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CREATION OF LUMPED PARAMETER THERMAL MODEL BY THE USE OF FINITE ELEMENTS

SPERRY SUPPORT SERVICES
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Hampton, Virginia 23665

VOLUME I

Section 1

INTRODUCTION

Thermal analysis by the lumped parameter finite difference technique is the most widely used and accepted approach to the solution of complex, mixed-mode, heat transfer problems. Computer programs such as CINDA[1], SINDA[2], and MITAS[3] are widely distributed and have found diverse application in aerospace and commercial industries.

In the finite difference technique, the thermal network is represented by an analogous electrical network. The development of this network model, which is used to describe a physical system, often requires tedious and menial data preparation and checkout by the analyst. The data preparation and checkout can be greatly reduced through the use of the computer programs described in this report. These programs automatically develop the mathematical model and associated input data and graphically display the analytical model to facilitate model verification.

Three separate programs are involved which are linked through common mass storage files and data card formats. These programs are SPAR (processors TAB, TELD and AU$), CINGEN and GEOMPLT. The objectives of the programs were to:

1. Develop thermal models for the MITAS II thermal analyzer program
2. Produce geometry plots of the thermal network
3. Produce temperature distribution and time history plots.

1.1 METHOD

The basic approach used to generate a thermal model (MITAS data) was to develop an equivalent finite element model, convert this model to a lumped parameter thermal network, and display the network graphically for verification. Figure 1 illustrates the basic program flow diagram.

A lumped parameter thermal model inherently lacks the geometric data necessary for graphical display. A finite element model, however,

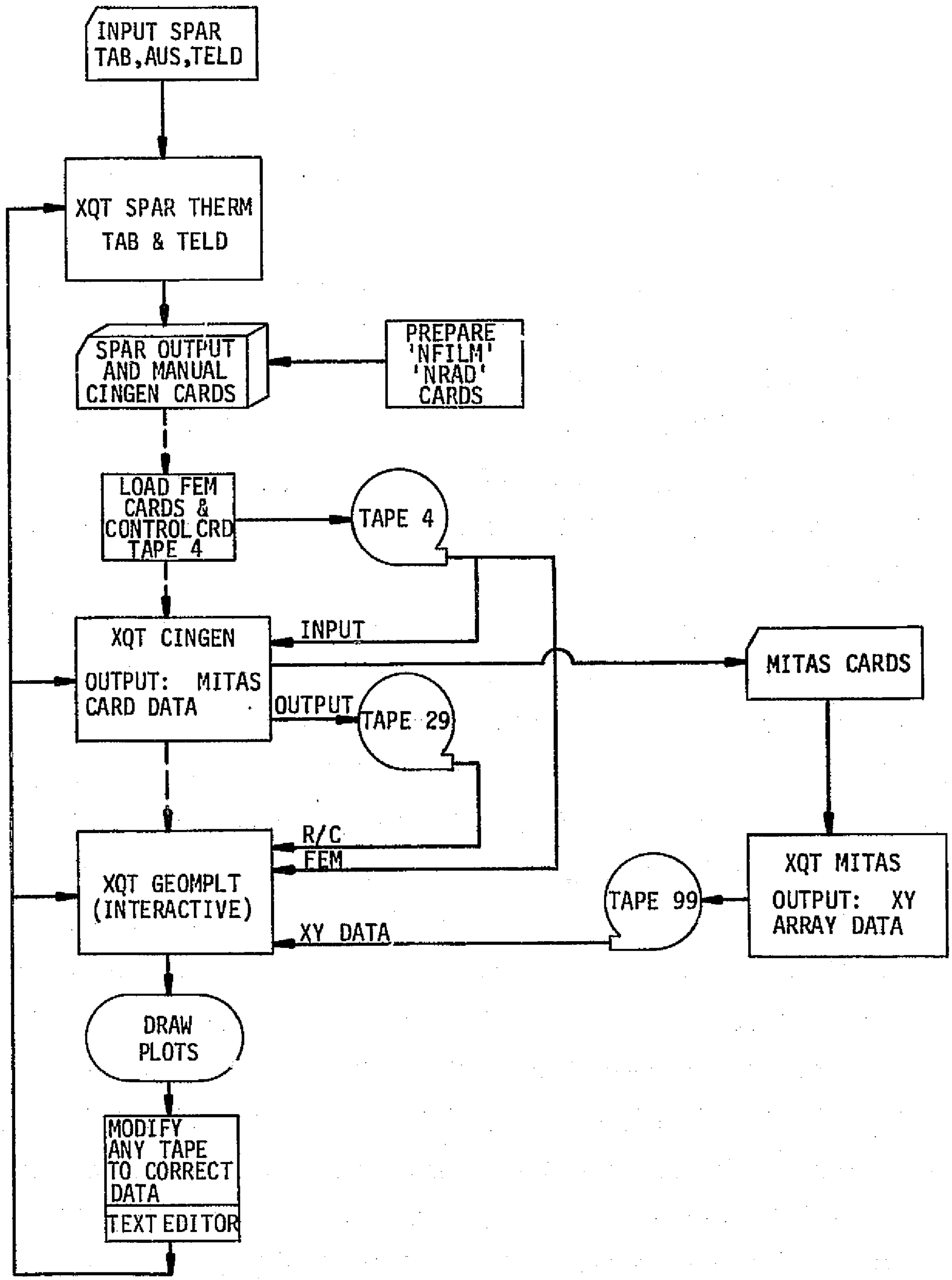


Figure 1, Integrated Flow Diagram SPAR/CINGEN/GEOMPLT contains all of the geometric and physical data necessary to create a graphical display. Furthermore, there are numerous finite element mesh generation programs which can be utilized to develop large analytical models with a minimum of data input and user preparation. Some of these programs are COONS[4], COON3D[5], ICES TOPOLOGY[6], and SPAR TAB/ELD[7]. The latter program was selected for thermal model mesh generation since a modified version developed by Sperry has the capability of producing both NASTRAN[8] and SPAR finite element thermal or structural models, and the simplicity of use was judged superior to the other programs.

Having produced a finite element model using the SPAR formatted data cards, the second program (CINGEN) is used to convert the finite element model into a lumped parameter model. The output of this program is MITAS nodal and conductor data cards.

Finally the resulting MITAS data and the SPAR finite element data are processed by the GEOMPLT[9] interactive graphics program for visually displaying the thermal conductor network and the finite element mesh. The analyst would normally view the model from several angles and "partial views." If model refinement or error corrections were required, the entire process may be repeated or the local file containing the data may be edited using the computer system text editor processor. When the nodal and conductor data are correct,they may be combined with the necessary MITAS control cards for processing in a thermal analysis.

An option for post processing thermal data in the form of XY plots is also available in the GEOMPLT program.

1.2 USER PROCEDURES

Detailed input and output requirements for each program are described in Section 2, 3 and 4 of this report. The following discussion is an overview of the procedure recommended for developing MITAS or SINDA data.

a. When using the SPAR program for mesh generation, three processors must be executed. The TAB (CDC-SPARPUNCH) or TABX (UNIVAC) processor is used to generate joint (grid point) locations for the finite element model. The user is required to set the "ONLINE = 3 or 4" flag which indicates that GRID cards will be punched. The TELD (CDC-SPARPUNCH or UNIVAC) processor is used to generate the NASTRAN finite element connection cards. The SPAR TELD (CDC or UNIVAC) processor can be used to obtain conduction, convection, and radiation elements. The user is required to RESET CINGEN=1 to punch the element cards.

b. Any other finite element mesh generation program may be used provided that standard NASTRAN formatted BULKDATA cards are punched or that the SPAR thermal element punch format is used.

c. If convection or radiation is present in the thermal problem, the coefficients h_c and $\varepsilon\sigma F$ must be manually inserted into the finite element PUNCH file or CINGEN input deck.

d. The user is now ready to execute the CINGEN program. The input cards are placed on TAPE4 (CDC) or file 4 (UNIVAC). This may be accomplished by renaming the PUNCH file resulting from the SPAR execution or loading the cards into a local (temporary) file (TAPE4). The CINGEN program will read this file and compute the lumped thermal characteristics of each finite element. This data will then be punched on cards in the appropriate MITAS (CDC) or SINDA (UNIVAC) format. In addition, a mass storage file TAPE29 (CDC) or 29 (UNIVAC) is written for use by the graphics program.

e. When file TAPE4 and TAPE29 have been attached to a demand RUN using a Textronix terminal, the GEOMPLT program may be used to display either the finite element model or the thermal model or both. Labeling is provided for conductor and node type and number. Partial views may be plotted and each view may be rotated to any viewing angle.

f. Finally, the user may create an output file from MITAS which contains tabular Node-Temperature or Time-Temperature data from the thermal analysis. This data can then be displayed by the GEOMPLT program as an X-Y plot. Node-Temperature plots will be scaled along the abscissa proportional to the geometric relationship of the nodes.

1.3 THERMAL NODE AND CONDUCTOR REQUIREMENTS

This section describes the type of lumped parameter thermal nodes and conductors which can be defined by SPAR finite elements and converted to MITAS data by the CINGEN program. The description includes the characteristic input for each type.

Diffusion Node -

- Diffusion nodes are located at the geometric centroid of an K or F-type finite element.
- K-type elements include bar (K21), triangular (K31) and quadrilaterial (K41) plates, wedge (K61) and hexahedron (K81) solids. F-type elements are restricted to bars (F21).
- Positive values of density (ρ) required.
- Negative values of specific heat (C_v) or conductivity (K) produce a reference to an ARRAY table.
- ARRAY tables are not automatically generated and must be supplied by the user.

Arithmetic Node -

- Arithmetic nodes are located at the geometric centroid of any K or F-type finite element.
- Any K-type element (K21, K31, K41, K61, or K81) or F-type (F21) may be used to generate an arithmetic node.
- If area of K21 or thickness of K31 or K41 is input as 0, a surface arithmetic node is generated.
- Negative value of density required.
- Arithmetic surface nodes are generated for C and R - type finite elements provided these elements are not applied to a surface element.

Boundary Node -

- Boundary nodes are located at the geometric centroid of any K or F-type finite element.
- Any K-type element (K21, K31, K41, K61, or K81), or F-type (F21) may be used to generate an arithmetic node.
- If area of K21 or thickness of K31 or K41 is input as 0. then a surface boundary node is generated.
- Density (ρ) must equal 0.

Standard Conductor -

- A conduction conductor is generated for all the K21, K31, or K41 elements with adjoining edges for all K61 and K81 elements with adjoining faces.
- Surface nodes are considered to have faces only.
- Negative values of thermal conductivity (K) for temperature dependent K.
- ARRAY tables must be manually input by the user.

One-Way Conductor -

- A one-way conductor is generated for all F-type (F21) elements having a common edge, connecting the cg of these elements.
- The conductor value is calculated a $\dot{M}$ Cp A where, $\dot{M}$, flowrate per unit flow area (input in the K location of the NMAT card) Cp, specific heat, and A input cross-sectional area.
- Negative value of flowrate ($\dot{M}$) for temperature dependent $\dot{M}$.
- ARRAY tables must be manually input by the user.

Convection Conductor -

- One standard conductor generated for each C-type (C21, C31 or C41) element input connecting the element defined by the grid points input on the C-type element and the element on the NFILM card.
- NFILM card is required for each different convective sink node or convective rate (Hc).

- NFILM cards are manually input by the user.

- Negative value of convective rate (Hc) for temperature dependent Hc.

- ARRAY tables must be manually input by the user.

- An arithmetic surface node is created on the element to which the C-type element is applied except when applied to surface elements and 2-grid point elements.

- Only one surface node is created regardless to the number of C-type elements applied to the surface.

Radiation Conductor -

- One radiation conductor generated for each R-type (R21, R31, or R41) element. The connecting elements are defined by the grid points on the R-type element and the element on the NRAD card.

- NRAD card is required for each different radiation sink node or radiative rate ($\varepsilon\sigma F$).

- NRAD cards are manually input by the user.

- Negative value of radiative rate ($\varepsilon\sigma F$) for temperature dependent $\varepsilon\sigma F$.

- ARRAY tables must be manually input by the user.

- An arithmetic surface node is created on the element to which the R-Type element is applied except when applied to surface elements and 2 grid point elements.

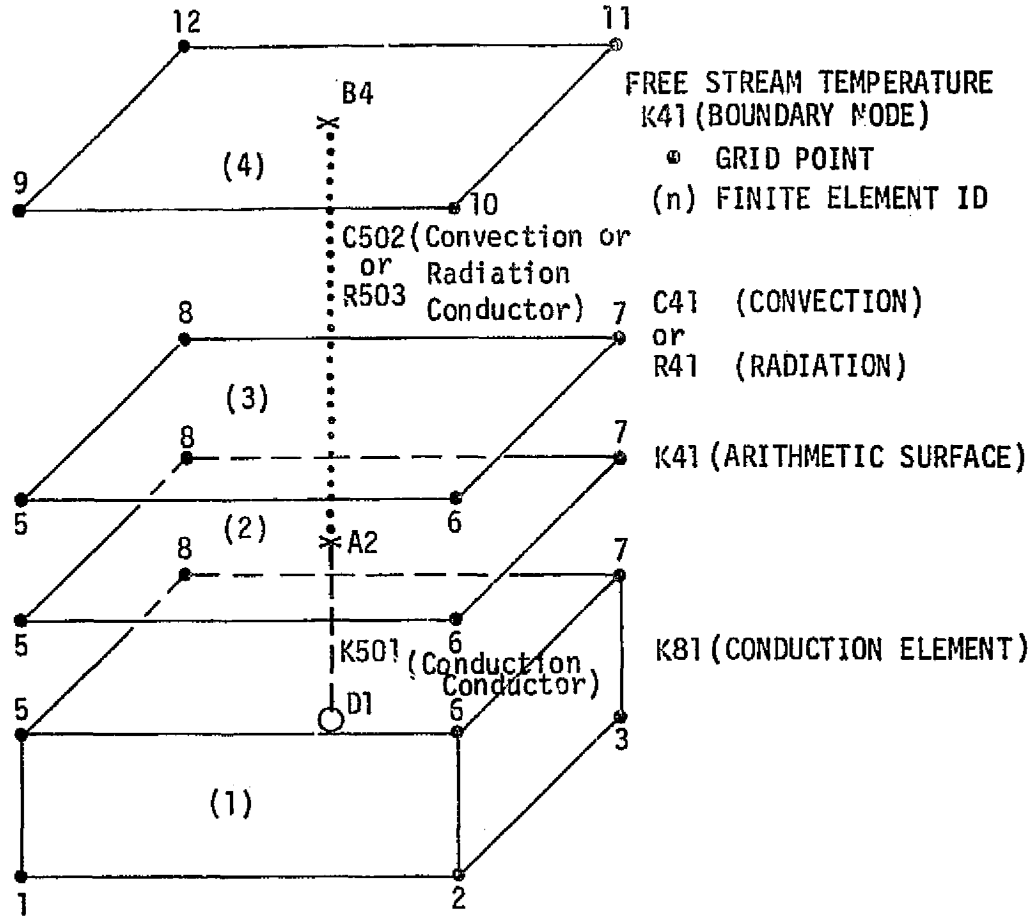
- Only one surface node is created regardless to the number of R-Type elements applied to the surface.

1.4 MODELING TECHNIQUE

To familiarize the user with the method of thermal modeling using the finite elements discussed in Section 1.2, Figures 2 thru 4 are presented. Figure 2 presents a typical model of a conduction element with radiation and convection. An arithmetic surface (K41) is placed on the conduction element (K81) so the thermal resistance between the conduction element and the surface will be accounted for in the lumped parameter model. If desired, the K41 element could have been excluded. A convection element (C41) and radiation element (R41) are applied to the surface element. As many C41 and R41 elements required can be applied to an element. For this example, the convection and radiation elements are connected to a K41 boundary element. These elements can be graphically displayed to aid in model check-out. The lumped parameter designation will appear as in Figure 2 with D1 representing the K81 element, A2 representing the arithmetic element (K41), and B4 representing the boundary element. "D" signifies a diffusion node, "A" signifies an arithmetic node, and "B" a boundary node. The conductor network can also be graphically displayed. As in the labeled conductors of the example, "K" signifies a standard conduction conductor, "C" a convection conductor, and "R" a radiation conductor.

Figure 3 presents a typical pipe/fluid model. This figure shows the finite element representation, the thermal idealization of the model, and the graphical display of thermal model. It is important to note in fluid flow analysis, that F-type elements must be used because they represent thermal nodes which are connected by "one-way" conductors. F-type conductors are graphically represented by "F" preceeding the conductor number.

When a transition from 1-D to 2-D or 3-D, or 2-D to 3-D elements is required, special modeling is required. Figure 4 gives the method required to change from 1-D to 2-D elements. As shown in the figure, an arithmetic surface is applied to (1) and (2) and a zero length arithmetic surface added to the element (4). These arithmetic surfaces cause conductors K101, K102, and K103 to be added to the thermal network, but these conductors aren't connected (see graphical display of model). To connect these conductors, nodes A5, A6, and A7 must be converted to a single node. That is delete two of these nodes from the MITAS node data block and convert these deleted node numbers to the remaining node number on all the conductor cards in the MITAS conductor block. Resulting in the thermal idealization shown in the figure. These changes can be made with the text editor. Other dimensional transitions are similarly made.



* NOTE: C41 and R41 will perform function of K41 (arithmetic surface) if desired. Above shown for demonstration only.

Figure 2. Typical Convection or Radiation Model

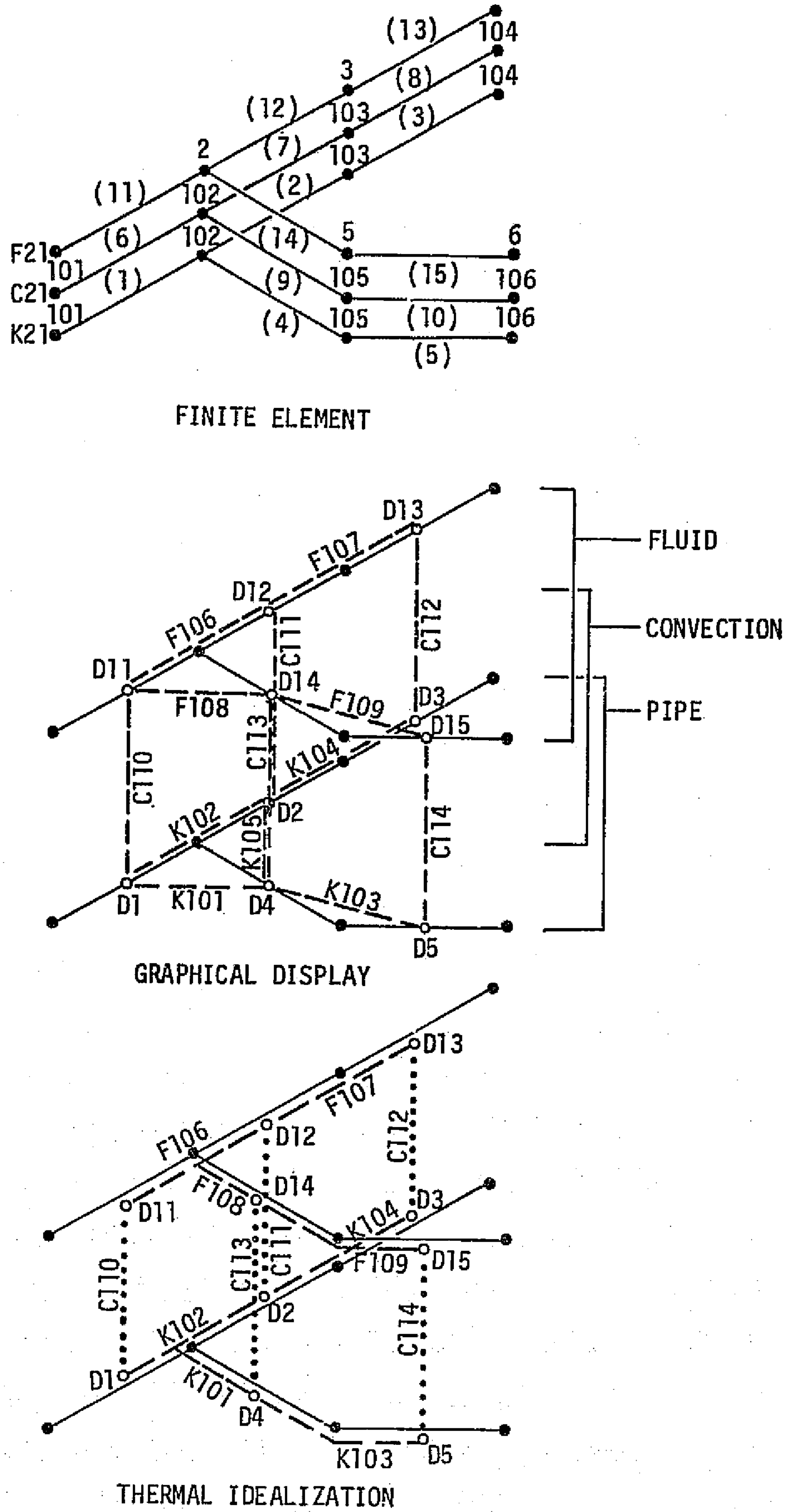
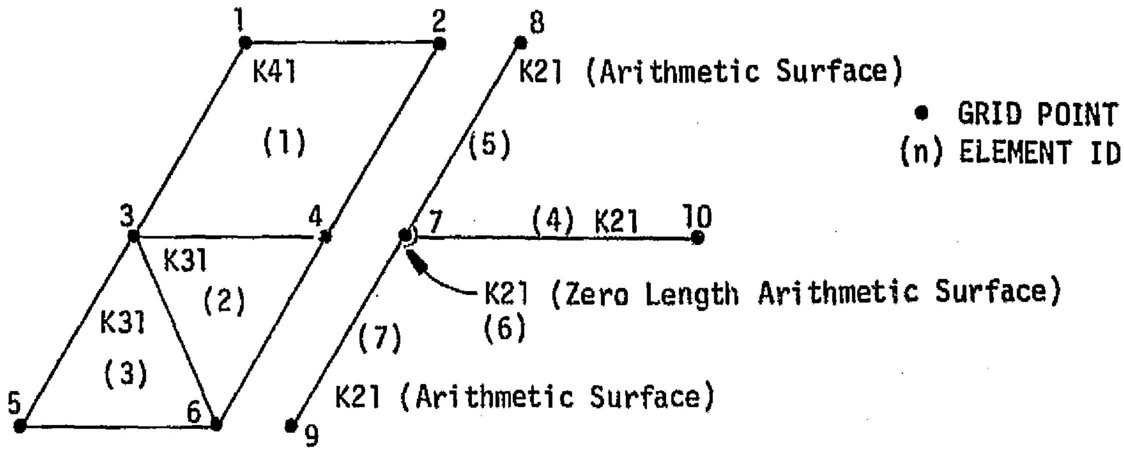
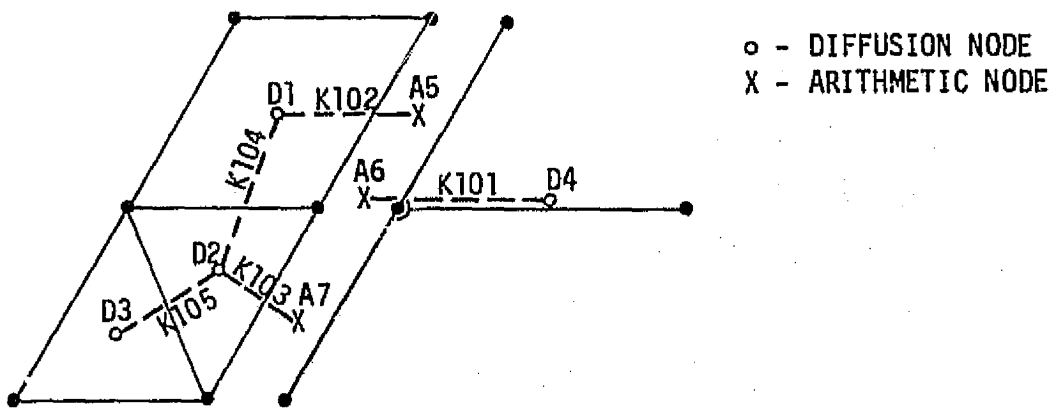


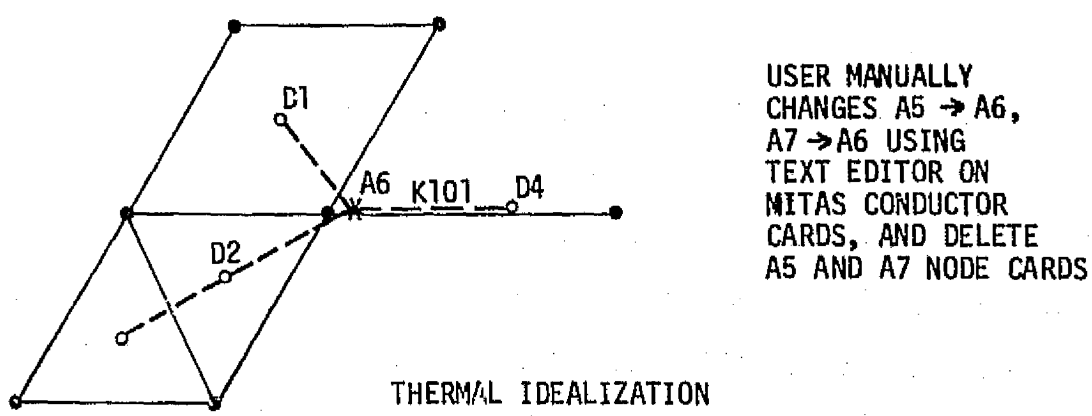
Figure 3 . Typical Pipe/Fluid Model



FINITE ELEMENT IDEALIZATION



GRAPHICAL DISPLAY



THERMAL IDEALIZATION

Figure 4. Conduction Transistion From 1-D to 2-D Elements.

Section 2

THERMAL MESH GENERATION -SPAR PROGRAM

The SPAR program is a finite element structural and thermal analysis program which operates on a common data base using mutiple processors. Three of these processors are designed to input to the data base, all of the necessary physical and material properties of the thermal problem. These processors, TAB, TELD and AUS are well suited for the task of finite element mesh generation since they utilize free field input and have extensive options for automated mesh generation. The TAB and TELD processors have been modified to output joint location and element connection data cards of the thermal model, which can be interpreted by the CINGEN program.

The following sections describe the capability of the SPAR, TAB, TELD and AUS processors for mesh generation, illustrate typical deck setups, and describe input and output data cards.

2.1 CAPABILITY

Within the TAB and TELD processors are several subprocessors which perform specific input and output tasks. The following subprocessors are used for thermal model mesh generation.

Processor TAB (CDC) or TABX (UNIVAC)

Parameter:

ONLINE - A parameter used to control printout and punch card output.

Subprocessors:

START - Used to define the number of joints or grid points used in the finite element model; list of excluded joint motion components.

JLOC - Used to define the joint location (X,Y,Z) with a reference coordinate system. This subprocessor allows for automatic mesh generation through "loop-limit" logic.

Processor TELD (CDC or UNIVAC)

The TELD processor provides for thermal element definition. Elements which may be generated include conduction, one-way flow conductors, convection and radiation. The subprocessors described below are used to select the type of element and to direct card output for the CINGEN program.

Parameter,

CINGEN - A RESET parameter used to control punch card output.
NUTED - A RESET parameter used to select thermal element generation.

Subprocessors,

K21, K31, K41, K61, K81 - Used to generate 1-, 2-, and 3-dimensional thermal conduction finite elements. These subprocessors allow for automatic element generation through "Loop-Limit" logic.

Note: To obtain a one-way conductor (F21), a K21 element must be placed in element Group 2 during processing in the TELD processor (see Appendix A for a description on placing selected elements in a GROUP).

C21, C31, C41 - Used to generate 2-, 3-, and 4-node thermal convection surfaces. These processors allow for automatic element generation through "Loop-Limit" logic.

R21, R31, R41 - Used to generate 2-, 3-, and 4-node thermal radiation surfaces. These processors allow for automatic element generation through "Loop-Limit" logic.

Processor AUS (CDC or UNIVAC)

The AUS processor is a general matrix and table manipulation package which is used to input material and section properties, convection coefficients and radiation coefficients when generating a thermal finite element model. The procedure for using this processor has not been modified and no card output occurs from this processor. SPAR data blocks are generated for use in the TELD processor. Therefore, the AUS processor must be used to input properties prior to execution of the TELD processor.

TABLE - The table processor is used to input the SPAR thermal analyzer the conduction, convection and radiation properties, conductor thickness, and surface areas.

2.2 LIMITATIONS

The SPAR thermal analyzer is still under going development. As a result, material properties were not punched out automatically during TAB, AUS or TELD execution. These properties must be prepared manually by the user for input to the CINGEN program. This was not considered a severe limitation since most thermal problems involve only a small number of dissimilar materials.

Temperature dependent conduction, convection and radiation properties defined on SPAR input cards COND PROP, etc. are currently not used to generate the MITAS (or SINDA) temperature dependent ARRAYS. SPAR INPUT cards are described, however, for completeness; since some users may choose to analyze a problem using MITAS and SPAR.

There are no problem size restrictions when using SPAR for thermal model mesh generation. However, when large problems are involved, the user must RESET the CORE in the manner prescribed by the SPAR program and adequare mass storage must be provided for holding the punch card output.

2.3 INPUT/OUTPUT DESCRIPTION

This section describes each type of input card available for generating grid mesh and thermal finite element networks. The OUTPUT from SPAR is punched cards. The output format of each card is described under "REMARKS" on each input card description.

SPAR DATA CARD DESCRIPTION

Subprocessor: JLOC

Description: Use to produce the position coordinates of the finite element joints.

Format and Example:

JLOC

K, XA_1, XA_2, XA_3, XB_1, XB_2, XB_3, NI, IJUMP, NJ,
(if NJ is given a second card must appear)
JJUMP, XC_1, XC_2, XC_3, XD_1, XD_2, XD_3

JLOC

1, 0.1, 5.2, 3.0 (Figure A)

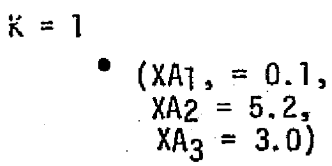
66, 1.0, 1.0, 2.0, 10.0, 1.0, 2.0, 10 (Figure B)

5, 1.0, 1.0, 2.0, 10.0, 1.0, 2.0, 10, 2, 2 (Figure C)
1, 1.0, 1.0, 4.0, 10.0, 1.0, 4.0

Field	Contents
JLOC	Subprocessor of TABX (UNIVAC) or SPAR PUNCH TAB
K	Joint index
XA_1, XA_2, XA_3	Joint A coordinate location
XB_1, XB_2, XB_3	Joint B coordinate location
XC_1, XC_2, XC_3	Joint C coordinate location
XD_1, XD_2, XD_3	Joint D coordinate location
NI	Number of joints defined in the I-direction
IJUMP	Increment added to the joint index in the I-direction.
NJ	Number of joints defined in the J-direction
JJUMP	Increment added to the joint index in the J-direction.

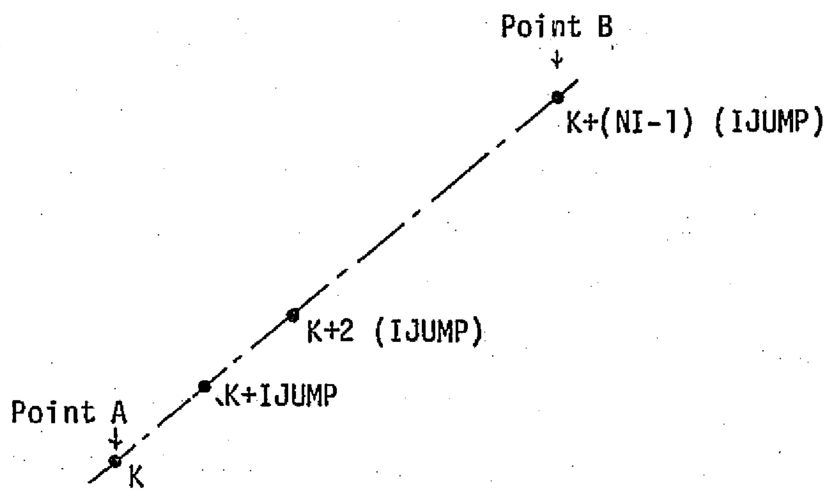
<u>OPTION 1</u>

Only one joint (k) is define at location XA_1, XA_2, XA_3



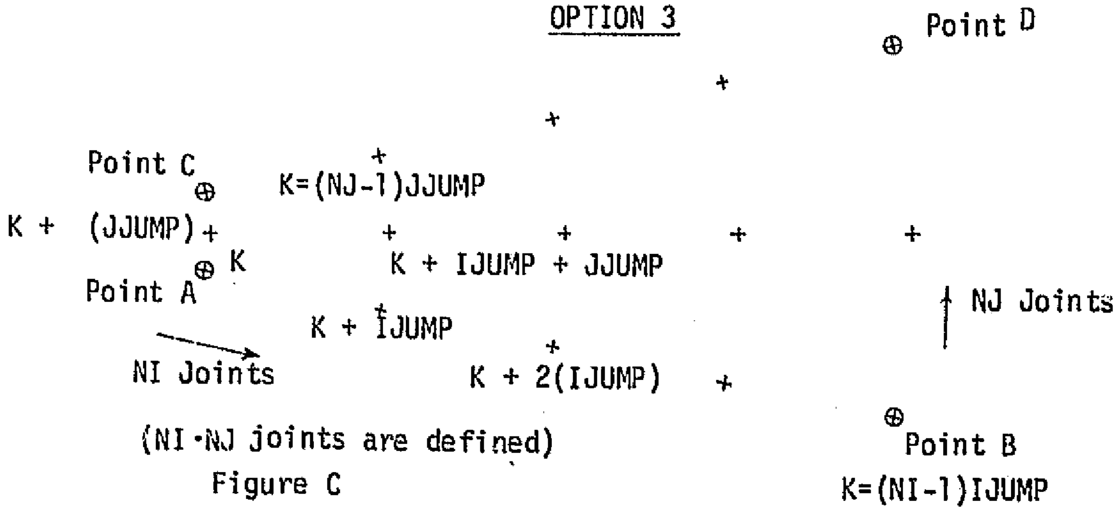
<u>Figure A</u>

<u>OPTION 2</u>



<u>Figure B</u>

OPTION 3



(NI·NJ joints are defined)

Figure C

Remarks:

1. There are three possible interpretations of the input card. Each is described in Figures A, B, and C.

2. TABX (Univac) or Sparpunch TAB (CDC) must be used to obtain Grid card punch output for use by the CINGEN or GEOMPLT programs.

3. Punch card output is selected by the ONLINE parameter. Where,

ONLINE = 0 Minimum printout
1 Normal printout (DEFAULT)
2 Maximum printout
3 Print SPAR output and punch NASTRAN GRID card with displacement coordinate system (Field 7) blank.
4 Print SPAR output and punch NASTRAN GRID card with displacement coordinate system (Field 7) equal to local grid point coordinate system.

Example:
```
@XQT TABX
ONLINE = 3
Start 125
JLOC
5, 1.0, 1.0, 10.7
```

4. The GRID card punch output format is:

GRID GID GD X1 X2 X3 CD (A4, 4X, 2I8, 3F8.3, I8)

Where,

GID = Grid point number.
GD = Local coordinate system used to define GRID location
X1 = Local X position coordinate
X2 = Local Y position coordinate
X3 = Local Z position coordinate
CD = Displacement coordinate system.

5. See Appendix A for detail discussion on JLOC prodecures.

Subprocessor: K21, C21 or R21

Description: These subprocessors are used to generate a 2-node, one-dimensional conduction, convection or radiation element.

Format and Example (Typical):

K21

NMAT = nmat
NSECT = J

J1, J2, Netopt, NI, JK, JINC (if Netopt = 1 or 2)
J1, J2, Newtop, NI, IINC, NJ, JINC (if Netopt =3)

K21

NMAT = 5
NSET = 2
NSECT
9, 12, 1, 4, 2, 100 (Figure a)

9, 12, 2, 4, 2, 100 (Figure b)

4, 37, 3, 4, 10, 2, 100 (Figure c)

Field	Contents
K21	2-node conduction element subprocessor
C21	2-node convection element subprocessor
R21	2-node radiation element subprocessor
J1	First joint number of first element generated
J2	Second joint number of first element generated
Netopt	Element network option
NI	Number of elements generated in the I-direction
NJ	Number of elements generated in the J-direction
IINC	Increment added to joints in the I-direction
JINC	Increment added to joints in the J-direction
NMAT	Material property table pointer (nmat, nfilm, nrad)
NSECT	Section property table pointer (J)

NETOPT = 1

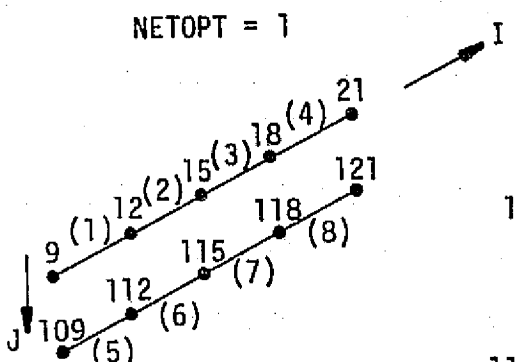


Figure a

NETOPT = 2

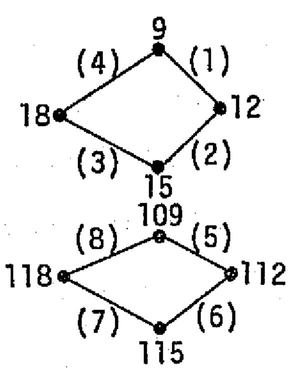


Figure b

NETOPT = 3

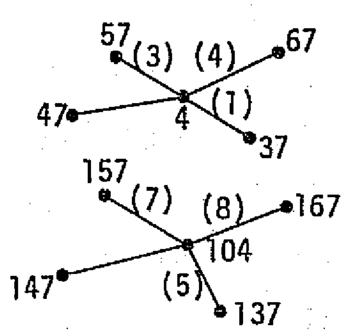


Figure c

Remarks:

1. The order in which the elements are defined is indicated by the number enclosed in parentheses. The index number (EID) identifying elements within each group are determined by the order in which the elements are defined.

2. Conduction properties are selected by the table pointer NMAT = nmat, where nmat = table number (default = 1) of the data block "COND PROP NMAT 9".

3. Section properties (Area) are selected by the table pointer nsect = J, where J = table number (default = 1) of the data block "K Area nsect 9" for conduction elements; "C CIRC nsect 2" for convection element; and "R CIRC nsect 2" for radiation elements.

4. Convection properties (h) are selected by the table pointer NMAT = nfilm where nfilm = table number (default = 1) of the data block "CONV PROP nmat 2".

5. Radiation properties ($\varepsilon\sigma F$) are selected by the table pointer NMAT = nrad, where nrad = table number (default = 1) of the data block" RADI PROP nmat 2".

6. One card is punched for each element if the parameter CINGEN = 1 is RESET. Punch card format is,

```
K21   EID  nmat    J1    J2   Area     (A3, 5X, 4I8, 1PE16.7)
C21   EID  nfilm   J1    J2   Acirf.   (A3, 5X, 4I8, 1PE16.7)
R21   EID  nrad    J1    J2   Acirf.   (A3, 5X, 4I8, 1PE16.7)
```

7. A single element may be generated by specifying only J1, J2.

8. Surface elements are defined for CINGEN arithmetic nodes if:

   Area = 0.0 for K21 elements

9. Arithmetic nodes are defined at the centroid of C21 and R21 elements. If more than one element type exists at the same spatial location, CINGEN will generate only one MITAS arithmetic node. Nodes are not created for 2-grid point elements.

10. To obtain a one-way conductor (F21), a K21 element must be placed in element GROUP 2, e.g.,

```
@XQT TELD
RESET CINGEN = 1, NUTED = 1
K21
GROUP 1' Pipe Conduction )
46   47   1   3   1        )          Punch K21 elements
50   51   1   4   1        )
GROUP 2' One-way Flow Conduction )
55   56   1   2   1              )    Punch F21 elements
```

Subprocessor: K31, C31, R31
K41, C41, R41

Description: These subprocessors are used to generate 3- or 4-node two-dimensional conduction, convection or radiation elements.

Format and Example (Typical):

K31

NMAT = nmat
NSECT = J

J1, J2, J3, Netopt, NI, NJ (if Netopt = 1
J1, J2, J3, Netopt, NI, NJ, JINC (if Netopt = 2 or 3)

K41

NMAT = nmat

J1, J2, J3, J4, Netopt, NI, NJ, NK, KINC (if Netopt = 1)
J1, J2, J3, J4, Netopt, NI, NJ (if Netopt = 2)

K31

NMAT = 5
NSECT =3

2, 3, 103, 1, 3, 2 (Figure a)

2, 5, 7, 2, 6, 30 (Figure b)

2, 5, 7, 3, 6, 2, 30 (Figure c)

K41

2, 3, 23, 22, 1, 2, 3, 2, 200 (Figure d)

1, 11 12, 2, 2, 6, 3 (Figure e)

Field	Contents
K31,K41	3- or 4-node conduction element subprocessor
C31,C41	3- or 4-node convection element subprocessor
R31,R41	3- or 4-node radiation element subprocessor
J1	first joint number of first element generated
J2	second joint number of first element generated
J3	third joint number of first element generated
J4	fourth joint number of first element generated
Netopt	element network option
NI	number of elements generated in the I-direction
NJ	number of elements generated in the J-direction
NK	number of elements generated in the K-direction
KINC	increment added to joints in the K-direction
NMAT	material property table pointer (nmat, nfilm, nrad)
NSECT	section property table pointer (J)

3 NODE, NETOPT = 1

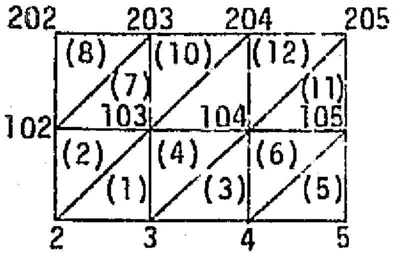


Figure a

3 NODE, NETOPT = 2

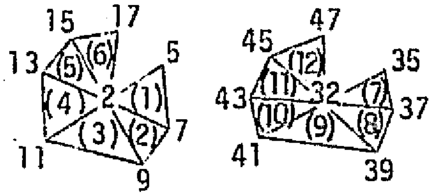


Figure b

3 NODE, NETOPT = 3

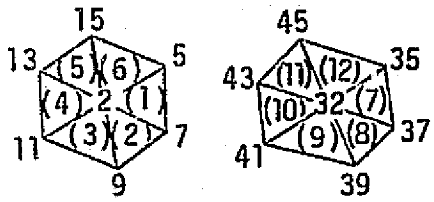


Figure c

4 NODE, NETOPT = 1

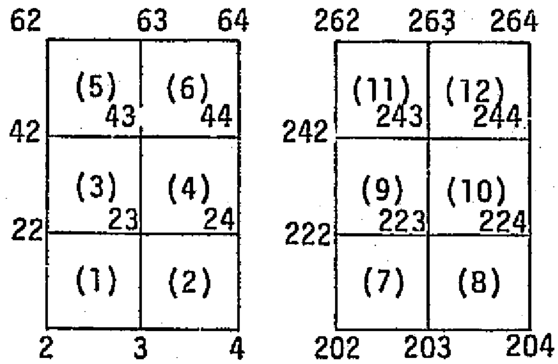


Figure d

4 NODE, NETOPT = 2

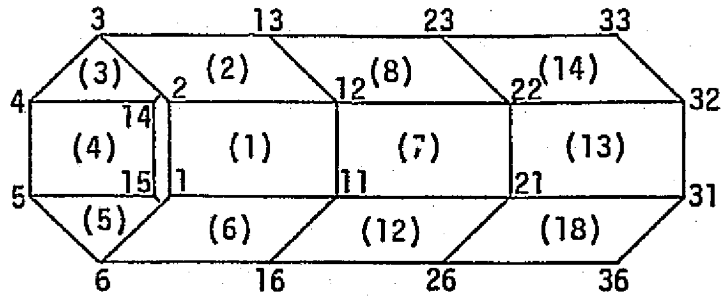


Figure e

Remarks:

1. The order in which the elements are defined is indicated in the above figures by the number enclosed in parentheses. The index number (EID) identifying elements within each group are determined by the order in which the elements are defined.

2. Conduction properties are selected by the table pointer NMAT= nmat, where nmat = table number (default = 1) of the data block COND PROP nmat 9".

3. Section properties (thickness) are selected by the table pointer NSECT=J, where J = table number (default = 1) of the data block "K THIC nsect 2" for conduction elements.

4. Convection properties (h) are selected by the table pointer NMAT = nfilm where nfilm = table number (default = 1) of the data block, "CONV PROP nfilm 2".

5. Radiation properties ($\varepsilon\sigma F$) are selected by the table pointer NMAT = nrad where nrad = table number (default = 1) of the data block "RADI PROP nrad 2".

Remarks:

6. One card is punched for each element if the parameter CINGEN = 1 is RESET. Punch card format is,

K31	EID	MID	J1	J2	J3	thick		(A3, 5X, 5I8, 1PE16.7)
C31	EID	NFILM	J1	J2	J3			(A3, 5X, 5I8)
R31	EID	NRAD	J1	J2	J3			(A3, 5X, 5I8)
K41	EID	MID	J1	J2	J3	J4	thick	(A3, 5X, 6I8, 1PE16.7)
C41	EID	NFILM	J1	J2	J3	J4		(A3, 5X, 6I8)
R41	EID	NRAD	J1	J2	J3	J4		(A3, 5X, 6I8)

7. A single element may be generated by specifying only J1, J2, J3, or J1, J2, J3, J4.

8. Surface elements are defined for CINGEN arithmetic nodes if:

   Thick = 0.0, for K31 and K41 elements.

9. Arithmetic nodes are defined at the centroid of C31, C41, R31, and R41 elements. If more than one element type exists at the same spatial location, CINGEN will generate only one MITAS arithmetic node.

SPAR DATA CARD DESCRIPTION

SUBPROCESSOR: K61

Description: Subprocessor used to generate a 6-node pentahedron conduction element.

Format and Example:

K61 (A3)

NMAT = nmat

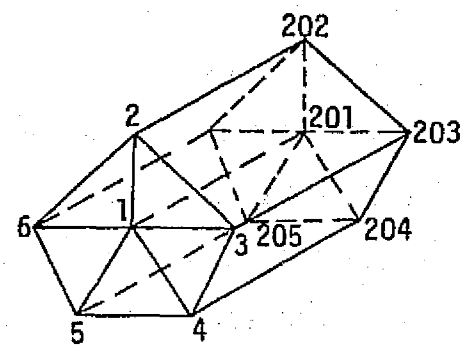
JA, JB, NJ, NK, JINC, KINC, ICLOSE, NETOPT (free field, use space or comma as delimiter)

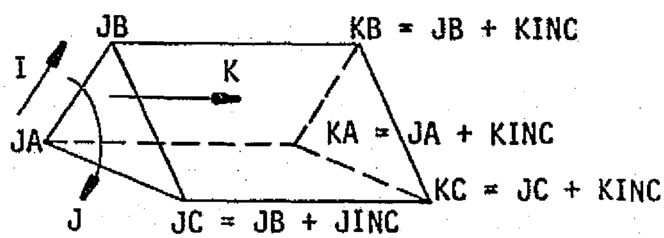
K61

NMAT = 5

1, 2, 5, 1, 1, 200, 1, 1

Field	Contents
K61	Element generation processor for 6-node pentahedron conduction element
JA	First node of a fan of elements (pivotal node)
JB	Second node (first node on outer edge of fan)
NJ	Number of elements in the fan (default = 1)
NK	Number of element layers (default = 1)
JINC	Increment added to JB resulting in index for JC = JB + JINC
KINC	Increment added to JA, JB, JC resulting in KA, KB, KC
ICLOSE	0 = Open Fan (default) 1 = Closed Fan
NETOPT	Element Network option, 0 = Single element (default) 1 = Fan network
NMAT	Table pointer for conduction properties (default = 1) See COND PROP input card description





CLOSED PENTAHEDRON FAN

REMARKS:

1. Conduction properties are selected by the table pointer, NMAT = nmat, where nmat = table number (default = 1) of the data block "COND PROP nmat 9."

2. Element identification numbers (EID) are assigned by the SPAR Program.

3. One card is punched for each element if the parameter CINGEN is RESET to 1 at the start of the TELD processor e.g.,

   @XQT TELD

   RESET CINGEN = 1, NUTED = 1

   K61

   etc.....

4. Punch card format is:

Card 1: K61 EID MID JA JB JC KA KB KC (A3, 5X, 8I8)

5. When NETOPT=0, input 6 joints for a single element.

SPAR DATA CARD DESCRIPTION

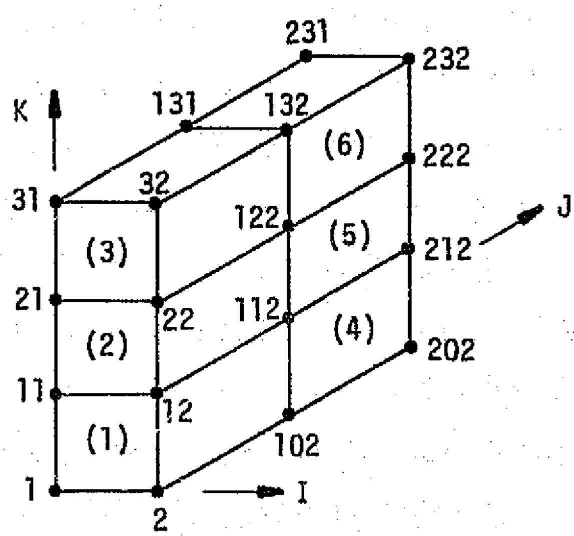
Subprocessor: K81

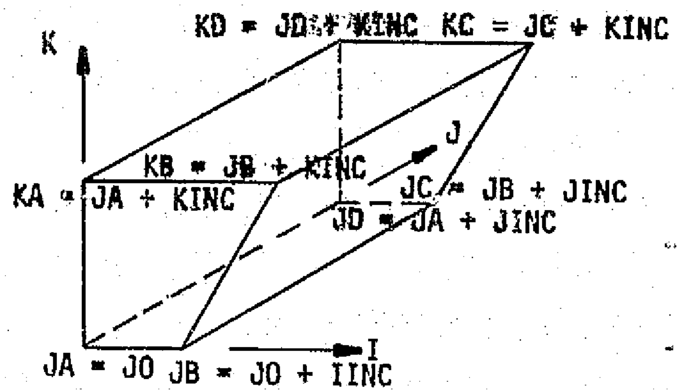
Description: Subprocessor used to generated an 8-node hexahedron conduction element.

Format and Example:

```
K81
J0, NI, NJ, NK, IINC, JINC, KINC, ICLOSE, NETOPT

K81
NMAT=2
1, 1, 2, 3, 1, 100, 10, 0, 1
```

Field	Contents
K81	Element generation subprocessor for 8-node hexahedron conduction element.
J0	Starting joint number
NI	Number of elements in the I-direction
NJ	Number of elements in the J-direction
NK	Number of elements in the K-direction
IINC	Increment added to joints in I-direction
JINC	Increment added to joints in J-direction
KINC	Increment added to joints in K-direction
ICLOSE	0 = OPEN string of elements in I-direction 1 = CLOSED (Ring) string of elements in I-direction
NMAT	Table pointer for conduction properties (default = 1)
NETOPT	Element network option 0 = single element (default) 1 = network in 3 directions





REMARKS:

1. Conduction properties are selected by the table pointer, NMAT = nmat where nmat = table number (default =1) of the data block "COND PROP nmat 9."

2. Element identification numbers (EID) are assigned by the SPAR Program in the order they are generated.

3. Two cards are punched for each element if the parameter CINGEN is RESET to 1 at the start of the TELD processor.

4. Punch card format is:

Card 1:	K81 EID NMAT JA JB JC JD KA KB	(A3, 5X, 8I8)
Card 2:	KC KD	(8X, 2I8)

5. When NETOPT = 0, input 8 joints for a single element.

Table: K AREA
or
K THIC

Description: Defines tables of conduction area or thickness

Format and Example:

```
TABLE (NI = 1, NJ = j) ; K  AREA 1 ; J = 1, j
A1, A2, .. Aj

TABLE (NI = 1, NJ = 3) ; K  AREA 1 ; J = 1, 3
0.16, 2.45, 1.73
                OR

TABLE (NI = 1, NJ = j) ; K  THIC 1 ; J = 1, j
t1, t2, .....tj

TABLE (NI = 1, NJ = 1) ; K  THIC 1 ; J = 1
0.025
```

Field	Contents
TABLE	name of the AUS subprocessor used to create a new table in the SPAR data complex.
j	number of areas or thickness input in table.
A	area
t	thickness

Remarks:

1. The thickness is selected by the table pointer nsect = J, during K31 or K41 conduction element generation in processor TELD.

2. The area is selected by the table pointer nsect = J, during K21 Conduction element generation in processor TELD. J points to a data item in "K AREA 1" Table.

3. No punch card output is created for CINGEN.

4. The 5/8 punch (: on UNIVAC) or 12/8/7 punch (; on CDC) terminates one record and initiates a new record on the same card.

SPAR DATA CARD DESCRIPTION

Table: C CIRC
R CIRC

Description: Defines tables for convection and radiation surface areas for 1 dimensional elements.

Format and Example:

TABLE (NI = 1, NJ = j) ; C CIRC 1 ; J = 1, j
C_1, C_2,... C_j

TABLE (NI = 1, NJ = 3) ; C CIRC 1 ; J = 1, 3
0.16, 2.45, 1.73

OR

TABLE (NI = 1, NJ = j) ; R CIRC 1 ; J = 1, j
C_1, C_2, ...C_j

TABLE (NI = 1, NJ = 1) ; R CIRC 1 ; J = 1
0.025

Field	Contents
TABLE	name of the AUS subprocessor used to create a new table in the SPAR data complex
j	number of circumferences input in table
C	circumference

Remarks:

1. The circumference is selected by the table pointer ,nsect = J, during C21 or R21 convection or radiation element generation in processor TELD.
2. No punch card output is created for CINGEN.
3. The 5/8 punch (: on UNIVAC) or 12/8/7 punch (; on CDC) terminates one record and initiates a new record on the same card.

SPAR DATA CARD DESCRIPTION

Table: COND PROP

Description: Defines the temperature dependent property tables.

Format and Example:

Table (NI = i, NJ = j) ; COND PROP nmat ; I = 1, 2, .. NI; J = 1, j
T, ρ, c, K_{11}, K_{22}, K_{33}, K_{12}, K_{23}, K_{31}

Table (NI = 9, NJ = 1) ; COND PROP 1 ; I= 1, 2, 3, 4 ; J=1
0., 1., 1., 20

Field	Contents
TABLE	name of the AUS subprocessor used to create a new table in the SPAR data complex
i	number of constants input
j	number of data lines corresponding to temperature T.
nmat	material ID (integer > 0)
T	Temperature
ρ	mass density (at temperature T)
c_v	specific heat (at temperature T)
K_{11} - K_{31}	conductivity (at temperature T)defined with respect to the element coordinates. Default = 0.

Remarks:

1. Conduction properties are selected by the table pointer, NMAT = nmat during conduction element (K21, K31, etc) generation in processor TELD.

2. If conduction properties are temperature dependent, set NJ = j where j equal the number of temperatures used to define the material properties. "j" data lines follow the TABLE card, each data line defines the properties corresponding to Temperature T.

3. No punch card output is created for CINGEN.

4. All required K_{ij} must be input.

SPAR DATA CARD DESCRIPTION

Table: CONV PROP

DESCRIPTION: Defines the temperature dependent convective film coefficient.

Format and Example:

```
TABLE (NI = 2 NJ = j) ; CONV PROP nfilm ; J = 1, j
T, h

TABLE (NI = 2, NJ = 2); CONV PROP nfilm; J = 1, 2
100., 1. + 5
200., 1.5 + 5
```

Field	Contents
TABLE	name of the AUS subprocessor used to create a new table in the SPAR data complex.
j	number of data lines following the TABLE card.
nfilm	film coefficient property ID (integer > 0)
T	Temperature
h	film coefficient

Remarks:

1. Convection properties are selected by the table pointer, NMAT = nfilm, during convection (C21, C31, C41) element generation in processor TELD.

2. If convection properties are temperature dependent, set NJ = j, where j equal the number of temperatures used.

3. No punch card output is created for CINGEN.

SPAR DATA CARD DESCRIPTION

Table: RADI PROP

Description : Defines the temperature dependent radiation coefficient.

Format and Example:

```
TABLE (NI = 2  NJ = j)  ;  RADI PROP  nrad ; J = 1, j
T, ε

TABLE (NI = 2, NJ = 2)  ;  RADI PROP  nrad ; J = 1, 2
100., 0.5
200., 0.6
```

Field	Contents
TABLE	name of the AUS subprocessor used to create a new table in the SPAR data complex.
j	number of data lines following the TABLE card.
nrad	radiation coefficient ID (integer >0)
T	Temperature
ε	emissivity

Remarks

1. Radiation properties are selected by the table pointer, NMAT = nrad, during radiation (R21, R31, R41) element generation in processor TELD.

2. If radiation properties are temperature dependent, set NJ = j, where j equals the number of temperatures used.

3. No punch card output is created for CINGEN.

Section 3

FINITE ELEMENT TO LUMPED PARAMETER CONVERSION - CINGEN PROGRAM

CINGEN is a computer program developed by Sperry Support Services to aid the analyst in the development of thermal models. The program utilizes finite element input data, which can be generated from mesh generators, such as the SPAR TAB and ELD processors. This data is used to create a lumped parameter themal network formatted for thermal analyzer programs, such as CINDA, SINDA, and MITAS. CINGEN also creates data files for the production of temperature graphs and thermal network plots by the GEOMPLT program.

3.1 CAPABILITY AND METHOD

The CINGEN computer program has the capability of accepting SPAR or NASTRAN finite element data and generating 1-, 2-, and 3-dimensional lumped parameter thermal networks. Permissable element types include: conduction, one-way flow conductors, convection, and radiation. The conduction elements can have 2,3,4,6, or 8 grid points, the one-way flow element can have 2 grid points and radiation and convection elements can have 2,3, and 4 grid points. In each conduction or one-way flow, element, a thermal node is assigned to the element. These nodes can be either diffusion, arithmetic, or boundary nodes as determined by the density value selected for the element. Arithmetic and boundary type surface nodes are also available. Figure 5 presents a functional flow diagram of CINGEN.

In determining a diffusion node capacitance ($\rho C_V V$) a positive, real value must be input for the density (ρ). The specific heat (C_V) can be a positive, real value or a negative, real value for temperature dependent property. The volume (V) is calculated by the CINGEN program for each finite element. The volume of six (6) and eight (8) grid point elements is calculated by dividing the element into tetrahedrons and employing vector calculus to yield the exact volume. The volume of three (3) and four (4) grid point elements is calculated as the product of the element surface area (A) and the element thickness (t). The area is computed from the coordinate location of the element grid points, and the thickness is an

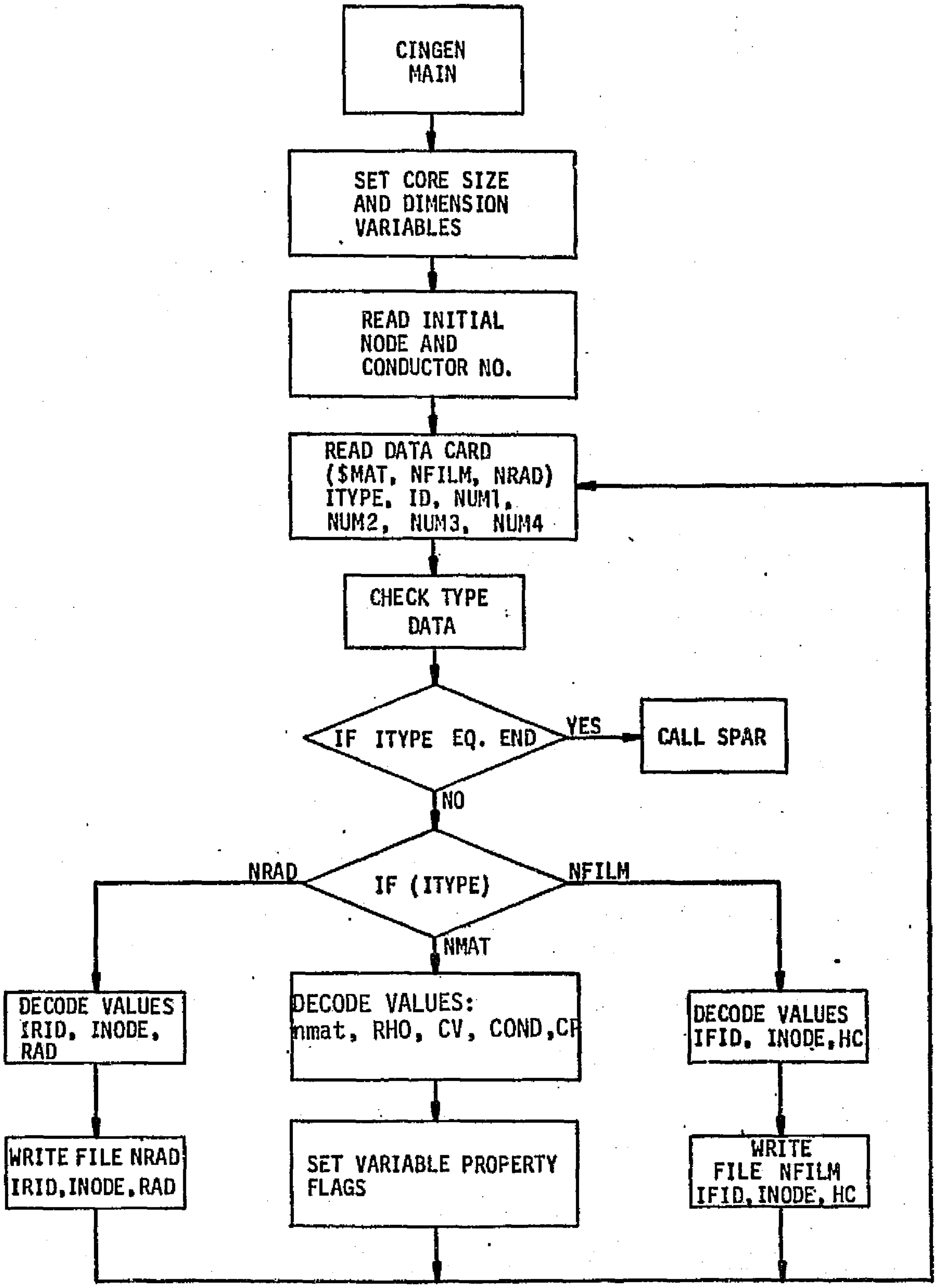


Figure 5, CINGEN Functional Flow Diagram

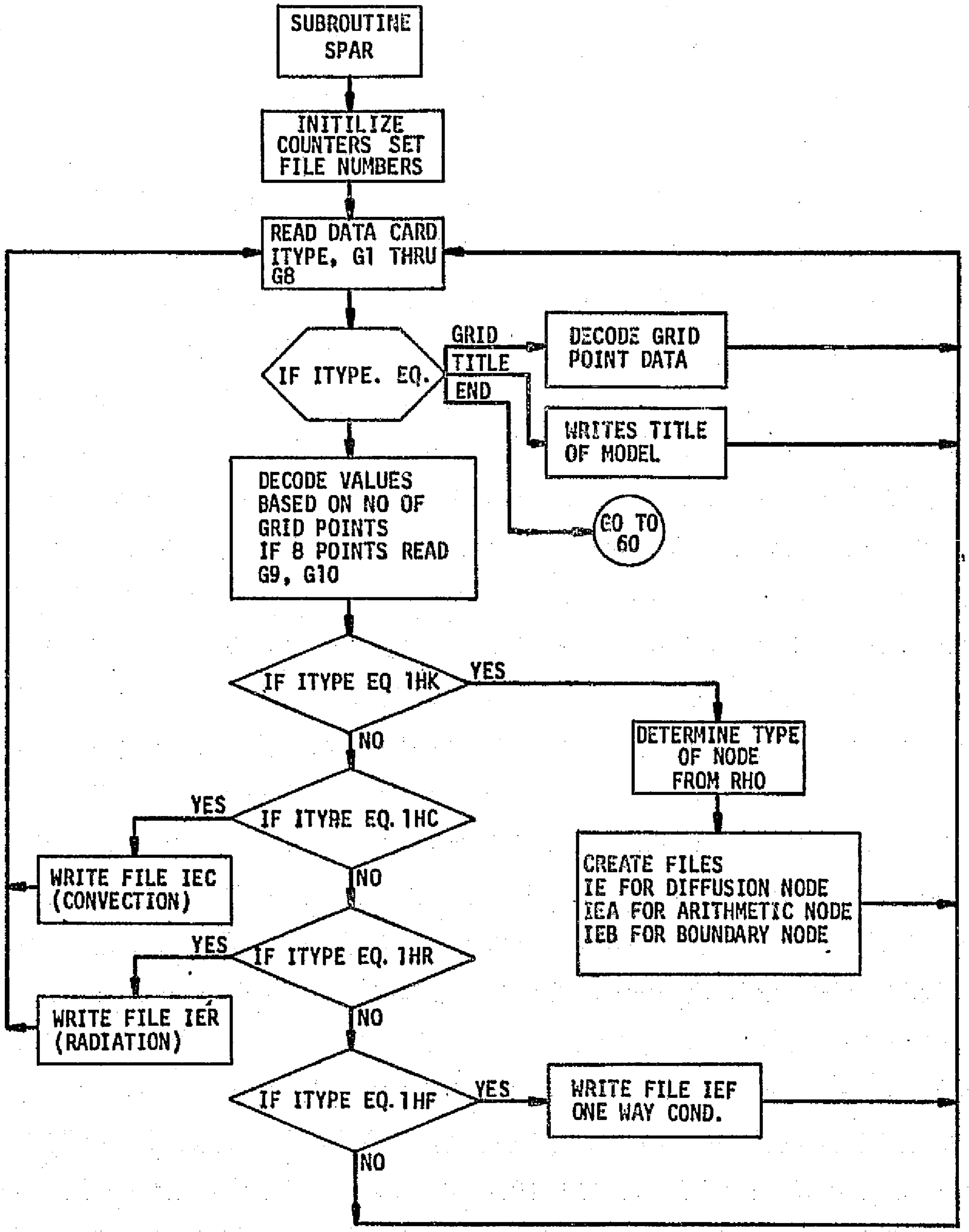


Figure 5 (continued)

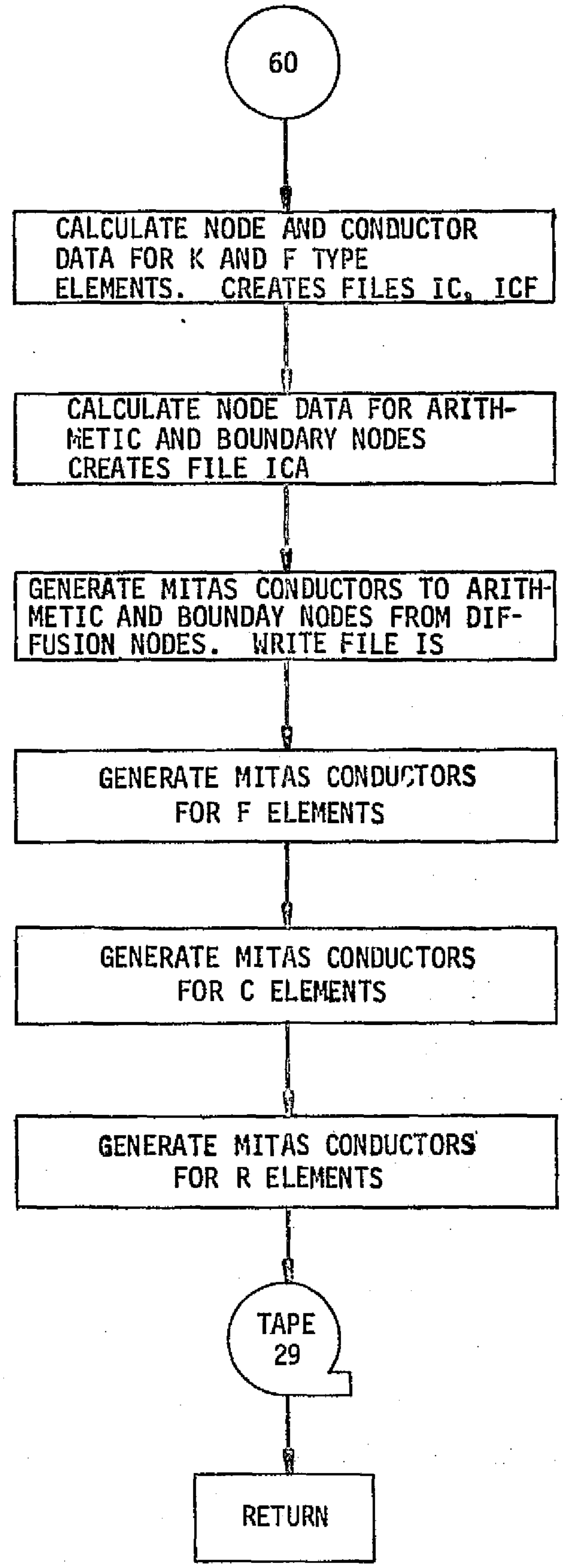


Figure 5 (continued)

input parameter (see CINGEN Data Card Section). The volume of a 2-grid point element is calculated as a product of the length of the element and the cross sectional area. The length is determined by the coordinate location of the grid points and the cross sectional area is an input parameter (see CINGEN Data Card Section). If there is variable specific heat (temperature dependent), the diffusion node would be output by CINGEN as a single interpolated node (MITAS type CGS). Variable specific heat is specified by using a negative specific heat on the element material card. The absolute value of the negative specific heat is used as the specific heat array number on the MITAS CGS card. (User must supply MITAS ARRAY DATA BLOCK.)

The center of gravity of the element is computed. Thermal resistance from the center of gravity to each face or edge is determined by the equation.

$$R = \frac{2 \cdot L_{cg}^2}{K \cdot Vol}$$

where

K = thermal conductivity
L_{cg} = distance from cg of element to the cg of the surface or edge
Vol = volume of element.

This equation produces accurate values of thermal resistance for elements with constant cross-secitonal area perpendicular to the direction of heat flow. Finite element modeling techniques require that element (triangular and quadrilateral plates) aspect ratios less than 3 to 1 be used for structural acceptable accuracy. This same rule should be applied to thermal modeling to assure modeling accuracy.

Temperature dependent thermal conductivity is defined similar to the variable specific heat. That is the conductivity is input as a negative value. Each edge (1D and 2D element) or face (3D element) is then assigned a coded number. After all of the conduction and one-way elements have been processed, the coded numbers are compared to determine common edges or faces. When two elements have a common edge or face, they are connected by a conductor equal to the reciprocal of the sum of the resistance to each face.

After all the conduction and one-way elements are connected by conductors the convection elements are processed. Convection can be applied to any type of element. The grid points on the convection element card are assigned a coded number then compared with the coded numbers for the conduction and one-way elements. When common edge or face is found a conductor is connected to that element given on the NFILM card. The convection rate (hc) is defined on the NFILM card (can be temperature varying) and the area is detrmined from the grid points on the convection card or read from the element card for 2 grid point nodes. Radiation conductors are processed after convection conductors. Radiation is applied the same way as convection except NRAD cards are used to define the radiative rate ($\epsilon\sigma F$). CINGEN multiplies this value by the area. An arithmetic node is generated on the surface. to which convection and radiation are applied. Only one node is generated for each surface.

3.2 LIMITATIONS

CINGEN has built-in program limitations which were used to reduce core requirements. These limitations are the number of material property cards and number of nodes. Explanation of these limitations and how to increase the number of material property cards and nodes is given below.

1. NMAT cards are currently limited to 50 which should be adequate for most thermal problems. If more NMAT cards are required the following dimensional variables in common block /PROP/ of CINGEN (main program and subroutine SPAR) must have their dimensions increased to the desired limit. These variables are MAT7, RHO, CONDUC, CP, CV, CFLAG, and CVFLAG.

2. CINGEN is currently limited to a maximum of 500 nodes. This maximum can be changed by changing the following cards in the main routine of CINGEN

   COMMON BUCKET (19500)
   LOAN = 19500

   The number of nodes allowed is determined by the core size assigned (19500) to COMMON BUCKET. For 1000 nodes these cards would be

   COMMON BUCKET (39000) e.g. $\frac{\text{CORE}}{19500} = \frac{\text{NODES}}{500}$
   LOAN = 39000

3. The element ID (EID) and CINGEN node number must be the same if a node and conductor network are to be graphically displayed by GEOMPLT. That is, NODADD must be input as 0 (See page 3-13).

3.3 INPUT/OUTPUT DESCRIPTION

CINGEN is capable of processing both SPAR and NASTRAN elements. The acceptable SPAR elements are conduction (K21, K31, K41, K61 and K81), one-way flow element (F21), convection elements (C21, C31, and C41), and radiation elements (R21, R31, and R41). The acceptable property cards are NMAT, NFILM, and NRAD. NASTRAN type elements are CBAR, CTRI, CQUAD, CWEDGE, and CHEX. The program keys only on the first two characters of these element names. CINGEN reads data from files as assigned by the variable INP in the MAIN program. This value is currently set to 4 for reading file 4, change INP = 5 for card reader. Figure 6 shows the basic data set-up for CINGEN. The data is broken into two blocks. BLOCK 1 contains the NMAT, NFILM, and NRAD cards. The cards can be mixed and in any order. BLOCK 1 must be preceeded by '1st Input Record' and ended with an END card. These two cards are required by CINGEN. BLOCK 2 contains the TITLE card, GRID cards, and ELEMENT cards. These cards can be mixed and in any order. The TITLE card is not required. This data block is ended with a ENDDATA card.

CINGEN outputs a complete MITAS data deck except for the ARRAY and CONSTANTS data cards. The user must add these cards according to the array numbers assigned on the NMAT, NFILM, and NRAD cards and the constants required by his particular problem. Figure 7 is an example CINGEN output. CINGEN also creates a data file 29 (TAPE 29) which is used by GEOMPLT to graphically display the model. Figure 8 defines the variables output on TAPE 29 and their formats.

Data is input in any consistent set of units and the following pages describe the format of these data cards.

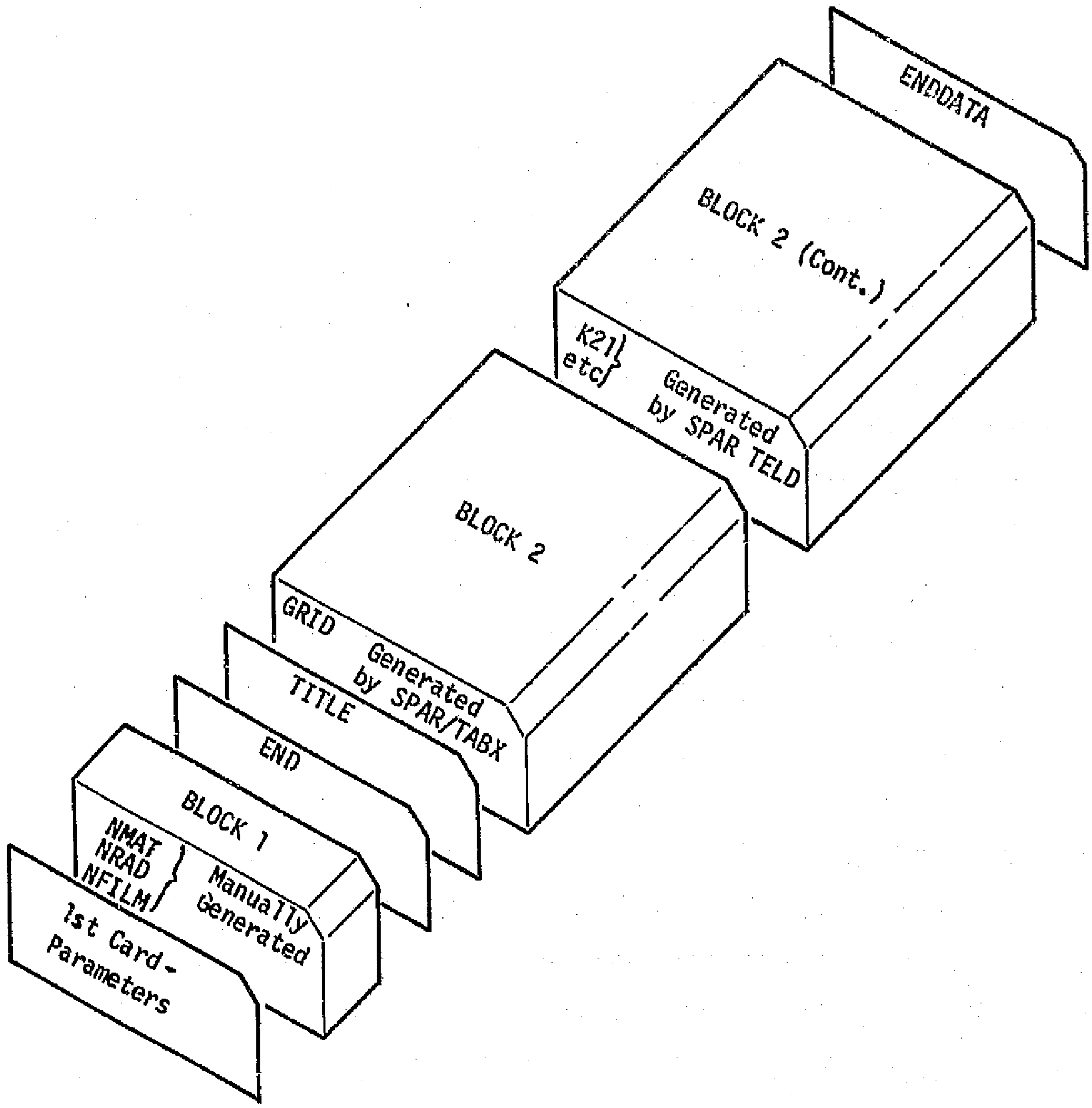


Figure 6, Deck Set Up for File 4, Input to CINGEN and GEOMPLT Programs.

```
000    BCD 6TITLE EXAMPLE NUMBER 2
000    BCD 6
000    END
000    BCD 3NODE DATA
000    CGS    1,   75.00,     A11,   .6312+01
000    CGS    2,   75.00,     A11,   .6312+01
000    CGS    3,   75.00,     A11,   .6312+01
000    CGS    4,   75.00,     A11,   .6312+01
000    CGS    5,   75.00,     A11,   .6312+01
000    CGS    6,   75.00,     A11,   .6312+01
000    CGS    7,   75.00,     A11,   .6312+01
000    CGS    8,   75.00,     A11,   .6312+01
000    CGS    9,   75.00,     A11,   .3156+01
000    CGS   10,   75.00,     A11,   .3156+01
000    CGS   11,   75.00,     A11,   .3156+01
000    CGS   12,   75.00,     A11,   .3156+01
000    CGS   13,   75.00,     A11,   .6312+01
000    CGS   14,   75.00,     A11,   .6312+01
000    CGS   15,   75.00,     A11,   .6312+01
000    CGS   16,   75.00,     A11,   .6312+01
000    CGS   17,   75.00,     A11,   .6312+01
000    CGS   18,   75.00,     A11,   .6312+01
000          47,   75.00,   .0000
000          48,   75.00,   .1025+00
000          49,   75.00,   .1025+00
000          56,   75.00,   .1380-01
000          57,   75.00,   .1380-01
000          19,   75.00,  -.1000+01
000          20,   75.00,  -.1000+01
000          21,   75.00,  -.1000+01
000          22,   75.00,  -.1000+01
000          23,   75.00,  -.1000+01
000          32,   75.00,  -.1000+01
000          33,   75.00,  -.1000+01
000          34,   75.00,  -.1000+01
000          35,   75.00,  -.1000+01
000          36,   75.00,  -.1000+01
000         -50,   75.00,   .0000
000         -51,   75.00,   .0000
000         -52,   75.00,   .0000
000         -53,   75.00,   .0000
000         -54,   75.00,   .0000
000         -55,   75.00,   .0000
000    END
000    BCD 3CONDUCTOR DATA
000    CGS    1,   19,    5,     A13,   .2000+02
000    CGS    2,   20,    6,     A13,   .2000+02
000    CGS    3,   21,    7,     A13,   .2000+02
000    CGS    4,   22,    8,     A13,   .2000+02
000    CGS    5,   23,   18,     A13,   .5625+01
000    CGS    6,   32,   11,     A13,   .1000+02
000    CGS    7,   33,   12,     A13,   .1000+02
000    CGS    8,   34,   14,     A13,   .2000+02
000    CGS    9,   35,   16,     A13,   .2000+02
000    CGS   10,   36,   18,     A13,   .2000+02
```

DIFFUSION NODES

ARITHMETIC NODES

BOUNDARY NODES

Figure 7. Thermal Model Created By CINGEN For MITAS

000056	000	CGS	11,	1,	2,	A13,	.2500+01	
000057	000	CGS	12,	1,	3,	A13,	.2500+01	
000058	000	CGS	13,	1,	5,	A13,	.1000+02	
000059	000	CGS	14,	2,	4,	A13,	.2500+01	
000060	000	CGS	15,	2,	6,	A13,	.1000+02	
000061	000	CGS	16,	3,	4,	A13,	.2500+01	
000062	000	CGS	17,	3,	7,	A13,	.1000+02	
000063	000	CGS	18,	3,	9,	A13,	.1800+01	
000064	000	CGS	19,	4,	8,	A13,	.1000+02	
000065	000	CGS	20,	4,	10,	A13,	.2647+01	
000066	000	CGS	21,	5,	6,	A13,	.2500+01	
000067	000	CGS	22,	5,	7,	A13,	.2500+01	
000068	000	CGS	23,	6,	8,	A13,	.2500+01	
000069	000	CGS	24,	7,	8,	A13,	.2500+01	
000070	000	CGS	25,	7,	11,	A13,	.1800+01	
000071	000	CGS	26,	8,	12,	A13,	.2647+01	
000072	000	CGS	27,	9,	10,	A13,	.1406+01	
000073	000	CGS	28,	9,	11,	A13,	.5000+01	
000074	000	CGS	29,	9,	13,	A13,	.2812+01	
000075	000	CGS	30,	10,	12,	A13,	.5000+01	
000076	000	CGS	31,	10,	15,	A13,	.2813+01	
000077	000	CGS	32,	11,	12,	A13,	.1406+01	
000078	000	CGS	33,	11,	14,	A13,	.2812+01	
000079	000	CGS	34,	12,	16,	A13,	.2813+01	
000080	000	CGS	35,	13,	14,	A13,	.1000+02	
000081	000	CGS	36,	13,	17,	A13,	.2813+01	
000082	000	CGS	37,	14,	18,	A13,	.2813+01	
000083	000	CGS	38,	15,	16,	A13,	.1000+02	
000084	000	CGS	39,	15,	17,	A13,	.2813+01	
000085	000	CGS	40,	16,	18,	A13,	.2813+01	
000086	000	CGS	41,	17,	18,	A13,	.1000+02	
000087	000		42,	47,	48,	.5065-04		
000088	000		43,	48,	49,	.2533-04		
000089	000		44,	-56,	57,	.8624+00		ONE-WAY CONDUCTOR
000090	000		45,	19,	50,	.2500+01		
000091	000		46,	20,	50,	.2500+01		
000092	000		47,	21,	51,	.2500+01		
000093	000		48,	22,	51,	.2500+01		
000094	000		49,	32,	52,	.1250+01		
000095	000		50,	33,	52,	.2500+01		
000096	000		51,	34,	53,	.5000+01		
000097	000		52,	35,	53,	.2500+01		
000098	000		53,	36,	53,	.2500+01		
000099	000		54,	40,	56,	.3925+01		
000100	000		55,	49,	57,	.3925+01		
000101	000		-56,	19,	33,	.5750-13		
000102	000		-57,	20,	50,	.5750-13		
000103	000		-50	21,	51,	.5750-13		
000104	000		-59,	22,	51,	.5750-13		
000105	000		-60,	32,	52,	.2875-13		RADIATION CONDUCTORS
000106	000		-61,	33,	52,	.2875-13		
000107	000		-62,	34,	53,	.5750-13		
000108	000		-63,	35,	53,	.5750-13		
000109	000		-64,	36,	53,	.5750-13		
000110	000		-65,	40,	54,	.4396-13		
000111	000		-66,	49,	55,	.4396-13		
000112	000	END						

Figure 7. (continued)

```
000          BCD 3CONSTANTS DATA
000          END
000          BCD 3ARRAY DATA
000          END
000          BCD 3EXECUTION
000              FORWRD
000          END
000          BCD 3VARIABLES 1
000          END
000          BCD 3VARIABLES 2
000          END
000          BCD 3OUTPUT CALLS
000              TPRINT
000          END
000          BCD 3END OF DATA
```


Figure 7 (continued)

000001	000	K	1A	19D	5	20.000	2.500	5.000	2.500	2.500	3.750	2.500
000002	000	K	2A	20D	6	20.000	2.500	5.000	7.500	2.500	3.750	7.500
000003	000	K	3A	21D	7	20.000	7.500	5.000	2.500	7.500	3.750	2.500
000004	000	K	4A	22D	8	20.000	7.500	5.000	7.500	7.500	3.750	7.500
000005	000	K	5A	23D	10	5.625	20.000	3.750	5.000	18.333	3.750	5.000
000006	000	K	6A	32D	11	10.000	11.667	5.000	3.333	11.667	3.750	3.333
000007	000	K	7A	33D	12	10.000	11.667	5.000	6.667	11.667	3.750	6.667
000008	000	K	8A	34D	14	20.000	15.000	5.000	1.667	15.000	3.750	1.667
000009	000	K	9A	35D	16	20.000	15.000	5.000	8.333	15.000	3.750	8.333
000010	000	K	10A	36D	18	20.000	18.333	5.000	5.000	18.333	3.750	5.000
000011	000	K	11D	1D	2	2.500	2.500	1.250	2.500	2.500	1.250	7.500
000012	000	K	12D	1D	3	2.500	2.500	1.250	2.500	7.500	1.250	2.500
000013	000	K	13D	1D	5	10.000	2.500	1.250	2.500	2.500	3.750	2.500
000014	000	K	14D	2D	4	2.500	2.500	1.250	7.500	7.500	1.250	7.500
000015	000	K	15D	2D	6	10.000	2.500	1.250	7.500	2.500	3.750	7.500
00[illegible]	000	K	16D	3D	4	2.500	7.500	1.250	2.500	[illegible]	[illegible]	7.500
0000[illegible]	[illegible]	K	17D	3D	7	10.000	7.500	1.250	2.[illegible]	15.000	3.750	8.333
000035	000	[illegible]	18D	[illegible]	9	1.800	[illegible]	1.2[illegible]	1.667	15.000	3.750	1.667
000036	000	K	[illegible]	13D	[illegible]	[illegible]	15.000	1.250	1.667	18.333	1.250	5.000
000037	000	K	37D	14D	18	2.813	15.000	3.750	1.667	18.333	3.750	5.000
000038	000	K	38D	15D	16	10.000	15.000	1.250	8.333	15.000	3.750	8.333
000039	000	K	39D	15D	17	2.813	15.000	1.250	8.333	18.333	1.250	5.000
000040	000	K	40D	16D	18	2.813	15.000	3.750	8.333	18.333	3.750	5.000
000041	000	K	41D	17D	18	10.000	18.333	1.250	5.000	18.333	3.750	5.000
000042	000	K	42D	47D	48	.000	20.000	3.750	5.000	22.500	3.750	5.000
000043	000	K	43D	48D	49	.000	22.500	3.750	5.000	27.500	3.750	5.000
000044	000	F	48D	56D	57	.062	22.500	8.000	5.000	27.500	8.000	5.000
000045	000	C	45A	19B	50	2.500	2.500	5.000	2.500	2.500	10.000	5.000
000046	000	C	46A	20B	50	2.500	2.500	5.000	7.500	2.500	10.000	5.000
[illegible]	000	C	[illegible]	[illegible]	[illegible]	[illegible]	2.500	5.000	2.500	7.500	10.000	5.000
000[illegible]	000	C	[illegible]A	22B	51	.000	7.500	5.000	7.500	7.500	10.000	5.000
000060	[illegible]	[illegible]	60A	32B	52	.000	11.667	5.000	3.333	12.500	10.000	5.000
000061	000	R	61A	33B	52	.000	11.667	5.000	6.667	12.500	10.000	5.000
000062	000	R	62A	34B	53	.000	15.000	5.000	1.667	17.500	10.000	5.000
000063	000	R	63A	35B	53	.000	15.000	5.000	8.333	17.500	10.000	5.000
000064	000	R	64A	36B	53	.000	18.333	5.000	5.000	17.500	10.000	5.000
000065	000	R	65D	48B	54	.000	22.500	3.750	5.000	22.500	10.000	5.000
000066	000	R	66D	49B	55	.000	27.500	3.750	5.000	27.500	10.000	5.000

Figure 8. Typical Data File 29 as Created by CINGEN

Card: 1st INPUT RECORD

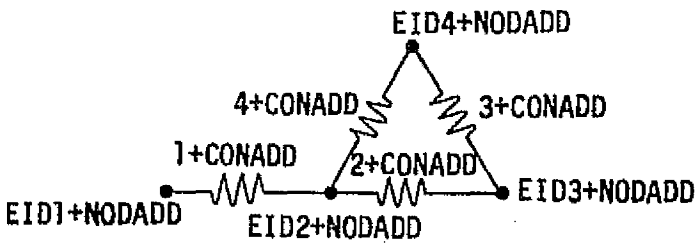
Description: This card increments all element and conductor numbers, specifies the type of coordinate system used, and defines initial reference temperature of all thermal nodes.

Format and Example:

NODADD, CONADD, ICS, $T_{initial}$, ETYPE (2I8,7X,A1,F8.3)

0 500 R 75.

Field	Contents
NODADD	Integer that will be added to element number to form the node number, NODE NO. = EID+NODADD.
CONADD	The conductors are numbered sequently from beginning with CONADD.
ICS	≠C retangular coordinate system
	=C cylinderical coordinate system
$T_{initial}$	Initial reference temperature used on all MITAS node cards.
ETYPE	= NAST, NASTRAN type elements ≠ NAST, SPAR type input



Where, the EIDi are element numbers assigned during element generation in the SPAR program. Then,
NODE NO. = EID + NODADD

Remarks:

1. The EID's shown in the above figure are the element numbers assigned during finite element generation in the SPAR program.

2. The node number assigned by CINGEN will be
   NODE NO. = EID + NODADD

3. The conductors shown in the above figure are numbered by the CINGEN program. The numbering sequence begins with the first conductor generated by CINGEN and is numbered in the following way
   1st conductor NO.= 1 + CONADD
   2nd conductor NO.= 2 + CONADD
   :
   Nth conductor NO.= N + CONADD

4. NODADD must equal 0 for plotting (See page 3-6).

5. This card must be input.

CINGEN DATA CARD DESCRIPTION

Card: NMAT

Description: This card is used to input material properties of the element.

Format and Example:

NMAT	MID	RHO	CV	COND	CP	(6A8,free field)
NMAT	6	0.12	0.25	1.6	0.20	

Field	Contents
NMAT	NMAT to signal material properties
MID	material ID
RHO	density

=0 elements with this MID will be boundary nodes

<0 elements with this MID will be arithmetic surface nodes

>0 elements with this MID will be diffusion nodes and RHO will be their density

CV specific heat at constant volume

<0 temperature variable specific heat, absolute value of CV used as MITAS array number

≥0 specific heat of element

COND thermal conductivity

<0 temperature variable thermal conductivity absolute value of COND used as MITAS array number

≥0 thermal conductivity of element

CP specific heat at constant pressure (used only in one-way flow conductors) If CP is to be temperature dependent put the array number containing the product of the flow rate per unit surface area and CP (MCP) in the COND location and 1.0 in the CP location.

Remarks:

1. This data card must be manually prepared by the user and inserted on file 4 along with the SPAR generated finite element data.

2. This card should be placed behind the "1st INPUT RECORD" card and ahead of the finite element connection cards on file 4.

Card: NFILM

Description: Inputs convective heat transfer coefficient

Format and Example:

```
NFILM   FID   ELEM   Hc                                (4A8,free field)
NFILM   500    99  0.1
```

Field	Contents
NFILM	NFILM to signal convection properties
FID	convection property ID
ELEM	element number to which the H_c will be connected
H_c	heat transfer coefficient <0 temperature dependent coefficients, absolute value of H_c used as array number ≥ 0 heat transfer coefficient per unit area

Remarks:

1. Conductor value is calculated as node area times H_c.
2. Convection property ID number must be unique with respect to all other convection property ID numbers.
3. The field length for H_c is 15 columns.

CINGEN DATA CARD DESCRIPTION

Card: NRAD

Description: Inputs Radiation heat transfer coefficient

Format and Example:

NRAD	RID	ELEM	SCRIPT	(3A8, A16, free field)
NRAD	6	16	0.2E-10	

Field	Contents
NRAD	NRAD to signal radiation properties
RID	radiation property ID
ELEM	element number to which SCRIPT is connected
SCRIPT	$\varepsilon\sigma F$

<0 temperature dependent absolute value of SCRIPT used as array number.

≥ 0 radiative heat rate per unit area

Remarks:

1. Conductor value is calculated as node area times SCRIPT.
2. Radiation property ID numbers must be unique with respect to all other radiation property ID numbers.
3. The field length for SCRIPT is 16 columns.

Card: PBAR

Description: Property card for NASTRAN 2 grid point element (CBAR)

Format and Example:

PBAR	PID	MID	A	(4A8,free field)
PBAR	6	9	.47	

Field	Contents
PBAR	PBAR to signal material property card
PID	property ID
MID	material ID
A	cross-sectional area

Remarks:

1. Property ID numbers must be unique with respect to all other PBAR property numbers.

Card: PTRIA2 and PQUAD2

Description: Property card for NASTRAN 3 and 4 grid point elements (CRTIA2 and CQUAD2)

Format and Example:

PTRIA2	PID	MID	T	BLANK	PID	MID	T	(8A8, free field)
PQUAD2	PID	MID	T	BLANK	PID	MID	T	(8A8, free field)
PTRIA2	100	26	1.8		59	96	.74	

Field	Contents
PTRIA2	PTRIA2 to signal material property card
PQUAD2	PQUAD2 to signal material property card
PID	property ID
MID	material ID
T	thickness of element
BLANK	blank field

Remarks:

1. One or two element properties may be defined on a single card.
2. PTRIA2 property ID numbers must be unique with respect to all other PTRIA2 property numbers.
3. PQUAD2 property ID numbers must be unique with respect to all other PQUAD2 property numbers.

Card: END

Description: This card ends the first data block input.

Format and Example:

VALUE (A8,free field)

END

Field	Contents
VALUE	END to denote end of first data block.

Remarks:

1. This data card must be input.

CINGEN DATA CARD DESCRIPTION

Card: TITLE

Description: Title of the model

Format and Example:

```
TITLE     NAME                          (A8, 8A8)
TITLE     Example problem 2
```

Field	Contents
TITLE	TITLE - signals a title card
NAME	up to 64 characters, model description

Remarks:

1. This card supplies title information for the MITAS data deck.
2. Format of the MITAS title card punched by CINGEN is

   BCD 6(first 36 characters on the title card)

   BCD 6(last 36 characters on the title card)
3. Every character in the first 72 columns is printed.
4. This data card may be omitted.

CINGEN DATA CARD DESCRIPTION

Card: GRID

Description: Defines the coordinate locations of the grid point

Format and Example:

GRID	ID	B	X	Y	Z	(6A8,free field)
GRID	102		5.	3.	9.	

Field	Contents
GRID	GRID to signal grid point card
ID	grid point ID
B	blank field
X	X coordinate of grid point
Y	Y coordinate of grid point
Z	Z coordinate of grid point

CINGEN DATA CARD DESCRIPTION

Card: K21, K31, K41, K61 or K81

Description: Conduction elements with 2, 3, 4, 6 and 8 grid points

Format and Example:

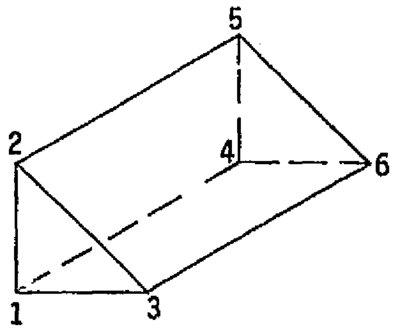
K21	EID	MID	J1	J2	AREAC					(9A8,free field)
K31	EID	MID	J1	J2	J3	THICK				
K41	EID	MID	J1	J2	J3	J4	THICK			
K61	EID	MID	J1	J2	J3	J4	J5	J6		
K81	EID	MID	J1	J2	J3	J4	J5	J6		(9A8,8X,2A8,free field)
	J7	J8								
K31	42	13	8	9	10					

Field	Contents
K21	2-node conduction element
K31	3-node conduction element
K41	4-node conduction element
K61	6-node conduction element
K81	8-node conduction element
EID	element ID
MID	material ID
J1, J2, J3, J4, J5, J6, J7, J8	grid points defining the element
AREAC	cross-sectional area
THICK	thickness of the element

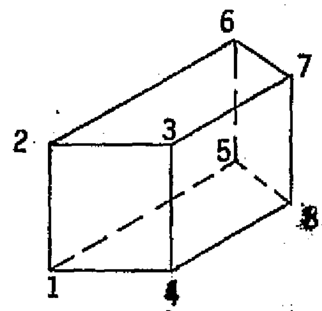
Remarks:

1. The grid points of K31 and K41 elements must be input in a consecutive order around the element.

2. Grid point numbering of K61 and K81 elements must be input in a consecutive order around any face but the opposite face has to be input in a similar way starting on the same edge as the first face as shown in the following examples:



K61 (Typical)



K81 (Typical)

3. K21, K31, and K41 become surface node elements if AREA = 0.0 for K21 and THICK = 0.0 for the K31 and K41 elements. Use K31 or K41 elements to obtain surface nodes on faces of K61 and K81 elements.

4. Element ID numbers must be unique with respect to <u>all</u> other element ID numbers.

5. The field width for AREAC and THICK are 16 columns each.

CINGEN DATA CARD DESCRIPTION

Card: F21

Description: One-way fluid flow element

Format and Example:

F21	EID	MID	J1	J2	AREA	(6A8,free field)
F21	101	3	12	6	11.	

Field	Contents
F21	F21 signals a 2-node, one-way fluid flow element
EID	element ID
MID	material ID
J1	upstream grid point
J2	downstream grid point
AREA	cross-sectional flow area

Remarks:

1. Grid point J1 must be the upstream grid point.
2. The conductor value is calculated as AREA x Cp x COND. Cp and COND are obtained from material ID. COND is the flow rate per unit surface area.
3. Element ID numbers must be unique with respect to all other element ID numbers.
4. The field length for AREA is 16 columns.

Card: C21, C31, or C41

Description: Convection elements

Format and Example:

C21	EID	NFILM	J1	J2	CIRC		(7A8,free field)
C31	EID	NFILM	J1	J2	J3		
C41	EID	NFILM	J1	J2	J3	J4	
C41	10	17	1	8	7	2	

Field	Contents
C21	2-node convection element
C31	3-node convection element
C41	4-node convection element
EID	element ID
NFILM	convection property ID
J1, J2, J3, J4	Grid points defining surface of element to which the convection is applied
CIRC	circumference of the element

Remarks:

1. Grid points must be input in a consecutive order around the element.
2. Element ID numbers must be unique with respect to all other element ID numbers.
3. An arithmetic surface node is created on the element surface to which the C-type element is applied except when applied to surface elements and 2 grid point elements.
4. Only one surface node is created regardless to the number of C-type elements applied to the surface.
5. The field length for CIRC is 16 columns.

Card: R21, R31, or R41

Description: Radiation elements

Format and Example:

R21	EID	NRAD	J1	J2	CIRC		(7A8,free field)
R31	EID	NRAD	J1	J2	J3		
R41	EID	NRAD	J1	J2	J3	J4	
R31	12	120	7	8	9		

Field	Contents
R21	2-node radiation element
R31	3-node radiation element
R41	4-node radiation element
EID	element ID
NRAD	radiation property ID
J1, J2, J3, J4	grid points defining surface of element to which the radiation is applied
CIRC	circumference of the element

Remarks:

1. Grid points input in any consecutive order around the element.
2. Element ID numbers must be unique with respect to all other element ID numbers.
3. An arithmetic surface node is created on the element surface to which the R-type element is applied except when applied to surface elements and 2 grid point elements.
4. Only one surface node is created regardless to the number of R-type elements applied to the surface.
5. The field length for CIRC is 16 columns.

Card: CBAR, CTRI, CQUAD, CWEDGE, CHEX

Description: NASTRAN conduction element types for 2, 3, 4, 6 and 8 grid points

Format and Example:

CBAR	EID	PIDB	J1	J2				
CTRIA2	EID	PIDT	J1	J2	J3			
CQUAD2	EID	PIDQ	J1	J2	J3	J4		
CWEDGE	EID	MID	J1	J2	J3	J4	J5	J6
CHEX	EID	MID	J1	J2	J3	J4	J5	J6
	J7	J8						
CWEDGE	7	18	1	9	7	6	20	22

Field	Contents
CBAR	CBAR, 2-node conduction element
CTRIA2	CTRI, 3-node conduction element
CQUAD2	CQUAD, 4-node conduction element
CWEDGE	CWEDGE, 6-node conduction element
CHEX	CHEX, 8-node conduction element
EID	element ID
PIDB	property ID card number (PBAR card)
PIDT	property ID card number (PTRIA2 card)
PIDQ	property ID card number (PQUAD2 card)
MID	material ID
J1, J2, J3, J4 J5, J6, J7, J8	grid points defining the element

Remarks:

1. Element ID numbers must be unique with respect to all other element ID numbers.

2. NASTRAN and SPAR elements cannot be mixed. The type of elements (NASTRAN or SPAR) processed is determined by the 1st INPUT RECORD (See page 3-13.)

CINGEN DATA CARD DESCRIPTION

Card: END DATA

Description: This card ends the input data.

Format and Example:

VALUE (A8, free field)

ENDDATA

Field	Contents
VALUE	ENDDATA to denote the last card in the input set.

Remarks:

1. This data card must be input.

Section 4

INTERACTIVE GRAPHICS - GEOMPLT PROGRAM

The GEOMPLT program is an interactive graphics program developed, initially, for the display of finite element data. It has now been modified and expanded to include plotting a MITAS or SINDA thermal network, which has been created through the use of the CINGEN program (see Section 2.2.0). In addition, an XYPLOT capability has been added for displaying MITAS or SINDA results in the form of Time-Temperature or Spatial - Temperature graphs.

A functional flow diagram of the GEOMPLT program is illustrated in Figure 9. Figure 10 is a detailed flow diagram of the XYPLOT logic. It is recommended that the user acquaint himself with the overall logic flow of the program and its parameter options before entering into a graphics session on a terminal. However, the program will prompt the user with questions and options which are generally self explanatory. Best results are most often obtained after carefully planning the view angles, partial view selection and labeling options.

Appendix B contains a user guide to the GEOMPLT program as it existed before the recent improvements for thermal network and XY plotting. This information has been included for completeness, however, the following sections describe the capabilities, limitations, INPUT requirements and OUTPUT options necessary to perform finite element, thermal network and XY plotting.

4.1 CAPABILITY

The GEOMPLT program has the following general capabilities:

1. Graphically displays finite element models.
2. Graphically displays thermal networks.
3. Prepares data file for use by CONTUR program.
4. Edits finite element data file (CDC only).

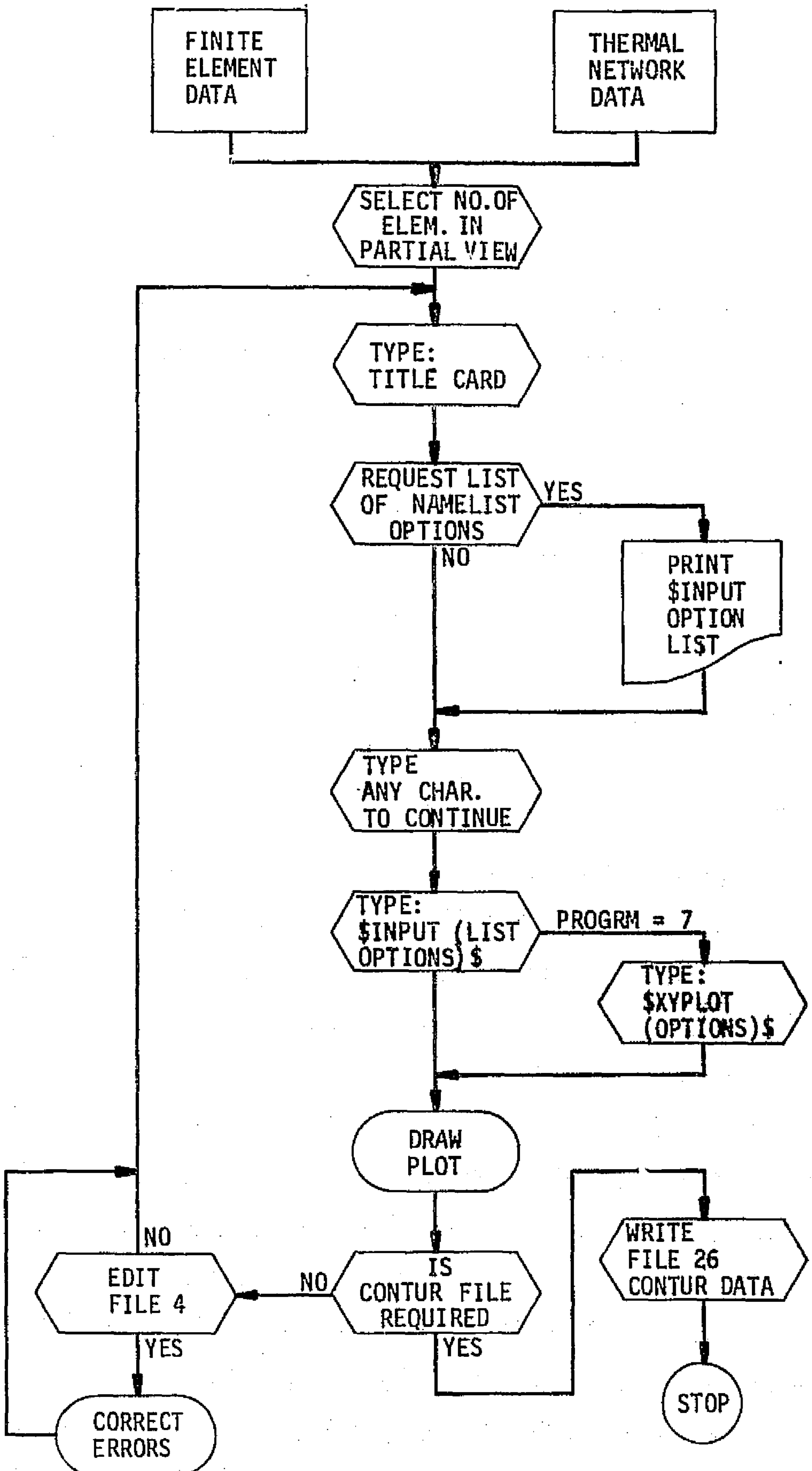


Figure 9. GEOMPLT Flow Diagram

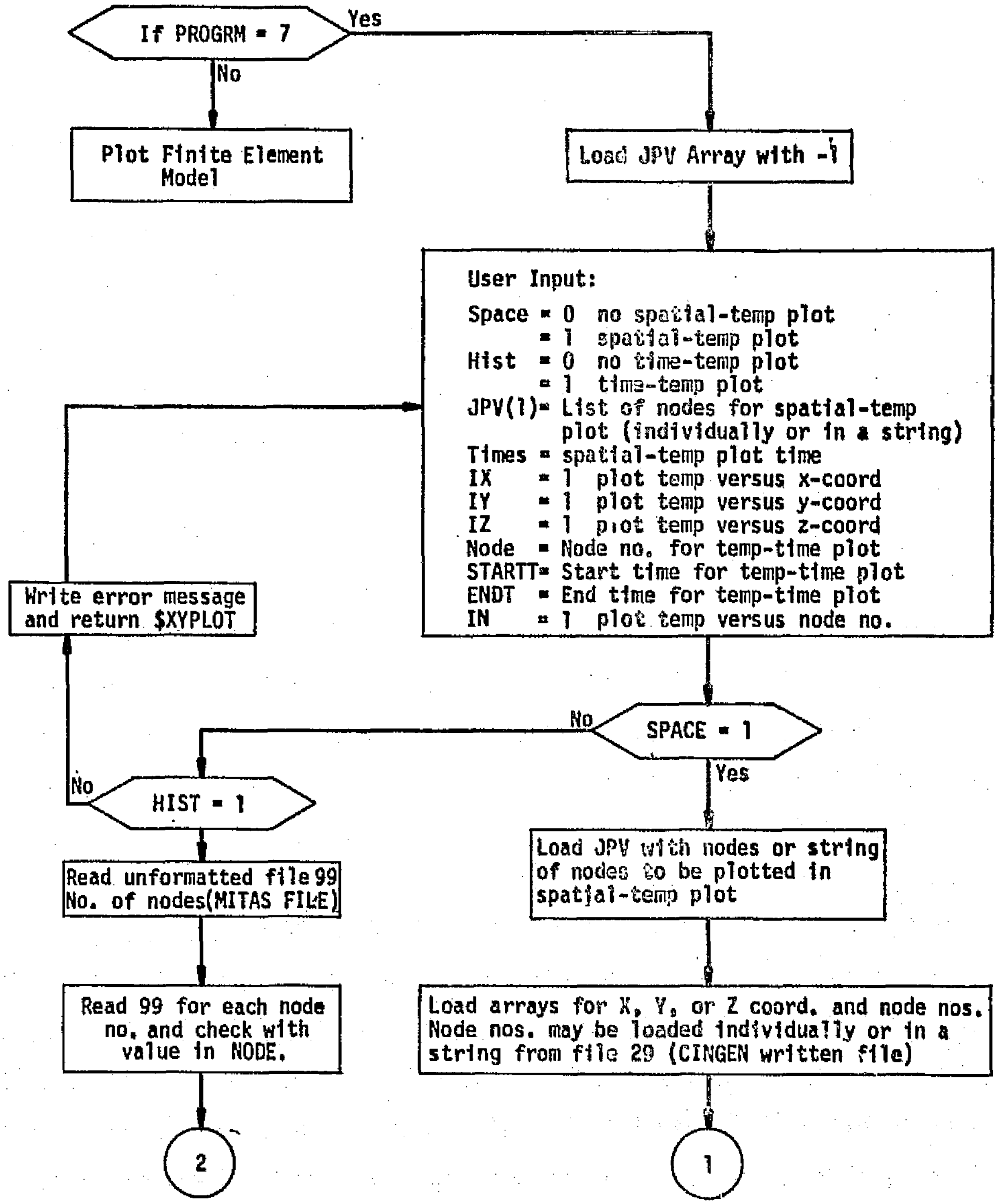


Figure 10, Detail Flow Diagram for XY Plot Logic

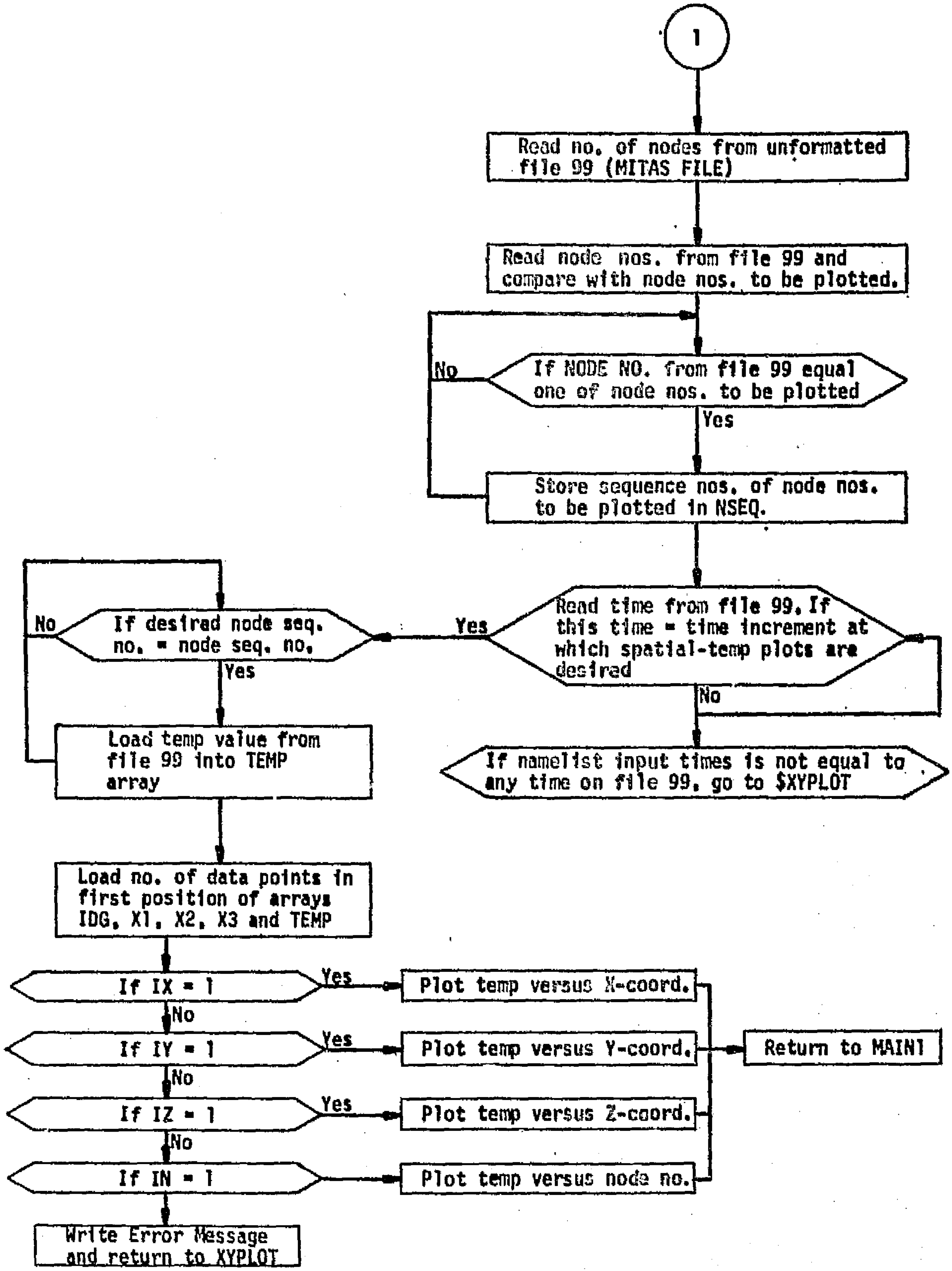


Figure 10, (continued)

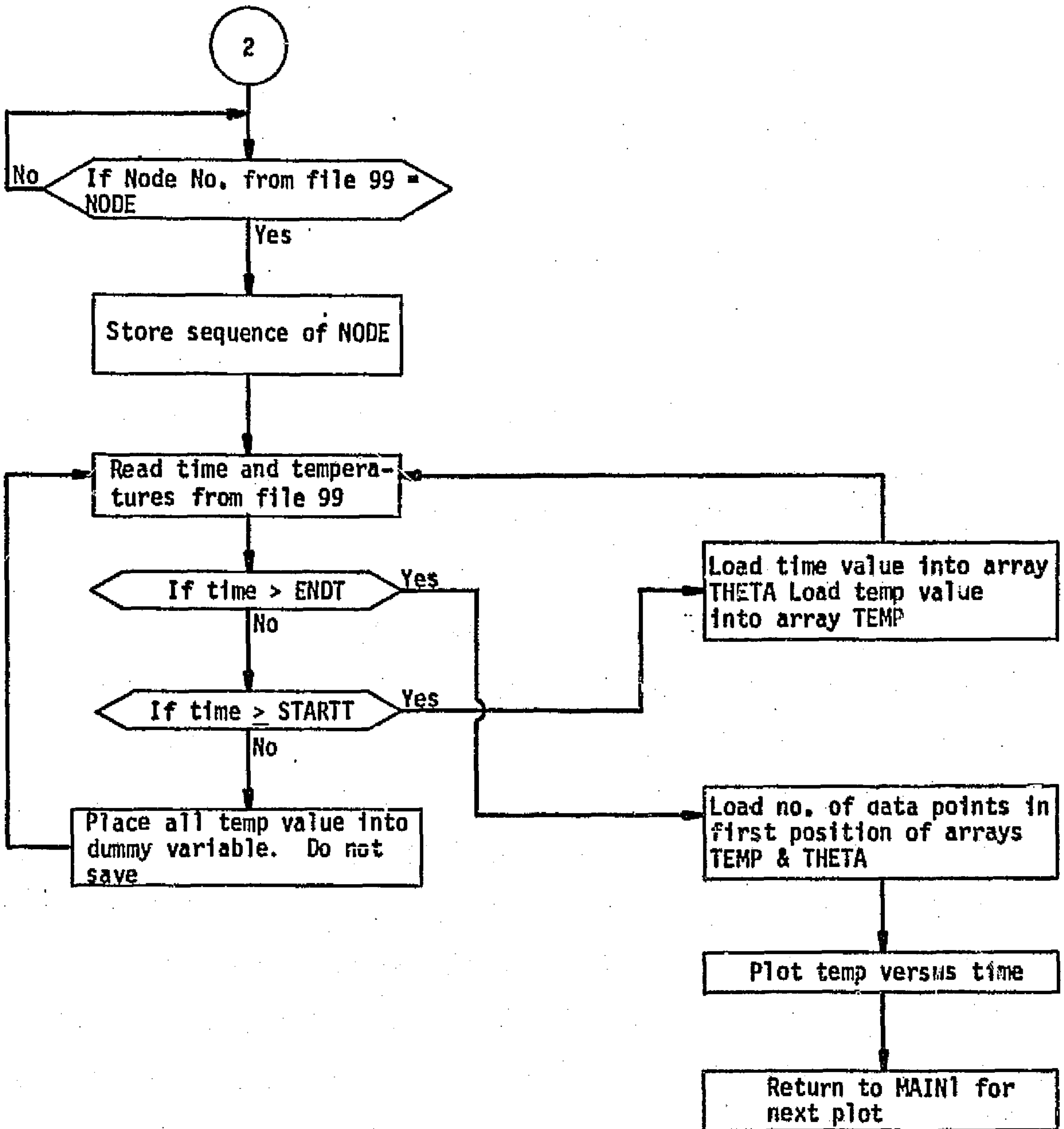


Figure 10, (continued)

5. Creates an alternate print file with diagnostic information for review after terminal session.

6. Writes a data file for obtaining hard copies of geometric plots via Calcomp or Houston Instrument drum plotters.

7. Graphically displays XY plots.

Computer Configuration - Versions of the program are being maintained for the CDC 6600 and UNIVAC 1100 computer systems. Both versions are essentially the same with minor programming changes to accommodate a variable core concept on the UNIVAC and CDC systems.

1.	Computer	CDC 6600	UNIVAC 1100
2.	Core size required	26K min. (user re-compiles main to expand)	22K min. (Dyn expand for problem size)
3.	Language	FORTRAN IV	FORTRAN IV
4.	System	Scope 3.4 or NOS	Exec 8
5.	Plotter	Tektronix 4000 Series	Same
6.	Card Punch	Optional	Optional
7.	Tape Drive	None	None
8.	Mass Storage (Disk)	1-min problem size dependent	Same
9.	Run time	221 elem. 441 grid - 7.03 cps. 1 plot	14 cpu sec.
10.	Restart	None	None

Geometric Plot - The purpose of this feature is to provide a 3-D view of the finite element model and/or the thermal network on a Tektronix CRT terminal. Options may be selected through the NAMELIST input. Two NAMELIST's are used; Table I lists the options available under the $INPUT NAMELIST and Table II lists the options available under the $PVIEW NAMELIST. Table III lists element names which are recognized and plotted by the GEOMPLT program. Specific capabilities include:

1. Graphically display finite element, CINGEN (MITAS models), and SPAR models.

2. Display grid, element, thermal node and conductor number.

3. Display the conductor and thermal node type with an alpha character preceding the ID number.

4. Rotate any view about three axes.

5. Plot partial views of a finite element model containing all of one type element by simply naming the type in a list, plot partial views by providing a list of element numbers, or a combination of both.

6. Change plot scale factors for increasing or decreasing the size at the image plotted.

Data Editor - The data editor provided in the CDC Version is limited in its capability, and is not recommended for general use. The CDC or UNIVAC system TEXT EDITOR is recommended. This editor can be used in a demand mode to correct errors found through plotting the finite element or thermal network data contained on files 4 and 29 respectively.

Hard Copy - This feature is used to obtain high quality hard copies of the plot displayed on the screen. Appendix B, section 3.3, contains a detailed discussion on this option.

CONTUR Plot Pre-Processor - This feature is used to create two data files (10 and 11 which contain transformed grid coordinate data and connection date) for use by the CONTUR program. Appendix B, section 3.4, contains a detailed discussion on this option.

Alternate Print File - This feature provides a permanent record of the plotting session. File 7 (CDC) is used and the user must divert the file to a printer if a copy is desired. Appendix B, section 35, contains a description of information contained on this file.

X-Y Plotting - This feature is used to display analytical results from a MITAS (or SINDA) model which was developed using the CINGEN program. An unformatted tabular data file must be written through execution of MITAS subroutine TSAVE. This subroutine copies thermal data to tape 'PLOT' which then must be copied to file 99 for plotting. This data file may contain any thermal parameter (e.g. temperature, heat flux) in tabular form as a function of:

1. Time
2. Node
3. Spatial coordinate (X, Y, or Z)

Options are selected thorugh the use of $XYPLOT NAMELIST input. Table IV lists the options available under the $XYPLOT NAMELIST. Formatted tabular data may be input on file 30. XY data is selected from file 30 or 99 using the IN30 parameter in $XYPLOT NAMELIST (default is file 99).

A typical procedure is as follows:

1. Generate spatial coordinates (file 29) in CINGEN for use by plotting program.
2. Create thermal results (file 99) with MITAS (or SINDA) for XY plotting.
3. Attach file 29 and 30 or 99 for use by GEOMPLT.
4. Begin interactive XY plotting. Note parameter PROGRAM in $INPUT NAMELIST must be set equal to 7 for XY plots.

   See example on page 4-10.

Table I. Namelist $INPUT Parameter Definition (CDC ONLY)

Parameter	Description	Default	Other
BAUD*	Transmission rate from computer to terminal, BAUD/10	30	Integer
CONDNO	Print conductor numbers for thermal network	0-NO	1-YES
CONTUR	Saves XY plotter coordinates on file KC and connector data on file KD to be read by CONTUR program. NOTE: When CONTUR = 1, the following default changes are used KTEST = 1 KD = 11 MPLOT = 0 NPLOT = 1	0-NO	1 or 9-YES
ENO	Print element numbers at element centroids	0-NO	1-YES
GNO	Print grid numbers at grid point	0-NO	1-YES
IHUSTN	Write hard copy plot commands on file 25; request to permanently save plot on file 26 is made after plot is complete	0-NO	1-YES
KC	File number to use when CONTUR = 1	10	Integer
KD	File number to use when LTEST or KTEST = 1	7	Integer
KTEST	Option for CONTUR element punch option if KTEST = 9; plotting is suppressed	0-NO	1 or 9-YES
LTEST	Option for CONTUR XY data punch options if LTEST = 9; plotting is suppressed	0-NO	1 or 9-YES
MPLOT	Option for multiple plots. Set MPLOT = 0 to terminate plotting	1-YES	0-NO
NCHBDY	NASTRAN thermal elements to be plotted	0-NO	1-YES
NODENO	Print capacitance node number for thermal network	0-NO	1-YES
NPLOT	Number of plots if MPLOT = 1	10	Integer
NTEST	Option to print rotated coordinate data on file 7	0-NO	1-YES

Table I. (Continued)

Parameter	Description	Default	Other
PROGRM	Type of input data on file 4, 29, 30 or 99 1 = Finite element (file 4) 2 = Thermal network (CINGEN) only plotted (file 29) 3 = CINGEN and finite element data plotted (file 4 and 29) 7 = CINGEN and MITAS XY-PLOT (file 29 and 30 or 99)	1	1-5
PV	Option for partial views; if PV = 1 Namelist $JPVLST is used to specify element numbers to be plotted	0-NO	1-YES
SCALEX	Option for adjusting the apparent width of the screen	10	REAL
SCALEY	Option for adjusting the apparent height of the screen	7	REAL
SYMB	Option to place a symbol at the grid point 29 ⇒ •	29	Integer
X*	Angle of rotation about x-axis (deg)	34.27	REAL
Y*	Angle of rotation about y-axis (deg)	23.17	REAL
Z*	Angle of rotation about z-axis (deg)	43.0	REAL
XAXIS	Axis to be placed in screen x-axis (+ left to right)	1	1-6
YAXIS	Axis to be placed in screen y-axis (+ up)	2	1-6
ZAXIS	Axis to be placed in screen z-axis (+ out of screen) Structure yes may be interchanged with screen axes for changing view, where: 1 = x, 2 = y, 3 = z, 4 = -x, 5 = -y, 6 = -z	3	1-6
IDASH*	Option for dashed lines in thermal network plot. Default is straight lines.	0	1

Notes:

1. Parameters marked by * retain input value until changed by a new input value.

2. The PROGRAM parameter must be set equal to 7 for XY plotting. All other parameters in $INPUT NAMELIST are used for geometry only. See Table II for $XYPLOT NAMELIST parameters which may be selected for XY plotting.

Table II. Namelist $PVIEW Parameter Definition

JPV(1) = List of elements to be displayed in a partial view. Elements to be displayed in one of the following ways:

1) Individually

2) A set of consecutive element numbers in increasing order by naming the first and last number in the set.

3) A set of element numbers of the same type.

```
EXAMPLE:  JPV(1) = 1, 5, 9, 13, -0, 18,
                        6HK81       $
```

will plot element numbers 1, 5, 9, 13, 14, 15, 16, 17, 18 and all K81 elements.

Table III.

SUMMARY OF FINITE ELEMENTS RECOGNIZED BY GEOMPLT

NASTRAN Type	SPAR Type
CBAR	K21
CONROD	C21
CROD	R21
CTUBE	F21
CTRIA1	K31
CTRIA2	C31
CTRMEM	R31
CTRPLT	K41
CQDMEM	C41
CQDPLT	R41
CQUAD1	K61
CQUAD2	K81
CSHEAR	
CTWIST	
CTETRA	
PLOTEL	
CTRAPR	
CTRIAR	
CTORDR	
CWEDGE	
CHEXA1	
CHEXA2	
CIS3D8	
CIS3D20	
CHBDY	

Table IV. $XYPLOT NAMELIST Parameters

PARAMETERS	DEFINITION	DEFAULT	OTHER
SPACE	SPATIAL PLOT	0-NO	1-YES
HIST	TIME-HISTORY PLOT	0-NO	1-YES
IN30	PLOTS FORMATTED DATA	0-NO	1-YES
IX	PLOT NODAL X-COORDINATES	0-NO	1-YES
IY	PLOT NODAL Y-COORDINATES	0-NO	1-YES
IZ	PLOT NODAL Z-COORDINATES	0-NO	1-YES
IN	PLOT NODE NUMBERS	0-NO	1-YES
NODE	NODE NO FOR TIME-HISTORY PLOT	BLANK	INTEGER
TIMES	INSTANT OF TIME FOR SPATIAL PLOT	0.0	REAL
STARTT	STARTING TIME FOR TIME-HISTORY PLOT	0.0	REAL
ENDT	ENDING TIME FOR TIME-HISTORY PLOT	0.0	REAL
SYMB	SELECTS DATA POINT SYMBOLS	1-⊙	INTEGER

JPV IS AN ARRAY CONTAINING THE NODE NOS TO BE PLOTTED.
(-0) IS USED FOR CONSECUTIVE NUMBERS. INPUT EXAMPLE:
JPV (1) = 1, 2, 3, 4, -0, 8, 17, 20 (PLOTS NODE NOS 1 THRU 8, 17 and 20)

4.2 LIMITATIONS

1. Only finite elements in Table III may be plotted.
2. The number of elements plotted depends upon the size of core available.

   Core = Code + Data + Open Core

   Code + Data = 21000_D

   Open Core = 4 x NGD + 4 x NEL + JSIZE + 10 + NJPV

   NGD = No. of Grid Points

   NEL = No. of Elements

   JSIZE = No. of Connections = (NEL x No. Grid PTS/Elem.)

   NJPV = (300 - NEL/2) if NEL $\leq$ 600

   = 0 if NEL > 600
3. Program stops if 100 plots are generated.
4. If contour data is required for several views, a new execution must be initiated for each view.
5. Up to three conductor labels can be plotted between any two nodes.
6. Labeling will be overwritten if two or more nodes occupy the same spatial coordinates.
7. Maximum number of time increments which may be plotted must not exceed LENGB/12, where LENGB = 7000. This parameter may be changed in the MAIN program.

4.3 INPUT/OUTPUT DESCRIPTION

As previously discussed, the user's response during execution of the GEOMPLT program is generally an answer to a question or a NAMELIST input. The parameters which may be selected or redefined in the NAMELIST arguments are described in Tables I, II, and IV. The user is cautioned that some parameters in the $INPUT and $XYPLOT NAMELISTS revert back to their original default value while others retain their new value until changed. All parameters have a default value which is listed in Table I, II, or IV.

The Table V lists all files (input and output) which may be used by GEOMPLT.

Table V. File Allocation

File Number	Description	Reqmnt	Input/Output
4	Finite element data	Req'd	Input
5	TEKTRONIX Keyboard	Req'd	Input
6	TEKTRONIX Screen	Req'd	Output
7	Alternate print file (CDC only)	Optional	Output
8	EDIT file for Finite Element Data (CDC only)	Optional	Output
10	Grid data for CONTUR	Optional	Output
11	Connection data for CONTUR	Optional	Output
21	Alternate print file (UNIVAC only)	Optional	Output
25	Hard copy Scratch file	Optional	-
26	Plot Commands for Hard Copy	Optional	Output
29	CINGEN Thermal Network data (MITAS model)	Optional	Input
30	FORMATTED XY - DATA	Optional	Input
99	UNFORMATTED MITAS XY - DATA	Optional	Input

GEOMPLT FILE DESCRIPTION

FILE: 4

Description: Finite element data cards

Record	Description					Format
1	Grid GID		X1	X2	X3	(A4, 4X, I8, 8X, 3F8.2)
2	K21 EID	MID	J1	J2	A	(A3, 5X, 4I8, E16.7)
3	F21	(See Section 2.1.3 "SPAR DATA				
4	C21	CARD DESCRIPTION", a description				
•	R21	of all Element output card				
•	K31	formats are contained under "REMARKS.")				
•	C31					
	R31					
	K41					
	C41					
	R41					
	K61					
	K81					
	(K81 Continuation)					
Last	ENDDATA					(A7)

REMARKS:

1. Only SPAR Thermal Elements are shown above, however, NASTRAN element types shown in Table III are also permitted.
2. Elements may be in unsorted order.
3. If GRDSET card is used it must preceed the first GRID card.
4. If local coordinate definition cards are used, they must appear before the GRID cards.
5. All continuation cards must follow their parent.
6. The last card image in the file must be an ENDDATA card.
7. File 4 may contain additional records to be used by the CINGEN program. These will be ignored by GEOMPLT.
8. If a CINGEN thermal network is to be displayed the thermal node numbers must be equal to the finite element numbers.

FILE: 29

Description: Thermal Network Data Cards

RECORD	DESCRIPTION	FORMAT
1	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
2	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
3	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
4	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
.	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
.	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
.	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)
LAST	TY, M, TN1, J, TN2, K, GV, X, Y, Z, A, B, C	(3(A1,I7), 7F8.3)

FIELD	CONTENTS
TY	ELEMENT TYPE (eg: K, F, C or R)
M	ELEMENT NO.
TN1	NODE 1 TYPE (eg: A, B, or D)
J	NODE 1 NO.
TN2	NODE 2 TYPE (eg: A, B, or D)
K	NODE 2 NO.
GV	ELEMENT CONDUCTOR VALUE
X, Y, Z	NODE 1 SPATIAL COORDINATES
A, B, C,	NODE 2 SPATIAL COORDINATES

REMARKS:

1. The records shown above are generated by the CINGEN program.
2. File 29 contains thermal element types and numbers, thermal node types and numbers, element conductor values, and node coordinates.
3. The values of J and K (thermal node numbers) must be the same as the finite element ID numbers (EID'S).

FILE: 30

Description: XY Data (Formatted)

RECORD	DESCRIPTION	FORMAT
1	NM, N(1), N(2), N(3)...N(NM)	(10I8)
2	TIME (1), DATA (1), DATA (2)...DATA (NM)	(10F8.3)
3	TIME (2), DATA (1), DATA (2)...DATA (NM)	(10F8.3)
.		
.		
LAST	TIME(K), DATA (1), DATA (2)...DATA (NM)	(10F8.3)

FIELD	CONTENTS
NM	number of nodes
N(i)	i th node ID number

REMARKS:

1. File 30 contains formatted data used for XY - Plotting.
2. To select file 30 for XY data input, reset parameter IN30 = 1 in $XYPLOT NAMELIST.

FILE: 99

Description: MITAS OUTPUT (UNFORMATTED)

RECORD	DESCRIPTION	FORMAT
1	NM, N(1), N(2), N(3),... N(NM)	NONE
2	TIME (1), DATA (1), DATA (2),...DATA(NM)	NONE
3	TIME (2), DATA (1), DATA (2),...DATA(NM)	NONE
.		
.		
LAST	TIME(K), DATA (1), DATA (2),...DATA(NM)	NONE

FIELD	CONTENTS
NM	number of nodes
N(i)	i th node ID number

REMARKS:

1. File 99 contains unformatted data used for XY - Plotting.
2. The XY Plotting routine will read file 99 for XY data unless parameter IN30 is reset to IN30 = 1 in the $XYPLOT NAMELIST.
3. See MITAS (or SINDA) Users Manual for a discussion of variables which may be written on file 99, and the method used.

Typical XY Output

The following example assumes the GEOMPLT program has been loaded on the machine and all necessary data files (4 for finite element model, 29 for CINGEN thermal network, and 99 for MITAS XY data tables) have been attached. After execution, the program is conversational and the user must respond to requests by the program in a step - by - step manner. The > symbol is used to identify response by the user.

This example displays XY plots for temperature vs. node numbers, temperature vs. time, temperature vs. X-coordinate, temperature vs. Y-coordinate, and temperature vs. Z-coordinate. Multiple plots are displayed by typing a 'blank' (or any other character) after each plot appears. After 'blank' is transmitted the screen is cleared and the lines from 'TYPE (C) FOR A LIST OF $XYPLOT NAMELIST OPTIONS' will appear. After typing an 'A' for a list of $XYPLOT NAMELIST options or a 'C' for no list the user must input the correct parameter values to $XYPLOT NAMELIST to obtain the desired type of plot. To terminate XY plotting the word 'STOP' must be typed and transmitted.

```
THE FOLLOWING TABLE ALLOWS THE USER TO VARY THE CORE

  USAGE IN ORDER TO ALLOW PLOTTING OF LARGER MODELS

ESTIMATED NO. OF
ELEMENTS TO BE PLOTTED
IN ANY PARTIAL VIEW

     0.0
   121.0
   241.0
   357.0
   471.0
   579.0

TYPE IN ONE OF THE ABOVE FLOATING POINT NUMBERS.

TYPE IN MAX NUMBER IF X-Y GRAPHS ARE DESIRED.

> 579.0

MAXIMUM NO. OF ELEMENTS THAT CAN BE PLOTTED IN A COMPLETE VIEW IS = 583

MAXIMUM NO. OF ELEMENTS THAT CAN BE PLOTTED IN A PARTIAL VIEW IS = 579
```

```
  TYPE IN TITLE CARD

> (USER TYPES IN PLOT TITLE)

    TO HAVE DEFINITIONS OF 'INPUT' NAME LIST VARIABLES DISPLAYED, TYPE IN C

    OTHERWISE, TYPE IN ANY OTHER CHARACTER

> C

    GNO = 1 TO PRINT GRID NUMBERS. DEFAULT = 0
    ENO = 1 TO PRINT ELEMENT NUMBERS. DEFAULT = 0
    MPLOT = 1  FOR MULTIPLE PLOTS.  DEFAULT = 1
    NPLOT = NUMBER OF PLOTS IF MPLOT = 1. DEFAULT = 10
    PV = 1  FOR PARTIAL VIEW OPTION.  DEFAULT = 0
    CONTUR = 1  SAVES XY PLOTTER COORDINATES ON FILE KC AND
      CONNECTOR DATA ON FILE KD TO BE READ BY CONTOUR
      PLOTTING PROGRAM. DEFAULT = 0
     NOTE-UP TO 2000 GRIDS ARE ALLOWED PER CONTOUR PLOT.
    THE FOLLOWING DEFAULT CHANGES ARE USED WHEN CONTUR = 1
       KTEST = 1, KD = 11
     NOTE-WHEN CONTUR = 1, MULTIPLE PLOTS ARE NOT ALLOWED
       MPLOT IS SET = 0, NPLOT IS SET = 1
    CONTUR = 9 FOR CONTUR PLOTS ONLY - SAME AS CONTUR = 1
      EXCEPT GEOMETRY PLOTS ARE SUPPRESSED.
    X=ANGLD = ANGLE OF ROTATION ABOUT BASIC X- AXIS
      DEFAULT = 34.27
    Y = ELEV = ANGLE OF ROTATION ABOUT BASIC Y - AXIS
      DEFAULT = 23.17
    Z =ROTX = ANGLE OF ROTATION ABOUT BASIC  Z-AXIS
      DEFAULT = 0.0
    IDENTIFY TYPE OF DATA TO BE PLOTTED, OPTIONS ARE:
      PROGRM  = 1 FOR FINITE ELEMENT DATA
      PROGRM  = 2 FOR THERMAL NETWORK (CINGEN) DATA
      PROGRM  = 3 FOR FINITE ELEMENT + CINGEN DATA
      PROGRM  = 7 FOR CINGEN + MITAS XY PLOT
    BAUD = BAUD RATE (DEFAULT = 30)
    XAXIS = AXIS TO BE PREPOSITIONED IN BASIC X DIRECTION , (+ UP THE PAGE)
    YAXIS = AXIS TO BE PREPOSITIONED IN BASIC Y DIRECTION , (+ RIGHT TO LEFT)
    ZAXIS = AXIS TO BE PREPOSITIONED IN BASIC Z DIRECTION , (+ OUT OF PAGE)

     NOTE - LOOKING TOWARD ORIGIN FROM POSITIVE END OF EACH AXIS
       CLOCKWISE ROTATIONS ARE POSITIVE
     NOTE - CODES FOR PREPOSITIONING ARE
       XX = 1, YY = 2, ZZ=3, MX = 4,  MY = 5, MZ = 6
     DEFAULT AXIS VALUES ARE XAXIS = 1, YAXIS = 2, ZAXIS = 3

    **TYPE IN A CHARACTER TO CONTINUE**
```

```
> C
  TYPE IN NAMELIST/$INPUT/
NOTE-THE FIRST COLUMN IS IGNORED IN NAMELIST INPUT
  THE LAST CHARACTER MUST BE A $, NOT ON A SEPARATE LINE, BUT AFTER
  LAST VARIABLE.
> $INPUT PROGRAM = 7 $ (EXAMPLE)
TYPE (C) FOR A LIST OF 'XYPLOT' NAMELIST OPTIONS
TYPE ANY OTHER CHARACTER FOR NO LIST

> C

PARAMETERS *********** DEFINITION ***************** DEFAULT ** OTHER *******

SPACE       SPATIAL PLOT                          0-NO       1-YES
HIST        TIME-HISTORY PLOT                     0-NO       1-YES
IN30        PLOTS FORMATTED DATA                  0-NO       1-YES
IX          PLOT NODAL X-COORDINATES              0-NO       1-YES
IV          PLOT NODAL Y-COORDINATES              0-NO       1-YES
IZ          PLOT NODAL Z-COORDINATES              0-NO       1-YES
IN          PLOT NODE NUMBERS                     0-NO       1-YES
NODE        NODE NO FOR TIME-HISTORY PLOT         BLANK      INTEGER
TIMES       INSTANT OF TIME FOR SPATIAL PLOT      0.0        REAL
STARTT      STARTING TIME FOR TIME-HISTORY PLOT   0.0        REAL
ENDT        ENDING TIME FOR TIME-HISTORY PLOT     0.0        REAL
SYMB        SELECTS DATA POINT SYMBOLS            1-⊙        INTEGER
****************************************************************************

JPV IS AN ARRAY CONTAINING THE NODE NOS TO BE PLOTTED.
(-0) IS USED FOR CONSECUTIVE NUMBERS,  INPUT EXAMPLE:
JPC (1) = 1, 2, 3, 4, -0, 8, 17, 20  (PLOTS NODE NOS 1 THRU 8, 17 and 20)
**TYPE ($XYPLOT (OPTIONS) $ )
** NOTE - 1ST CHARACTER IS IGNORED FOR NAMELIST INPUT
**      (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE
**      ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT.
> $XYPLOT SPACE = 1, TIMES = 4.0, IN = 1, JPV (1) = 5001, -0, 5004 $ (EXAMPLE)
AFTER PLOT IS COMPLETE TYPE IN A BLANK TO CONTINUE PLOTTING
  TYPE C TO CONTINUE
> C

(PLOT APPEARS)   SEE FIG. 11
```

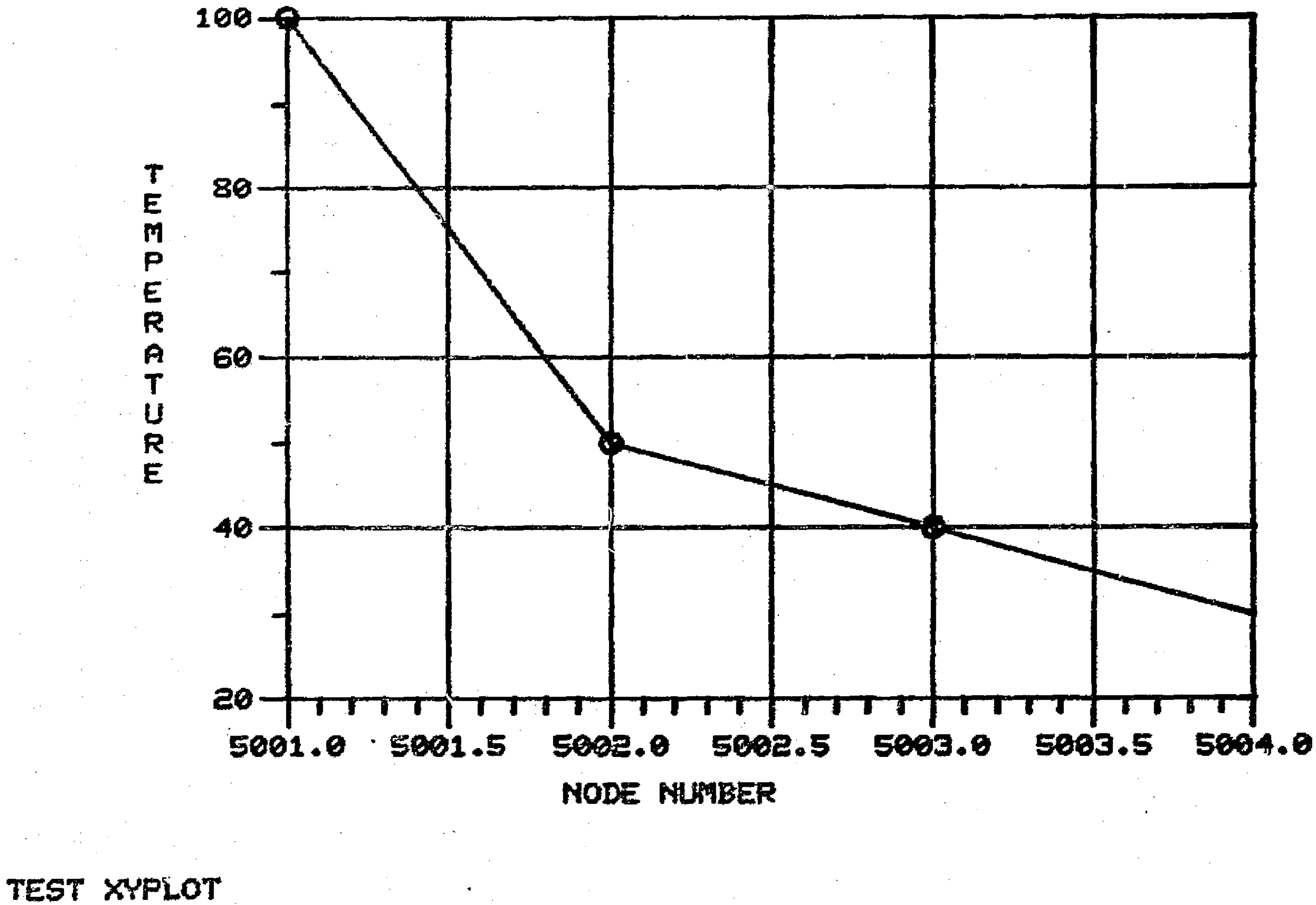


Figure 11, Typical XY Plot Generated by GEOMPLT

```
TYPE (C) FOR A LIST OF $XYPLOT NAMELIST OPTIONS

TYPE ANY OTHER CHARACTER FOR NO LIST

> A

**TYPE ($XYPLOT (OPTIONS) $ )

** NOTE - 1ST CHARACTER IS IGNORED FOR NAMELIST INPUT

**      (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE

**      ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT.

> $XYPLOT HIST = 1, NODE = 5002, STARTT = 0.0, ENDT = 10.   (EXAMPLE)

AFTER PLOT IS COMPLETE TYPE IN A BLANK TO CONTINUE

  TYPE C TO CONTINUE

> C

(PLOT APPEARS) SEE FIG. 11a.
```

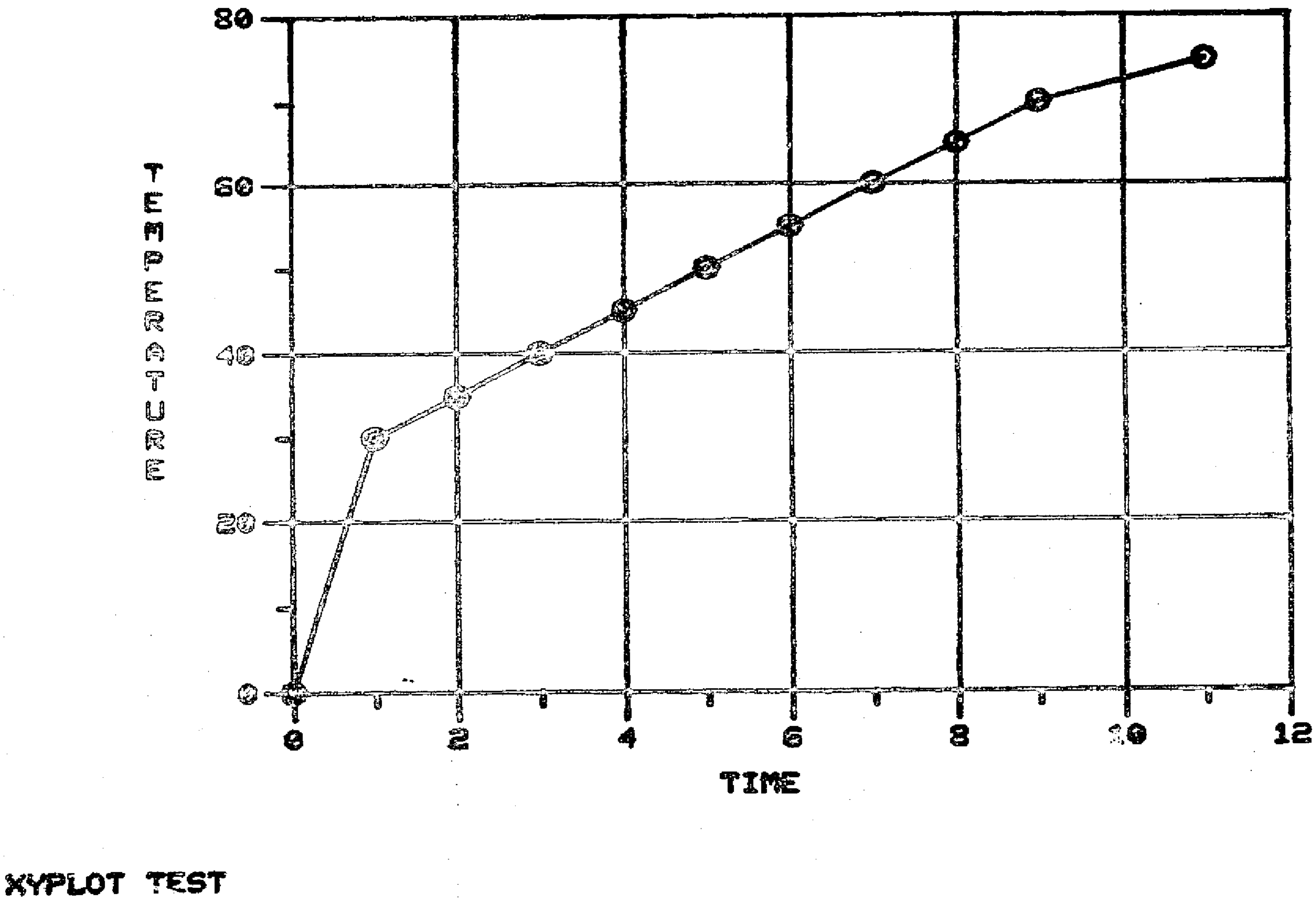
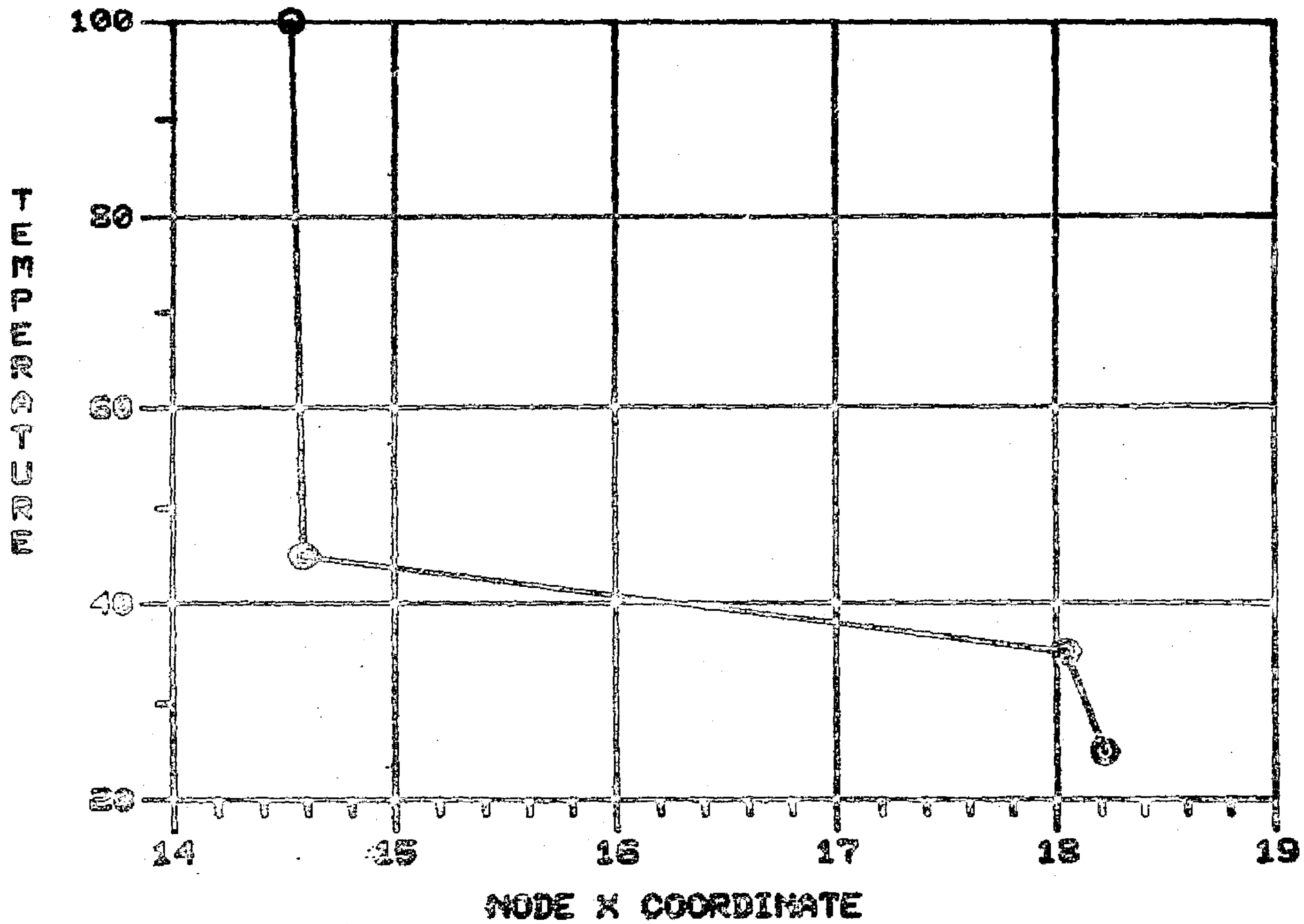


Figure 11a. Typical XY Plot Generated by GEOMPLT

```
 TYPE (C) FOR A LIST OF $XYPLOT NAMELIST OPTIONS
 TYPE ANY OTHER CHARACTER FOR NO LIST
> A
 **TYPE ($XYPLOT (OPTIONS) $ )
 ** NOTE - 1ST CHARACTER IS IGNORED FOR NAMELIST INPUT
 **      (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE
 **      ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT.
> $XYPLOT SPACE = 1, TIMES = 4.0, IX = 1, JPV (1) = 5001, -0 5004 $ (EXAMPLE)
 AFTER PLOT IS COMPLETE TYPE IN A BLANK TO CONTINUE
   TYPE C TO CONTINUE
> C
```

(PLOT APPEARS) SEE FIG. 11b.

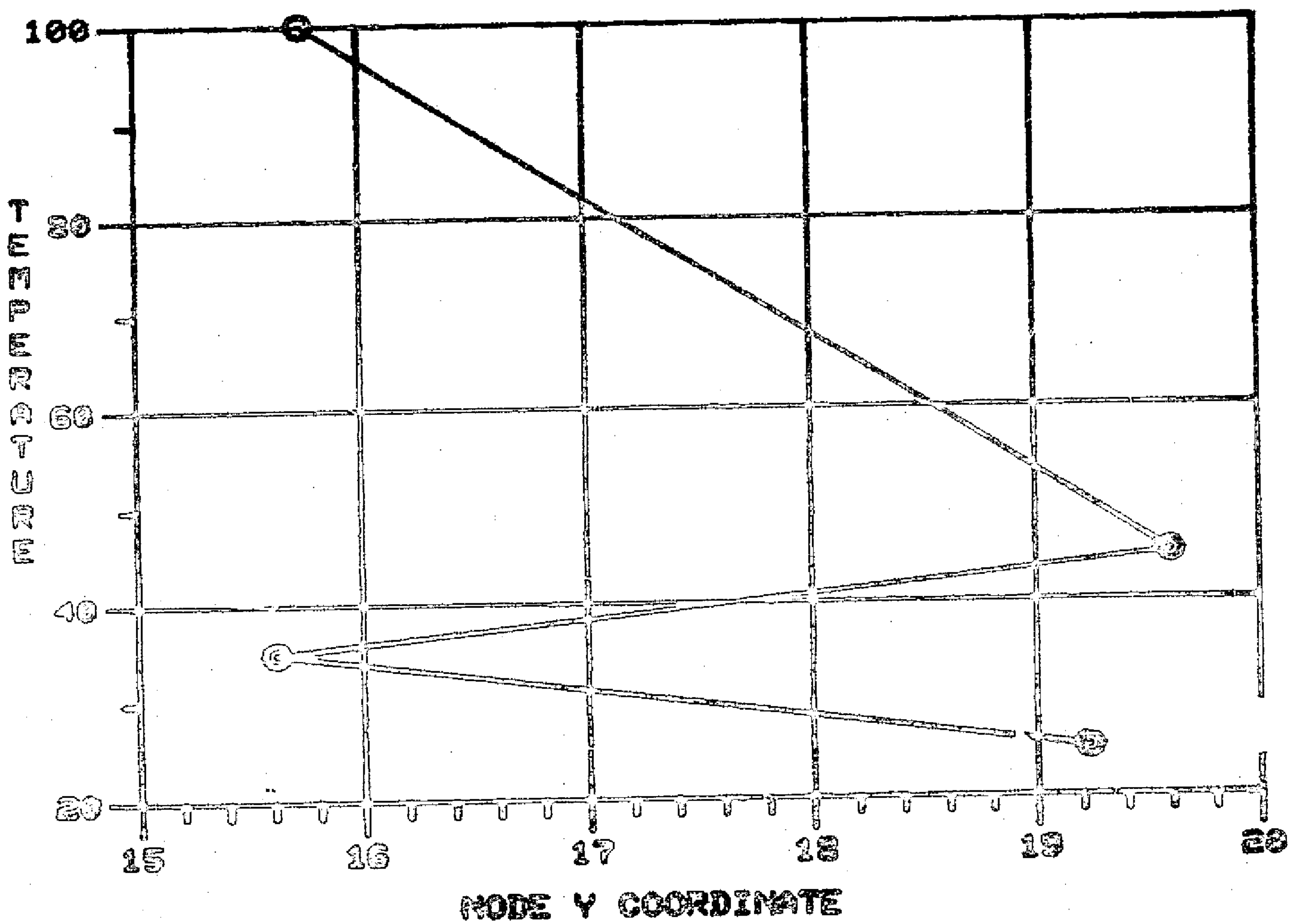


TEMP VS X-COORDINATE XYPLOT EXAMPLE

Figure 11b. Typical XY Plot Generated by GEOMPLT

```
TYPE (C) FOR A LIST OF $XYPLOT NAMELIST OPTIONS

TYPE ANY OTHER CHARACTER FOR NO LIST

>  A

**TYPE ($XYPLOT (OPTIONS) $ )

** NOTE - 1ST CHARACTER IS IGNORED FOR NAMELIST INPUT

**      (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE

**      ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT.

> $XYPLOT SPACE = 1, TIMES = 4.0, IY = 1, JPV (1) = 5001, -0 5004 $ (EXAMPLE)

AFTER PLOT IS COMPLETE TYPE IN A BLANK TO CONTINUE

  TYPE C TO CONTINUE

> C
```

(PLOT APPEARS) SEE FIG. 11c.

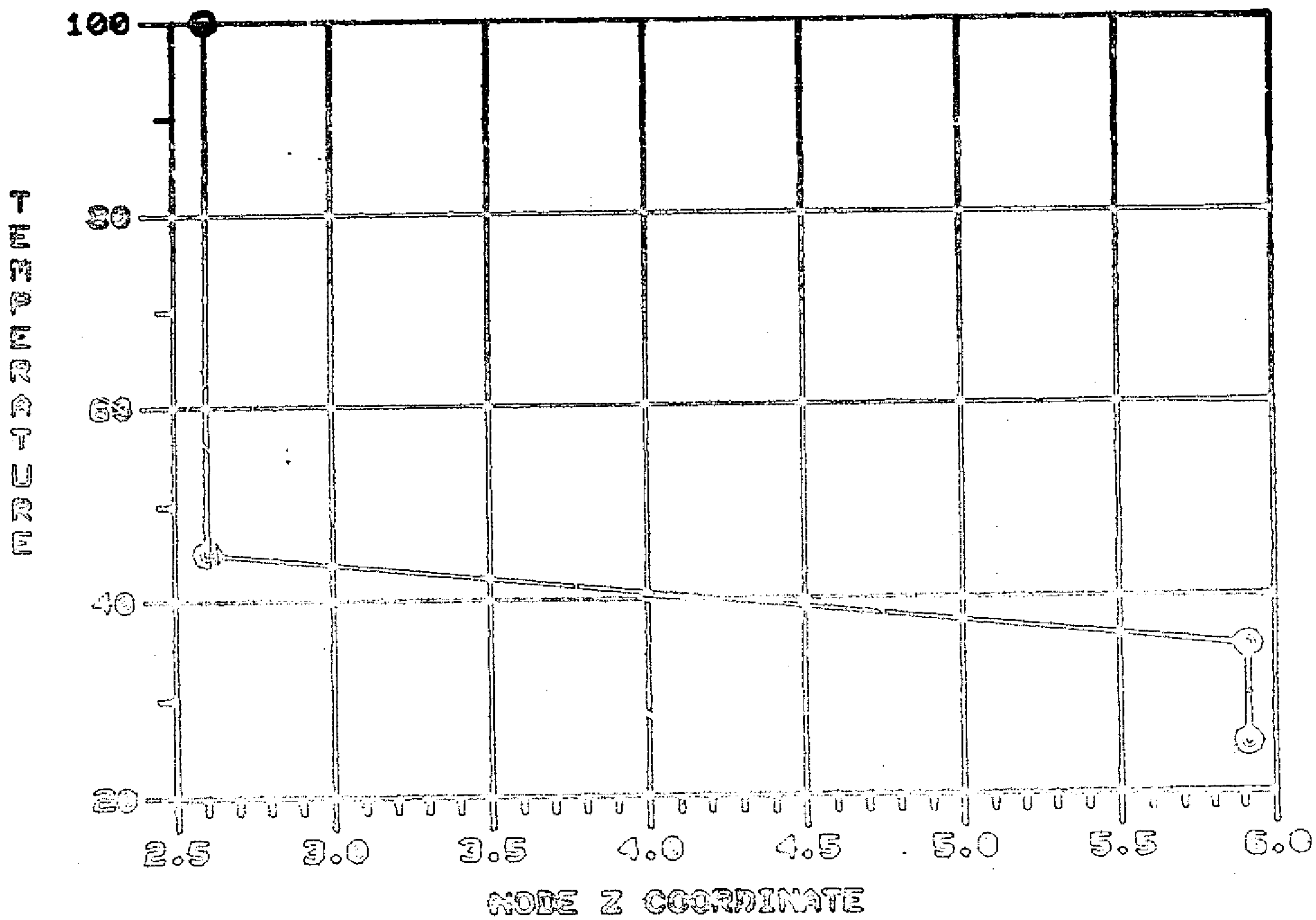


TEMP VS Y COORDINATE

Figure 11c. Typical XY Plot Generated by GEOMPLT

```
TYPE (C) FOR A LIST OF $XYPLOT NAMELIST OPTIONS
TYPE ANY OTHER CHARACTER FOR NO LIST
>
**TYPE ($XYPLOT (OPTIONS) $ )
** NOTE - 1ST CHARACTER IS IGNORED FOR NAMELIST INPUT
**      (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE
**      ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT.
> $XYPLOT SPACE = 1, TIMES = 4.0, IZ = 1, JPV (1) = 5001, -0 5004 $ (EXAMPLE)
AFTER PLOT IS COMPLETE TYPE IN A BLANK TO CONTINUE
  TYPE C TO CONTINUE
> C
```

(PLOT APPEARS) SEE FIG. 11d.



TEMP VS Z-COORDINATE XYPLOT EXAMPLE, T=4. SEC

Figure 11d. Typical XY Plot Generated by GEOMPLT

TYPE STOP TO TERMINATE PLOTTING OR ANY OTHER CHARACTER TO CONTINUE

> STOP

Section 5

SAMPLE PROBLEM

This section presents a thermal problem which was modeled using SPAR finite elements. The problem (Figure 12) consists of conduction, convection, radiation, and fluid flow. This problem was created only to illustrate program capability and has no real physical identity. Data input and output for the three programs used in automated data generation are presented.

5.1 SPAR MODELING

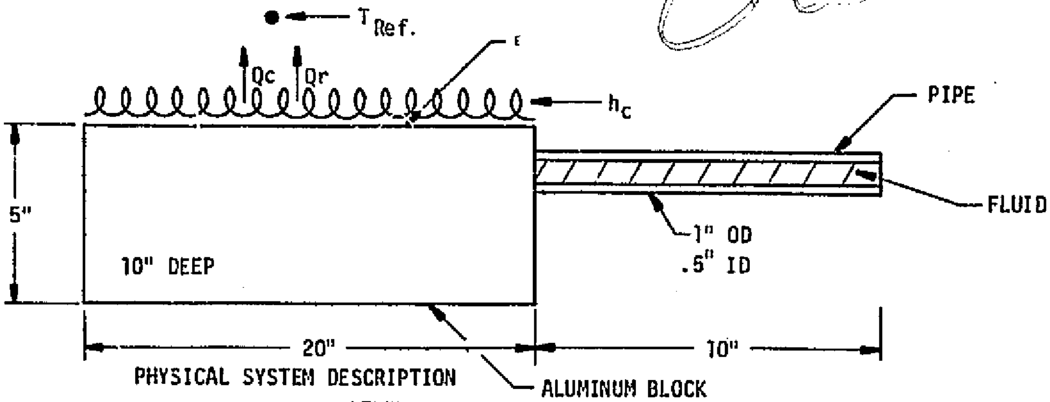
The physical system was represented by SPAR finite elements. Every type of element available to the user is included in the problem. Figure 13 is a listing of the SPAR input describing the model. Figure 14 shows SPAR output to file 4. Grid points and element card are contained on this file.

5.2 CINGEN MODELING

Before data file 4 can be used by CINGEN to produce a MITAS data deck, property and end cards must be added. Figure 15 shows file 4 after these cards have been added. These cards are preceeded by the word "New" in the listing. Figure 16 is the MITAS deck output by CINGEN. Figure 17 is a listing of file 29 which is used by GEOMPLT.

5.3 MODEL CHECK-OUT

Check-out of the thermal network created by SPAR/CINGEN can be accomplished by the use of GEOMPLT. Several types of plots can be generated to assure correct modeling. Some typical plots are presented. The first page of each plot gives the required input to generate the plot that follows it.



PHYSICAL SYSTEM DESCRIPTION

FLUID-OIL

ρ = 0.032
c_p = 0.44
c_v = 0.44
$\dot{m}$ = 10.0

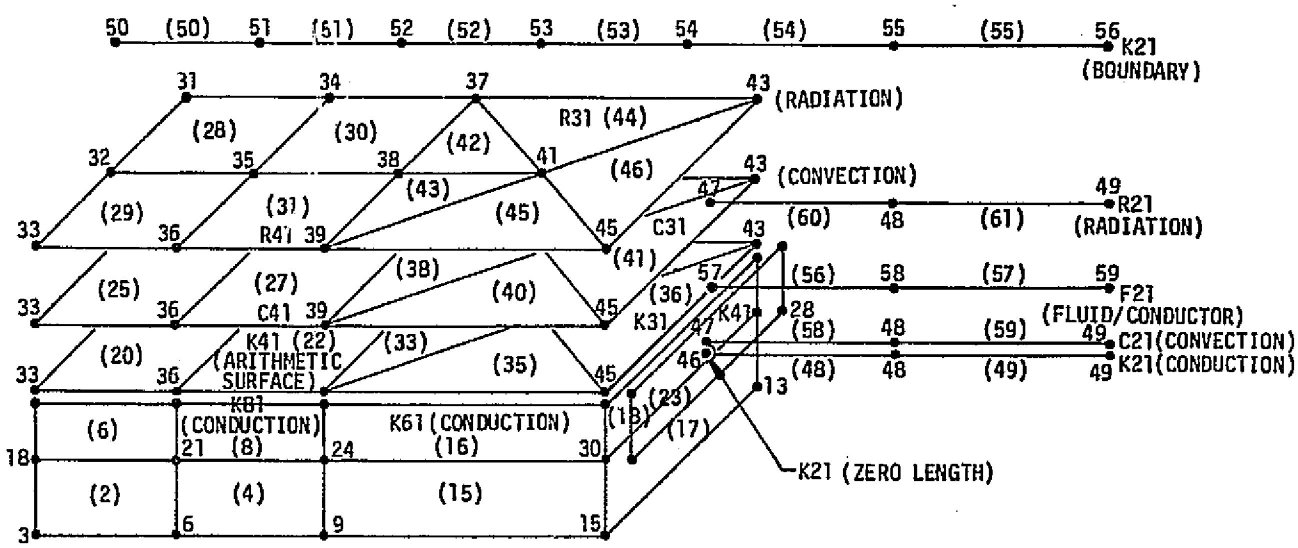
STEEL

ρ = 0.290
c_v = 0.12
k = 215 x 10^{-6}
ε = 0.85

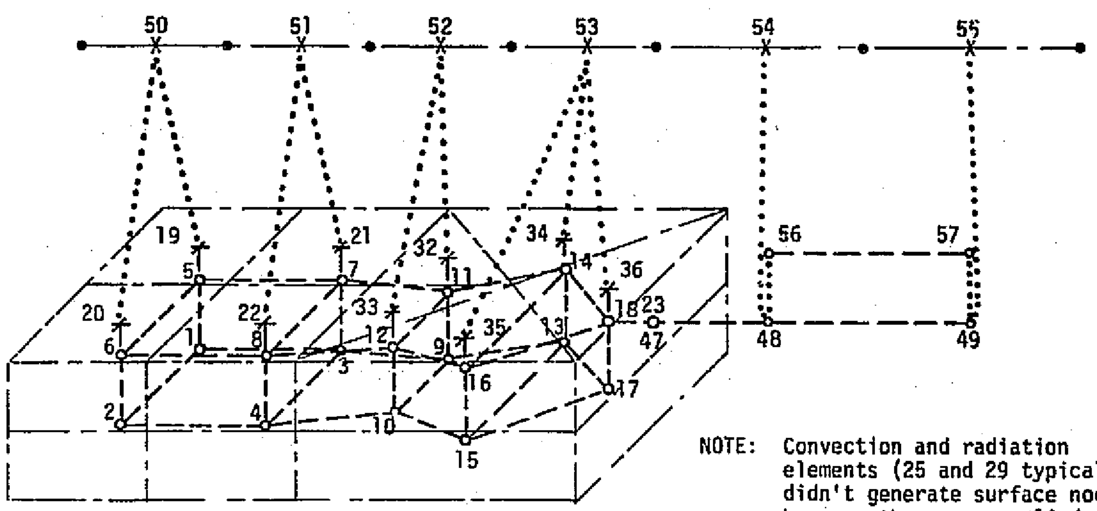
ALUMINUM

ρ = 0.101
c_v = 0.21 @ 0°
0.22 @ 300°
0.235 @ 500°

k = 1680 x 10^{-6} @ 0°
2070 x 10^{-6} @ 500°
ε = 0.7



FINITE ELEMENT IDEALIZATION



NOTE: Convection and radiation elements (25 and 29 typically) didn't generate surface nodes because they were applied to surface elements.

THERMAL IDEALIZATION

Figure 12, Sample Problem

```
000   @XQT TABX
000   ONLINE=3 $ PUNCH GRID CARDS
000   START 59 2 3 4 5 6 $
000   JLOC $
000   1 0. 0. 0. 0. 0. 10. 3 1 5 $
000   3 20. 0. 0. 20. 0. 10. $
000   16 0. 2.5 0. 0. 2.5 10. 3 1 5 $
000   3 20. 2.5 0. 20. 2.5 10. $
000   31 0. 5. 0. 0. 5. 10. 3 1 5 $
000   3 20. 5. 0. 20. 5. 10. $
000   46 20. 3.75 5. $
000   47 20. 3.75 5. 30. 3.75 5. 3 1 $
000   50 0. 10. 5. 30. 10. 5. 7 1 $
000   57 20. 8. 5. 30. 8. 5. 3 1 $
000   @XQT AUS
000   $FLUID-OIL NMAT
000   TABLE (NI=9,NJ=1);COND PROP 3;I=1 2    ;J=1 $
000   0. 2.-6 $
000   $ALUMINUM NMAT
000   TABLE (NI=9,NJ=3);COND PROP 1;I=1 2 3 4;J=1,3 $
000   0. 0.101 0.21 1680.-6 $
000   300. 0.101 0.22 1800.-6 $
000   500. 0.101 0.235 2070.-6 $
000   $STEEL  NMAT
000   TABLE (NI=9,NJ=1);COND PROP 2;I=1 2 3 4;J=1 $
000   0. 0.29 0.12 215.-6 $
000   $SECTION PROPERTIES  NSECT
000   TABLE (NI=1,NJ=3);K AREA 1;J=1,3 $
000   0.589,0.,0.196 $ NSECT=1,2,3, FOR K21,F21
000   TABLE (NI=1,NJ=1);C CIRC 1;J=1 $
000   1.57 $ FOR C21 ELEMENTS, NSECT=1 CONVECTION FROM INSIDE AREA
000   TABLE (NI=1,NJ=1);R CIRC 1;J=1 $
000   3.14 $ FOR R21 ELEMENTS, NSECT=1 RADIATION FROM OUTSIDE AREA
000   $CONVECTION COEFFICIENT NFILM
000   TABLE (NI=2,NJ=1);CONV PROP 1;J=1 $
000   0. 1. $ AIR C21,C31,C41, NFILM=1
000   TABLE (NI=2,NJ=1);CONV PROP 2;J=1 $
000   0. 5. $ OIL C21, NFILM=2
000   $RADIATION COEFFICIENT NRAD
000   TABLE (NI=2,NJ=1);RADI PROP 1;J=1 $
000   0. 0.7 $ R21,R31,R41, NRAD=1
000   $ARITHMETIC NODE PROPERTIES, NMAT, K31 K41
000   TABLE (NI=9,NJ=1);COND PROP 4;I=1 2;J=1 $
000   0. 0. $
000   TABLE (NI=1,NJ=1);K THIC 1;J=1 $
000   0.0 $ ARITHMETIC SURFACE K31 K41
000   $BOUNDARY NODE PROPERTIES NMAT K21
000   TABLE (NI=9,NJ=1);COND PROP 5;I=1 2;J=1 $
000   0. -1. $
000   TABLE (NI=9,NJ=1);COND PROP 6;I=1,2;J=1 $
000   0. 0.1 $ DUMMY COND PROP FOR CONVECTION ELEMENTS
000   @XQT TELD
000   RESET CINGEN=1,NUTE=1 $ TURN ON PUNCH AND THERMAL ELEMENTS
000   K81 $
000   NMAT=1 $
```

Figure 13. SPAR Input For Sample Problem

```
000   1 2 2 2 1 3 15 0 1 $
000   K61 $
000   11 7 2 2 1 15 0 1 $
000   11 7 1 2 6 15 0 1 $
000   11 9 1 2 6 15 0 1 $
000   11 13 1 2 2 15 0 1 $
000   K41 $
000   NMAT=4 $
000   31 32 35 34 1 2 2 $
000   28 30 45 43 $
000   C41 $
000   NMAT=1;31 32 35 34 1 2 1 $
000   NMAT=2;34 35 38 37 1 2 1 $
000   R41 $
000   NMAT=1;31 32 35 34 1 2 1 $
000   NMAT=2;34 35 38 37 1 2 1 $
000   K31 $
000   NMAT=4 $
000   41 37 38 2 2 $
000   41 37 43 ; 41 39 45 ; 41 43 45 $
000   C31 $
000   NMAT=3 $
000   41 37 38 2 2 $
000   NMAT=4 $
000   41 37 43 ; 41 39 45 ; 41 43 45 $
000   R31 $
000   NMAT=3 $
000   41 37 38 2 2 $
000   NMAT=4 $
000   41 37 43 ; 41 39 45 ; 41 43 45 $
000   K21 $
000   GROUP 1" REGULAR K21 ELEMENTS
000   NMAT=2;46 47 1 3 1 $
000   NMAT=5;NSECT=2;50 51 1 6 1 $
000   GROUP 2" FLUID ELEMENTS F21
000   NMAT=3;NSECT=3;57 58 1 2 1 $
000   C21 $
000   NSECT=1;NMAT=5;47 48 $
000   NSECT=1;NMAT=6;48 49 $
000   R21 $
000   NSECT=1;NMAT=5;47 48 $
000   NSECT=1;NMAT=6;48 49 $
000   @XQT DCU
000   TOC 1
```

Figure 13 (continued)

000001	000	GRID	1	0	.000	.000	.000
000002	000	GRID	2	0	.000	.000	5.000
000003	000	GRID	3	0	.000	.000	10.000
000004	000	GRID	4	0	5.000	.000	.000
000005	000	GRID	5	0	5.000	.000	5.000
000006	000	GRID	6	0	5.000	.000	10.000
000007	000	GRID	7	0	10.000	.000	.000
000008	000	GRID	8	0	10.000	.000	5.000
000009	000	GRID	9	0	10.000	.000	10.000
000010	000	GRID	10	0	15.000	.000	.000
000011	000	GRID	11	0	15.000	.000	5.000
000012	000	GRID	12	0	15.000	.000	10.000
000013	000	GRID	13	0	20.000	.000	.000
000014	000	GRID	14	0	20.000	.000	5.000
000015	000	GRID	15	0	20.000	.000	10.000
000016	000	GRID	16	0	.000	2.500	.000
000017	000	GRID	17	0	.000	2.500	5.000
000018	000	GRID	18	0	.000	2.500	10.000
000019	000	GRID	19	0	5.000	2.500	.000
000020	000	GRID	20	0	5.000	2.500	5.000
000021	000	GRID	21	0	5.000	2.500	10.000
000022	000	GRID	22	0	10.000	2.500	.000
000023	000	GRID	23	0	10.000	2.500	5.000
000024	000	GRID	24	0	10.000	2.500	10.000
000025	000	GRID	25	0	15.000	2.500	.000
000026	000	GRID	26	0	15.000	2.500	5.000
000027	000	GRID	27	0	15.000	2.500	10.000
000028	000	GRID	28	0	20.000	2.500	.000
000029	000	GRID	29	0	20.000	2.500	5.000
000030	000	GRID	30	0	20.000	2.500	10.000
000031	000	GRID	31	0	.000	5.000	.000
000032	000	GRID	32	0	.000	5.000	5.000
000033	000	GRID	33	0	.000	5.000	10.000
000034	000	GRID	34	0	5.000	5.000	.000
000035	000	GRID	35	0	5.000	5.000	5.000
000036	000	GRID	36	0	5.000	5.000	10.000
000037	000	GRID	37	0	10.000	5.000	.000
000038	000	GRID	38	0	10.000	5.000	5.000
000039	000	GRID	39	0	10.000	5.000	10.000
000040	000	GRID	40	0	15.000	5.000	.000
000041	000	GRID	41	0	15.000	5.000	5.000
000042	000	GRID	42	0	15.000	5.000	10.000
000043	000	GRID	43	0	20.000	5.000	.000
000044	000	GRID	44	0	20.000	5.000	5.000
000045	000	GRID	45	0	20.000	5.000	10.000
000046	000	GRID	46	0	20.000	3.750	5.000
000047	000	GRID	47	0	20.000	3.750	5.000
000048	000	GRID	48	0	25.000	3.750	5.000
000049	000	GRID	49	0	30.000	3.750	5.000
000050	000	GRID	50	0	.000	10.000	5.000
000051	000	GRID	51	0	5.000	10.000	5.000
000052	000	GRID	52	0	10.000	10.000	5.000
000053	000	GRID	53	0	15.000	10.000	5.000
000054	000	GRID	54	0	20.000	10.000	5.000
000055	000	GRID	55	0	25.000	10.000	5.000

Figure 14. SPAR Output to File 4 for Sample Problem

000056	000	GRID	56	0	30.000	10.000	5.000			
000057	000	GRID	57	0	20.000	8.000	5.000			
000058	000	GRID	58	0	25.000	8.000	5.000			
000059	000	GRID	59	0	30.000	8.000	5.000			
000060	000	K81	1	1	1	2	5	4	16	17
000061	000		20	19						
000062	000	K81	2	1	2	3	6	5	17	18
000063	000		21	20						
000064	000	K81	3	1	4	5	8	7	19	20
000065	000		23	22						
000066	000	K81	4	1	5	6	9	8	20	21
000067	000		24	23						
000068	000	K81	5	1	16	17	20	19	31	32
000069	000		35	34						
000070	000	K81	6	1	17	18	21	20	32	33
000071	000		36	35						
000072	000	K81	7	1	19	20	23	22	34	35
000073	000		38	37						
000074	000	K81	8	1	20	21	24	23	35	36
000075	000		39	38						
000076	000	K61	9	1	11	7	8	26	22	23
000077	000	K61	10	1	11	8	9	26	23	24
000078	000	K61	11	1	26	22	23	41	37	38
000079	000	K61	12	1	26	23	24	41	38	39
000080	000	K61	13	1	11	7	13	26	22	28
000081	000	K61	14	1	26	22	28	41	37	43
000082	000	K61	15	1	11	9	15	26	24	30
000083	000	K61	16	1	26	24	30	41	39	45
000084	000	K61	17	1	11	13	15	26	28	30
000085	000	K61	18	1	26	28	30	41	43	45
000086	000	K41	19	4	31	32	35	34	0.0000000	
000087	000	K41	20	4	32	33	36	35	0.0000000	
000088	000	K41	21	4	34	35	38	37	0.0000000	
000089	000	K41	22	4	35	36	39	38	0.0000000	
000090	000	K41	23	4	28	30	45	43	0.0000000	
000091	000	C41	24	1	31	32	35	34		
000092	000	C41	25	1	32	33	36	35		
000093	000	C41	26	2	34	35	38	37		
000094	000	C41	27	2	35	36	39	38		
000095	000	R41	28	1	31	32	35	34		
000096	000	R41	29	1	32	33	36	35		
000097	000	R41	30	2	34	35	38	37		
000098	000	R41	31	2	35	36	39	38		
000099	000	K31	32	4	41	37	38	0.0000000		
000100	000	K31	33	4	41	38	39	0.0000000		
000101	000	K31	34	4	41	37	43	0.0000000		
000102	000	K31	35	4	41	39	45	0.0000000		
000103	000	K31	36	4	41	43	45	0.0000000		
000104	000	C31	37	3	41	37	38			
000105	000	C31	38	3	41	38	39			
000106	000	C31	39	4	41	37	43			
000107	000	C31	40	4	41	39	45			
000108	000	C31	41	4	41	43	45			
000109	000	R31	42	3	41	37	38			
000110	000	R31	43	3	41	38	39			
000111	000	R31	44	4	41	37	43			
000112	000	R31	45	4	41	39	45			

Figure 14. (continued)

000113	000	R31	46	4	41	43	45
000114	000	K21	47	2	46	47	5.8900000-01
000115	000	K21	48	2	47	48	5.8900000-01
000116	000	K21	49	2	48	49	5.8900000-01
000117	000	K21	50	5	50	51	0.0000000
000118	000	K21	51	5	51	52	0.0000000
000119	000	K21	52	5	52	53	0.0000000
000120	000	K21	53	5	53	54	0.0000000
000121	000	K21	54	5	54	55	0.0000000
000122	000	K21	55	5	55	56	0.0000000
000123	000	F21	56	3	57	58	1.9600000-01
000124	000	F21	57	3	58	59	1.9600000-01
000125	000	C21	58	5	47	48	1.5700000+00
000126	000	C21	59	6	48	49	1.5700000+00
000127	000	R21	60	5	47	48	3.1400000+00
000128	000	R21	61	6	48	49	3.1400000+00

Figure 14. (continued)

```
000001    000           0        0       R   75.      SPAR
000002    000   NMAT    1         .101    -11.      -13.
000003    000   NMAT    2         .29      .12     215.E-6
000004    000   NMAT    3         .032     .44      10.       .44
000005    000   NMAT    4        -1.0
000006    000   NMAT    5        0.0
000007    000   NFILM   1        50       .1
000008    000   NFILM   2         51      .1
000009    000   NFILM   3        52       .1
000010    000   NFILM   4        53       .1
000011    000   NFILM   5        56        0.5
000012    000   NFILM   6        57        0.5
000013    000   NRAD    1        50       2.3E-15
000014    000   NRAD    2        51            2.3E-15
000015    000   NRAD    3        52       2.3E-15
000016    000   NRAD    4        53       2.3E-15
000017    000   NRAD    6        55       2.8E-15
000018    000   NRAD    5        54       2.8E-15
000019    000   END
000020    000   TITLE EXAMPLE NUMBER 2
000021    000   GRID            1        0      .000      .000      .000
000022    000   GRID            2        0      .000      .000     5.000
000023    000   GRID            3        0      .000      .000    10.000
000024    000   GRID            4        0     5.000      .000      .000
000025    000   GRID            5        0     5.000      .000     5.000
000026    000   GRID            6        0     5.000      .000    10.000
000027    000   GRID            7        0    10.000      .000      .000
000028    000   GRID            8        0    10.000      .000     5.000
000029    000   GRID            9        0    10.000      .000    10.000
000030    000   GRID           10        0    15.000      .000      .000
000031    000   GRID           11        0    15.000      .000     5.000
000032    000   GRID           12        0    15.000      .000    10.000
000033    000   GRID           13        0    20.000      .000      .000
000034    000   GRID           14        0    20.000      .000     5.000
000035    000   GRID           15        0    20.000      .000    10.000
000036    000   GRID           16        0      .000     2.500      .000
000037    000   GRID           17        0      .000     2.500     5.000
000038    000   GRID           18        0      .000     2.500    10.000
000039    000   GRID           19        0     5.000     2.500      .000
000040    000   GRID           20        0     5.000     2.500     5.000
000041    000   GRID           21        0     5.000     2.500    10.000
000042    000   GRID           22        0    10.000     2.500      .000
000043    000   GRID           23        0    10.000     2.500     5.000
000044    000   GRID           24        0    10.000     2.500    10.000
000045    000   GRID           25        0    15.000     2.500      .000
000046    000   GRID           26        0    15.000     2.500     5.000
000047    000   GRID           27        0    15.000     2.500    10.000
000048    000   GRID           28        0    20.000     2.500      .000
000049    000   GRID           29        0    20.000     2.500     5.000
000050    000   GRID           30        0    20.000     2.500    10.000
000051    000   GRID           31        0      .000     5.000      .000
000052    000   GRID           32        0      .000     5.000     5.000
000053    000   GRID           33        0      .000     5.000    10.000
000054    000   GRID           34        0     5.000     5.000      .000
000055    000   GRID           35        0     5.000     5.000     5.000
```

Figure 15. CINGEN Input For Sample Problem

000056	000	GRID	36	0	5.000	5.000	10.000			
000057	000	GRID	37	0	10.000	5.000	.000			
000058	000	GRID	38	0	10.000	5.000	5.000			
000059	000	GRID	39	0	10.000	5.000	10.000			
000060	000	GRID	40	0	15.000	5.000	.000			
000061	000	GRID	41	0	15.000	5.000	5.000			
000062	000	GRID	42	0	15.000	5.000	10.000			
000063	000	GRID	43	0	20.000	5.000	.000			
000064	000	GRID	44	0	20.000	5.000	5.000			
000065	000	GRID	45	0	20.000	5.000	10.000			
000066	000	GRID	46	0	20.000	3.750	5.000			
000067	000	GRID	47	0	20.000	3.750	5.000			
000068	000	GRID	48	0	25.000	3.750	5.000			
000069	000	GRID	49	0	30.000	3.750	5.000			
000070	000	GRID	50	0	.000	10.000	5.000			
000071	000	GRID	51	0	5.000	10.000	5.000			
000072	000	GRID	52	0	10.000	10.000	5.000			
000073	000	GRID	53	0	15.000	10.000	5.000			
000074	000	GRID	54	0	20.000	10.000	5.000			
000075	000	GRID	55	0	25.000	10.000	5.000			
000076	000	GRID	56	0	30.000	10.000	5.000			
000077	000	GRID	57	0	20.000	8.000	5.000			
000078	000	GRID	58	0	25.000	8.000	5.000			
000079	000	GRID	59	0	30.000	8.000	5.000			
000080	000	K81	1	1	1	2	5	4	16	17
000081	000		20	19						
000082	000	K81	2	1	2	3	6	5	17	18
000083	000		21	20						
000084	000	K81	3	1	4	5	8	7	19	20
000085	000		23	22						
000086	000	K81	4	1	5	6	9	8	20	21
000087	000		24	23						
000088	000	K81	5	1	16	17	20	19	31	32
000089	000		35	34						
000090	000	K81	6	1	17	18	21	20	32	33
000091	000		36	35						
000092	000	K81	7	1	19	20	23	22	34	35
000093	000		38	37						
000094	000	K81	8	1	20	21	24	23	35	36
000095	000		39	38						
000096	000	K61	9	1	11	7	8	26	22	23
000097	000	K61	10	1	11	8	9	26	23	24
000098	000	K61	11	1	26	22	23	41	37	38
000099	000	K61	12	1	26	23	24	41	38	39
000100	000	K61	13	1	11	7	13	26	22	28
000101	000	K61	14	1	26	22	28	41	37	43
000102	000	K61	15	1	11	9	15	26	24	30
000103	000	K61	16	1	26	24	30	41	39	45
000104	000	K61	17	1	11	13	15	26	28	30
000105	000	K61	18	1	26	28	30	41	43	45
000106	000	K41	19	4	31	32	35	34	0.0000000	
000107	000	K41	20	4	32	33	36	35	0.0000000	
000108	000	K41	21	4	34	35	38	37	0.0000000	
000109	000	K41	22	4	35	36	39	38	0.0000000	
000110	000	K41	23	4	28	30	45	43	0.0000000	
000111	000	C41	24	1	31	32	35	34		
000112	000	C41	25	1	32	33	36	35		

Figure 15. (continued)

000113	000	C41	26	2	34	35	38	37
000114	000	C41	27	2	35	36	39	38
000115	000	R41	28	1	31	32	35	34
000116	000	R41	29	1	32	33	36	35
000117	000	R41	30	2	34	35	38	37
000118	000	R41	31	2	35	36	39	38
000119	000	K31	32	4	41	37	38	0.0000000
000120	000	K31	33	4	41	38	39	0.0000000
000121	000	K31	34	4	41	37	43	0.0000000
000122	000	K31	35	4	41	39	45	0.0000000
000123	000	K31	36	4	41	43	45	0.0000000
000124	000	C31	37	3	41	37	38	
000125	000	C31	38	3	41	38	39	
000126	000	C31	39	4	41	37	43	
000127	000	C31	40	4	41	39	45	
000128	000	C31	41	4	41	43	45	
000129	000	R31	42	3	41	37	38	
000130	000	R31	43	3	41	38	39	
000131	000	R31	44	4	41	37	43	
000132	000	R31	45	4	41	39	45	
000133	000	R31	46	4	41	43	45	
000134	000	K21	47	2	46	47	5.8900000-01	
000135	000	K21	48	2	47	48	5.8900000-01	
000136	000	K21	49	2	48	49	5.8900000-01	
000137	000	K21	50	5	50	51	0.0000000	
000138	000	K21	51	5	51	52	0.0000000	
000139	000	K21	52	5	52	53	0.0000000	
000140	000	K21	53	5	53	54	0.0000000	
000141	000	K21	54	5	54	55	0.0000000	
000142	000	K21	55	5	55	56	0.0000000	
000143	000	F21	56	3	57	58	1.9600000-01	
000144	000	F21	57	3	58	59	1.9600000-01	
000145	000	C21	58	5	47	48	1.5700000+00	
000146	000	C21	59	6	48	49	1.5700000+00	
000147	000	R21	60	5	47	48	3.1400000+00	
000148	000	R21	61	6	48	49	3.1400000+00	
000149	000	ENDDATA						

Figure 15. (continued)

```
000001      000      BCD 6TITLE EXAMPLE NUMBER 2
000002      000      BCD 6
000003      000      END
000004      000      BCD 3NODE DATA
000005      000      CGS     1,   75.00,     A11,   .6312+01
000006      000      CGS     2,   75.00,     A11,   .6312+01
000007      000      CGS     3,   75.00,     A11,   .6312+01
000008      000      CGS     4,   75.00,     A11,   .6312+01
000009      000      CGS     5,   75.00,     A11,   .6312+01
000010      000      CGS     6,   75.00,     A11,   .6312+01
000011      000      CGS     7,   75.00,     A11,   .6312+01
000012      000      CGS     8,   75.00,     A11,   .6312+01
000013      000      CGS     9,   75.00,     A11,   .3156+01
000014      000      CGS    10,   75.00,     A11,   .3156+01
000015      000      CGS    11,   75.00,     A11,   .3156+01
000016      000      CGS    12,   75.00,     A11,   .3156+01
000017      000      CGS    13,   75.00,     A11,   .6312+01
000018      000      CGS    14,   75.00,     A11,   .6312+01
000019      000      CGS    15,   75.00,     A11,   .6312+01
000020      000      CGS    16,   75.00,     A11,   .6312+01
000021      000      CGS    17,   75.00,     A11,   .6312+01
000022      000      CGS    18,   75.00,     A11,   .6312+01
000023      000             47,   75.00,   .0000
000024      000             48,   75.00,   .1025+00
000025      000             49,   75.00,   .1025+00
000026      000             56,   75.00,   .1380-01
000027      000             57,   75.00,   .1380-01
000028      000             19,   75.00,  -.1000+01
000029      000             20,   75.00,  -.1000+01
000030      000             21,   75.00,  -.1000+01
000031      000             22,   75.00,  -.1000+01
000032      000             23,   75.00,  -.1000+01
000033      000             32,   75.00,  -.1000+01
000034      000             33,   75.00,  -.1000+01
000035      000             34,   75.00,  -.1000+01
000036      000             35,   75.00,  -.1000+01
000037      000             36,   75.00,  -.1000+01
000038      000            -50,   75.00,   .0000
000039      000            -51,   75.00,   .0000
000040      000            -52,   75.00,   .0000
000041      000            -53,   75.00,   .0000
000042      000            -54,   75.00,   .0000
000043      000            -55,   75.00,   .0000
000044      000      END
000045      000      BCD 3CONDUCTOR DATA
000046      000      CGS     1,   19,     5,     A13,   .2000+02
000047      000      CGS     2,   20,     6,     A13,   .2000+02
000048      000      CGS     3,   21,     7,     A13,   .2000+02
000049      000      CGS     4,   22,     8,     A13,   .2000+02
000050      000      CGS     5,   23,    18,     A13,   .5625+01
000051      000      CGS     6,   32,    11,     A13,   .1000+02
000052      000      CGS     7,   33,    12,     A13,   .1000+02
000053      000      CGS     8,   34,    14,     A13,   .2000+02
000054      000      CGS     9,   35,    16,     A13,   .2000+02
000055      000      CGS    10,   36,    18,     A13,   .2000+02
```

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Figure 16. MITAS Data Deck of Sample Problem as Created by CINGEN

000056	000	CGS	11,	1,	2,	A13,	.2500+01
000057	000	CGS	12,	1,	3,	A13,	.2500+01
000058	000	CGS	13,	1,	5,	A13,	.1000+02
000059	000	CGS	14,	2,	4,	A13,	.2500+01
000060	000	CGS	15,	2,	6,	A13,	.1000+02
000061	000	CGS	16,	3,	4,	A13,	.2500+01
000062	000	CGS	17,	3,	7,	A13,	.1000+02
000063	000	CGS	18,	3,	9,	A13,	.1800+01
000064	000	CGS	19,	4,	8,	A13,	.1000+02
000065	000	CGS	20,	4,	10,	A13,	.2647+01
000066	000	CGS	21,	5,	6,	A13,	.2500+01
000067	000	CGS	22,	5,	7,	A13,	.2500+01
000068	000	CGS	23,	6,	8,	A13,	.2500+01
000069	000	CGS	24,	7,	8,	A13,	.2500+01
000070	000	CGS	25,	7,	11,	A13,	.1800+01
000071	000	CGS	26,	8,	12,	A13,	.2647+01
000072	000	CGS	27,	9,	10,	A13,	.1406+01
000073	000	CGS	28,	9,	11,	A13,	.5000+01
000074	000	CGS	29,	9,	13,	A13,	.2812+01
000075	000	CGS	30,	10,	12,	A13,	.5000+01
000076	000	CGS	31,	10,	15,	A13,	.2813+01
000077	000	CGS	32,	11,	12,	A13,	.1406+01
000078	000	CGS	33,	11,	14,	A13,	.2812+01
000079	000	CGS	34,	12,	16,	A13,	.2813+01
000080	000	CGS	35,	13,	14,	A13,	.1000+02
000081	000	CGS	36,	13,	17,	A13,	.2813+01
000082	000	CGS	37,	14,	18,	A13,	.2813+01
000083	000	CGS	38,	15,	16,	A13,	.1000+02
000084	000	CGS	39,	15,	17,	A13,	.2813+01
000085	000	CGS	40,	16,	18,	A13,	.2813+01
000086	000	CGS	41,	17,	18,	A13,	.1000+02
000087	000		42,	47,	48,	.5065-04	
000088	000		43,	48,	49,	.2533-04	
000089	000		44,	-56,	57,	.8624+00	
000090	000		45,	19,	50,	.2500+01	
000091	000		46,	20,	50,	.2500+01	
000092	000		47,	21,	51,	.2500+01	
000093	000		48,	22,	51,	.2500+01	
000094	000		49,	32,	52,	.1250+01	
000095	000		50,	33,	52,	.2500+01	
000096	000		51,	34,	53,	.5000+01	
000097	000		52,	35,	53,	.2500+01	
000098	000		53,	36,	53,	.2500+01	
000099	000		54,	48,	56,	.3925+01	
000100	000		55,	49,	57,	.3925+01	
000101	000		-56,	19,	50,	.5750-13	
000102	000		-57,	20,	50,	.5750-13	
000103	000		-58	21,	51,	.5750-13	
000104	000		-59,	22,	51,	.5750-13	
000105	000		-60,	32,	52,	.2875-13	
000106	000		-61,	33,	52,	.2875-13	
000107	000		-62,	34,	53,	.5750-13	
000108	000		-63,	35,	53,	.5750-13	
000109	000		-64,	36,	53,	.5750-13	
000110	000		-65,	48,	54,	.4396-13	
000111	000		-66,	49,	55,	.4396-13	
000112	000	END					

Figure 16. (continued)

```
000113      000          BCD 3CONSTANTS DATA
000114      000          END
000115      000          BCD 3ARRAY DATA
000116      000          END
000117      000          BCD 3EXECUTION
000118      000              FORWRD
000119      000          END
000120      000          BCD 3VARIABLES 1
000121      000          END
000122      000          BCD 3VARIABLES 2
000123      000          END
000124      000          BCD 3OUTPUT CALLS
000125      000              TPRINT
000126      000          END
000127      000          BCD 3END OF DATA
```

Figure 16. (continued)

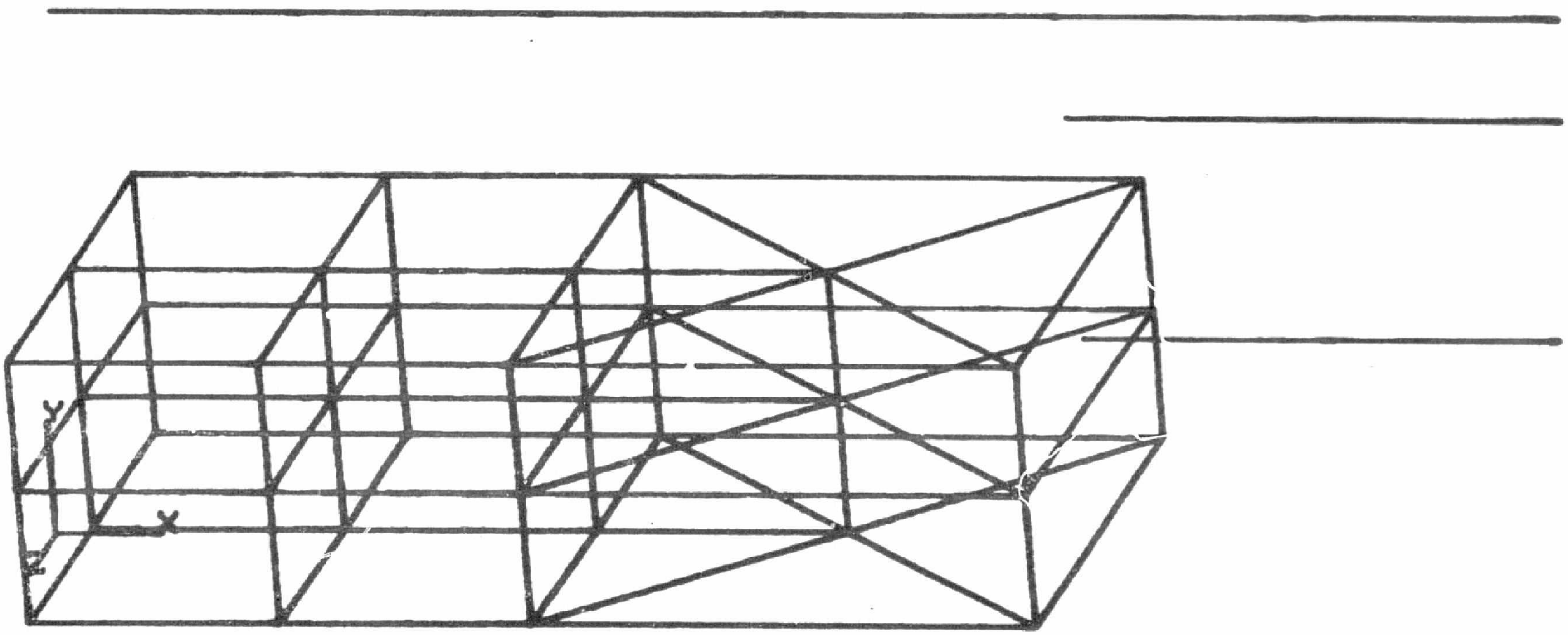
000001	000	K	1A	19D	5	20.000	2.500	5.000	2.500	2.500	3.750	2.500
000002	000	K	2A	20D	6	20.000	2.500	5.000	7.500	2.500	3.750	7.500
000003	000	K	3A	21D	7	20.000	7.500	5.000	2.500	7.500	3.750	2.500
000004	000	K	4A	22D	8	20.000	7.500	5.000	7.500	7.500	3.750	7.500
000005	000	K	5A	23D	18	5.625	20.000	3.750	5.000	18.333	3.750	5.000
000006	000	K	6A	32D	11	10.000	11.667	5.000	3.333	11.667	3.750	3.333
000007	000	K	7A	33D	12	10.000	11.667	5.000	6.667	11.667	3.750	6.667
000008	000	K	8A	34D	14	20.000	15.000	5.000	1.667	15.000	3.750	1.667
000009	000	K	9A	35D	16	20.000	15.000	5.000	8.333	15.000	3.750	8.333
000010	000	K	10A	36D	18	20.000	18.333	5.000	5.000	18.333	3.750	5.000
000011	000	K	11D	1D	2	2.500	2.500	1.250	2.500	2.500	1.250	7.500
000012	000	K	12D	1D	3	2.500	2.500	1.250	2.500	7.500	1.250	2.500
000013	000	K	13D	1D	5	10.000	2.500	1.250	2.500	2.500	3.750	2.500
000014	000	K	14D	2D	4	2.500	2.500	1.250	7.500	7.500	1.250	7.500
000015	000	K	15D	2D	6	10.000	2.500	1.250	7.500	2.500	3.750	7.500
000016	000	K	16D	3D	4	2.500	7.500	1.250	2.500	7.500	1.250	7.500
000017	000	K	17D	3D	7	10.000	7.500	1.250	2.500	7.500	3.750	2.500
000018	000	K	18D	3D	9	1.800	7.500	1.250	2.500	11.667	1.250	3.333
000019	000	K	19D	4D	8	10.000	7.500	1.250	7.500	7.500	3.750	7.500
000020	000	K	20D	4D	10	2.647	7.500	1.250	7.500	11.667	1.250	6.667
000021	000	K	21D	5D	6	2.500	2.500	3.750	2.500	2.500	3.750	7.500
000022	000	K	22D	5D	7	2.500	2.500	3.750	2.500	7.500	3.750	2.500
000023	000	K	23D	6D	8	2.500	2.500	3.750	7.500	7.500	3.750	7.500
000024	000	K	24D	7D	8	2.500	7.500	3.750	2.500	7.500	3.750	7.500
000025	000	K	25D	7D	11	1.800	7.500	3.750	2.500	11.667	3.750	3.333
000026	000	K	26D	8D	12	2.647	7.500	3.750	7.500	11.667	3.750	6.667
000027	000	K	27D	9D	10	1.406	11.667	1.250	3.333	11.667	1.250	6.667
000028	000	K	28D	9D	11	5.000	11.667	1.250	3.333	11.667	3.750	3.333
000029	000	K	29D	9D	13	2.812	11.667	1.250	3.333	15.000	1.250	1.667
000030	000	K	30D	10D	12	5.000	11.667	1.250	6.667	11.667	3.750	6.667
000031	000	K	31D	10D	15	2.813	11.667	1.250	6.667	15.000	1.250	8.333
000032	000	K	32D	11D	12	1.406	11.667	3.750	3.333	11.667	3.750	6.667
000033	000	K	33D	11D	14	2.812	11.667	3.750	3.333	15.000	3.750	1.667
000034	000	K	34D	12D	16	2.813	11.667	3.750	6.667	15.000	3.750	8.333
000035	000	K	35D	13D	14	10.000	15.000	1.250	1.667	15.000	3.750	1.667
000036	000	K	36D	13D	17	2.813	15.000	1.250	1.667	18.333	1.250	5.000
000037	000	K	37D	14D	18	2.813	15.000	3.750	1.667	18.333	3.750	5.000
000038	000	K	38D	15D	16	10.000	15.000	1.250	8.333	15.000	3.750	8.333
000039	000	K	39D	15D	17	2.813	15.000	1.250	8.333	18.333	1.250	5.000
000040	000	K	40D	16D	18	2.813	15.000	3.750	8.333	18.333	3.750	5.000
000041	000	K	41D	17D	18	10.000	18.333	1.250	5.000	18.333	3.750	5.000
000042	000	K	42D	47D	48	.000	20.000	3.750	5.000	22.500	3.750	5.000
000043	000	K	43D	48D	49	.000	22.500	3.750	5.000	27.500	3.750	5.000
000044	000	F	44D	56D	57	.862	22.500	8.000	5.000	27.500	8.000	5.000
000045	000	C	45A	19B	50	2.500	2.500	5.000	2.500	2.500	10.000	5.000
000046	000	C	46A	20B	50	2.500	2.500	5.000	7.500	2.500	10.000	5.000
000047	000	C	47A	21B	51	2.500	7.500	5.000	2.500	7.500	10.000	5.000
000048	000	C	48A	22B	51	2.500	7.500	5.000	7.500	7.500	10.000	5.000
000049	000	C	49A	32B	52	1.250	11.667	5.000	3.333	12.500	10.000	5.000
000050	000	C	50A	33B	52	1.250	11.667	5.000	6.667	12.500	10.000	5.000
000051	000	C	51A	34B	53	2.500	15.000	5.000	1.667	17.500	10.000	5.000
000052	000	C	52A	35B	53	2.500	15.000	5.000	8.333	17.500	10.000	5.000
000053	000	C	53A	36B	53	2.500	18.333	5.000	5.000	17.500	10.000	5.000
000054	000	C	54D	48D	56	3.925	22.500	3.750	5.000	22.500	8.000	5.000
000055	000	C	55D	49D	57	3.925	27.500	3.750	5.000	27.500	8.000	5.000

Figure 17. Data File 29 for Sample Problem as Created by CINGEN

000056	000	R	56A	19B	50	.000	2.500	5.000	2.500	2.500	10.000	5.000
000057	000	R	57A	20B	50	.000	2.500	5.000	7.500	2.500	10.000	5.000
000058	000	R	58A	21B	51	.000	7.500	5.000	2.500	7.500	10.000	5.000
000059	000	R	59A	22B	51	.000	7.500	5.000	7.500	7.500	10.000	5.000
000060	000	R	60A	32B	52	.000	11.667	5.000	3.333	12.500	10.000	5.000
000061	000	R	61A	33B	52	.000	11.667	5.000	6.667	12.500	10.000	5.000
000062	000	R	62A	34B	53	.000	15.000	5.000	1.667	17.500	10.000	5.000
000063	000	R	63A	35B	53	.000	15.000	5.000	8.333	17.500	10.000	5.000
000064	000	R	64A	36B	53	.000	18.333	5.000	5.000	17.500	10.000	5.000
000065	000	R	65D	48B	54	.000	22.500	3.750	5.000	22.500	10.000	5.000
000066	000	R	66D	49B	55	.000	27.500	3.750	5.000	27.500	10.000	5.000

Figure 17. (continued)

```
 ** TYPE TITLE CARD (80 CHARACTERS)
>SAMPLE FINITE ELEMENT DATA
 ** TYPE (C) FOR A LIST OF NAMELIST OPTIONS
 ** OR TYPE ANY OTHER CHARACTER FOR NO LIST
>A
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
> $INPUT X=-20.,Y=15.,Z=0.,SCALEX=12.,SCALEY=15. $
```



SAMPLE FINITE ELEMENT DATA

```
                                    *
 ** TYPE TITLE CARD (80 CHARACTERS)
CINGEN + FINITE ELEMENT DATA, K81 K61
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 $INPUT NODENO=1,CONDNO=1,PV=1 $
 ** TYPE ( $PVIEW JPV(1)= ,(ELEMENT NUMBERS) $)
 ** TO DEFINE PARTIAL VIEW

 ** NOTE - 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 **        (-0) IS USED FOR CONSECUTIVE NUMBERS,
 **        (6H(6 CHAR ELEMENT NAME)) TO PLOT ALL OF ONE
 **                  TYPE ELEMENT
 **        EXAMPLE JPV(1)=1,2,3,-0,8,6HCBAR  $
 **        PLOTS ELEMENTS 1,2,3,4,5,6,7,8 AND ALL CBARS
 $PVIEW JPV(1)=6HK81    ,6HK61    $
```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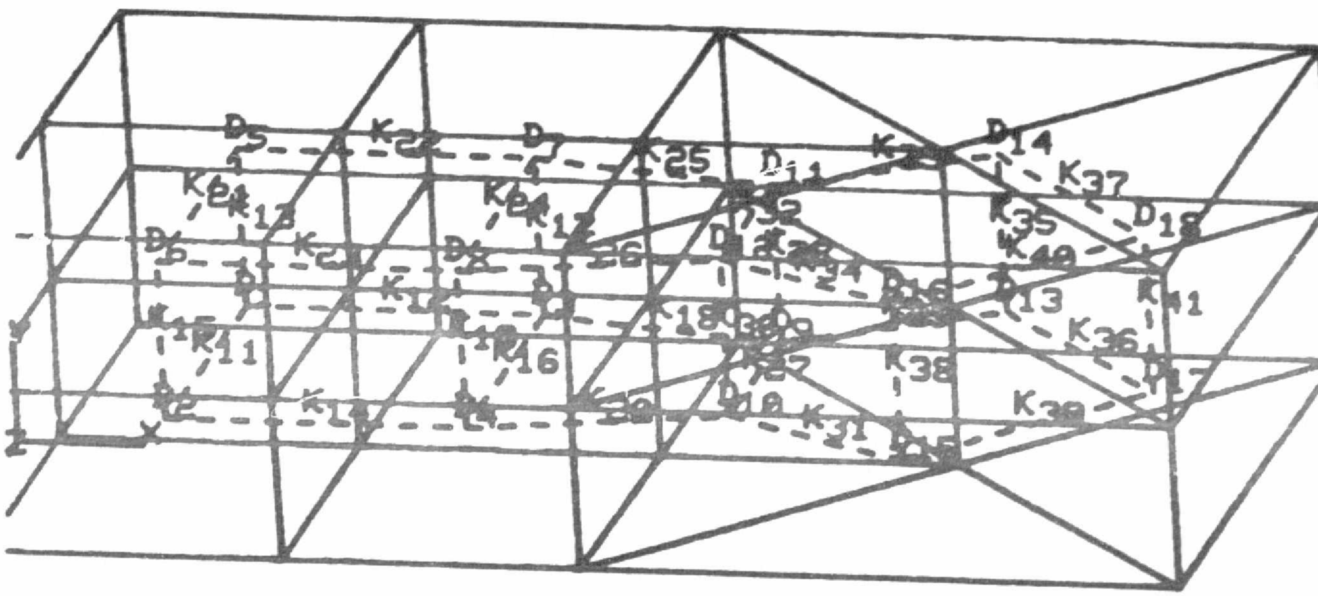
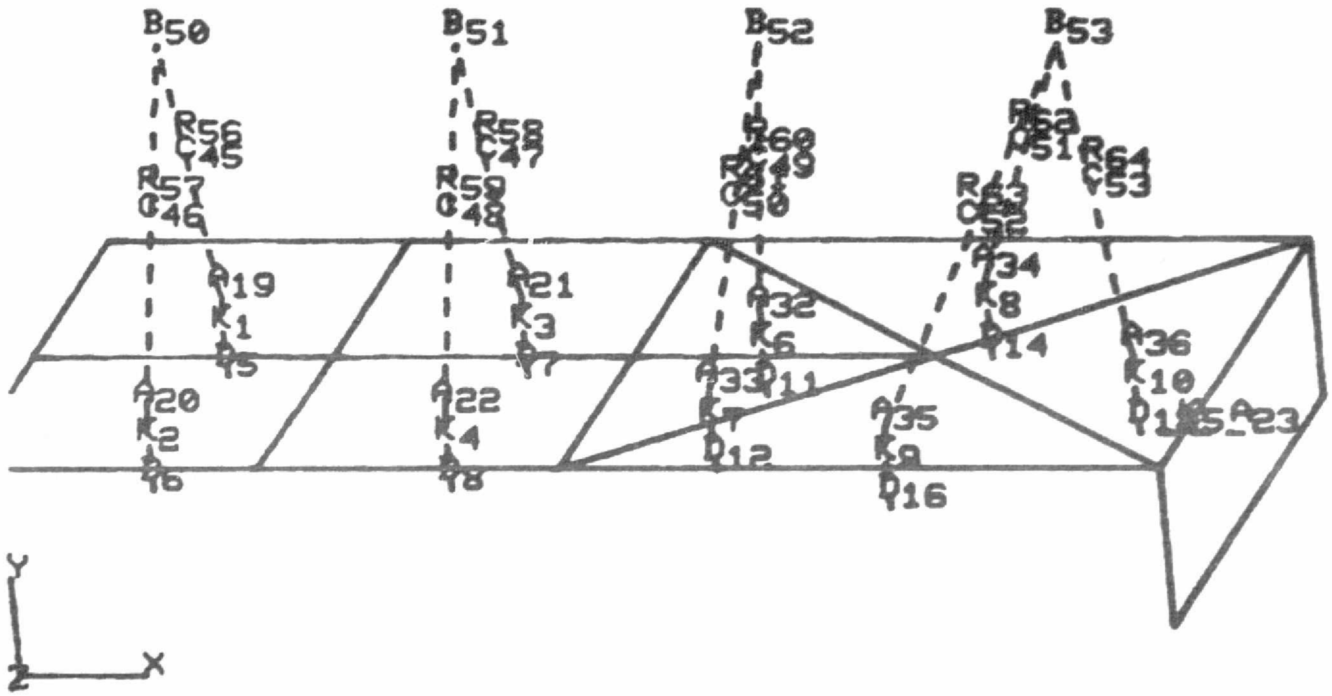


CINGEN + FINITE ELEMENT DATA, K81 K61

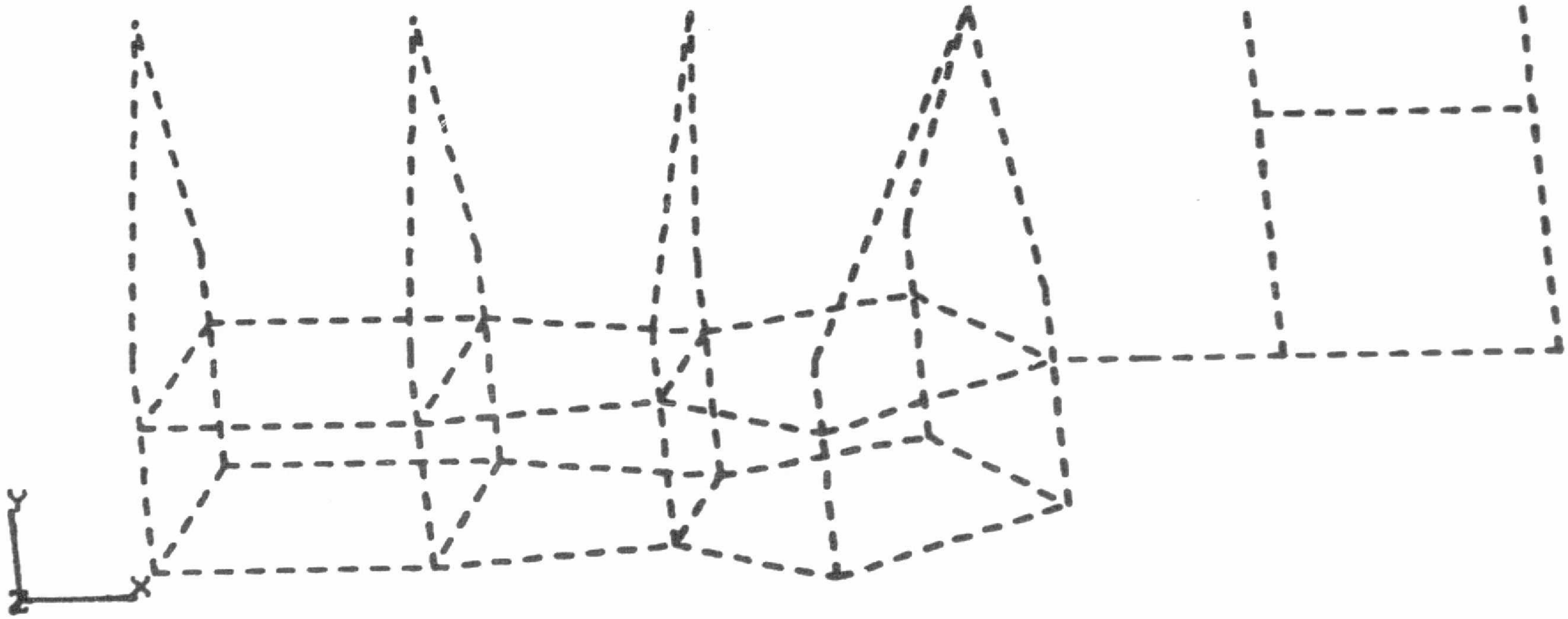
```
                                    *
 ** TYPE TITLE CARD (80 CHARACTERS)
CINGEN + FINITE ELEMENT DATA K41 + K31
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 $INPUT CONDNO=1,NODENO=1,PV=1 $
 ** TYPE ( $PVIEW JPV(1)= ,(ELEMENT NUMBERS) $)
 ** TO DEFINE PARTIAL VIEW

 ** NOTE - 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 **        (-0) IS USED FOR CONSECUTIVE NUMBERS,
 **        (6H(6 CHAR ELEMENT NAME)) TO PLOT ALL OF ONE
 **                  TYPE ELEMENT
 **        EXAMPLE JPV(1)=1,2,3,-0,8,6HCBAR  $
 **        PLOTS ELEMENTS 1,2,3,4,5,6,7,8 AND ALL CBARS
 $PVIEW JPV(1)=6HK41   ,6HK31    $
```



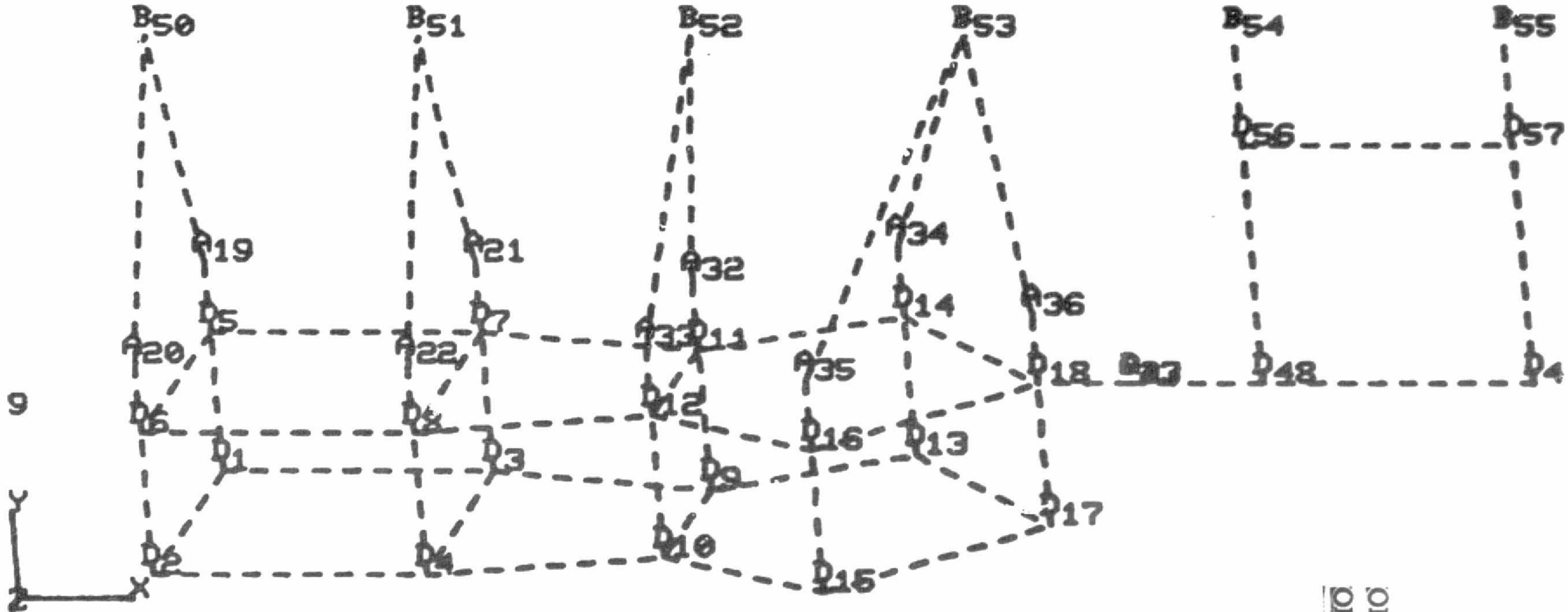
CINGEN + FINITE ELEMENT DATA K41 + K31

```
>C
                                        *
 ** TYPE TITLE CARD (80 CHARACTERS)
>CINGEN THERMAL DATA
 ** TYPE (C) FOR A LIST OF NAMELIST OPTIONS
 ** OR TYPE ANY OTHER CHARACTER FOR NO LIST
>A
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
> ●
●
 $INPUT X=-20.,Y=15.,Z=0.,SCALEX=13.,SCALEY=15. $
```



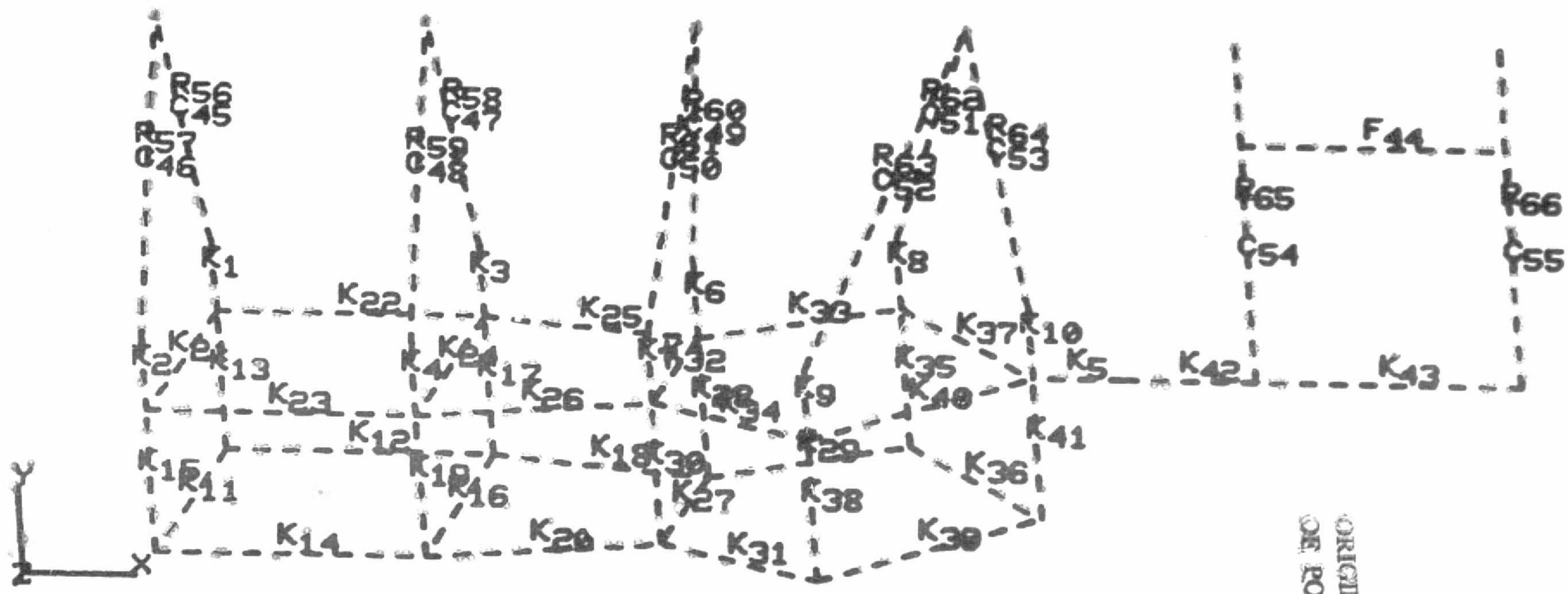
CINGEN THERMAL DATA

```
 ** TYPE TITLE CARD (80 CHARACTERS)
>CINGEN THERMAL DATA WITH NODE NO.
 ** TYPE (C) FOR A LIST OF NAMELIST OPTIONS
 ** OR TYPE ANY OTHER CHARACTER FOR NO LIST
>A
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **        (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **        ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
> $INPUT SCALEX=13.,SCALEY=15.,X=-20.,Y=15.,Z=0.,NODENO=1 $
```



CINGEN THERMAL DATA WITH NODE NO.

```
 ** TYPE TITLE CARD (80 CHARACTERS)
>CINGEN THERMAL DATA WITH CONDUCTOR NOS.
 ** TYPE (C) FOR A LIST OF NAMELIST OPTIONS
 ** OR TYPE ANY OTHER CHARACTER FOR NO LIST
>A
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **          (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **          ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
> $INPUT CONDNO=1,X=-20.,Y=15.,Z=0.,SCALEX=13.,SCALEY=15. $
```



CINGEN THERMAL DATA WITH CONDUCTOR NOS.

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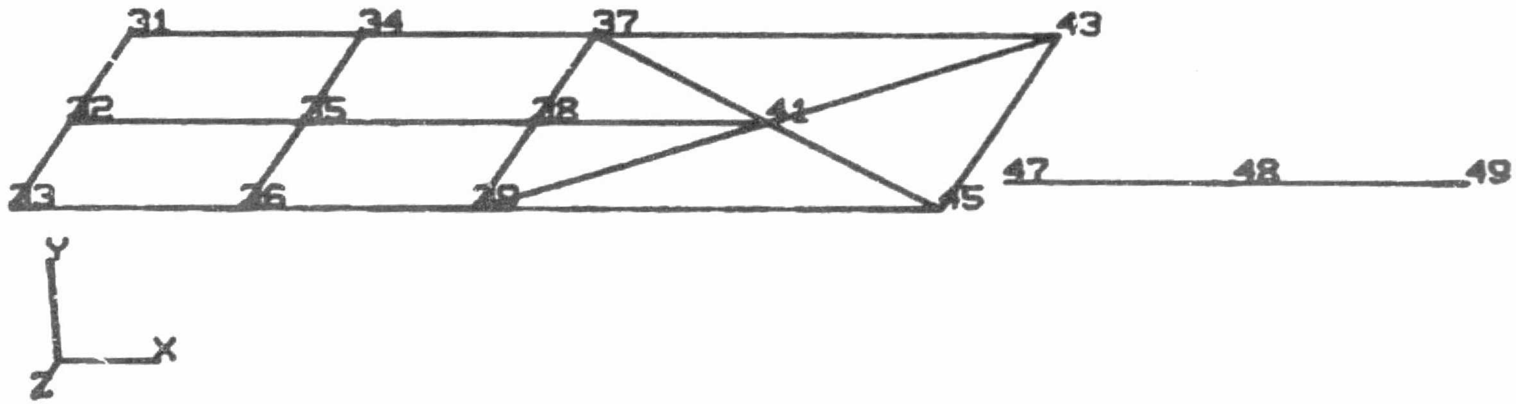
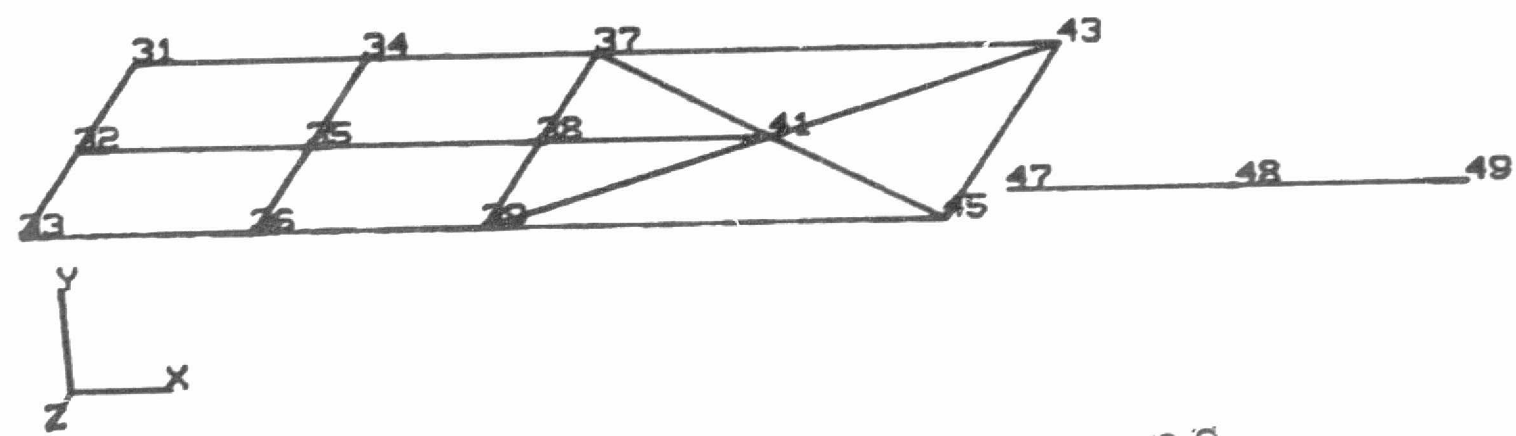
```
                                         *
 ** TYPE TITLE CARD (80 CHARACTERS)
FINITE ELEMENTS C41,C31,C21 WITH NODE N0.
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **         (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **         ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 $INPUT PV=1,GNO=1 $
 ** TYPE ( $PVIEW JPV(1)= ,(ELEMENT NUMBERS) $)
 ** TO DEFINE PARTIAL VIEW

 ** NOTE - 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **         (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **         ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 **         (-0) IS USED FOR CONSECUTIVE NUMBERS,
 **         (6H(6 CHAR ELEMENT NAME)) TO PLOT ALL OF ONE
 **                   TYPE ELEMENT
 **         EXAMPLE JPV(1)=1,2,3,-0,8,6HCBAR  $
 **         PLOTS ELEMENTS 1,2,3,4,5,6,7,8 AND ALL CBARS
 $PVIEW JPV(1)=6HC41   ,6HC31   ,6HC21   $
```



FINITE ELEMENTS C41,C31,C21 WITH NODE NO.

```
                                       *
 ** TYPE TITLE CARD (80 CHARACTERS)
FINITE ELEMENTS R41,R31,R21 WITH NODE NO.
 ** TYPE ( $INPUT (OPTIONS) $)
 **  NOTE- 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **          (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **          ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 $INPUT GNO=1,PV=1 $
 ** TYPE ( $PVIEW JPV(1)= ,(ELEMENT NUMBERS) $)
 ** TO DEFINE PARTIAL VIEW

 ** NOTE - 1ST COLUMN IS IGNORED FOR NAMELIST INPUT,
 **          (,) AS LAST CHARACTER TO CONTINUE ON NEXT LINE,
 **          ($) AS LAST CHARACTER TERMINATES NAMELIST INPUT
 **          (-0) IS USED FOR CONSECUTIVE NUMBERS,
 **          (6H(6 CHAR ELEMENT NAME)) TO PLOT ALL OF ONE
 **                    TYPE ELEMENT
 **          EXAMPLE JPV(1)=1,2,3,-0,8,6HCBAR  $
 **          PLOTS ELEMENTS 1,2,3,4,5,6,7,8 AND ALL CBARS
 $PVIEW JPV(1)=6HR41    ,6HR31    ,6HR21    $
```



FINITE ELEMENTS R41,R31,R21 WITH NODE NO.

SECTION 6

References

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3. Kannady, Roy, Jr., Connor, Robert, Shirley, Eugene, "Martin Marietta Interactive Thermal Analysis System Version-2.0", Contract No. NAS1-14684, April, 1977, Martin Marietta Data Systems, Denver, Colorado.

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8. McCormick, C. W., "The Nastran Users Manual", May, 1973, NASA SP-222(01) National Aeronautics and Space Administration, Washington, D.C.

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APPENDIX A

SPAR USER'S GUIDE

(Selected pages from NASA CR - 145098.1)

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Section 3

STRUCTURE DEFINITION

Four programs – TAB, ELD, E, and EKS – are used to generate and store in the data complex data sets that define the finite element model of the structure.

TAB and ELD are used to generate the basic definition of the structure. Subprocessors within TAB translate card input data into tables of joint locations, material constants, section properties, etc. Subprocessors within ELD translate card input data into data tables that define individual finite elements of various types.

Using the data produced in TAB and ELD, programs E and EKS generate an array of data sets, collectively known as the E-state, that contain a complete description of every element in the structure, including details of element geometry, intrinsic stiffness matrices, etc.

Except where specifically noted to the contrary, all data sets produced by TAB, ELD, E, and EKS should be retained in library 1.

3.1 TAB – BASIC TABLE INPUT

Function. TAB contains an array of sub-processors which generate tables of material constants, section properties, joint locations, etc., and various other data sets comprising a substantial portion of the definition of the structure. Each of these sub-processors is identified either by a multi-word (long form) name, such as JOINT LOCATIONS, or by a short name, e.g., JLOC. Each sub-processor generates a data set having the same name as the sub-processor. Sub-processor names and functions are summarized in Table TAB-1.

TAB may be used to either (1) create new data sets, or (2) update existing data sets by replacing individual entries in them. The update mode is commonly used in Demand (teletype) interactive operation. Only one direct access library, SPAR logical 1, is usable in conjunction with TAB. When beginning a new problem, the first data card following @XQT TAB (and any RESET commands) must be

START j, m_1, m_2, - - -

In the above, j = the total number of joints in the structure. It is not harmful to have some unused joints (i.e. joints connected to no elements), for convenience in interpreting the output. This should not be carried to extremes, however, since it wastes core storage. It should be noted that it is not necessary to set aside large blocks of unused joint numbers in areas where you expect to later augment the model. The JSEQ sub-processor and an array of data modifier statements allow models to be extended without extensive repunching of existing data cards.

The parameters m_1, m_2, - - - on the START card list joint motion components which are identically zero for all joints. Those components are relative to the joint reference frames. For m=1, 2, or 3 a direction m displacement is indicated. For m=4, 5, or 6, a direction m-3 rotation is indicated.

For example, a 1000 joint space truss would begin with

START 1000, 4, 5, 6

The above indicates that all three rotation components are zero at all joints. As another example, a 500 joint plane frame would begin with

START 500 3, 4, 5

The above assumes that the the direction-3 displacements are normal to the plane of the frame, and the frame deforms in-plane only.

SPAR uses the m's given on the START card to determine submatrix storage block size (see Ref.1, Sec. 4). Therefore the START card (rather than the CON sub-processor) should be used to suppress joint motions in cases such as those illustrated above.

Following the START card, or directly following @XQT TAB if Library 1 already exists, the TAB card input stream is as illustrated below.

$Proc_1$

-

-

data cards read by $Proc_1$

-

-

$Proc_2$

-

-

data cards read by $Proc_2$

-

-

-

-

-

etc.

In the above, $Proc_i$ represents a data card containing either the short or long-form name of a sub-processor to be executed, Sub-processors may be executed in any order, subject to the following restriction: if the data read by one sub-processor refers to another TAB-generated table, the other table must already exist. It is always safe to execute sub-processors in the order they appear in Table TAB-1.

TAB input card rules

In addition to the rules generally applying to SPAR free-field input, the following rules apply specifically to TAB.

(1) Trailing items omitted on data cards are assumed to be zero, except when indicated otherwise in discussions of specific sub-processors.

(2) Input should be in real (fixed on floating point) format, except for integer items such as entry numbers, joint numbers, table entry pointers, and control variables.

(3) Within the data card stream being read by any sub-processor, the following commands may be injected.

FORMAT = j

MOD = m

NREF = n

In the above,

- j identifies which of several admissible formats is to apply to subsequent cards. Details are given in discussions of individual sub-processors.

- m is added to the table entry indicator (usually called k), in all processors <u>other than</u> TEXT, JLOC, RMASS, JREF, CON and JSEQ. In JLOC, RMASS, JREF, and CON, m is added to joint numbers indicated on subsequent input cards.

- In processors JLOC, JREF, and MREF, reference frame n applies to data on subsequent cards.

These three commands may be used repeatedly in the card streamof any sub-processor. Upon beginning execution of a new sub-processor, these parameters are internally reset to their default values, FORMAT=1, MOD=0, and NREF=1.

(4) Each input record, including continuation cards, if any, must not contain more than <u>thirty words</u>.

Correcting existing data sets

To enter the "update" mode of operation, the following command is injected in the input stream.

UPDATE=1

To leave the update mode, the command is

UPDATE=0

UPDATE commands should immediately precede sub-processor execution commands. When operating in the update mode, the output data set produced in the current execution is identical to that produced in the preceding execution, except for entries defined by the card input of the current execution. The only sub-processors which cannot be operated in the update mode are TEXT and JSEQ.

As an example, suppose the location of joint 1742 is found to be in error. The JLOC data set could be repaired by the following card sequence.

UPDATE=1

JLOC

1742, 947.62, 1841.9 23.487$

Library Title

The following statement will cause an identifying title to be embedded in library 1:

TITLE' 60-character alphanumeric title

The title, which resides in a data set named NDAL---, is displayed at the beginning of printouts of library Tables of Contents (e.g., via DCU/TOC).

RESET Controls

No special RESET controls are available in TAB.

Core Requirements

Working core requirements will not significantly exceed the larger of (1) 13 times the number of joints, or (2) the longest table generated (see Table TAB-1).

Code Release Data

Level 9 (UNIVAC, CDC) July 1975, coded by W. D. Whetstone.

Table TAB-2: TAB Sub-Processors

Short Name	Table Length*	Long Form Name, Function
TEXT	15 n	TEXT. Creates a data set containing alphanumeric text documenting the analysis.
MATC	20 n	MATERIAL CONSTANTS. Entries define linear material constants E, ν, etc.
NSW	n	DISTRIBUTED WEIGHT. Entries define nonstructural distributed weight parameters (weight/length or weight/area).
ALTREF	12 n	ALTERNATE REFERENCE FRAMES. Entries describe reference frames selected by the analyst for convenience in defining joint locations, etc.
JLOC	3 j	JOINT LOCATIONS.
JREF	j	JOINT REFERENCE FRAMES. Entries define the orientation of reference frames associated with joints, used in defining constraint, applied loading, etc.
MREF	5 n	BEAM ORIENTATION. Entries define beam cross-section orientation.
BRL	8 n	BEAM RIGID LINKS. Entries define rigid links offsetting the end points of elastic 2-node elements from the joints they connect.
BA	31 n	E21 SECTION PROPERTIES.
BB	21 n	BEAM S6x6. Entries define elastic characteristics of type E22 and E25 elements.
BC	6 n	E23 SECTION PROPERTIES.
BD	8 n	E24 SECTION PROPERTIES.
SA	See Sec. 8.1.12	SHELL SECTION PROPERTIES.
SB	4 n	PANEL SECTION PROPERTIES.
CON	j, 6j	CONSTRAINT DEFINITION.
JSEQ	j	JOINT ELIMINATION SEQUENCE.
RMASS	6j	RIGID MASSES.

*n is the number of entries in the table, and j is the total number of joints in the structure.

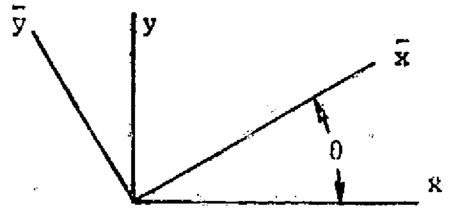
3.1.1 TEXT

The TEXT subprocessor gives the analyst a means of embedding in the output library a data set containing alphanumeric text descriptive of the analysis being performed. Each card has a 4/8 punch in column 1, followed by a 60-character alphanumeric string. The contents of TEXT data sets may be printed using the DCU/PRINT command.

3.1.2 MATERIAL CONSTANTS (MATC)

MATC generates a table of material constants. The data sequence on the card defining the k-th entry in the table is k, E, ν, ρ, α_1, α_2, θ, where

- E = Modulus of elasticity
- ν = Poisson's Ratio
- ρ = Weight per unit volume
- α_1 = Thermal expansion coefficient, direction $\bar{x}$
- α_2 = Thermal expansion ceefficient, direction $\bar{y}$
- θ = Angle between axes of element reference frame (x,y) and ($\bar{x}$,$\bar{y}$). Element reference frame orientation is discussed in Section 3.2.



$\varepsilon_{\bar{x}} = \alpha_1$. temperature

$\varepsilon_{\bar{y}} = \alpha_2$. temperature

$\gamma = 0$

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If θ is omitted, the program sets $\theta = 0$. If α_2 is omitted, the program sets $\alpha_2 = \alpha_1$ (isotropic material). θ must be given in <u>degrees</u>.

Material constants associated with specific elements are established by inputs to processor ELD, by pointing to entries in the MATC table.

3.1.4 DISTRIBUTED WEIGHT (NSW)

A table of non-structural distributed weight parameters is defined. The data sequence for the input card defining the k-th entry in the table is k, W, where

for 2-node elements, W = weight per unit length, and

for 3 or 4-node elements, W = weight per unit area.

Non-structural weight attached to specific elements is defined in processor ELD by pointing to entries in the NSW table.

3.1.4 ALTERNATE REFERENCE FRAMES (ALTREF)

In addition to the global reference frame, the analyst may find it convenient to define additional reference frames. These frames have several uses, including the following:

(1) Joint locations may be defined in any frame the analyst finds most convenient (see JLOC).

(2) Joint reference frame orientations may be defined via the alternate frames (see JREF).

Each frame is uniquely identified by a positive integer. The global frame is always frame 1; accordingly the analyst is free to define only frames 2, 3, - - -. The order of data on the input card defining frame k is

$$k,\ i_1, a_1,\ \ i_2, a_2,\ \ i_3, a_3,\ \ x_1,\ x_2,\ x_3.$$

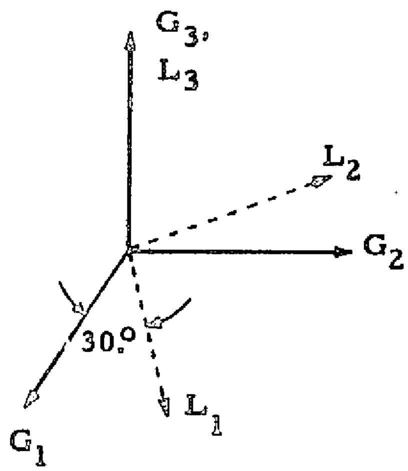
In the above x_1, x_2, and x_3 are position coordinates, relative to the global frame, of the origin of frame k. The x's need not be given if only the orientation of frame k is of significance, which often is the case.

The parameters i_1, a_1, - - - i_3, a_3 indicate ordered rotations defining axis orientations. Two formats are provided. In both cases, we begin with a local frame parallel to the global frame. After the ordered rotations are completed, the local frame is parallel to frame k. Each of the i's may be 1, 2, or 3, in any order. The a's are angles in degrees.

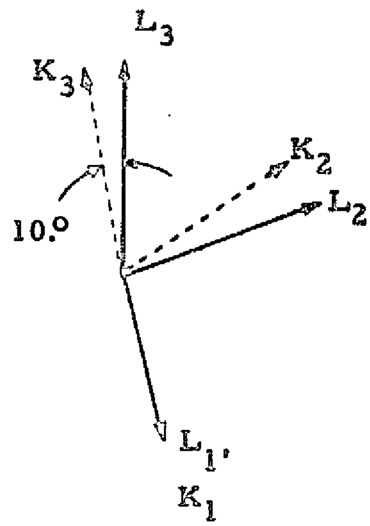
If FORMAT=1(default), the sequence is: (1) rotate the local frame a_1 degrees about local axis i_1, then (2) from the new position, rotate the local frame a_2 degrees about axis i_2, then (3) from the resulting position, rotate the local frame a_3 degrees about axis i_3. If FORMAT=2, the i's and a's indicate rotation of the global frame relative to frame k.

In the following example of an input card defining frame 27, it is assumed that FORMAT=1.

27 3,30. 1,10.$



First rotation,
G_i = Global axes



K_i = axes of Frame 27.

3.1.5 JOINT LOCATIONS (JLOC)

JLOC produces a table containing the position coordinates of the joints. The data sequence on input cards is as follows:

k, xa_1, xa_2, xa_3, xb_1, xb_2, xb_3, ni, ijump, nj

If nj is given, a second card must appear,

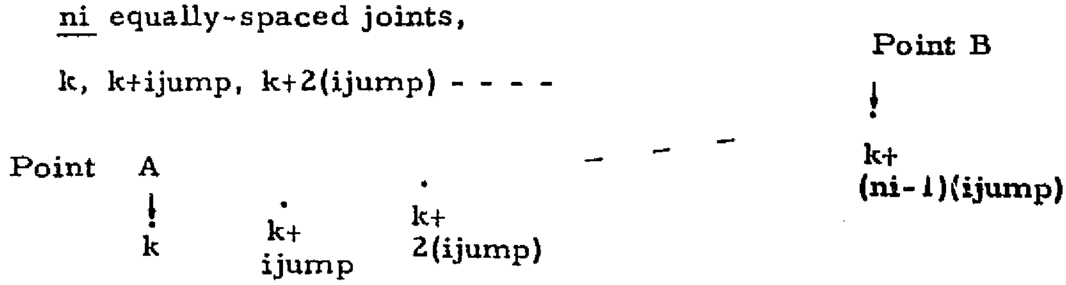
jjump, xc_1, xc_2, xc_3, xd_1, xd_2, xd_3

There are three possible interpretations of the above:

(1) If only k, xa_1, xa_2 and xa_3 are given, the xa's are coordinates of joint k.

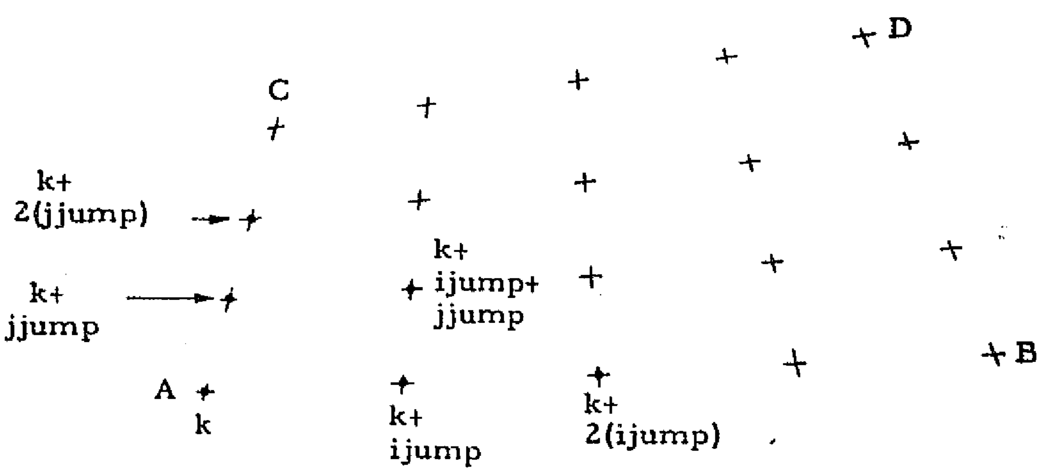
(2) If k, xa_1, - - - - xb_3, ni, and ijump are given, the xa's and xb's are coordinates of points A and B terminating a string of <u>ni</u> equally-spaced joints,

k, k+ijump, k+2(ijump) - - - -



The default value of ijump is 1.

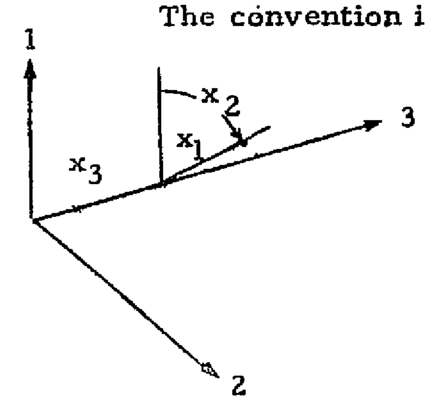
(3) If nj is given, a linearly interpolated two-dimensional mesh of (ni)(nj) joints is defined, as indicated below.



Although the output table generated by JLOC is in rectangular coordinates relative to the global frame, coordinate data appearing on the input cards may be either rectangular or cylindrical, and may be relative to any frame already defined in ALTREF. The associated control cards are summarized below.

Control	Meaning
NREF= n	Coordinate data on subsequent cards is relative to frame n (until another NREF command is encountered).
FORMAT=2	Subsequent data is in cylindrical coordinates, relative either to frame 1 (global) or to any other frame selected by an NREF command. The convention is shown below.

Frame n



x_1 = radial distance from 3-axis.

x_2 = angle, in degrees, from the 1-3 plane.

x_3 = linear distance from the 1-2 plane.

FORMAT=1	Switch back to rectangular coordinates.

Switching among frames, and between rectangular and cylindrical coordinates is unrestricted.

If cylindrical coordinates are used in connection with mesh generation, interpolation is performed before transformation to rectangular coordinates; so that regular meshes on circles, cylinders and cones are readily generated.

3.2 ELD – ELEMENT DEFINITION PROCESSOR

Function - ELD translates element definition data from input cards into data sets which are readily usable by other SPAR processors. Elements may be defined singly or through a variety of network generators, or combinations thereof. An element is defined by specifying (1) the joints to which it is connected, and (2) pointers to applicable entries in tables of section properties, material constants, etc. The tables of section properties, etc., are usually generated by the TAB processor. As the ELD input is processed, checks are performed to detect errors such as references to nonexistent table entries, joint numbers, etc.; however, ELD does not extract any data from TAB generated tables. Accordingly, if TAB is subsequently re-executed to alter values of section properties, joint position coordinates, etc., it is not necessary to re-execute ELD, provided the connected joint numbers, table entry pointers, etc., of the elements are unchanged. Alphanumeric names used to identify specific types of elements used to model frame/shell structures are summarized in Table ELD-1. The formulations on which these elements are based are discussed in Volume II of the SPAR Reference Manual.

Table ELD-1: Summary of One and Two-dimensional Elastic Elements

Name	Description
E21	General beam elements, such as angles, wide flanges, tees, zees, tubes, etc.
E22	Beams of finite length for which the 6 x 6 intrinsic stiffness matrix is directly specified.
E23	Bar elements having only axial stiffness.

Name	Description
E24	Plane beam.
E25	Zero-length element used to elastically connect two coincident joints.
E31	Triangular membrane, flat, aeolotropic, using TM constant-stress formulation.
E32	Triangular bending element, flat aeolotropic.
E33	Triangular membrane + bending element, flat, aeolotropic, using TM and TPB7 formulations.
E41	Quadrilateral membrane, aeolotropic, using QMB5 hybrid formulation.
E42	Quadrilateral bending element, aeolotropic, using hybrid formulation.
E43	Quadrilateral membrane + bending element, aeolotropic, using hybrid formulation.
E44	Quadrilateral shear panel, using hybrid formulation.

For purposes of explaining card input, we will consider ELD to be comprised of an array of sub-processors, one for each type of element. The function of each sub-processor is to read input cards defining all of the elements of a particular type. A sub-processor is activated by an input card containing the name of the element type. Sub-processors may be called in any order. A typical input stream is shown below.

```
@XQT  ELD
 E43
 -
 -
 (Data cards defining all of the E43 elements in the structure)
 -
 -
 E21
 (Data cards defining all of the E21  elements in the structure)
 -
 -
 -
```

Execution of each sub-processor results in production of data sets having the following names (EXY represents the name of an element type, such as E21, E33, etc.):

DEF	EXY	=	Basic (integer form) element definitions.
GD	EXY	=	Group directory.
GTIT	EXY	=	Group titles.

When a sub-processor is executed, the resultant output data sets replace all data previously generated by the same sub-processor in any previous execution.*

Elements of each type may be assigned by the analyst to separate groups. Within each group, each element has an identifying index number. The grouping of elements serves various purposes, which new users will learn with experience. It is almost always best to use many groups. Definition of the elements in group n is preceded by an input card in the following form:

GROUP n' - - - title describing group n - - -. All elements defined by input cards following such a card belong to group n. Groups must appear sequentially (group 1, group 2, - -). If no GROUP card appears, all elements are assigned by default to group 1. The order in which individual element definitions appear following a GROUP card determines the index numbers they are assigned within the group.

* It is planned in a future release to provide an "update" mode of operation allowing deletions, additions, and corrections to be made.

Element definition cards have the forms shown below.

All 2-node elements:

$$\text{J1, J2} \qquad \overbrace{\text{NETOPT, NET(1), NET(2) - - -}}^{\text{Optional}}$$

All 3-node elements:

J1, J2, J3 NETOPT, NET(1), NET(2), - -

All 4-node elements:

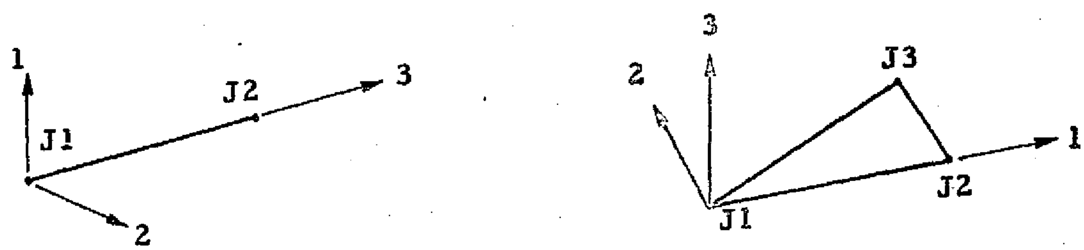
J1, J2, J3, J4 NETOPT, NET(1), NET(2), - - -

It should be noted that the order in which J1, J2 - - appear on the element definition cards is very important, since the orientation of element reference frames is defined on the basis of this information (see Fig. ELD-1). All element-related quantities, such as stiffness coefficients, stresses, etc., are relative to these reference frames.

In the above, J1, J2, - - indicate the joints interconnected by the first element defined by the card. If the optional network operation parameters, NETOPT, NET(1), NET(2), - -, are given, they result in definition of additional elements, in accordance with specific rules which will be defined subsequently.

The section properties, material properties, etc. associated with each element depend upon the values of various table reference pointers prevailing at the time the element definition card appears. These pointers are summarized below.

Table Pointer	Default Value	Associated Table
NMAT	1	Material constants, MATC.
NSECT	1	Section properties. E44 elements refer to Table SB. All other 3 and 4-node elements refer to Table SA. E21, E22, E23, E24, and E25 refer to BA, BB, BC, BD, and BB, respectively.
NOFF	0	Beam rigid link offsets, BRL (2-node elements, only).
NNSW	0	Nonstructural distributed weight, NSW.
NREF	1	Beam reference frame orientation, MREF (2-node elements other than E25, only). For E25 elements, NREF points to an entry in the ALTREF table. For 3 and 4-node elements NREF is not a table entry pointer. Instead, NREF is used to specify the direction of action of positive pressure exerted on the element. If NREF=0, pressure exerts no force on the element. If NREF=1, positive pressure acts in the direction of the 3-axis of the element reference frame (see Fig. FLD-1, below). If NREF=-1, pressure acts in the opposite direction.



(1) All systems right-hand rectangular.

(2) Orientation of 1, 2 axes of 2 node elements depends on the entry in MREF table indicated by NREF.

(3) For 3, 4-node elements, J3 lies in quadrant 1 of plane 1-2.

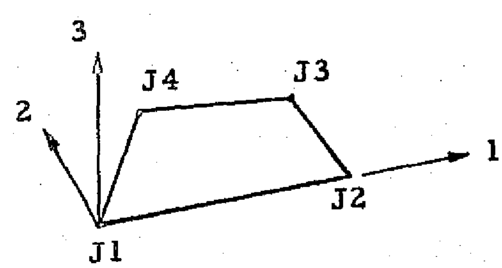
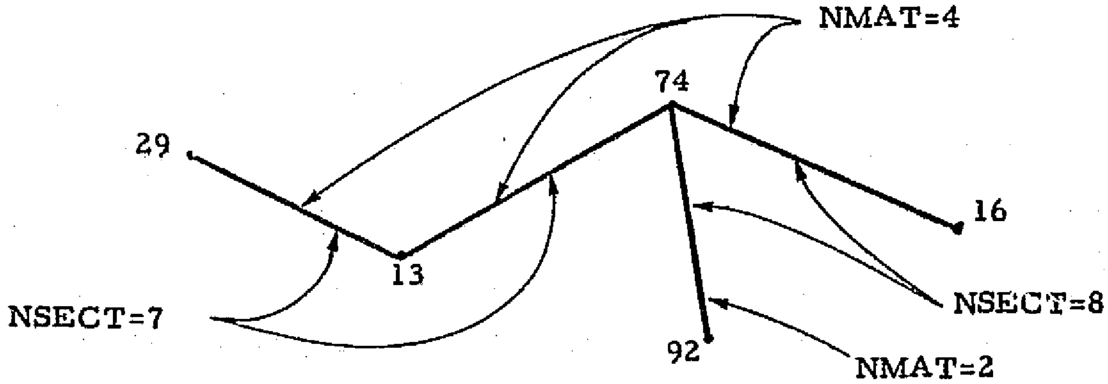


Figure ELD-1. Element Reference Frames

An example of the use of the table reference parameters is shown below.



NMAT=4: NSECT=7: 29, 13: 13, 74: NSECT=8: 74, 16: NMAT=2: 74, 92$

ELD also accepts input commands which have the effect of modifying the data given on subsequent input cards. These commands are summarized below.

Command			Meaning of n (n default is zero in all cases)
MOD	JOINT=	n	Add n to all joint numbers.
MOD	GROUP=	n	Add n to all group numbers.
MOD	NSECT=	n	Add n to NSECT pointers.
MOD	NMAT=	n	" NMAT "
MOD	NNSW=	n	" NNSW "
MOD	NREF=	n	" NREF "
MOD	NOFF=	n	" NOFF "
INC	NSECT=	n	See below.
INC	NMAT=	n	" "
INC	NNSW=	n	" "
INC	NREF=	n	" "
INC	NOFF=	n	" "

A frequently encountered situation is the one in which a substantial portion of a finite element model is comprised of a regular mesh, which can be automatically defined by a mesh generation command, but the section properties are so nonuniform that it becomes necessary or highly desirable for simplicity of input preparation to associate with each element a unique entry in the section property table. A common example is an aircraft fuselage, where cutouts, doublers, stiffeners, etc., result in extensive variations in section properties over a mesh that is topologically and geometrically regular. A similar situation involving distributed nonstructural weight also sometimes occurs; e.g. thermal protection material of varying thickness. The INC command is intended primarily to address situations of this type.

The INC commands are used to cause the associated table reference pointers to be automatically incremented by n as successive elements are defined. This is especially useful in conjunction with network generation options, which are defined in detail on subsequent pages. For example, the element definition command 701, 702, 1, 50 causes fifty elements to be defined, connecting joint pairs (701, 702), (702, 703) - - - - (750, 751). If section property table entries 101, 102, - - -150 apply, successively, to these elements, the following input would suffice.

NSECT= 101: INC NSECT=1: 701, 702, 1, 50$

All MOD and INC parameters are internally reset to zero after conclusion of each sub-processor execution. The MOD and INC commands are not cumulative. That is, MOD NSECT 7: - - - - MOD NSECT 3: - - is not equivalent to MOD NSECT 10.

Reset Controls

Only one reset command is permitted:

OUTLIB = Destination library for ELD output. The TAB-generated data sets must already be resident in this library.

Core Requirements

ELD rarely requires ore than 1500-3000 words of working core space, regardless of the size of the problem.

Code Release Data

Level 7 (UNIVAC, CDC), July 1974, coded by W. D. Whetstone.

Two-node element network generators.

If NETOPT=1,

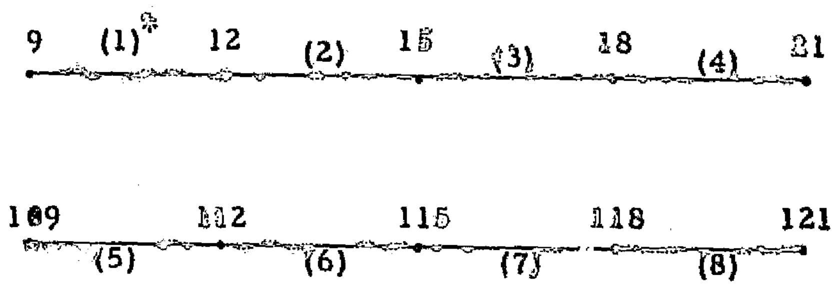
```
NI=   NET(1)  (default=1),
NJ=   NET(2)  (default=1),
JINC= NET(3).
```

Implied sequence:

```
         N1=J1
         IDIFF=J2-J1
         DO   200  J=1, NJ
         DO   100  I=1, NI
         N2=N1+IDIFF
         Define element connecting node N1 to N2
    100  N1=N2
    200  N1=J1 + J * JINC
```

Example:

J1	J2	Netopt	NI	NJ	JINC
9	12	1	4	2	100



*The order in which the elements are defined is indicated by the number enclosed in parentheses. The index number identifying elements within each group are determined by the order in which the elements are defined.

Two-node element network generators (continued).

If NETOPT=2,

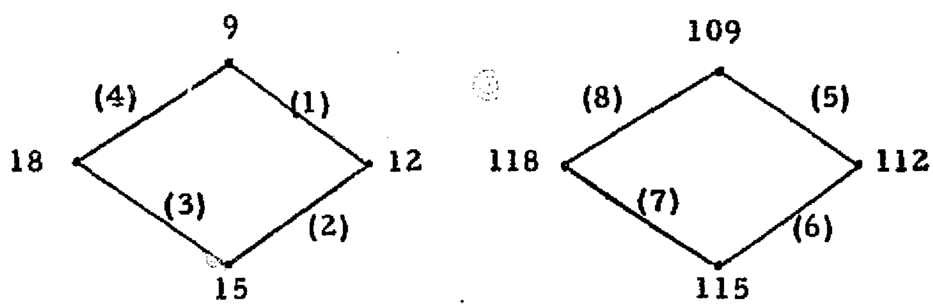
NI= NET(1) (default=1),
NJ= NET(2) (default=1),
JINC= NET(3).

Implied sequence:

```
     N1=    J1
     IDIFF= J2-J1
     DO  200  J=1,NJ
     DO  100  I=1,NI
     N2 = N1 + IDIFF (except for closing element, when I=NI)
     Define element connecting N1,N2.
100  N1=N2
200  N1=J1 + J*JINC
```

Example:

J1	J2	Netopt	NI	NJ	JINC
9	12	2	4	2	100



Two-node element network generators(continued).

<u>If NETOPT=3,</u>

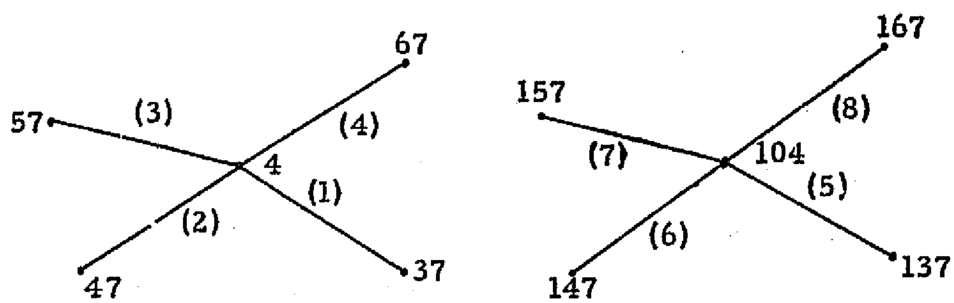
NI= NET(1),
IINC= NET(2),
NJ= NET(3) (default=1)
JINC= NET(4).

Implied sequence:

```
        N1=J1
        N2=J2
        DO  200  J=1, NJ
        DO  100  I=1, NI
        Define element connecting N1 to N2
  100   N2 = N2 + IINC
        N1 = J1 + JINC*J
  200   N2 = J2 + JINC*J
```

Example:

J1	J2	Netopt	NI	IINC	NJ	JINC
4	37	3	4	10	2	100



Three-node element network generators.

If Netopt=1,

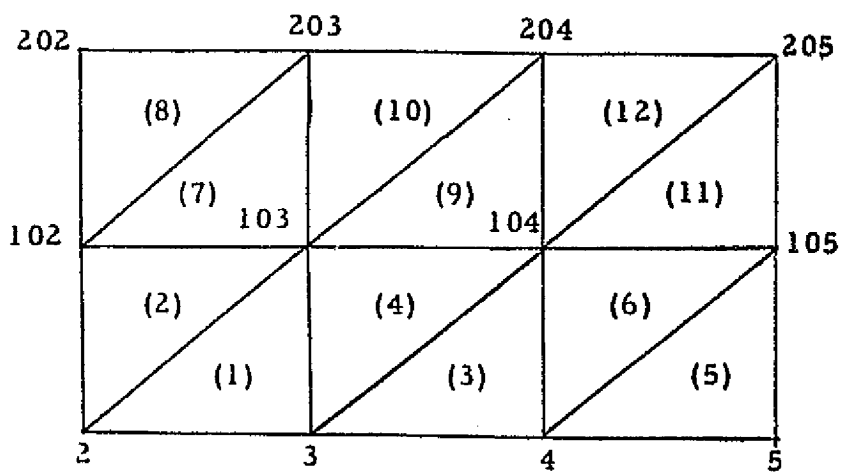
NI= NET(1),
NJ= NET(2) (default=1).

Implied sequence:

```
        IINC=  J2-J1
        JINC=  J3-J2
        N1=  J1
        N2=  J2
        N3=  J3
        N4=  J3-IINC
        DO  200  J=1, NJ
        DO  100  I=1, NI
        Define element connecting  N1, N2, N3
        Define element connecting  N3, N4, N1
        N1=  N1 + IINC
        N2=  N2 + IINC
        N3=  N3 + IINC
 100    N4=  N4 + IINC
        N1=  J1 + JINC
        N2=  J2 + JINC
        N3=  J3 + JINC
 200    N4=  N3 - IINC
```

Example:

J1	J2	J3	Netopt	NI	NJ
2	3	103	1	3	2



Three-node element network generators (continued).

If Netopt=2,

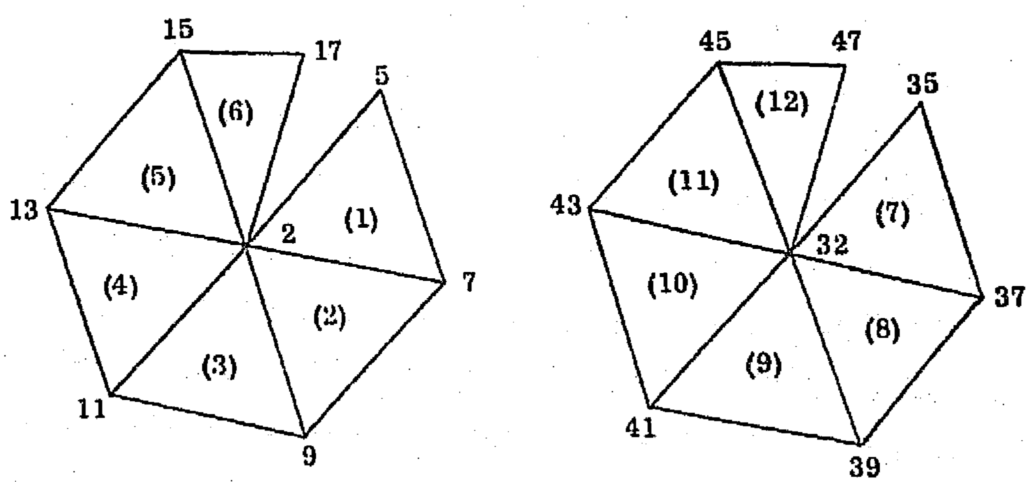
NI= NET(1) (NI must be greater than 1),
NJ= NET(2) (default=1),
JINC= NET(3).

Implied sequence:

```
    IINC= J3-J2
    N1= J1
    N2= J2
    DO 200 J=1, NJ
    DO 100 I=1, NI
    N3= N2 + IINC
    Define element connecting N1, N2, N3
100 N2=N3
    N1= J1 + J*JINC
200 N2= J2 + J*JINC
```

Example:

J1	J2	J3	Netopt	NI	NJ	JINC
2	5	7	2	6	2	30



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Three-node element network generators (continued).

If Netopt=3,

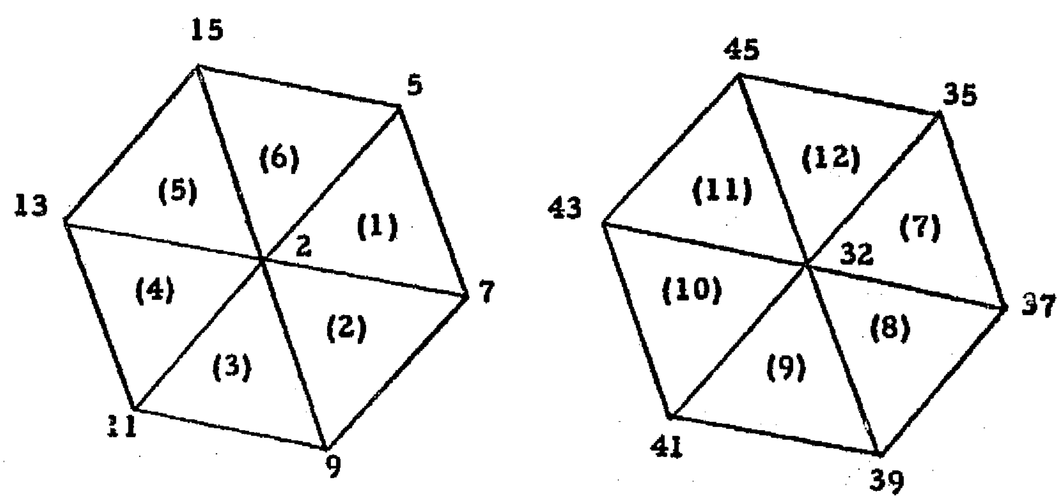
NI= NET(1),
NJ= NET(2) (default=1),
JINC= NET(3).

Implied sequence:

```
     IINC= J3-J2
     N1= J1
     N2= J2
     DO  200  J=1, NJ
     DO  100  I=1, NI
     N3= N2 + IINC (except closure when I=NI)
     Define element connecting N1,N2,N3
100  N2=N3
     N1 = J1 + J*JINC
200  N2 = J2 + J*JINC
```

Example:

J1	J2	J3	Netopt	NI	NJ	JINC
2	5	7	3	6	2	30



Four-node element network generators.

If Netopt=1,

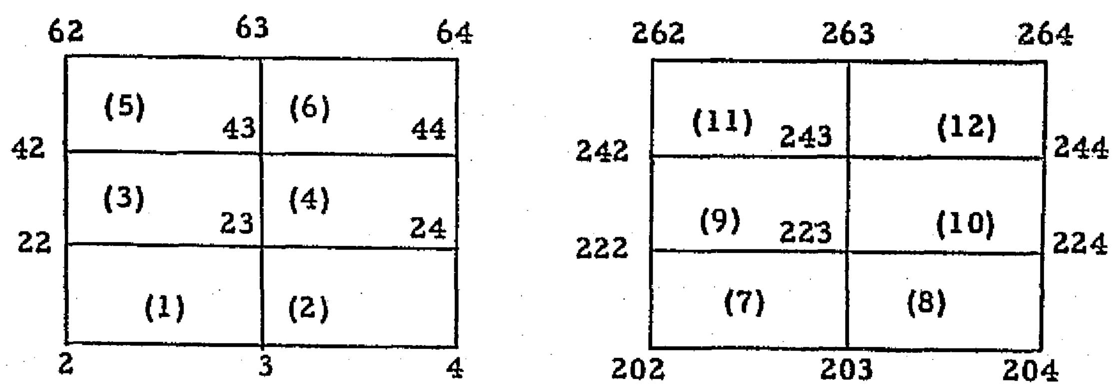
```
NI=     NET(1),
NJ=     NET(2)  (default=1),
NK=     NET(3)  (default=1),
KINC=   NET(4).
```

Implied sequence*:

```
      IINC= J2-J1
      JINC= J4-J1
      DO  300  K=1, NK
      N1  = J1
      DO  200  J=1,  NJ
      DO  100  I=1,  NI
      N2= N1+IINC
      N3= N2+JINC
      N4= N1+JINC
      Define element connecting N1, N2, N3, N4
  100 N1 = N1+IINC
  200 N1 = J1+J*JINC
  300 J1 = J1+KINC
```

Example*:

J1	J2	J3	J4	NETOPT	NI	NJ	NK	KINC
2	3	23	22	1	2	3	2	200



*Note: J3 must be present, although not used.

Four-node element network generators (continued).

If Netopt=2,

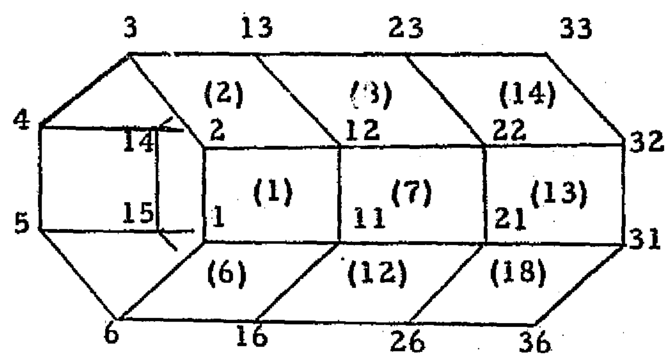
NI= NET(1),
NJ= NET(2) (default=1).

Implied sequence:

```
     IINC=   J2-J1
     JINC=   J4-J1
     N1=     J1
     DO  200  J=1,NJ
     DO  100  I=1, NI
     N2 = N1 + IINC
     N3 = N2 + JINC  (except closure when I=NI)
     N4 = N1 + JINC  (except closure when I=NI)
     Define element connecting N1,N2,N3,N4
100  N1 = N1 + IINC
200  N1 = J1 + J*JINC
```

Example:

J1	J2	J3	J4	Netopt	NI	NJ
1	11	12	2	2	6	3



TA1.1 ELEMENT DEFINITIONS

The SPAR thermal element library consists of conducting elements

K21, 2-node

K31, 3-node, 2D

K41, 4-node, 2D

K61, 6-node, 3D

K81, 8-node, 3D

convecting elements

C21, 2-node

C31, 3-node, 2D

C41, 4-node, 2D

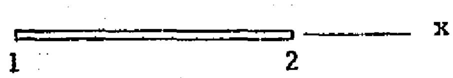
and radiating elements

R21, 2-node

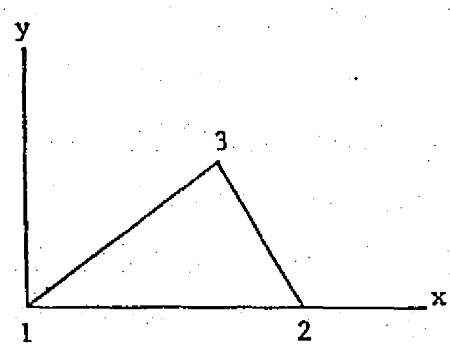
R31, 3-node, 2D

R41, 4-node, 2D.

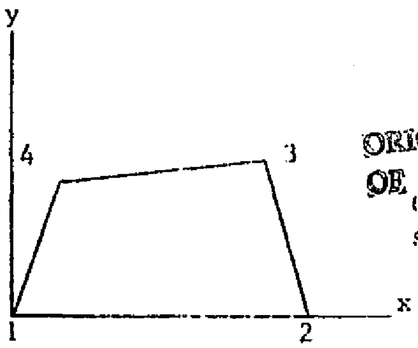
Element definition data is input via TELD. Element node numbering and local reference frames are pictured below.



Bar elements can have zero lengths to simulate point sources, convectors, and radiators. Zero-length bar elements are defined by prescribing the same node point at each end or by identifying zero-length bars in processor TGEO.

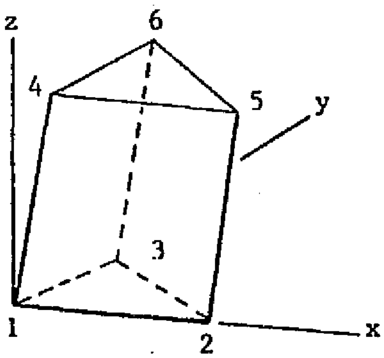


Triangular elements must be numbered as shown.

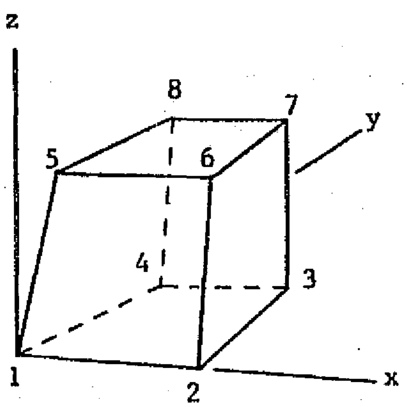


Quadrilateral elements must be numbered as shown and should be nearly flat.

First two nodes set + X direction axes 3rd node sets +Y direction.



Pentahedral elements must be numbered as shown. They should have faces that are very nearly flat (all points in a plane). Nodes 4-6 must lie above the x-y plane in + Z direction.



Hexahedral elements must be numbered as shown. They should have faces that are very nearly flat. Nodes 5-8 must lie above the x-y plane.

Element shape and size parameters are adjusted via RESET controls in processor TGEO.

Table TA1-2 Element Definition Data Sets

In the following tabulation, ngroup identifies a group of elements of a particular type. The parameters nmat, nfilm, and nrad point to the applicable tables of CONDuction, CONVection, and RADIation properties. The j's are connected points.

The number of elements in a group is indicated by the TOC item NJ. Each data line corresponds to the j-th element within its group (j=1,..., NJ).

Data Set Name

N1	N2	N3	NI*	Contents of data line								
TED	K21	ngroup	7	nmat	j_1	j_2	area					
TED	K31	ngroup	13	nmat	j_1	j_2	j_3	thickness				
TED	K41	ngroup	16	nmat	j_1	j_2	j_3	j_4	thickness			
TED	K61	ngroup	27	nmat	j_1	j_2	j_3	j_4	j_5	j_6		
TED	K81	ngroup	35	nmat	j_1	j_2	j_3	j_4	j_5	j_6	j_7	j_8
TED	C21	ngroup	7	nfilm[#]	j_1	j_2	circumference					
TED	C31	ngroup	13	nfilm[#]	j_1	j_2	j_3					
TED	C41	ngroup	16	nfilm[#]	j_1	j_2	j_3	j_4				
TED	R21	ngroup	7	nrad	j_1	j_2	circumference					
TED	R31	ngroup	13	nrad	j_1	j_2	j_3					
TED	R41	ngroup	16	nrad	j_1	j_2	j_3	j_4				

All group titles for element type K21 (or K31, etc.) will reside in a data set named GT K21, produced by AUS/ALPHA. The first block corresponds to group 1, the second to group 2, etc.

---

* The NI values are greater than the number of quantities actually input to allow certain system computed information to reside in these data sets.

[#] If nfilm is negative, its absolute value points to an entry in a table of FILM transfer COEFFicients.

Temperature dependent material property tables are constructed with AUS/TABLE as shown below. Each data line defines properties corresponding to temperature T. Properties at intermediate times are determined by linear interpolation. The number of temperature points (parameter NJ) may be different for each table. If only one data line is given (NJ=1), properties are constant.

Data Set Name

N1	N2	N3	NI	Data Line Contents
CONDuction	PROPerties	nmat	9	T, ρ, c, α_{11} α_{22} α_{33} α_{12} α_{23} α_{31}(input all values, no default)
CONVection	PROPerties	nfilm	2	T, h
RADIation	PROPerties	nrad	2	T, ε

Film transfer coefficients which are functions of geometry (e.g. variation along an aerodynamic boundary layer) can be defined in one data set. The TOC parameters are NI=1 and NJ=number of film transfer coefficients.

N1	N2	Data Line Contents
FILM	COEFficients	h_1, h_2, h_3, ..., h_{NJ}

The SI units for the above material properties are listed below. If a different homogeneous set of units is used, the Stefan-Boltzmann constant must be redefined via an SSTA or TRTA reset control (Sections TA1.5, TA1.6).

T = temperature, degrees Kelvin (K)

ρ = mass density (kg/m^3)

c = specific heat (J/kg K)

α_{ij} = conductivities (W/mK), defined with respect to the element coordinates shown in Section TA1.1. Any conductivity not specified is assumed to be zero.

h = film transfer coefficient (W/m^{2}K).

ε = emissivity (dimensionless)

TELD FOR THERMAL ANALYSIS

RESET CONTROLS

	default	
NUTED	0	Unit on which to save TED elname ngroup data sets. If NUTED is not reset, no data sets are created
LRTED	896	Record length of TED elname ngroup data sets.

Thermal elements are defined in exactly the same manner as structural and fluid elements are defined.

The table pointers NSECT are used for thermal definition.

TABLE POINTER:

	default	
NMAT	1	Material properties pointer nmat for conduction properties nfilm for convection properties nrad for radiation properties (See Table TA1.2, page TA1-8)
NSECT	1	Entry in the appropriate table constructed via AUS/TABLE K AREAS (K21 elements) K THICknesses (K31, K41 elements) C CIRCumference (C21 element) R CIRCumference (R21 element) These data sets must exist before ELD is executed. For example; if K21 elements are to be constructed, the data set K AREA must exist.

If nfilm is negative, its absolute value points, to an entry in a table of FILM transfer COEFficients (See page TAI-8)

5.1.3 Data Set Constructors

Several kinds of data sets may be generated or modified by the TABLE, SYSVEC, ELDATA, and ALPHA subprocessors. Examples are summarized in the following tabulation:

Subprocessor	Kind of Data Set Produced or Operated On
TABLE	TABLE.* Examples: Nodal pressures, temperatures, and TAB-produced tables.
SYSVEC	SYSVEC.* Examples: System vectors of applied forces, motions, and eigenvectors.
ELDATA	ELDATA.* Examples: Element-applied load data, e.g. pressures, temperatures, and dislocations.
ALPHA	ALPHA.* Examples: Arrays of alpha character strings used as load case titles, or to describe eigenvectors.

In the following, XXXX is any of the subprocessor names: TABLE, SYSVEC, ELDATA, or ALPHA. To initiate production of a new data set named N1 N2 n3 n4, the following language sequence is used:

XXXX (optional parameters): N1 N2 n3 n4 : --- data cards ---

To initiate modification (updating) of an existing data set, the following language is used:

XXXX, U (optional parameters): N1 N2 n3 n4: --- data cards ---

*See Section 2.5.

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The output data set, N1 N2 n3 n4, is resident in the current data destination library defined by the last OUTLIB Statement. If omitted, N2, n3, and n4 assume default values of AUS, 1, and 1.

The following characteristics of the Oper, U (update) mode of operation are noted:

- The data set is actually overwritten in mass data storage, rather than modified and stored in a new area.
- Existing data sets must not be extended (i.e., additional blocks cannot be appended in this mode of operation).

The following example input indicates a typical application of a data set constructor. In this case SYSVEC is used to create a data set, named APPL FORC 88, comprised of two blocks. The first block defines load case 1 of static load set 88; and the second block defines case 2 of set 88.

```
@XQT AUS
 SYSVEC$                             Enter SYSVEC
 APPLIED  FORCES  88$                Name of output data set.
 CASE 1$
        I=          2,     3$        Direction 2 and 3 forces.
        J= 7,9$                      List of joint numbers.
                  7.2    7.3$        f2, f3  at joint 7.
                  8.2    8.3$         "   "         8.
                  9.2    9.3$         "   "         9.
 CASE 2$
        I= 1:  J=10:  14.6$          f1  at joint 10.
        I= 3:  J= 7:  19.2$          f3  at joint  7.
```

Many examples of SYSVEC, etc., input are given in Section 6. It is suggested that these examples be scanned briefly before reading Sections 5.1.3.1-4.

Because of the central role played by the data set constructors, it is strongly recommended that new users perform a series of test executions of them, using DCU/PRINT and/or VPRT to verify that the intended results are achieved.

The TRAN sub-activity of TABLE provides a very general method of transmitting information from one data set to another. New users should not attempt to use TRAN without advice from an experienced analyst.

5.1.3.1 TABLE. Execution begins as indicated below. If appropriate, any of the underlined words may be omitted.

TABLE, U(NI= ni, NJ= nj): N1 N2 n3 n4: -- data ---

The optional parameters NI and NJ have the same meaning as defined in Section 2.5; i.e., each block of the output data set is a rectangular matrix of dimension (ni, nj). The default value of ni is 1, and the default value of nj is the number of joints in the structure. The input defining the nth block of the output data set has the following structure:

BLOCK n

OPERATION = SUM $ or XSUM, or MULTIPLY, or DIVIDE

J= j_1: j_2: j_3: - - - $, a list of columns.*

$e^1_{j_1}$ $e^2_{j_1}$ $e^3_{j_1}$ - - - $e^{ni}_{j_1}$ $ Data record 1, applies to column j_1

$e^1_{j_2}$ $e^2_{j_2}$ $e^3_{j_2}$ - - - $e^{ni}_{j_2}$ $ Data record 2, applies to column j_2

—

—

etc.

*Loop-limit format is also permitted (see Section 2.3).

If there are fewer data records of the latter type than there are j's in the list of columns, the last record will be associated with each of the remaining j's. The meaning of the e_j^i's depends upon current arithmetic mode, as established by the OPERATION= XXXX statement. In the following, x_j^i is the element in row i and column j of block n of the output data set. The range of i is 1, 2, - - - ni, and the range of j is j_1, j_2, j_3 - - - .

Operation	Arithmetic mode
SUM	$x_j^i \leftarrow x_j^i + e_j^i$
XSUM	$x_j^i \leftarrow e_j^i$
MULTIPLY	$x_j^i \leftarrow x_j^i e_j^i$
DIVIDE	$x_j^i \leftarrow x_j^i / e_j^i$

The sequence (OPERATION=XXX ..... List of j's ..... data records for each j in the list) may be repeated as many times as necessary to produce the desired data in block n.

The OPERATION statement continues in effect, not only for the current block but for all subsequent blocks as well, until another OPERATION statement supersedes it. The default OPERATION is SUM.

The following control statement is frequently useful:

$$I= i^1, i^2 -- i^m \$ \text{ (each } i^k \text{ between 1 and ni)}$$

This statement indicates that the data records will have the following content:

$$e_j^{i^1}, e_j^{i^2} -- e_j^{i^m} \$.$$

For example:

BLOCK n: etc. : - - - $

I= 3,5: J= 7,9 $

e_7^3, e_7^5: e_8^3, e_8^5: e_9^3, e_9^5 $

I= 1: J= 10: e_{10}^1 $

The $I= i^1, i^2$ --- statement continues in effect, not only for the current block but for all subsequent blocks as well, until another $I= i^1, i^2$ --- statement is encountered. Default is, in effect,

I= 1, 2, --- ni.

The following statement may immediately precede a list of j's:

$$\text{DDATA} = d_1, d_2, \text{---} d_m \ \$$$

When data records are being duplicated, the DDATA command has the effect of incrementing each item in the data record by the corresponding d_i. The DDATA statement will apply <u>only</u> to the j-list immediately following the statement.

<u>Example:</u>

I= 1, 3: DDATA= .2, .1: J= 2, 5: 7., 8.$

The foregoing statement produces the same result as:

I= 1,3 : J= 2,5$

7.0, 8.0	\$	=	e_2^1, e_2^3
7.2, 8.1	\$	=	e_3^1, e_3^3
7.4, 8.2	\$	=	e_4^1, e_4^3
7.6, 8.3	\$	=	e_5^1, e_5^3

To cause an integer constant, jshift, to be added to each j in subsequent lists of j's, the following command is used: JSHIFT= jshift. The jshift parameter will remain in effect until superseded by another JSHIFT command.

Rules for ordering control and input statements:

- No statement may precede the first BLOCK= n statement (Exception: if operation is confined to block 1, the BLOCK= 1 statement may be omitted).
- When the BLOCK= n statement appears, block n - 1 must already exist.
- No control card of any kind (OPERATION= --, I= ---, JSHIFT= ---, or DDATA= ---) may appear anywhere between the beginning of a j-list and the end of the subsequent data records $\left(\text{the } e_j^i\text{'s}\right)$.

Synonyms. If desired, the control word CASE may be used instead of BLOCK, and JOINT instead of J.

Multiple data records on a single card. In the preceding, it has been indicated that each data record should contain exactly ni words, or m words if the statement $I = i^1, i^2 --- i^m$ is used. It is also permitted to place several such complete data records on the same card; i.e., both of the following are legal cards and have the same effect:

1.2, 2.9: 4.5, 2.7: 3.2, 9.$

1.2, 2.9, 4.5, 2.7, 3.2, 9.$

An error stop will occur if a card does not contain complete records.

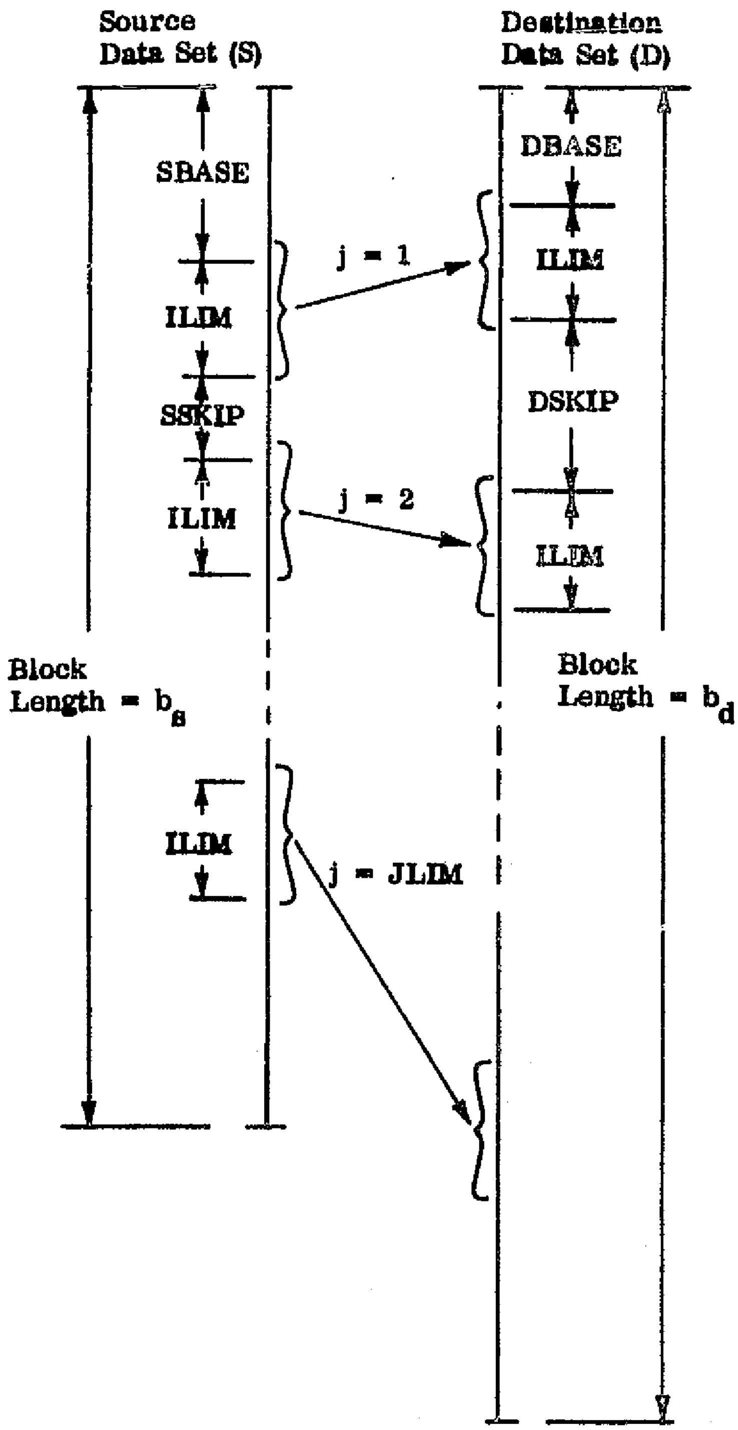
<u>The TRANSFER Statement.</u> This command provides a general method of extracting real data from designated areas of one data set, and adding them to data in designated areas of another data set. TRANSFER statements may appear as the first or last statement in a TABLE execution, or immediately prior to any BLOCK statement. The command form is as follows:

$$\text{TRANSFER(List of arguments } P_{\overline{1}} \; v_1, P_{\overline{2}} \; v_2, \text{ ---)}$$

Any or all of the arguments summarized in the following table may be used.

Argument Name	Default Value	Meaning
SOURCE	None	Name (a single alpha word) of the source data set. May be established by a DEFINE statement.
L1	1	Successive blocks of the source data set are added to blocks L1, L1 + 1, --- L2 of the destination data set unless L1=L2.
L2	1	
ILIM	Lesser of b_s, b_d	See Fig. 5.1.3.1-1
JLIM	1	
SSKIP	0	
DSKIP	0	
SBASE	0	
DBASE	0	

The TABLE/operation statement has no meaning in TRANSFER.



Fortran equivalent, repeated for blocks L1, L1 + 1, ... L2:

```
   IS = SBASE
   ID = DBASE

   DO 20  J = 1, JLIM
   DO 10  I = 1, ILIM
   IS = IS + 1
   ID = ID + 1
10 D(ID) = D(ID) + S(IS)
   IS = IS + SSKIP
20 ID = ID + DSKIP
```

Fig. 5.1.3.1-1: TRANSFER Parameters

Figure 5.1.3.1-1 illustrates the function of the TRANSFER statement for the case in which the number of blocks in the source data set is equal to the number of blocks in the destination data set (i.e., L2-L1+1).

If L1= L2, the function is similar, except that successive blocks of the source data set are transmitted to successive areas within block L1 of the destination data set.

The following are a few examples of the TRANSFER statement.

@XQT AUS	
DEFINE OLDV= 2 VIBR MODE 200 1 1, 10 $ TABLE(NI=6, NJ=1700): VIBR MODE 1 1 $ TRANSFER(SOURCE= OLDV, LI=1, L2=10) $	Salvage vibrational modes from a previous analysis for use as initial approximations of modes of a modified structure having additional joints.
DEFINE U7= STAT DISP 1 1 7 $ TABLE(NI=3, NJ=400): DEFORMED POSITION $	Store node point locations of the deformed structure in DEFO POSI.
TRANSFER(SOURCE= JLOC) $	JLOC= original position.
TRAN(SOURCE=U7, ILIM=3, JLIM=400, SSKIP=3) $	U7= Joint motion due to static load case 7 of set 1.
DEFINE X= VIBR MODE 1 2 1 8 $ TABLE(NI=30, NJ=8): T MODE 1 2 $ TRANSFER(SOURCE=X, SBASE=600, ILIM=30) $	Form a single-block matrix having 8 columns, each column corresponding to a mode. Each column contains all 6 motion components of joints 101-105.

5.2 DCU - DATA COMPLEX UTILITY PROGRAM

Function - DCU performs an array of utility functions, as subsequently defined in this section. New users should review Sections 2.2 and 2.5 before reading this section.

In defining DCU command syntax, the symbol Lib will be used repeatedly to represent a SPAR library internal designation (1, 2, etc.), and Id will identify one or more data sets. Id may be in any of the three forms indicated below, unless specifically stated otherwise:

(1) The four-word data set name, MASK-filled.

Example: K SPAR is the same as

K SPAR MASK MASK.

(2) An integer, n, indicating the data set associated with sequence number n in the table of contents.

(3) Integers n, m, indicating (m-n + 1) data sets associated with sequence numbers n, n+1, - - - m.

(4) Omitted - meaning all data sets in a library.

Consider as an example, the most commonly executed command,

TOC Lib Id.

Examples:

- TOC 1 K SPAR$ Id form (1) causes a single line of the Table of Contents of library 1 to be printed, i.e. the line corresponding to the first data set named K SPAR MASK MASK to be located.

- TOC 1 27$ Id form (2) causes printout of line 27 of the Table of Contents of library 1.

- TOC 1 32,50$ Id form (3) causes printout of lines 32 through 50 of the Table of Contents of library 1.

- TOC 1 $ Id form (4) causes the entire Table of Contents of library 1 to be printed.

Other commands currently available in DCU are summarized below:

- DISABLE Lib Id$. Data set(s) are marked as disabled. The data set(s) are still present in the library, but cannot be accessed until they are re-enabled via the following command:

- ENABLE Lib, Id$. Only forms (2) or (3) of Id are allowed for this command.

- PRINT Lib Id$, or

PRINT Lib N1, N2, n3, n4, j_1, j_2, i_1, i_2, b_1, b_2. The one or more identified data sets are printed in tabular form*. Only matrix-form data sets (e.g., TABLE, SYSVEC, ELDATA, and ALPHA forms, as defined in Section 2.5) should be PRINTed. If the second form is used, the printout will be restricted to columns j_1 through j_2, rows (items) i_1 through i_2, for successive blocks b_1, b_1+1 --- b_2. Using the terminology of Section 2.5, default parameters are $j_1 = 1$, $j_2 = NJ$, $i_1 = 1$, $i_2 = NI$, $b_1 = 1$, b_2 = total number of blocks in the data set.

> NOTE
>
> PRINT displays data set items sequentially, so that matrices appear in transposed form.

Data produced by processors E, EKS, TOPO, K, M, KG, and INV should not normally be named in a PRINT command.

- COPY Lib_1, Lib_2, Id$. Copy the indicated data sets from Lib_1 to Lib_2. Disabled data sets are not copied. This is the recommended method of packing libraries.

- XCOPY Lib_1, n, Id$. The indicated data set (in Lib) is written on ordinary sequential file n in a sequence of physical records identical to individual blocks of the data set as it resides in Lib. As an example,

* An auxiliary command, NCPL= n, controls the number of columns per printed line. Default NCPL= 10. For teletype display, select NCPL= 5.

XCOPY 1, 5, VIBR MODE $ causes eigenvectors to be written onto a file known externally as SPAR-E (UNIVAC) or SPARIE (CDC), corresponding to n = 5. The output file will contain one physical record for each eigenvector.

- <u>XLOAD n, Lib, nwords, nj, ninj, type, N1, N2, n3, n4 $.</u> This command causes data from sequential file n to be loaded as a data set named N1, N2, n3, n4 in Lib. The other parameters have the same meaning as defined in Section 5.2. As an example, suppose a sequential file, SPAR-D, contains five blocks (physical records produced by direct binary writes, <u>not</u> unformatted Fortran writes) of real data and that each block is a matrix with 6 rows and 100 columns. To load these data into library 1 as a data set named XX YY 1 2, the following command would be used:

  XLOAD 4,1, 3000, 100, 600, -1, XX YY 1 2 $

- <u>REWIND n $.</u> Used in conjunction with XCOPY, XLOAD, this command causes sequential file n to be rewound (i.e., set to starting point). It should be noted that neither XCOPY nor XLOAD rewinds sequential files either before or after the data transmission, so that one sequential file may contain many multiblock data sets.

- <u>SCALE C_1, C_2\$.</u> This command may precede a COPY or XCOPY command. If it does, the output data sets will = C_1 (source) + C_2.

- CHANGE Lib Id_{old}, Id_{new}\$. This command causes the name of data set to be changed from Id_{old} to Id_{new}. Only the full 4-word name form is permitted for both Id's.

- DUPLICATE Lib_1, Lib_2\$. Lib_2 is created identical to existing Lib_1, including disabled data sets, if any.

- TWRITE Lib\$. Lib is written onto tape nt (see NTAPE command). The complete library is written in physical records as large as the available core will allow.

- TREAD Lib\$. Lib is read from tape nt (see NTAPE command). Available working core space must be as large as it was when the TWRITE was executed.

- NTAPE= nt\$. The internal unit number of the tape to be used in the next TWRITE or TREAD command is nt (default=20). Note that logical 20 is Univac file SPAR-T, CDC file SPARLT.

- STORE Lib, ID\$. Lib is stored as a data set named Id, in library nℓ (see LIBLIB command). Id may only be a full 4-word name, the first two words of which are typeless.

- RETRIEVE Lib, Id$. The data set Id is recovered from the library $n\ell$ and constituted as library Lib.

- LIBLIB= $n\ell$$. The internal unit number of the library library is $n\ell$ (default=12). Note that logical 12 is Univac file SPAR-L, CDC file SPARLL.

- TITLE Lib' - - - Alphanumeric title for Lib - - - -. The label-field title is embedded in Lib, and will be displayed at the beginning of each table of contents printout produced by a TOC command.

- STATUS Lib$. The number of library entries and the current I/O counts for Lib are printed.

- ABORT n$. To cause an error-abort if an abnormal event occurs in DCU, set ABORT=1$.

Core Requirements. Working core must be sufficient to accommodate one block of each data set transmitted through core (e.g. via COPY, XCOPY, etc.). See also the discussion of TWRITE and TREAD.

Code Release Data. Level 9, July 1975, coded by W. D. Whetstone.

APPENDIX B

GEOMPLT USER'S GUIDE

(w/o updates for LaRC installed Jan. 1978)

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ABSTRACT

The GEOMPLT program is an interactive graphics program for finite element and thermal network models. The program was developed for use on a Tektronix 4000 series CRT thermal connected to a UNIVAC 1100 series or CDC 6600 computer. The program has the following features:

1) Plot data from the NASTRAN, SPAR, STRUDL (UNIVAC only) and CINGEN programs.
2) Automatically expands core for NASTRAN and STRUDL bulk data (UNIVAC only).
3) Create hard copy plot file for drum plotters.
4) Create input data files for CONTUR program.
5) Provides an alternate print file for post plotting diagnostics.

ACKNOWLEDGEMENT

The GEOMPLT program is a product of a continuous effort at Sperry to develop a conversational graphics program. Since the program has evolved out of several other earlier programs, a number of programmers and engineers have been involved in its development. Mr. E. M. Holder developed the early code for use with the SAMIS program and an off-line CalComp drum plotter. Mr. L. Stephen was responsible for coding changes developed for the U.S. Army Missile Command resulting in thermal network plotting, and speed improvements. Mr. D. Roberts maintained the program and developed the early editor routines. Mr. H. Turner of UNIVAC Service Center Huntsville, was responsible for the code changes to the ED processor currently used as the UNIVAC editor routine. Mr. J. Chiou was responsible for the SPAR conversion routine. Mr. W. E. Shultz and Mr. L. D. Craig implemented the thermal network and XY-Plot capability.

1.0 INTRODUCTION

It has long been recognized that a graphic presentation of a finite element model is necessary to validate the model prior to structural analyses. Most finite element programs contain some form of general purpose plotting. The plotting capability of such programs as NASTRAN (Ref. 1) and other general purpose structures programs are quite extensive and very useful; however, they generally require large core and offline plotters which results in delayed processing and, therefore, delays in data editing. With the increased use of mesh generators (Ref. 2) operated in a demand terminal environment, it has been necessary to develop stand alone, small core, graphics programs for use in this new modeling environment.

The GEOMPLT program in its current state of development, provides a program which operates with small core (as little as 22K), on a Tektronix CRT graphics terminal connected to a UNIVAC 1100 series or CDC 6600 computer. The initial development of the program began in 1968 with a small off line plotting program which utilized a small core computer (16K) and a CalComp drum plotter. The program was first used in conjunction with the SAMIS program and since that time it has been modified and improved. In 1970 it was converted to plot NASTRAN data and to operate on the UNIVAC 1108 computer system. In 1971 an interactive graphics version was written for use on the UNIVAC Advanced Graphics terminal. In 1972 a version for use on the 4000 series Tektronix CRT terminals was completed. Since that time, the program has been expanded to plot data from other finite element programs and conductance/capacitance networks for thermal analysis programs.

The program is written in FORTRAN with the exception of two assembly routines (UNIVAC only) used to control system parameters. The program in its present configuration and combined with the use of mesh generators, provides the necessary software for complete model generation, and viewing. All data can be prepared and checked prior to execution from a demand terminal.

The following sections of this manual describe the program installation and initiation, program features and their use, and finally a brief description of each subroutine.

2.0 OPERATING ENVIRONMENT

The most recent version of GEOMPLT program (Version 4.0) is designed to operate on the UNIVAC 1108 Exec 8 Level 31 system, with a Tektronix 4000 series CRT terminal. Earlier versions exist for the CDC-6600/Tektronix 4000 series terminal, UNIVAC 1108/CalComp model 565 drum plotter, UNIVAC 1108/UNIVAC Advanced Graphics terminal and IBM 1130/CalComp Model 565 drum plotter.

The earlier versions represent historic developments of the program leading to the current version described in this manual.

2.1 PROGRAM INSTALLATION

UNIVAC PROGRAM SETUP

The program is contained on a 9 track tape, recorded on three files in 800 bits per inch (BPI) density. A fourth file contains a small NASTRAN bulk data deck for testing the program.

All files were written with @COPY,GM executive instruction. Therefore, they may be read into the local system with the following instructions:

```
@ASG,T IN,T,#                  GEOMPLT PROGRAM TAPE
@ASG,UP ABS,F2
@ASG,UP SR, F2
@ASG,UP TCS,F2
@ASG,UP 4,F2
@REWIND IN.
@COPY,G IN.,ABS.               (Absolute element = .MPA)
@COPY,G IN.,SR.                (Source and Relocatable element)
@COPY,G IN.,TCS.               (Terminal Control System Library)
@COPY,G IN.,4.                 (NASTRAN Bulk data sample)
@FREE  ABS.
@FREE  SR.
@FREE  TCS.
@FREE 4.
@FREE  IN.
@FIN
```

2.2 PROGRAM EXECUTION FROM TEKTRONIX TERMINAL

The GEOMPLT program as described in this manual is currently operated by Sperry in two environments.

The first uses a Tektronix 4013 connected to a UNIVAC 1108 3x2 system, Exec 8 Level 31, with 1200 baud transmission rates. On this system the program is cataloged using the SECURE processor. The user enters the following commands to initiate a plotting session:

A1. Set modem to "talk".

A2. Dial (241), when high pitched tone is heard, push "data" button and set phone into receiver.

A3. Clear screen - push "reset" -

A4. Type site ID - DTK230

A5. When system responds, type run card @RUN - - - -

A6. Set qualifier for secured file @QUAL SPERRY

A7. Secure program

```
@SRG
SPERRY*GEOM,*
@USE TPE$.,*GEOM.
```

A8. Data to be plotted is obtained from one of the following sources:

- A previously written tape
- A previously cataloged data file
- A mesh generator program
- The CINGEN program
- The TOPOLOGY I program
- The SPAR program
- A newly created data file using the DATA,ELT or ED processors and keyboard input.

Data must be placed in or attached to file 4 for reading by GEOMPLT, e.g., @USE 4.,BULK. (Data on file BULK).

or

@ASG,A 4. (Data cataloged on file 4).

An exception occurs if the data to be plotted is from the SPAR program. In this case the TAB and ELD processors are executed and the print file is BRAKPT to a cataloged file 9. File 9 is the GEOMPLT input file for plots of SPAR data, e.g.,:

```
@ASG,UP   9,F2
@BRKPT PRINT$/9
@XQT TAP
          :
  (SPAR INPUT DATA)
          :
@XQT ELD
          :
  (SPAR INPUT DATA)
@BRKPT PRINT$
@FREE 9.
@ASG,A 9.
```

A9. Execute GEOMPLT Program

```
@ASG,T   21,F2///500
@XQT     .MPA
```

A10. The program is conversational from this point on and the user must respond to requests by the program in a step-by-step manner.

The second system is a UNIVAC 1108 1x0 system, Exec 8 Level 31, with a 300 baud transmission rate. On this system the program is stored on tape and must be cataloged by a batch job prior to initating the graphics sessior

```
@RUN - - -
@ASG,T IN,T, delivery tape #
@ASG,UP GEOM,F2
@REWING IN.
@COPY,G IN.,GEOM.
@FREE GEOM.
@FIN
```

With the program cataloged, the Graphics Job can then be started:

B1. Turn Acoustic Coupler modem to "on"

B2. Dial UNIVAC phone number, when a high pitch tone is heard, place phone into Acoustic Coupler.

B3. Type Site ID (switch on 4013 to "LINE")

B4. When the system responds, type in a run card,

```
@RUN - - -
```

B5. The requirement for data files 4 or 9 are the same as described in steps A.8 or A.9.

B6. To execute GEOMPLT program

```
@ASG,T  21,F2///200
@XQT GEOM.MPA
```

B7. The program is conversational from this point on and the user must respond to requests by the program in a step-by-step manner.

CDC PROGRAM SETUP

A. Computer Configuration

1.	Computer	CDC 6600
2.	Core size required	26K Decimal
3.	Language	FORTRAN IV
4.	System	SCOPE 3.4 or NOS
5.	Plotter required	Yes - Tektronix model 4000 series
6.	Card punch required	Yes - If punch option on
7.	Tape Assignments	None

B. Estimated Running Time

CPU time in GEOMPLT was 7.03 seconds with a problem size of 221 elements and 411 grid points, and 1 plot. An additional 86 seconds was required when data was generated for the CONTUR program (CONTUR = 1 or 9).

C. Restart Procedure

Not required due to small amount of run time required.

D. Deck Sequence

The finite element data is read into the CDC remote system terminal and then batched to Tektronix graphics terminal.

For Intercom Job:
Notes:
1. Δ=send button
2. Comments are enclosed in brackets { }
3. SS = two numbers assigned by the operating system
4. ∇=Blank space

UT-200 Terminal (LX)
R, BULKΔ
BATCH, BULK, PRINT, LW, ZZΔ

Tektronix Terminal (LW)
H, 0Δ
EΔ
BATCH, IZZLXSS, LOCALΔ

```
BATCH, IZZLXSS, RENAME, TAPE4
REWIND, TAPE4
ETL = 500Δ
ATTACH, NASB, LPXXXA2, ID = LPXXX, CY = 2Δ
ATTACH, AGII, LPTEKTRONIX, ID = LPPATRICK, CY = 2Δ
XEQΔ
LDSET, LIB = AGIIΔ
NASBΔ
TITLEΔ  {Up to 80 characters may be used for the title]

∇ $INPUT∇ {Enter options desired from Table II, for example, ENO = 1,
           GNO = 1, PV = 1, etc}$Δ
∇ $PVIEW∇{Use only if PV = 1, in $INPUT, for example,
          JPV(1) = first element number, - 0, last element number
          of a desired set of elements to be plotted, first element
          number of another set to be plotted at the same time, -0,
          Last element number of the second set of elements to be
          plotted, single element number, single element number,
          etc}$Δ

EDITΔ  {Option after each plot if editing of NASTRAN connection
        or GRID cards are desired.}

or

NΔ  {No editing at this time and the next plot is initiated
     by typing title, $INPUT and $PVIEW.}
```

3.0 PROGRAM FEATURES

The GEOMPLT program performs the following functions:

- Graphically displays finite element models (NASTRAN, SPAR or STRUDL), including partial views, rotated views, a resistance network with dashed lines and element and grid point numbers.
- Creates data files of geometry and connection data for use by the CONTUR program (Ref. 3).
- Edits finite element data through addition, deletion, and modification of bulk data card images.
- Creates an alternate print file which provides a permenant record of the terminal session for review at a later time.
- Writes a data file for obtaining hard copies of plots via CalComp or Houston Instrument drum plotters.
- Automatically expands core to the minimum required for the NASTRAN problem.

3.1 GEOMETRIC PLOT

Purpose: To display a 3-D view of the finite element model on a terminal CRT.

Options:
- Plot NASTRAN, CINGEN, SPAR or STRUDL (UNIVAC only) models.
- Print grid, element, capacitance and conductance numbers.
- Draw any element type listed in Table I.
- Plot partial views to obtain a clear view of local areas or selected elements.
- Print a title at the bottom of the frame.
- Change plot scale factors for increasing or decreasing the size of the image plotted.
- Rotate the view about three axes.
- Interchange axes to obtain a rotated view or view utilizing a left handed coordinate system.

Procedure: The various plot options are selected via the Namelist's $INPUT and $PVIEW. Table II contains a list of the $INPUT Namelist parameters, a description of the parameters, and the default value set by the program at the start of the program. All of these parameters may be omitted from the Namelist input or they may be changed prior to each plot. Parameters marked by * in Table II retain an input value until changed by a new input value; all other parameters revert to their default values once the plot is complete.

The request for Namelist parameters is made conversationally by the program, i.e., a message appears on the screen requesting that the appropriate Namelist be supplied by the terminal operator at the appropriate time.

The partial view is selected via the $PVIEW Namelist. Element numbers are listed thru strings of numbers and/or the use of (-0) symbol to indicate consecutive numbers, e.g., $PVIEW JPV(1) = 1,3,5,-0,10,13 $ is the same as, $PVIEW JPV(1) = 1,3,5,6,7,8,9,10,13$

Note - Namelist input must start in Column 2 and end with a "$". Parameters may be listed on several lines by using a "," at the end of one line and beginning the next line in column 2 or greater.

To terminate the program type "N" after end of current plot.

Limitations:

- Only elements listed in Table I may be plotted.
- The number of elements plotted depends upon the size of core available. Since the program will dynamically expand core the size limit is determined only by local restrictions on using a Tektronix terminal. 1305 grid points and 1305 element with an average of 4 connections per element will fit in 36K core.
- 100 plots are permitted as a default. If more are desired set Namelist parameter NPLOT>100.

Core Size Calculation:

CORE = (IBANK + DBANK) + OPEN CORE

IBANK+DBANK = 21651

OPEN CORE = 4 x NUMGRD + 4 x NELEM + JSIZE + 10 + NJPV

NUMGRD = Number of Grid Points

NELEM = Number of Elements

JSIZE = Number of Connections = Σ(NELEM x Number of Grid Points per Elements).

NJPV = (300-NELEM/2) , if NELEM $\leq$ 600

= 0 , if NELEM > 600

Table I. List of Bulk Data Cards Used by GEOMPLT

Element Types Plotted

CBAR	CTRIA1	CQDMEM	CTETRA	PLOTEL
CONROD	CTRIA2	CQDPLT	CWEDGE	CHBDY:
CROD	CTRMEM	CQUAD1	CHEXA1	POINT
CTUBE	CTRPLT	CQUAD2	CHEXA2	ALINE
CTORDRG	CTRIARG	CSHEAR	CIS3D8	REV
		CTWIST	CIS3D20	AREA3
		CTRAPRG		AREA4

Other Types Used

GRDSET
GRID
CORD2R
CORD2C
CORD2S

All other types ignored

Table II. Namelist $INPUT Parameter Definition (UNIVAC only)

Parameter	Description	Default	Other
BAUD*	Transmission rate from computer to terminal, BAUD/10	120	Integer
CONDNO	Print conductor numbers for thermal network	0-NO	1-YES
CONTUR	Saves XY plotter coordinates on file KC and connector data on file KD to be read by CONTUR program. NOTE: When CONTUR = 1, the following default changes are used KTEST = 1 KD = 11 MPLOT = 0 NPLOT = 1	0-NO	1 or 9-YES
ENO	Print element numbers at element centroids	0-NO	1-YES
GNO	Print grid numbers at grid point	0-NO	1-YES
IHUSTN	Write hard copy plot commands on file 25; request to permanently save plot on file 26 is made after plot is complete	0-NO	1-YES
KC	File number to use when CONTUR = 1	10	Integer
KD	File number to use when LTEST or KTEST = 1	7	Integer
KTEST	Option for CONTUR element punch option if KTEST = 9; plotting is supressed	0-NO	1 or 9-YES
LTEST	Option for CONTUR XY data punch options if LTEST = 9; plotting is supressed	0-NO	1 or 9-YES
MPLOT	Option for multiple plots. Set MPLOT = 0 to terminate plotting	1-YES	0-NO
NCHBDY	NASTRAN thermal elements to be plotted	0-NO	1-YES
NODENO	Print capacitance node number for thermal network	0-NO	1-YES
NPLOT	Number of plots if MPLOT = 1	10	Integer
NTEST	Option to print rotated coordinate data on file 21	0-NO	1-YES

Parameter	Description	Default	Other
PROGRM	Type of input data on file 4, 9 or 30 1 = NASTRAN (file 4) 2 = CINGEN DATA only plotted (file 30) 3 = CINGEN and NASTRAN element data plotted (file 4 and 30) 4 = SPAR (file 9) } (UNIVAC only) 5 = STRUDL (file 4) } (UNIVAC only)	1	1-5
PV	Option for partial views; if PV = 1 Namelist $PVIEW is used to specify element numbers to be plotted	0-NO	1-YES
SCALEX*	Option for adjusting the apparent width of the screen	10	REAL
SCALEY*	Option for adjusting the apparent height of the screen	7	REAL
SYMB	Option to place a symbol at the grid point 29 = •	29	Integer
X*	Angle of rotation about x-axis (deg)	34.27	REAL
Y*	Angle of rotation about y-axis (deg)	23.17	REAL
Z*	Angle of rotation about z-axis (deg)	43.0	REAL
XAXIS	Axis to be placed in screen x-axis (+ left to right)	1	1-6
YAXIS	Axis to be placed in screen y-axis (+ up)	2	1-6
ZAXIS	Axis to be placed in screen z-axis (+ out of screen) Structure yes may be interchanged with screen axes for changing view, where: 1 = x, 2 = y, 3 = z, 4 = -x, 5 = -y, 6 = -z	3	1-6

NOTE: Parameters marked by * retain input value until changed by a new input value.

3.2 DATA EDITOR

The data editor present in Level 3.0 has been removed in Level 4.0. This was done to minimize the core requirements of the program and thereby increase the problem size for a given core size. Those who wish to edit their data may do so using the Standard Text Editor available on the UNIVAC system. When editing is complete, the revised data may be viewed by re-executing the GEOMPLT program.

3.3 HARD COPY

Purpose: To obtain a high quality hard copy of the plot displayed on the screen. The "hard copy" is drawn on a drum plotter of the CalComp or Huston Instruments type.

Options: The user must select the hard copy option prior to plotting a view, then decide to keep the plot or discard it after the plot is complete.

Procedure: The user sets parameter IHUSTN = 1 at the time NAMELIST $INPUT is specified.

- The program then writes general purpose plot commands on file 25 while the plot is being generated on the screen.
- When the plot is complete the user is given the choice of saving or discarding the plot. If he elects to save the plot, file 25 (scratch file) is automatically copied to file 26 (save file) and file 25 is rewound for the next frame.
- The file created by GEOMPLT will not drive a drum plotter directly. A special program must be written to read file 26 and write the proper plot commands, depending upon the type of drum plotter available at the local computer site. File 26 contains the following information:

  First record: Title Format (13A6,A2)

  Second record: Xminimum, Yminimum, Xmaximum, Ymaximum Format (4E15.7)

  Following records: BRANCH, X, Y, ID Format (I5,2E15.7,I6)

  Where branch indicates the appropriate plotting action to be taken:

  1 = Not used

  2 = Draw a line from present pen position to the X,Y coordinates

  3 = Move pen to the X,Y coordinates

  4 = Write the Grid ID at the X,Y coordinates

  5 = Write the Element ID at the X,Y coordinates

  6 = Plot is finished, read a new first record

7 = A symbol should be written at the X,Y coordinates

8 = Write an X at the X,Y coordinates

9 = Write a Y at the X,Y coordinates

10 = Write a Z at the X,Y coordinates

Last record: Title Format (13A6,A2) where the first word in the title is ENDRUN

3.4 CONTUR PLOT PRE-PROCESSOR

Purpose: To create two data files (10 & 11) which contain transformed grid coordinate data and connection data for use by the CONTUR program.

Options: The user must select the Contour option prior to plotting a view using Namelist $INPUT parameters.

The options available are:

- To punch transformed grid coordinate data on file 10.
- To punch Grid data on file 10 and suppress plotting.
- To punch element connection data on file 11.
- To punch element connection data on file 11 and suppress plotting.
- To specify alternate file numbers for output of grid and element data for CONTUR.

Procedure: The user sets parameter CONTUR = 1 or 9 at the time Namelist $INPUT is specified.

(Option 1 does not suppress the screen plot. Option 9 suppresses the screen plot).

- A set of transformed grid coordinates and element connection numbers are written on files 10 and 11 respectively. The transformed grid coordinates are the xy screen coordinates of the projected view.
- If the output is desired in the form of punched cards the parameters KC and KD are set equal to the punch symbiont file number (normally file 1 on standard UNIVAC systems).

Limitations: When CONTUR = 1 is used, the multiple frame plot parameter (NPLOT 1) is set to terminate the run after the next plot. If contour data is required for several views, a new execution must be initiated for each view.

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3.5 ALTERNATE PRINT FILE

Purpose: To provide a permanent record of the plotting session.

Options: The following output is written on file 21.

- Maximum number of elements
- Title card
- Namelist parameters
- Grid and connector listing
- Transformed grid coordinates (from local to basic coordinate system).
- Number of grid points and elements in plot.
- X,Y,Z coordinate max and min values.
- Scale factor
- Error messages

Procedure: File 21 is always written. To obtain a printout, the user must catalog file 21 prior to execution or copy file 21 into a cataloged file. The file is then SYM'ed to a system printer.

Limitations: Not Applicable.

4.0 REFERENCES

1. McCormick, C. W., The NASTRAN User's Manual NASA SP-222(01), June 1972.

2. "Pre Processing Programs for NASTRAN", Sperry Support Services, Huntsville, Alabama, November 1, 1974.

3. "CONTUR User's Manual", Sperry Support Services, Huntsville, Alabama, November 1974.

4. "UNIVAC 1100 Series Operating System Programmer Reference", UP-4144 Rev. 3, Sperry UNIVAC Computer Systems, 1974.

APPENDIX A

Subroutine Descriptions

ABSA

Purpose: Calculates absolute value of vector VK

External References: SQRT

Called by: TFORM

Calling Argument: (VK,AABS)

VK = Vector input

AABS = Absolute value of vector

ACROSB

Purpose: Calculates vector cross product AxB = C

External References: None

Called by: TFORM

Calling Argument: (A,B, Cross)

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AXIS

Purpose: Adds three dummy bar elements for use in drawing x,y,z references axes.

External Reference: None

Called by: COMBS

Calling Argument: (IPOINT,G1,X1,X2,X3,XMAX,YMAX)ZMAX,NOEL,NOGD,IDG,ELTYP,IDEL)

AXESLG

Purpose: Calculate the coordinate position of three grid points used to draw the reference axes.

External References: None

Called by: MAIN1

Calling Argument: (X1,X2,X3,XMAX,YMAX,ZMAX,XMIN,YMIN,ZMIN,NOGD)

AXIS1

Purpose: To change max/min values for axis prepositioning (interchanging axes or creating a left hand coordinate system).

External References: None

Called by: MAIN1

Calling Argument: (XAXIS,YAXIS,ZAXIS,YMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN)

AXIS2

Purpose: To change grid coordinates for axis prepositioning.

External References: None

Called by: MAIN1

Calling Argument: X1,X2,X3,I1,I2,J1,XAXIS,YAXIS,ZAXIS,NGRID)

CINGEN

Purpose: Read file 29 which contains thermal network data created by the CINGEN Program.

External References: None

Called by: MAIN1

Calling Argument: (NL,NS,ICONDS,NA,NB,XNA,YNA,ZNA,XNB,YNB,ZNB)

COMBS

Purpose: Counts grid points element and coordinate systems, transforms grid points to basic coordinate system, determines max and min x,y,z coordinates and renumbers grid ID's with internal ID's.

External References: AXES,TFORM,MAXIMIM

Calling Argument: (NOGD,LDS,X1,X2,X3,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX, NOFL,FLTYPE,IDEL,G1,IPOINT,CP,NTEST)

COUNT

Purpose: To count the number of elements, grid points and element connection points to determine the minimum core size required for the given data.

Called by: MAIN

Calling Argument: (NUMEL,NUMGRD,JSIZE,SIZE,$)

DECODE

Purpose: Decode NASTRAN free field variables

External References: None

Called by: READB

Calling Argument: (M,NUMB)

DSCRI

Purpose: Writes a table describing the Namelist parameter options on the CRT screen.

External References: None

Called by: MAIN1

Calling Argument: None

Dummy

Purpose: To load blank common after Editor is completed

Called by: MAIN,MAIN1

EDITOR

The Editor has been removed from Level 4.0.

GENERT (UNIVAC only)

Purpose: To generate intermediate points for CIS3D20 so that a smooth curve can be fitted through the input grid points.

External References: MATINV

Called by: PLOT1

Calling Argument: (B,INTERV,ISKIP,ISIDES)

LOAD

Purpose: To load values of thermal conductors to arrays for plotting.

External References: None

Called by: MAIN1

Calling Argument: (NGRID,I1,S1,NL,IN,ICONDS,NA,NB,XNA,YNA,ZNA,XNB,YNB,ZNB,GTEMP,X1,X2,X3)

MAIN

Purpose: To apportion common into ten segments for plotting, calculates maximum number of elements which may be plotted, identifies file usage, plot title page, and clears plot buffers prior to terminating execution.

External References: DUMMY,MAIN1,COUNT,SIZ,MCORE,LCORE

Comments: The main program was designed to open the core size to fit the problem being plotted.

MAIN1

Purpose: To set the default values for Namelist ($INPUT) and control the flow of the program.

External References: DSCRI,SPAR,RDB,TFOR,PVW,AXESLG,AXIS1,VW1,AXIS2,VW2,CINGEN,LOAD,XYSAVE,EDITOR,DUMMY,STRUDL

Called by: MAIN

Calling Argument: (IDG,X1,X2,X3,IDEL,ELTYP,G1,1POINT,JPV,YY)

Comments: The communication line transmission rate can be changed through Namelist $INPUT prior to the first plot. See BAUD = Rate/10. The default value is 120 = 1200 Baud. Once it has been changed it will remain changed for the current execution.

MATINV

Purpose: Invert matrix for subroutine GENERT.

External References: None

Called by: GENERT

Calling Argument: (A,N,NA)

MAXMIN

Purpose: To find largest and smallest numbers in an array of grid coordinates.

External References: None

Called by: COMBS

Calling Argument: (JJ,XX,MAX,MIN)

MPS

Purpose: Map symbolic for segmenting the program.

NUMBER

Purpose: To write a number at the grid point and/or element centroid.

External References: None

Called by: PLOTVG,PLOT3G,PLOT1

Calling Argument: (XN,X,Y)

OUTASC

Purpose: To switch from vector generation to hardware character generation after each plot.

External References: None

Called by: MAIN1

Calling Argument: None

PLOT

Purpose: To convert drum plotter calls to Tektronix plot calls.

External References: None

Called by: PLOTVG,PLOT3G,PLOT1,YSMBOL,VIEW1

Calling Argument: (X,Y,IP)

PLOTVG

Purpose: To draw a line between grid points and place a symbol and grid number at each grid point if requested. Used for 20 grid elements only.

External References: NUMBER,SYMBOL,PLOT

Called by: PLOT1

Calling Argument: (C,GNO,SYMB,NL,J1,AH,AH2,PIBI2,JPT,NO,INTERV,CHAR,ISKIP)

PLOT1

Purpose: To plot finite elements and conductors and write element, grid, conductor, capacitor numbers at grid point and element centroids and to draw a symbol at the grid point if requested.

External References: NUMBER,SYMBOL,PLOT,XYZLAB,PLOT3G,GENERT,PLOTVG

Called by: VIEW2

Calling Argument: (C,GNO,ENO,KL,K1,NGRID,NND,SYMB,JK,NOEL,IBR)

PLOT3G

Purpose: To draw a line between grid points, and place a symbol and grid number at each grid point if requested. Used for all elements except the 20 grid isoparametric element.

External References: NUMBER,SYMBOL,PLOT

Called by: PLOT1

Calling Argument: (C,GNO,SYMB,NL,J1,AH,AH2,PIBI2,JPT,NO,CHAR)

PVIEW

Purpose: To read Namelist $PVIEW and calculate data for the partial view.

External References: SEARCH

Called by: PVW

Calling Argument: (NOEL,IDEL,G1,NOGD,X1,X2,X3,IPOINT,XMIN,XMAX,YMIN, YMAX,ZMIN,ZMAX,YY,IDG,JPV,NJPV,LENGB,LP9)

PVW

Purpose: Dummy routine for calling PVIEW.

External Reference: PVIEW

Called by: MAIN1

RDB

Purpose: Dummy routine for calling READB

External References: READB

Called by: MAIN1

READB

Purpose: To read finite element data from file 4, decodes free field data, stores in arrays for plotting and calculates maximum and minimum coordinate values.

External References: DCODE

Called by: RDB

Calling Argument: (NOGD,IDG,X1,X2,X3,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,NOEL, ELTYP,IDEL,G1,IPOINT,NCHBDY,NTEST,CP,PROGRAM,LP9,LENGB)

SEARCH

Purpose: Not fully implemented at this time.

SPAR (UNIVAC only)

Purpose: To convert SPAR print file (9) to NASTRAN Bulk Data format (file 4).

External References: None

Called by: MAIN1

Calling Argument: None

SYMBOL

Purpose: To plot symbols at grid point for structural plots or at element centroid for thermal network plots.

External References: PLOT

Called by: PLOTVG,PLOT1,PLOT3G

Calling Argument: (X,Y,SYM)

TFOR

Purpose: Dummy routine for calling TFORM

External References: COMBS

Called by: MAIN1

TFORM

Purpose: To transform grid point coordinates from local coordinate systems to a basic rectangular coordinate system.

External References: ABSA,ACROSB

Called by: COMBS

Calling Argument: (NOGD,NCORD,X1,X2,X3,CTYPE,CP,CID,RID,A)

Comment: Only NASTRAN CORD2R, CORD2C and CORD2S coordinate definition cards are currently permitted.

VIEW1

Purpose: To calculate plot parameter, such as, center of plot and scaling factors.

External References: PLOT

Called by: VW1

Calling Argument: (ANGLD,ELEV,ROTX,XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,XMEAN, YMEAN,ZMEAN,ANGLE,T,ROTR,C1)

VIEW2

Purpose: To rotate and scale each set of grid coordinates for each element and call plot subroutine.

External References: PLOT1

Called by: VW2

Calling Argument: (C,NGRID,XMEAN,YMEAN,ZMEAN,ANGLE,T,ROTR,NL,J1,NTEST,ENO, GNO,SYMB,NND,C1,JK,NOEL,IBR)

VW1

Purpose: Dummy routine for calling VIEW1

External References: VIEW1

Called by: MAIN1

VW2

Purpose: Dummy routine for calling VIEW2.

External References: VIEW2

Called by: MAIN1

XYSAVE

Purpose: To write grid point number and X,Y location on CONTUR data file KC (KC = 10, default).

External References: None

Called by: MAIN1

Calling Argument: (KC,LAST,IDG,NGRID,G1,C)

XYZLAB

Purpose: To label the trial coordinate symbol with X,Y and Z labels.

External References: None

Called by: PLOT1

Calling Argument: (C1,C2,NO)

STRUDL (UNIVAC only)

Purpose: To read STRUDL finite element data from file 4, decodes data, stores in arrays for plotting and calculates max and min coordinate values.

External References: DCODE

Called by: MAIN1

Calling Argument: (B(LP1),B(LP2),B(LP3),B(LP4),B(LP5),B(LP7),B(LP8))