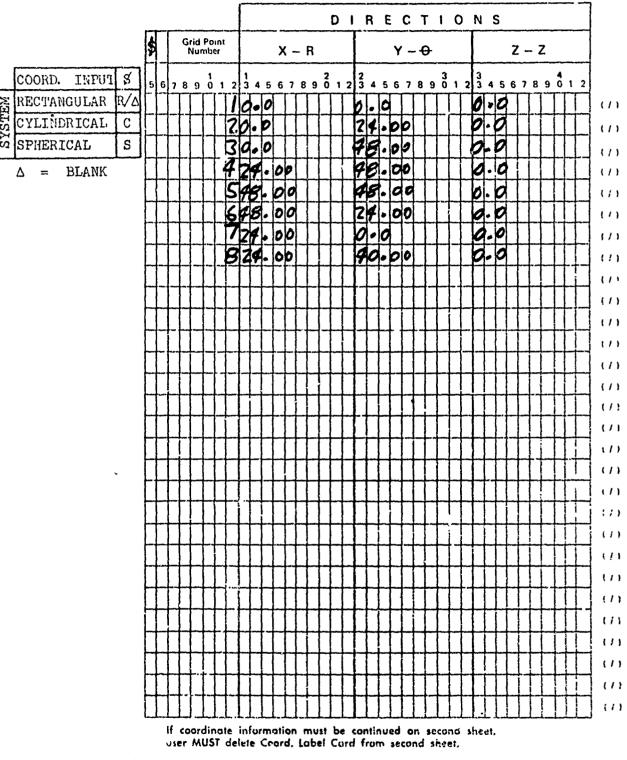
BAC 1672

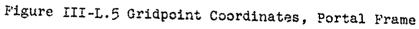
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### MAGIC STRUCTURAL ANALYSIS SYSTEM IN/UT DATA FORMAT



### GRIDPOINT, COORDINATE

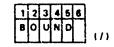




### MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

### BOUNDARY CONDITIONS

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



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# MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

### DYNAMICS INFORMATION



1. Number of Eigenvalues Requested (Less than or Equal to 20)

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- 2. Convergence Criteria (Floating Point) (Default Option - 0.001)
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- 3. Maximum Number of Iterations (Derault Option - 500 lterations)
- 4. Debug Iteration Print Iteration Print ON = 1 Iteration Print OFF = 0 (Default Option - Print OFF)
- 5. First Normalizing Element for Frint (Default Option - No First Normalization)
- 6. Second Normalizing Element For Frint (Default Option - No Second Normalization)
- 7. Control for Guess Vector Iteration Start Column Iteration Start = 0 Row Iteration Start = 1 (Default Option - Column Iteration Start)

Figure III-L.7 Dynamics Information, Portal Frame







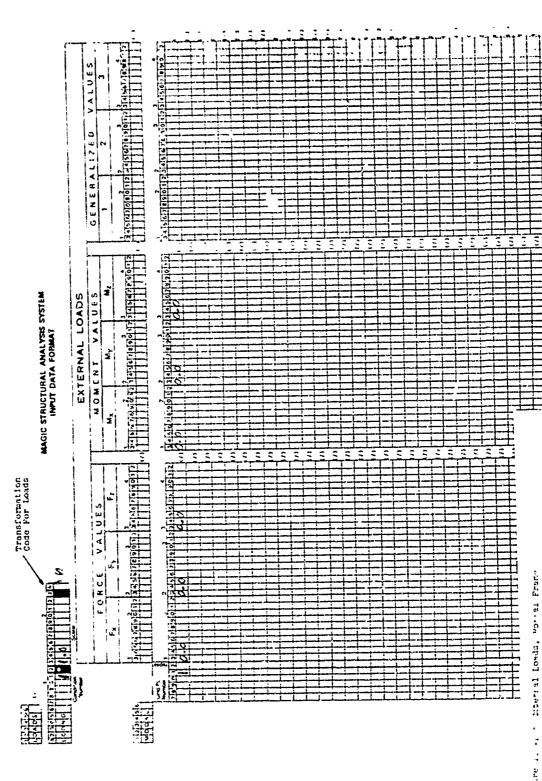




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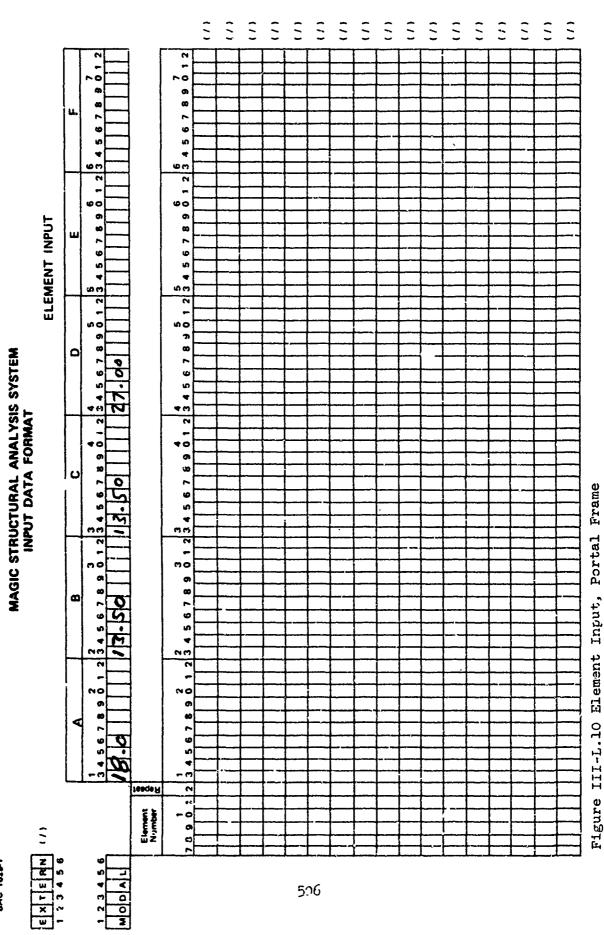
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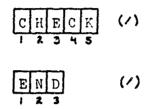
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MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

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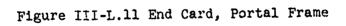


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Figures 111-L.13 thru 111-L.16 display the output from the Structural Systems Monitor. These figures record the input data pertiment to the problem being solved.

Figure III-L.14 displays the coordinate and boundary condition information. In the Boundary Condition Information Section of the figure, zeros ('0') represent degrees-of-freedom that are fixed, ones ('1') represent degrees-of-freedom that have unknown values of displacement and twos ('2') represent degreesof-freedom that are to be condensed (eliminated) from the system. The last two columns list the cumulative total of ones and twos for this analysis. Note that for this case, a total of 7 degrees-of-freedom are condensed from the system.

MAGIC System output of final results is displayed in Figures III-L.17 thru III-L.24.

Figure III-L.17 shows the reduced (uncondensed) stiffness matrix for this problem. The stiffness matrix is presented row-wise and is shuffled so that the degrees-of-freedom corresponding to ones ('1') occupy the first eight rows and columns of the matrix while the degrees-of-freedom associated with twos ('2') occupy the last seven rows and columns of the stiffness matrix.

Figure III-L.18 displays the reduced (uncondensed) mass matrix for this problem. Note that its ordering is consistent with the Stiffness Matrix of Figure III-L.17.

Figures IJI-L.19 and III-L.20 display selected mode shapes and frequencies for this application.

Figure III-L.19 displays the results predicted for the first natural frequency and its associated mode shape. In an analogous manner, Figure III-L.20 displays the fifth predicted natural frequency with its associated mode shape.

Note that for both cases, the mode shape is normalized on the largest element contained in the eigenvector.

Figure III-L.21 displays the generalized mass and stiffness matrices for this application. Note the diagonal nature of these matrices which verifies the orthogonality of the predicted eigenvectors.

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Figure III-L.22 displays the dynamic matrix (MATRIX DYNAM). This matrix is the product of the following:

 $\begin{bmatrix} DYNAM \end{bmatrix} = \begin{bmatrix} K_R \end{bmatrix}^{-1} \begin{bmatrix} M_R \end{bmatrix}$ where  $\begin{bmatrix} K_R \end{bmatrix}$  is the reduced, condensed stiffness matrix  $\begin{pmatrix} 8 \\ x \\ 8 \end{pmatrix}$ and  $\begin{bmatrix} M_R \end{bmatrix}$  is the reduced condensed mass matrix  $\begin{pmatrix} 8 \\ x \\ 8 \end{pmatrix}$ 

As final items of information, Figures III-L.23 and III-L.24 display the reduced condensed stiffness matrix (MATRIX  $K_R$ ) and mass matrix (MATRIX  $M_R$ ) respectively. These matrices are of the order 8 x 8 since a total of 7 degrees-of-freedom were condensed from the system in this particular analysis.

### MAGIC ABSTRACTION INSTRUCTION LISTING

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FIGURE III-L.12 DYNAMICSC ABSTRATION INSTRUCTION LISTING

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MAGIC ABSTRACTION INSTRUCTION LISTING

PAGE 2

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FIGURE III-L.12 DYNAMICSC ABSTRATION INSTRUCTION LISTING (CONTINUED)

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FIGURE III-L.14 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT. PORTAL FRAME

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FIGURE 111-L.15 FINITE ELEMENT DESCRIPTION OUTPUT, PORTAL FRAME

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FIGURE III-L.16 TRANSFORMED EXTERNAT LOAD COLUMN. PORTAL FRAME

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FIGURE III-L.IB REDUCED (UNCOUDENSED) MASS MATRIX. FORTAN FRAME

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FIGURE III-L.19 FREQUENCY AND MODE SHAPE RESULTS, MODE 1, PORTAL FRAME

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FIGURE III-L.22 DYNAMIC MATRIX, PORTAL FRAME

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FIGURE III-L.23 REDUCED CONDENSED STIFFNESS MATRIX, PORTAL FRAME

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FIGURE III-L.24 REDUCED CONDENSED MASS MATRIX, PORTAL FRAME

### SECTION IV

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### APPENDIX I

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### MAGIC ERROR MESSAGES

The following is a list of all MAGIC error messages. The list is divided into three sections. The first section contains all Format error messages (Reference 6) and is divided into two parts. the preprocessor error message, and the execution error message. The second section contains error messages from all arithmetic and non-arithmetic modules developed to be used in conjunction with the structural generative module. The third section contains error messages generated by the structural generative system itself, which is the .USERO4. module. In each section the error messages are in alphabetic order. The error message codes are significant in that the first six characters identify the subroutine from which the error message eminates. The occurrence of **** in the error message indicates that additional descriptive information will be supplied.

### SECTION 1. FORMAT ERROR MESSAGES

### ALOCO1 INSUFFICIENT STORAGE FOR ALLOCATION

The number of words of working storage available to the allocator is less than the minimum required for complete allocation of this job. This condition can be remedied by reducing the number of abstraction instructions.

### ALOCO2 INVALID NO. OF MASTER INPUT/OUTPUT DATA SETS SPECIFIED

The number of master input data sets and/or master output data sets specified on "INPUT TAPE" or "OUTPUT TAPE" cards is greater than the number of master input and/or master output data sets defined in the machine resources area as being available to FORMAT II. This condition can be remedied by reducing the number of "INPUT TAPE" and/or "OUTPUT TAPE" cards.

### ALOCO3 INSUFFICIENT UTILITY DATA SETS FOR ALLOCATION

The number of data sets with the FORMAT II system function IOUTIL is less than the minimum number required by the FORMAT II Preprocessor during the preprocessing phase. This condition can be remedied by reducing the number of "INPUT TAPE" or "OUTPUT TAPE" cards used in this job or by modifying the machine resources area. (i.e., define additional data sets with the FORMAT II system function IOUTIL.

### ALOCO4 MASTER OUTPUT DATA SET ****** SPECIFIED IN SAVE INSTRUCTION NOT DEFINED

A "SAVE" instruction in the abstraction instruction sequence refers to a master output data set name which has not been defined on an "OUTPUT TAPE" card. This condition can be remedied by including the appropriate "OUTPUT TAPE" card in the job.

### ALOCO5 MASTER INPUT DATA SET ****** HAS NOT BEEN MOUNTED

The FORMAT II allocator has not been able to locate a master input data set which has been specified on an "INPUT TAPE" card. This condition is usually caused by mounting the correct master input data set on the wrong unit or by misspelling the name of a properly mounted data set on the "INPUT TAPE" card.

### ALOCO6 MATRIX ****** IS NON-EXISTENT

A matrix, which appears in the abstraction instruction sequence and which has not been created in the abstraction instruction sequence prior to its use, has not been card input and does not appear on any master input data set. This condition can be remedied by inputting the required matrix.

ALCCO7 DUPLICATE MATRICES ****** IN MATRIX DATA

Two or more matrices with the same name have been card input. This condition can be remedied by ensuring that all card input matrices have unique names.

### ALOCO8 CREATED MATRIX ****** IS CARD INPUT

A matrix which is created in the abstraction instruction sequence has the same name as a matrix which is card input. This condition can be remedied by removing the matrix in question from the card input matrix data.

### ALOCO9 SUBSCRIPTS OF ****** EXCEED DIMENSIONS OF MATRIX

The indices of a scalar element to be extracted from a matrix are larger than the dimensions of that matrix. This condition can be remedied by changing the indices c? the scalar element specified in the abstraction instruction sequence.

### ALOCIO DUPLICATE MATRICES CREATED -- NAME ******

A matrix in the abstraction instruction sequence appears more than once on the left side of an equal sign. This condition can be remedied by ensuring that all matrix names, which appear on the left side of an equal sign in the abstraction instruction sequence, have unique names.

ALOC11 MATRIX ****** IS USED MORE THAN ONCE IN INSTRUCTION ***

The matrix names appearing in the indicated instruction in the abstraction instruction sequence do not have unique names. This condition can be remedied by ensuring that all matrix names appearing in a given abstraction instruction have unique names.

### ALOC12 CREATED MATRIX ****** HAS BEEN INPUT

A matrix which appears on the left side of an equal sign in the abstraction instruction sequence has the same name as a required input matrix. This condition can be remedied by either changing the name of the required input matrix or by changing the name of the matrix which appears on the left side of the equal sign.

### ALOC13 MATRICES CREATED IN INSTRUCTION *** NEVER REFERENCED

The indicated abstraction instruction in the abstraction instruction sequence creates matrices, none of which are referenced in subsequent abstraction instructions. This condition can be remedied by removing the indicated abstraction instructions from the abstraction instruction sequence.

### ALOC14 DUPLICATE STATEMENT NUMBERS ******

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Duplicate statement numbers occur in the abstraction instruction sequence. This condition can be remedied by ensuring that each statement number occuring in the abstraction instruction sequence is unique.

### ALOC15 GO TO DESTINATION ****** IS MISSING OR OCCURS BEFORE IF TEST

An abstraction instruction "IF" in the abstraction instruction sequence conditionally transfers to a non-existent statement number or transfers to a statement number on an abstraction instruction which is sequentially earlier than the "IF" abstraction instruction in question. This condition can be remedied by ensuring that all "IF" abstraction instructions conditionally transfer to a statement number which occurs sequentially after the "IF" abstraction instruction.

### ALOC16 NGN CONFORMABLE MATRICES IN INSTRUCTION ***

Two matrices occur in the indicated abstraction instruction in the abstraction instruction whose dimensions are such that the matrix operation in the indicated abstraction instruction is not defined.

EXEQCI THE FORMAT SYSTEM IS UNABLE TO LOCATE MATRIX ******

This message signifies a malfunction of the user-coded subroutine which creates the specified matrix.

EXEQ02 CONFORMABILITY ERROR IN INSTRUCTION CREATING MATRIX ******

The matrices involved on the right side of the equals sign in the instruction creating the specified matrix are unconformable.

EXEQ03 MATRIX ***** IS SINGULAR

TARANA TARANA TARANA

The matrix is singular in a "Solution of Equations" routine, i.e., in "STRCUT," "SEQEL" or "INVERS."

EXEQ04 AN ERROR HAS OCCURRED IN THE USER ** MODULE

An error recognized by the indicated user-coded subroutine has occurred. This will usually be associated with incorrect definition of the special data for use by thesubroutine.

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EXEQ05 AN IMPROPER UPDATE HAS BEEN MADE TO THE FORMAT SYSTEM - EXECUTION TERMINATED

A new permanent module has not been properly incorporated. The FORMAT II systems analyst should be contacted if this error message occurs.

EXEQ05 AN ERROR HAS OCCURRED IN A USER-CODED MODULE, ERROR HAS BEEN WRITTEN BY MODULE

An error has occurred in a non-Format module. The specific error has been written by the subroutine in which the error was found.

EUTL3 THE SYSTEM IS UNABLE TO LOCATE A MATRIX. A TAPE SUMMARY OF LOGICAL UNIT **** WILL FOLLOW

The Format system is unable to locate a matrix. A tape summary of the data set on which the matrix should have been is printed out. The name of the matrix will appear in the next error message.

INSTOL ILLEGAL OPTION SPECIFIED ON \$INSTRUCTION CARD

An option other than "SOURCE" or "NOSOURCE" has been specified on the "\$INSTRUCTION" card or a valid option starts before card column 16 in the "\$INSTRUCTION" card.

INSTO2 INVALID STATEMENT NUMBER SPECIFIED

The statement number which is specified in card columns 1-5 of the abstraction instruction preceding this error message is composed of characters which are not all numeric.

INSTO3 INVALID CHARACTER IN COLUMN 6

Card column 6 of the abstraction instruction preceding this error message contains a character other than a blank or zero.

### INSTO4 UNRECOGNIZABLE OPERATION CODE

The operation specified in the abstraction instruction preceding this error message is not contained in the FORMAT II library of valid operations.

INST04 SYNTAX ERROR IN - GPRINT - INSTRUCTION

INSTO4 ILLEGAL NEGATIVE INPUT VALUE FOR SUPPRESSION OF MATRIX ELEMENTS, ABSOLUTE VALUE TAKEN

The effective zero value for suppression of element print in the GPRINT instruction must be positive.

INSTO4 INVALID SPECIFICATION OF INPUT MATRICES

An incorrect number of input matrices has been specified in the GPRINT instruction.

INSTOU ILLEGAL SPECIFICATION OF COLUMN HEADERS

Incorrect syntax in GPRINT when written column headers.

INST05 SYNTAX ERROR IN - IF - INSTRUCTION

The abstraction instruction "IF" which precedes this error message contains an unrecognizable field.

INST05 SYNTAX ERROR IN - EPRINT - INSTRUCTION

INST05 INVALID PRINT CONTROL

The print control in the EPRINT instruction was incorrectly specified.

INSTO5 ILLEGAL NEGATIVE INFUT VALUE FOR SUPPRESSION OF MATRIX ELEMENTS, ABSOLUTE VALUE TAKEN

The effective zero value for suppression of element print in the EPRINT INSTRUCTION must be position.

INST05 ILLEGAL SUPPRESSION OF PARAMETER

The code indicating either stress or force matrices to be printed has been omitted.

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INSTO6 SYNTAX ERROR IN - PRINT - INSTRUCTION

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The abstraction instruction "PRINT" which precedes this error message contains an unrecognizable field.

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INSTO7 SYNTAX ERROR IN - SAVE - INSTRUCTION

The abstraction instruction "SAVE" which precedes this error message contains an unrecognizable field.

INST08 OPERATION CODE NOT INCLOSED BY PERIODS

The operation code in the abstraction instruction preceding this error message is not inclosed by periods.

INSTO9 SYNTAX ERROR IN ARITHMETIC INSTRUCTION

The arithmetic abstraction instruction preceding this error message contains an unrecognizable field.

INSTIO THIS INSTRUCTION IS NOT AVAILABLE

An incomplete modification to the instruction card processor area has been made. The FORMAT II systems analyst should be notified immediately.

INST43 INVALID SPECIFICATION OF PARAMETERS

A syntax error has occurred in the DEJOIN instruction.

INST43 - INVALID INDEX SPECIFIED

Parameter specifying row or column dejoin is illegal.

INST43 INVALID MATRIX NAME

The DEJOIN instruction contains one invalid matrix name.

MATRO1 UNRECOGNIZABLE OPTIONS ON \$MATRIX CARD STANDARD OPTIONS USED WARNING ONLY

An option other than "LIST", "NOLIST", "PRINT" or "NOPRINT" has been specified on the "\$MATRIX" card or a valid option starts before column 16 on the "\$MATRIX" card. MATRO2 CARD FOLLOWING \$MATRIX CONTROL CARD IS NOT A HEADER CARD OR HAS - H - MISSING IN COLUMN 1

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The first card following the "\$MATRIX" card must be the header card of the first card input matrix. All data up to the first header card will be ignored.

MATRO3 NAME ON DATA CARD IS DIFFERENT FROM NAME ON HEADER CARD. THIS MATRIX WILL BE IGNORED

The matrix header card and all associated matrix data must have the same name in card columns 67-72.

MATRO4 ROW AND/OR COLUMN VALUE EXCLED MATRIX SIZE, IS NEGATIVE OR IS ZERO AND VALUE IS NONZERO. THIS MATRIX WILL BE IGNORED.

An element specified in the matrix card input data is outside the dimensions of the matrix, of which it is supposed to be an element.

MATRO5 MATRIX EXCEEDS ALLOTTED STORAGE. THIS MATRIX WILL BE IGNORED.

The number of words of working storage available to the matrix card reader module is less than the number of words necessary to contain all the nonzero elements in one of the card input matrices. The number of words of working storage required for a given matrix is approximately three (3) times the number of nonzero elements in the matrix. This condition can be remedied by decreasing the number of nonzero elements in the card input matrix.

MATRO6 DUPLICATE I-J VALUES ENCOUNTERED. THIS MATRIX WILL BE IGNORED. I = **** J = ****

Two or more values have been specified for the same matrix element in the matrix card input data. This condition can be remedied by ensuring that each matrix element has a unique set of I - J values.

MATRO7 I VALUE ON HEADER CARD EXCEEDS ALLOTTED SIZE OR IS LESS THAN OR EQUAL TO ZERO. THIS MATRIX WILL BE IGNORED.

The number of rows specified in the header card of a card input matrix is greater than the maximum number of rows permitted in a matrix which is processed by the FORMAT II system, or is less than or equal to zero. This condition can be remedied by reducing the dimensions of the card input matrix.

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MATRO8 J VALUE ON HEADER CARD EXCEEDS ALLOTTED SIZE OR IS LESS THAN OR EQUAL TO ZERO. THIS MATRIX WILL BE IGNORED.

The number of columns specified in the header card of a card input matrix is greater than the maximum number of columns permitted in a matrix which is processed by the FORMAT II system, or is less than or equal to zero. This condition can be remedied by reducing the dimensions of the matrix.

MATRO9 FIRST CHARACTER OF MATRIX NAME ON HEADER MUST BE ALPHABETIC. THIS MATRIX WILL BE IGNORED.

The matrix name which is to be given to a set of matrix card input data and which is punched in card column 67-72 of the header card and all associated data cards must follow the rules for valid matrix names as defined for the FORMAT II system. The rule which applies in this case is that the first character of a matrix name must be alphabetic.

MATRIO ILLEGAL CARD ENCOUNTERED. FOLLOWING CARDS IGNORED UNTIL ANOTHER - \$ - CONTROL CARD IS FOUND.

A card has been encountered in the matrix card input data which has an illegal character punched in card column 1. The only valid characters which may appear in card column 1 are "H", "E", and blank.

MATR11 CARD FOLLOWING E CARD IS NOT A \$ CONTROL CARD - WARNING ONLY.

In a valid FORMAT II deck setup the only cards which may follow the "E" card which is the last card in the matrix card input data, are the "\$SPECIAL" card and the "\$END" card.

MRESO1 FIRST CARD IS NOT A - \$ - CONTROL CARD

The first card of all FORMAT II jobs must be a "\$MAGIC" or a "\$FCRMAT" card.

MRES02 FIRST - \$ - CONTROL CARD IS NOT A \$MAGIC CARD. ALLOCATION SUPPRESSED

The first card of all FORMAT II jobs must be a "\$MAGIC" or a "\$FORMAT" card.

### MRESO3 UNRECOGNIZABLE OPTION ON - \$MAGIC CARD STANDARD OPTION ASSUMED

An option other than "NEW", "STANDARD" (or blank) or "CHANGE" has been specified on the "\$MAGIC" card or a valid option starts before column 16 on the "\$MAGIC" card.

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### MRESO4 ILLEGAL CARD FOR - CHANGE - OPTION - ALLOCATION SUPPRESSED

The "DELETE" card and the "UPDATE" card are the only valid machine resources data cards which are calid when the "CHANGE" option has been specified on the "\$FORMAT" card. The "SETUP" card is the only valid machine resources data card which is valid when the "NEW" option has been specified on the "\$FORMAT" card.

### MRESO5 THE SYSTEM INPUT DATA SET OR OUTPUT DATA SET HAS BEEN SPECIFIED AS A FORMAT II SYSTEM FUNCTION

Two Fortran logical data sets which must not be specified on "UPDATE", "DELETE", or "SETUP" cards are the system input data set and the system output data set.

### MRESO6 DUPLICATE DATA SETS SPECIFIED - ALLOCATION SUPPRESSED

A Fortran logical data set has been specified more than once on "SETUP" or "UPDATE" cards.

### MRES07 INVALID **** VALUE DETECTED ALLOCATION SUPPRESSED

An invalid field has been specified on an "UPDATE" or "SETUP" card. The valid fields are as follows. The first field must contain the logical data set number (an integer). The second field a valid FORMAT II system function (e.g., "MASTRI", "MASTRO", or "IOUTIL"). The third field must contain the physical device containing the data set. The valid specifications in the field are "TAPE", "DISK", "DRUM"; or "CELL". The fourth field must contain the logical channel designation. This consists of a letter A to H. The fifth field must contain the capacity of the data set in basic machine units (e.g., bytes, etc.). This field must be an integer number. The error message indicates which of the five fields is in error.

MRESO8 INCORRECT SETUP OR UPDATE CARD ALLOCATION SUPPRESSED

A missing field has been detected on a "SETUP" or "UPDATE" card.

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### MRES09 INSUFFICIENT I/O UTILITY DATA SETS - ALLOCATION • SUPPRESSED

A minimum number of Fortran logical data sets available to FORMAT II must have the FORMAT II system function of "IOUTIL". The FORMAT II preprocessor selects several of the data sets with this function for scratch data sets during preprocessing. This condition can be remedied by specifying additional data sets on "SETUP" or "UPDATE" cards with the FORMAT II system function "IOUTIL".

### MRES10 ILLEGAL DEVICE SPECIFIED FOR MASTER INPUT DATA SET

The only valid device types which may be specified for a FORMAT II data set whose system function is "MASTRI" are "TAPE" and "DISK". A "SETUP" or "UPDATE" card is the source of the error.

### MRES11 ILLEGAL DEVICE SPECIFIED FOR MASTER OUTPUT DATA SET

The only valid device types which may be specified for a FORMAT II data set whose system function is "MASTRO" are "TAPE" and "DISK". A "SETUP" or "UPDATE" card is the source of the error.

### PREPO1 INVALID CONTROL CARD OR INCORRECT DECK SETUP

The FORMAT II preprocessor has encountered a control card which is unrecognizable or which is valid but does not occur in its proper place. Recommended corrective action is to check the spelling of all control cards and check the deck set up.

PREPO2 NOT A - \$ - CONTROL CARD. CARD IGNORED

When an invalid control card is encountered or incorrect deck setup is recognized, the preprocessor searches for the next "\$" control card.

PREP03 PREPROCESSING TERMINATED EXECUTION HALTED

Whenever a serious error occurs the preprocessing is terminated and a "NCGO" condition is established.

PROBQ1 UNRECOGNIZABLE OFTION ON - \$RUN - CARD. STANDARD OPTION USED.

An option other than "GO", "NOGO", "LOGIC" or "NOLOGIC" has been specified on the "\$RUN" card or a valid option starts before column 16 in the "\$RUN" card.

PROB02 CONTRADICTORY EXECUTION OPTIONS - ALLOCATION SUPPRESSED

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The options "GO" and "NOGO" have been specified on the "RUN" card.

PROB03 CONTRADICTORY LGOIC OPTIONS - ALLOCATION SUPPRESSED

The options "LOGIC" and "NOLOGIC" have been specified on the "\$RUN" card.

PROB04 MISSING LEFT PARENTHESIS - ALLOCATION SUPPRESSED

A problem specification data card has a missing left parenthesis.

### PROB05 UNRECOGNIZABLE CARD

A problem specification data card is unrecognizable. The valid problem specification data cards are the "ANALYSIS" card, the "PROBLEM" card, the "PAGE SIZE" card, the "INPUT TAPE" card, and the "OUTPUT TAPE" card.

PROB06 MISSING COMMA ON MASTER I/O TAPE CARD - ALLOCATION SUPPRESSED

There is a missing field on an "INPUT TAPE" card or on an "OUTPUT TAPE" card in the problem specification data.

PROB07 ILLEGAL MASTER I/O DATA SET NAME - ALLOCATION SUPPRESSED

The master input or master output data set name which has been specified on "INPUT TAPE" card or on "OUTPUT TAPE" card in the problem specification data is invalid. Master Input/Output data set names follow the same rules as matrix names. In particular, the name must be 1-6 characters long and the first character must be alphabetic.

PROB08 ILLEGAL INTEGER ON MASTER I/O TAPE CARD

The second field of an "INPUT TAPE" or "OUTPUT TAPE" card in the problem specification data is not an integer number.

PROB09 ILLEGAL PAGE SIZE - ALLOCATION SUPPRESSED

An invalid page size has been specified on the "PAGE SIZE" card in the problem specification data. The valid page sizes are "ll * 8", "8 * 11" and "14 * 11".

### PROB10 MASTER INPUT OR OUTPUT DATA SET USED PREVIOUSLY

All master input and output data set names as specified on "INPUT TAPE" and "OUTPUT TAPE" cards in the problem specification data must be unique.

### PROBIL INVALID SIZE SPECIFIED ON SIZE CARD

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An integer number must be specified in the only field of the "SIZE" card.

		updated to allow the user to assemble a system with NSYS degrees of freedom.
ASSEMC		Element number *****, generated a LISTEL value of *****, while NSYS = *****.
		If this error occurs see the MAGIC system analyst.
ASSEMS	-	Must update the dimension of the list and format arrays to allow for ***** degrees of freedom.
-		The dimension of two arrays in subroutine ASSEMS must be updated to assemble more degrees of freedom inan allowed. If this error occurs see the MAGIC system analyst.
COLREP	-	Input matrix ###### exceeds allowable size IMAX = #####.
		The number of rows of the input matrix exceeds the value cf KONST. IMAX is the number of rows in the input matrix.
DEJNC	-	The partition number = *****, is greater than or equal to the column dimension = ***** of the input matrix.
		An invalid column partition number has been specified in the DEJOIN instruction 1 $\leq$ JPART < ICOL.
DEJNR	-	The partition number = <b>#####</b> , is greater than or equal to the row dimension = <b>#####</b> of the input matrix.
		An invalid row partition number has been specified in the DEJOIN instruction $1 \leq JPART < IROW$ .
DEJOIN	-	Invalid partition number = *****
		The matrix partition number must be greater than one.
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MISCELLANEOUS ARITHMETIC MODULE ERROR MESSAGE

The order of the assembled - unreduced system, NSYS = *****, the maximum size system can only = ***** D.O.F.

The variable KONST in subroutine MRES must be

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SECTION 2.

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EPRINT	-	Unable to execute the EPRINT module. The work array is not long enough for execution.
		The variable NWORK in subroutine MRES must be updated for more work storage.
EPRINT	-	The element information is for element number **** - go to next element.
		Unable to print out stresses or forces for this element, continue execution. If this error occurs contact the MAGIC system analyst
EPRINT	-	The number of elements in the input matrices are not the same.
		If this error occurs contact the MAGIC system analyst.
EPRINT	-	Printing for element type <b>*****</b> , are not available, proceeding to next element.
		The EPRINT module has not been updated to handle this element type. Contact the MAGIC system analyst.
FORCE1	-	Unable to execute the force module. The work array contains ******** words, and ******** words are needed to process the maximum element.
		There is not enough work storage to calculate the forces for all elements. The variable NWORK must be updated in subroutine MRES.
FORCE2	-	Forces for element type <b>*****</b> , are not available, proceeding to next element.
		The FORCE module has not been updated to handle this element type. The MAGIC system analyst should be contacted if this error occurs.
FREEUP	-	The number of matrices to be kept was input as MATOUT = ******, the number of non-zero elements of MAT = ****.
		lf this error should occur contact the MAGIC system analyst.
GPRNT1	-	The row dimension of TR(transformation matrix for application of boundary conditions) = ******. The number of columns of TR = ******. This should equal row dimension.

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An incorrect matrix was input in the .GPRINT. instruction.

GPRNT1	-	The analyst has asked for <b>*****</b> eigenvalues to be printed. Subroutine GPRINT allows a maximum of <b>*****</b> values to be printed - see a program analyst to correct this error.
		Subroutine GPRINT must be updated to allow more eigenvalues to be printed.
CPRNT1	-	Error while processing matrix ******.
		An error has occurred in the GPRINT instruction while processing matrix named.
GPRNT1	-	The matrix to be printed has <b>******</b> rows while TR indicates that it should have <b>******</b> rcws.
		The input matrix to be printed is incorrect or the input transformation matrix is incorrect.
GPRNT1	-	Eigenvector matrix has ***** eigenvectors, while the eigenvalue matrix has ***** eigenvalues.
		The eigenvector and eigenvalue matrices input into the GPRINT instruction are not compatable.
STRES1	-	Unable to execute the STRESS module. The work array contains ******** words, and ******** words are needed to process the maximum element.
		Theme to not enough your stanges to coloulate

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There is not enough work storage to calculate the stresses for all elements. The variable NWORK must be updated in subroutine MRES.

STRES2 - Stresses for element type *****, are not available proceeding to next element.

The STRESS module has not been updated to handle this element type. The MAGIC system analyst should be contacted if this error message occurs.

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CHEK - Input section ******** has not been found. This input section is required for generation of the following matrices.

The named matrices cannot be generated due to the omission of the specified input section.

CONTRL - System information card missing. Cannot allocate storage.

All input data decks must have SYSTEM section to allocate storage for processing of input.

CONTRL - System information card missing. Cannot allocate storage.

The SYSTEM card is missing from the report form input deck.

CONTRL - \$END card encountered while reading .USER04. input, indicating absence of end or check card. Check card will be inserted.

END or CHECK card missing from report form input deck.

DEFLEX - .USER04. Module unable to locate matrix ******.

The system is unable to locate a matrix.

DEFLEX - Matrix ****** does not qualify as an input displacement matrix for the .USER04. module. Dimensions are ***** by ***** and should be ***** by *****.

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The input displacement matrix used to calculate incrementals is of the wrong order.

DEFLEX - Matrix ********* does not qualify as an input displacement or stress matrix.

The input matrix used to calculate incrementals is of the wrong order. If the matrix was a stress matrix then it must have been generated using the .STRESS. abstraction instruction.

ELEM - Element control error in subroutine ELEM. Flement number ***** calls plug number ***. Plug number should be greater than zero. Execution terminated.

All element type code numbers are greater than zero. Proper element type cannot be selected.

ELEM - Element control error in subroutine ELEM. Element number ***** has material number ******. Material identification must be different from zero. Execution terminated.

Self-explanatory.

ELEM - Element control error in subroutine ELEM. Element number ***** has number of grid points = ***. Number of grid points must be greater than zero and no greater than eight. Execution terminated.

Self explanatory.

ELPLUG - Element input error No. *. Plug No *. Element No. ****.

ELEM - Element control error in subroutine ELEM. Element number ***** has number of input points = **. Number of input points must be position. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM. Element node point is negative or zero in element number *****.

> No element defining point number may be negative and only mid-points may be zero.

ELEM	-	Input error in subroutine ELEM, after inter- polation value of Young's Modulus equals +.********* + ** in material number ******, ******************************
		Self-explanatory.
ELEM	-	Input error in subroutine ELEM, after inter- polation Poisson value equals +.************************************
		Self-explanatory.
ELEM	-	Input error in subroutine ELEM, after inter- polation thermal coefficient values equals +.************************************
		Self-explanatory.
ELEM	-	Input error in subroutine ELEM, after inter- polation rigidity value equals <u>+</u> .************************************
		Self-explanatory.
ELEM	-	Input error in subroutine ELEM. Mass density value equals <u>+</u> . XXXXXXXE + <b>**</b> in material number <b>******</b> , <b>************************</b> . Value should be greater than zero. Execution terminated.
		Self-explanatory.
ELEM	-	Input error in subroutine ELEM. Value of IP = ***, value of IPRE = *** for element number one. Request to repeat data from element previous to first element is illogical. Execution terminated.
		IP and IPRE cannot be negative for first element.

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ELEM - Input error in subroutine ELEM. Element number ****** is defined by node points for which no coordinates have been input. Calculation of material temperature impossible. Execution terminated.

Self explanatory.

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ELEM - Cannot locate material library.

The system cannot locate the material library matrix.

ELEM - Material error in subroutine ELEM. Material number ****** was not located on material tape. Execution terminated.

> The specified material number was not available in the material library.

ELPLUG - Element input error no. ****, Plug No. ****, and Element No. ****.

> An error has occurred in generation of specified element. Error No. = 1 Plug number (element type) incorrect Error No. = 2 Number of nodes incorrect Error No. = 3 Number of input elecent cards incorrect.

Self explanatory.

Self-explanatory.

Self-explanatory.

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FMAT	-	Input error in subroutine FMAT. Rigidity value
		equals + . *******E + ** in material number ******, ******************************
		be greater than 1.0. Execution terminated.

Self-explanatory.

Self-explanatory.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Attempt to delete material number ****** using lock code **. Incorrect lock code, request ignored

Self-explanatory.

Self-explanatory.

FMAT

 Error message from subroutine FMAT. Attempt to revise material number ****** using lock code **.
 Input lock code does not match tape lock code for this material. Revisions or deletions not allowed without proper lock code. Execution terminated.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Additions requested exceed capacity of material tape. Maximum number of materials cannot exceed ***.

Self-explanatory.

FMA'Г	-	Error message from subroutine FMAT. Request for print of material that was not on tape. Material number ******. Material identification is ************************************
		Self-explanatory.
FMAT	-	Error message from subroutine FMAT. Unrecognizable

Self-explanatory.

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FMAT - Error message from subroutine FMAT. Number cf requests received is zero.

Number of requests must not be zero. Value of zero indicates improper operation of program.

Usage of an input code of "P" requires that the material to be revised already exists in the material library.

FMAT - New material tape not generated. All revisions and/or deletions requested by this case have been ignored.

Due to a previous error, generation of a new material library has been abandoned. Execution will be terminated.

FORMIN - Unexpected label card read - point *****.

Input section label card encountered while reading table form input. Point reflects entry now being processed.

FORMIN - Repeat for first point ignored.

Repeat option on table forms of report form input cannot be used for first value entered.

FRED	-	There is a mistake in the coordinates for this transformation, we will calculate the remaining in spite of this.
		An error has occurred in generating a grid point axes transformation matrix. Execution will continue.
F6211	-	The integral of (LN(A+B*X)/X) DX is not allowed for A+B*X=0. A = +.*******E + **., B = + .*******E + **, X = + .********E + **
		Natural log of zero is undefined.
INDECK	-	.USER04. input matrix <b>******</b> is not a valid deck (word count error).
		The specified matrix does not qualify as a valid interpreted input deck.
INDECK	-	.USER04. input matrix <b>******</b> is not a valid deck (compression error).
		The specified matrix does not qualify as a valid interpreted input deck.
INPUT	-	Input error, number of directions of grid points not equal to number of directions of vransformation matrix. Execution terminated.
		Order of grid point axes transformation matrices must be equal to three.
INPUT	-	Input error, number of reference points input exceeds ****.
		Program cannot accommodate more than the given number of input points.
INPUT	-	Label card error ******.
		Input card read should have been label card. Execution will be terminated.
LOGFLO	-	Logical input error - matrix ****** cannot be

GFLO - Logical input error - matrix sector cannot be generated by .USER04. module due to suppression of fourth input matrix. Execution phase suppressed. Input processing continuing.

> The incremental matrices cannot be generated because the input displacement or stress matrix has been suppressed.

PDISP - Input section ****** matrix not generated due to prescribed displacement conditions .NE. 1 and .LT. Load conditions input.

> The Prescribed Displacement matrix has not been generated because of an illegal combination of external load conditions and prescribed di.placement conditions.

PHASE1 - Unexpected blank label card encountered.

Card read should have contained an input section label. Input processor will attempt to continue.

PHASE1 - No option has been selected for request number *** of material library.

Self-explanatory.

PHASE1 - More than one option has been selected for request number *** of material library. Only the first selection will be retained.

Self-explanatory.

PHASE1 - Maximum number of load conditions allowed is 100. This problem contains ****.

Self-explanatory.

PHASE1 - Load condition ******* sub-label is incorrect. Program cannot distinguish between load conditions.

Load condition sub-label in report form input is in error.

PHASE1 - Illegal MODAL card encountered. Card will be ignored.

A MODAL card has been found while reading an input section for which no MODAL card has been defined.

PHASE1 - Due to previously encountered error condition this section is being skipped. Program will flush data deck until next recognizable input section is encountered.

PHASE1 - inrecognizable input section.

Input section label has been read which is undefined in input processor.

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PHASE1 - Due to above error message this section will be omitted and check card inserted.

Self-explanatory.

PHASE2 - Number of entries read for this section, *****, does not agree with number that was to be read, *****. Actual number read will be used.

Self-explanatory.

PHASE2 - This section has either been cmitted or flushed by phase one error. In either case this section is considered critical and execution will not be allowed.

Self-explanatory.

> The final processing of certain sections requires data from other sections which by omission or other input error are not present.

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PHASE2 - This section is to be merged with ****** and ****** for which values have been assigned by both for point number *****. Two values cannot be assigned to the same point. Neither value will be used.

Self-explanatory.

PHASE2 - This section is to be merged with ****** and ****** for which modal cards have been encountered for both. Two values cannot be assigned to the same point. Loth modal cards will be ignored.

Self-explanatory.

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PHASE2 - Number of elements read ********* is greater than 9999. Number of elements will be set at 9999.

Self explanatory, execution will be suppressed.

PHASE2	-	No end or check card has been found. Check card will be inserted, suppressing execution.
		Self-explanatory.
PHASE2	-	Due to above error condition check card will be inserted. Execution will be suppressed.
		Self-explanatory.
PHASE2	-	Internal tape error has occurred. Processing abandoned.
		Report form input preprocessor cannot retrieve information stored on a scratch data set.
PLUG1	-	Value of sin (alpha) is zero - run terminated.
		Element defining points are in error for Quadrilateral Thin Shell Element.
PLUG5	-	For I = XX and N = XX integral does not converge.
		No convergence has been obtained for the given integral calculated by the Romberg technique in the Toroidal Ring Element.
PLUG5	-	Maximum number of iterations reached in Romberg integration routine.
		Convergence was not obtained in 15 iterations for an integral in the toroidal thin shell element. Processing will continue, using 15 iteration result.
PRINT5	-	Toroidal ring element with coordinates R1 = $+$ . ********E + **, R2 = $+$ .*******E + **, Z1 = $+$ .********E + **, Z2 = $+$ .******** + ** is not diagonally dominant and should be subdivided.
		Element stiffness matrices must be diagonally dominant.
P7PRT	-	PLUG7 error - third point to define plane was not given - input error.
		Three element defining points are required for the frame element, the third supplying definition of the plane.

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TRAIC - Subroutine MINV has determined array GAMABQ to be singular, execution terminated by subroutine TRAIC.

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.

US04A - Available scratch data sets ******** is less than the required 4.

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The .USER04. module requires at least four scratch data sets. The addition of more data sets is required by the program.

US04A - Input routine, core storage required ****** exceeds that available ***** to displacement method matrix generator.

Blank common work area is not large enough for processing input.

US04A - Report routine core storage required ****** exceeds that available ***** to displacement method matrix generator.

Blank common work area is not large enough for processing report form input data.

US04A - Grid point loads matrix storage required ****** exceeds that available ****** to displacement method matrix generator.

Blank common work area is not large enough for generation of grid point loads matrix.

US04A - Reduction of transformation matrixes storage ****** exceeds that available to displacement method matrix generator.

Blank common work area is not large enough for generation of reduction transformation matrix.

US04A - Element generation core storage required ****** exceeds that available ***** to displacement method matrix generator.

Blank common work area is not large enough for generation of element matrices.

US04A - Assembly transformation matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Grid point load matrix size ****** exceeds limit ***** of MAGIC system.

Self-explanatory.

US04A - Reduction transformation matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Stiffness matrix size ****** exceeds limit of MAGIC system.

Self-explanatory.

USO4A - Stress natrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

US04A - Number elements size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

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USO4A - Output matrix ***** will be a duplicate of input matrix *****.

The user is saving the interpreted input deck when he already has an interpreted input matrix.

US04B - Element sort routine core storage required ****** exceeds that available ****** to displacement method matrix generator.

Blank common work area is not large enough for output of generated matrices.