MEMORANDUM REPORT RSI-0049

DATA INPUT MANUAL FOR RSI/TRANCO:

A FINITE ELEMENT HEAT CONDUCTION COMPUTER PROGRAM

Submitted To

Office of Waste Isolation
Oak Ridge, Tennessee

operated by

Union Carbide Corporation
Nuclear Division

for the

Energy Research and Development Administration

By

Gary D. Callahan
and
Arlo F. Fossum

February 1, 1977

This report was prepared by RE/SPEC Inc., under Subcontract No. 89Y-22303C with Union Carbide Corporation, Nuclear Division, under Contract No. W-7405-eng-26 with the Energy Research and Development Administration. The subcontract was administered by the Office of Waste Isolation, Union Carbide Corporation, Nuclear Division.

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FOREWORD

This report was prepared under a subcontract with Union Carbide Corporation, Nuclear Division, an ERDA contractor. The subcontract was administered by the Office of Waste Isolation and is part of the National Waste Terminal Storage (NWTS) Program. The principal objective of the NWTS Program is to provide facilities in various deep geologic formations at multiple locations in the United States which will safely dispose of commercial radioactive waste, which must be delivered to a Federal Repository for terminal storage. Some of the expected wastes produce both heat and radioactivity. This situation leads to many unique problems in rock mechanics. This report addresses a particular problem relative to the Rock Mechanics Program.

The overall objective of the OWI Rock Mechanics Program is to predict the response of a rock mass hosting a waste repository during its construction and operation, as well as the post-operational phase. The operational phase is expected to be approximately 20 years while the post-operational phase will last until the repository no longer poses any potential hazard to mankind, a period that may last several hundred thousand years. The Rock Mechanics Program is concerned with near field effects on mine stability as well as far field effects relative to the overall integrity of the geologic containment of waste.

In order to accomplish the objectives of the Rock Mechanics Program, numerical simulation, laboratory (including bench scale), and field studies are under way. The laboratory and field studies provide input to the numerical simulations and also the opportunity for validation of the predictive capabilities of the computer codes. Ultimately, the computer codes will provide the predicted response of the host rock mass and thereby form an essential part of the overall Rock Mechanics Program.

This report provides information on input data as well as FORTRAN listing of RSI/TRANCO: A Finite Element Heat Conduction Computer Program. Documentation of all computer codes used in the NWTS Program is important in order to provide for continuity in the program and acceptance by both the scientific community and the public. ✓

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February 1, 1977

MEMORANDUM REPORT RSI-0049

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FROM: Mr. Gary D. Callahan
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Rapid City, SD 57701

SUBJECT: Data Input Manual for RSI/TRANCO: A Finite Element Heat
Transfer Computer Program (Ref.: Union Carbide Corporation,
Nuclear Division Subcontract No. 89Y-22303 (RSI-001000/FY77)).

1. INTRODUCTION

Program: RSI/TRANCO

Function: RSI/TRANCO solves plane isotropic or anisotropic
transient or steady state heat transfer problems.
Boundary condition types include fixed temperature,
constant flux, and convective. In addition, constant
internal heat sources and constant or temperature
dependent thermal properties are included.

Output: Input data, if desired, and the nodal values of the
temperature field are printed.

Arbitrarily shaped, plane, boundary value problems in heat transfer
may be solved with RSI/TRANCO utilizing eight noded isoparametric elements
and six noded subparametric (i.e. geometry polynomial is of a lower order
than the displacement polynomial) triangular elements or a combination of
both. For a discussion of the finite element method, the reader is directed
to References 1 and 2.

Figure 1 presents a segment of a finite element mesh which is represen-
tative of most problems and defines certain items which may not be common
terminology.

(a) Segment from a Typical Finite Element Discretization.

(b) Typical Eight-Noded Isoparametric Element.

Primary Nodes	-	i, k, m, o
Secondary Nodes	-	j, l, n, p
Global Coordinate Axes	-	x, y
Local Coordinate Axes	-	η, ξ

Figure 1. Segment of a typical finite element mesh utilizing eight noded isoparametric elements.

In Section 2, each required data card type is described. The bulk of the input data is associated with card types 8 and 9 which are required to describe the finite element mesh. At times, one may find advantages in writing a small computer program to generate the nodal coordinates and element nodal identifications automatically.

In the final section, an example problem is presented to illustrate the mesh preparation, data input, and sample output. A fortran listing of the computer program is given in the Appendix, along with current program limits.

The following pages illustrate and describe the required data for running various heat transfer problems utilizing RSI/TRANCO. Each data card type is discussed separately and requires no further discussion at this point.

nodal coordinates	-	ft.
thermal conductivity	-	$\frac{\text{Btu}}{\text{ft} - \text{hr} - ^\circ\text{F}}$
specific heat	-	$\frac{\text{Btu}}{\text{lb}_m - ^\circ\text{F}}$
density	-	$\frac{\text{lb}_m}{\text{ft}^3}$
convective film coefficient	-	$\frac{\text{Btu}}{\text{ft}^2 - \text{hr} - ^\circ\text{F}}$
time-step	-	hr.
heat generation rate	-	$\frac{\text{Btu}}{\text{hr} - \text{ft}^3}$

In the following text, dimensions are given in terms of mass (M), length (L), time (t), and temperature (T).

[illegible]

ITDEP = 1 temperature dependent thermal properties

[illegible]

One SLOPE card is supplied for each material type (NELMAT, data card 4).

DATA CARD(S) 7

SLOP2(N,1,1)										SLOP2(N,2,1)										SLOP2(N,1,2)										SLOP2(N,2,2)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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One SLOP2 card is supplied for each material type (NELMAT, data card 4).

DATA CARDS 8 consist of the global nodal coordinates of the finite element mesh. When nodal point cards are omitted, the coordinates are generated at equal intervals between the nodal point data supplied, say nodes n_1 and n_n . In addition, with $JIG = 0$ on the ending nodal point card of the generation sequence (n_n in this case) ITYPN and TCONS are set equal to zero for each generated nodal point. However, with $JIG > 0$, ITYPN and TCONS are set equal to the values provided for the first node in the generation sequence (n_1 in this case).

DATA CARD(S) 8

N	JIG	ITYPN	CORDS(N,1)	CORDS(N,2)	TCONS(N)
1	15	13	10.2	10.2	10.2
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
10	10	10	10	10	10
 

N

$NELCON (N, 1) - NELCON (N, 8)$

A diagram showing a rectangle labeled N in the center. The vertices and midpoints of the rectangle are marked with dots. The labels for these points are as follows:

- Top-left vertex: $NELCON(N, 7)$
- Top-middle point: $NELCON(N, 6)$
- Top-right vertex: $NELCON(N, 5)$
- Left-middle point: $NELCON(N, 8)$
- Bottom-left vertex: $NELCON(N, 1)$
- Bottom-middle point: $NELCON(N, 2)$
- Bottom-right vertex: $NELCON(N, 3)$
- Right-middle point: $NELCON(N, 4)$

ANG (N)

DATA CARD(S) 10

[illegible]
$$NCBN(N, 1) - NCBN(N, 3)$$
$$NCBN(N, 4)$$
 $CFC(N)$ $TCONV(N)$

Omit data card(s) 10 if NCB = 0 (data card 4).

DATA CARD 11

```

IR          is a format control parameter.
IR = 1      initial temperatures are read
             in for every node

IR = 0      Temperatures may be generated
             between nodes, or temperatures
             may be specified at particular
             nodes

```

The IR = 1 option is used together with data card type 12 that follows. This option requires that each nodal temperature be specified. For instance, if IWRIT = 2 (data card 1), the temperature field at the final time-step (JTMAX) is punched according to the format specification for data card type 12. These punch cards could subsequently be used with IR = 1 to restart the program at a later date.

[illegible]

are the initial nodal temperatures.
Omit data card(s) 12 for $IR = .0$ and for
steady-state problems ($DELT = 0.0$,
data card 2)

[illegible]

Data card type 13 is used if $IR = 0$ (card type 11). Using card type 13 reduces data input since automatic generation is utilized where nodal temperatures are identical.

End data card 13 sequence with one blank card unless the initial temperature field is zero. The following table illustrates the input procedure.

N	K	TT	Comments
0	0	0	All initial nodal temperatures are zero except those specified as constant temperature boundary nodes. No blank end card required.
N1	0	TT1	Nodes N1 through NN are all initialized to temperature TT1. Blank end card.
NN	1	TT1	
0	0	0	
N1	0	TT1	Nodes N1 through NN1 are all initialized to temperature TT1 and nodes N2 through NN2 are all initialized to temperature TT2. Nodes not specified are taken to be zero and constant temperature boundary nodes are maintained. Blank end card.
NN1	1	TT1	
N2	0	TT2	
NN2	1	TT2	
0	0	0	

Examples: Suppose we desire to give nodes 1 through 5 the temperature 100 and nodes 6 through 10 the temperature 200; then we would have:

N	K	TT	Comment
5	1	100	specifies nodes 1-5
10	1	200	specifies nodes 6-10
0	0		end sequence card

Suppose we desire to give only nodes 5 and 10 the temperatures 100 and 200, respectively, then we would have:

N	K	TT	Comment
5	0	100	Specifies just node 5
10	0	200	Specifies just node 10
0	0	0	End sequence card

Omit data card(s) 13 for $IR = 1$ and for steady state problems ($DELT = 0.0$, data card 2).

3. EXAMPLE PROBLEM

3.1. Problem Description

Consider heat conduction in a slab of width $2L$, initially at uniform temperature T_i . For times $t > 0$, both boundaries ($x = \pm L$) are kept at constant temperature T_b as depicted in Figure 2.

Figure 2. Example problem geometry

The above problem is presented by Ozisik (3) who utilized the numerical results of Dowty and Haworth (4) where the thermal conductivity of the material varied linearly with temperature, viz

$$k = k_0 (1 + \beta T)$$

where:

k_0 = thermal conductivity for temperature of zero degrees.

$k_0 \beta$ = temperature coefficient of conductivity (SLOPE parameter)

T = temperature at time t .

Results are presented graphically for centerline temperatures (T_c) by Ozisik (3) in terms of dimensionless temperature, θ , and dimensionless times, τ , for various values of ψ with

$$\theta = (1 + 0.4 \beta T_i) \frac{T_c - T_b}{T_i - T_b}$$

$$\tau = \frac{\alpha_0 t}{L^2}, \quad \begin{aligned} \alpha_0 &= \text{initial thermal diffusivity} \\ t &= \text{time} \\ L &= \text{slab half width} \\ \psi &= 10 \beta T_b \end{aligned}$$

Choosing the initial and boundary conditions as:

$$\begin{aligned} T_i &= 100^\circ \text{F} \\ T_b &= 500^\circ \text{F} \end{aligned}$$

and the following values for material parameters;

$$\text{initial thermal conductivity, } k_0 = 1.0 \frac{\text{Btu}}{\text{ft-hr-}^\circ \text{F}}$$

$$\begin{aligned} &\text{temperature coefficient of thermal conductivity,} \\ &\beta = 1.6 \times 10^{-3} / ^\circ \text{F} \end{aligned}$$

$$\text{density: } \rho = 100 \text{ lb}_m / \text{ft}^3$$

$$\text{specific heat: } C_p = 0.1 \frac{\text{Btu}}{\text{lb}_m - ^\circ \text{F}}$$

$$\text{initial thermal diffusivity: } \alpha_0 = 0.1 \text{ ft}^2 / \text{hr}$$

$$\text{slab half width: } L = 1 \text{ ft}$$

results in the following expressions for centerline temperature and time for a fixed value of ψ :

$$T_c = 500 - 375.94\theta$$

$$t = 10 \tau$$

$$\psi = 8.0$$

Extrapolating several points from the plot presented by Ozisik we obtain:

τ	t (hrs.)	θ	$T_c (^{\circ}F)$
0.4	4	0.3	387
0.5	5	0.2	425
1.0	10	0.02	493
1.5	15	0.002	499

3.2. Finite Element Discretization

In modeling the slab problem, the characteristic height of the finite element model is arbitrary and 0.25 ft. is chosen. The slab is symmetric about the y-axis, thus a section 0.25 ft. high with a slab half width of one foot is chosen.

The mesh is shown with the appropriate boundary conditions in Figure 3. The circled numbers represent the element numbers with the remainder representing the nodal numbers.

Figure 3. Finite element discretization

3.3 Input Data

After the preliminary items regarding a specific problem (as completed in Section 3.1 and 3.2) have been finalized, one may proceed to describe the problem for adaption to the computer program. This has been done following the procedure of data input described in Section 2 and is illustrated by the coding forms on the following pages.

PROJECT NAME	RSI/TRANCO	PUNCHING INSTRUCTIONS	GRAPHIC							PAGE 1 OF 2
PROGRAMMER	GDC		PUNCH							CARD ELECTRO NUMBER

[illegible]

* A standard card form, IBM electro 888157, is available for punching statements from this form.

*Number of forms per pad may vary slightly

(RSI-0049)

IBM

FORTTRAN Coding Form

GX28-7327-B U/M 050**
Printed in U.S.A.

(RSI-0049)

[illegible][illegible]

* A standard card form, IBM electro 888157, is available for punching statements from this form.

* Number of forms per pad may vary slightly

3.4. Results

The following pages illustrate the output from the computer code and the results of the example problem including the input data and the nodal temperatures for each time step. Nodes 1, 2, and 3 represent the center line of the slab. Comparing these temperatures with those computed in Section 3.1 for times $t = 4, 5, 10,$ and 15 hrs., one observes that the two solutions agree within a few percent.

RSI/TRANCO EXAMPLE PROBLEM WITH LINEAR TEMPERATURE DEP. CONDUCTIVITIES

NNODES= 23
NELEM= 4
NCB= 0
NELMAT= 1

MAT. CONDUCT SP HEAT DENSITY HFAT GEN

1 0.10000 01 0.0 0.0 0.10000 01 0.10000 00 0.10000 03 0.0

MAT INITIAL CONDUCTIVITY CHANGE W.R.T. TEMPERATURE

1 0.16000-02 0.0 0.0 0.16000-02

MAT INITIAL CONDUCTIVITY CHANGE W.R.T. TEMPERATURE*TEMPERATURE

1 0.0 0.0 0.0 0.0

NNODES IITPN COORDINATES TEMPERATURE

1	-1	0.0	0.250	0.0
2	-1	0.0	0.125	0.0
3	-1	0.0	0.0	0.0
4	-1	0.125	0.250	0.0
5	-1	0.125	0.0	0.0
6	-1	0.250	0.250	0.0
7	-1	0.250	0.125	0.0
8	-1	0.250	0.0	0.0
9	-1	0.375	0.250	0.0
10	-1	0.375	0.0	0.0
11	-1	0.500	0.250	0.0
12	-1	0.500	0.125	0.0
13	-1	0.500	0.0	0.0
14	-1	0.625	0.250	0.0
15	-1	0.625	0.0	0.0
16	-1	0.750	0.250	0.0
17	-1	0.750	0.125	0.0
18	-1	0.750	0.0	0.0
19	-1	0.875	0.250	0.0
20	-1	0.875	0.0	0.0
21	1	1.000	0.250	0.50000 03
22	1	1.000	0.125	0.50000 03
23	1	1.000	0.0	0.50000 03

ELEMENTS NODAL CONNECTIONS IELMAT ANGLE

1	1	2	3	5	8	7	6	4	1
2	6	7	8	10	13	12	11	9	1
3	11	12	13	15	18	17	16	14	1
4	16	17	18	20	23	22	21	19	1

TIME= 0.0

1	0.1000000 03	2	0.1000000 03	3	0.1000000 03	4	0.1000000 03	5	0.1000000 03	6	0.1000000 03
7	0.1000000 03	8	0.1000000 03	9	0.1000000 03	10	0.1000000 03	11	0.1000000 03	12	0.1000000 03
13	0.1000000 03	14	0.1000000 03	15	0.1000000 03	16	0.1000000 03	17	0.1000000 03	18	0.1000000 03
19	0.1000000 03	20	0.1000000 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME= 0.500000 00

1	0.1088960 03	2	0.1091310 03	3	0.1088960 03	4	0.1108870 03	5	0.1108870 03	6	0.1161770 03
7	0.1176230 03	8	0.1161770 03	9	0.1311390 03	10	0.1311390 03	11	0.1555380 03	12	0.1569140 03
13	0.1555380 03	14	0.2045810 03	15	0.2045810 03	16	0.2853200 03	17	0.3022560 03	18	0.2853200 03
19	0.4488580 03	20	0.4488580 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.100000 01

1	0.1390110 03	2	0.1407410 03	3	0.1390110 03	4	0.1459700 03	5	0.1459700 03	6	0.1617340 03
7	0.1630620 03	8	0.1617340 03	9	0.1933600 03	10	0.1933600 03	11	0.2382550 03	12	0.2426860 03
13	0.2382550 03	14	0.3050590 03	15	0.3050590 03	16	0.3821810 03	17	0.3724380 03	18	0.3821810 03
19	0.4164370 03	20	0.4164370 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.150000 01

1	0.1896410 03	2	0.1911640 03	3	0.1896410 03	4	0.1980030 03	5	0.1980030 03	6	0.2167320 03
7	0.2189010 03	8	0.2167320 03	9	0.2513530 03	10	0.2513530 03	11	0.2942010 03	12	0.2937980 03
13	0.2942010 03	14	0.3383420 03	15	0.3383420 03	16	0.3845530 03	17	0.3918200 03	18	0.3845530 03
19	0.4510180 03	20	0.4510180 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.200000 01

1	0.2425620 03	2	0.2425670 03	3	0.2425620 03	4	0.2502720 03	5	0.2502720 03	6	0.2666340 03
7	0.2575160 03	8	0.2666340 03	9	0.2936300 03	10	0.2936300 03	11	0.3267210 03	12	0.3289440 03
13	0.3267210 03	14	0.3687860 03	15	0.3687860 03	16	0.4184440 03	17	0.4130420 03	18	0.4184440 03
19	0.4535890 03	20	0.4535890 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.250000 01

1	0.2892660 03	2	0.2902640 03	3	0.2892660 03	4	0.2949790 03	5	0.2949790 03	6	0.3075190 03
7	0.3088370 03	8	0.3075190 03	9	0.3304100 03	10	0.3304100 03	11	0.3590010 03	12	0.3589290 03
13	0.3590010 03	14	0.3906050 03	15	0.3906050 03	16	0.4242270 03	17	0.4266350 03	18	0.4242270 03
19	0.4634310 03	20	0.4634310 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.300000 01

1	0.3277110 03	2	0.3287330 03	3	0.3277110 03	4	0.3325190 03	5	0.3325190 03	6	0.3428510 03
7	0.3435050 03	8	0.3428510 03	9	0.3606550 03	10	0.3606550 03	11	0.3825480 03	12	0.3835450 03
13	0.3825480 03	14	0.4097380 03	15	0.4097380 03	16	0.4401650 03	17	0.4393510 03	18	0.4401650 03
19	0.4688740 03	20	0.4688740 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.350000 01

1	0.3598100 03	2	0.3604860 03	3	0.3598100 03	4	0.3634700 03	5	0.3634700 03	6	0.3714530 03
7	0.3722020 03	8	0.3714530 03	9	0.3860110 03	10	0.3860110 03	11	0.4041680 03	12	0.4041110 03
13	0.4041680 03	14	0.4256530 03	15	0.4256530 03	16	0.4489340 03	17	0.4497340 03	18	0.4489340 03
19	0.4745060 03	20	0.4745060 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.400000 01

1	0.3859240 03	2	0.3865380 03	3	0.3859240 03	4	0.3889220 03	5	0.3889220 03	6	0.3954050 03
7	0.3958850 03	8	0.3954050 03	9	0.4069480 03	10	0.4069480 03	11	0.4212360 03	12	0.4217330 03
13	0.4212360 03	14	0.4390450 03	15	0.4390450 03	16	0.4587540 03	17	0.4586570 03	18	0.4587540 03
19	0.4789170 03	20	0.4789170 03	21	0.5000000 03	22	0.5000000 03	23	0.5000000 03		

TIME = 0.450000 01

1 0.407406D 03	2 0.407856D 03	3 0.407406D 03	4 0.409757D 03	5 0.409757D 03	6 0.414874D 03
7 0.415322D 03	8 0.414874D 03	9 0.424222D 03	10 0.424222D 03	11 0.435871D 03	12 0.436120D 03
13 0.435871D 03	14 0.450153D 03	15 0.450153D 03	16 0.465777D 03	17 0.466083D 03	18 0.465777D 03
19 0.482738D 03	20 0.482738D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.500000 01

1 0.424872D 03	2 0.425254D 03	3 0.424872D 03	4 0.426777D 03	5 0.426777D 03	6 0.430905D 03
7 0.431236D 03	8 0.430905D 03	9 0.438392D 03	10 0.438392D 03	11 0.447689D 03	12 0.447970D 03
13 0.447689D 03	14 0.459351D 03	15 0.459351D 03	16 0.472222D 03	17 0.472278D 03	18 0.472222D 03
19 0.485875D 03	20 0.485875D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.550000 01

1 0.439131D 03	2 0.439426D 03	3 0.439131D 03	4 0.440647D 03	5 0.440647D 03	6 0.443945D 03
7 0.444225D 03	8 0.443945D 03	9 0.449986D 03	10 0.449986D 03	11 0.457515D 03	12 0.457703D 03
13 0.457515D 03	14 0.466918D 03	15 0.466918D 03	16 0.477249D 03	17 0.477393D 03	18 0.477249D 03
19 0.488485D 03	20 0.488485D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.600000 01

1 0.450708D 03	2 0.450950D 03	3 0.450708D 03	4 0.451931D 03	5 0.451931D 03	6 0.454589D 03
7 0.454589D 03	8 0.454589D 03	9 0.459446D 03	10 0.459446D 03	11 0.465451D 03	12 0.465663D 03
13 0.465451D 03	14 0.473122D 03	15 0.473122D 03	16 0.481536D 03	17 0.481504D 03	18 0.481536D 03
19 0.490627D 03	20 0.490627D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.650000 01

1 0.460117D 03	2 0.460309D 03	3 0.460117D 03	4 0.461097D 03	5 0.461097D 03	6 0.463230D 03
7 0.463230D 03	8 0.463230D 03	9 0.467147D 03	10 0.467147D 03	11 0.472030D 03	12 0.472159D 03
13 0.472030D 03	14 0.478191D 03	15 0.478151D 03	16 0.484975D 03	17 0.485055D 03	18 0.484975D 03
19 0.492385D 03	20 0.492385D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.700000 01

1 0.467743D 03	2 0.467899D 03	3 0.467743D 03	4 0.468534D 03	5 0.468534D 03	6 0.470252D 03
7 0.470394D 03	8 0.470252D 03	9 0.473407D 03	10 0.473407D 03	11 0.477338D 03	12 0.477448D 03
13 0.477338D 03	14 0.482324D 03	15 0.482324D 03	16 0.487822D 03	17 0.487875D 03	18 0.487822D 03
19 0.493821D 03	20 0.493821D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.750000 01

1 0.473325D 03	2 0.474050D 03	3 0.473325D 03	4 0.474560D 03	5 0.474560D 03	6 0.475943D 03
7 0.476058D 03	8 0.475943D 03	9 0.478447D 03	10 0.478447D 03	11 0.481659D 03	12 0.481746D 03
13 0.481659D 03	14 0.485686D 03	15 0.485686D 03	16 0.490124D 03	17 0.490173D 03	18 0.490124D 03
19 0.494992D 03	20 0.494992D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.800000 01

1 0.478928D 03	2 0.479030D 03	3 0.478928D 03	4 0.479441D 03	5 0.479441D 03	6 0.480555D 03
7 0.480647D 03	8 0.480555D 03	9 0.482606D 03	10 0.482606D 03	11 0.485163D 03	12 0.485233D 03
13 0.485163D 03	14 0.488417D 03	15 0.488417D 03	16 0.492006D 03	17 0.492043D 03	18 0.492006D 03
19 0.495945D 03	20 0.495945D 03	21 0.500000D 03	22 0.500000D 03	23 0.500000D 03	

TIME= 0.850000 01

13 0.488000 03 14 0.4906320 03 15 0.4906320 03 16 0.4935300 03 17 0.4935610 03 18 0.4935300 03
19 0.4967180 03 20 0.4967180 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.900000 01

1 0.4862520 03 2 0.4863170 03 3 0.4862520 03 4 0.4865840 03 5 0.4865840 03 6 0.4873070 03
7 0.4873680 03 8 0.4873070 03 9 0.4882640 03 10 0.4886410 03 11 0.4903050 03 12 0.4903510 03
13 0.4903050 03 14 0.4924270 03 15 0.4924270 03 16 0.4947680 03 17 0.4947920 03 18 0.4947680 03
19 0.4973460 03 20 0.4973460 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.950000 01

1 0.4888980 03 2 0.4889510 03 3 0.4888980 03 4 0.4891660 03 5 0.4891660 03 6 0.4897490 03
7 0.4897980 03 8 0.4897490 03 9 0.4908250 03 10 0.4908250 03 11 0.4921670 03 12 0.4922040 03
13 0.4921670 03 14 0.4938800 03 15 0.4938800 03 16 0.4957700 03 17 0.4957900 03 18 0.4957700 03
19 0.4978540 03 20 0.4978540 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.100000 02

1 0.4910370 03 2 0.4910790 03 3 0.4910370 03 4 0.4912530 03 5 0.4912530 03 6 0.4917230 03
7 0.4917620 03 8 0.4917230 03 9 0.4925910 03 10 0.4925910 03 11 0.4936730 03 12 0.4937030 03
13 0.4936730 03 14 0.4950560 03 15 0.4950560 03 16 0.4965820 03 17 0.4965580 03 18 0.4965820 03
19 0.4982660 03 20 0.4982660 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.105000 02

1 0.4927640 03 2 0.4927980 03 3 0.4927640 03 4 0.4929380 03 5 0.4929380 03 6 0.4933170 03
7 0.4933490 03 8 0.4933170 03 9 0.4940180 03 10 0.4940180 03 11 0.4948910 03 12 0.4949150 03
13 0.4948910 03 14 0.4960070 03 15 0.4960070 03 16 0.4972390 03 17 0.4972520 03 18 0.4972390 03
19 0.4985990 03 20 0.4985990 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.110000 02

1 0.4941590 03 2 0.4941870 03 3 0.4941590 03 4 0.4943000 03 5 0.4943000 03 6 0.4946060 03
7 0.4946310 03 8 0.4946060 03 9 0.4951700 03 10 0.4951700 03 11 0.4958750 03 12 0.4958940 03
13 0.4958750 03 14 0.4967760 03 15 0.4967760 03 16 0.4977700 03 17 0.4977810 03 18 0.4977700 03
19 0.4988690 03 20 0.4988690 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.115000 02

1 0.4952860 03 2 0.4953080 03 3 0.4952860 03 4 0.4953990 03 5 0.4953990 03 6 0.4956460 03
7 0.4956660 03 8 0.4956460 03 9 0.4961010 03 10 0.4961010 03 11 0.4966700 03 12 0.4966850 03
13 0.4966700 03 14 0.4973970 03 15 0.4973970 03 16 0.4981950 03 17 0.4982080 03 18 0.4981950 03
19 0.4990870 03 20 0.4990870 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.120000 02

1 0.4961950 03 2 0.4962130 03 3 0.4961950 03 4 0.4962870 03 5 0.4962870 03 6 0.4964860 03
7 0.4965020 03 8 0.4964860 03 9 0.4968530 03 10 0.4968530 03 11 0.4973120 03 12 0.4973240 03
13 0.4973120 03 14 0.4978990 03 15 0.4978990 03 16 0.4985460 03 17 0.4985530 03 18 0.4985460 03
19 0.4992630 03 20 0.4992630 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.125000 02

1 0.4969300 03 2 0.4969440 03 3 0.4969300 03 4 0.4970030 03 5 0.4970030 03 6 0.4971640 03
7 0.4971770 03 8 0.4971640 03 9 0.4974600 03 10 0.4974600 03 11 0.4978300 03 12 0.4978400 03
13 0.4978300 03 14 0.4983040 03 15 0.4983040 03 16 0.4988260 03 17 0.4988320 03 18 0.4988260 03

19 0.4994050 03 20 0.4994050 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.130000 02

1 0.4975220 03 2 0.4975340 03 3 0.4975220 03 4 0.4975820 03 5 0.4975820 03 6 0.4977110 03
 7 0.4977220 03 8 0.4977110 03 9 0.4979500 03 10 0.4979500 03 11 0.4982490 03 12 0.4982570 03
 13 0.4982490 03 14 0.4986310 03 15 0.4986310 03 16 0.4990530 03 17 0.4990570 03 18 0.4990530 03
 19 0.4995190 03 20 0.4995190 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.135000 02

1 0.4980010 03 2 0.4980100 03 3 0.4980010 03 4 0.4980490 03 5 0.4980490 03 6 0.4981530 03
 7 0.4981620 03 8 0.4981530 03 9 0.4983460 03 10 0.4983460 03 11 0.4985870 03 12 0.4985930 03
 13 0.4985870 03 14 0.4988950 03 15 0.4988950 03 16 0.4992350 03 17 0.4992390 03 18 0.4992350 03
 19 0.4996120 03 20 0.4996120 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.140000 02

1 0.4983870 03 2 0.4983940 03 3 0.4983870 03 4 0.4984250 03 5 0.4984250 03 6 0.4985100 03
 7 0.4985170 03 8 0.4985100 03 9 0.4986650 03 10 0.4986650 03 11 0.4988250 03 12 0.4988550 03
 13 0.4988600 03 14 0.4991080 03 15 0.4991080 03 16 0.4993830 03 17 0.4993860 03 18 0.4993830 03
 19 0.4996870 03 20 0.4996870 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.145000 02

1 0.4986980 03 2 0.4987040 03 3 0.4986980 03 4 0.4987290 03 5 0.4987290 03 6 0.4987970 03
 7 0.4988030 03 8 0.4987970 03 9 0.4989230 03 10 0.4989230 03 11 0.4990800 03 12 0.4990840 03
 13 0.4990800 03 14 0.4992800 03 15 0.4992800 03 16 0.4995020 03 17 0.4995040 03 18 0.4995020 03
 19 0.4997470 03 20 0.4997470 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.150000 02

1 0.4989500 03 2 0.4989540 03 3 0.4989500 03 4 0.4989750 03 5 0.4989750 03 6 0.4990300 03
 7 0.4990340 03 8 0.4990300 03 9 0.4991310 03 10 0.4991310 03 11 0.4992570 03 12 0.4992610 03
 13 0.4992570 03 14 0.4994190 03 15 0.4994190 03 16 0.4995980 03 17 0.4996000 03 18 0.4995980 03
 19 0.4997960 03 20 0.4997960 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.155000 02

1 0.4991520 03 2 0.4991560 03 3 0.4991520 03 4 0.4991730 03 5 0.4991730 03 6 0.4992170 03
 7 0.4992210 03 8 0.4992170 03 9 0.4992990 03 10 0.4992990 03 11 0.4994010 03 12 0.4994040 03
 13 0.4994010 03 14 0.4995310 03 15 0.4995310 03 16 0.4996760 03 17 0.4996770 03 18 0.4996760 03
 19 0.4998350 03 20 0.4998350 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.160000 02

1 0.4993160 03 2 0.4993190 03 3 0.4993160 03 4 0.4993320 03 5 0.4993320 03 6 0.4993680 03
 7 0.4993710 03 8 0.4993680 03 9 0.4994340 03 10 0.4994340 03 11 0.4995160 03 12 0.4995190 03
 13 0.4995160 03 14 0.4996220 03 15 0.4996220 03 16 0.4997380 03 17 0.4997400 03 18 0.4997380 03
 19 0.4998670 03 20 0.4998670 03 21 0.5000000 03 22 0.5000000 03 23 0.5000000 03

TIME= 0.165000 02

1 0.4994480 03 2 0.4994510 03 3 0.4994480 03 4 0.4994610 03 5 0.4994610 03 6 0.4994950 03
 7 0.4994930 03 8 0.4994900 03 9 0.4995430 03 10 0.4995430 03 11 0.4996100 03 12 0.4996120 03
 13 0.4996100 03 14 0.4996950 03 15 0.4996950 03 16 0.4997890 03 17 0.4997900 03 18 0.4997890 03

TIME= 0.170000 02

1 0.4995550 03	2 0.4995570 03	3 0.4995550 03	4 0.4995650 03	5 0.4995650 03	6 0.4995890 03
7 0.4995910 03	8 0.4995890 03	9 0.4996320 03	10 0.4996320 03	11 0.4996850 03	12 0.4996270 03
13 0.4996850 03	14 0.4997540 03	15 0.4997540 03	16 0.4998300 03	17 0.4998300 03	18 0.4998300 03
19 0.4999140 03	20 0.4999140 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.175000 02

1 0.4996410 03	2 0.4996420 03	3 0.4996410 03	4 0.4996490 03	5 0.4996490 03	6 0.4996680 03
7 0.4996700 03	8 0.4996680 03	9 0.4997030 03	10 0.4997030 03	11 0.4997460 03	12 0.4997470 03
13 0.4997450 03	14 0.4998010 03	15 0.4998010 03	16 0.4998630 03	17 0.4998630 03	18 0.4998630 03
19 0.4999300 03	20 0.4999300 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.180000 02

1 0.4997100 03	2 0.4997120 03	3 0.4997100 03	4 0.4997170 03	5 0.4997170 03	6 0.4997320 03
7 0.4997330 03	8 0.4997320 03	9 0.4997600 03	10 0.4997600 03	11 0.4997950 03	12 0.4997950 03
13 0.4997950 03	14 0.4998400 03	15 0.4998400 03	16 0.4998890 03	17 0.4998900 03	18 0.4998890 03
19 0.4999440 03	20 0.4999440 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.185000 02

1 0.4997660 03	2 0.4997670 03	3 0.4997660 03	4 0.4997720 03	5 0.4997720 03	6 0.4997840 03
7 0.4997850 03	8 0.4997840 03	9 0.4998060 03	10 0.4998060 03	11 0.4998350 03	12 0.4998350 03
13 0.4998350 03	14 0.4998710 03	15 0.4998710 03	16 0.4999110 03	17 0.4999110 03	18 0.4999110 03
19 0.4999550 03	20 0.4999550 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.190000 02

1 0.4998110 03	2 0.4998120 03	3 0.4998110 03	4 0.4998160 03	5 0.4998160 03	6 0.4998260 03
7 0.4998260 03	8 0.4998260 03	9 0.4998440 03	10 0.4998440 03	11 0.4998670 03	12 0.4998670 03
13 0.4998670 03	14 0.4998960 03	15 0.4998960 03	16 0.4999280 03	17 0.4999280 03	18 0.4999280 03
19 0.4999630 03	20 0.4999630 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.195000 02

1 0.4998480 03	2 0.4998480 03	3 0.4998480 03	4 0.4998510 03	5 0.4998510 03	6 0.4998550 03
7 0.4998550 03	8 0.4998550 03	9 0.4998740 03	10 0.4998740 03	11 0.4998920 03	12 0.4998930 03
13 0.4998920 03	14 0.4999160 03	15 0.4999160 03	16 0.4999420 03	17 0.4999420 03	18 0.4999420 03
19 0.4999700 03	20 0.4999700 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

TIME= 0.200000 02

1 0.4998770 03	2 0.4998780 03	3 0.4998770 03	4 0.4998800 03	5 0.4998800 03	6 0.4998870 03
7 0.4998870 03	8 0.4998870 03	9 0.4998980 03	10 0.4998980 03	11 0.4999130 03	12 0.4999140 03
13 0.4999130 03	14 0.4999320 03	15 0.4999320 03	16 0.4999530 03	17 0.4999530 03	18 0.4999530 03
19 0.4999760 03	20 0.4999760 03	21 0.5000000 03	22 0.5000000 03	23 0.5000000 03	

IAC0021 STDP 0

REFERENCES

1. Zienkiewicz, O.C., The Finite Element Method in Engineering Science, McGraw-Hill, 1971.
2. Desai, C.S., and Abel, J.F., Introduction to the Finite Element Method, A Numerical Method for Engineering Science, Van Nostrand Reinhold Company, 1972.
3. Ozisik, M.N., Boundary Value Problems of Heat Conduction, International Textbook Co., 1968, pp. 377-381.
4. Dowty, E.L. and Haworth, D.R., "Solution Charts for Heat Conduction in Materials with Variable Thermal Conductivity," ASME Paper 65-WA/HT-29, 1965.

APPENDIX AFortran Listing of Computer Code RSI/TRANCO

Included in the following pages is a fortran listing of computer code RSI/TRANCO. With the current dimensions, the program may be run as a Class C Job on the ORNL IBM 360/91 system.

Program limits are as follows:

<u>ITEM</u>	<u>MAXIMUM</u>
Number of Nodes	1500
Number of Elements	310
Number of Different Material Types	4
Number of Convective Boundaries	50
Maximum Semi-Band Width	120

PILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=60,SIZE=6000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF

C PROGRAM RSI TRanco

C			30
C			100
C			110
C	.....	TRanco SOLVES TRANSIENT OR STEADY STATE HEAT	40
C	.....	CONDUCTION PROBLEMS WITH FIXED TEMPERATURE BOUNDARIES OR .	50
C	.....	CONVECTIVE BOUNDARIES WHERE HEAT TRANSFER MAY BE	60
C		SYMBOL IDENTIFICATION	90
C	IJ	1 FOR CONVECTIVE BOUNDARIES,	140
C		AND 0 WITHOUT	150
C	IPRN	1 TO PRINT INPUT DATA	160
C	ITDEP	0 CONSTANT CONDUCTIVITY	
C		1 TEMP. DEP. CONDUCTIVITY	
C		ACCORDING TO SLOPE AND SLOP2	
C	ITYPN	1 FOR SPECIFIED TEMPERATURE,	170
C		AND 0 FOR EXTERNAL HEAT FLOW SP.	180
C		-1 FOR INITIAL TEMPERATURE SPECIF	190
C	IWRIT	1 TO WRITE NODAL TEMPERATURES	200
C		2 TO WRITE NODAL TEMP AND PUNCH	
C		TEMPS AT THE LAST TIME STEP	
C	MIT	PARAMETER PERTAINING TO A	
C		SUBSEQUENT RUN. I.E. NPROB .GT.	
C		1 AND ON SECOND PROBLEM MIT.LT.0	
C		INDICATES A CONTINUATION OF	
C		PROB. 1 WITH CHANGES AS INDICATED	
C		IN DATA CARD TYPES 1-7. FOR NO	
C		RESTART SET MIT .GT. 0.	
C	NCB	NUMBER OF CONVECTIVE BOUNDARIES	260
C		ONE BOUNDARY CONSISTS OF TWO NODE	270
C	NELEM	NUMBER OF ELEMENTS	280
C	NELMAT	NUMBER OF MATERIALS	290
C	NNODES	NUMBER OF NODES	300
C			310
C			320

IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)

COMMON BEQMIX(240,120),HEAT(1500),TOL,MBAND,MIT

COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)

COMMON/TVE/ NELFM,NELMAT,NNODES

COMMON/DELCOM/ DELT,TM,JT,JTMAX,IPR

COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)

1 , SLOPE(4,2,2) , SLOP2(4,2,2),ANG(310)

COMMON/TBOUN/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4),

1 ITYPN(1500)

COMMON/HAL/ A(8),QG(8)

COMMON /VAR1/ IAMT, JTROL, JCNT, ITDEP

C			410
C			430

1 READ (5,500,END=2) NPROB,JTMAX,IJ,IWRIT,MIT

32 READ 510, DELT,IPR, ITDEP

C			490

CALL INPUT

C			500
C			530

JT = 1

JJ = 1

TM=0.0

IF(MIT .LT. 0) GO TO 15

C			540
			550
			8670

C	READ INITIAL TEMPERATURE FIELD	8680
C	FOR K .GT. 0 TEMPS ARE GENERATED BETWEEN NODS	8690
C	----- END SEQUENCE WITH ONE BLANK CARD	8700
	----- ENTER BLANK CARD FOR ZERO INITIAL TEMPERATURE	8710
	FOR DIRECT SOLUTION DO NOT READ IN	8720
C	INITIAL TEMPS FOR CONSTANT TEMP BOUNDARIES	8730
C	OR READ THEM IN AS ZERO	8740
C		8750
C	READ INITIAL TEMP TYPE FORMAT	8760
C	IR=1 5(5X,F10.2)	8770
C	IR=0 (2I5,F10.2) AND GENERATE	8780
C		8790
	READ 320, IR	
320	FORMAT(I5)	8810
	IF(IR.EQ.0) GO TO 321	8820
	READ 322, (TCONS(N),N=1,NNODES)	
322	FORMAT(5(5X,F10.2))	8840
	GO TO 323	8850
321	NN=0	8860
922	READ 921, N,K,TT	
	IF(N.LE.0) GO TO 924	8880
	IF(K.LE.0) GO TO 292	8890
	I=NN+1	8900
	J=N-1	8910
	DO 293 L=I,J	8920
293	TCONS(L)=TT	8930
292	TCONS(N)=TT	8940
	NN=N	8950
	GO TO 922	8960
921	FORMAT(2I5,F10.2)	8970
924	CONTINUE	8980
		8990
C	PRINT INITIAL NODAL TEMPERATURES	9000
C		9010
323	PRINT 513,IM	
	PRINT 514, (N,TCONS(N),N=1,NNODES)	
15	CONTINUE	560
		570
C	CALL BEKMTX(IJ)	580
10	CONTINUE	590
	IM=JJ*DELT	600
		610
C	CALL SOLCON (IWRIT)	
	JJ = JJ + 1	640
	JT=JJ	
	IF (JJ .NE. (JTMAX + 1) .AND. ITDEP .NE. 0) GO TO 15	650
	IF (JJ.LE. JTMAX) GO TO 10	670
		680
20	CONTINUE	690
	IF(NPROB .GT. 1) GO TO 1	700
		710
C	500 FORMAT(9I5)	720
510	FORMAT(F15.6,2I5,E15.6)	730
513	FORMAT(1H0,30X,'TIME=',E12.5, '//')	
514	FORMAT (6(I6,E14.6))	
	STOP	
	END	750

C ..... OPTIONS = NAME = MAIN, OPT=02, LINECNT=60, SIZE=0000K,
 C ..... SOURCE, EBCDIC, NOLIST, NODECK, LOAD, MAP, NOEDIT, NOID, NOXREF
 C ..... SUBROUTINE INPUT
 C ..... IMPLICIT REAL*8(A-H, O-Z), INTEGER(I-N)

C	.....	770
C	..... INPUT CONTROLS DATA INPUT. INCLUDED ARE THE MATERIAL	780
C	..... PROPERTIES, THE NODAL COORDINATES, THE ELEMENT NODAL	790
C	..... CONNECTIONS, AND THE CONVECTIVE BOUNDARY CONDITIONS,	800
C	..... IF ANY. IN ADDITION, IF IPR=1, THE DATA IS PRINTED OUT	810
C	.....	820
C	.....	830
C	..... WHEN NODAL POINT CARDS ARE OMITTED, THE NODES AND	840
C	..... COORDINATES ARE GENERATED AT EQUAL INTERVALS TO THE	850
C	..... NEXT SPECIFIED POINT. FOR GENERATED POINTS, EXTERNAL	860
C	..... HEAT FLOW IS SET EQUAL TO ZERO.	870
C	.....	880
C	..... WHEN ELEMENT NODAL CONNECTIONS ARE OMITTED, THE NEXT	890
C	..... CONNECTION IS GENERATED BY INCREMENTING THE PREVIOUS	900
C	..... ELEMENT ARRAY AND THE MATERIAL IS ASSUMED THE SAME.	910
C	.....	920
C	.....	930
	COMMON BEQMTX(240,120),HEAT(1500),TOL,MBAND,MIT	
	COMMON/TVEB/ CORDS(1500,2),NELCON(310,8),IELMAT(310)	
	COMMON/TVE/ NELEM,NELMAT,NNODES	
	COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)	
	1 , SLOPE (4, 2, 2) , SLOP2(4,2,2),ANG(310)	
	COMMON/TBOUN/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4),	
	1 ITYPN(1500)	
	COMMON/DELCOM/ DELT,TM,JT,JTMAX,IPR	
	COMMON /VAR1/ IAMT, JTROL, JCNT, ITDEP	
	DIMENSION NAME(18)	
C		1020
	READ 500, NAME	
	PRINT 510, NAME	
C		1050
	READ 520, NNODES,NELEM,NCB,NELMAT,IDENT,IPRN	
	PRINT 530, NNODES,NELEM,NCB,NELMAT	
C		1080
C	..... READ MATERIAL PROPERTIES	1090
C		1100
	WRITE(6,550)	
	READ(5,540) (L,((COND(N,I,J),I=1,2),J=1,2),CP(N),DEN(N),GHGEN(N),	
	1 N=1,NELMAT)	
	WRITE(6,551) (N,((COND(N,I,J),I=1,2),J=1,2),CP(N),DEN(N),	1140
	\$GHGEN(N),N=1,NELMAT)	1150
C		1160
	IF(ITDEP .NE. 1) GO TO 7004	
	READ 7000, (((SLOPE(N,I,J), I = 1, 2), J = 1, 2), N = 1, NELMAT)	1170
7000	FORMAT (4E20.4)	1180
	READ 7000, (((SLOP2(N,I,J), I = 1, 2), J = 1, 2), N = 1, NELMAT)	11
	PRINT 7002	1190
	PRINT 7001, (N, ((SLOPE(N,I,J),I= 1,2), J= 1, 2), N= 1, NELMAT)	1200
7002	FORMAT ('0', 2X, 'MAT', 10X, 'INITIAL CONDUCTIVITY', 5X, 'CHANGE W.R	1210
	1.T. TEMPERATURE')	1220
	PRINT 7003	
	PRINT 7001, (N, ((SLOP2(N,I,J),I= 1,2), J= 1, 2), N= 1, NELMAT)	
7003	FORMAT ('0', 2X, 'MAT', 10X, 'INITIAL CONDUCTIVITY', 5X, 'CHANGE W.R	1
	1.T. TEMPERATURE*TEMPERATURE')	

7001	FORMAT (10,15,4E15.4)	1230
7004	IF (MIT .LT. 0) GO TO 200	1240
C	..... READ AND/OR GENERATE NODAL COORDINATES	1250
26	IGC=0	1260
	KC=1	1270
60	READ 560, N, JIG, ITYPN(N), (CORDS(N,J), J=1,2), TCONS(N)	1280
	IGC=IGC+1	1300
	IF (IGC .LE. N) GO TO 61	1310
	PRINT 650, IGC	
650	FORMAT(1H,/, ' DATA OUT OF ORDER AT NODE', I5, /)	1330
	JTMAX=1	1340
61	DNOD=N+1-KC	1350
	IF (N=KC) 80,80,70	1360
C		1370
70	MC=KC-1	1380
	DX=(CORDS(N,1)-CORDS(MC,1))/DNOD	1390
	DY=(CORDS(N,2)-CORDS(MC,2))/DNOD	1400
C		1410
75	ITYPN(KC)=0	1420
	IF (JIG .GT. 0) ITYPN(KC)=ITYPN(MC)	1430
	IGC=IGC+1	1440
	MC=KC-1	1450
	CORDS(KC,1)=CORDS(MC,1)+DX	1460
	CORDS(KC,2)=CORDS(MC,2)+DY	1470
	TCONS(KC)=0.0	1480
	IF (JIG .GT. 0) TCONS(KC)=TCONS(MC)	1490
C		1500
80	KC=KC+1	1510
	IF (N=KC) 90,80,75	1520
90	IF (NNODES+1-KC) 100,100,60	1530
100	CONTINUE	1540
C		1550
C	..... READ AND/OR GENERATE NODAL CONNECTION ARRAY	1560
C		1570
	LEN=0	1580
	IHH=0	1590
	NEL=0	1600
	DO 175 N=1, NELEM	1610
	IHH=IHH+1	1630
	IF (NEL=N) 120,170,150	1640
120	READ 528, NEL, (NELCON(N,J), J=1,8), IELMAT(N), ANG(N)	30
	ISID=8	
	IF (NELCON(N,7) .EQ. 0) ISID=6	
	IF (IHH .LE. NEL) GO TO 119	1660
	PRINT 660, IHH	
660	FORMAT(1H,/, ' DATA OUT OF ORDER AT ELEMENT', I5, /)	1680
	IHH=NEL	1690
	PRINT 520, NEL, (NELCON(N,J), J=1,8), IELMAT(N), ANG(N)	40
	JTMAX=1	1710
119	IF (NEL=1-N) 170,130,130	1720
C		1730
130	IF (LEN .EQ. NEL) GO TO 150	1740
	DO 135 I=1, ISID	
135	NELCON(NEL,I)=NELCON(N,I)	1760
	IELMAT(NEL)=IELMAT(N)	1770
	ANG(NEL)=ANG(N)	
	LEN=NEL	1780

```

C
150 M=N-1
C
    IF (NELCON(M,7) .GT. 0) GO TO 159
    ISID=6
159 DO 160 I=1,ISID
    NELCON(N,I)=NELCON(M,I)+2
    IF (ISID.EQ.6) GO TO 160
    IF (I.EQ.4 .OR. I.EQ.8) NELCON(N,I)=NELCON(N,I)-1
160 CONTINUE
    ANG(N)=ANG(M)
    IELMAT(N)=IELMAT(M)
    IF (NELEM=N-1) 180,180,170
170 IF (IELMAT(N) .LE. 0) IELMAT(N)=IELMAT(N-1)
175 CONTINUE
180 CONTINUE
C
C
C ..... READ CONVECTIVE BOUNDARY DATA .....
C
    IF (NCB) 200,200,190
190 DO 192 N=1,NCB
    READ 580, (NCBN(N,K),K=1,4),CFC(N),TCONV(N)
    IF (N.EQ.1) GO TO 192
    IF (CFC(N) .LE. 0.0) CFC(N)=CFC(N-1)
    IF (TCONV(N) .LE. 0.0) TCONV(N)=TCONV(N-1)
192 CONTINUE
C
C ..... PRINT INPUT DATA IF DESIRED .....
C
200 IF (IPRN .NE. 1) GO TO 220
C
    PRINT 590
    PRINT 600, (I,ITYPN(I),(CORDS(I,J),J=1,2),TCONS(I),I=1,NNODES)
    PRINT 610
    PRINT 620, (I,(NELCON(I,J),J=1,8),IELMAT(I),ANG(I),I=1,NELFM)
    IF (NCB) 220,220,210
210 PRINT 630
    PRINT 640, ((NCBN(I,J),J=1,3),CFC(I),TCONV(I),I=1,NCB)
C
C ..... FORMAT STATEMENTS .....
C
500 FORMAT(18A5)
510 FORMAT(1H1,25X,18A4)
520 FORMAT(10I5,F10.3)
528 FORMAT(10I5,F10.0)
530 FORMAT(1H0, 'NNODES=',I4,/, ' NELEM=',I5,/, ' NCB=',I7,/, ' NELMAT=',I
    $4,/)
540 FORMAT(15,7E10.2)
550 FORMAT(1H1,22X,'MAT',30X,'CONDUCT',28X,'SP HEAT',8X,'DENSITY',6X,
    $'HEAT GEN',/)
551 FORMAT(1H,15,7E15.4)
560 FORMAT(15,12,I3,3F10.2)
580 FORMAT(4I5,2E15.6)
590 FORMAT(/,3X,'NODES',5X,'ITYPN',11X,'COORDINATES',
    $6X,'TEMPERATURE',/)
600 FORMAT(16,110,6X,2F10.3,E15.4)
610 FORMAT(/, 'ELEMENTS',16X,'NODAL CONNECTIONS',12X,'IELMAT',2X,'ANGLE

```


(RSI-0049)

A-7

1 ' , /)

2330

620 FORMAT(I5,9X,9I5,F10.3)

90

630 FORMAT(//,4X,'NODES',10X,'FILM COEFF',2X,'AMBIENT TEMP.',//)

2350

640 FORMAT(3I5,2E15.4)

2360

C

2370

220 CONTINUE

2380

RETURN

2390

END

2400

```

C
C ..... BFKMTX CALLS CONMTX TO FORM ELEMENTAL CONDUCTIVITY .....
C ..... THEN FORM THE CONDUCTIVITY MATRIX FOR THE WHOLE BODY .....
C
      IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)
      COMMON/IVE/ NELEM,NELMAT,NNODES
      COMMON /TEMPS/ TDUM(1500)
      COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)
      COMMON/MXARG/ QRES,QP,ELCON(8,8),D(6,6)
      COMMON/DELCOM/ DELT,TM,JT,JTMAX,IPR
      COMMON/TBOUN/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4),
1 ITYPN(1500)
      COMMON/SOLT/ HKD(1500),HKB(1500)
      COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)
1 , SLOPE(4,2,2) , SLOP2(4,2,2),ANG(310)
      COMMON BEQMTX(240,120),HEAT(1500),TOL,MBAND,MIT
      COMMON/HAL/ A(8),QG(8)
      COMMON /BLK/ NUMBLK, NB, NMM, NL, NH, KSHIFT
      COMMON /VAR1/ IAMT, JTROL, JCNT, ITDEP
      DIMENSION XCOND(310,2,2),T(2,2),SAVE(2,2),LC(8)
      REWIND 10
C
      MAXBAN = 120
      MAXDIF=0
      DO 5 I=1,NELEM
      LIM=8
      IF(NELCON(I,7).EQ.0) LIM=6
      DO 5 J=1,LIM
      DO 5 K=1,LIM
      LL= IABS(NELCON(I,J) - NELCON(I,K))
      IF(LL.GT. MAXDIF) MAXDIF=LL
5 CONTINUE
      MBAND=MAXDIF + 1
      IF (MBAND.LE. MAXBAN ) GO TO 7
      PRINT 7373, MBAND
7373 FORMAT ('0', ' BANDWIDTH = ', I5, ' TOO000 LARGE',//)
      STOP
      7 CONTINUE
C
      IF(ITDEP.EQ.1) GO TO 22
      DO 1 I=1,NELMAT
      DO 1 J=1,2
      DO 1 K=1,2
      SLOPE(I,J,K)=0.0
1 SLOP2(I,J,K)=0.0
22 DO 700 I=1,NELEM
C
      CS=DCOS(ANG(I)*0.01745329)
      SS=DSIN(ANG(I)*0.01745329)
C
      T(1,1)=CS
      T(2,1)=SS
      T(1,2)=-SS
      T(2,2)=CS
      NM = IELMAT(I)

```

```

TOLD = 0.0
KK = 0
DO 750 J = 1, 8
IF ( NELCON(I,J) .EQ. 0 ) GO TO 750
KK = KK + 1
IF (MIT.GE.0 .AND. JT.EQ.1 ) TDUM(NELCON(I,J)) = TCONS(NELCON(I,J))
TOLD = TOLD + TDUM(NELCON(I,J))
750 CONTINUE
TOLD=TOLD / DFLOAT(KK)
DO 775 J = 1, 2
DO 775 K = 1, 2
775 SAVE(J,K) = SLOP2(NM,J,K)*TOLD**2 + SLOPE(NM,J,K)*TOLD + COND
1 (NM,J,K)
DO 781 J=1,2
DO 781 M=1,2
XCOND(I,J,M)=0.0
DO 781 K=1,2
DO 781 L=1,2
781 XCOND(I,J,M)=XCOND(I,J,M) + T(J,K)*SAVE(K,L)*T(M,L)
700 CONTINUE
C
8 DO 10 I=1,NNODES
HKD(I)=0.0
HKB(I)=0.0
10 CONTINUE
LIMIT = 2* MBAND
DO 14 I = 1, LIMIT
DO 14 J = 1, MBAND
14 BEQMTX(I,J) = 0.0
DO 11 I=1,6
DO 11 J=1,6
D(I,J)=1./12.
IF(I.EQ.J) D(I,J)=2./12.
11 CONTINUE
C
DO 12 I=1,3
DO 12 J=4,6
D(J,I)=0.0
12 D(I,J)=0.0
ND = MBAND
NUMBLK = 0
25 NUMBLK = NUMBLK + 1
NMM = ND * NUMBLK
NL = NMM + ND + 1
KSHIFT = NL - 1
C
C
C ..... CONSTRUCT CONDUCTIVITY MATRIX FOR EACH ELEMENT FROM .....
C ..... CONMTX AND RETURN ELCON .....
C
DO 180 N=1,NELEM
C
MNUM=IELMAT(N)
DO 785 I = 1, 2
DO 785 J = 1, 2
SAVE(I,J) = COND(MNUM,I,J)
785 COND(MNUM,I,J) = XCOND(N,I,J)
26 LIM=8

```

2820
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2960
2970
2980
2990
3000
3010
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3030
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3080
3090
3100
3110
3120
3130
3170
3180
3190
3200
3210
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3250
3260
3270
3280
3290
3300
3310
3320
3330
3340
3350

```

IF (NELCON(N,7).EQ.0) LIM=6
DO 31 I = 1, LIM
IF ( NELCON(N,I) = NL) 31, 30, 30
30 IF ( NELCON(N,I) = NMM) 32, 32, 31
31 CONTINUE
GO TO 181
32 CONTINUE
IF(LIM.EQ.8) GO TO 73
CALL CONMTX(N)
GO TO 74
73 CALL INTG(N)
C
GO TO 20
C
74 DO 49 I=2,LIM,2
N1=NELCON(N,I)
IF ((N1.LT.NL) .OR. (N1.GT.NMM)) GO TO 49
50 HKD(N1)=HKD(N1) + QRES
HKB(N1)=HKB(N1) + QP
49 CONTINUE
C
GO TO 28
C
20 DO 21 I=1,LIM
N1=NELCON(N,I)
IF ((N1.LT.NL) .OR. (N1.GT.NMM)) GO TO 21
HKD(N1)=HKD(N1) + QG(I)
HKB(N1)=HKB(N1) + A(I)
21 CONTINUE
C
GO TO 69
C
28 DO 2 K=1,3
IJ=2*K-1
LC(K)=IJ
2 LC(K+3)=IJ+1
C
GO TO 68
C
69 DO 3 K=1,8
3 LC(K)=K
C
ASSEMBLE GLOBAL STIFFNESS
C
68 DO 176 I=1,LIM
II=LC(I)
ISAV=NELCON(N,II)
ISAV = ISAV - KSHIFT
IF ( ISAV .LE. 0 .OR. ISAV .GT. ND) GO TO 176
C
157 DO 175 J=1,LIM
JJ=LC(J)
JJSA=NELCON(N,JJ)
JSAV=JJSA-ISAV+1
JSAV = JSAV - KSHIFT
165 IF(JSAV) 195,175,170
170 BEQMTX(ISAV,JSAV)=BEQMTX(ISAV,JSAV) + ELCON(I,J)

```

C

```
175 CONTINUE
176 CONTINUE
181 CONTINUE
    DO 795 I = 1, 2
    DO 795 J = 1, 2
795 COND(MNUM,I,J) = SAVE(I,J)
180 CONTINUE
    CALL BYCON ( JE )
    DO 182 N=1,MBAND
182 WRITE(10) (BEQMTX(N,M),M=1,MBAND)
    DO 190 I = 1, ND
    DO 190 J = 1, ND
190 BEQMTX(I,J) = 0.0
    IF ( NMM .LT. NNODES ) GO TO 25
    RETURN
    END
```

4000
4010
4020
370
3450
3460
3470
4030
4040
4060
4070
4080
4090
4100
4110

COMPILER OPTIONS = NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,

SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF

SUBROUTINE BYCON (JE)

```

C ..... BYCON ANALYZES THE CONVECTIVE AND TEMPERATURE BOUNDARY ...
C ..... CONDITIONS AND INCLUDES THEM IN THE CONDUCTIVITY .....
C ..... MATRIX FOR THE WHOLE BODY (BEQMTX) .....
C
C      IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)
C      COMMON/IVE/ NELEM,NELMAT,NNODES
C      COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)
C      COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)
1   , SLOPE(4,2,2),SLOP2(4,2,2)
C      COMMON/TBOUN/ CFX(50),TCONX(50),TCONS(1500),NCB,NCBN(50,4),
1   ITYPN(1500)
C      COMMON/SOLT/ HKD(1500),HKB(1500)
C      COMMON/MXARG/ QRES,QP,ELCON(8,8),D(6,6)
C      COMMON BEQMTX(240,120),HEAT(1500),TOL,MBAND,MIT
C      COMMON /BLK/ NUMBLK, NB, NM, NL, NH, KSHIFT
C      DIMENSION A(8),B(2,8),ZN(8),ZNXI(8),ZNET(8)
C      DIMENSION CFC(50),TCONV(50)
C
C      IF(JE) 70,70,10
C ..... CONVECTIVE BOUNDARIES .....
10  AG1 = -0.5773502692
   AG2 =  0.5773502692
   AG3 = -1.0
   AG4 =  1.0
   DO 69 N = 1, NCB
   DO 800 I = 1, 3
       IF ( NCBN(N,I)=NL) 800, 801, 801
801  IF ( NCBN(N,I)=NM) 802,802,800
800  CONTINUE
   GO TO 69
802  CONTINUE
C
   NOD1=NCBN(N,1)
   NOD2=NCBN(N,2)
   NOD3 = NCBN(N,3)
   NOD4 = NCBN(N,4)
   NODX = NOD1 = KSHIFT
   NODY = NOD2 = KSHIFT
   NODZ = NOD3 = KSHIFT
   IF(NELCON(NOD4,7) .NE.0) GO TO 68
   HYP=DSQRT((CORDS(NOD3,1)-CORDS(NOD1,1))*2+(CORDS(NOD3,2)-CORDS(
1  NOD1,2))*2)
C
30  TCONV(N)=CFX(N)*HYP*TCONX(N)/3.
   CFC(N)=CFX(N)*HYP /30.
C
   IF ((NODX.LE.0).OR.(NODX.GT.MBAND)) GO TO 31
   HKB(NOD1)=HKB(NOD1)+TCONV(N) /2.
31  IF ((NODY.LE.0).OR.(NODY.GT.MBAND)) GO TO 32
   HKB(NOD2)=HKB(NOD2)+TCONV(N) *2.

```

```

32 IF ((NOD7.LE.0).OR.(NODZ.GT.MBAND)) GO TO 33
   HK8(NOD3) = HK8(NOD3) + TCONV(N)/2.
33 CONTINUE

   IF ((NODX.LE.0).OR.(NODX.GT.MBAND)) GO TO 150
   BEQMTX(NODX,1)=BEQMTX(NODX,1)+CFC(N)*4.0
150 IF ((NODY.LE.0).OR.(NODY.GT.MBAND)) GO TO 160
   BEQMTX(NODY,1)=BEQMTX(NODY,1)+CFC(N)*16.0
160 IF ((NODZ.LE.0).OR.(NODZ.GT.MBAND)) GO TO 170
   BEQMTX(NODZ,1) = BEQMTX(NODZ,1) + CFC(N) * 4.
170 CONTINUE

C
   LL=NODY=NODX+1
   IF(LL) 50,50,40
40 BEQMTX(NODX,LL)=BEQMTX(NODX,LL)+CFC(N)*2.0
   GO TO 60
50 LL=NODX=NODY+1
   BEQMTX(NODY,LL)=BEQMTX(NODY,LL)+CFC(N)*2.0
60 CONTINUE
   LL = NODZ = NODX + 1
   IF (LL) 61, 61, 62
62 BEQMTX(NODX, LL) = BEQMTX(NODX,LL) - CFC(N)
   GO TO 65
61 LL = NODX = NODZ + 1
   BEQMTX(NODZ, LL) = BEQMTX(NODZ, LL) - CFC(N)
65 LL = NODY = NODZ + 1
   IF (LL) 63,63, 64
64 BEQMTX(NODZ, LL) = BEQMTX(NODZ,LL) + 2. * CFC(N)
   GO TO 69
63 LL = NODZ = NODY + 1
   BEQMTX(NODY, LL) = BEQMTX(NODY, LL) + 2.*CFC(N)
   GO TO 69
68 CONTINUE
   DO 1 II=1,8
   A(II) = 0.0
   DO 1 JJ=1,8
1 ELCON(II,JJ)=0.0

C
   DO 900 J=1,2
   IF(NOD2.NE.NELCON(NOD4,2)) GO TO 898
   JJ = 3
   II = J
   GO TO 895
898 IF(NOD2.NE.NELCON(NOD4,4)) GO TO 897
   II = 4
   JJ = J
   GO TO 895
897 IF(NOD2.NE.NELCON(NOD4,6)) GO TO 896
   JJ = 4
   II = J
   GO TO 895
896 IF(NOD2.NE.NELCON(NOD4,8)) GO TO 894
   II = 3
   JJ = J

   GO TO 895
894 PRINT 1000, NOD2
1000 FORMAT('D',10X,'***** NOD2 EQUALS',I10,'WHICH IS IN ERROR')

```

```

895 CALL SHAPE(II,JJ,DETJAC,NOD4,AG1,AG2,AG3,AG4,B,ZN,2,ZNXI,ZNET)
SY = 0.0
SX = 0.0
IF (NOD2.EQ.NELCON(NOD4,2).OR.NOD2.EQ.NELCON(NOD4,6)) GO TO 27
DO 26 LR=1,8
NOD=NELCON(NOD4,LR)
SX = ZNET(LR)*CORDS(NOD,1) + SX
26 SY = ZNET(LR)*CORDS(NOD,2) + SY
GO TO 29
27 DO 28 LR = 1,8
NOD=NELCON(NOD4,LR)
SX=ZNXI(LR)*CORDS(NOD,1) + SX
28 SY = ZNXI(LR)*CORDS(NOD,2) + SY
29 SX2 = SX*SX
SY2 = SY*SY
HYP = DSQR( SX2 + SY2)

C
DO 900 NROW = 1,8
NN = N
A(NROW) = A(NROW)+ZN(NROW)*CFX(NN)*TCONX(NN)*HYP
DO 900 NCOL=NROW,8
900 ELCON(NROW,NCOL) = ELCON(NROW,NCOL) + ZN(NROW)*ZN(NCOL)*CFX(NN)
1 * HYP
DO 901 K=2,8
DO 901 L=1,K
901 ELCON(K,L) = ELCON(L,K)

C
DO 3 I=1,8
N2 = NELCON(NOD4,I)
N1 = N2 - KSHIFT
IF ( N1 .LE. 0 .OR. N1 .GT. MBAND ) GO TO 3
HKB(N2) = HKB(N2) + A(I)
DO 4 J = 1,8
N21 = NELCON(NOD4,J)
N2 = N21-N1 + 1 - KSHIFT
IF(N2) 4,4,5
5 BEQMTX(N1,N2) = BEQMTX(N1,N2) + ELCON(I,J)
4 CONTINUE
3 CONTINUE
2 CONTINUE
69 CONTINUE
70 CONTINUE

C
C ..... TEMPERATURE BOUNDARIES .....
C
LIMIT = NM + MBAND
DO 140 N = NL, LIMIT
IF ( N .GT. NNODES ) GO TO 140

C
IF(ITYPN(N) .LT. 0) GO TO 140
HKB(N)=HKB(N)+TCONS(N)
IF(ITYPN(N))140,140,80

C
80 DO 130 M=2,MBAND
L=N-M+1
J = L - KSHIFT
IF ((J.LE.0) .OR. (J.GT.MBAND)) GO TO 100
IF(L) 100,100,90

```


90	HKB(L)=HKB(L)-BEQMTX(J,M)*TCONS(N)	8020
	BEQMTX(J,M)=0.0	8030
100	LL=N+M-1	8040
	J = N - KSHIFT	8050
	IF ((J.LE.6) .OR. (J.GT.MBAND)) GO TO 130	8060
	IF (NNODES=EL) 120,110,110	8070
110	HKB(LL)=HKB(LL)-BEQMTX(J,M)*TCONS(N)	8080
120	BEQMTX(J,M)=0.0	8090
130	CONTINUE	8100
	J = N - KSHIFT	8110
	IF ((J.LE. 0) .OR. (J.GT. MBAND)) GO TO 140	8120
C		8130
	BEQMTX(J,1)=1.0	8140
	HKB(N)=TCONS(N)	8150
140	CONTINUE	8160
	RETURN	8170
	END	8180

PILER OPTIONS = NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,

SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF

SUBROUTINE CONMTX(N)

```

C ..... CONMTX CREATES ELEMENTAL CONDUCTIVITY MATRICES .....
C
  IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)
  COMMON/TVE/ NELEM,NELMAT,NNODES
  COMMON/TVE6/ CORDS(1500,2),NELCON(310,8),IELMAT(310)
  COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)
  1 , SLOPE(4,2,2),SLOP2(4,2,2)
  COMMON/TBOUN/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4),
  1 ITPN(1500)
  COMMON/SOL/ HKD(1500),HKB(1500)
  COMMON/DELCOM/ DELT,TM,JT,JTMAX,IPR
  COMMON/MXARG/ QRES,QP,ELCON(8,8),D(6,6)
  COMMON BEQMTX(240,120),HEAT(1500),TOL,MBAND,MIT
  REAL*8 KMAT(6,6)
  DIMENSION DN(6,6),XLCON(6,6)

C
C
  DO 10 I=1,6
  DO 10 J=1,6
  KMAT(I,J)=0.0
10 ELCON(I,J)=0.0

C
  NOD1=NELCON(N,1)
  NOD3=NELCON(N,3)
  NOD5=NELCON(N,5)
  NOD7=NELCON(N,7)
  MNUM=IELMAT(N)

C
  DO 11 I=1,6
  CON1=COND(MNUM,1,1)
  IF(I.GT.3) CON1=COND(MNUM,2,2)
11 KMAT(I,I)=CON1

C
  KMAT(1,4) = COND(MNUM,1,2)
  KMAT(2,5) = COND(MNUM,1,2)
  KMAT(3,6) = COND(MNUM,1,2)
  KMAT(4,1) = COND(MNUM,2,1)
  KMAT(5,2) = COND(MNUM,2,1)
  KMAT(6,3) = COND(MNUM,2,1)

C
C
12 A1 = CORDS(NOD5,1) - CORDS(NOD3,1)
  A2 = CORDS(NOD1,1) - CORDS(NOD5,1)
  A3 = CORDS(NOD3,1) - CORDS(NOD1,1)
  B1 = CORDS(NOD3,2) - CORDS(NOD5,2)
  B2 = CORDS(NOD5,2) - CORDS(NOD1,2)
  B3 = CORDS(NOD1,2) - CORDS(NOD3,2)

C
  X=1.0

C
40 AR= A3*B2 - A2*B3
  IF(AR .GT. (.0) GO TO 33
  PRINT 500,N
  IQUIT=1

```

500 FORMAT(' ELEMENT NO. ',I5,' ZERO OR NEGATIVE AREA')

33 RATIO=X/(2.*AR)

IF(N.EQ.NELEM.AND.IQUIT.EQ.1) CALL EXIT

QP=X*AR*GHGEN(MNUM)/6.

42 QRES=AR*X*CP(MNUM)*DEN(MNUM)/6.0

DN(1,5) = 0.0

DN(2,6) = 0.0

DN(3,4) = 0.0

DN(4,5) = 0.0

DN(5,6) = 0.0

DN(6,4) = 0.0

DN(1,1)=3.*B1

DN(1,2) = -B2

DN(3,2) = -B2

DN(1,3) = -B3

DN(2,3) = -B3

DN(1,4) = 4.*B2

DN(3,5) = 4.*B2

DN(1,6) = 4.*B3

DN(2,5) = 4.*B3

DN(2,1) = -B1

DN(3,1) = -B1

DN(2,2)=3.*B2

DN(2,4) = 4.*B1

DN(3,6) = 4.*B1

DN(3,3)=3.*B3

DN(4,1)=3.*A1

DN(4,2) = -A2

DN(6,2) = -A2

DN(4,3) = -A3

DN(5,3) = -A3

DN(4,4) = 4.*A2

DN(6,5) = 4.*A2

DN(4,6) = 4.*A3

DN(5,5) = 4.*A3

DN(5,1) = -A1

DN(6,1) = -A1

DN(5,2)=3.*A2

DN(5,4) = 4.*A1

DN(6,6) = 4.*A1

DN(6,3)=3.*A3

..... FORM CONDUCTIVITY MATRIX

DO 88 I=1,6

DO 88 J=1,6

XLCON(I,J)=0.0

DO 88 K=1,6

88 XLCON(I,J)= XLCON(I,J) + KMAT(I,K)*DN(K,J)

DO 90 I=1,6

DO 90 J=1,6

ELCON(I,J)=0.0

(RSI-0049)

(A-18)

DO 90 K=1,6

5010

DO 90 L=1,6

5020

5030

-- ELCON(I,J)=ELCON(I,J) + DN(K,I)*D(K,L)*XLCON(L,J)*RATIO

5060

DO 91 I = 1, 6

5070

DO 91 J = 1, I

5080

91 ELCON(J,I) = ELCON(I,J)

5090

RETURN

5100

END

5110

PILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,

SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF

SUBROUTINE INTG(M)

IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)

REAL*8 N,NXI,NET

COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)

COMMON/MXARG/ QRES,QP,ELCON(8,8),D(6,6)

COMMON/HAL/ A(8),QG(8)

COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)

1 , SLOPE(4,2,2),SLOP2(4,2,2)

DIMENSION B(2,8),N(8),CONX(2,2),NXI(8),NET(8)

M1=IELMAT(M)

DO 6 K=1,8

QG(K)=0.0

A(K) = 0.0

DO 6 L=K,8

6 ELCON(K,L)=0.0

CONX(1,1) = DSQRT(COND(M1,1,1))

CONX(1,2) = COND(M1,1,2)/CONX(1,1)

CONX(2,2) = DSQRT(COND(M1,2,2) - CONX(1,2)*CONX(1,2))

GAUSS QUAD. LOOP

AREA = 0.0

AG1 = -0.5973502692

AG2 = 0.5973502692

AG3 = 0.0

DO 20 II=1,2

DO 20 JJ=1,2

CALL SHAPE(II,JJ,DETJAC,M,AG1,AG2,AG3,AG3,B,N,O,NXI,NFT)

IF (DETJAC .LE. 0.0) PRINT 1000, M, DETJAC

1000 FORMAT('0',10X,'***** DETJAC OF ELEMENT ....',I5,5X,'EQUALS ...

1',E15.3,5X,'*****')

DO 9 K=1,2

DO 9 L=1,8

DUM1 = 0.

DO 8 MM =K,2

8 DUM1 = DUM1 + CONX (K,MM)*B(MM,L)

B(K,L) = DUM1

DUM1 = DETJAC

AREA = AREA + DUM1

DO 20 NROW=1,8

QG(NROW)=QG(NROW)+N(NROW)*DEN(M1)*CP(M1)*DUM1

A(NROW) = A(NROW) + N(NROW)*GHGEN(M1)*DUM1

17 CONTINUE

DO 20 NCOL = NROW, 8

DUM2 = 0.

DO 18 LL=1,2

18 DUM2=DUM2+B(LL,NROW)*B(LL,NCOL)

20 ELCON(NROW,NCOL) = ELCON(NROW,NCOL) + DUM1 *DUM2

DO 30 K=2,8

DO 30 L=1,K

50 ELCUN(K,L) = ELCUN(L,K)

FORM LUMPED HEAT CAPACITY MATRIX (1/4 ON SEC. NODES)

5640

5650

5660

5670

5680

5690

5700

C QRES= DEN(M1) * CP(M1) * AREA / 4.0

/QG(1) = 0.0

QG(3) = 0.0

QG(5) = 0.0

QG(7) = 0.0

QG(2) = QRES

QG(4) = QRES

QG(6) = QRES

QG(8) = QRES

5730

5740

5750

C RETURN

END

MPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,		
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF		
SUBROUTINE SHAPE (II,JJ,DETJAC,M,A1,A2,A3,A4,B,N,MOR,NXI,NET)		5760
IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)		
COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)		
COMMON/MXARG/ QRES,GP,ELCON(8,8),D(6,6)		5780
REAL*8 N(8), NXI(8), NET(8), JAC(2,2)		
DIMENSION AA(4), B(2,8)		5800
C		5810
	AA(1) = A1	5820
	AA(2) = A2	5830
	AA(3) = A3	5840
	AA(4) = A4	5850
C		5860
	N(1) = 0.25*(1.-AA(II))*(1.-AA(JJ))*(-AA(II)-AA(JJ)-1.)	5870
	N(2) = 0.5*(1.-AA(II)*AA(II))*(1.-AA(JJ))	5880
	N(3) = 0.25*(1.+AA(II))*(1.-AA(JJ))*(AA(II)-AA(JJ)-1.)	5890
	N(4) = 0.5*(1.+AA(II))*(1.-AA(JJ)*AA(JJ))	5900
	N(5) = 0.25*(1.+AA(II))*(1.+AA(JJ))*(AA(II)+AA(JJ)-1.)	5910
	N(6) = 0.5*(1.-AA(II)*AA(II))*(1.+AA(JJ))	5920
	N(7) = 0.25*(1.-AA(II))*(1.+AA(JJ))*(-AA(II)+AA(JJ)-1.)	5930
	N(8) = 0.5*(1.-AA(II))*(1.-AA(JJ)*AA(JJ))	5940
C		5950
	NXI(1) = 0.25*(1.-AA(JJ))*(AA(JJ)+2.*AA(II))	5960
	NXI(2) = -AA(II)*(1.-AA(JJ))	5970
	NXI(3) = 0.25*(1.-AA(JJ))*(-AA(JJ)+2.*AA(II))	5980
	NXI(4) = 0.5*(1.-AA(JJ)*AA(JJ))	5990
	NXI(5) = 0.25*(1.+AA(JJ))*(AA(JJ)+2.*AA(II))	6000
	NXI(6) = -AA(II)*(1.+AA(JJ))	6010
	NXI(7) = 0.25*(1.+AA(JJ))*(-AA(JJ)+2.*AA(II))	6020
	NXI(8) = -0.5*(1.-AA(JJ)*AA(JJ))	6030
C		6040
	NET(1) = 0.25*(1.-AA(II))*(AA(II)+2.*AA(JJ))	6050
	NET(2) = -0.5*(1.-AA(II)*AA(II))	6060
	NET(3) = 0.25*(1.+AA(II))*(-AA(II)+2.*AA(JJ))	6070
	NET(4) = -AA(JJ)*(1.+AA(II))	6080
	NET(5) = 0.25*(1.+AA(II))*(AA(II)+2.*AA(JJ))	6090
	NET(6) = 0.5*(1.-AA(II)*AA(II))	6100
	NET(7) = 0.25*(1.-AA(II))*(-AA(II)+2.*AA(JJ))	6110
	NET(8) = -AA(JJ)*(1.-AA(II))	6120
C		6130
C	JACOBIAN, INVERSE JACOBIAN, AND DET JACOBIAN	6140
C		6150
	DO 10 I=1,2	6160
	DO 10 J=1,2	6170
10	JAC(I,J) = 0.	6180
	DO 15 I=1,8	6190
	NN= NELCON(M,I)	6200
	JAC(1,1) = JAC(1,1)+ NXI(I)*CORDS(NN,1)	6210
	JAC(1,2) = JAC(1,2)+NXI(I)*CORDS(NN,2)	6220
	JAC(2,1) = JAC(2,1)+NET(I)*CORDS(NN,1)	6230
15	JAC(2,2) = JAC(2,2)+NET(I)*CORDS(NN,2)	6240
C		6250
	DETJAC = JAC(1,1)*JAC(2,2)-JAC(2,1)*JAC(1,2)	6260
	IF(MOR.GT.0) GO TO 31	6270
	DUM1 = JAC(1,1)/DETJAC	6280
	JAC(1,1) = JAC(2,2)/DETJAC	6290
	JAC(1,2) = -JAC(1,2)/DETJAC	6300

(RSI-0049)

 $JAC(2,1) = - JAC(2,1) / DETJAC$ $JAC(2,2) = DUM1$

DO 20 L=1,8

 $B(1,L) = JAC(1,1)*NXI(L) + JAC(1,2)*NET(L)$ 20 $B(2,L) = JAC(2,1)*NXI(L) + JAC(2,2)*NET(L)$

C

31 CONTINUE

RETURN

END

6310
6320
6330
6340
6350
6360
6370
6380
6390
6400

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=60,SIZE=0000K,
SOURCE,EBCDIC,NCLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF
SUBROUTINE SOLCON (IWRIT)

	8200
..... SOLCON CONTROLS THE SOLUTION TO PROCEDURE TO THE	8210
C ..... CONDUCTIVITY MATRIX. IF THE TIME STEP (DELT) IS ZERO	8220
C ..... OR NEGATIVE THE STEADY-STATE NODAL POINT TEMPERATURES	8230
C ..... ARE CALCULATED USING SUBROUTINE SOLVE. SPECIFYING DELT ...	8240
C ..... RESULTS IN TRANSIENT TEMPERATURE SOLUTIONS OVER THE	8250
C ..... NUMBER OF TIME STEPS INITIATED IN TRANCO.	8260
C	8270
C	8280
IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N)	
COMMON/TVE/ NELEM,NELMAT,NNODES	
COMMON/TVES/ CORDS(1500,2),NELCON(310,8),IELMAT(310)	
COMMON/DELCOM/ DELT,TM,JT,JTMAX,IPR	
COMMON/TBOUN/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4),	
1 ITYPN(1500)	
COMMON/SOLT/ HKD(1500),HKB(1500)	
COMMON/PROP/ COND(4,2,2),CP(4),DEN(4),GHGEN(4)	
1 , SLOPE(4,2,2),SLOP2(4,2,2)	
COMMON BEQMTX(240,120),HEAT(1500),TOL,MBAND,MIT	
COMMON /VAR1/ IAMT, JTROL, JCNT, ITDEP	
COMMON /TEMPS/ TDUM(1500)	
C	8390
C ..... STEADY STATE OR TRANSIENT SOLUTION	8400
C	8410
IF(DELT) 100,100,10	8420
10 IF(JT.GT.1 .AND. ITDEP.EQ. 0) GO TO 45	
15 TLED=1./DELT	8440
REWIND 1	8460
IAMT=IDINT(TLED)	
IF(IPR.LE.0) IPR=1	8480
IF(JT.GT.1) GO TO 16	
JTROL=0	8490
JCNT=0	8500
16 DO 40 I = 1, NNODES	8510
IF (ITYPN(I) .EQ. 1) GO TO 40	8520
HKD(I) = HKD(I) * TLED	8530
40 CONTINUE	8540
CALL SOLVE(1,NNODES)	8570
C	8590
C ..... FIND NODAL TEMPERATURES BY CONSTRUCTING EFFECTIVE LOAD ...	8600
C ..... MATRIX AND CALLING SOLVE	8610
C	8620
45 JTROL=JTROL+1	9040
JCNT=JCNT+1	9050
C	9060
DO 60 J=1,NNODES	9070
IF(MIT.LT.0 .OR. JT.NE.1) GO TO 48	
TDUM(J) = TCONS(J)	9090
48 CONTINUE	9100
HEAT(J)=HKB(J) * 3.0	9110
IF(ITYPN(J)) 50,50,60	9120
50 HEAT(J) = 3.0*HKB(J) + HKD(J)*TDUM (J) * 4.5	9130
60 CONTINUE	9140
	9150
C ..... CALCULATE TEMPERATURES	9160

	CALL SOLVE(2,NNODES)	9170
32	DO 95 M=1,NNODES	9180
95	TDUM (M)= (HEAT(M) - TDUM(M))/2.0	9190
		9200
	*****	9210
		9220
		9230
		9240
	IF(TM.LE. 5.0) GO TO 85	
	IF(JTROL.EQ.IAMT) GO TO 86	
85	IF(JCNT.NE.IPR) GO TO 120	9260
86	JTROL=0	9270
		9280
	PRINT 500, TM	
	IF(IWRIT) 71,120,71	
71	INCR=NNODES	9310
75	PRINT 510,(N,TDUM (N),N=1,INCR)	
	JCNT=0	9360
	IF (IWRIT .NE. 2) GO TO 120	9410
	IF (JT .NE. JTMAX) GO TO 120	
	PUNCH 7761, (I, TDUM (I), I = 1, NNODES)	
		9430
	GO TO 120	9440
		9450
	..... STEADY STATE	9460
		9470
100	DO 110 L=1,NNODES	9480
110	HEAT(L)=HKB(L)	9490
	CALL SOLVE(1,NNODES)	9500
	CALL SOLVE(2,NNODES)	9510
	PRINT 510,(I,HEAT(I),I=1,NNODES)	
		9540
500	FORMAT(1H0,30X,'TIME=',E12.5, '//')	9550
510	FORMAT(8(I4,E12.4))	
520	FORMAT(//,40X,'ELEMENTAL TEMPERATURES',//)	9570
7761	FORMAT(8(I3,F7.1))	
		9580
120	CONTINUE	9590
	RETURN	9610
	END	9620

COMPILE OPTIONS - NAME = PATH,OPT=02,LINECNT=60,SIZE=0000K, SOURCE,EBODIC,NCLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF SUBROUTINE SOLVE(IP,NUMEQ)		9630
..... SOLVE SOLVES THE CONDUCTIVITY MATRIX FOR THE NODAL TEMP...		9640
C	IMPLICIT REAL*8(A-H,O-Z),INTEGER(I-N) COMMON AK(240,120),R(1500),TOL,MBAND,MIT COMMON /BLK/, NUMBLK, NB, NM, NL, NH, KSHIFT COMMON/DELCOM/ DELT, TM, JT, JTMAX, IPR COMMON/TBOUND/ CFC(50),TCONV(50),TCONS(1500),NCB,NCBN(50,4), 1 ITYPN(1500) COMMON/SOLI/, HKD(1500),HKB(1500)	9650 9660
C	THE UNTRIANGULARIZED STIFFNESS IS STORED ON TAPE 10. RFWIND 20 NN = MBAND NL = NN + 1 NH = 2 * MBAND NB = 0 IF (IP .EQ. 2) GO TO 90 RFWIND 10 GO TO 25	9680 9730 9740 9750 9760 9770 9780 9790 9800
10	NB = NB + 1 DO 20 N = 1, NN NM = NN + N DO 20 M = 1, MBAND AK(N, M) = AK(NM, M)	9820 9830 9840 9850 9860
20	AK(NM, M) = 0.0 IF (NUMBLK .EQ. NB) GO TO 40	9870 9880
25	CONTINUE DO 30 N=NL,NH	

30	READ (10) (AK(N,M), M = 1, MBAND)
	IF (DELT .EQ. 0.0) GO TO 32
	DO 31 I1 = NL, NH
	I2 = I1 + NN * (NB - 1)
	IF (I2 .GT. NUMEQ) GO TO 31
	IF (ITYPN(I2) .EQ. 1) GO TO 31
	AK(I1, 1) = AK(I1, 1) + HKD(I2) * 1.5
		9900
		9910
		9920
		9930
		9940
		9950

31	CONTINUE	9960
32	CONTINUE	9970
	IF (NB .EQ. 0) GO TO 10	9980
40	DO 70 N = 1, NN	9990
	IF (AK(N, 1) .EQ. 0.0) GO TO 70	10000
	DO 60 L = 2, MBAND	10010
	IF (DABS(AK(N,L)) .LE. 1.D-15) GO TO 60	
	C = AK(N, L) / AK(N, 1)	10030
	I = N + L - 1	10040
	J = 0	10050
	DO 50 K = L, MBAND	10060
	J = J + 1	10070
50	AK(I, J) = AK(I, J) - C * AK(N, K)	10080
	AK(N, L) = C	10090
60	CONTINUE	10100
70	CONTINUE	10110
	DO 80 N=1,NN	
80	WRITE (20) (AK(N,M), M = 1, MBAND)	
	IF (NUMBLK .LE. NB) GO TO 170	10130
	GO TO 10	10140

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50 NB = 0
100 NE = NB + 1
    NH = NN * NE
    NM = NH - NN / 2
    NL = NM - NN/2 + 1
    KSHIFT = 2*NL - 2
    DO 101 I=1,NN
101    READ (20) ( AK(I,J), J = 1, MBAND)
    DO 130 I = 1, NN
    IF ( DABS(AK(I,1)).LE. 1.D-15) GO TO 130
    INDEX = I + (NB - 1)*MBAND
    IF ( INDEX .GE. NUMEQ) GO TO 120
    CP = R(INDEX)
    R(INDEX) = CP/AK(I, 1)
    DO 110 J = 2, MBAND
    JINDEX = INDEX + J - 1
    IF (JINDEX .GT. NUMEQ) GO TO 110
    R(JINDEX) = R(JINDEX) - AK(I,J) * CP
110 CONTINUE
    GO TO 130
120 IF (INDEX .GT. NUMEQ) GO TO 130
    R ( NUMEQ) = R(NUMEQ) / AK(I,1)
130 CONTINUE
    IF (NB.LT. NUMBLK) GO TO 100
    DO 131 K1=1,NN
    BACKSPACE 20
131 CONTINUE
140 DO 160 M = 1, NN
    N = NN + 1 - M
    INDEX = NB*MBAND - M + 1
    IF (INDEX.GE. NUMEQ)GO TO 160
    DO 150 K = 2, MBAND
    JINDEX = INDEX + K - 1
    IF (JINDEX .GT. NUMEQ)GO TO 150
    R(INDEX) = R(INDEX) - AK(N, K)*R(JINDEX)
150 CONTINUE
160 CONTINUE
    NB = NB - 1
    IF (NB .EQ. 0 ) GO TO 170
    DO 102 K1=1,NN
    BACKSPACE 20
102 CONTINUE
    DO 161 N = 1, NN
161 READ (20) ( AK(N,M), M = 1, MBAND)
    DO 163 K1=1,NN
    BACKSPACE 20
163 CONTINUE
    GO TO 140
170 RETURN
END

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