A COMPUTER PROGRAM FOR SOLVING TRANSIENT HEAT CONDUCTION PROBLEMS

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THESIS

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ABSTRACT

A computer program, with the code name TRUMP, was developed in 1965 by the Lawrence Livermore Laboratory to solve a variety of transient and steady-state conduction heat flow problems in simple or complicated geometric configurations. The purpose of this investigation was to adapt "TRUMP" to the Naval Postgraduate School IBM/360 Model 67 computer system. Several heat conduction problems are solved with the adapted version of TRUMP and the results compare closely with the analytical solutions to these problems. The example problem inputs may be used as guides in preparing input data for future problems. Some suggestions are also given for further development of the program.

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I. INTRODUCTION

A computer program with the code name TRUMP, was developed in 1965 by Edwards [Reference 1] of the Lawrence Livermore Laboratory (LLL) to solve a wide variety of non-linear, conduction heat transfer problems. TRUMP has been extensively used and continually improved since its initial development and has been successfully adapted to a number of computer systems including the CDC/6600 (LLL), IBM/7094 (Bell Labs), UNIVAC/1108 (Battelle Northwest, Gulf General Atomics, NBS), and the IBM/360 (B.F. Goodrich, NASA Lewis Research Center, Bendix Electro-dynamics, Cockerill-Ougee-Providence), to name a few. The objective of this thesis project was to adapt TRUMP to the Naval Postgraduate School (NPS) IBM/360 Model 67 computer system.

The B.F. Goodrich Corporation supplied a listing of a version of the TRUMP program that they had converted for use in their IBM/360 system. Cards were punched from this listing and a version of TRUMP was thus secured.

The B.F. Goodrich version was not complete. In addition to errors that resulted from punching 3,350 cards, the program also had an alignment error in one subroutine of the program. Also, several options that are available in the complete LLL version of TRUMP were missing in the B.F. Goodrich version.

With a great deal of assistance from the NPS Computer Facility staff, the majority of these problems have been corrected and a running version of TRUMP is now available at NPS.

No attempt is made in this thesis to give a complete description of the TRUMP program. Rather, limitations of the NPS IBM/360 version as

compared to the LLL CDC/6600 version are discussed. In addition, several example problems are solved and may be used as guides in preparing input data for future problems. For a complete description of the program, reference should be made to the TRUMP users manual [Reference 1].

II. DESCRIPTION OF THE PROGRAM

A. GENERAL

The program solves the general, non-linear, parabolic partial differential heat equation. Transient and steady-state heat conduction problems in multidimensions may be solved. Initial conditions, material properties, source and sink strength and boundary conditions may vary with time, spatial position and/or temperature.

In order to solve problems with TRUMP, the user specifies input data in "BLOCK" form to 12 input data blocks. A description of each of these blocks and their use will be given in Section B 2.

Following the definition of the problem a model must be constructed. Complex geometric shapes are divided into regions and if there is symmetry, the symmetry planes are represented by insulated surfaces in order to simplify the model. Regions may have different materials with specified properties.

The regions may be subdivided into volume elements or nodes having arbitrarily any size and shape. Nodes or volume elements must have a representative nodal point whose location may be anywhere in the node or on the surface of the node. However, in transient problems, for maximum accuracy, node shapes and nodal point locations are chosen so that the lines joining the nodal points of connected nodes are perpendicularly bisected by the connected area. In steady-state problems, due to the lack of heat capacity effects, the nodal points may be located anywhere in the node without loss of accuracy. A variety of boundary conditions may be given to the surface nodes. Constant temperature, variable temperature, constant heat flux, variable heat flux,

forced convection conditions, free convection conditions, radiation boundary conditions or combinations of the above may be treated.

Instead of having very fine zoning of the regions, rather crude zoning will give the solution with less effort. Later, the solution may be obtained for a finer subdivision of the system. Also, with the crude zoning one can easily understand which regions need finer zoning.

The accuracy of the given problem depends on how well the problem can be modeled, and the fineness of the spatial subdivisions and time steps used in the calculations.

Allowable problem size limits for the NPS IBM/360 version of TRUMP are summarized in Table 1.

TABLE I

Problem Size Limits

Item	Data Block	Parameter	Size
Materials	2	M_2	15
Reactants	3	M_3	5
Nodes	4	M_4	355
Internal thermal connections	5	M_5	950
External thermal connections	6	M_6	60
Boundary nodes	7	M_7	20
Heat generation tables	8	M_8	5
Initial conditions	9	M_4	355
Mass flow connections	10	M_{10}	50
Temp. versus time plot nodes	11	M_{11}	10
Temp. versus plot times	-	M_1	1
Remotely dependent properties	12	M_{12}	75
Table lengths	2, 3, 6, 7, 8, 10	M_9	12

In general, any consistent set of units may be used for the input data; output quantities are then given in the same unit system.

Each material, system node, and boundary node can be identified by a non-zero integer number fitting within 5-column fields on the data cards. These identifications can be in any sequence. In order to reduce the number of input cards arithmetic sequencing is suggested so that the nodes having identical descriptions can be submitted as input on only one card.

For non-symmetric, symmetric with respect to an axis, or to a center, the nodal volumes and the thermal connection areas can be calculated by a control value in the input data.

Initial conditions may be specified in BLOCK 1 of the input data. These values will be assigned to all nodes described in BLOCK 4, unless other values are specified for individual nodes in BLOCK 9.

Each internal thermal connection between nodes must be described in the input data by specifying the two node identification numbers, two connector lengths, and two interface dimensional factors. The selection of connector lengths depends on the location of the nodal point within each node. These locations may be arbitrary, but in transient problems should usually be at the geometric centers of the nodes. If the amount of the heat flow depends on surface temperatures, then they can be located on the surface.

A system that exchanges heat with its surrounding must have external temperatures specified along its boundary. In the input data, boundary node identification numbers and their temperatures, which may be constant or a function of time, must be given. The term "boundary node" is identical in meaning to an external temperature.

Surface temperatures can be specified by using boundary nodes with specified temperatures and connecting the surface nodes to a boundary node with a very large convection coefficient. In order to reach a high degree of accuracy, surface nodes should be selected as either zero-volume nodes, or very thin nodes. When a large number of surface nodes are connected to the same boundary node and the heat transfer coefficients are not tabulated, the number of external connections can be reduced by replacing them with connections to a single zero-volume node that is connected to the boundary node with a very large convection coefficient.

In order to generate steady-state solutions, TRUMP must first go through a set of transient calculations. The steady-state solution is obtained by allowing enough problem time to take the transient to its conclusion. However, if only steady-state results are desired, the control on the average temperature change during a time step (TVARY) can be made very large. This allows the program to neglect transient stability limitations on its choice of time steps resulting in a minimum expenditure of computer time on transient calculations.

B. USE OF COMPUTER

1. General

The data deck must include a problem name card, any number of block number cards with their input cards, and a data end card. The first card of each data deck must be a problem name card. The symbol "*" must be in column 1, any identification of the problem in columns 2 through 71 and 73 through 80.

In the program there are 12 allowed input data blocks, with block numbers from 1 through 12. Each block must begin with a block number card, and except for BLOCKS 1 and 11, must end with a blank card. The block number card must begin with the word "BLOCK" in columns 1 through 5, and the block number, from 01 through 12, in columns 6 and 7.

Data BLOCK 1 must follow the problem name card; all other data blocks may be placed in any order.

The last card of each data deck must be a data end card, with the word "ENDED" in columns 1 through 5, and "-1" in columns 6 and 7.

Additional cards containing comments without "*" in column 1 may precede the name card and will appear on the printout. Any desired block description in columns 9 through 80 may be made on the block number card. This will also appear on the printout.

2. Block Item Descriptions

Basically, one should refer to the TRUMP users manual [Reference 1] for format details and the original descriptions of the input values. In this section the main difference between the IBM/360, Model 67 version of TRUMP and the LLL, CDC/6600 version are discussed.

In BLOCK 1;

MCYC Maximum allowed number of time steps. If zero, negative, or unspecified will be 30,000.

MSEC Maximum allowed machine time, in seconds. If zero, negative, or unspecified will be 30,000.

NPUNCH Indicates that the final values of temperatures of nodes, weight fractions of reactants, and constant heat generation rates of nodes will be punched. Since punched

output is not obtained in this version of TRUMP, the value of NPUNCH should not be used.

IRITE Number of time steps between data output on unit ITAPE of problem time and table of node numbers and node temperatures, in addition to output of first, second, and last time steps. Only used in TRUMP/6600/DS version. This control is not in use in this version.

ITAPE Output unit on which output data will be written as described in IRITE. This input value is not in use for IBM/360 Model 67 version of TRUMP.

TIMEP Problem time interval between data output, in addition to output on first, second, and last time steps. This input control value is also not in use for this version of TRUMP.

In addition to the above differences, the data transfer option is not in use in this version of TRUMP.

3. Numerical Output

The amount of output data is controlled by the value of KDATA. However, for every problem, all input data and several other quantities such as node volumes and connection areas are written out. The results of the first, second, and last time steps are always written out. In addition, output data are written out at problem time step intervals of IPRINT. For the notations used on the printouts one should refer to TRUMP users manual [Reference 1].

4. Evaluation of Results

Any desired end to the problem may be made with the specified input values in BLOCK 1. These may be maximum problem time, TIMAX,

maximum temperature, TMAX, minimum temperature, TMIN, maximum number of time steps, MCYC, or maximum number of seconds of machine time, MSEC. On the printouts, the value of the problem-end sentinel, KWIT, will appear. Table II shows the values of KWIT, and the descriptions of these values.

TABLE II

Values of KWIT

KWIT	Cause of Problem Ending
1	The problem time, SUMTIM, reached TIMAX
2	A temperature exceeding TMAX
3	A temperature less than TMIN
4	Steady-state
5	Data
6	Relates to the tape usage
7	The number of time steps reached MCYC
8	Machine time reached MSEC
9	BLOCK 2 or BLOCK 4 missing
10	Convergence failure
11	Items exceeded the size limits
12	Table lengths exceeded the size

C. DESCRIPTIONS OF SUBROUTINES

THERM	Subroutine for material properties and node descriptions. BLOCKS 2, 4, and 12 are included.
TALLY	Subroutine for initialization, totaling, and checking results, converting regular to special nodes, testing for ending the problem. BLOCKS 1 and 9 are included.
CHEM	Subroutine for chemical reaction. BLOCK 3 is included.
SPECK	Subroutine for heat flow between special nodes and other nodes or boundary nodes. Iterates to solve set of implicit difference equations when special nodes connected to each other.
FINK	Subroutine for heat flow between nodes by conduction, convection, and radiation. Treats all nodes as regular nodes. BLOCK 5 is included.
GEN	Subroutine for internal heat generation. BLOCK 8 is included.
SURE	Subroutine for heat flow between surface nodes, boundary nodes by radiation, free and forced convection treats all surface nodes as regular nodes. BLOCKS 6 and 7 are included.
FLOW	Subroutine for mass flow between nodes. Treats all nodes as regular nodes. BLOCK 10 is included.
SEEK1	Subroutine for finding an identification number of a material, reactant, node or boundary node in a block item list.
SEEK2	Subroutine for finding the identification numbers of a pair of nodes in a block item list.

CLOCK,CLOCK1	Subroutines for initialization before first time step.
PLOT	Subroutine for making CRT plots and tables of temperature versus node location, temperature versus time, and node location versus time. BLOCK 11 is included.
PATCH	Subroutine for converting a number with a decimal point to floating number, otherwise substituting a specified floating point number.
REFER	Subroutine for finding array subscripts of materials, reactants, nodes or boundary nodes referred to by identification number in another data block, and writing out diagnostic statements whenever one can not be found.
SRCON	Subroutine which is related to PATCH. Converts a number having decimal point to a floating point number.

III. EXAMPLE PROBLEMS

A. SLAB-MELT PROBLEM

A semi-infinite slab $(-\infty < x < \infty, -\infty < y < \infty, 0 \leq z < \infty)$, has thermal conductivity 1.0 cal/sec-$^{\circ}$C, density 1.0 g/cm^3, heat capacity 1.0 cal/sec-$^{\circ}$C, a melting point of 50.0°C, and a latent heat of fusion of 25.0 cal/g. The initial temperature is 100.0°C, and for times $t > 0$, the surface, $z = 0$, is maintained at 0.0°C. TRUMP is used to calculate the temperature distribution in the slab, and the motion of the solid-liquid interface, Z_{int}, for times up to 200 sec. The results are compared with the exact solution.

1. Analytic Solution

From Reference 3 analytic results are:

$$T_1 = 112.4 \, \mathrm{erf}\left(\frac{Z}{2\sqrt{t}}\right) \quad \text{for} \quad 0 \leq T < 50^{\circ}C$$

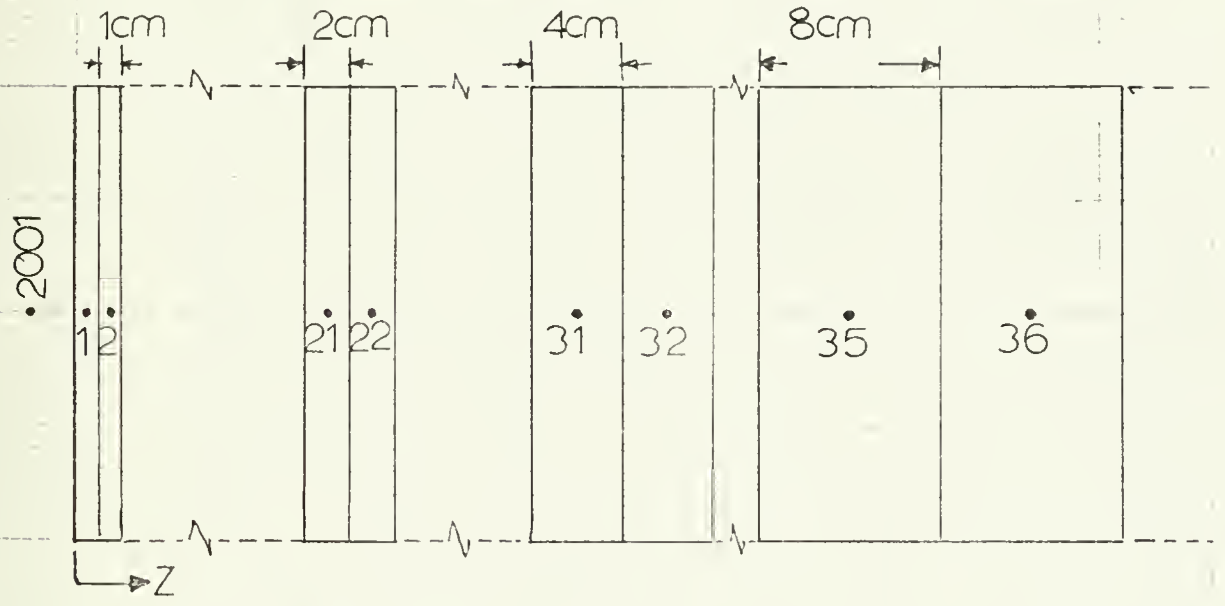
$$T_2 = 9.9 + 90.1 \, \mathrm{erf}\left(\frac{Z}{2\sqrt{t}}\right) \quad \text{for} \quad 50 \leq T \leq 100^{\circ}C$$

$$Z_{int} = 0.835 \cdot \sqrt{t} \quad \text{for } T = 50^{\circ}C$$

2. Trump Solution

The input data for this problem are shown in Figure 1. In order to have output at every 10 cycles, in addition to output on the first, second, and last time steps, IPRINT is selected as 10 in BLOCK 1. For temperature accuracy, TVARY is 1.0°C and the problem is ended at 200 sec by setting TIMAX equal to 200.0. TONE is 100.0 since the initial temperature of the slab is 100.0°C. However, since the zero-volume surface node, node -1, is at 0.0°C for $t > 0$ its temperature is specified in BLOCK 9 by setting the value of TT equal to 0.0. In BLOCK 2, the

material name, AMAT, and material identification number are arbitrarily selected at SMELT and 50, respectively. Other slab thermal properties such as density, heat capacity, thermal conductivity, temperature at which the latent heat is released and the latent heat of fusion are also specified in BLOCK 2. In order to give node descriptions in BLOCK 4 the slab is divided into nodes as shown below.



A total field depth of 100.0 cm is chosen so that at 200 sec no appreciable temperature change will take place at the maximum value of Z. In this figure, the node identification numbers, and the node thicknesses are shown. The nodal points of all nodes are at the node centers. In BLOCK 5, internal connection node numbers, lengths of heat conduction paths from the nodal points to the connected interfaces, and the area of the connected interfaces are defined. In BLOCK 6, a zero-volume surface node, node -1, is connected to a boundary node, node 2001, with a heat transfer coefficient of 1.0×10^8 cal/sec-cm^2-^{o}C,

and the external surface area of the surface node is selected as unity. In BLOCK 7, a constant boundary node temperature is defined as 0.0°C. Computer running time for this problem was 65.52 sec.

```
*      SLAB  MELT  PROBLEM.  SEPT.  1971
NOTE.    H(M) = 25 CAL/G, T(M) = 50.0, TIME 0-200 SEC.
NOTE.    THIS PROBLEM DOES NOT USE GEN, CHEM, OR FLOW SUBROUTINES.
BLOCK 1
   10
                                   1.0              200.0
 100.0
BLOCK 2  MATERIAL NAMES, NUMBERS, CHEMICAL COMPONENTS, AND THERMAL PROPERTIES.
SMELT   50                         1.0       1.0       1.0       50.0      25.0

BLOCK 4   NODE NUMBERS, MATERIALS, TYPES, AND DIMENSIONS.
   -1               50
    1   19     1    50             1.0       1.0       1.0
   21    9     1    50             2.0       1.0       1.0
   31    4     1    50             4.0       1.0       1.0
   36    4     1    50             8.0       1.0       1.0

BLOCK 5  INTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1    1                         0.5       1.0       1.0
    1    2  18   1   1   0.5       0.5       1.0       1.0
   20   21               0.5       1.0       1.0       1.0
   21   22   8   1   1   1.0       1.0       1.0       1.0
   30   31               1.0       2.0       1.0       1.0
   31   32   3   1   1   2.0       2.0       1.0       1.0
   35   36               2.0       4.0       1.0       1.0
   36   37   3   1   1   4.0       4.0       1.0       1.0

BLOCK 6  EXTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1 2001                         1.0       1.0       1.0    E8

BLOCK 7  BOUNDARY NODE TEMPERATURES.
 2001                    0.0

BLOCK 9   INITIAL CONDITIONS.
   -1          1         0.0

ENDED-1  LAST CARD OF DATA DECK.  MORE DATA DECKS MAY FOLLOW.
```

FIG. 1 INPUT DATA FOR SLAB MELT

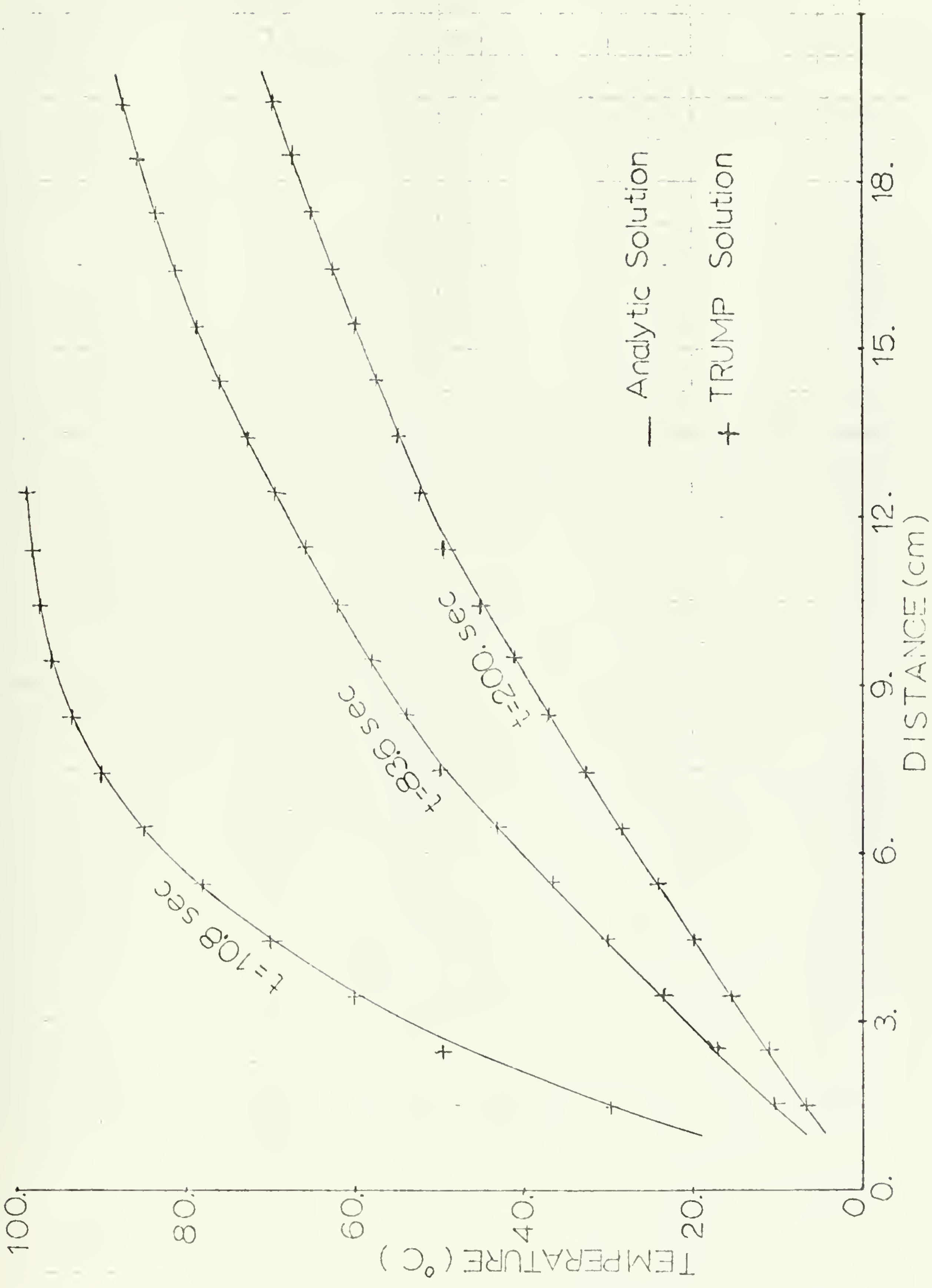


FIG. 2 TEMPERATURE DISTRIBUTION IN THE SLAB-MELT PROBLEM

TABLE III

SOLID-LIQUID INTERFACE IN THE SLAB MELT

Time (sec)	Z_{int} (Analytic)	Z_{int} (Trump)
3.56	1.57	1.37
4.19	1.71	1.77
4.77	1.82	2.00
5.92	2.03	2.00
8.13	2.38	2.04
9.67	2.60	2.46
10.81	2.74	2.86
12.08	2.90	3.00
15.90	3.33	3.02
18.43	3.58	3.44
20.13	3.75	3.84
22.21	3.94	4.00
28.24	4.44	4.16
30.91	4.64	4.56
33.10	4.80	4.97
38.20	5.16	5.00
44.21	5.55	5.37
47.20	5.74	5.77
50.42	5.93	6.00
60.16	6.48	6.23
64.03	6.68	6.63
67.34	6.85	7.00
78.78	7.41	7.13
83.62	7.64	7.54
87.67	7.82	7.94
106.12	8.60	8.46
110.92	8.79	8.87
120.92	9.18	9.00
131.54	9.58	9.42
137.10	9.78	9.82
146.27	10.10	10.00
160.05	10.56	10.39
166.34	10.77	10.79
175.46	11.06	11.00
191.54	11.56	11.37
198.54	11.77	11.77
200.00	11.81	11.86

TRUMP OUTPUT DATA DATA DECK 1

* SLAB MELT. SAMPLE PROBLEM FOR TRUMP REPORT.

PRINTOUT	CYCLE	TOO FAST	TOO SLOW	KWIT	DELTMX	SMALL	TVARY	NUTS
52	493	0	0	1	4.57143E 00	1.60000E-02	1.00000E 00	1

TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
2.00000E 02	1.59607E-01	-1.78806E 03	-1.78806E 01	-8.94029E 00	-8.94029E-02

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
8.50838E 01	1.00000D 02	1.07118E 04	0.0	0.0	0.0

NODE	TEMP	DT	DDT	GEN RATE	W	H	F	CURE AT 280 F
-1	0.4457D-07	-0.1321D-10	-0.2939D-10	0.0	0.4457E-31	-0.2500E-22	0.3657E-02	0.2492E 00
1	0.2229D 01	-0.6736D-03	-0.1498D-02	0.0	0.2229E 01	-0.1228E 03	-0.1228E 03	0.3077E 00
2	0.6682D 01	-0.1968D-02	-0.4379D-02	0.0	0.6682E 01	-0.1183E 03	-0.1183E 03	0.4724E 00
3	0.1112D 02	-0.3106D-02	-0.6909D-02	0.0	0.1112E 02	-0.1139E 03	-0.1139E 03	0.6936E 00
4	0.1554D 02	-0.3996D-02	-0.8890D-02	0.0	0.1554E 02	-0.1095E 03	-0.1094E 03	0.9619E 00
5	0.1994D 02	-0.4570D-02	-0.1017D-01	0.0	0.1994E 02	-0.1051E 03	-0.1050E 03	0.1270E 01
6	0.2431D 02	-0.4786D-02	-0.1065D-01	0.0	0.2431E 02	-0.1007E 03	-0.1007E 03	0.1610E 01
7	0.2865D 02	-0.4635D-02	-0.1031D-01	0.0	0.2865E 02	-0.9635E 02	-0.9634E 02	0.1977E 01
8	0.3296D 02	-0.4143D-02	-0.9216D-02	0.0	0.3296E 02	-0.9204E 02	-0.9203E 02	0.2365E 01
9	0.3724D 02	-0.3347D-02	-0.7445D-02	0.0	0.3724E 02	-0.8776E 02	-0.8775E 02	0.2769E 01
10	0.4150D 02	-0.2281D-02	-0.5074D-02	0.0	0.4150E 02	-0.8349E 02	-0.8349E 02	0.3183E 01
11	0.4575D 02	-0.6179D-03	-0.1375D-02	0.0	0.4575E 02	-0.7924E 02	-0.7924E 02	0.3602E 01
12	0.5000D 02	0.5829D-14	0.1297D-37	0.0	0.5339E 02	-0.7161E 02	-0.7161E 02	0.4022E 01
13	0.5267D 02	-0.1947D-02	-0.4332D-02	0.0	0.7767E 02	-0.4732E 02	-0.4732E 02	0.4437E 01
14	0.5534D 02	-0.4957D-02	-0.1103D-01	0.0	0.8034E 02	-0.4466E 02	-0.4466E 02	0.4853E 01
15	0.5797D 02	-0.7405D-02	-0.1647D-01	0.0	0.8297E 02	-0.4203E 02	-0.4202E 02	0.5266E 01
16	0.6056D 02	-0.9629D-02	-0.2142D-01	0.0	0.8556E 02	-0.3944E 02	-0.3944E 02	0.5675E 01
17	0.6308D 02	-0.1160D-01	-0.2581D-01	0.0	0.8808E 02	-0.3692E 02	-0.3691E 02	0.6075E 01
18	0.6554D 02	-0.1329D-01	-0.2957D-01	0.0	0.9054E 02	-0.3446E 02	-0.3446E 02	0.6466E 01
19	0.6791D 02	-0.1466D-01	-0.3260D-01	0.0	0.9291E 02	-0.3209E 02	-0.3209E 02	0.6846E 01
20	0.7019D 02	-0.1569D-01	-0.3490D-01	0.0	0.9519E 02	-0.2981E 02	-0.2981E 02	0.7213E 01
21	0.7346D 02	-0.1676D-01	-0.3729D-01	0.0	0.1969E 03	-0.5308E 02	-0.5308E 02	0.7750E 01
22	0.7740D 02	-0.1708D-01	-0.3800D-01	0.0	0.2048E 03	-0.4520E 02	-0.4520E 02	0.8392E 01
23	0.8091D 02	-0.1665D-01	-0.3704D-01	0.0	0.2118E 03	-0.3817E 02	-0.3817E 02	0.8965E 01
24	0.8401D 02	-0.1578D-01	-0.3511D-01	0.0	0.2180E 03	-0.3198E 02	-0.3198E 02	0.9468E 01
25	0.8671D 02	-0.1468D-01	-0.3266D-01	0.0	0.2234E 03	-0.2657E 02	-0.2657E 02	0.9900E 01
26	0.8905D 02	-0.1346D-01	-0.2994D-01	0.0	0.2281E 03	-0.2191E 02	-0.2191E 02	0.1027E 02
27	0.9104D 02	-0.1218D-01	-0.2711D-01	0.0	0.2321E 03	-0.1791E 02	-0.1791E 02	0.1057E 02
28	0.9273D 02	-0.1089D-01	-0.2422D-01	0.0	0.2355E 03	-0.1453E 02	-0.1453E 02	0.1082E 02
29	0.9415D 02	-0.9604D-02	-0.2136D-01	0.0	0.2383E 03	-0.1169E 02	-0.1169E 02	0.1103E 02
30	0.9533D 02	-0.8361D-02	-0.1860D-01	0.0	0.2407E 03	-0.9340E 01	-0.9340E 01	0.1119E 02
31	0.9678D 02	-0.6558D-02	-0.1459D-01	0.0	0.4871E 03	-0.1287E 02	-0.1287E 02	0.1138E 02
32	0.9806D 02	-0.4678D-02	-0.1041D-01	0.0	0.4922E 03	-0.7755E 01	-0.7755E 01	0.1153E 02
33	0.9887D 02	-0.3176D-02	-0.7065D-02	0.0	0.4955E 03	-0.4515E 01	-0.4515E 01	0.1162E 02
34	0.9936D 02	-0.2063D-02	-0.4590D-02	0.0	0.4974E 03	-0.2550E 01	-0.2550E 01	0.1167E 02
35	0.9965D 02	-0.1292D-02	-0.2874D-02	0.0	0.4986E 03	-0.1414E 01	-0.1414E 01	0.1169E 02
36	0.9988D 02	-0.5411D-03	-0.1204D-02	0.0	0.9990E 03	-0.9774E 00	-0.9774E 00	0.1171E 02
37	0.9997D 02	-0.1663D-03	-0.3700D-03	0.0	0.9997E 03	-0.2500E 00	-0.2500E 00	0.1172E 02
38	0.9999D 02	-0.4538D-04	-0.1009D-03	0.0	0.9999E 03	-0.5805E-01	-0.5805E-01	0.1172E 02
39	0.1000D 03	-0.1119D-04	-0.2490D-04	0.0	0.1000E 04	-0.1238E-01	-0.1238E-01	0.1172E 02
40	0.1000D 03	-0.2957D-05	-0.6578D-05	0.0	0.1000E 04	-0.2833E-02	-0.2833E-02	0.1172E [illegible]

B. FINITE-SLAB PROBLEM (suggested by Professor Paul Pucci)

A large, 1.0 inch thick steel plate, initially at 80.0°F, is suddenly submerged in a fluid at temperature 680.0°F. TRUMP is used to calculate the transient temperature distribution in the plate assuming a constant surface heat transfer coefficient of 1248.0 BTU/hr-ft^2-°F. The thermophysical properties of the steel were taken as: thermal conductivity 26.0 BTU/hr-ft-°F, density 487.0 lbm/ft^3, and specific heat 0.133 BTU/lbm-°F.

1. Analytic Solution

$$\frac{T - T_\infty}{T_i - T_\infty} = 2\sum_{n=1}^{\infty} \frac{\sin\lambda_n L}{\lambda_n L + \sin\lambda_n L \cos\lambda_n L} e^{-(\lambda_n L)^2 Fo} \cos(\lambda_n L \frac{x}{L})$$

Applying the Biot number, $Bi = \frac{hL}{k} = 2.0$ to the eigen value problem of $\cot(\lambda_n L) = \frac{\lambda_n L}{Bi}$, the two eigen values $\lambda_1 L = 1.0769$ and $\lambda_2 L = 3.6436$ can be found. After substituting the appropriate value of the Fourier number, $Fo = \frac{\alpha t}{L^2} = 230.4t$ in the above series solution and considering only the first two terms, the result becomes:

$$T(x,t) = 680 - 1200\left[0.58923153\, e^{-267.2t} \cos(1.0769\frac{x}{L}) - 0.11836085 e^{-3058.75t} \cos(3.6436\frac{x}{L})\right]$$

2. Trump Solution

The input data for this problem are shown in Figure 3. For unit consistency, lengths in inches are converted to feet and applied to the problem. Since the plate has symmetry with respect to the mid-plane, this plane is taken as an insulated plane in the TRUMP solution. So, in BLOCK 1 symmetry type indicator, KD, is applied as 1 for the non-symmetric case, and the total thickness of the steel plate is considered as 0.5 inches. Temperature scale indicator, KT, is selected as 3 because of the Fahrenheit scale. For temperature accuracy, the desired

maximum temperature change in each time step, TVARY, is selected as 1.0°F. Maximum problem time, TIMAX, is given as 1.0 hr. TONE is set equal to 80.0 making the initial temperature of all nodes equal to 80.0°F. In BLOCK 2, material name and material number are given as, FSLAB and 50, respectively. Also, the steel properties such as density, specific heat, thermal conductivity are defined. In BLOCK 4 node numbers, materials of nodes and their dimensions are given with respect to the equally spaced 10 nodes for the 0.5 inches of thickness of the slab. In BLOCK 6, the zero-volume surface node, node -1, is connected to a boundary node, node 2001, with a surface heat transfer coefficient of 1248.0 BTU/hr-ft^2-°F. In BLOCK 7, a boundary node temperature of 680.0°F is given. The computer running time for this problem was 24.46 sec.

In order to see the effect of finer zoning on the results, the same problem was also solved using 20 and 40 nodes. However, the results were all within 1°F accuracy and not much improvement was obtained with the finer grid sizes. Computer running time, on the other hand, was increased from 24.46 sec. to 53.76 sec. and to 172.64 sec. for 10, 20, and 40 nodes, respectively.

```
* TEMPERATURE DISTRIBUTION IN A FINITE SLAB. 10/5/1971.
BLOCK 1   PROBLEM  CONTOLS.
  10
   1   3                               1.                  1.
     80.
BLOCK 2  MATERIAL NAMES, NUMBERS, CHEMICAL COMPONENTS, AND THERMAL PROPERTIES.
FSLAB   50                            487.       .133      26.

BLOCK 4   NODE NUMBERS, MATERIALS, TYPES, AND DIMENSIONS.
  -1              50
   1    0    1    50           .004166667        1.        1.

BLOCK 5  INTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
  -1    1                      .002083333        1.        1.
   1    2   8   1   1 .002083333.002083333        1.        1.

BLOCK 6  EXTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
  -1 2001                              1.        1.1.248   E3

BLOCK 7  BOUNDARY NODE TEMPERATURES.
 2001                      680.

ENDED-1  LAST CARD OF DATA DECK.  MORE DATA DECKS MAY FOLLOW.
```

FIG. 3 INPUT DATA FOR FINITE SLAB

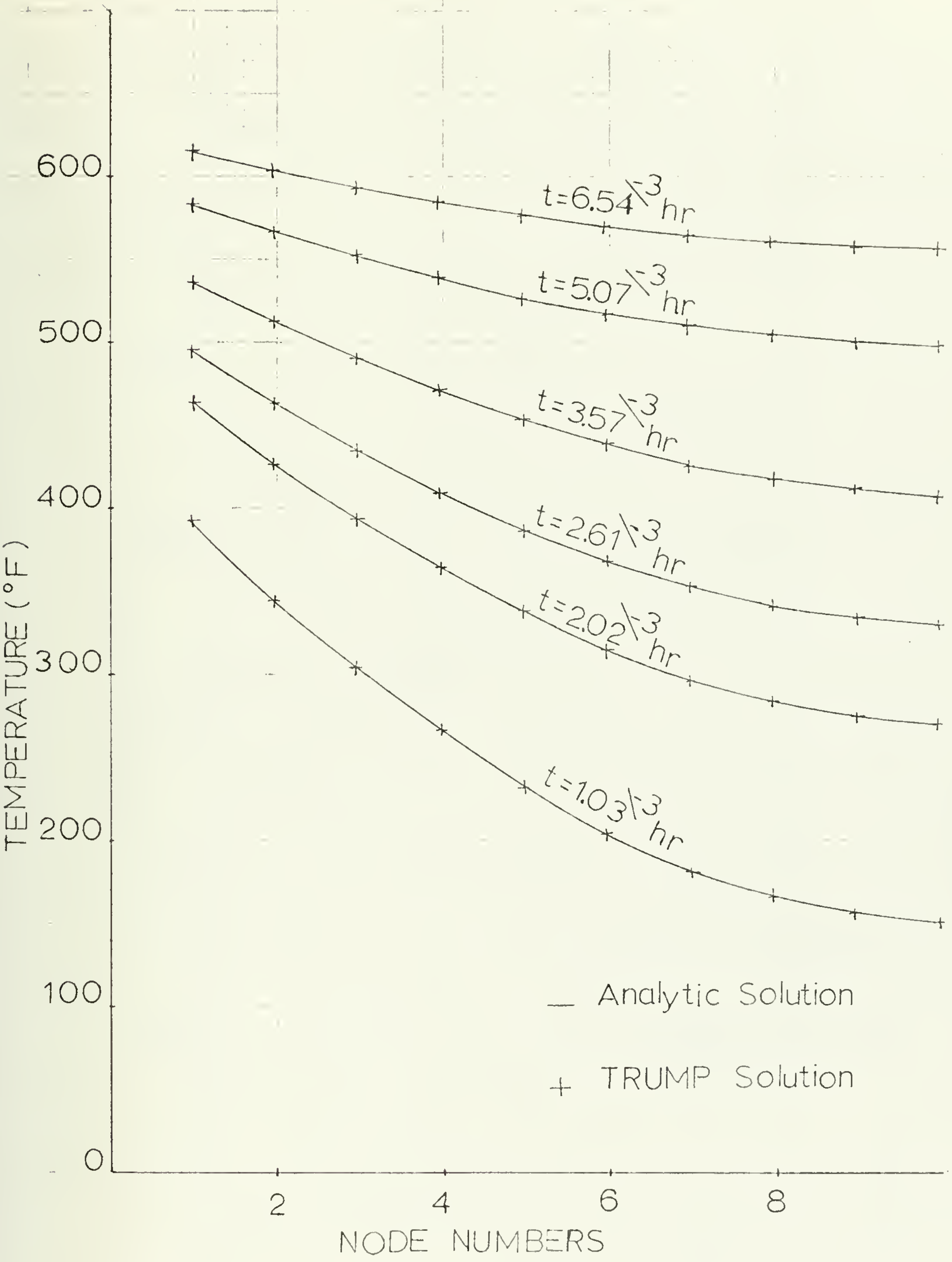


FIG. 4 TEMPERATURE DISTRIBUTION IN THE FINITE SLAB PROBLEM

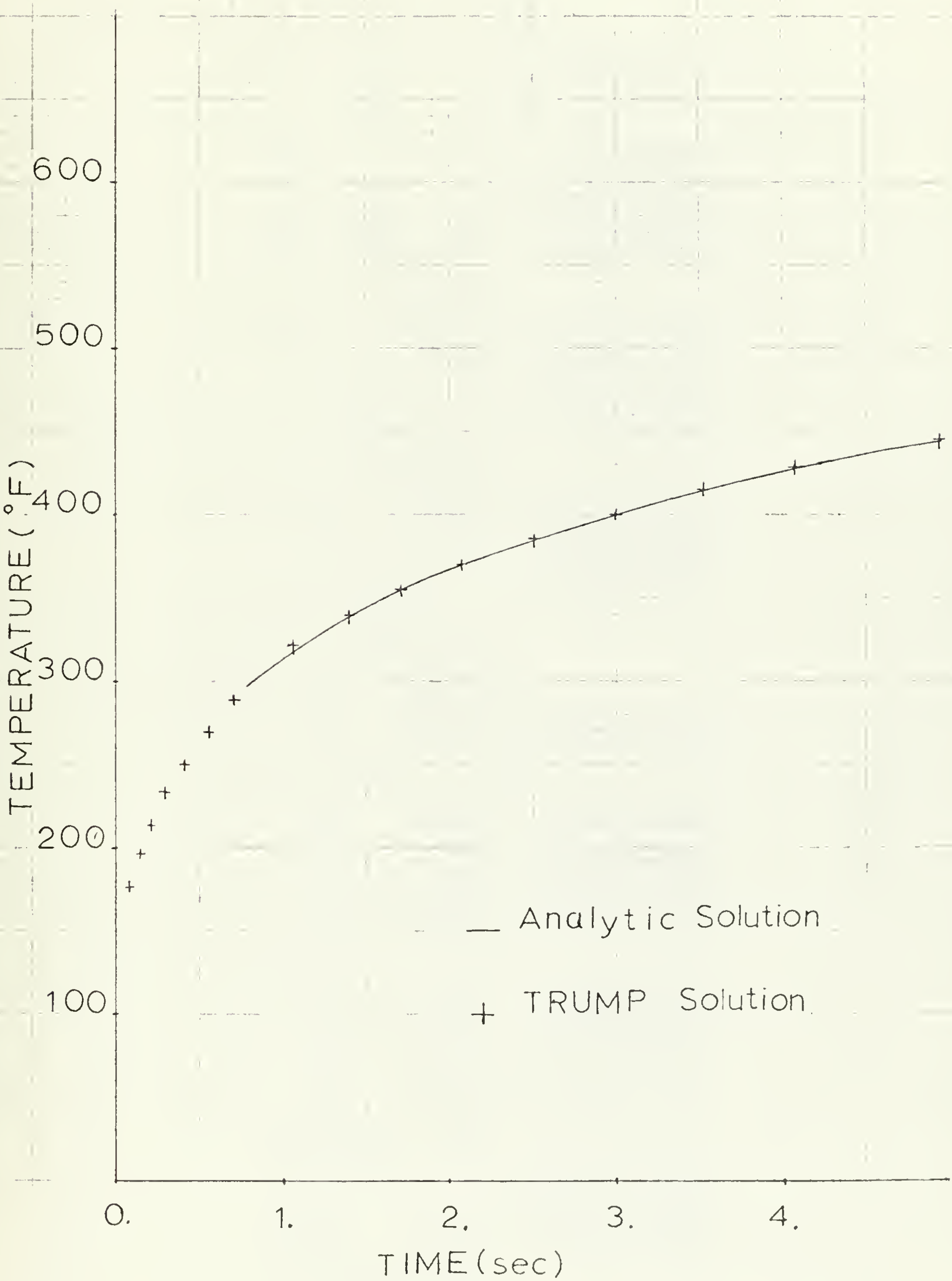


FIG. 5 SURFACE TEMPERATURE HISTORY OF FINITE SLAB PROBLEM

TRUMP OUTPUT DATA DATA DECK 1

* TEMPERATURE DISTRIBUTION IN A FINITE SLAB. 10/5/1971.

PRINTOUT	CYCLE	TOO FAST	TOO SLOW	KWIT	DELTMX	SMALL	TVARY	NUTS
91	889	0	0	1	1.00000E 12	1.44166E-07	1.00000E 00	0

TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
1.00000E 00	2.04880E-01	1.61419E 03	5.98117E 02	1.61419E 03	5.98117E 02

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
6.80007E 02	2.69879D 00	1.83519E 03	0.0	0.0	0.0

NODE	TEMP	DT	DDT	GE N RATE	W	H	F	CURE AT 280 F
-1	0.6800D 03	-0.4474D-04	-0.2183D-03	0.0	0.4404E-19	0.3886E-19	-0.3576E 00	0.0
1	0.6800D 03	-0.4885D-04	-0.2384D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
2	0.6800D 03	-0.5448D-04	-0.2659D-03	0.0	0.1835E 03	0.1619E 03	0.1615E 03	0.0
3	0.6800D 03	-0.5971D-04	-0.2914D-03	0.0	0.1835E 03	0.1619E 03	0.1615E 03	0.0
4	0.6800D 03	-0.6405D-04	-0.3126D-03	0.0	0.1835E 03	0.1619E 03	0.1615E 03	0.0
5	0.6800D 03	-0.6782D-04	-0.3310D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
6	0.6800D 03	-0.7105D-04	-0.3468D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
7	0.6800D 03	-0.7262D-04	-0.3545D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
8	0.6800D 03	-0.7430D-04	-0.3626D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
9	0.6800D 03	-0.7396D-04	-0.3605D-03	0.0	0.1835E 03	0.1619E 03	0.1614E 03	0.0
10	0.6800D 03	-0.7484D-04	-0.3653D-03	0.0	0.1835E 03	0.1619E 03	0.1617E 03	0.0

C. SEMI-INFINITE SLAB PROBLEM

A semi-infinite slab is initially at a uniform temperature of 100.0°C. At time t = 0, the surface temperature is suddenly lowered and maintained at a temperature of 0.0°C. The slab has a thermal conductivity of 1.0 cal/sec cm-°C, density of 1.0 g/cm^3, and a heat capacity of 1.0 cal/sec-°C. The temperature distibution in the slab, and the total heat flow from the slab are calculated as a function of time for times up to 200 sec using TRUMP, and the results are compared with the analytical solutions.

1. Analytical Solution

$$T(x,t) = 100 \text{ erf} \left(\frac{x^2}{4t} \right)^{1/2}$$

$$Q_{tot} = -112.84 \sqrt{t}$$

2. Trump Solution

The input data form is shown in Figure 6. In BLOCK 1, problem controls such as problem time, TIMAX = 200.00 sec, maximum temperature change in each time step, TVARY = 1.0°C, and the initial temperature of all nodes, TONE = 100.0°C are given. In BLOCKS 2, 4, 5, 6, 7 and 9, the thermal properties, zoning procedure, identification numbers, internal and external connection descriptions, boundary node temperatures, and initial conditions are defined identically as in the slab-melt problem. Computer running time for this problem was 27.05 sec.

```
* TRANSIENT HEAT FLOW IN SEMI-INFINITE SOLID. 10/5/1971.
NOTE.    TIME 0-200 SEC.
BLOCK 1   PROBLEM  CONTROLS.
   10
                                  1.0                200.0
 100.0
BLOCK 2  MATERIAL NAMES, NUMBERS, CHEMICAL COMPONENTS, AND THERMAL PROPERTIES.
SLAB    50                        1.0        1.0        1.0

BLOCK 4   NODE NUMBERS, MATERIALS, TYPES, AND DIMENSIONS.
   -1                50
    1   19    1      50           1.0        1.0        1.0
   21    9    1      50           2.0        1.0        1.0
   31    4    1      50           4.0        1.0        1.0
   36    4    1      50           8.0        1.0        1.0

BLOCK 5  INTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1    1                        0.5        1.0        1.0
    1    2 18   1   1   0.5       0.5        1.0        1.0
   20   21              0.5       1.0        1.0        1.0
   21   22  8   1   1   1.0       1.0        1.0        1.0
   30   31              1.0       2.0        1.0        1.0
   31   32  3   1   1   2.0       2.0        1.0        1.0
   35   36              2.0       4.0        1.0        1.0
   36   37  3   1   1   4.0       4.0        1.0        1.0

BLOCK 6  EXTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1 2001                        1.0        1.0        1.0    E8

BLOCK 7  BOUNDARY NODE TEMPERATURES.
 2001                   0.0

BLOCK 9   INITIAL CONDITIONS.
   -1          1        0.0

ENDED-1  LAST CARD OF DATA DECK.  MORE DATA DECKS MAY FOLLOW.
```

FIG. 6 INPUT DATA FOR SEMI-INFINITE SLAB

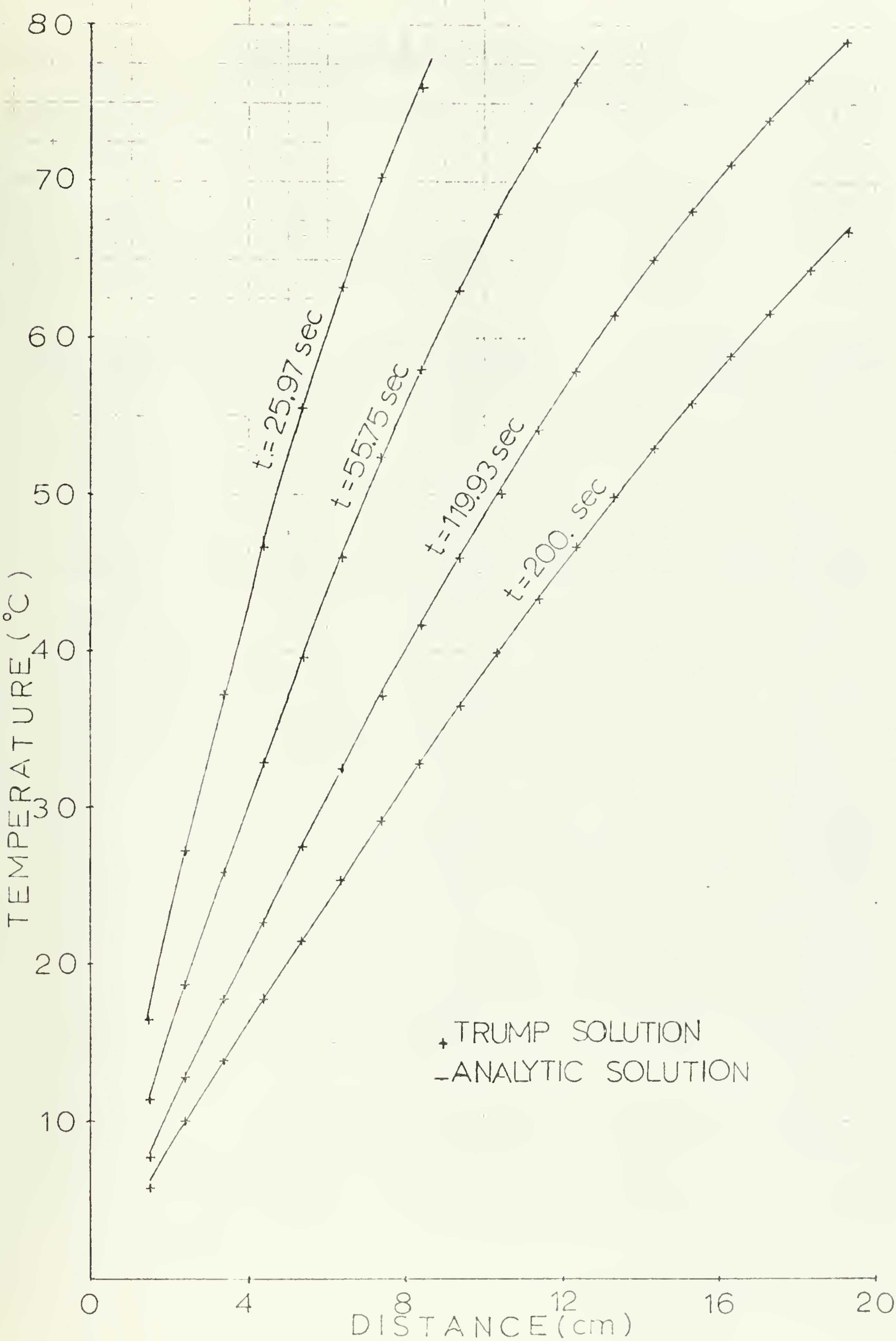


FIG. 7 TEMPERATURE DISTRIBUTION IN THE SEMI-INFINITE SLAB PROBLEM

TABLE IV

HEAT FLOW FROM SEMI-INFINITE SLAB

Time (sec)	Q_{tot} (Trump)	Q_{tot} (Analytic)
1.26	-119.42	-126.56
1.81	-146.12	-151.86
2.65	-178.93	-183.56
3.85	-217.69	-221.43
5.63	-264.69	-267.69
8.21	-320.90	-323.39
12.06	-389.63	-391.79
17.70	-472.82	-474.75
25.97	-573.36	-575.00
38.02	-694.20	-695.73
55.75	-841.12	-842.50
81.76	-1019.00	-1020.29
119.93	-1234.40	-1235.71
175.44	-1493.20	-1494.59
200.00	-1594.30	-1595.77

TRUMP OUTPUT DATA   DATA DECK 1

* TRANSIENT HEAT FLOW IN SEMI-INFINITE SOLID. 10/5/1971.

PRINTOUT	CYCLE	TOO FAST	TOO SLOW	KWIT	DELTMX	SMALL	TVARY	NUTS
24	214	0	0	1	1.82857E 01	1.60000E-02	1.00000E 00	13

TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
2.00000E 02	3.34782E 00	-1.59431E 03	-1.59431E 01	-7.97156E 00	-7.97155E-02

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
8.40531E 01	1.00000D 02	8.40531E 03	0.0	0.0	0.0

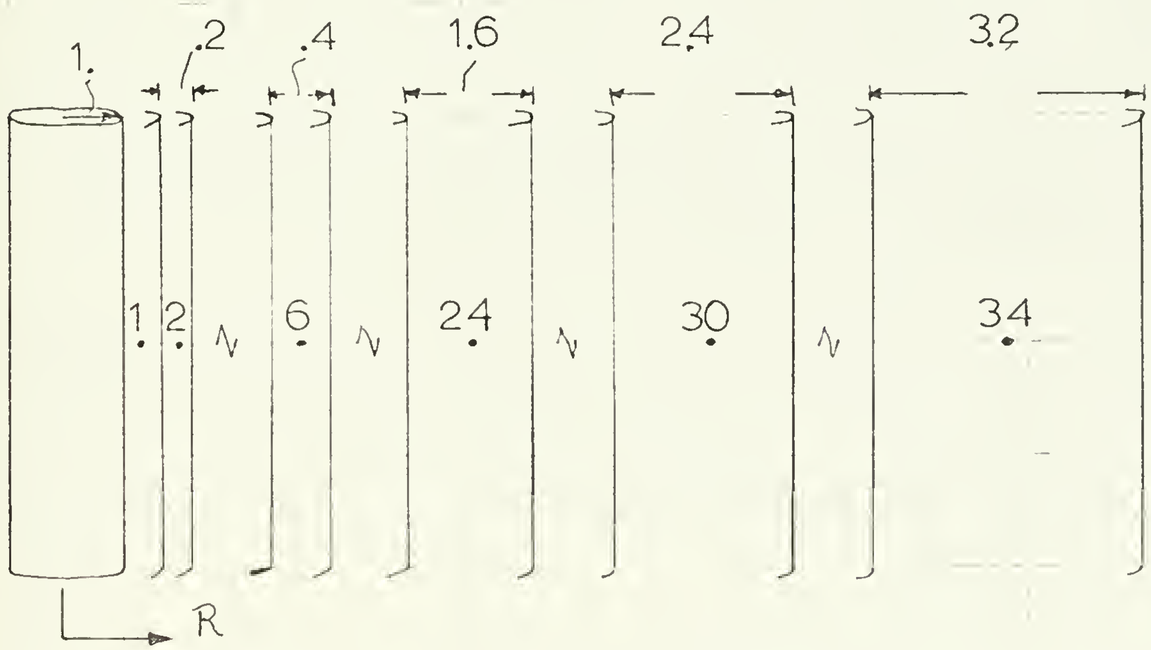
NODE	TEMP	DT	DDT	GEN RATE	W	H	F	CURE AT 280 F
-1	0.3991D-07	-0.3393D-09	-0.4062D-10	0.0	0.3991E-31	0.3989E-31	0.4355E-02	0.2492E 00
1	0.1996D 01	-0.1697D-01	-0.2031D-02	0.0	0.1996E 01	-0.9800E 02	-0.9800E 02	0.3003E 00
2	0.5982D 01	-0.5078D-01	-0.6078D-02	0.0	0.5982E 01	-0.9402E 02	-0.9401E 02	0.4428E 00
3	0.9954D 01	-0.8421D-01	-0.1008D-01	0.0	0.9954E 01	-0.9005E 02	-0.9003E 02	0.6339E 00
4	0.1390D 02	-0.1170D 00	-0.1400D-01	0.0	0.1390E 02	-0.8610E 02	-0.8608E 02	0.8664E 00
5	0.1781D 02	-0.1489D 00	-0.1782D-01	0.0	0.1781E 02	-0.8219E 02	-0.8216E 02	0.1135E 01
6	0.2168D 02	-0.1797D 00	-0.2151D-01	0.0	0.2168E 02	-0.7832E 02	-0.7829E 02	0.1434E 01
7	0.2550D 02	-0.2092D 00	-0.2504D-01	0.0	0.2550E 02	-0.7450E 02	-0.7448E 02	0.1760E 01
8	0.2925D 02	-0.2371D 00	-0.2838D-01	0.0	0.2925E 02	-0.7075E 02	-0.7072E 02	0.2109E 01
9	0.3293D 02	-0.2633D 00	-0.3152D-01	0.0	0.3293E 02	-0.6707E 02	-0.6704E 02	0.2476E 01
10	0.3654D 02	-0.2877D 00	-0.3444D-01	0.0	0.3654E 02	-0.6346E 02	-0.6343E 02	0.2858E 01
11	0.4006D 02	-0.3100D 00	-0.3711D-01	0.0	0.4006E 02	-0.5994E 02	-0.5991E 02	0.3253E 01
12	0.4349D 02	-0.3302D 00	-0.3953D-01	0.0	0.4349E 02	-0.5651E 02	-0.5648E 02	0.3656E 01
13	0.4682D 02	-0.3482D 00	-0.4168D-01	0.0	0.4682E 02	-0.5318E 02	-0.5315E 02	0.4065E 01
14	0.5005D 02	-0.3638D 00	-0.4355D-01	0.0	0.5005E 02	-0.4995E 02	-0.4993E 02	0.4477E 01
15	0.5317D 02	-0.3772D 00	-0.4515D-01	0.0	0.5317E 02	-0.4683E 02	-0.4681E 02	0.4889E 01
16	0.5619D 02	-0.3882D 00	-0.4646D-01	0.0	0.5619E 02	-0.4381E 02	-0.4380E 02	0.5298E 01
17	0.5908D 02	-0.3968D 00	-0.4750D-01	0.0	0.5908E 02	-0.4092E 02	-0.4091E 02	0.5703E 01
18	0.6186D 02	-0.4031D 00	-0.4825D-01	0.0	0.6186E 02	-0.3814E 02	-0.3813E 02	0.6100E 01
19	0.6452D 02	-0.4071D 00	-0.4873D-01	0.0	0.6452E 02	-0.3548E 02	-0.3548E 02	0.6488E 01
20	0.6706D 02	-0.4089D 00	-0.4895D-01	0.0	0.6706E 02	-0.3294E 02	-0.3294E 02	0.6865E 01
21	0.7069D 02	-0.4085D 00	-0.4890D-01	0.0	0.1414E 03	-0.5863E 02	-0.5863E 02	0.7421E 01
22	0.7504D 02	-0.4002D 00	-0.4790D-01	0.0	0.1501E 03	-0.4993E 02	-0.4993E 02	0.8093E 01
23	0.7891D 02	-0.3851D 00	-0.4610D-01	0.0	0.1578E 03	-0.4218E 02	-0.4218E 02	0.8698E 01
24	0.8233D 02	-0.3646D 00	-0.4364D-01	0.0	0.1647E 03	-0.3534E 02	-0.3534E 02	0.9234E 01
25	0.8531D 02	-0.3398D 00	-0.4068D-01	0.0	0.1706E 03	-0.2937E 02	-0.2937E 02	0.9700E 01
26	0.8789D 02	-0.3121D 00	-0.3735D-01	0.0	0.1758E 03	-0.2421E 02	-0.2421E 02	0.1010E 02
27	0.9010D 02	-0.2825D 00	-0.3382D-01	0.0	0.1802E 03	-0.1980E 02	-0.1980E 02	0.1043E 02
28	0.9197D 02	-0.2523D 00	-0.3021D-01	0.0	0.1839E 03	-0.1606E 02	-0.1606E 02	0.1071E 02
29	0.9354D 02	-0.2224D 00	-0.2662D-01	0.0	0.1871E 03	-0.1292E 02	-0.1292E 02	0.1093E 02
30	0.9484D 02	-0.1935D 00	-0.2316D-01	0.0	0.1897E 03	-0.1032E 02	-0.1032E 02	0.1111E 02
31	0.9645D 02	-0.1526D 00	-0.1827D-01	0.0	0.3858E 03	-0.1421E 02	-0.1421E 02	0.1133E 02
32	0.9785D 02	-0.1073D 00	-0.1284D-01	0.0	0.3914E 03	-0.8585E 01	-0.8586E 01	0.1150E 02
33	0.9874D 02	-0.7217D-01	-0.8639D-02	0.0	0.3950E 03	-0.5025E 01	-0.5025E 01	0.1160E 02
34	0.9928D 02	-0.4658D-01	-0.5576D-02	0.0	0.3971E 03	-0.2861E 01	-0.2861E 01	0.1166E 02
35	0.9960D 02	-0.2926D-01	-0.3503D-02	0.0	0.3984E 03	-0.1602E 01	-0.1602E 01	0.1169E 02
36	0.9986D 02	-0.1231D-01	-0.1473D-02	0.0	0.7989E 03	-0.1137E 01	-0.1137E 01	0.1171E 02
37	0.9997D 02	-0.3973D-02	-0.4756D-03	0.0	0.7997E 03	-0.2716E 00	-0.2716E 00	0.1172E 02
38	0.9999D 02	-0.9891D-03	-0.1184D-03	0.0	0.7999E 03	-0.5662E-01	-0.5662E-01	0.1172E 02
39	0.1000D 03	-0.2133D-03	-0.2554D-04	0.0	0.8000E 03	-0.1057E-01	-0.1057E-01	0.1172E 02
40	0.1000D 03	-0.4717D-04	-0.5647D-05	0.0	0.8000E 03	-0.2025E-02	-0.2025E-02	0.1172E 02

D. CYLINDER PROBLEM

An infinitely long cylinder of unit radius, with a unit surface temperature, is embedded in a medium with a zero initial temperature. TRUMP is used to calculate the temperature distribution in the medium. All thermal properties for the medium have unit values. Results are compared with an analytical solution.

1. Trump Solution

The input data are shown in Figure 8. Because of the geometrical shape of cylinder, the symmetry type indicator, KD, in BLOCK 1 is selected as 2. Maximum problem time, TIMAX, is made 50, and the medium initial temperature, TONE, is set to 0.0. Also, for temperature accuracy, TVARY, is selected as 0.05. In BLOCK 2, unit properties of the medium are defined. Nodal point locations are chosen so as to be able to compare the TRUMP solution with the given table in Reference 5 rather easily. The zoning of the medium is shown in the figure below.



In BLOCK 4, the arithmetic mean average radii, DRAD, are used to obtain correct nodal volumes for cylindrical shaped nodes. Actual node interfaces are used as interface radii, DRAD, in BLOCK 5, to obtain the areas of the connected interfaces. In BLOCK 6, zero-volume surface node, node -1, is connected to the boundary node with a heat transfer coefficient of 1.0×10^8, and geometric factors for external surface node area are defined. Computer running time for this problem was 15.46 sec.

```
*  CYLINDER  PROBLEM.  OCT.  1971.
BLOCK 1   PROBLEM  CONTROLS.
    5          1
    2                           0.05                50.0
    0.0
BLOCK 2  MATERIAL NAMES, NUMBERS, AND THERMAL PROPERTIES.
AAIR    50                      1.0       1.0       1.0

BLOCK 4  NODF NUMBERS, MATERIALS, TYPES, AND DIMENSIONS.
   -1              50                               1.0
    1              50           1.0       0.2       1.1
    2              50           1.0       0.2       1.3
    3              50           1.0       0.2       1.5
    4              50           1.0       0.2       1.7
    5              50           1.0       0.2       1.9
    6              50           1.0       0.4       2.2
    7              50           1.0       0.4       2.6
    8              50           1.0       0.4       3.0
    9              50           1.0       0.4       3.4
   10              50           1.0       0.4       3.8
   11              50           1.0       0.4       4.2
   12              50           1.0       0.4       4.6
   13              50           1.0       0.4       5.0
   14              50           1.0       0.4       5.4
   15              50           1.0       0.4       5.8
   16              50           1.0       0.4       6.2
   17              50           1.0       0.4       6.6
   18              50           1.0       0.4       7.0
   19              50           1.0       0.4       7.4
   20              50           1.0       0.4       7.8
   21              50           1.0       0.4       8.2
   22              50           1.0       0.4       8.6
   23              50           1.0       0.4       9.0
   24              50           1.0       1.6       10.0
   25              50           1.0       1.6       11.6
   26              50           1.0       1.6       13.2
   27              50           1.0       1.6       14.8
   28              50           1.0       1.6       16.4
   29              50           1.0       1.6       18.0
   30              50           1.0       2.4       20.0
   31              50           1.0       2.4       22.4
   32              50           1.0       2.4       24.8
   33              50           1.0       2.4       27.2
   34              50           1.0       3.2       30.0

BLOCK 5  INTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1   1           0.0         0.1       1.0       1.0
    1   2           0.1         0.1       1.0       1.2
```

FIG. 8 INPUT DATA FOR CYLINDER

```
  2   3         0.1    0.1    1.0    1.4
  3   4         0.1    0.1    1.0    1.6
  4   5         0.1    0.1    1.0    1.8
  5   6         0.1    0.2    1.0    2.0
  6   7         0.2    0.2    1.0    2.4
  7   8         0.2    0.2    1.0    2.8
  8   9         0.2    0.2    1.0    3.2
  9  10         0.2    0.2    1.0    3.6
 10  11         0.2    0.2    1.0    4.0
 11  12         0.2    0.2    1.0    4.4
 12  13         0.2    0.2    1.0    4.8
 13  14         0.2    0.2    1.0    5.2
 14  15         0.2    0.2    1.0    5.6
 15  16         0.2    0.2    1.0    6.0
 16  17         0.2    0.2    1.0    6.4
 17  18         0.2    0.2    1.0    6.8
 18  19         0.2    0.2    1.0    7.2
 19  20         0.2    0.2    1.0    7.6
 20  21         0.2    0.2    1.0    8.0
 21  22         0.2    0.2    1.0    8.4
 22  23         0.2    0.2    1.0    8.8
 23  24         0.2    0.8    1.0    9.2
 24  25         0.8    0.8    1.0    10.8
 25  26         0.8    0.8    1.0    12.4
 26  27         0.8    0.8    1.0    14.0
 27  28         0.8    0.8    1.0    15.6
 28  29         0.8    0.8    1.0    17.2
 29  30         0.8    1.2    1.0    18.8
 30  31         1.2    1.2    1.0    21.2
 31  32         1.2    1.2    1.0    23.6
 32  33         1.2    1.2    1.0    26.0
 33  34         1.2    1.6    1.0    28.4
BLOCK 6  EXTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1 2001                    1.0    1.0    1.0    E8

BLOCK 7  BOUNDARY NODE TEMPERATURES.
 2001             1.0

BLOCK 9  INITIAL CONDITIONS.
   -1             1.0

ENDED-1  LAST CARD OF DATA DECK.
```

FIG. 8 (CONT'D)

TABLE V

TEMPERATURE DISTRIBUTION FOR CYLINDER (TIME = 50)

R	T (Trump)	T (Analytic)
1.0	1.0	1.0
1.1	0.961	0.963
1.3	0.897	0.898
1.5	0.842	0.843
1.7	0.794	0.794
1.9	0.751	0.751
3.0	0.574	0.574
5.0	0.382	0.381
7.0	0.261	0.260
9.0	0.179	0.177
10.0	0.146	0.146
20.0	0.016	0.016
30.0	0.001	0.001

TRUMP OUTPUT DATA DATA DECK 1

* CYLINDER PROBLEM

PRINTOUT	CYCLE	TCC FAST	TCC SLOW	KWIT	DELTMX	SMALL	TVARY	NUTS
13	53	0	0	1	1.00000E 12	8.53332E-03	5.00000E-02	2

TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
5.00000E 01	2.46155E-01	1.54873E 02	4.94183E-02	3.09746E 00	9.88366E-04

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
4.97682E-02	3.13392D 03	1.55970E 02	0.0	0.0	0.0

NODE	TEMP	DT	DDT	GEN RATE	W	H	F	CURE AT 280 F
-1	0.1000D 01	0.9042D-13	0.1682D-12	0.0	0.1000E-23	-0.1359E-33	-0.8966E-02	0.0
1	0.9614D 00	0.2641D-04	0.4912D-04	0.0	0.1329E 01	0.1329E 01	0.1315E 01	0.0
2	0.8971D 00	0.7112D-04	0.1323D-03	0.0	0.1465E 01	0.1465E 01	0.1438E 01	0.0
3	0.8419D 00	0.1097D-03	0.2041D-03	0.0	0.1587E 01	0.1587E 01	0.1541E 01	0.0
4	0.7937D 00	0.1449D-03	0.2695D-03	0.0	0.1696E 01	0.1696E 01	0.1633E 01	0.0
5	0.7509D 00	0.1793D-03	0.3335D-03	0.0	0.1793E 01	0.1793E 01	0.1731E 01	0.0
6	0.6931D 00	0.2322D-03	0.4318D-03	0.0	0.3832E 01	0.3832E 01	0.3781E 01	0.0
7	0.6290D 00	0.2859D-03	0.5317D-03	0.0	0.4110E 01	0.4110E 01	0.4057E 01	0.0
8	0.5742D 00	0.3290D-03	0.6118D-03	0.0	0.4329E 01	0.4329E 01	0.4270E 01	0.0
9	0.5265D 00	0.3649D-03	0.6786D-03	0.0	0.4499E 01	0.4499E 01	0.4433E 01	0.0
10	0.4843D 00	0.3954D-03	0.7353D-03	0.0	0.4625E 01	0.4625E 01	0.4555E 01	0.0
11	0.4466D 00	0.4213D-03	0.7835D-03	0.0	0.4714E 01	0.4714E 01	0.4640E 01	0.0
12	0.4125D 00	0.4432D-03	0.8243D-03	0.0	0.4769E 01	0.4769E 01	0.4695E 01	0.0
13	0.3816D 00	0.4617D-03	0.8587D-03	0.0	0.4796E 01	0.4796E 01	0.4724E 01	0.0
14	0.3534D 00	0.4771D-03	0.8873D-03	0.0	0.4796E 01	0.4796E 01	0.4728E 01	0.0
15	0.3275D 00	0.4897D-03	0.9108D-03	0.0	0.4774E 01	0.4774E 01	0.4712E 01	0.0
16	0.3036D 00	0.4998D-03	0.9295D-03	0.0	0.4731E 01	0.4731E 01	0.4677E 01	0.0
17	0.2816D 00	0.5076D-03	0.9440D-03	0.0	0.4671E 01	0.4671E 01	0.4625E 01	0.0
18	0.2612D 00	0.5133D-03	0.9547D-03	0.0	0.4595E 01	0.4595E 01	0.4559E 01	0.0
19	0.2422D 00	0.5172D-03	0.9619D-03	0.0	0.4505E 01	0.4505E 01	0.4478E 01	0.0
20	0.2246D 00	0.5193D-03	0.9658D-03	0.0	0.4404E 01	0.4404E 01	0.4384E 01	0.0
21	0.2083D 00	0.5206D-03	0.9683D-03	0.0	0.4292E 01	0.4292E 01	0.4278E 01	0.0
22	0.1930D 00	0.5243D-03	0.9751D-03	0.0	0.4172E 01	0.4172E 01	0.4162E 01	0.0
23	0.1788D 00	0.5314D-03	0.9883D-03	0.0	0.4045E 01	0.4045E 01	0.4039E 01	0.0
24	0.1458D 00	0.5453D-03	0.1014D-02	0.0	0.1465E 02	0.1465E 02	0.1465E 02	0.0
25	0.1059D 00	0.5021D-03	0.9337D-03	0.0	0.1235E 02	0.1235E 02	0.1235E 02	0.0
26	0.7611D-01	0.4392D-03	0.8169D-03	0.0	0.1010E 02	0.1010E 02	0.1010E 02	0.0
27	0.5401D-01	0.3705D-03	0.6891D-03	0.0	0.8036E 01	0.8036E 01	0.8035E 01	0.0
28	0.3783D-01	0.3030D-03	0.5635D-03	0.0	0.6237E 01	0.6237E 01	0.6236E 01	0.0
29	0.2616D-01	0.2407D-03	0.4476D-03	0.0	0.4734E 01	0.4734E 01	0.4734E 01	0.0
30	0.1581D-01	0.1725D-03	0.3208D-03	0.0	0.4769E 01	0.4769E 01	0.4769E 01	0.0
31	0.8616D-02	0.1110D-03	0.2065D-03	0.0	0.2910E 01	0.2910E 01	0.2910E 01	0.0
32	0.4621D-02	0.6896D-04	0.1283D-03	0.0	0.1728E 01	0.1728E 01	0.1728E 01	0.0
33	0.2539D-02	0.4331D-04	0.8055D-04	0.0	0.1041E 01	0.1041E 01	0.1041E 01	0.0
34	0.1452D-02	0.2811D-04	0.5228D-04	0.0	0.8761E 00	0.8761E 00	0.8760E 00	0.0

E. SPHERE PROBLEM

A sphere with a unit radius and a unit surface temperature is embedded in a medium with a zero initial temperature. The temperature distribution in the medium is calculated using TRUMP assuming all the thermal properties have unit values. Results are compared with the analytical solution.

1. <u>Analytic Solution</u>

$$T(r,t) = \operatorname{erfc}\left(\frac{r-1}{2\ t}\right)$$

2. <u>Trump Solution</u>

The input data from the cylinder problem can be used to solve this problem if the symmetry type indicator, KD, in BLOCK 1 is changed from 2 to 3 to correspond to the centrisymmetric geometry. All other input conditions are identical with the cylinder problem. The computer time used for this problem was 11.61 sec.

TABLE VI

TEMPERATURE DISTRIBUTION FOR SPHERE (TIME = 50)

R	T (Trump)	T (Analytic)
1.0	1.0	1.00
1.1	0.89	0.90
1.3	0.75	0.75
1.5	0.64	0.64
1.7	0.56	0.56
1.9	0.49	0.49
3.0	0.28	0.28
5.0	0.14	0.14
7.0	0.08	0.08
9.0	0.05	0.05
10.0	0.04	0.04
20.0	0.00	0.00
30.0	0.00	0.00

TRUMP OUTPUT DATA DATA DECK 1

* SPHERE PROBLEM

PRINTOUT	CYCLE	TOO FAST	TOO SLOW	KWIT	DELTMX	SMALL	TVARY	NUTS
11	43	0	0	1	1.00000E 12	8.49293E-03	5.00000E-02	79

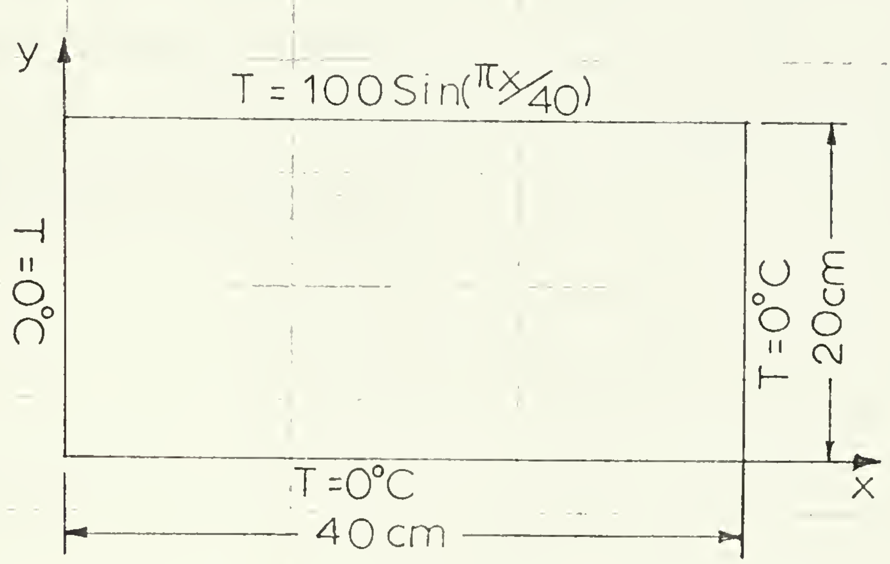
TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
5.00000E 01	1.43451E 01	7.10860E 02	5.38320E-03	1.42172E 01	1.07664E-04

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
5.93038E-03	1.32052D 05	7.83115E 02	0.0	0.0	0.0

NODE	TEMP	DT	DDT	GE N RATE	W	H	F	CURE AT 280 F
-1	0.1000D 01	0.2270D-12	0.4634D-14	0.0	0.1000E-23	-0.1307E-34	-0.1158E 00	0.0
1	0.8946D 00	0.1819D-02	0.3715D-04	0.0	0.2720E 01	0.2720E 01	0.2526E 01	0.0
2	0.7481D 00	0.4319D-02	0.8819D-04	0.0	0.3177E 01	0.3177E 01	0.2726E 01	0.0
3	0.6404D 00	0.6111D-02	0.1248D-03	0.0	0.3621E 01	0.3621E 01	0.2787E 01	0.0
4	0.5579D 00	0.7428D-02	0.1517D-03	0.0	0.4052E 01	0.4052E 01	0.2785E 01	0.0
5	0.4927D 00	0.8417D-02	0.1718D-03	0.0	0.4470E 01	0.4470E 01	0.3064E 01	0.0
6	0.4133D 00	0.9563D-02	0.1953D-03	0.0	0.1005E 02	0.1005E 02	0.8643E 01	0.0
7	0.3398D 00	0.1055D-01	0.2153D-03	0.0	0.1154E 02	0.1154E 02	0.9752E 01	0.0
8	0.2857D 00	0.1120D-01	0.2287D-03	0.0	0.1293E 02	0.1293E 02	0.1052E 02	0.0
9	0.2442D 00	0.1166D-01	0.2380D-03	0.0	0.1420E 02	0.1420E 02	0.1116E 02	0.0
10	0.2116D 00	0.1198D-01	0.2446D-03	0.0	0.1536E 02	0.1536E 02	0.1170E 02	0.0
11	0.1851D 00	0.1221D-01	0.2494D-03	0.0	0.1641E 02	0.1641E 02	0.1220E 02	0.0
12	0.1632D 00	0.1238D-01	0.2527D-03	0.0	0.1736E 02	0.1736E 02	0.1269E 02	0.0
13	0.1448D 00	0.1248D-01	0.2548D-03	0.0	0.1820E 02	0.1820E 02	0.1320E 02	0.0
14	0.1291D 00	0.1253D-01	0.2558D-03	0.0	0.1893E 02	0.1893E 02	0.1375E 02	0.0
15	0.1156D 00	0.1252D-01	0.2557D-03	0.0	0.1955E 02	0.1955E 02	0.1434E 02	0.0
16	0.1039D 00	0.1246D-01	0.2544D-03	0.0	0.2007E 02	0.2007E 02	0.1498E 02	0.0
17	0.9352D-01	0.1234D-01	0.2519D-03	0.0	0.2048E 02	0.2048E 02	0.1563E 02	0.0
18	0.8438D-01	0.1217D-01	0.2484D-03	0.0	0.2078E 02	0.2078E 02	0.1528E 02	0.0
19	0.7624D-01	0.1194D-01	0.2438D-03	0.0	0.2099E 02	0.2099E 02	0.1687E 02	0.0
20	0.6896D-01	0.1167D-01	0.2382D-03	0.0	0.2109E 02	0.2109E 02	0.1739E 02	0.0
21	0.6241D-01	0.1135D-01	0.2318D-03	0.0	0.2109E 02	0.2109E 02	0.1779E 02	0.0
22	0.5650D-01	0.1101D-01	0.2247D-03	0.0	0.2100E 02	0.2100E 02	0.1803E 02	0.0
23	0.5115D-01	0.1064D-01	0.2172D-03	0.0	0.2083E 02	0.2083E 02	0.1895E 02	0.0
24	0.3906D-01	0.9648D-02	0.1970D-03	0.0	0.7854E 02	0.7854E 02	0.7784E 02	0.0
25	0.2628D-01	0.7858D-02	0.1604D-03	0.0	0.7110E 02	0.7110E 02	0.7072E 02	0.0
26	0.1770D-01	0.6187D-02	0.1263D-03	0.0	0.6201E 02	0.6201E 02	0.6179E 02	0.0
27	0.1190D-01	0.4741D-02	0.9680D-04	0.0	0.5240E 02	0.5240E 02	0.5232E 02	0.0
28	0.7972D-02	0.3547D-02	0.7242D-04	0.0	0.4312E 02	0.4312E 02	0.4313E 02	0.0
29	0.5326D-02	0.2597D-02	0.5302D-04	0.0	0.3469E 02	0.3469E 02	0.3476E 02	0.0
30	0.3108D-02	0.1683D-02	0.3436D-04	0.0	0.3749E 02	0.3749E 02	0.3756E 02	0.0
31	0.1664D-02	0.9838D-03	0.2021D-04	0.0	0.2518E 02	0.2518E 02	0.2525E 02	0.0
32	0.8999D-03	0.5787D-03	0.1182D-04	0.0	0.1669E 02	0.1669E 02	0.1575E 02	0.0
33	0.5146D-03	0.3531D-03	0.7209D-05	0.0	0.1148E 02	0.1148E 02	0.1153E 02	0.0
34	0.3181D-03	0.2308D-03	0.4712D-05	0.0	0.1151E 02	0.1151E 02	0.1153E 02	0.0

F. TWO DIMENSIONAL PLATE PROBLEM

A rectangular plate, 40 x 20 cm, has a thermal conductivity of 400 cal/cm-sec-^{o}C, a density of 1.0 g/cm^{3}, and a heat capacity of 1.0 cal/g-^{o}C and is initially at 0.0^{o}C. Three sides of the plate are maintained at 0.0^{o}C. The upper side of the plate has a temperature distribution that varies sinusoidally with x, starting at 0^{o}C, reaching a maximum of 100^{o}C at the midpoint and decreasing to 0^{o}C at the outer edge (see figure below). The steady-state temperature distribution is calculated in the plate using TRUMP. Results are compared with the analytical solution.



1. Analytic Solution

$$T(x,y) = 100 \frac{\sinh(\frac{\pi y}{40})}{\sinh(\frac{\pi}{2})} \sin(\frac{\pi x}{40})$$

where $0 \leqslant x \leqslant 40$ and $0 \leqslant y \leqslant 20$

2. Trump Solution

The input data are shown in Figure 9. Because the boundary conditions of the plate and the plate itself are symmetric with respect to the plane at x = 20 cm, this symmetry plane is assumed to be an insulated surface. The zoning of the plate is shown in Figure 10. In BLOCK 1 of the input data, IPRINT, is selected as 9999, so that printouts are obtained only for the first, second, and last time steps. To obtain a rapid conclusion to the transient problem, TVARY, is selected as 100.0^{o}C. In BLOCK 4, instead of using a very large number of surface nodes for sides x = 40 cm and y = 0, surface node -1 and surface node -4 are used, respectively, in order to reduce the number of the input cards, and in BLOCK 6 they are connected to the boundary nodes 2001 and 2004. In BLOCK 7, the boundary node temperatures, and in BLOCK 9, the initial temperatures of the surface nodes are given. The computer running time for this problem was 28.71 sec.

```
*  TWO-DIMENSIONAL SLAB PROBLEM.  NOVEMBER 1971
BLOCK 1  PROBLEM LIMITS AND CONTROLS.
 9999        1
   1                          100.0
  0.0
BLOCK 2  MATERIAL NAME AND NUMBER, THERMAL PROPERTIES.
AAG     50                    1.0        1.0        400.0

BLOCK 4   NODE NUMBERS, MATERIALS, TYPES, AND DIMENSIONS.
    1   99    1   50          2.0        2.0          1.0
   -1             50
   -4             50
  -31             50
  -32             50
  -33             50
  -34             50
  -35             50
  -36             50
  -37             50
  -38             50
  -39             50
  -40             50

BLOCK 5  INTERNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
    1    2   8   1   1   1.0      1.0        2.0         1.0
   11   12   8   1   1   1.0      1.0        2.0         1.0
   21   22   8   1   1   1.0      1.0        2.0         1.0
   31   32   8   1   1   1.0      1.0        2.0         1.0
   41   42   8   1   1   1.0      1.0        2.0         1.0
   51   52   8   1   1   1.0      1.0        2.0         1.0
   61   62   8   1   1   1.0      1.0        2.0         1.0
   71   72   8   1   1   1.0      1.0        2.0         1.0
   81   82   8   1   1   1.0      1.0        2.0         1.0
   91   92   8   1   1   1.0      1.0        2.0         1.0
    1   11  89   1   1   1.0      1.0        2.0         1.0
   -1    1   9       1            1.0        2.0         1.0
   -4    1   9      10            1.0        2.0         1.0
  -31   91                        1.0        2.0         1.0
  -32   92                        1.0        2.0         1.0
  -33   93                        1.0        2.0         1.0
  -34   94                        1.0        2.0         1.0
  -35   95                        1.0        2.0         1.0
  -36   96                        1.0        2.0         1.0
  -37   97                        1.0        2.0         1.0
  -38   98                        1.0        2.0         1.0
  -39   99                        1.0        2.0         1.0
  -40  100                        1.0        2.0         1.0
```

FIG. 9 INPUT DATA FOR TWO-DIMENSIONAL-PLATE

```
BLOCK 6  EXTEPNAL CONNECTION NODE NUMBERS AND DESCRIPTIONS.
   -1 2001                     20.0       1.0       1.0      E8
   -4 2004                     20.0       1.0       1.0      E8
  -31  310                      2.0       1.0       1.0      E8
  -32  320                      2.0       1.0       1.0      E8
  -33  330                      2.0       1.0       1.0      E8
  -34  340                      2.0       1.0       1.0      E8
  -35  350                      2.0       1.0       1.0      E8
  -36  360                      2.0       1.0       1.0      E8
  -37  370                      2.0       1.0       1.0      E8
  -38  380                      2.0       1.0       1.0      E8
  -39  390                      2.0       1.0       1.0      E8
  -40  400                      2.0       1.0       1.0      E8

BLOCK 7  BOUNDARY NODE TEMPERATURES.
 2001             0.0
 2004             0.0
  310             7.84590964
  320             23.3445364
  330             38.2683433
  340             52.2498565
  350             64.9448049
  360             76.0405968
  370             85.2640186
  380             92.3879660
  390             97.2370492
  400             99.6919339

BLOCK 9  INITIAL CONDITIONS.
   -1              0.0
   -4              0.0

ENDED-1  LAST CARD OF DATA DECK.
```

FIG. 9 (CONT'D)

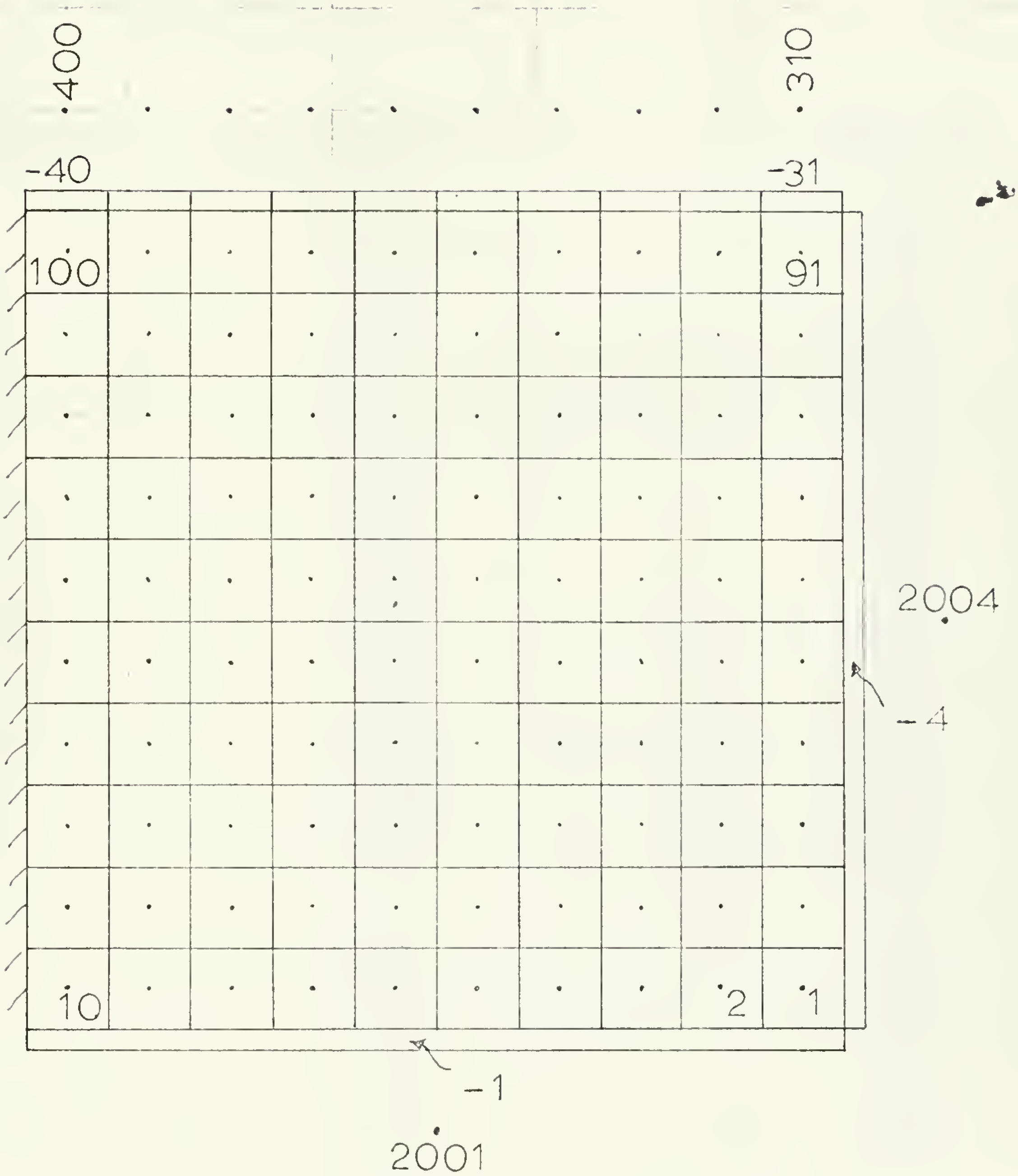


FIG. 10 ZONING OF THE TWO DIMENSIONAL PLATE PROBLEM

TABLE VII

TEMPERATURE DISTRIBUTION FOR TWO-DIMENSIONAL PLATE IN STEADY-STATE

Node Number	T (Trump)	T (Analytic)
1	0.26	0.27
5	2.17	2.23
10	3.34	3.41
11	0.79	0.81
15	6.57	6.71
20	10.10	10.30
21	1.35	1.37
25	11.14	11.37
30	17.13	17.45
31	1.93	1.97
35	16.02	16.31
40	24.63	25.03
41	2.58	2.62
45	21.32	21.65
50	32.77	33.24
51	3.28	3.33
55	27.19	27.53
60	41.77	42.26
61	4.08	4.12
65	33.75	34.09
70	51.84	52.33
71	4.97	5.01
75	41.18	41.49
80	63.24	63.69
81	6.00	6.03
85	49.65	49.92
90	76.23	76.62
91	7.17	7.20
95	59.36	59.58
100	91.12	91.45

* TWO-DIMENSIONAL SLAB PROBLEM. NOVEMBER 1971

PRINTOUT	CYCLE	TCC FAST	TCC SLOW	KWIT	DELTMX	SMALL	TVARY	NLTS
3	54	0	3	4	1.00000E 12	1.66667E-05	1.00000E 02	0

TOTAL TIME	TIME STEP	HEAT FLOW	TEMP FROM FLUX	FLUX RATE	TEMP RATE
3.25100E 12	1.00000E 12	2.37981E 15	5.94952E 12	7.32024E 02	1.83006E 00

AVG TEMP	HEAT CAPACITY	HEAT CONTENT	GEN RATE	HEAT GEN	TEMP FROM GEN
2.63375E 01	4.00000D 02	1.05350E 04	0.0	0.0	0.0

NODE	TEMP	DT	DDT	GEN RATE	W	H	F	CURE AT 280 F
1	0.2619D 00	0.1587D-03	0.1587D-39	0.0	0.1047E 01	0.1047E 01	0.1169E 13	0.0
2	0.7793D 00	0.4663D-03	0.4663D-39	0.0	0.3117E 01	0.3117E 01	0.2872E 13	0.0
3	0.1278D 01	0.7596D-03	0.7596D-39	0.0	0.5111E 01	0.5111E 01	0.4624E 13	0.0
4	0.1745D 01	0.1030D-02	0.1030D-38	0.0	0.6979E 01	0.6979E 01	0.6306E 13	0.0
5	0.2169D 01	0.1267D-02	0.1267D-38	0.0	0.8676E 01	0.8676E 01	0.7660E 13	0.0
6	0.2540D 01	0.1465D-02	0.1465D-38	0.0	0.1016E 02	0.1016E 02	0.8968E 13	0.0
7	0.2849D 01	0.1615D-02	0.1615D-38	0.0	0.1140E 02	0.1140E 02	0.9852E 13	0.0
8	0.3089D 01	0.1717D-02	0.1717D-38	0.0	0.1235E 02	0.1235E 02	0.1056E 14	0.0
9	0.3252D 01	0.1765D-02	0.1765D-38	0.0	0.1301E 02	0.1301E 02	0.1086E 14	0.0
10	0.3336D 01	0.1762D-02	0.1762D-38	0.0	0.1334E 02	0.1334E 02	0.8676E 13	0.0
11	0.7929D 00	0.4554D-03	0.4554D-39	0.0	0.3172E 01	0.3171E 01	0.2807E 13	0.0
12	0.2360D 01	0.1338D-02	0.1338D-38	0.0	0.9439E 01	0.9439E 01	0.6540E 13	0.0
13	0.3869D 01	0.2180D-02	0.2180D-38	0.0	0.1547E 02	0.1547E 02	0.1071E 14	0.0
14	0.5283D 01	0.2954D-02	0.2954D-38	0.0	0.2113E 02	0.2113E 02	0.1429E 14	0.0
15	0.6568D 01	0.3637D-02	0.3637D-38	0.0	0.2627E 02	0.2627E 02	0.1780E 14	0.0
16	0.7692D 01	0.4203D-02	0.4203D-38	0.0	0.3077E 02	0.3077E 02	0.2033E 14	0.0
17	0.8627D 01	0.4639D-02	0.4639D-38	0.0	0.3451E 02	0.3451E 02	0.2274E 14	0.0
18	0.9351D 01	0.4929D-02	0.4929D-38	0.0	0.3741E 02	0.3740E 02	0.2411E 14	0.0
19	0.9846D 01	0.5071D-02	0.5071D-38	0.0	0.3938E 02	0.3938E 02	0.2493E 14	0.0
20	0.1010D 02	0.5061D-02	0.5061D-38	0.0	0.4040E 02	0.4040E 02	0.1866E 14	0.0
21	0.1345D 01	0.7069D-03	0.7069D-39	0.0	0.5382E 01	0.5382E 01	0.4332E 13	0.0
22	0.4004D 01	0.2078D-02	0.2078D-38	0.0	0.1602E 02	0.1602E 02	0.1024E 14	0.0
23	0.6565D 01	0.3384D-02	0.3384D-38	0.0	0.2626E 02	0.2626E 02	0.1645E 14	0.0
24	0.8964D 01	0.4589D-02	0.4589D-38	0.0	0.3586E 02	0.3586E 02	0.2251E 14	0.0
25	0.1114D 02	0.5649D-02	0.5649D-38	0.0	0.4458E 02	0.4458E 02	0.2721E 14	0.0
26	0.1305D 02	0.6534D-02	0.6534D-38	0.0	0.5220E 02	0.5220E 02	0.3195E 14	0.0
27	0.1464D 02	0.7210D-02	0.7210D-38	0.0	0.5855E 02	0.5855E 02	0.3490E 14	0.0
28	0.1587D 02	0.7667D-02	0.7667D-38	0.0	0.6346E 02	0.6346E 02	0.3755E 14	0.0
29	0.1671D 02	0.7887D-02	0.7887D-38	0.0	0.6682E 02	0.6682E 02	0.3855E 14	0.0
30	0.1713D 02	0.7874D-02	0.7874D-38	0.0	0.6854E 02	0.6854E 02	0.2893E 14	0.0
31	0.1934D 01	0.8892D-03	0.8892D-39	0.0	0.7737E 01	0.7737E 01	0.5481E 13	0.0
32	0.5756D 01	0.2612D-02	0.2612D-38	0.0	0.2303E 02	0.2303E 02	0.1276E 14	0.0
33	0.9437D 01	0.4258D-02	0.4258D-38	0.0	0.3775E 02	0.3775E 02	0.2097E 14	0.0
34	0.1289D 02	0.5771D-02	0.5771D-38	0.0	0.5155E 02	0.5155E 02	0.2789E 14	0.0
35	0.1602D 02	0.7110D-02	0.7110D-38	0.0	0.6408E 02	0.6408E 02	0.3483E 14	0.0
36	0.1876D 02	0.8223D-02	0.8223D-38	0.0	0.7504E 02	0.7504E 02	0.3950E 14	0.0
37	0.2104D 02	0.9083D-02	0.9083D-38	0.0	0.8417E 02	0.8417E 02	0.4435E 14	0.0
38	0.2281D 02	0.9658D-02	0.9658D-38	0.0	0.9122E 02	0.9122E 02	0.4673E 14	0.0
39	0.2401D 02	0.9942D-02	0.9942D-38	0.0	0.9604E 02	0.9604E 02	0.4851E 14	0.0
40	0.2463D 02	0.9922D-02	0.9922D-38	0.0	0.9851E 02	0.9851E 02	0.3621E 14	0.0
41	0.2575D 01	0.9836D-03	0.9836D-39	0.0	0.1030E 02	0.1030E 02	0.6023E 13	0.0
42	0.7662D 01	0.2891D-02	0.2891D-38	0.0	0.3065E 02	0.3065E 02	0.1425E 14	0.0
43	0.1256D 02	0.4711D-02	0.4711D-38	0.0	0.5025E 02	0.5025E 02	0.2293E 14	0.0
44	0.1715D 02	0.6390D-02	0.6390D-38	0.0	0.6861E 02	0.6861E 02	0.3143E 14	0.0

NODE	TEMP	DT	DDT	GEN RATE	h	H	F	CURE AT 280 F
45	0.2132D 02	0.7871D-02	0.7871D-38	0.0	0.8529E 02	0.8529E 02	0.3786E 14	0.0
46	0.2497D 02	0.9112D-02	0.9112D-38	0.0	0.9988E 02	0.9988E 02	0.4454E 14	0.0
47	0.2800D 02	0.1007D-01	0.1007D-37	0.0	0.1120E 03	0.1120E 03	0.4827E 14	0.0
48	0.3035D 02	0.1071D-01	0.1071D-37	0.0	0.1214E 03	0.1214E 03	0.5212E 14	0.0
49	0.3195D 02	0.1103D-01	0.1103D-37	0.0	0.1278E 03	0.1278E 03	0.5319E 14	0.0
50	0.3277D 02	0.1101D-01	0.1101D-37	0.0	0.1311E 03	0.1311E 03	0.4011E 14	0.0
51	0.3283D 01	0.9822D-03	0.9822D-39	0.0	0.1313E 02	0.1313E 02	0.6038E 13	0.0
52	0.9769D 01	0.2886D-02	0.2886D-38	0.0	0.3908E 02	0.3908E 02	0.1412E 14	0.0
53	0.1602D 02	0.4705D-02	0.4705D-38	0.0	0.6406E 02	0.6406E 02	0.2318E 14	0.0
54	0.2187D 02	0.6380D-02	0.6380D-38	0.0	0.8748E 02	0.8748E 02	0.3095E 14	0.0
55	0.2719D 02	0.7865D-02	0.7865D-38	0.0	0.1087E 03	0.1087E 03	0.3861E 14	0.0
56	0.3183D 02	0.9104D-02	0.9104D-38	0.0	0.1273E 03	0.1273E 03	0.4366E 14	0.0
57	0.3570D 02	0.1007D-01	0.1007D-37	0.0	0.1428E 03	0.1428E 03	0.4906E 14	0.0
58	0.3869D 02	0.1071D-01	0.1071D-37	0.0	0.1548E 03	0.1548E 03	0.5127E 14	0.0
59	0.4073D 02	0.1104D-01	0.1104D-37	0.0	0.1629E 03	0.1629E 03	0.5349E 14	0.0
60	0.4177D 02	0.1102D-01	0.1102D-37	0.0	0.1671E 03	0.1671E 03	0.3964E 14	0.0
61	0.4076D 01	0.8847D-03	0.8847D-39	0.0	0.1631E 02	0.1631E 02	0.5420E 13	0.0
62	0.1213D 02	0.2601D-02	0.2601D-38	0.0	0.4852E 02	0.4852E 02	0.1278E 14	0.0
63	0.1989D 02	0.4238D-02	0.4238D-38	0.0	0.7954E 02	0.7954E 02	0.2071E 14	0.0
64	0.2715D 02	0.5751D-02	0.5751D-38	0.0	0.1086E 03	0.1086E 03	0.2829E 14	0.0
65	0.3375D 02	0.7087D-02	0.7087D-38	0.0	0.1350E 03	0.1350E 03	0.3428E 14	0.0
66	0.3952D 02	0.8212D-02	0.8212D-38	0.0	0.1581E 03	0.1581E 03	0.4020E 14	0.0
67	0.4432D 02	0.9080D-02	0.9080D-38	0.0	0.1773E 03	0.1773E 03	0.4343E 14	0.0
68	0.4803D 02	0.9673D-02	0.9673D-38	0.0	0.1921E 03	0.1921E 03	0.4697E 14	0.0
69	0.5056D 02	0.9963D-02	0.9963D-38	0.0	0.2022E 03	0.2022E 03	0.4749E 14	0.0
70	0.5184D 02	0.9951D-02	0.9951D-38	0.0	0.2074E 03	0.2074E 03	0.3608E 14	0.0
71	0.4974D 01	0.7020D-03	0.7020D-39	0.0	0.1990E 02	0.1990E 02	0.4300E 13	0.0
72	0.1480D 02	0.2062D-02	0.2062D-38	0.0	0.5920E 02	0.5920E 02	0.1010E 14	0.0
73	0.2426D 02	0.3363D-02	0.3363D-38	0.0	0.9706E 02	0.9706E 02	0.1650E 14	0.0
74	0.3313D 02	0.4561D-02	0.4561D-38	0.0	0.1325E 03	0.1325E 03	0.2224E 14	0.0
75	0.4118D 02	0.5624D-02	0.5624D-38	0.0	0.1647E 03	0.1647E 03	0.2761E 14	0.0
76	0.4822D 02	0.6515D-02	0.6515D-38	0.0	0.1929E 03	0.1929E 03	0.3141E 14	0.0
77	0.5407D 02	0.7211D-02	0.7211D-38	0.0	0.2163E 03	0.2163E 03	0.3521E 14	0.0
78	0.5860D 02	0.7681D-02	0.7681D-38	0.0	0.2344E 03	0.2344E 03	0.3660E 14	0.0
79	0.6168D 02	0.7918D-02	0.7918D-38	0.0	0.2467E 03	0.2467E 03	0.3835E 14	0.0
80	0.6324D 02	0.7905D-02	0.7905D-38	0.0	0.2530E 03	0.2530E 03	0.2816E 14	0.0
81	0.5998D 01	0.4511D-03	0.4511D-39	0.0	0.2399E 02	0.2399E 02	0.2766E 13	0.0
82	0.1785D 02	0.1326D-02	0.1326D-38	0.0	0.7138E 02	0.7138E 02	0.6491E 13	0.0
83	0.2925D 02	0.2161D-02	0.2161D-38	0.0	0.1170E 03	0.1170E 03	0.1057E 14	0.0
84	0.3994D 02	0.2932D-02	0.2932D-38	0.0	0.1598E 03	0.1598E 03	0.1437E 14	0.0
85	0.4965D 02	0.3615D-02	0.3615D-38	0.0	0.1986E 03	0.1986E 03	0.1758E 14	0.0
86	0.5813D 02	0.4190D-02	0.4190D-38	0.0	0.2325E 03	0.2325E 03	0.2054E 14	0.0
87	0.6519D 02	0.4636D-02	0.4636D-38	0.0	0.2608E 03	0.2607E 03	0.2226E 14	0.0
88	0.7064D 02	0.4943D-02	0.4943D-38	0.0	0.2826E 03	0.2825E 03	0.2408E 14	0.0
89	0.7435D 02	0.5094D-02	0.5094D-38	0.0	0.2974E 03	0.2974E 03	0.2417E 14	0.0
90	0.7623D 02	0.5089D-02	0.5089D-38	0.0	0.3049E 03	0.3049E 03	0.1848E 14	0.0
91	0.7171D 01	0.1571D-03	0.1571D-39	0.0	0.2868E 02	0.2868E 02	0.1156E 13	0.0
92	0.2134D 02	0.4615D-03	0.4615D-39	0.0	0.8534E 02	0.8534E 02	0.2827E 13	0.0
93	0.3498D 02	0.7523D-03	0.7523D-39	0.0	0.1399E 03	0.1399E 03	0.4595E 13	0.0
94	0.4775D 02	0.1020D-02	0.1020D-38	0.0	0.1910E 03	0.1910E 03	0.6226E 13	0.0
95	0.5936D 02	0.1259D-02	0.1259D-38	0.0	0.2374E 03	0.2374E 03	0.7707E 13	0.0
96	0.6950D 02	0.1459D-02	0.1459D-38	0.0	0.2780E 03	0.2780E 03	0.8837E 13	0.0
97	0.7793D 02	0.1615D-02	0.1615D-38	0.0	0.3117E 03	0.3117E 03	0.9891E 13	0.0
98	0.8444D 02	0.1721D-02	0.1721D-38	0.0	0.3378E 03	0.3378E 03	0.1027E 14	0.0
99	0.8887D 02	0.1775D-02	0.1775D-38	0.0	0.3555E 03	0.3555E 03	0.1078E 14	0.0
100	0.9112D 02	0.1773D-02	0.1773D-38	0.0	0.3645E 03	0.3645E 03	0.8389E 13	0.0
-1	0.8514D-05	0.4960D-08	0.4960D-44	0.0	0.8514E-29	0.8514E-29	0.3042E 14	0.0
-4	0.1296D-04	0.2632D-08	0.2632D-44	0.0	0.1296E-28	0.1296E-28	0.1616E 14	0.0

NODE	TEMP	DT	DDT	GEN RATE	W	H	F	CURE AT 280 F
-31	0.7846D 01	0.6486D-09	0.6486D-45	0.0	0.7846E-23	0.7846E-23	0.3986E 12	0.0
-32	0.2334D 02	0.1906D-08	0.1906D-44	0.0	0.2334E-22	0.2334E-22	0.1169E 13	0.0
-33	0.3827D 02	0.3106D-08	0.3106D-44	0.0	0.3827E-22	0.3827E-22	0.1900E 13	0.0
-34	0.5225D 02	0.4215D-08	0.4215D-44	0.0	0.5225E-22	0.5225E-22	0.2568E 13	0.0
-35	0.6494D 02	0.5196D-08	0.5196D-44	0.0	0.6494E-22	0.6494E-22	0.3164E 13	0.0
-36	0.7604D 02	0.6026D-08	0.6026D-44	0.0	0.7604E-22	0.7604E-22	0.3696E 13	0.0
-37	0.8526D 02	0.6670D-08	0.6670D-44	0.0	0.8526E-22	0.8526E-22	0.4026E 13	0.0
-38	0.9239D 02	0.7114D-08	0.7114D-44	0.0	0.9239E-22	0.9239E-22	0.4352E 13	0.0
-39	0.9724D 02	0.7334D-08	0.7334D-44	0.0	0.9724E-22	0.9724E-22	0.4345E 13	0.0
-40	0.9969D 02	0.7329D-08	0.7329D-44	0.0	0.9969E-22	0.9969E-22	0.4441E 13	0.0

IV. CONCLUSIONS

The adaptation of the computer program "TRUMP" to the Naval Postgraduate School IBM/360 Model 67 has been achieved, with success. Analytical temperature distributions of various transient and steady-state heat conduction problems compared very well with the results obtained from TRUMP. The complete adaptation has not yet been established, however. At present, punched output and plotted graphs have not been obtained. The computer solutions of the example problems did not require the use of subroutines CHEM, GEN, and FLOW. Thus, the adaptation of these subroutines is yet to be evaluated. Since, the accuracy of the solutions are dependent on the zoning, this effort can be reduced if an existing program "FED: A computer program to generate geometric input for the heat-transfer code TRUMP" by Dale A. Schauer [Reference 4] is adapted to the IBM/360 Model 67 version of TRUMP.

The example problems presented herein will provide a useful reference for preparation of input data for future problems.

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C**** LISTING 16050006 *****
C     FORTRAN              HEART    TRUMP LOGIC CONTROL SUB.  FORTRAN MON-40
C""   VERSION 02/20/68   17.3 FOR CDC-6600 ONLY.  (*XEQ OR *CONTROLLEE)
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 DFS
      REAL*8 TBS
      REAL*8 ERROR,ERRORX
      REAL*8 HMELT,A
      REAL*8 DELF1,DELF2
      REAL*8 NAME,CAPS
      REAL*8 FLOWN
      REAL*8 FB
      DIMENSION ABLOCK(12)
      REAL*8 ADATA,ABLOCK
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 AREA,DEL1,DEL2
      REAL*8 AREAS,HSURE
      REAL*8 TRANS
      COMMON /CURE/ EQCURE(355)
      COMMON /AFINK/ AREA(950),DEL1(950),DEL2(950),HINT(950),
     1       NOX1(950),NOX2(950),RINT(950)
      COMMON /ACHEMS/ KA(15),KAX(15),KB(15),KBX(15),
     1       P(355),BB(355),DB(355),DDB(355)
      COMMON /AFLOW/ DELF1(50),DELF2(50),FLAPS(50),FLOWT(12,50),
     1       FLINT(355),FLIPS(355),FLOPS(355),FLOUT(355),
     2       LTABFL(50),NOXF1(50),NOXF2(50),
     3       SLOFL(12,50),TVARFL(12,50)
      COMMON /APLOT/ NODEP(12),NOXEP(12)
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NP,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODES,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
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3          VOL(355),W(355),
4          DFI(950),FI(950),NOD1(950),NOD2(950),
5          F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
1          LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
2          TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
3  NOXMAT(355),
4          NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
1          NOXE(355),NTYPES(355),TT(355)
      COMMON /AFLOWS/ FLOWN(50),NODF1(50),NODF2(50)
      COMMON /ASPECK/ ERROR(355),ERRORX(355)
      COMMON /ASURE/   AREAS(60),HSURF(60),FB(20),TBS(20),
1          FS(60),HSURT(12,60),LTABH(60),NOXS(60),NODSB(60),
2          NOXSB(60),POWER(60),PSURE(60),SLOH(12,60),TVARH(12,60),
3          LTABT(20),NODB(20),SLOT(12,20),TB(20),TEMPB(12,20),
4          TIMEB(12,20)
      COMMON /ASURES/ DFS(60),TRANS(60),NODS(60)
      COMMON /AGEN/ GT(12,5),LTABG(5),NODG(5),NOXG(5),
1          SLOG(12,5),TVARG(12,5)
      COMMON /ACHEM/ AKEM(5),ET(12,5),KEM(5),LTABE(5),LTABQ(5),
1          LTABZ(5),QT(12,5),SLOE(12,5),SLOQ(12,5),
2          SLOZ(12,5),TVARE(12,5),TVARQ(12,5),
3          TVARZ(12,5),ZT(12,5),
4          EA(355),EB(355),QA(355),QB(355),ZA(355),ZB(355)
  806 FORMAT(10X,'KWIT...1=TIMAX, 2=TMAX, 3=TMIN, 4=S.S., 5=DATA, 6=CARD
     1 OR  KEY, 7=MCYC, 8=MSEC, 9=BLK 2 OR 4'/, 15X,'10=CONVERGENCE FAIL
     2URE, 11=PROBLEM LIMIT, 12= TABLE LENGTH')
  825 FORMAT(10X,14HMACHINE TIME (,A6,4H) = ,I5,2X,7HSECONDS)
  830 FORMAT(38X,39HTHIS DATA ADDS TO DATA ALREADY READ IN.)
  840 FORMAT(A5,I2,I1,12A6)
  845 FORMAT(10X,4HDATA,1X,A5,I3,I1,14X,12A6)
  850 FORMAT(38X,12A6)
  855 FORMAT(A1,14A5,A1,4A2)
  865 FORMAT(10X,100(1H=))
  905 FORMAT(10X,12HINPUT UNIT =,I4,16H.  OUTPUT UNIT =,I5,1H.)
  945 FORMAT(10X,17HEND OF TRUMP JOB.)
C$$$$$**************THIS IS INITIAL ENTRY POINT FOR /* XEQ/ JOBS.********
      M1=1
      M2=15
      M3=5
      M4=355
      M5=950
      M6=60
      M7=20
      M8=5
      M9=12
      M10=50
```

```
      M11=10
      M12=75
      DO 5 N=1,355
    5 EQCURE(N)=0.0
      NVARFL=0
      NOFLOW=0
      NVARO=0
      NVARZ=0
      NOGEN=0
      NKEM=0
      NOCON=0
      NOSCON=0
      NMELT=0
      NOSPEC=0
      NVARE=0
      NVARG=0
      NTABS=0
      NRS=5
      MW=6
  805 FORMAT(10X,10HENDED PROB,I5,5X,7HKCYC = ,I5,5X,7HKWIT = ,I2,5X,9HS
     1 UMTIM = ,E12.5)
   20 NPROB = 0
      NR = NRS
      M = MW
      NDATA=0
      NSAVE=0
   40 NPROB = NPROB + 1
      KCYC = -1
CCC   INITIALIZE CONTROL PARAMETERS.
      NCHECK=0
      NOW=0
      NOFF=0
      NDUMP=0
      NDISC=0
      NSTOP=0
      KWIT=0
      IBLOCK=0
      DO 45 N = 1,15
      NEWBL(N) = 0
   45 CONTINUE
      DO 48 N = 1,20
      NX1(N) =0
   48 CONTINUE
   50 READ(5,855)NAME
      WRITE(6,855)NAME
C--------COME HERE WHEN PROBLEM I. D. HAS BEEN READ IN.
   72 WRITE(6,905)NR,M
CCC   ZERO ALL COUNTERS WHEN NO DATA IS CARRIED OVER FROM LAST PROBLEM.
```

```
      NOSPEC=0
CCC   SAVE INITIAL NUMBER OF ITEMS IN EACH BLOCK.
  100 DO 102 N = 1,12
      ITEMS(N) = NOSPEC
  102 CONTINUE
C--------READ IN BLOCK NUMBER CARDS.
  105 WRITE(6,865)
  106 READ(5,840)ADATA,IBLOCK,MOE,ABLOCK
      IF(IBLOCK)107,3160,107
 3160 WRITE(6,850)ABLOCK
      GO TO 106
  107 WRITE(6,845)ADATA,IBLOCK,MOE,ABLOCK
      IF(IBLOCK)180,106, 3170
 3170 MODS = 0
      IF(MOE-1) 109,3180,109
 3180 MODS=1
      WRITE(6,830)
  109 MOE = MODS
      NB = NR
      NEWBL(IBLOCK) = NEWBL(IBLOCK) + 1
      IF(MOE)115, 3200,115
 3200 ITEMS(IBLOCK) = 0
C--------GO TO SUBROUTINES TO READ IN BLOCKS ITEMS.
  115 GO TO(165,120,140,120,150,160,160,130,165,155,170,120),IBLOCK
  120 CALL THERM
      GO TO 105
C READ IN BLOCKS 2, 4, 12.
  130 CALL GEN
      GO TO 105
C READ IN BLOCK 8.
  140 CALL CHEM
      GO TO 105
C READ IN BLOCK 3.
  150 CALL FINK
      GO TO 105
C READ IN BLOCK 5.
  155 CALL FLOW
      GO TO 105
C READ IN BLOCK 10.
  160 CALL SURE
      GO TO 105
C READ IN BLOCKS 6 AND 7.
  165 CALL TALLY
      GO TO 105
C READ IN BLOCKS 1 AND 9.
  170 CALL PLOT
      GO TO 105
C READ IN BLOCK 11.
```

```
C--------INITIALIZE BEFORE FIRST TIME STEP.
  180 WRITE(6,865)
      WRITE(6,865)
      CALL CLOCK(CLOCKB,CLOCKA)
       CALL CLOCK1(KSEC,CLICKA)
      KSECS = KSEC
      KSECD=MOD(86400+KSEC-KSECS,86400)
      WRITE(6,825)CLOCKA,KSECD
  190 CALL TALLY
      IF(KWIT - 9) 3230,400, 3230
 3230 CALL SPECK
C INITIALIZE
C--------INCREMENT CYCLE COUNTER, DO NEXT TIME STEP.
  200 KCYC = KCYC + 1
C--------RETURN HERE AFTER A TIME STEP IS REJECTED.
CCC   GO TO SUBROUTINES TO DO TIME STEP CALCULATIONS AND WRITE OUT DATA.
  210 CALL THERM
      IF(NOGEN)230,230, 3240
 3240 CALL GEN
C HEAT SOURCES.
  230 IF(NKEM)240,240, 3250
 3250 CALL CHEM
C CHEM REACTION.
  240 IF(NOCON)245,245, 3260
 3260 CALL FINK
C INTERNAL FLUX.
  245 IF(NOFLOW)250,250, 3270
 3270 CALL FLOW
C MASS FLOW.
  250 IF(NOSCON)255,255, 3280
 3280 CALL SURE
C SURFACE NODES.
  255 IF(NMELT)260,260, 3290
 3290 CALL THERM1
C PHASE CHANGE.1
  260 IF(NOSPEC)270,270, 3300
 3300 CALL SPECK
C SPECIAL NODES.
  270 IF(NMELT)280,280, 3310
 3310 CALL THERM2
C PHASE CHANGE.2
C--------MAKE CRT PLOTS WHEN REQUIRED.
  280 IF(NUP)300,300, 3320
 3320 IF(NSTOP)500, 3330,290
 3330 IF((KCYC-2)*MOD(KCYC-1,JPIC))3340,3340,300
 3340  IF(KCYC)300,300, 3350
 3350 CONTINUE
  290 CALL PLOT
```

```
C MAKE PLOTS.
  200 IF(NSTOP)500, 3360,400
 3360 IF(NDISC) 3370,310, 3370
 3370 KWIT = 6
  310 CALL TALLY
       IF(KWIT)210,200, 3380
 3380 IF((KWIT - 5)*(KWIT - 9)) 3390,400, 3390
 3390 NSTOP = 1
      GO TO 200
  400 KCYC = KCYC - 1
      WRITE(6,805)NPROB,KCYC,KWIT,SUMTIM
      WRITE(6,806)
      IF(M - MW) 3490,480, 3490
 3490 WRITE(6,805)NPROB,KCYC,KWIT,SUMTIM
  480 IF(NDISC) 3500, 3500,20
 3500 IF(NDUMP)500,500,500
C---------COME HERE WHEN JOB HAS BEEN COMPLETED.
  500 WRITE(6,945)
C     SINCE COMP. WORK IS MADE WITH DISK (NOT TAPE) THE FOLLOWING
C     TWO STATEMENTS ARE CHANGED TO COMMENT. SEPT 1971
C     END FILE 9
C     REWIND 9
      IF(M - MW) 3510,520, 3510
 3510 WRITE(6,945)
  520 WRITE(6,945)
      STOP
      END


      SUBROUTINE THERM
C     LIST 8
C     CARDS COLUMN         THERM VERSION 5/29/68.
C     FORTRAN              THERM   TRUMP MATERIAL AND NODE SUB. FORTRAN-400
CCC   VERSION  5/29/68.
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 NAME,CAPS
      REAL*8 HMX,DTX,DAX,EX
      REAL*8 HMELT,A
      REAL*8 FORD
      REAL*8 NAMEL(3)
      DIMENSION APROP(8)
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
```

```
      CCMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPPOB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),F1(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
      COMMON /ACHEMS/ KA(15),KAX(15),KB(15),KBY(15),
     1       B(355),BB(355),DB(355),DDB(355)
      DATA NAMEL/8H3        ,8H4        ,8HA=BLS   /
  800 FORMAT(A5,5I5,4E10.3,10A1)
  806 FORMAT(/10X95HNAME MATL INDEX  KA  KB LTABC LTABK   DENSITY       C
     *APACITY   CONDUCTIVITY   TMELT          HMELT)
  807 FORMAT(10X,A5,2I5,2I4,2I6,1P5E13.4)
  810 FORMAT (8E10.3)
  815 FORMAT(5I5,5X,5E10.3)
  816 FORMAT(//,12X,22HNODE INDEX MATL NTYPE,4X,5HDLONG,10X,5HDWIDE,
     $    10X,4HDRAD,11X,6HVOLUME)
  817 FORMAT(10X,4I6,1P4E15.5)
  825 FORMAT(10X,100(1H=))
  828 FORMAT(10X,9HNODE DATA)
  830 FORMAT(/,10X, 95HNODE  MATL NTYPE   RADIUS        VOLUME       MASS
     $      CAPACITY  CONDUCTIVITY    ZIP           SLIM)
  835 FORMAT(10X,3I5,1X,7E12.4)
  840 FORMAT(//,11X,29HNODP1 NODP2 INDEX NPROP  PROP)
  845 FORMAT(7I5)
  850 FORMAT(10X,4I6,2X,A6)
  860 FORMAT(//,10X,16HMATERIAL SUMMARY,//,12X,92HNAME  MATL NODES   DEN
     $SITY       CAPACITY      TOT VOL       TOT MASS      TOT CAP       TOT
     $HEAT)
  870 FORMAT(10X,A6,2I6,1P6E13.5)
```

```
  876 FORMAT(/17X12HCONDUCTIVITY5X5HSLOPE9X5HTVARK/,(15X1P3E15.6))
  880 FORMAT(10X,13HMATERIAL DATA,//,12X,10HNAME  MATL,5X,7HTOT CAP,
     1    8X,8HTOT HEAT,7X,8HAVG TEMP,7X,5HTMELT,10X,5HHMELT)
  885 FORMAT(/,10X,12HSYSTEM TOTAL,I6,26X,1P4E13.5)
  890 FORMAT(10X,A6,I6,1P5E15.5)
  899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
  941 FORMAT(/19X65HCAPACITY          SLOPE                ENERGY              SLOPE
     $             TVARC/,(15X1P5E15.6))
      IF(KCYC) 3000,100,200
 3000 IF(IBLOCK - 2) 3010,10, 3010
 3010 IF(IBLOCK - 4) 3020,70, 3020
 3020 IF(IBLOCK - 12)7, 3030,7
 3030 CONTINUE
CARD BLOCK 12.  TABLE LOOK-UP CONNECTIONS.
      N= NTABS
      L = 0
      IF(MOE)1, 3040,1
 3040 NTABS=0
      N=NTABS
    1 READ(5,845)N1,N2,NP,NSEQ,NADP1,NADP2,NADPR
      IF(N1) 3050,7, 3050
 3050 CONTINUE
    2 IF(MOE) 3060,3,3
 3060 CALL SEEK2(N,N1,N2,NOXP1,NOXP2,NTABS,K)
      ITEMS(12)=MIN0(N-1,ITEMS(12))
      GO TO 4
    3 NTABS=N+1
      N=NTABS
    4 IF(N - M12)5,5, 3070
 3070 NTABS=M12
      N=M12
      KWIT= 11
      WRITE(6,899)N, IBLOCK
    5 NOXP1(N)=N1
      NODP1(N)=NOXP1(N)
      NOXP2(N)=N2
      NODP2(N)=NOXP2(N)
      NPROP(N) =NP
      L= L + 1
      IF(MOD(L-1,57))6,3080,6
 3080 WRITE(6,840)
    6 WRITE(6,850)NODP1(N),NODP2(N),N,NPROP(N),APROP(NP)
      IF(NSEQ)1,1, 3090
 3090 NSEQ = NSEQ - 1
      N1 = N1 + NADP1
      N2 = N2 + NADP2
      NP = NP + NADPR
      GO TO 2
```

```
    7 RETURN
C COMPLETED BLOCK 12.
CARD BLOCK 2.  MATERIAL NAMES,NUMBERS,CHEMICAL  COMPONENTS,THERM PROP.
   10 N= NMAT
      LABEL = 1
      IF(MOE)12, 3100,12
 3100 NMAT=0
      NVARK=NMAT
      NVARC=NVARK
      NMELT=NVARC
      N=NMELT
   12 READ(5,800)A1,N1,K1,K2,L1,L2,P1,P2,P3,P4,NX1
      IF(N1) 3110,68, 3110
 3110 IF(MOE) 3120,20,20
 3120 CALL SEEK1(N,N1,MAT,NMAT,K)
      IF(K)18,18, 3130
 3130 IF(HMELT(N)) 3140,14, 3140
 3140 NMELT = NMELT - 1
   14 IF(LTABC(N)) 3150,16, 3150
 3150 NVARC = NVARC - 1
   16 IF(LTABK(N)) 3160,18, 3160
 3160 NVARK = NVARK - 1
   18 ITEMS(2)=MIN0(N-1,ITEMS(2))
      GO TO 22
   20 NMAT=N+1
      N=NMAT
   22 IF(N - M2)25,25, 3170
 3170 NMAT=M2
      N=NMAT
      KWIT = 11
      WRITE(6,899)N,IBLOCK
   25 AMAT(N) = A1
      MAT(N) = N1
      KAX(N)=K1
      KA(N)=KAX(N)
      KBX(N)=K2
      KB(N)=K2
      LTABC(N)=L1
      LTABK(N)=L2
      DENS(N) = P1
      CAPT(1,N) = P2
      CONT(1,N) = P3
      TMELT(N) = P4
      CALL PATCH(NX1,0.0,P5,LBX)
      HMELT(N)=ABS(P5)
      IF(LABEL)30,30, 3180
 3180 LABEL = 0
      WRITE(6,806)
```

```
   30 WRITE(6,807)AMAT(N),MAT(N),N,KA(N),KB(N),LTABC(N),
     $ LTA3K(N),DENS(N),CAPT(1,N),CONT(1,N),TMELT(N),HMELT(N)
      IF(HMELT(N)) 3190,35, 3190
 3190 NMELT = NMELT + 1
      KB(N)=0
      KA(N)=KB(N)
   35 LTAB=IABS(LTABC(N))
      IF(LTAB - 2) 3200,38,38
 3200 LTABC(N) = 0
      GO TO 62
   38 NVARC = NVARC + 1
      LABEL = 1
      READ(5,810) (CAPT(J,N),TVARC(J,N),J=1,LTAB)
      DO 40 J = 2,LTAB
      SLOC(J,N) = (CAPT(J,N)-CAPT(J-1,N))/(TVARC(J,N)-TVARC(J-1,N))
   40 CONTINUE
      SLOC(1,N) = SLOC(2,N)
CCC   FIND ENERGY PEFERRED TO TVARC(1,N)
   42 IF(LTABC(N))60,60, 3210
 3210 WT(1,N) = 0.0
      DO 44 J = 2,LTAB
      F3(J) = 0.5*(CAPT(J,N) + CAPT(J-1,N))
      WT(J,N) = WT(J-1,N) + F3(J)*(TVARC(J,N) - TVARC(J-1,N))
   44 CONTINUE
      F3(1) = F3(2)
CCC   FIND CALCULATED ENERGY AT ZERO DEGREES
      DO 50 J= 1,LTAB
      J=J
      IF(TVARC(J,N)) 3220,54,52
 3220 CONTINUE
   50 CONTINUE
   52 CAPX = CAPT(J,N) - 0.5*SLOC(J,N)*TVARC(J,N)
      CORR = WT(J,N) - CAPX*TVARC(J,N)
      GO TO 56
   54 CORR = WT(J,N)
CCC   CALCULATE HEAT CONTENT RELATIVE TO ZERO DEGREES.
   56 DO 58 J= 1,LTAB
      WT(J,N) = WT(J,N) - CORR
   58 CONTINUE
   60 WRITE(6,941)(CAPT(J,N),SLOC(J,N),WT(J,N),F3(J),
     *   TVARC(J,N), J = 1,LTAB)
      IF(LTAB - M9)62,62, 3230
 3230 KWIT = 12
   62 LTAB=IABS(LTABK(N))
      IF(LTAB - 2) 3240,64,64
 3240 LTABK(N) = 0
      GO TO 12
   64 NVARK = NVARK + 1
```

```
       LABEL = 1
      READ(5,810) (CONT(J,N),TVARK(J,N),J=1,LTAB)
      DO 65 J = 2,LTAB
      SLOK(J,N) = (CONT(J,N)-CONT(J-1,N))/(TVARK(J,N)-TVARK(J-1,N))
   65 CONTINUE
      SLOK(1,N) = SLOK(2,N)
      WRITE(6,876)(CONT(J,N),SLOK(J,N),TVARK(J,N),J=1,LTAB)
      IF(LTAB-M9)12,12, 3250
 3250 KWIT = 12
      GO TO 12
   68 NEWBL(4) = NEWBL(4) + 1000
      RETURN
C COMPLETED BLOCK 2.
CARD BLOCK 4. NODE NUMBERS,MATERIALS,DIMENSIONS,INIT. T, A, B, G.
   70 N = NODES
      L= 0
      IF(MOE)74, 3260,74
 3260 NOSPEC=0
      NODES=NOSPEC
      N=NODES
   74 READ(5,815)N1,NSEQ,NADD,N2,KS,DLONG,DWIDE,DRAD
      IF(N1) 3270,94, 3270
 3270 ADD = 0.0
      IF(DRAD) 3280,75,75
 3280 ADD = -(DRAD + DRADS)
      DRAD = DRADS
   75 IF(MOE) 3290,80,80
 3290 CALL SEEK1(N,N1,NODE,NODES,K)
      IF(K)78,78,3300
 3300 IF(NTYPE(N)) 3310,78, 3310
 3310 NOSPEC =NOSPEC - 1
   78 ITEMS(4)=MIN0(N-1,ITEMS(4))
      GO TO 82
   80 NODES=N+1
      N=NODES
   82 IF(N - M4)84,84, 3320
 3320 NODES=M4
      N=M4
      KWIT=11
      WRITE(6,899)N,IBLOCK
   84 NODE(N) = N1
      NOXMAT(N)=N2
      NODMAT(N)=NOXMAT(N)
      DO 86 J = 1,8
      NLOOK(N,J) = N
   86 CONTINUE
      T(N) = TONE
       A(N) = ALONE
```

```
      B(N) = BONE
      G(N) = GONE
      NTYPE(N) = 0
      DRAD=DRAD+ADD
      DRADS=DRAD
      RADIUS(N) = DRAD*SCALE
      VOL(N) = GEOM*DLONG*DWIDE*DRAD**KSYM*SCALE**3
      IF(VOL(N))88, 3330,88
 3330 VOL(N) = 1.0E-24
       NTYPE(N) = 2
       NOSPEC = NOSPEC + 1
       GO TO 89
   88 IF(KS) 3340, 89, 3340
 3340  NTYPE(N) = 3
       NOSPEC = NOSPEC + 1
   89 L = L + 1
      IF(MOD(L-1,57))90,3350,90
 3350 WRITE(6,816)
   90 WRITE(6,817)NODE(N),N,NODMAT(N),NTYPE(N),
     $ DLONG,DWIDE,DRAD,VOL(N)
      IF(NSEQ)74,74, 3360
 3360 NSEQ = NSEQ - 1
      N1 = N1 + NADD
      GO TO 75
   94 NX=NEWBL(7)
      DO 95 N = 5,12
      NEWBL(N) = NEWBL(N) + 1000
   95 CONTINUE
      NEWBL(7) = NX
      NEWBL(1) = NEWBL(1) + 1000
      RETURN
C COMPLETED BLOCK 4. RETURN TO HEART.
  100 IBLOCK = 4
      CALL REFER(NODMAT,NOXMAT,NODES,MAT,NMAT)
      IF(NTABS)140,140,3370
 3370 IBLOCK = 12
      CALL REFER(NODP1,NOXP1,NTABS,NODE,NODES)
      CALL REFER(NODP2,NOXP2,NTABS,NODE,NODES)
      IF(KWIT)600, 3380,600
 3380 DO 135 N = 1,NTABS
      J= NODP1(N)
      K= NPROP(N)
      NLOOK(J,K) = NODP2(N)
  135 CONTINUE
CCC   CALC. NODE MASSES, CAPACITIES, CONDUCTIVITIES.
  140 IF(KWIT)600, 3390,600
 3390 DO 150 N = 1,NODES
       J = NODMAT(N)
```

```
      ZIP(N) = 0.0
      HEFT(N) = VOL(N)*DENS(J)
      IF(HEFT(N)) 3400, 3400,142
 3400 HEFT(N) = 1.0E-36
  142 CAP(N) = HEFT(N)*CAPT(1,J)
      IF(CAP(N)) 3410, 3410,144
 3410 CAP(N) = 1.0E-36
  144 W(N) = CAP(N)*T(N)
      CON(N) = CONT(1,J)
      IF(CON(N)) 3420, 3420,150
 3420 CON(N) = 1.0E-24
  150 CONTINUE
CCC   FIND AND WRITE OUT TOTAL NODES, VOLUME, MASS, CAP OF EACH MATL.
      WRITE(6,860)
      HEFTS=0.0
      VOLS=0.0
      HEAT=0.0
      CAPS=0.0
      DO 170 K = 1,NMAT
      WMS=0.0
      CAPMS=WMS
      HEFTMS=CAPMS
      VOLMS=HEFTMS
      NODMS=VOLMS
      DO 160 N = 1,NODES
       IF(NODMAT(N) - K)160, 3430,160
 3430 NODMS = NODMS + 1
      VOLMS = VOLMS + VOL(N)
      CAPMS = CAPMS + CAP(N)
      HEFTMS = HEFTMS + HEFT(N)
      WMS = WMS + W(N)
  160 CONTINUE
      CAPS = CAPS + CAPMS
      VOLS = VOLS + VOLMS
      HEFTS = HEFTS + HEFTMS
      HEAT = HEAT + WMS
      IF(CAPMS)170,170, 3440
 3440 WRITE(6,870)AMAT(K),MAT(K),NODMS,DENS(K),
     $CAPT(1,K),VOLMS,HEFTMS,CAPMS,WMS
  170 CONTINUE
      WRITE(6,885)NODES,VOLS,HEFTS,CAPS,HEAT
CCC  START EACH NEW PROBLEM  WITH PHASES IN EQUILIBRIUM.
      IF(NMELT) 3450,200,3450
 3450 IF(1.-0.)200,3451,200
 3451 IF(NAME(16)-NAMEL(1))3455,200,3455
 3455 IF(NAME(16)-NAMEL(2))3460,200,3460
 3460 IF(NAME(15)-NAMEL(3))3470,200,3470
 3470 CONTINUE
```

```
C COLUMNS 67-71, RETAIN BLOCK 9 A.
      DO 190 N = 1,NODES
       J = NODMAT(N)
      IF(HMELT(J)) 3480,190, 3480
 3480 A(N) = 1.0
      IF(T(N)-TMELT(J))190,190, 3490
 3490 A(N) = 0.0
  190 CONTINUE
  200 FORD = FOR*DELT
      IF(KWIT)215, 3500, 3500
 3500 IF(NOW)215,215, 3510
 3510 IF(KCYC - 1)215,202, 3520
 3520  IF(KDATA)215, 3530, 3530
 3530 CONTINUE
CCC   FIND, WRITE TOTAL CAP, HEAT CONTENT, AVG TEMP OF EACH MATL.
  202 WRITE(6,880)
      DO 210 K = 1,NMAT
      TMS=0.0
      WMS=TMS
      CAPMS=WMS
      DO 205 N = 1,NODES
       IF(NODMAT(N)-K)205, 3540,205
 3540 CAPMS = CAPMS + CAP(N)
      WMS= WMS + W(N)
      TMS = TMS + CAP(N)*T(N)
  205 CONTINUE
      IF(CAPMS)210,210, 3550
 3550 TMS = TMS/CAPMS
      WRITE(6,890)AMAT(K),MAT(K),CAPMS,WMS,TMS,
     1   TMELT(K),HMELT(K)
  210 CONTINUE
      WRITE(6,825)
CCC   INITIALIZE HEAT CONTENT, CHANGES IN T, A, B AND FLUX EACH CYCLE.
  215 DO 220 N = 1,NODES
      DF(N)=0.0
      DT(N)=0.0
      DB(N)=0.0
      DA(N)=0.0
      KOP1=NODMAT(N)
      IF(LTABC(KOP1))220,3560,220
 3560 W(N)=CAP(N)*T(N)+HMELT(KOP1)*HEFT(N)*(1.0-A(N))
  220 CONTINUE
CCC   WRITE OUT DATA ON PRINT-OUT CYCLES.
      IF(NOW)228,228, 3570
 3570  IF(KCYC - 1)228,222, 3580
 3580  IF(KDATA)228,228, 3590
 3590 IF(NVARC + NVARK + NVARH + NORAD + NORADS)228,228, 3600
 3600 CONTINUE
```

```
CCC    WRITE OUT PROPERTIES OF EACH NODE.
  222 WRITE(6,828)
      DO 225 N = 1,NODES
      IF(MOD(N-1,57))224,3610,224
 3610 WRITE(6,830)
  224 WRITE(6,835)NODE(N),NOXMAT(N),NTYPE(N),RADIUS(N),
     1   VOL(N), HEFT(N), CAP(N), CON(N), ZIP(N), SLIM(N)
  225 CONTINUE
      WRITE(6,825)
CCC   FIND NEW NODE HEAT CAPACITIES, HEAT CONTENT
  228 IF(NVARC)300,300, 3620
 3620 DO 280 N = 1,NODES
       J = NODMAT(N)
       K = NLOOK(N,1)
      IF(LTABC(J)) 3630,280,230
 3630 SET = SUMTIM + FORD
      GO TO 235
  230 EX = FORD*DDT(K)
      SET = T(K) + EX
  235 CAPS = CAPS - CAP(N)
       BET = CAP(N)
      BETW = W(N)
      MIN = 1
      MAX=IABS(LTABC(J))
  240 MID = (MIN + MAX)/2
       IF(SET - TVARC(MID,J))250,270,260
  250 MAX = MID
       IF(MAX - 2)270,240,240
  260 MIN = MID
       IF(MAX - MIN - 2)270,240,240
  270 CAPX = CAPT(MID,J) + SLOC(MID+1,J)*(SET - TVARC(MID,J))
      CAP(N) = HEFT(N)*CAPX
      IF(CAP(N)) 3640, 3640,272
 3640 CAP(N) = 1.0E-36
  272 IF(LTABC(J))275,280, 3650
 3650 CAPX = 0.5*(CAPT(MID,J) + CAPX - SLOC(MID+1,J)*EX)
      W(N) = HEFT(N)*(WT(MID,J) + CAPX*(SET - EX - TVARC(MID,J)))
      W(N) = W(N) + HEFT(N)*HMELT(J)*(1.0 - A(N))
  275 CAPS = CAPS + CAP(N)
      BETW=ABS(BETW-W(N))/BET
      BET=100.0*DABS(BET-CAP(N))/BET
      DTMAX=AMAX1(DTMAX,BET*TVARY)
      DTMAX=AMAX1(DTMAX,BETW)
  280 CONTINUE
CCC   FIND NEW NODE THERMAL CONDUCTIVITIES.
  300 IF(NCCON*NVARK)600,600, 3660
 3660 DO 380 N = 1,NODES
       J = NODMAT(N)
```

```
      K = NLOOK(N,2)
      IF(LTABK(J)) 3670,380,320
 3670  SET = SUMTIM + FORD
      GO TO 330
  320 SET = T(K) + FORD*DDT(K)
  330 MIN = 1
      MAX=IABS(LTABK(J))
      BET = CON(N)
  340 MID = (MIN + MAX)/2
       IF(SET - TVARK(MID,J))350,370,360
  350 MAX = MID
       IF(MAX - 2)370,340,340
  360 MIN = MID
       IF(MAX - MIN - 2)370,340,340
  370 CON(N) = CONT(MID,J) + SLOK(MID+1,J)*(SET - TVAPK(MID,J))
      IF(CON(N)) 3680, 3680,375
 3680 CON(N) = 1.0E-24
  375 SCON=CON(N)
      BET=100.0*ABS(BET-SCON)/BET
      DTMAX=AMAX1(DTMAX,BET*TVARY)
  380 CONTINUE
  600 RETURN
      ENTRY THERM1
      IF(KWIT) 3690,3690,600
 3690 CONTINUE
CCC   ESTIMATE EFFECT OF PHASE CHANGE IN NODE TEMPS,SAVE AS DDA.
      DO 660 N= 1,NODES
       J = NODMAT(N)
       IF(HMELT(J)) 3700,660, 3700
 3700 IF(NTYPE(N) - 2)610, 3710,610
 3710 DDA(N) = 0.0
      GO TO 660
  610 HMX = HEFT(N)*HMELT(J)/CAP(N)
      DTX = T(N) + DELT*(DDT(N) - HMX*DDA(N)) - TMELT(J)
      DDA(N)=HMX*DMAX1(-A(N),DMIN1(-DTX/HMX,1.0-A(N)))
      DT(N) = DT(N) + DDA(N)
  660 CONTINUE
       RETURN
C COMPLETED THERM1.  RETURN TO HEART.
      ENTRY THERM2
      IF(KWIT) 3720,3720,600
 3720 CONTINUE
CCC   FIND EFFECT OF PHASE CHANGE ON CONCENTRATION AND TEMP IN NODES.
      DO 760 N = 1,NODES
       J = NODMAT(N)
       IF(HMELT(J)) 3730,760, 3730
 3730 DT(N) = DT(N) - DDA(N)
      DDA(N) = 0.0
```

```
      DTX = T(N) + DT(N) - TMELT(J)
      HMX = HEFT(N)*HMELT(J)/CAP(N)
  710 IF(NTYPE(N) - 2)740, 3740,740
 3740 HMX=1.0E-06*DABS(DTX)
  740 DAX=DMAX1(-A(N),DMIN1(-DTX/HMX,1.0-A(N)))
      IF(DAX) 3750,760, 3750
 3750 ABDT=DABS(DT(N))
      DTMAX=AMAX1(DTMAX,ABDT)
      DT(N) = DT(N) + DAX*HMX
      DA(N) = DA(N) + DAX
  760 CONTINUE
      RETURN
C COMPLETED THERM2. RETURN TO HEART.
      END


      SUBROUTINE TALLY
C     CARDS COLUMN       TALLY STD VERSION 5/29/68
C     LIST 8
C     FORTRAN            TALLY   TRUMP CALC. CONTROL SUB.      FORTRAN-400
CCC   STD VERSION 5/29/68.  (DO NOT USE WITH TRUMP/DS VERSION.)
CCC   5/14/68  ADDED TEST AT 225 TO COMPARE SMALL WITH SMALT.
CCC   5/29/68 CHANGED NSTORE CALC AND FORMAT TO CORRECT FOR REMOVAL OF
CCC           ARRAY SLOW(M9,12) FROM COMMON ATHERM.
      REAL*8 HMELT,A
      REAL*8 HMX
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 NAME,CAPS
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 TMM,CNN
      REAL*8 DFFF(355)
      COMMON /CURE/ EQCURE(355)
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKFM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
```

```
3         TMAX,TMIN,TONE,TVARY
  COMMON  HMELTX(15),LTABK(15),
1         NLOOK(355,8),NODE(355),
2         NODMAT(355),NTYPE(355),RADIUS(355),
3         VOL(355),W(355),
4         DFI(950),FI(950),NOD1(950),NOD2(950),
5         F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
  COMMON  AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
1         LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
2         TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
3  NOXMAT(355),
4         NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
  COMMON  AA(355),F(355),GG(355),H(355),NOTE(355),
1         NOXE(355),NTYPES(355),TT(355)
  COMMON  /ACHEMS/ KA(15),KAX(15),KB(15),KBX(15),
1         R(355),BB(355),DR(355),DDF(355)
803 FORMAT(/10X5HCYCLEI5,10H MADE NODEI5,15H \ SPECIAL NODE)
805 FORMAT(//10X,25HINPUT ERROR, MATERIALS =,I5,10H, NODES = ,I5,1H.)
810 FORMAT (8E10.3)
811 FORMAT(//12X89H TONE          ALONE          BONE          GONE          FO
   $NE          HONE          RONE          PONE/10X1P8E12.4)
812 FORMAT(1H1,9X,17HTRUMP OUTPUT DATA,69X,9HDATA DECK,I5,//,
   1    10X,A1,14A5,A1,4A2,4X,2(2X,A6))
815 FORMAT(/,10X,59H PRINTOUT     CYCLE   TOO FAST  TOO SLOW      KWIT
   $    DELTMX,10X,5HSMALL,11X,5HTVARY,6X,4HNUTS,/,7X,5I10,1P3E16.5,I5)
820 FORMAT(/,10X,87H    TOTAL TIME       TIME STEP      HEAT FLOW     TEMP
   $ FROM FLUX   FLUX RATE       TEMP RATE,/,8X,1P6E15.5,//,
   *10X,89H   AVG TEMP      HEAT CAPACITY   HEAT CONTENT     GEN RATE
   $     HEAT GEN      TEMP FROM GEN,/,8X,1P6E15.5)
830 FORMAT(28HBLOCK 9.  T, A, B, G AT TIME,20X,1PE13.5,5X,I6)
835 FORMAT (3I5,5X,40A1)
836 FORMAT(//,12X,10HNOTE INDEX,10X,2HTT,13X,2HAA,13X,2HPB,13X,2HGG)
837 FORMAT(10X,2I6,4X,1P4E15.6)
840 FORMAT(I5,15X,1P4E10.3)
850 FORMAT(2H**,5X,A1,5A5,15X,2A6)
855 FORMAT(9I5,15X,E10.3)
860 FORMAT (2I5,7E10.3)
861 FORMAT(//11X,95H KD    KT       DELTO          SMALL          TVARY
   $  TAU           TIMAX         TMIN         TMAX,/,10X2I5,1P7E13.5)
862 FORMAT(//10X45H    KD KSYM     GEOM           SIGMA          TBASE,/,
   $ 10X2I5,1P3E13.5)
865 FORMAT(10X,12HFINAL HEAT =,1PE15.5,5X,12HFINAL FLOW =,E15.5)
870 FORMAT(//10X,54HIPRINT   NUM KDATA KSPEC  MCYC  MSEC NPUNCH NDOT I
   1RITE,22X,5HSCALE,/,10X,9I6,18X,E13.5)
875 FORMAT(//,10X,94H  NODE     TEMP          NODE    TEMP          NODE
   $ TEMP          NODE    TEMP          NODE    TEMP,/,(10X,I6,1PE14.5,
   $ I6,E14.5,I6,E14.5,I6,E14.5,I6,E14.5))
880 FORMAT(/12X,93HNODE          TEMP          W/F A         DA          D
```

```
     $DA             W/F B          DB                DDB)
 882 FORMAT(10X,I6,3X,1P7E13.4)
 885 FORMAT(/7X,112HNODE          TEMP          DT              DDT         GE
    1N RATE        W              H              F          CURE AT 280 F)
 886 FORMAT(5X,I6,3X,8E13.4)
 890 FORMAT(5X,115(1H=))
 899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
 900 FORMAT(/,26X,31HMAXIMUM ALLOWED TABLE LENGTH IS,I4,1H.)
 905 FORMAT(/,10X,94HARRAY STORAGE = 3*M11+M1*(1+M11)+M2*(11+7*M9)+M3*(
    15+9*M9)+56*M4+12*M5+M6*(12+3*M9)+M7*(5+3*M9),/,
    2   26X,38H+M8*(3+3*M9)+M10*(9+3*M9)+5*M12+3*M9 =,I8,1H.)
 910 FORMAT(/,10X,6HTABLES,10X,60H  CAPT  CONT    QT    ZT      ET HSURT
    1TEMPB    GT FLOWT TOTAL,/,26X,10I6)
 915 FORMAT(//10X,21HSUMMARY OF INPUT DATA,/10X12HBLOCK NUMBER,4X11I6)
 920 FORMAT(10X,12HMAXIMUM SIZE,4X,11I6)
 925 FORMAT(10X,12HINITIAL SIZE,4X,11I6)
 926 FORMAT(10X,15HUNMODIFIED SIZE,1X,11I6)
 930 FORMAT(10X,12HFINAL SIZE  ,4X,11I6)
 935 FORMAT(10X,12HITEM NAME   ,4X,66H  MAT   KEM  NODE  NOD1  NODS  N
    1ODB  NODG  NOTE NODF1 NODEP NODP1)
 940 FORMAT(/10X,12HOTHER TOTALS,4X,36HNOSPEC NOGEN NORAD NORADS NMELT
    1NRFACT,/,26X,6I6)
 945 FORMAT(10X,13HTIMES READ IN,3X,11(2X,I4))
 950 FORMAT(10X,17HWILL REPEAT CYCLE,I6,4X,8H DTMAX =,1PE10.3,
    1   8H DTPRE =,E10.3,7H DELT =,E10.3,9H SUMTIM =,E10.3)
 955 FORMAT(5(1H*),4HNODE,I6,2X,16HT,DDT,A,B,G,EO =,1P6E12.4,
    1     1X,7HAT TIME,E12.4)
     IF(KCYC) 3000,160,200
3000 IF(IBLOCK)100,3010,30
3010 WRITE(6,915) (I,I=2,12)
     WRITE(6,935)
     WRITE(6,925) (ITEMS(I),I=2,12)
     NIT = NODES
     IF(NOW - 2)15,3020,15
3020 CONTINUE
C NOW = NAME(16)
CCC  RESTORE NODE TYPE TO INITIAL VALUE OF PREVIOUS PROBLEM.
     DO 10 N = 1,NODES
     IF(NTYPE(N)-NTYPES(N)) 3030,10, 3030
3030 NTYPE(N)=NTYPES(N)
     NOSPEC=NOSPEC-1
  10 CONTINUE
     GO TO 25
CCC  CHANGE INTERNAL BLOCK 9 TO FINAL T, A, B, OF PREVIOUS PROBLEM.
  15 DO 20 N = 1,NODES
     TT(N) = T(N)
     AA(N) = A(N)
     BB(N) = B(N)
```

```
   20 CONTINUE
   25 RETURN
   30 IF(IBLOCK - 9) 3040,91, 3040
 3040 IF(IBLOCK - 1)400, 3050,400
 3050 CONTINUE
CARD BLOCK 1. PROBLEM LIMITS, CONTROLS, CONSTANT I.C. AND B.C.
CCC   IRITE ONLY USED IN TRUMP/6600/DS VERSION.
      NIT=0
      READ(5,855) IPRINT,NUM,KDATA,KSPEC,MCYC,
     $  MSEC,NPUNCH,NDOT,IRITE,SCALE
      IPRINT=MAX0(1,IPRINT)
      NUMX = NUM
      KDATAX = KDATA
      IF(SCALE) 3060, 3060,32
 3060 SCALE = 1.0
   32 IF(MCYC) 3070, 3070,36
 3070 MCYC = 30000
   36 IF(MSEC) 3080, 3080,40
 3080 MSEC = 30000
   40 WRITE(6,870) IPRINT,NUM,KDATA,KSPEC,MCYC,MSEC,
     1   NPUNCH,NDOT,IRITE,SCALE
      READ(5,860) KD,KT,DELTO,SMALL,TVARY,TAU,TIMAX,TMIN,TMAX
      KD=MAX0(1,KD)
      KT=MAX0(1,KT)
      KSYM = (KD + 3)/3
      GEOM = 2.0**(KD - 1)*3.1415926**(KD/2)
      IF((DELTO -1.0E-10)*(DELTO - 1.0E12))50,50,3090
 3090  DELTO = 1.0E12
   50 SMALL=AMAX1(SMALL,1.0E-12)
       SMALT = SMALL
      IF(TMAX - TMIN) 3100, 3100, 60
 3100  TMAX = 1.0E12
       TMIN =-1.0E12
   60 IF(TIMAX) 3110, 3110, 65
 3110  TIMAX = 1.0E06*DELTO
   65 IF(TVARY) 3120, 3120, 70
 3120 TVARY=AMIN1(5.0,0.005*(TMAX-TMIN))
   70 WRITE(6,861)KD,KT,DELTO,SMALL,TVARY,TAU,TIMAX,TMIN,TMAX
      TMIN = TMIN - 0.001*TVARY
       TMAX = TMAX + 0.001*TVARY
      GO TO(81,82,83,84,85),KT
   81 TBASE = 273.15
       SIGMA = 1.355E-12
      GO TO 90
   82 TBASE = 0.0
       SIGMA = 1.355E-12
      GO TO 90
   83 TBASE = 460.0
```

```
      SIGMA = 0.173E-8
     GO TO 90
  84 TBASE = 0.0
      SIGMA = 0.173E-8
     GO TO 90
  85 TBASE = 0.0
      SIGMA = 1.0
  90 WRITE(6,862)KD,KSYM,GEOM,SIGMA,TBASE
     READ(5,810)TONE,ALONE,BONE,GONE,FONE,HONE,RONE,PONE
     WRITE(6,811)TONE,ALONE,BONE,GONE,FONE,HCNE,RONE,PONE
     RETURN
C COMPLETED BLOCK 1. RETURN TO HEART.
CAPD BLOCK 9. INITIAL VALUES OF T, A, B, AND G.
  91 N = NIT
     L = 0
     IF(MOE)92, 3130,92
3130 NIT=0
     N=0
  92 READ(5,835)N1,NSEQ,NADD,NX1,NX2,NX3,NX4
     IF(N1) 3140,98, 3140
3140 CALL PATCH(NX1,TONE,TX,LXX)
     CALL PATCH(NX2,ALONE,AX,LXX)
     CALL PATCH(NX3,BONE,BX,LXX)
     CALL PATCH(NX4,GONE,GX,LXX)
  93 IF(MOE) 3150,94,94
3150 CALL SEEK1(N,N1,NOXE,NIT,K)
     ITEMS(9)=MIN0(N-1,ITEMS(9))
     GO TO 95
  94 NIT=N+1
     N=N+1
  95 IF(N - M4)96,96, 3160
3160 NIT=M4
     N=M4
     KWIT= 11
     WRITE(6,899)N, IBLOCK
  96 NOXE(N)=N1
     NOTE(N)=N1
     TT(N) = TX
     AA(N) = AX
     BB(N) = BX
     GG(N) = GX
     L = L + 1
     IF(MOD(L-1,57))97,3170,97
3170 WRITE(6,836)
  97 WRITE(6,837)NOTE(N),N,TT(N),AA(N),BB(N),GG(N)
     IF(NSEQ)92,92, 3180
3180 NSEQ = NSEQ - 1
     N1 = N1 + NADD
```

```
      GO TO 93
   98 RETURN
C COMPLTED BLOCK 9.
  100 WRITE(6,915)(I,I=2,12)
      WRITE(6,945)(NEWBL(I),I=2,12)
      WRITE(6,935)
      WRITE(6,920)M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12
      WRITE(6,926)(ITEMS(I),I=2,12)
      NTABLE =NVARC+NVARK + NVARQ+NVARZ+NVARE + NVARH+NVART+NVARG+NVARFL
      WRITE(6,910)NVARC,NVARK,NVARQ,NVARZ,NVARE,NVARH,
     1   NVART,NVARG,NVARFL,NTABLE
      WRITE(6,900)M9
      IF(NMAT)102,102, 3190
 3190 IF(NODES) 3200,3200,105
 3200 CONTINUE
  102 KWIT = 9
C     IN FOLLOWING WRITE STATEMENT LOGICAL UNIT NUMBER 3 IS
C     CHANGED TO 6.SEPT 1971
      WRITE(6,805)NMAT,NODES
      RETURN
C MISSING BLOCK 2 OR 4.  RETURN TO HEART.
  105 IF(NUM) 3210,108, 3210
 3210 IBLOCK = 1
      CALL REFER(NUM,NUMX,1,NODE,NODES)
  108 IF(NIT)115,115, 3220
 3220 IBLOCK = 9
      CALL REFER(NOTE,NOXE,NIT,NODE,NODES)
      IF(KWIT)130, 3230,130
 3230 CONTINUE
C ASSIGN INITIAL CONDITIONS TO NODES.
      DO 110 N = 1,NIT
      J = NOTE(N)
      T(J) = TT(N)
      A(J) = AA(N)
      B(J) = BB(N)
      G(J) = GG(N)
  110 CONTINUE
CCC   SET UP INTERNAL BLOCK 9 WITH INITIAL CONDITIONS OF THIS PROBLEM.
  115 DO 120 N = 1,NODES
      NOTE(N) = N
      NOXE(N) = NODE(N)
      TT(N) = T(N)
      AA(N) = A(N)
      BB(N) = B(N)
      GG(N) = G(N)
      NTYPES(N) = NTYPE(N)
  120 CONTINUE
C MAKE ALL NODES SPECIAL IF KSPEC IS POSITIVE.
```

```
      IF(KSPEC)130,130, 3240
 3240 DO 125 N= 1,NODES
      IF(NTYPE(N))125, 3250,125
 3250 NTYPE(N) = 5
      NOSPEC = NOSPEC + 1
  125 CONTINUE
CCC  INITIALIZE  BEFORE  FIRST TIME INCREMENT.
  130 NOGEN = 0
      NREACT = 0
      DO 135 N = 1,NODES
      H(N)=0.0
      F(N)=0.0
      IF(A(N))132, 3260,132
 3260 IF(B(N)) 3270,134, 3270
 3270 CONTINUE
  132 NREACT = NREACT +1
  134 IF(G(N)) 3280,135, 3280
 3280 NOGEN = NOGEN + 1
  135 CONTINUE
      NSTORE = 3*M11+M1*(1+M11)+M2*(11+7*M9)+M3*(5+9*M9)+56*M4+12*M5+
     1   M6*(12+3*M9)+M7*(5+3*M9)+M8*(3+3*M9)+M10*(9+3*M9)+5*M12+3*M9
      WRITE(6,905)NSTORE
      WRITE(6,940)NOSPEC,NOGEN,NORAD,NORADS,NMELT,NREACT
      NREACT = NREACT + NMELT + NKEM
      NOGEN = NOGEN + NVARG
CCC   INITIALIZE BEFORE FIRST TIME STEP (KCYC = 0, DELT = 1.0E-12).
      SUMTIM = TAU
      DELT = 1.0E-12
      DTMAX=0.0
      DELTSS=0.0
      DELTS=0.0
      DELTMX=AMAX1(1.0E-10,DELTO)
      FOR = 1.0
      GO TO 710
  160 IF(KWIT) 3290, 3290,750
 3290 CONTINUE
C INITIALIZE AT END OF CYCLE 0.
      MF = 0
       MS = 0
       KGOOD = 0
       NPRINT = 0
      KDATA = KDATAX
      DTMAX = 0.
       GENS = 0.
       RAT1 = 1.0
       BIG= 0.99999999E12
      GO TO 205
CCC   START HERE WHEN KCYC = 1 OR MORE, TALLY RESULTS OF CALCULATIONS.
```

```
  200 IF(KCYC - 1) 3300, 3300,202
 3300 DTMAX = 0.
  202 IF(KWIT) 3310, 3310,410
 3310  KWIT = 0
       NOW = 0
      IF(BIG - DELTMX)225,225, 3320
 3320 CONTINUE
C FIND MAX STABLE TIME STEP.
      IF(KCYC - 1)205,205, 3330
 3330  IF(NTABLE) 3340, 3340,205
 3340  IF(KSPEC)225, 3350, 3350
 3350 CONTINUE
  205 DELTMX = 1.5E12
      NREG =0
      DO 210 N = 1,NODES
      SLIM(N) = 1.E24
      IF(ZIP(N))208,208, 3360
 3360 CAPZIP=CAP(N)/ZIP(N)
      SLIM(N)=AMAX1(1.0E-24,CAPZIP)
  208 IF(NTYPE(N))210, 3370, 210
 3370 NREG=NREG+1
      SSLIM=SLIM(N)
      DELTMX=AMIN1(DELTMX,SSLIM)
  210 CONTINUE
      DELTMX=AMAX1(1.0E-10,DELTMX/1.5)
      IF(DELTMX - DELTO)215,225, 3380
 3380 DELTMX = DELTO
      GO TO 225
CCC   CHANGE NODES TO SPECIAL NODES IF NECESSARY TO INCREASE DELTMX.
  215 IF(MS)225,225, 3390
 3390 IF(NREG)225,225, 3400
 3400 IF(KSPEC)225, 3410, 3410
 3410 NEWS = 0
      DO 220 N = 1,NODES
      IF(NTYPE(N))220, 3420,220
 3420 IF(1.8*DELTMX-SLIM(N))220, 3430, 3430
 3430 NTYPE(N)=4
      NOSPEC=NOSPEC+1
      NEWS=1
      WRITE(6,803)KCYC,NODE(N)
  220 CONTINUE
      IF(NEWS)225,225,3440
 3440 KGOOD = 0
      MS = 0
      GO TO 205
CCC   RESTORE SMALL TO SMALT,IF SMALL HAS DECREASED BELOW SMALT.
  225 IF(SMALT - SMALL)226,226, 3450
 3450 SMALL = SMALT
```

```
CCC    CALC SMALL IF NOT READ IN, DELTMX NOT 1.E12, NREG NOT 1/4 NODES.
  226  IF(SMALL - DELTMX)228, 3460, 3460
 3460  SMALL = 0.99999999*DELTMX
  228  IF(1.0 - BIG*SMALT)230, 3470, 3470
 3470   IF(4*NREG - NODES)230, 3480, 3480
 3480  IF(BIG - DELTMX)230, 3490, 3490
 3490   SMALL = 0.01*DELTMX
CCC    FIND LARGEST TEMPERATURE CHANGE AMONG ALL BUT ZERO-VOLUME NODES.
  230  DTPRE = DTMAX
        DO 235 N = 1,NODES
       IF(KCYC - 1) 3500, 3500,232
 3500  IF(NTYPE(N) - 2) 3510,235, 3510
 3510  CONTINUE
  232  DABDT=DABS(DT(N))
       DTMAX=AMAX1(DTMAX,DABDT)
  235  CONTINUE
       RATIO=TVARY/AMAX1(1.0E-24,DTMAX)
CCC    REPEAT CYCLE IF MAX TEMP CHANGE MORE THAN DOUBLE TVARY.
       IF(RATIO - 0.5) 3520,240,240
 3520   IF(DELT - 1.2*SMALL)240,240, 3530
 3530  WRITE(6,950)KCYC,DTMAX,DTPRE,DELT,SUMTIM
       KWIT = -1
        KGOOD = 0
        GO TO 245
  240  SUMTIM = SUMTIM + DELT
        KGOOD = KGOOD + 1
  245  DELTSS = DELTS
       DELTS = DELT
       DTMAX = 0.
       RAT2 = RAT1
        RAT1= RATIO
CCC    START OFF WITH SMALL TIME INCREMENT WITH NO REG NODES.
       IF(KCYC) 3540, 3540,248
 3540  IF(NREG) 3550, 3550,260
 3550  RATIO = 0.01*RATIO
       GO TO 260
CCC    CHANGE DELT TO MAKE NEXT DTMAX CLOSER TO TVARY.
  248  IF(RATIO-1.0) 3560,260,250
 3560  RATIO=AMAX1(0.5,RATIO*RATIO)
       GO TO 260
  250  RATIO = AMIN1( 2.0,0.5*(1.0 + RATIO))
  260  DELT = DELTS*RATIO
        DELTSX = DELTS
       IF(KGOOD - 2)270, 3570, 3570
 3570   IF(RAT1 - RAT2)270, 3580,3580
 3580  DELTSX = DELT/((RAT1/RAT2)**(-DELTS/DELTSS) + 1.0E-24)
CCC    FIND INTERPOLATION FACTOR FOR NEXT TIME STEP.
  270  FOR=AMAX1(0.57,AMAX1(1.0,RAT1)/(1.0+RAT1))
```

```
      IF(KSPEC - 2)271, 3590, 3590
 3590 FOR = 1.0
      IF(KSPEC - 3)272, 3600, 3600
 3600 FOR = 0.5
      GO TO 272
  271 IF(DELT - BIG)272, 3610, 3610
 3610 FOR = 1.0
CCC   KEEP TIME STEP IN RANGE FROM SMALL TO DELTMX OR DELTO.
  272 IF(DELT - SMALL) 3620,275,275
 3620 DELT = SMALL
      MF = MF + 1
      GO TO 280
  275 IF(DELT - DELTMX)280,280, 3630
 3630  DELT = DELTMX
       MS = MS + 1
  280 IF(KWIT) 3640,300,300
 3640  RETURN
C REPEAT CYCLE WITH NEW DELT.
CCC   FIND NEW TEMPERATURES, HEAT CONTENTS,AND FLUXES.
  300 GS = 0.0
      DO 301 K=1,NODES
  301 DFFF(K)=DF(K)
       TMAX1 = -1.E8
       TMIN1 = 1.E8
      CUF=DELTS*60.0
      DO 310 N = 1,NODES
      T(N) = T(N) + DT(N)
C     EQCURE CALCULATION IS CHANGED TO COMMENT .SEPT 1971
C     EQCURE(N)=EQCURE(N)+2.0**((T(N)-280.0)/18.0)*CUF
      GS = GS + G(N)
      SIPT=T(N)
      TMAX1=AMAX1(TMAX1,SIPT)
      TMIN1=AMIN1(TMIN1,SIPT)
      H(N) = H(N) + DT(N)*CAP(N)
       W(N) = W(N) + DT(N)*CAP(N)
      F(N)=F(N)+DFFF(N)
       DEX = DT(N)/DELTSX
      IF(NTYPE(N)) 3650,302,3650
 3650 IF(KCYC - 1) 3660, 3660,302
 3660 IF(NTYPE(N) - 2) 3670,310, 3670
 3670 DEX = DEX/(1.0 + DELTSX/SLIM(N))
  302 IF(DEX*DDT(N)) 3680,305,305
 3680 DEX = DEX*1.0E-24
  305 DDT(N) = DEX
  310 CONTINUE
      GENS = GENS + GS*DELTS
CCC   FIND NEW REACTANT OR PHASE CONCENTRATIONS.
      IF(NREACT)370,370, 3690
```

```
 3690 DO 320 N = 1,NODES
      A(N) = A(N) + DA(N)
      B(N) = B(N) + DB(N)
      K=NODMAT(N)
      HMX=HEFT(N)*HMELT(K)*DA(N)
      W(N)=W(N)-HMX
      H(N)=H(N)-HMX
      DEXA = DA(N)/DELTSX
       DEXB = DB(N)/DELTSX
      IF(NTYPE(N)) 3700,315, 3700
 3700  IF(KCYC - 1)320,320, 3710
 3710 CONTINUE
  315 IF(DEXA*DDA(N)) 3720,316,316
 3720 DEXA = DEXA*1.0E-24
  316 DDA(N) = DEXA
      IF(DEXB*DDB(N)) 3730,318,318
 3730 DEXB = DEXB*1.0E-24
  318 DDB(N) = DEXB
  320 CONTINUE
CCC   TEST CRITERIA FOR ENDING PROBLEM.
  370 IF(TMIN1 - TMIN) 3740,375,375
 3740  KWIT = 3
       GO TO 410
  375 IF(TMAX1 - TMAX)376,376, 3750
 3750  KWIT = 2
       GO TO 410
  376 IF(KSPEC)380, 3760, 3760
 3760 IF(DELTMX - BIG) 3770,378,378
 3770 IF(DELTMX - DELTO) 3780,378,378
 3780 IF(DELTMX - DELT) 3790, 3790,380
 3790 CONTINUE
  378 IF(RAT1-1.E3)380,3800,3800
 3800 IF(RAT2-1.E3)380,3810,3810
 3810 IF(KCYC-10)380,3820,3820
 3820 IF(KGOOD-3)380,3830,3830
 3830 KWIT=4
      GO TO 410
  380 IF(SUMTIM+DELT-TIMAX)385,385,3840
 3840 IF(SUMTIM-TIMAX)384,3850,3850
 3850 KWIT=1
      GO TO 410
  384 DELT=TIMAX-SUMTIM+1.0E-12
  385 IF(KCYC - MCYC)390, 3860, 3860
 3860  KWIT = 7
      GO TO 410
  390 IF(MOD(KCYC,2000/NODES))400,3870,400
 3870 CALL CLOCK1(KSEC,CLICKA)
      IF(MOD(86400+KSEC-KSECS,86400)-MSEC)400,3880,3880
```

```
 3880 KWIT=8
CCC    FIND OUT IF A PRINOUT IS REQUIRED NOW.
  400 IF(KWIT)700,3890,410
 3890 IF((KCYC-1)*MOD(KCYC,IPRINT))3900,3900,700
 3900 CONTINUE
  410 NPRINT=NPRINT+1
      NOW=1
      HEAT=0.
      FLUX=0.
      TX=0.
      CNN=0.0
      DO 414 K=1,NODES
      TMM=F(K)
  414 CNN=CNN+TMM
      FLUX=CNN
      DO 415 N=1,NODES
      HEAT=HEAT+W(N)
      TX=TX+CAP(N)*T(N)
  415 CONTINUE
      TEMPAD=TX/CAPS
      TEMPER=FLUX/CAPS
      TEMPLE=GENS/CAPS
      FX=FLUX/AMAX1(SUMTIM-TAU,1.0E-12)
      TX = FX/CAPS
      WRITE(6,812)NPROB,NAME,CLOCKB,CLOCKA
      WRITE(6,890)
      WRITE(6,815)NPRINT,KCYC,MF,MS,KWIT,DELTMX,
     1SMALL,TVARY,NUTS
      WRITE(6,820)SUMTIM,DELTS,FLUX,TEMPER,
     1FX,TX,TEMPAD,CAPS,HEAT,GS,GENS,TEMPLE
      WRITE(6,890)
      IF(KWIT)418,418,3910
 3910 KDATA=1
  418 IF(KCYC-1)420,420,3920
 3920 IF(KDATA)3930,420,420
 3930 WRITE(6,875)(NODE(N),T(N),N=1,NODES)
      WRITE(6,890)
      GO TO 500
  420 WRITE(6,885)
      DO 424 N=1,NODES
      IF(MOD(N+13,58))422,3940,422
 3940 WRITE(6,885)
  422 WRITE(6,886)NODE(N),T(N),DT(N),DDT(N),G(N),W(N),H(N),F(N)
     1,EQCURE(N)
  424 CONTINUE
      WRITE(6,890)
 3945 IF(NREACT)500,500,3950
 3950 NX=0
```

```
      DO 430 N=1,NODES
       IF(A(N))425, 3960,425
 3960  IF(B(N)) 3970,430, 3970
 3970 CONTINUE
  425 NX = NX + 1
      IF(MOD(NX-1,28))428,3980,428
 3980 WRITE(6,880)
  428 WRITE(6,882)NODE(N),T(N),A(N),DA(N),DDA(N),
     $ B(N),DB(N),DDB(N)
  430 CONTINUE
      WRITE(6,890)
  500 IF(KWIT)700,700,3990
 3990 CONTINUE
      ENTRY TALLY1
      IF(NPUNCH) 4000,700, 4000
 4000 CONTINUE
C PUNCH FINAL CONDITIONS IN BLOCK 9 FORMAT.
C     PUNCH STATEMENTS ARE CHANGED TO COMMENT.SEPT 1971
C     PUNCH 850,(NAME(I), I = 1,6),CLOCKB,CLOCKA
C     PUNCH 830, SUMTIM, NODES
C     PUNCH 840,(NODE(N),T(N),A(N),B(N),GG(N), N = 1,NODES)
      N = 0
      PUNCH 835,N
  700 IF(NOW) 4010, 4010,705
 4010 IF(NUM)705,705, 4020
 4020 N = NUM
      WRITE(6,955)NUMX,T(N),DDT(N),A(N),B(N),G(N),EQCURE(N),SUMTIM
  705 IF(NDOT) 4030,750, 4030
 4030 CONTINUE
  710 DO 720 N = 1,NODES
      DDT(N)=0.0
      DDB(N)=0.0
      DDA(N)=0.0
  720 CONTINUE
  750 RETURN
C COMPLETED TALLY.  RETURN TO HEART.
      END


      SUBROUTINE CHEM
C     CARDS COLUMN       CHEM VERSION 5/29/68.
C     FORTRAN            CHEM    TRUMP CHEMICAL REACTION SUB. FORTRAN-400
CCC   VERSION 5/29/68.
      REAL*8 HMELT,A
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 NAME,CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
```

```
      REAL*8 FORD                                                        17320
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVAREL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAR,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
      COMMON /ACHEMS/ KA(15),KAX(15),KB(15),KBX(15),
     1       B(355),BB(355),DB(355),DCB(355)
      COMMON /ACHEM/ AKEM(5),ET(12,5),KEM(5),LTABE(5),LTABQ(5),
     1       LTABZ(5),QT(12,5),SLOE(12,5),SLOQ(12,5),
     2       SLOZ(12,5),TVARE(12,5),TVARQ(12,5),
     3       TVARZ(12,5),ZT(12,5),
     4       EA(355),EB(355),QA(355),QB(355),ZA(355),ZB(355)
  810 FORMAT (8E10.3)                                                    17650
  815 FORMAT(10X,100(1H=))                                               17660
  820 FORMAT(10X,13HREACTANT DATA,//,11X,4HNODE,4X,6HA     B,4X,4HMASS,  17670
     1   8X,2HQA,10X,2HZA,10X,2HEA,10X,2HQB,10X,2HZB,10X,2HEB)            17680
  825 FORMAT(10X,3I5,1X,1P7E12.4)                                        17690
  877 FORMAT(/20X2HQT12X5HSLOPE10X5HTVARQ/,(15X,1P3E15.6))               17700
  878 FORMAT(/20X2HZT12X5HSLOPE10X5HTVARZ/,(15X,1P3E15.6))               17710
  879 FORMAT(/20X2HET12X5HSLOPE10X5HTVARE/,(15X,1P3E15.6))               17720
  899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)      17730
  915 FORMAT(A5,4I5,5X,5E10.3)                                           17740
  916 FORMAT(//,10X,36HNAME    REACT INDEX LTABQ LTABZ LTABE,8X,2HQT,11X, 17750
```

```
    1   2HZT,11X,2HET)
  917 FORMAT(10X,A5,I7,4I6,3X,1P3E13.5)
      IF(KCYC) 3000,100,200
 3000 CONTINUE
CARD BLOCK 3.  REACTANT PROPERTIES, VS TIME OR TEMPERATURE.
      N = NKEM
      LABEL = 1
      IF(MOE)10, 3010,10
 3010 NVARE=0
      NVARZ=0
      NVARQ=0
      NKEM=0
      N=0
   10 READ(5,915)A1,N1,L1,L2,L3,P1,P2,P3
      IF(N1) 3020,99, 3020
 3020 IF(MOE) 3030,20,20
 3030 CALL SEEK1(N,N1,KEM,NKEM,K)
      IF(K)18,18, 3040
 3040 IF(LTABQ(N)) 3050,14, 3050
 3050 NVARQ = NVARQ - 1
   14 IF(LTABZ(N)) 3060,16, 3060
 3060 NVARZ = NVARZ - 1
   16 IF(LTABE(N)) 3070,18, 3070
 3070 NVARE = NVARE - 1
   18 ITEMS(3)=MIN0(N-1,ITEMS(3))
      GO TO 25
   20 NKEM=N+1
      N=N+1
   25 IF(N - M3)30,30, 3080
 3080 NKEM=M3
      N=M3
      KWIT = 11
      WRITE(6,899)N, IBLOCK
   30 AKEM(N)=A1
      KEM(N) = N1
      LTABQ(N) = L1
      LTABZ(N) = L2
      LTABE(N) = L3
      QT(1,N) = P1
      ZT(1,N) = P2
      ET(1,N) = P3
      IF(LABEL)76,76, 3090
 3090 LABEL = 0
      WRITE(6,916)
   76 WRITE(6,917)AKEM(N),KEM(N),N,LTABQ(N),LTABZ(N),
     $ LTABE(N), QT(1,N),ZT(1,N),ET(1,N)
      LTAB=IABS(LTABQ(N))
      IF(LTAB - 2) 3100, 73, 78
```

```
 3100 LTABQ(N) = 0
       GO TO 85
   78 NVARQ = NVARQ + 1
       LABEL = 1
      READ(5,810)(QT(J,N),TVARQ(J,N),J=1,LTAB)
      DO  80 J=2,LTAB
      SLOQ(J,N) = (QT(J,N)-QT(J-1,N))/(TVARQ(J,N)-TVARQ(J-1,N))
   80 CONTINUE
      SLOQ(1,N) = SLOQ(2,N)
      WRITE(6,877)(QT(J,N),SLOQ(J,N),TVARQ(J,N),J=1,LTAB)
      IF(LTAB - M9)85,85, 3110
 3110 KWIT = 12
   85 LTAB=IABS(LTABZ(N))
       IF(LTAB - 2) 3120, 88, 88
 3120  LTABZ(N) = 0
       GO TO 95
   88 NVARZ = NVARZ + 1
       LABEL = 1
      READ(5,810)(ZT(J,N),TVARZ(J,N),J=1,LTAB)
      DO 90 J=2,LTAB
      SLOZ(J,N) = (ZT(J,N)-ZT(J-1,N))/(TVARZ(J,N)-TVARZ(J-1,N))
   90 CONTINUE
      SLOZ(1,N) = SLOZ(2,N)
      WRITE(6,878)(ZT(J,N),SLOZ(J,N),TVARQ(J,N),J=1,LTAB)
      IF(LTAB - M9)95,95, 3130
 3130 KWIT = 12
   95 LTAB=IABS(LTABE(N))
      IF(LTAB - 2) 3140,96,96
 3140 LTABE(N) = 0
      GO TO 10
   96 NVARE = NVARE + 1
       LABEL = 1
      READ(5,810)(ET(J,N),TVARE(J,N),J=1,LTAB)
      DO 97 J=2,LTAB
      SLOE(J,N) = (ET(J,N)-ET(J-1,N))/(TVARE(J,N)-TVARE(J-1,N))
   97 CONTINUE
      SLOE(1,N) = SLOE(2,N)
      WRITE(6,879)(ET(J,N),SLOE(J,N),TVARE(J,N),J=1,LTAB)
      IF(LTAB - M9)10,10, 3150
 3150 KWIT = 12
      GO TO 10
   99 NEWBL(2) = NEWBL(2) + 1000
      RETURN
C COMPLETED BLOCK 3.
  100 IBLOCK = 2
      CALL  REFER(KA,KAX,NMAT,KEM,NKEM)
      CALL  REFER(KB,KBX,NMAT,KEM,NKEM)
      IF(KWIT)600, 3160,600
```

```
 3160 RGAS = 1.987
CCC   FIND NODE REACTION HEATS, COLL.FREQ., AND ACTIVATION ENERGIES.
      DO 150 N = 1,NODES
       QA(N) = 0.
       QB(N) = 0.
      ZA(N) = 0.
      ZB(N) = 0.
      EA(N) = 0.
      EB(N) = 0.
      L1=NODMAT(N)
      LA=KA(L1)
      IF(LA)140,140, 3170
 3170 QA(N) = QT(1,LA)
      ZA(N) = ZT(1,LA)
      EA(N) = ET(1,LA)
  140 L1=NODMAT(N)
      LB=KB(L1)
      IF(LB)150,150, 3180
 3180 QB(N) = QT(1,LB)
      ZB(N) = ZT(1,LB)
      EB(N) = ET(1,LB)
  150 CONTINUE
  200 FORD = FOR*DELT
      IF(NOW)208,208, 3190
 3190 IF(KCYC - 1)208,205, 3200
 3200 IF(KDATA)208,208, 3210
 3210  IF(NVARZ + NVARQ + NVARE)208,208, 3220
 3220 CONTINUE
  205 WRITE(6,820)
      DO 206 N=1,NODES
      J = NODMAT(N)
      IF(KA(J))206,206, 3230
 3230 WRITE(6,825)NODE(N),KAX(J),KBX(J),HEFT(N),
     1   QA(N),ZA(N),EA(N),QB(N),ZB(N),EB(N)
  206 CONTINUE
      WRITE(6,815)
  208 IF(NVARQ)300,300, 3240
 3240 CONTINUE
CCC   FIND NEW HEATS OF REACTION.
      DO 290 N= 1,NODES
      L1=NODMAT(N)
      IF(KA(L1))3250,210,3250
 3250  NN = 1
      K=KA(L1)
       LTAB = LTABQ(K)
       BETA = QA(N)
      GO TO 215
  210 L1=NODMAT(N)
```

```
      IF(KB(L1))3260,290,3260
 3260  NN = 2
      K=KB(L1)
       LTAB = LTABQ(K)
       BETB = QB(N)
  215 IF(LTAB) 3270,285,220
 3270  SET = SUMTIM + FORD
      GO TO 230
  220 L = NLOOK(N,3)
       SET = T(L) + FORD*DDT(L)
  230 MIN = 1
      MAX=IABS(LTAB)
  240 MID = (MIN + MAX)/2
       IF(SET - TVARQ(MID,K))250,270,260
  250 MAX = MID
       IF(MAX -2)270,240,240
  260 MIN = MID
       IF(MAX - MIN - 2)270,240,240
  270 SET = QT(MID,K) + SLOQ(MID+1,K)*(SET - TVARQ(MID,K))
      GO TO (275,280),NN
  275 QA(N) = SET
      BETA=100.0*ABS((BETA-QA(N))/(1.0E-24+BETA))
      DTMAX=AMAX1(DTMAX,BETA*TVARY)
       GO TO 210
  280 QB(N) = SET
      BETB=100.0*ABS((BETB-QB(N))/(1.0E-24+BETB))
      DTMAX=AMAX1(DTMAX,BETB*TVARY)
  285 GO TO (210,290),NN
  290 CONTINUE
CCC   FIND NEW COLLISION FREQUENCIES.
  300 IF(NVARZ)400,400, 3280
 3280 DO 390 N = 1,NODES
      L1=NODMAT(N)
      IF(KA(L1))3290,310,3290
 3290  NN = 1
      K=KA(L1)
      LTAB = LTABZ(K)
      BETA = ZA(N)
      GO TO 315
  310 L1=NODMAT(N)
      IF(KB(L1))3300,390,3300
 3300  NN = 2
      K=KB(L1)
       LTAB = LTABZ(K)
      BETB = ZB(N)
  315 IF(LTAB) 3310,385,320
 3310  SET = SUMTIM + FORD
      GO TO 330
```

```
  320 L = NLOOK(N,4)
      SET = T(L) + FORD*DDT(L)
  330 MIN = 1
      MAX=IABS(LTAB)
  340 MID = (MIN + MAX)/2
       IF(SET - TVARZ(MID,K))350,370,360
  350 MAX = MID
       IF(MAX - 2)370,340,340
  360 MIN = MID
       IF(MAX - MIN - 2)370,340,340
  370 SET = (ZT(MID,K) + SLOZ(MID+1,K)*(SET - TVARZ(MID,K)))
      GO TO (375,380),NN
  375 ZA(N) = SET
      BETA=100.0*ABS((BETA-ZA(N))/(1.0E-24+BETA))
      DTMAX=AMAX1(DTMAX,BETA*TVARY)
       GO TO 310
  380 ZB(N) = SET
      BETB=100.0*ABS((BETB-ZB(N))/(1.0E-24+BETB))
      DTMAX=AMAX1(DTMAX,BETB*TVARY)
  385 GO TO (310,390),NN
  390 CONTINUE
CCC   FIND NEW ACTIVATION ENERGIES.
  400 IF(NVARE)500,500, 3320
 3320 DO 490 N= 1,NODES
      L1=NODMAT(N)
      IF(KA(L1))3330,410,3330
 3330  NN = 1
      K=KA(L1)
       LTAB = LTABE(K)
       BETA = EA(N)
       GO TO 415
  410 IF(KB(L1))3340,490,3340
 3340  NN = 2
      K=KB(L1)
       LTAB = LTABE(K)
      BETB = EB(N)
  415 IF(LTAB) 3350,485,420
 3350  SET = SUMTIM + FORD
       GO TO 430
  420 L=NLOOK(N,5)
       SET = T(L) + FORD*DDT(L)
  430 MIN = 1
      MAX=IABS(LTAB)
  440 MID = (MIN + MAX)/2
       IF(SET - TVARE(MID,K))450,470,460
  450 MAX = MID
       IF(MAX - 2)470,440,440
  460 MIN = MID
```

```
      IF(MAX - MIN - 2)470,440,440
  470 SET = (ET(MID,K) + SLOE(MID+1,K)*(SET - TVARE(MID,K)))
      GO TO (475,480),NN
  475 EA(N) = SET
      BETA=100.0*ABS((BETA-EA(N))/(1.0E-24+BETA))
      DTMAX=AMAX1(DTMAX,BETA*TVARY)
       GO TO 410
  480 EB(N) = SET
      BETB=100.0*ABS((BETB-EB(N))/(1.0E-24+BETB))
      DTMAX=AMAX1(DTMAX,BETB*TVARY)
  485 GO TO (410,490),NN
  490 CONTINUE
CCC   FIND CONCENTRATION AND TEMP CHANGE IN NODES.
  500 DO 520 N = 1,NODES
       TEX = (T(N) + FORD*DDT(N) + TBASE)*RGAS
      L1=NODMAT(N)
      IF(KA(L1))3360,510,3360
 3360 DEXA=DELT*EXP(AMIN1(50.0,ZA(N)-EA(N)/TEX))
      DEXA=-A(N)*AMIN1(1.0,DEXA)
      DT(N) = DT(N) - QA(N)*DEXA*HEFT(N)/CAP(N)
      DA(N) = DA(N) + DEXA
  510 K1=NODMAT(N)
      IF(KB(K1))3370,520,3370
 3370 DEXB=DELT*EXP(AMIN1(50.0,ZB(N)-EB(N)/TEX))
      DEXB=-B(N)*AMIN1(1.0,DEXB)
      DT(N) = DT(N) - QB(N)*DEXB*HEFT(N)/CAP(N)
      DB(N) = DB(N) + DEXB
  520 CONTINUE
  600 RETURN
CCC   END OF CHEM. GO BACK TO HEART.
      END


      SUBROUTINE SPECK
C     CARDS COLUMN       SPECK VERSION  5/29/68.
C     LIST 8
C     FORTRAN            SPECK   TRUMP SPECIAL NODE CALC. SUB. FORTRAN400
CCC   VERSION  5/29/68.
CCC   CONTAINS INSTRUCTIONS REQUIRED ONLY WITH FLOW (260, 365, 460).
CCC   CONTAINS INSTRUCTIONS REQUIRED ONLY WITH SURE (650).
      REAL*8 HMELT,A
      REAL*8 EX
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 TRANS
      REAL*8 NAME,CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 FLEX
```

```
      REAL*8 FORD
      REAL*8 DFS
      REAL*8 ERROR,ERRORX
      REAL*8 FLOWN
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
      COMMON /AFLOWS/ FLOWN(50),NODF1(50),NODF2(50)
      COMMON /ASPECK/ ERROR(355),ERRORX(355)
      COMMON /ASURES/ DFS(60),TRANS(60),NODS(60)
  815 FORMAT(/10X,6HKCYC =,I6,5X,35HNO CONVERGENCE.  WILL REPEAT CYCLE.)
  820 FORMAT(/10X,6HKCYC =,I6,5X,81HNO CONVERGENCE.  CAN NOT REPEAT CYCL
     1E, SO WILL END PROBLEM.  YOU MAY FIX BY USING,/,27X,73HLARGER NODE
     2S, LUMPING NODES, OR ELIMINATING HIGH CONDUCTANCE CONNECTIONS.)
  825 FORMAT(10X,28HTOTAL NUMBER OF ITERATIONS =,I6,5X,5HMAX =,I6)
      IF(KCYC) 3000,200,200
 3000  NUTX = 0
       NUTSUM = 0
       NUTMAX = 200
CCC   INITIALIZE CORRECTIONS TO TEMP CHANGES IN NODES.
      DO 120 N = 1,NODES
      ERRORX(N) = 0.0
```

```
  120 CONTINUE
CCC   SET ACCELERATION FACTOR AND CONVERGENCE FACTOR.
      NUTS = 0
       SPEED = 0.2
       ERRS = 5.E-5
       RETURN
  200 IF(KWIT)210,210, 3010
 3010 CONTINUE
C STRART HERE IF KCYC ) -1.
      WRITE(6,825)NUTSUM,NUTX
      GO TO 700
  210 FORD = FOR*DELT
CCC   INITIZLIZE CORRECTION FACTORS.
      DO 220 N = 1,NODES
      ERROR(N) = 0.0
      IF(NTYPE(N)) 3020,220, 3020
 3020  ERRORX(N) = DELT*DDT(N)
  220 CONTINUE
CCC   CALC CORRECTION FACTORS FOR SPECIAL NODES, COUNT SPEC-SPEC CONN.
      KNOT=0
      KNOFL=0
      KNOCK=0
      IF(NOCON)260,260, 3030
 3030 DO 250 N = 1,NOCON
      N1 = NOD1(N)
      N2 = NOD2(N)
      IF(NTYPE(N1))230, 3040,230
 3040 IF(NTYPE(N2)) 3050,250, 3050
 3050 ERROR(N2) = ERROR(N2) + TRAN(N)*DT(N1)
      GO TO 250
  230 IF(NTYPE(N2))240, 3060,240
 3060 ERROR(N1) = ERROR(N1) + TRAN(N)*DT(N2)
      GO TO 250
  240 ERROR(N1) = ERROR(N1) + TRAN(N)*ERRORX(N2)
      ERROR(N2) = ERROR(N2) + TRAN(N)*ERRORX(N1)
       KNOCK = KNOCK + 1
  250 CONTINUE
  260 CONTINUE
C REMOVE INSTRUCTIONS PRECEDING 300 IF FLOW NOT USED.
      IF(NOFLOW)300,300, 3070
 3070 CONTINUE
CCC   FIND CORRECTIONS DUE TO MASS FLOW.
      DO 280 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
      IF(NTYPE(N1))270, 3080,270
 3080 IF(NTYPE(N2)) 3090,280, 3090
 3090 ERROR(N2) = ERROR(N2) + FLOWN(N)*CAP(N1)*DT(N1)/HEFT(N1)
```

```
      GO TO 280
  270 IF(NTYPE(N2)) 3100,280, 3100
 3100 KNOFL = KNOFL + 1
      ERROR(N2)=ERROR(N2) + FLOWN(N)*CAP(N1)*ERRORX(N1)/HEFT(N1)
  280 CONTINUE
CCC   MAKE FIRST CORRECTION TO TEMP CHANGES IN SPECIAL NODES.
  300 NUTS = 0
       ESUM = 0.0
      HSUM = 1.E-12
       S1 = SPEED
       S2 = S1 + 1.
      IF((KNOCK + KNOFL)*KCYC) 3110, 3110,310
 3110 S1 = 0.0
      S2 = 1.0
  310 DO 320 N = 1,NODES
      IF(NTYPE(N)) 3120,320, 3120
 3120 EX = ERROR(N) + S1*ZIP(N)*ERRORX(N)
      ERROR(N) = 0.
      DT(N) = (CAP(N)*DT(N) + FORD*EX)/(CAP(N) + FORD*S2*ZIP(N))
      ERRORX(N) = DT(N)-ERRORX(N)
      ESUM=ESUM+CAP(N)*DABS(ERRORX(N))
      HSUM = HSUM + CAP(N)
CCC   CAPACITY OF SPECIAL NODES.
  320 CONTINUE
       HSUM = HSUM*TVARY
C MAX CHANGE IN HEAT CONTENT.
CCC   START ITERATING IF THERE ARE SPEC-SPEC CONNECTIONS, AND
CCC   RELATIVE CHANGE IN HEAT CONTENT IS GREATER THAN ERRS.
      IF(ESUM - ERRS*HSUM)400, 3130, 3130
 3130 IF(KNOCK + KNOFL)400,400, 3140
 3140 CONTINUE
  340 NUTS = NUTS + 1
C CALC CORRECTIONS FOR SPECIAL NODES.
      IF(KNOCK)365,365, 3150
 3150 DO 360 N = 1,NOCON
      N1 = NOD1(N)
      N2 = NOD2(N)
      IF(NTYPE(N1)*NTYPE(N2)) 3160,360, 3160
 3160 CONTINUE
CCC   BOTH MUST BE SPECIAL.
      ERROR(N1) = ERROR(N1) + TRAN(N)*ERRORX(N2)
      ERROR(N2) = ERROR(N2) + TRAN(N)*ERRORX(N1)
  360 CONTINUE
  365 CONTINUE
C REMOVE INSTRUCTIONS PRECEDING 375 IF FLOW NOT USED.
      IF(KNOFL)375,375, 3170
 3170 CONTINUE
CCC   FIND CORRECTIONS DUE TO MASS FLOW.
```

```
      DO 370 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
      IF(NTYPE(N1)*NTYPE(N2)) 3180,370, 3180
 3180 ERROR(N2)=ERROR(N2) + FLOWN(N)*CAP(N1)*ERRORX(N1)/HEFT(N1)
  370 CONTINUE
CCC CORRECT TEMP CHANGE IN SPECIAL NODES.
  375 ESUM = 0.
      DO 380 N = 1,NODES
      IF(NTYPE(N)) 3190,380, 3190
 3190 ERRORX(N) = (ERROR(N)+S1*ZIP(N)*ERRORX(N))/(S2*ZIP(N)+CAP(N)/FORD)
      DT(N) = DT(N) + ERRORX(N)
       ERROR(N) = 0.
      ESUM=ESUM+CAP(N)*DABS(ERRORX(N))
  380 CONTINUE
CCC   STOP ITERATING AFTER NUTMAX CYCLES.
      IF(NUTS - NUTMAX)390, 3200, 3200
 3200 NUTS=0
      DTMAX=AMAX1(DTMAX,200.0*TVARY)
      WRITE(6,815)KCYC
      IF(DELT - 2.0*SMALL) 3210, 3210,400
 3210 KWIT = 10
C     ITERATION FAILURE
      WRITE(6,820)KCYC
      GO TO 700
CCC   STOP ITERATING WHEN RELATIVE ERROR IN HEAT CONTENT CHANGES ERRS
  390 IF(ESUM-ERRS*HSUM) 3220,3220,340
 3220 CONTINUE
  400 NUTSUM=NUTSUM+NUTS
      NUTX=MAX0(NUTX,NUTS)
CCC   CORRECT INTERVAL FLUXES AND FIND CORRECTION FACTORS FOR REG NODES
      IF(NOCON)460,460,3230
 3230 DO 450 N=1,NOCON
      N1=NOD1(N)
      N2=NOD2(N)
      IF(NTYPE(N1))420,3240,420
 3240 IF(NTYPE(N2))3250,450,3250
 3250 ERROR(N1)=ERROR(N1)+TRAN(N)*(DT(N2)-DT(N1))
      GO TO 440
  420 IF(NTYPE(N2))440, 3260,440
 3260 ERROR(N2)=ERROR(N2)+TRAN(N)*(DT(N1)-DT(N2))
  440 FLEX=FORD*TRAN(N)*(DT(N2)-DT(N1))
      DFI(N)=DFI(N)+FLEX
      DF(N1)=DF(N1)+FLEX
      DF(N2)=DF(N2)-FLEX
  450 CONTINUE
  460 CONTINUE
C     REMOVE INSTRUCTIONS PRECEDING 500 IF FLOW NOT USED
```

```
      IF(NOFLOW)500,500,3270
 3270 DO 480 N=1,NOFLOW
      N1=NODF1(N)
      N2=NODF2(N)
      IF(NTYPE(N1)) 480,3280,480
 3280 IF(NTYPE(N2)) 3290,480,3290
 3290 ERROR(N1)=ERROR(N1)-FLOWN(N)*CAP(N1)*DT(N1)/HEFT(N1)
  480 CONTINUE
CCC   CALC CORRECTED TEMP CHANGE IN REG NODES CONN TO SPECIAL NODES.
  500 DO 520 N=1,NODES
      IF(NTYPE(N))520,3300,520
 3300 DT(N) = DT(N) + FORD*ERROR(N)/CAP(N)
  520 CONTINUE
  650 CONTINUE
C     REMOVE INSTRUCTIONS PRECEDING 700 IF SURE NOT USED
      IF(NOSCON)700,700,3310
 3310 CONTINUE
CCC   CORRECT FLUX OF EXTERNAL CONNECTIONS
      DO 660 N=1,NOSCON
      N1=NODS(N)
      FLEX=FORD*TRANS(N)*DT(N1)
      DF(N1)=DF(N1)-FLEX
      DFS(N)=DFS(N)-FLEX
  660 CONTINUE
  700 RETURN
C     COMPLETED SPECK. RETURN TO HEART.
      END


      SUBROUTINE FINK
C     CARDS COLUMN    FINK VERSION 5/29/68.
C     LIST 8
C     FORTRAN         FINK TRUMP  INTERNAL HEAT FLOW SUB.FORTRAN-400
      REAL*8 HMELT,A
      REAL*8 AREA,DEL1,DEL2
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 FORD
      REAL*8 NAME,CAPS
      REAL*8 HEX
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
```

```
     1          ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1          NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2          NVARZ,NVARE,NORAD,NVARH,NORADS,NOPCWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1          DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2          RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3          TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1          NLOOK(355,8),NODE(355),
     2          NODMAT(355),NTYPE(355),RADIUS(355),
     3          VOL(355),W(355),
     4          DFI(950),FI(950),NOD1(950),NOD2(950),
     5          F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1          LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2          TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4          NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1          NOXF(355),NTYPES(355),TT(355)
      COMMON /AFINK/ AREA(950),DEL1(950),DEL2(950),HINT(950),
     1          NOX1(950),NOX2(950),RINT(950)
  818 FORMAT(10X,I5,I6,I5,1P7E12.4)
  820 FORMAT(2I5,3I3,I1,4E10.3,20A1)
  821 FORMAT(//,11X,93HNOD1 NOD2 INDEX  DEL1         DEL2          DLONG
     $     DRAD         HINT           RINT             AREA)
  825 FORMAT(10X,100(1H=))
  830 FORMAT(10X,24HINTERNAL CONNECTION DATA)
  835 FORMAT(/,10X,87H       NOD1  NOD2     AREA           HINT          RINT
     $      TRAN          HEAT FLOW   AVG RATE)
  840 FORMAT(13X,2I6,1X,6F12.4)
  899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
      IF(KCYC) 3000,100,200
 3000 CONTINUE
CARD BLOCK 5.  INTERNAL CONNECTION NODE NUMBERS, DESCRIPTIONS.
      N = NOCON
      L = 0
      IF(MOE)2, 3010,2
 3010 NCRAD=0
      NOCON=0
      N=0
    2 READ(5,820)N1,N2,NSEQ,NAD1,NAD2,NZ,P1,P2,
     1   DLONG,DRAD,NX1,NX2
      IF(N1) 3020,30, 3020
 3020 IF(NZ)4,4, 3030
 3030 NZ = 10**NZ
```

```
      NAD1 = NAD1*NZ                                                    03370
      NAD2 = NAD2*NZ                                                    03380
    4 CALL PATCH(NX1,1.E12,HINTS,LBH)                                   03390
      CALL PATCH(NX2,0.0,RINTS,LBR)                                     03400
      IF(LBR) 3040,6, 3040                                              03410
 3040 NORAD = NORAD + 1 + NSEQ                                          03420
      IF(LBH) 3050,7, 3050                                              03430
 3050 CONTINUE                                                          03440
    6 IF(HINTS)8, 3060,8                                                03450
 3060 CONTINUE                                                          03460
    7 HINTS = 1.0E-24                                                   03470
    8 ADD = 0.0                                                         03430
      IF(DRAD) 3070,10,10                                               03490
 3070 ADD = -(DRAD + DRADS)                                             03500
      DRAD = DRADS                                                      03510
   10 IF(MOE) 3080,12,12
 3080 CALL SEEK2(N,N1,N2,NOX1,NOX2,NOCON,K)                             03530
      IF(K)11,11, 3090                                                  03540
 3090 IF(PINT(N))  3100,11, 3100                                        03550
 3100 NORAD = NORAD - 1                                                 03560
   11 ITEMS(5)=MIN0(N-1,ITEMS(5))                                       03570
      GO TO 14                                                          03580
   12 NOCON=N+1                                                         03590
      N=N+1                                                             03600
   14 IF(N - M5)16,16, 3110
 3110 NOCON=M5                                                          03620
      N=M5                                                              03630
      KWIT= 11                                                          03640
      WRITE(6,899)N, IBLOCK                                             03650
   16 NOX1(N)=N1                                                        03660
      NOD1(N)=N1                                                        03670
      NOX2(N)=N2                                                        03680
      NOD2(N)=N2                                                        03690
      DEL1(N) = P1*SCALE                                                03700
      DEL2(N) = P2*SCALE                                                03710
      HINT(N) = HINTS                                                   03720
      RINT(N) = RINTS                                                   03730
      DRADS=DRAD+ADD                                                    03740
      DRAD=DRADS                                                        03750
      AREA(N) = GEOM*DLONG*DRAD**KSYM*SCALE**2                          03760
      L = L + 1                                                         03770
      IF(MOD(L-1,57))20,3120,20                                         03780
 3120 WRITE(6,821)                                                      03790
   20 WRITE(6,818)NOD1(N),NOD2(N),N,DEL1(N),DEL2(N),                    03800
     1 DLONG,DRAD,HINT(N),RINT(N),AREA(N)                               03810
      IF(NSEQ)2,2, 3130                                                 03820
 3130 NSEQ = NSEQ - 1                                                   03830
      N1 = N1 + NAD1                                                    03840
```

```
      N2 = N2 + NAD2
      GO TO 10
   30 RETURN
C COMPLETED BLOCK 5.
  100 IBLOCK = 5
      CALL REFER(NOD1,NOX1,NOCON,NODE,NODES)
      CALL REFER(NOD2,NOX2,NOCON,NODE,NODES)
      IF(KWIT)700, 3140,700
 3140 CONTINUE
CCC   CALCULATE CONDUCTANCE OF INTERNAL CONNECTIONS.
      DO 180 N = 1,NOCON
      N1 = NOD1(N)
      N2 = NOD2(N)
      T1 = TBASE + T(N1)
       T2 = TBASE + T(N2)
      DT12=AMAX1(1.0E-24,ABS(T1-T2))
      RINTR=AMAX1(0.0,RINT(N))*SIGMA
      RINTC=AMAX1(0.0,-RINT(N))
      RAD = RINTR  *(T1 + T2)*(T1*T1 + T2*T2)
      RAD = 1.0/(RAD + HINT(N)*DT12**RINTC)
      TRAN(N) = AREA(N)/(DEL1(N)/CON(N1) + DEL2(N)/CON(N2) + RAD)
      ZIP(N1) = ZIP(N1) + TRAN(N)
       ZIP(N2) = ZIP(N2) + TRAN(N)
      DFI(N) = 0.
      FI(N) = 0.
  180 CONTINUE
CCC   FIND TOTAL HEAT FLUX ACROSS EACH INTERNAL CONNECTION.
  200 DO 215 N = 1,NOCON
  215 FI(N)= FI(N) + DFI(N)
      IF(NOW)300,300, 3150
 3150  IF(KCYC - 1)300,225, 3160
 3160  IF(KDATA)300,300, 3170
 3170 CONTINUE
CCC   WRITE OUT PROPERTIES OF EACH INTERNAL CONNECTION.
  225 WRITE(6,830)
      TX=AMAX1(SUMTIM -TAU,1.0E-12)
      DO 240 N = 1,NOCON
      IF(MOD(N-1,57))235,3180,235
 3180 WRITE(6,835)
  235 FX = FI(N)/TX
      WRITE(6,840)NOX1(N),NOX2(N),AREA(N),
     $ HINT(N),RINT(N),TRAN(N),FI(N),FX
  240 CONTINUE
      WRITE(6,825)
CCC   FIND NEW CONDUCTANCES OF INTERNAL CONNECTIONS.
  300 IF(NVARK + NORAD)500,500, 3190
 3190  FORD = FOR*DELT
      DO 420 N = 1,NOCON
```

```
      N1 = NOD1(N)
      N2 = NOD2(N)
      IF(RINT(N))415, 3200,415
 3200  J1 = NODMAT(N1)
       J2 = NODMAT(N2)
      IF(LTABK(J1))415, 3210,415
 3210  IF(LTABK(J2)) 3220,420, 3220
 3220 CONTINUE
  415 ZIP(N1) = ZIP(N1) - TRAN(N)
       ZIP(N2) = ZIP(N2) - TRAN(N)
      T1 = TBASE + T(N1)+FORD*DDT(N1)
      T2 = TBASE + T(N2)+FORD*DDT(N2)
      DT12=AMAX1(1.0E-24,ABS(T1-T2))
      RINTR=AMAX1(0.0,RINT(N))*SIGMA
      RINTC=AMAX1(0.0,-RINT(N))
      RAD = RINTR  *(T1 + T2)*(T1*T1 + T2*T2)
      RAD = 1.0/(RAD + HINT(N)*DT12**RINTC)
      TRAN(N) = AREA(N)/(DEL1(N)/CON(N1) + DEL2(N)/CON(N2) + RAD)
      ZIP(N1) = ZIP(N1) + TRAN(N)
       ZIP(N2) = ZIP(N2) - TRAN(N)
  420 CONTINUE
CCC   FIND TEMPERATURE CHANGES IN NODES DUE TO CONDUCTION.
  500 DO 510 N=1,NOCON
      N1=NOD1(N)
      N2=NOD2(N)
      HEX = DELT*TRAN(N)*(T(N2) - T(N1))
       DFI(N) = HEX
      DF(N1) = DF(N1) + HEX
       DF(N2) = DF(N2) - HEX
      DT(N1) = DT(N1) + HEX/CAP(N1)
       DT(N2) = DT(N2) - HEX/CAP(N2)
  510 CONTINUE
  700 RETURN
C COMPLETED FINK. RETURN TO HEART.
      END


      SUBROUTINE GEN
CCC   VERSION 5/29/68
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 NAME,CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FORD
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 HMELT,A
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
```

```
     2        DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3        T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1        ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1        NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2        NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1        DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2        RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3        TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1        NLOOK(355,8),NODE(355),
     2        NODMAT(355),NTYPE(355),RADIUS(355),
     3        VOL(355),W(355),
     4        DFI(950),FI(950),NOD1(950),NOD2(950),
     5        F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1        LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2        TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4        NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1        NOXE(355),NTYPES(355),TT(355)
      COMMON /AGEN/ GT(12,5),LTABG(5),NODG(5),NOXG(5),
     1        SLOG(12,5),TVARG(12,5)
  810 FORMAT (8E10.3)
  832 FORMAT(10X,3I6,3X,1PE15.6,15X,E15.6)
  833 FORMAT(31X,1P3E15.6)
  870 FORMAT (4I5,6E10.3)
  871 FORMAT(//,12X,16HNODG INDEX LTABG,8X,2HGT,12X,5HSLOPE,11X,5HTVARG)
  872 FORMAT(/,10X,66HFOLLOWING NODE HAS G(N) = GT(1,N)*EXPF(-0.69315*SU
     1MTIM/TVARG(1,N)))
  899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
      IF(KCYC) 3000,100,200
 3000 CONTINUE
CARD BLOCK 8.  TABLES OF HEAT GENERATION VS TIME OR TEMPERATURE.
      N = NVARG
      LABEL = 1
      IF(MOE)2, 3010,2
 3010 NVARG=0
      N=0
    2 READ(5,870)N1,NSEQ,NADG,L1,(F1(J),J=1,3)
      IF(N1) 3020,30, 3020
 3020 LTAB=IABS(L1)
      IF(LTAB - 2) 3030,4,4
```

```
3030 LTAB=0
     L1=0
     IF(F2(1))10, 3040,10
3040 F2(1) = 1.0E-24
     GO TO 10
   4 IF(LTAB - 4)7, 3050, 3050
3050 IF(LTAB - M9)6,6, 3060
3060 KWIT = 12
   6 READ(5,810)(F1(J),F2(J),J=4,LTAB)
   7 DO 8 J = 2,LTAB
     F3(J) = (F1(J) - F1(J-1))/(F2(J) - F2(J-1))
   8 CONTINUE
     F3(1) = F3(2)
  10 IF(MOE) 3070,12,12
3070 CALL SEEK1(N,N1,NOXG,NVARG,K)
     ITEMS(8)=MINO(N-1,ITEMS(8))
     GO TO 14
  12 NVARG=N+1
     N=N+1
  14 IF(N - M8)16,16, 3080
3080 NVARG=M8
     N=M8
     KWIT = 11
     WRITE(6,899)N,IBLOCK
  16 NOXG(N)=N1
     NODG(N)=N1
     LTABG(N) = L1
     GT(1,N) = F1(1)
     TVARG(1,N) = F2(1)
     IF(L1)18, 3090,18
3090 LABEL = 1
     WRITE(6,872)
  18 IF(LABEL)20,20, 3100
3100 LABEL = 0
     WRITE(6,871)
  20 WRITE(6,832)NODG(N),N,LTABG(N),GT(1,N),TVARG(1,N)
     IF(LTAB)24,24,3110
3110 DO 22 J = 2,LTAB
     GT(J,N) = F1(J)
     TVARG(J,N) = F2(J)
     SLOG(J,N) = F3(J)
  22 CONTINUE
     SLOG(1,N) =F3(1)
     WRITE(6,833)(GT(J,N),SLOG(J,N),TVARG(J,N),J=2,LTAB)
  24 IF(NSEQ)2,2, 3120
3120 NSEQ = NSEQ - 1
     N1 = N1 + NADG
     GO TO 10
```

```
   30 RETURN
C COMPLETED BLOCK 8.
  100 IF(NVARG)140,140, 3130
 3130 IBLOCK = 8
      CALL REFER(NODG,NOXG,NVARG,NODE,NODES)
  140 IF(KWIT)400, 3140,400
 3140 DO 150 N = 1,NODES
       G(N) = G(N)*VOL(N)
  150 CONTINUE
  200 FORD = FOR*DELT
      IF(NVARG)300,300, 3150
 3150 CONTINUE
CCC   FIND NEW HEAT GENERATION RATES.
      DO 280 N= 1,NVARG
       J = NODG(N)
       K = NLOOK(J,6)
       IF(LTABG(N)) 3160,275,220
 3160  SET = SUMTIM + FORD
       GO TO 230
  220 SET = T(K)+FORD*DDT(K)
  230 MIN = 1
      MAX=IABS(LTABG(N))
       BET = G(J)
  240 MID = (MIN + MAX)/2
       IF(SET - TVARG(MID,N))250,270,260
  250 MAX = MID
       IF(MAX - 2)270,240,240
  260 MIN = MID
       IF(MAX - MIN - 2)270,240,240
  270 G(J) = VOL(J)*(GT(MID,N) + SLOG(MID+1,N)*(SET - TVARG(MID,N)))
      BET= 100.0*DABS((BET-G(J))/(BET+1.0E-12))
      DTMAX=AMAX1(DTMAX,BET*TVARY)
      GO TO 280
  275 SET = 0.69314718/TVARG(1,N)
      SETD=SET*DELT
      SETD=AMAX1(-60.0,AMIN1(SETD,60.0))
      SETS=AMAX1(-60.0,AMIN1(SET*SUMTIM,60.0))
      IF(ABS(SETD)-1.0E-5)3170,3170,276
 3170 SET=EXP(-SETS)*(1.0-0.5*SETD)
      GO TO 277
  276 SET=EXP(-SETS)*(1.0-EXP(-SETD))/(SET*DELT)
  277 IF(SET - 1.0E-24) 3180, 3180,278
 3180 SET = 0.
  278 G(J) = VOL(J)*GT(1,N)*SET
  280 CONTINUE
CCC   FIND TEMPERATURE CHANGE FROM INTERNAL HEAT GENERATION.
  300 DO 310 N = 1,NODES
  310 DT(N) = DT(N) + DELT*G(N)/CAP(N)
```

```
  400 RETURN
C COMPLETED GEN. RETURN TO HEART.
      END

      SUBROUTINE SURE
C     CARDS COLUMN       SURE VERSION 5/29/68.
C     LIST 8
C     FORTPAN            SURE     TRUMP EXTERNAL HEAT FLOW SUB.FORTRAN-400
CCC   VERSION 5/29/68.
      REAL*8 HMELT,A
      REAL*8 NAME,CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 DFS
      REAL*8 FB
      REAL*8 FORD
      REAL*8 HEX
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 TRANS
      REAL*8 AREAS,HSURE
      REAL*8 TBS
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NP,NB,MN,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
```

```
      4        NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
       COMMON  AA(355),F(355),GG(355),H(355),NOTE(355),
      1        NOXE(355),NTYPES(355),TT(355)
       COMMON  /ASURE/   AREAS(60),HSURE(60),FB(20),TBS(20),
      1        FS(60),HSURT(12,60),LTABH(60),NOXS(60),NODSB(60),

      2        NOXSB(60),POWER(60),RSURE(60),SLOH(12,60),TVARH(12,60),
      3        LTABT(20),NODB(20),SLOT(12,20),TB(20),TEMPB(12,20),
      4        TIMEB(12,20)
       COMMON /ASURES/ DFS(60),TRANS(60),NODS(60)
   810 FORMAT(8E10.3)
   815 FORMAT(10X,100(1H=))
   820 FORMAT(10X,24HEXTERNAL CONNECTION DATA)
   825 FORMAT (6I5,2E10.3,30A1)
   826 FORMAT(/,10X,96H  NODS NODSB INDEX LTABH        POWER        DLONG
      1     DRAD         HSURE         RSURE        AREAS)
   827 FORMAT(10X,4I6,4X,1P6E12.4)
   828 FORMAT(/,19X,5HHSURT,10X,5HSLOPE,10X,5HTVARH,/,(15X,3E15.6))
   830 FORMAT (2I5,10X,6E10.3)
   831 FORMAT(//,12X,16HNODB INDEX LTABT,4X5HTEMPB,10X5HSLOPE,10X5HTIMEB)
   832 FORMAT(10X,3I6,1PE15.6,15X,E15.6)
   833 FORMAT(28X,1P3E15.6)
   835 FORMAT(/,10X,96H  NODS NODSB    AREAS        HSURE        POWER
      $  RSURE        TRANS        HEAT FLOW    AVG RATE)
   836 FORMAT(10X,2I6,1P7E12.4)
   838 FORMAT(10X,18HBOUNDARY NODE DATA,//,10X,5H NODB,4X,5HTEMPB,
      1   8X,9HHEAT FLOW,4X,8HAVG RATE)
   840 FORMAT(10X,I5,1P3E13.4)
   845 FORMAT(/,10X,12HSYSTEM TOTAL,6X,1P2E13.4)
   850 FORMAT(//,18X,55HTB = TEMPB(1) + TEMPB(2)*SINF(2.*PI*(SUMTIM + TIM
      1EB(2))/TIMEB(1)))
   899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
       IF(KCYC) 3000,100,200
  3000 IF(IBLOCK - 7) 3010,40, 3010
  3010 IF(IBLOCK - 6)700, 3020,700
  3020 CONTINUE
 CARD BLOCK 6.  EXTERNAL CONNECTIONS BETWEEN SURFACE AND BOUNDARY NODES.
       N = NOSCON
       L=0
       LABEL=0
       IF(MOE)2,3030,2
  3030 NOPOWS=0
       NORADS=NOPOWS
       NVARH=NORADS
       NOSCON=0
       N=0
     2 READ(5,825)N1,N2,NSEQ,NADS,NADSB,L1,
      $  DLONG,DRAD,NX1,NX2,NX3
```

```
      IF(N1) 3040,30, 3040
 3040 ADD = 0.0
      IF(DRAD) 3050,4,4
 3050 ADD = -(DRAD + DRADS)
      DRAD = DRADS
    4 CALL PATCH(NX1,HONE,HX,LXX)
      CALL PATCH(NX2,RONE,RX,LXX)
      IF(RX) 3060,5, 3060
 3060 NORADS = NORADS + 1 + NSEQ
    5 CALL PATCH(NX3,PONE,PX,LXX)
      IF(PX) 3070,6, 3070
 3070 NOPOWS = NOPOWS + 1 + NSEQ
    6 LTAB=IABS(L1)
      IF(LTAB - 2) 3080,7,7
 3080 L1=0
      LTAB=0
      GO TO 11
    7 NVARH = NVARH + 1 + NSEQ
      IF(LTAB - M9)8,8, 3090
 3090 KWIT = 12
    8 READ(5,810)(F1(J),F2(J),J=1,LTAB)
      DO 10 J = 2,LTAB
      F3(J) =  (F1(J) - F1(J-1))/(F2(J) - F2(J-1))
   10 CONTINUE
      F3(1) = F3(2)
   11 IF(MOE) 3100,15,15
 3100 CALL SEEK2(N,N1,N2,NOXS,NOXSB,NOSCON,K)
      IF(K)14,14, 3110
 3110 IF(RSURE(N)) 3120,12, 3120
 3120 NORADS = NORADS - 1
   12 IF(LTABH(N)) 3130,13, 3130
 3130 NVARH = NVARH - 1
   13 IF(POWER(N)) 3140,14, 3140
 3140 NOPOWS = NOPOWS - 1
   14 ITEMS(6)=MINO(N-1,ITEMS(6))
      GO TO 16
   15 NOSCON=N+1
      N=N+1
   16 IF(N-M6)18,18, 3150
 3150 NOSCON=M6
      N=M6
      KWIT=11
      WRITE(6,899)N,IBLOCK
   18 NOXS(N)=N1
      NODS(N)=N1
      NOXSB(N)=N2
      NODSB(N)=N2
      LTABH(N) = L1
```

```
      HSURT(1,N)=HX
      HSURE(N)=HX
      RSURE(N) = RX
      POWER(N) = PX
      DRADS = DRAD+ADD
      DRAD=DRADS
      AREAS(N) = GEOM*DLONG*DRAD**KSYM*SCALE**2
      IF(LABEL)20,20, 3160
 3160 LABEL = 0
      GO TO 22
   20 L = L + 1
      IF(MOD(L-1,57))24,3170,24
 3170 CONTINUE
   22 WRITE(6,826)
   24 WRITE(6,827)NODS(N),NODSB(N),N,LTABH(N),POWER(N),
     $ DLONG,DRAD,HSURE(N),RSURE(N),AREAS(N)
      IF(LTAB)28,28, 3180
 3180 DO 26 J = 1,LTAB
      HSURT(J,N) = F1(J)
      TVARH(J,N) = F2(J)
      SLOH(J,N) = F3(J)
   26 CONTINUE
      LABEL = 1
      WRITE(6,828) (HSURT(J,N),SLOH(J,N),TVARH(J,N),J=1,LTAB)
   28 IF(NSEQ)2,2, 3190
 3190 NSEQ = NSEQ - 1
      N1 = N1 + NADS
      N2 = N2 + NADSB
      GO TO 11
   30 RETURN
C COMPLETED BLOCK 6.
CARD BLOCK 7. EXTERNAL (BOUNDARY NODE) TEMPS, CONSTANT OR VS TIME.
   40 N = NODBS
      LABEL = 1
      IF(MOE)42, 3200,42
 3200 NVART=0
      NODBS=0
      N=0
   42 READ(5,830)N1,L1,(F1(J),F2(J),J=1,3)
      IF(N1) 3210,70, 3210
 3210 IF(MOE) 3220,46,46
 3220 CALL SEEK1(N,N1,NODB,NODBS,K)
      IF(K)44,44, 3230
 3230 IF(LTABT(N)) 3240,44, 3240
 3240 NVART = NVART - 1
   44 ITEMS(7)=MINO(N-1,ITEMS(7))
      GO TO 47
   46 NODBS=N+1
```

```
      N=N+1
   47 IF(N - M7)48,48, 3250
 3250 NODBS=M7
      N=M7
      KWIT = 11
      WRITE(6,899)N,IBLOCK
   48 NODB(N) = N1
      LTABT(N) = L1
      DO 49 J = 1,3
      TEMPB(J,N) = F1(J)
      TIMEB(J,N) = F2(J)
   49 CONTINUE
      LTAB=IABS(LTABT(N))
      LTABT(N)=LTAB
      TBS(N)=TEMPB(1,N)
      TB(N)=TBS(N)
      IF(LTAB - 100)50, 3260, 3260
 3260 LTAB = 2
      IF(TIMEB(1,N)) 3270, 3270,50
 3270 TIMEB(1,N) = 1.0E24
   50 IF(LABEL)52,52, 3280
 3280 LABEL = 0
      WRITE(6,831)
   52 WRITE(6,832)NODB(N),N,LTABT(N),TEMPB(1,N),TIMEB(1,N)
      IF(LTAB - 2) 3290,55,55
 3290 LTABT(N) = 0
      GO TO 42
   55 NVART = NVART + 1
      IF(LTAB - 4)60, 3300, 3300
 3300 LABEL = 1
      READ(5,810) (TEMPB(J,N),TIMEB(J,N),J=4,LTAB)
   60 DO  65 J=2,LTAB
      SLOT(J,N) = (TEMPB(J,N) - TEMPB(J-1,N))/(TIMEB(J,N)-TIMEB(J-1,N))
   65 CONTINUE
      SLOT(1,N) = SLOT(2,N)
      WRITE(6,833) (TEMPB(J,N),SLOT(J,N),TIMEB(J,N),J=2,LTAB)
      IF(LTAB - M9)68,68, 3310
 3310 KWIT = 12
   68 IF(LTABT(N) - 100)42, 3320, 3320
 3320 WRITE(6,850)
      GO TO 42
   70 NEWBL(6) = NEWBL(6) + 1000
      RETURN
C COMPLETED BLOCK 7.
  100 IBLOCK = 6
      CALL REFER(NODS,NOXS,NOSCON,NODE,NODES)
      CALL REFER(NODSB,NOXSB,NOSCON,NODB,NODBS)
      IF(KWIT)700,3330,700
```

```
 3330 CONTINUE
CCC   INITIALIZE FLUX, CHANGE NTYPE TO 1, UNLESS ALREADY 2.
      DO 130 N=1,NOSCON
      DFS(N)=0.0
      FS(N)=0.0
      N1=NODS(N)
      N2=NTYPE(N1)
      IF(N2 - 2) 3340,130, 3340
 3340 NTYPE(N1) = 1
      IF(N2) 130, 3350,130
 3350 NOSPEC = NOSPEC + 1
  130 CONTINUE
      FLUXS = 0.
CCC   CALC CONDUCTANCE BETWEEN SURFACE AND BOUNDARY NODES.
      DO 170 N = 1,NOSCON
       N1 = NODS(N)
      N2 = NODSB(N)
      HSURE(N) = HSURT(1,N)
      T1 = TBASE + T(N1)
      T2 = TB(N2) + TBASE
      DT12=AMAX1(1.0E-24,ABS(T1-T2))
      RAD = SIGMA*RSUPE(N)*(T1 + T2)*(T1*T1 + T2*T2)
      TRANS(N) = AREAS(N)*(RAD + HSURE(N)*DT12**POWER(N))
      ZIP(N1) = ZIP(N1) + TRANS(N)
      FB(N2) = 0.0
  170 CONTINUE
  200 FORD = FOR*DELT
      IF(KWIT)230, 3360, 3360
 3360 CONTINUE
CCC   FIND TOTAL HEAT FLUX ACROSS EACH EXTERNAL CONNECTION.
      DO 205 N = 1,NOSCON
      N2 = NODSB(N)
      FS(N) = FS(N) + DFS(N)
      FB(N2) = FB(N2)+DFS(N)
  205 CONTINUE
      IF(NOW)230,230, 3370
 3370  IF(KCYC - 1)230, 3380, 3380
 3380 WRITE(6,838)
      TX=AMAX1(SUMTIM-TAU,1.0E-12)
      FLUXS = 0.0
      DO 210 N = 1,NODBS
      FX = FB(N)/TX
      FLUXS = FLUXS + FB(N)
      WRITE(6,840)NODB(N),TB(N),FB(N),FX
  210 CONTINUE
      FX = FLUXS/TX
      WRITE(6,845)FLUXS,FX
      WRITE(6,815)
```

```
      IF(KCYC - 1)230,220, 3390
 3390  IF(KDATA)230,230, 3400
 3400 CONTINUE
  220 WRITE(6,820)
      DO 225 N =1,NOSCON
      FX = FS(N)/TX
      IF(MOD(N-1,57))222,3410,222
 3410 WRITE(6,835)
  222 WRITE(6,836)NOXS(N),NOXSB(N),AREAS(N),
     $ HSURE(N),POWER(N),RSURE(N),TRANS(N), FS(N), FX
  225 CONTINUE
      WRITE(6,815)
CCC   FIND NEW BOUNDARY NODE TEMPERATURES.
  230 IF(NVART)300,300, 3420
 3420 DO 280 N = 1,NODBS
      IF(LTABT(N)) 3430,280, 3430
 3430 BET = TB(N)
      SET = SUMTIM + DELT
      IF(LTABT(N) - 100)235, 3440, 3440
 3440 ARG=6.28318561*(SET+TIMEB(2,N))/(TIMEB(1,N))
      TB(N)=SIN(ARG)
      TB(N) = TEMPB(1,N) + TEMPB(2,N)*TB(N)
      GO TO 275
  235 MIN = 1
      MAX = LTABT(N)
  240 MID = (MIN + MAX)/2
       IF(SET - TIMEB(MID,N))250,270,260
  250 MAX = MID
       IF(MAX - 2)270,240,240
  260 MIN = MID
       IF(MAX - MIN - 2)270,240,240
  270 TB(N) = TEMPB(MID,N) + SLOT(MID+1,N)*(SET - TIMEB(MID,N))
  275 TBS(N) = BET + FOR*(TB(N) - BET)
      DTMAX=AMAX1(DTMAX,ABS(BET-TB(N)))
  280 CONTINUE
CCC   FIND NEW SURFACE HEAT TRANSFER COEFFICIENTS.
  300 IF(NVARH)400,400, 3450
 3450 DO 380 N = 1,NOSCON
       IF(LTABH(N)) 3460,380,320
 3460 SET = SUMTIM + FORD
       GO TO 330
  320 N1 = NODS(N)
       N2 = NODSB(N)
       K1 = NLOOK(N1,8)
      SET = 0.5*(TBS(N2) + T(K1) + FORD*DDT(K1))
  330 MIN = 1
      MAX=IABS(LTABH(N))
      BET = HSURE(N)
```

```
  340 MID = (MIN + MAX)/2
       IF(SET - TVARH(MID,N))350,370,360
  350 MAX = MID
       IF(MAX - 2)370,340,340
  360 MIN = MID
      IF(MAX - MIN -2)370,340,340
  370 HSURE(N) = HSURT(MID,N) + SLOH(MID+1,N)*(SET - TVARH(MID,N))
      SHSURE=HSURE(N)
      BET=100.0*ABS(BET-SHSURE)/(ABS(BET)+1.0E-12)
      DTMAX=AMAX1(DTMAX,BET*TVARY)
  380 CONTINUE
CCC   FIND NEW SURFACE BOUNDARY CONDUCTANCES.
  400 IF(NVARH + NORADS + NOPOWS)425,425, 3470
 3470 DO 420 N = 1,NOSCON
       IF(LTABH(N))410, 3480,410
 3480 IF(RSURE(N))410, 3490,410
 3490  IF(POWER(N)) 3500,420, 3500
 3500 CONTINUE
  410 N1 = NODS(N)
      N2 = NODSB(N)
      ZIP(N1) = ZIP(N1) - TRANS(N)
      T1 = TBASE + T(N1) + FORD*DDT(N1)
      T2 = TBASE + TBS(N2)
      DT12=AMAX1(1.0E-24,ABS(T1-T2))
      RAD = SIGMA*RSURE(N)*(T1 + T2)*(T1*T1 + T2*T2)
      TRANS(N) = AREAS(N)*(RAD + HSURE(N)*DT12**POWER(N))
      ZIP(N1) = ZIP(N1) + TRANS (N)
  420 CONTINUE
CCC   FIND TEMPERATURE CHANGES IN SURFACE NODES.
  425 DO 430 N=1,NOSCON
      N1=NODS(N)
      N2=NODSB(N)
      HEX = DELT*TRANS(N)*(TBS(N2) - T(N1))
      DT(N1) = DT(N1) + HEX/CAP(N1)
      DF(N1) = DF(N1) + HEX
       DFS(N) = HEX
  430 CONTINUE
  700 RETURN
C COMPLETED SURE. RETURN TO HEART.
      END

      SUBROUTINE FLOW
      REAL*8 DELF1,DELF2
      REAL*8 FLEX1,FLEX2,FLEX1A,FLEX2A
      REAL*8 HMELT,A
      REAL*8 NAME, CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
```

```
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 FLOWN
      REAL*8 FORD
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
      COMMON /AFLOWS/ FLOWN(50),NODF1(50),NODF2(50)
      COMMON /AFLOW/ DELF1(50),DELF2(50),FLAPS(50),FLOWT(12,50),
     1       FLINT(355),FLIPS(355),FLOPS(355),FLOUT(355),
     2       LTABFL(50),NOXF1(50),NOXF2(50),
     3       SLOFL(12,50),TVARFL(12,50)
      COMMON /ACHEMS/ KA(15),KAX(15),KB(15),KBX(15),
     1       B(355),BB(355),DB(355),DDB(355)
  805 FORMAT(/10X,20HMASS FLOW CONNECTION,I5,5X,5HNODES,I5,
     $   3HAND,I5,5X,27HARE OF DIFFERENT MATERIALS.)
  810 FORMAT(8E10.3)
  815 FORMAT(6I5,10A1,2E10.3)
  820 FORMAT(//,11X,24HNODF1 NODF2 INDEX LTABFL,3X,5HFLOWT,10X,
     1    5HSLOFL,10X,6HTVARFL,9X,5HDELF1,10X,5HDELF2)
  825 FORMAT(10X,4I6,1X,1PE15.6,30X,2E15.6)
  830 FORMAT(35X,3E15.6)
```

```
 835 FORMAT(10X,100(1H=))
 840 FORMAT(10X,14HMASS FLOW DATA,//,10X,75HSOURCE  SINK    FLOW RATE
    1  NET FLOW     AVG RATE      SOURCE WT      SINK WT)
 845 FORMAT(10X,2I6,1P5E13.5)
 850 FORMAT(/,10X,99H  NODE    RATE IN       RATE OUT    NET FLOW IN   NET
    1FLOW OUT AVG FLOW IN  AVG FLOW OUT RESIDENCE TIME)
 855 FORMAT(10X,I6,1P7E13.5)
 899 FORMAT(15(1H*),17HMORE THAN ALLOWED,I5,15H ITEMS IN BLOCK,I3)
     IF(KCYC) 3000,100,200
3000 CONTINUE
CARD BLOCK 10. MASS FLOW CONNECTIONS.
     N = NOFLOW
     L = 0
     IF(MOE)2, 3010,2
3010 NVARFL=0
     NOFLOW=0
     N=0
   2 READ(5,815)N1,N2,NSEQ,NADF1,NADF2,L1,NX1,D1,D2
     IF(N1) 3020,70, 3020
3020 DS = D1 + D2
     IF(DS)5, 3030,5
3030 DX1 = DX2
     GO TO 10
   5 DX1 = D2/DS
     DX2 = D1/DS
  10 CALL PATCH(NX1,FONE,FX,LXX)
     LTAB=IABS(L1)
     IF(LTAB - 2) 3040,15,15
3040 L1=0
     LTAB=0
     GO TO 30
  15 IF(LTAB - M9)20,20, 3050
3050 KWIT = 12
  20 READ(5,810)(F1(J),F2(J),J=1,LTAB)
     DO 25 J = 2,LTAB
     F3(J) = (F1(J) - F1(J-1))/(F2(J) - F2(J-1))
  25 CONTINUE
     F3(1) = F3(2)
     NVARFL = NVARFL + 1 + NSEQ
  30 IF(MOE) 3060,35,35
3060 CALL SEEK2(N,N1,N2,NOXF1,NOXF2,NOFLOW,K)
     IF(K)34,34, 3070
3070 IF(LTABFL(N)) 3080,34, 3080
3080 NVARFL = NVARFL - 1
  34 ITEMS(10)=MINO(N-1,ITEMS(10))
     GO TO 40
  35 NOFLOW=N+1
     N=N+1
```

```
   40 IF(N - M10)45,45, 3090
 3090 NOFLOW = M10
      N=M10
      KWIT = 11
      WRITE(6,899)N,IBLOCK
   45 NOXF1(N)=N1
      NODF1(N)=N1
      NOXF2(N)=N2
      NODF2(N)=N2
      LTABFL(N) = L1
      FLOWN(N) = FX
      DELF1(N) = DX1
      DELF2(N) = DX2
      L = L + 1
      IF(MOD(L-1,57))50,3100,50
 3100 WRITE(6,820)
   50 WRITE(6,825)NODF1(N),NODF2(N),N,LTABFL(N),FLOWN(N),D1,D2
      IF(LTAB)60,60, 3110
 3110 DO 55 J = 1,LTAB
      FLOWT(J,N) = F1(J)
      TVARFL(J,N) = F2(J)
      SLOFL(J,N) = F3(J)
   55 CONTINUE
      WRITE(6,830)(FLOWT(J,N),SLOFL(J,N),TVARFL(J,N),
     $ J=1,LTAB)
   60  IF(NSEQ)2,2, 3120
 3120 NSEQ = NSEQ - 1
      N1 = N1 + NADF1
      N2 = N2 + NADF2
      GO TO 30
   70 RETURN
C COMPLETED BLOCK 10.
  100 IBLOCK = 10
      CALL REFER(NODF1,NOXF1,NOFLOW,NODE,NODES)
      CALL REFER(NODF2,NOXF2,NOFLOW,NODE,NODES)
      IF(KWIT)500, 3130,500
 3130 CONTINUE
CCC   CHECK MATERIALS, WEIGHT FACTORS OF MASS FLOW CONNECTIONS.
      DO 120 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
      IF(NTYPE(N1)-2)110, 3140,110
 3140 DELF1(N)=1.0
      DELF2(N)=0.0
      GO TO 115
  110 IF(NTYPE(N2)-2)115, 3150,115
 3150 DELF2(N)=1.0
      DELF1(N)=0.0
```

```
  115 IF(NODMAT(N1) - NODMAT(N2)) 3160,120, 3160
 3160 WRITE(6,805)N,NOXF1(N),NOXF2(N)
  120 CONTINUE
CCC 2(ITIALIZE NET FLOW AND FLOW RATES FOR EACH NODE.
      DO 125 N = 1,NODES
      FLOUT(N)=0.0
      FLINT(N)=0.0
      FLIPS(N)=0.0
      FLOPS(N)=0.0
  125 CONTINUE
      DO 130 N = 1,NOFLOW
      FLAPS(N) = 0.0
  130 CONTINUE
      DO 140 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
CCC   REORCER CONNECTION IN DIRECTION OF POSITIVE MASS FLOW.
      IF(FLOWN(N)) 3170,140,135
 3170 FLOWN(N) = -FLOWN(N)
      D1 = DELF1(N)
      NODF1(N) = N2
      NOXF1(N) = NODE(N2)
      DELF1(N) = DELF2(N)
      NODF2(N) = N1
      NOXF2(N) = NODE(N1)
      DELF2(N) = D1
CCC   FIND NET FLOW RATES IN AND OUT OF EACH NODE.
  135 FLOUT(N1) = FLOUT(N1) + FLOWN(N)
      FLINT(N2) = FLINT(N2) + FLOWN(N)
CCC    FIND CONTRIBUTION OF MASS FLOW TO CONDUCTANCE OF EACH NODE.
      ZIP(N2) = ZIP(N2) + FLOWN(N)*CAP(N2)/HEFT(N2)
  140 CONTINUE
CCC   START HERE DURING CYCLING.
  200 FORD = FOR*DELT
      IF(KWIT)208, 3180, 3180
 3180 DO 205 N = 1,NOFLOW
       N1 = NODF1(N)
       N2 = NODF2(N)
      FLOWX = DELTS*FLOWN(N)
       FLAPS(N) = FLAPS(N) + FLOWX
      FLOPS(N1) = FLOPS(N1) + FLOWX
       FLIPS(N2) = FLIPS(N2) + FLOWX
  205 CONTINUE
  208 IF(NOW)215,215, 3190
 3190  IF(KCYC - 1)215,210, 3200
 3200 IF(KDATA)215,215, 3210
 3210  IF(NVARFL)215,215, 3220
 3220 CONTINUE
```

```
  210 WRITE(6,840)                                                          15490
      TX=AMAX1(SUMTIM-TAU,1.0E-12)                                          15500
      DO 212 N = 1,NOFLOW                                                   15510
      FX = FLAPS(N)/TX                                                      15520
      WRITE(6,845)NOXF1(N),NOXF2(N),FLOWN(N),FLAPS(N),FX,                   15530
     1   DELF1(N),DELF2(N)                                                  15540
  212 CONTINUE                                                              15550
      WRITE(6,835)                                                          15560
      WRITE(6,850)                                                          15570
      DO 214 N = 1,NODES                                                    15580
      IF(FLINT(N))214,214, 3230                                             15590
 3230 DFLOT = HEFT(N)/FLINT(N)                                              15600
      FX1 = FLIPS(N)/TX                                                     15610
      FX2 = FLOPS(N)/TX                                                     15620
      WRITE(6,855)NODE(N),FLINT(N),FLOUT(N),                                15630
     $  FLIPS(N),FLOPS(N),FX1,FX2,DFLOT                                     15640
  214 CONTINUE                                                              15650
      WRITE(6,835)                                                          15660
  215 IF(NVAPFL)300,300, 3240                                               15670
 3240 CONTINUE                                                              15680
CCC   FIND NEW MASS FLOW RATES.                                             15690
      DO 280 N = 1,NOFLOW                                                   15700
      N1 = NODF1(N)                                                         15710
      N2 = NODF2(N)                                                         15720
       K1 = NLOOK(N1,7)                                                     15730
      K2 = NLOOK(N2,7)                                                      15740
      IF(LTABFL(N)) 3250,280,220                                            15750
 3250  SET = SUMTIM + FORD                                                  15760
       GO TO 230                                                            15770
  220 SET = DELF1(N)*(T(K1)+FORD*DDT(K1))+DELF2(N)*(T(K2)+FORD*DDT(K2))     15780
  230  BET = FLOWN(N)                                                       15790
      ZIP(N2) = ZIP(N2) - FLOWN(N)*CAP(N2)/HEFT(N2)                         15800
      FLINT(N2) = FLINT(N2) - FLOWN(N)                                      15810
      FLOUT(N1) = FLOUT(N1) - FLOWN(N)                                      15820
      MIN = 1                                                               15830
      MAX=IABS(LTABFL(N))                                                   15840
  240 MID = (MIN + MAX)/2                                                   15850
       IF(SET - TVARFL(MID,N))250,270,260                                   15860
  250 MAX = MID                                                             15870
       IF(MAX - 2)270,240,240                                               15880
       IF(MAX - MIN - 2)270,240,240                                         15900
  260 MIN = MID                                                             15890
CCC   FIND NEW NET FLOW RATES, CONDUCTANCE CONTRIBUTIONS OF MASS FLOW.      15910
  270 FLOWN(N) = FLOWT(MID,N) + SLOFL(MID+1,N)*(SET - TVARFL(MID,N))        15920
CCC   REORDER CONNECTION IN DIRECTION OF POSITIVE MASS FLOW.                15930
      IF(FLOWN(N)) 3260,278,275                                             15940
 3260 FLOWN(N) = -FLOWN(N)                                                  15950
      D1 = DELF1(N)                                                         15960
```

```
      NODF1(N) = N2
      NOXF1(N) = NODE(N2)
      DELF1(N) = DELF2(N)
      NODF2(N) = N1
      NOXF2(N) = NODE(N1)
      DELF2(N) = D1
  275 ZIP(N2) = ZIP(N2) + FLOWN(N)*CAP(N2)/HEFT(N2)
      FLINT(N2) = FLINT(N2) + FLOWN(N)
      FLOUT(N1) = FLOUT(N1) + FLOWN(N)
  278 BET=100.0*DABS((BET-FLOWN(N))/(BET+1.0E-12))
      DTMAX=AMAX1(DTMAX,BET*TVARY)
  280 CONTINUE
CCC   FIND TEMPERETURE CHANGES DUE TO MASS FLOW.
  300 DO 320 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
      K11=NODMAT(N1)
      K12=NODMAT(N2)
      FLEX1=W(N1)/HEFT(N1)-FORD*DDA(N1)*HMELT(K11)
      FLEX2=W(N2)/HEFT(N2)-FORD*DDA(N2)*HMELT(K12)
      DT(N1) = DT(N1) + FLOWN(N)*DELF2(N)*(FLEX1 - FLEX2)*DELT/CAP(N1)
      DT(N2) = DT(N2) + FLOWN(N)*DELF1(N)*(FLEX1 - FLEX2)*DELT/CAP(N2)
  320 CONTINUE
CCC   FIND CHANGE IN CONCENTRATIONS DUE TO MASS FLOW.
      IF(NKEM)500,500,3270
 3270 DO 360 N = 1,NOFLOW
      N1 = NODF1(N)
      N2 = NODF2(N)
      K11 = NODMAT(N1)
      K12 = NODMAT(N2)
      IF(KA(K11))3280,360,3280
 3280 IF(KA(K12))3290,360,3290
 3290 FLOWX = DELT*FLOWN(N)
      FLEX1A = FLOWX*(A(N1) + FORD*DDA(N1))
      FLEX1B = FLOWX*(B(N1) + FORD*DDB(N1))
      FLEX2A = FLOWX*(A(N2) + FORD*DDA(N2))
      FLEX2B = FLOWX*(B(N2) + FORD*DDB(N2))
      DA(N1) = DA(N1) + DELF2(N)*(FLEX1A - FLEX2A)/HEFT(N1)
      DA(N2) = DA(N2) + DELF1(N)*(FLEX1A - FLEX2A)/HEFT(N2)
      DB(N1) = DB(N1 ) + DELF2(N)*(FLEX1B - FLEX2B)/HEFT(N1)
      DB(N2) = DB(N2) + DELF1(N)*(FLEX1B - FLEX2B)/HEFT(N2)
  360 CONTINUE
  500 RETURN
C COMPLETED FLOW. RETURN TO HEART.
      END
```

```
      SUBROUTINE SEEK2 (N, N1, N2, NB1, NB2, MAX, K)
CCC   VERSION 5/29/68.
CCC   SEEK2 LOOKS FOR PAIR OF NUMBERS N1, N2 INPAIR OF ARRAYD NB1, NB2,
CCC    SETS N TO SUBSCRIPT OF NB1, NB2 IF FOUND, OTHERWISE SETS N TO
CCC   ARRAY SIZE PLUS 1.
      REAL*8 NAME
      COMMON NAME(20)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      DIMENSION NB1(1),NB2(1),NBB1(75),NBB2(75)
  800 FORMAT(5(1H*),5HITEMS,2I6,33H NOT FOUND, ADDED TO END OF BLOCK,
     1   I4,1H.)
      IF(MAX)125,125, 3000
 3000 DO 100 I=1,MAX
      KOF=MAX-I+1
      NBB1(I)=NB1(KOF)
  100 NBB2(I)=NB2(KOF)
      DO 120 J=1,MAX
      IF(N1-NBB1(J)) 120,3010,120
 3010 IF(N1-NBB2(J)) 3020,130,3020
 3020 CONTINUE
  120 CONTINUE
  125 MAX = MAX + 1
      J = MAX
      K = 0
      WRITE(6,800) N1,N2,IBLOCK
  130 J=MAX-J+1
      N=4
      K = 1
      RETURN
      END


      SUBROUTINE SEEK1 (N, N1, NB1, MAX, K)
CCC   VERSION 5/29/68.
CCC   SEEK1 LOOKS FOR N1 IN ARRAY NB1, SETS N TO SUBSCRIPT OF NB1 IF
CCC     N1 FOUND, OTHERWISE SETS N TO ARRAY SIZE PLUS 1.
      REAL*8 NAME
      COMMON NAME(20)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      DIMENSION NB1(1),NBB1(75)
  800 FORMAT(5(1H*),5HITEM ,I6,6X,33H NOT FOUND, ADDED TO END OF BLOCK,
     1   I4,1H.)
      IF(MAX)125,125, 3000
 3000 DO 100 I=1,MAX
```

```
      KOF=MAX-I+1
  100 NBB1(I)=NB1(KOF)
      DO 120 J=1,MAX
      IF(N1-NBB1(J)) 3010,130,3010
 3010 CONTINUE
  120 CONTINUE
  125 MAX = MAX + 1
       J = MAX
      K = 0
      WRITE(6,800) N1,IBLOCK
  130 J=MAX-J+1
      N=J
      K = 1
      RETURN
      END


      SUBROUTINE CLOCK1(KSEC,CLICKA)
C     SUBROUTINE CLOCK1(KSEC,CLICKA)
      KSEC=0
      CLICKA=0.0
      RETURN
      END


      SUBROUTINE CLOCK(CLOCKA,CLOCKB)
C     SUBROUTINE CLOCK(CLOCKA,CLOCKB)
      CLOCKA=0.0
      CLOCKB=0.0
      RETURN
      END


      SUBROUTINE PLOT
      REAL*8 HMELT,A
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      REAL*8 NAME,CAPS
      INTEGER PNODE
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1      CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2      DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3      T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
```

```
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NCDE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3  NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXF(355),NTYPES(355),TT(355)
      COMMON /APLOT/ NODEP(12),NOXEP(12)
  824 FORMAT(I4,2F10.3,I4)
  855 FORMAT(16I5)
  856 FORMAT(//10X,47HNODES FOR TEMPERATURE VS TIME CRT PLOTS.  MAX =,
    1    I3,/,10X,5HINDEX,10I5,/,11X,4HNODE,10I5)
  865 FORMAT(4I5,6E10.3)
  875 FORMAT(//,12X,94HJPIC  LOGR LOGTEM LOGTIM    FRAD1       FRAD2
     $   FTEMP1       FTEMP2       FTIME1       FTIME2,/10X4I6,4X1P6E12.4)
  880 FORMAT( /,10X,30HWILL MAKE TEMP VS RADIUS PLOTS)
      IF(KCYC - 1) 3000,100,100
 3000 IF(IBLOCK -11)50, 3010,50
 3010 NUP=0
      NTARP=0
      NGRID=0
      ITHERM=0
      INTERP=0
      NOSTIM=1
      NOSTEM=1
      KKK=0
      READ(5,865) JPIC,LOGR,LOGTEM,LOGTIM,
     $ FRAD1, FRAD2, FTEMP1, FTEMP2, FTIME1, FTIME2
      IF(JPIC) 3020,50,30
 3020 NUP=1
      NTARP=1
      WRITE(6,880)
   30 LOGR=IABS(LOGR)
      IF(LOGR - 100) 32, 3030,3030
```

```
3030 LOGR=MOD(LOGR,100)
     INTERP = 1
  32 JPIC=IABS(JPIC)
     LOSR=MINO(1,LOGR)
     IF(IABS(LOGTEM)-100) 34,3040,3040
3040 NGRID = 1
     LOGTEM=MOD(LOGTEM,100)
  34 IF(LOGTEM) 3050,35,35
3050 NOSTEM = 2
     LOGTEM = -LOGTEM
  35 LOSTEM=MINO(1,LOGTEM)
     IF(IABS(LOGTIM)-100) 36,3060,3060
3060 ITHERM = 1
     LOGTIM=MOD(LOGTIM,100)
  36 IF(LOGTIM) 3070,38,38
3070 NOSTIM = 2
     LOGTIM = -LOGTIM
  38 LOSTIM=MINO(1,LOGTIM)
      IF(FRAD2) 40, 3080, 40
3080  FRAD2 = 1.0
  40 IF(FTEMP2) 41, 3090, 41
3090  FTEMP2 = 1.0
  41 IF(FTIME2) 42, 3100, 42
3100  FTIME2 = 1.0
  42 WRITE(6,875) JPIC,LOGR,LOGTEM,LOGTIM,FRAD1,
    $ FRAD2,FTEMP1,FTEMP2,FTIME1,FTIME2
     READ(5,855) (NODEP(J),J=1,12)
     DO 45 J=1,M11
     IF(NODEP(J)) 3110,46, 3110
3110 NOXEP(J) = NODEP(J)
     NUP = NUP + 1
  45 CONTINUE
  46 NUP1 = NUP - NTARP
      IF(NUP1) 50, 50, 3120
3120 WRITE(6,856)M11,(I,I=1,10),(NODEP(J),J=1,NUP1)
  50 RETURN
C COMPLETED BLOCK 11.
 100 KKK=KKK+1
C    THE DO LOOP BELOW CHANGED TO COMMENT. SEPT 1971
C    DO 300 I=1,10
C    PNODE=NODEP(I)
C    WRITE(9,824) NODE(PNODE),T(PNODE),SUMTIM,KKK
C 300 CONTINUE
 250 RETURN
     END
```

```
      SUBROUTINE PATCH (NXX,CONE,POUT,LBX)
C     CARDS COLUMN       PATCH VERSION 5/29/68.
C     FORTRAN            PATCH   TRUMP DEC PT FINDING SUB.     FORTRAN-400
CCC   VERSION 5/29/68.
CCC   PATCH STORES CONE IN POUT IF NXX CONTAINS NO DECIMAL POINT,
CCC      OTHERWISE CONVERTS NXX TO FLOATING POINT AND STORES IN POUT.
      DIMENSION NXX(10)
      REAL*8 HMELT,A
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 NAME,CAPS
      REAL*8 FOR,SLIM,T,GEOM
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NRS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAR,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
      DATA IPT/'.'/
      DO 10 J=1,10
      IF(NXX(J)-IPT) 3000,20,3000
 3000 CONTINUE
   10 CONTINUE
      POUT = CONE
      LBX = 0
```

```
      GO TO 30
   20 PXX=0
      CALL SRCON(NXX,1,10,PXX,POUT,NONUM)
      LBX = 1
   30 RETURN
      END


      SUBROUTINE REFER(LIST,LISTX,MAX,LISTR,MAR)
CCC   VERSION  5/29/68
CCC   FINDS J FOR WHICH LISTX(N) = LISTR(J), MAKES LIST(N) = J.
      DIMENSION LIST(1),LISTR(1),LISTX(1),LISTS(950)
      REAL*8 HMELT,A
      REAL*8 CON,DA,ZIP,TRAN
      REAL*8 NAME,CAPS
      REAL*8 DELT,DDA,DDT,CAP,DF,DT,G,HEFT
      REAL*8 FOR,SLIM,T,GEOM
      COMMON NAME(20)
      COMMON CAPS,DELT,FOR,GEOM,HMELT(15),A(355),
     1       CAP(355),CON(355),DA(355),DDA(355),DDT(355),
     2       DF(355),DT(355),G(355),HEFT(355),SLIM(355),
     3       T(355),ZIP(355),TRAN(950)
      COMMON M1,M2,M3,M4,M5,M6,M7,M8,M9,M10,M11,M12,M13
      COMMON NPS,NR,NB,MW,M,NDATA,IBLOCK,MOE,KWIT,
     1       ITEMS(15),NEWBL(15)
      COMMON NOSPEC,NMAT,NKEM,NODES,NOCON,NOSCON,NODBS,NVARG,NIT,
     1       NOFLOW,NUP1,NTABS,NVARC,NVARK,NMELT,NREACT,NVARQ,
     2       NVARZ,NVARE,NORAD,NVARH,NORADS,NOPOWS,NVART,NVARFL
      COMMON JPIC,KCYC,KD,KDATA,KSECS,KSYM,NOGEN,NOW,NPROB,NUP,NUTS
      COMMON ALONE,BONE,CLOCKA,CLOCKB,DELTS,
     1       DSTAB,DTMAX,FONE,GONE,HONE,PONE,
     2       RONE,SCALE,SIGMA,SMALL,SUMTIM,TAU,TBASE,
     3       TMAX,TMIN,TONE,TVARY
      COMMON HMELTX(15),LTABK(15),
     1       NLOOK(355,8),NODE(355),
     2       NODMAT(355),NTYPE(355),RADIUS(355),
     3       VOL(355),W(355),
     4       DFI(950),FI(950),NOD1(950),NOD2(950),
     5       F1(12),F2(12),F3(12),NX1(10),NX2(10),NX3(10),NX4(10)
      COMMON AMAT(15),CAPT(12,15),CONT(12,15),DENS(15),
     1       LTABC(15),MAT(15),SLOC(12,15),SLOK(12,15),
     2       TMELT(15),TVARC(12,15),TVARK(12,15),WT(12,15),
     3 NOXMAT(355),
     4       NODP1(75),NODP2(75),NOXP1(75),NOXP2(75),NPROP(75)
      COMMON AA(355),F(355),GG(355),H(355),NOTE(355),
     1       NOXE(355),NTYPES(355),TT(355)
  805 FORMAT(/,15(1H*),8HERROR IN,I5,17H'TH ITEM IN BLOCK,I3,
     1   52H.  REFERS TO UNSPECIFIED MATL, REACTANT, OR NODE NO.,I6,1H.)
```

```
      IF(MAR*MAX)150,150, 3000
 3000 IF(NEWBL(IBLOCK))150,150, 3010
 3010 N1 = 1
      IF(IBLOCK-1)150,90,3020
 3020 IF(NEWBL(IBLOCK) - 1000) 3030,3030,90
 3030 N1 = ITEMS(IBLOCK) + 1
   90 DO 95 I=1,MAR
      KOF=MAR-I+1
   95 LISTS(I)=LISTR(KOF)
  100 DO 120 N = N1,MAX
      DO 110 J=1,MAR
      IF(LISTX(N)-LISTS(J)) 3040,113,3040
 3040 CONTINUE
  110 CONTINUE
       IF(IBLOCK - 2)114, 3050,114
 3050  IF(LISTX(N)) 3060,120, 3060
 3060 CONTINUE
  114 WRITE(6,805) N,IBLOCK,LISTX(N)
      KWIT = 5
      GO TO 150
  113 J=MAR-J+1
  115 LIST(N) = J
  120 CONTINUE
  150 RETURN
CCC   END OF REFER. RETURN TO CALLER.
      END


      SUBROUTINE  SRCON(NXX,I,J,POWER,POUT,NER)
      REAL*8 POUT8
      INTEGER DIGIT(10)/'0','1','2','3','4','5','6','7','8','9'/
      INTEGER          I,J,POWER
      DIMENSION NXX(10)
      INTEGER  INT,FRAC,K
      INTEGER POINT/'.'/
      INTEGER BLNK/'    '/
      INTEGER NEX(4)/'D','E','+','-'/
      FRAC=0
      INT = 0
      NPS= 1
      II = I
      DO  1 N =II,J
      IF(NXX(N).EQ.POINT) GO TO 5
      IF(NXX(N).EQ.BLNK)GO TO 1
      IF(NXX(N).NE.NEX(4))GO TO 10
      NPS= -1
      GO TO 1
   10 CONTINUE
```

```
      DO  2 M = 1,10
      IF(NXX(N) .EQ. DIGIT(M)) GO TO 3
    2 CONTINUE
      NERR=1
      GO TO 50
    3 INT = INT*10+M-1
    1 CONTINUE
      GO TO 20
    5 II= N+1
      IF(II.GT. J) GO TO 20
      K = 0
      DO 6  N = II,J
      IF(NXX(N).EQ.BLNK)GO TO 120
      DO 7 M=1,10
      IF(NXX(N) .EQ. DIGIT(M)) GO TO 8
    7 CONTINUE
      DO 9  JF= 1,4
      IF(NXX(N).EQ.NEX(JF))GO TO 120
    9 CONTINUE
      NERR=2
      GO TO 50
    8 FRAC = FRAC*10+M-1
      K=K+1
    6 CONTINUE
   20 POUT8= FRAC
      POUT8= POUT8*10.**(-K)
      POUT=(POUT8+INT)*10.**POWER*NPS
      RETURN
  120 CONTINUE
      NSIGN= 1
      DO 130 JA= N,J
      DO 125  JG= 1,10
      IF(NXX(JA).EQ.DIGIT(JG))GO TO 150
  125 CONTINUE
      DO 130 JB= 1,4
      IF(NXX(JA).EQ.NEX(JB))GO TO 150
  130 CONTINUE
      GO TO 20
  150 CONTINUE
      DO 170 JC= JA,J
      IF(NXX(JC).EQ.NEX(4))NSIGN=-1
      IF(NXX(JC).EQ.BLNK)GO TO 170
      DO 170 JD= 1,10
      IF(NXX(JC).EQ.DIGIT(JD))GO TO 200
  170 CONTINUE
      NERR=3
      GO TO 50
  200 POWER=(JD-1)*NSIGN
```

```
      IF(JC.EQ.10)GO TO 20
      DO 210 JE= 1,10
      IF(NXX(JC+1).EQ.DIGIT(JE))POWER=POWER*10+(JE-1)*NSIGN
  210 CONTINUE
      GO TO 20
   50 WRITE(6,51) NERR,(NXX(JA),JA=I,J)
   51 FORMAT(////10X,'NERR = ',I2,//10X,'NXX = ',10A4/)
      RETURN
      END
```

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13. ABSTRACT

A computer program, with the code name TRUMP, was developed in 1965 by the Lawrence Livermore Laboratory to solve a variety of transient and steady-state conduction heat flow problems in simple or complicated geometric configurations. The purpose of this investigation was to adapt "TRUMP" to the Naval Postgraduate School IBM/360 Model 67 computer system. Several heat conduction problems are solved with the adapted version of TRUMP and the results compare closely with the analytical solutions to these problems. The example problem inputs may be used as guides in preparing input data for future problems. Some suggestions are also given for further development of the program.

14 KEY WORDS	LINK A		LINK B		LINK C	
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conduction						
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Trump						

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for solving transient
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