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A Computer Program for the Thermal Analysis of the Fire Endurance of Construction Walls

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National Bureau of Standards
Washington, D.C. 20234

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Abstract

A general one-dimensional transient heat and mass transfer numerical program has been developed for composite building constructions. Since typical building constructions consist of a series of composite layers and intermediate air layers, transient heat transfer is modeled by conduction through solids and by radiation and convection through air spaces. In addition the program has built-in features for ease of application to building constructions where various combinations of solid-to-solid and solid-to-air interfaces are encountered. The complete Fortran language program as used on the NBS Univac 1108 computer is given. A discussion of the program and instruction for its use are facilitated by the aid of examples. Numerical solutions using the present program compare favorably with experimental data in standard fire endurance tests.

Key words: Composite building constructions; convection; experimental data; fire endurance; heat generation or absorption; numerical solutions; radiation; one-dimensional; thermal conduction; transient heat transfer.

1. INTRODUCTION

The fire performance of building constructions is generally evaluated by a large scale laboratory fire endurance test (ASTM E 119) in which one surface is exposed to furnace gases with a prescribed increasing temperature history simulating the burnout of combustibles. The fire endurance rating of the construction is the time period during which it withstands the fire exposure without (a) structural failure, (b) the development of cracks through which flames or hot gases can pass, or (c) the temperature rise on the unexposed surface exceeding, a prescribed limit (250 °F average rise or 325 °F rise at a single point). Where the failure criterion is due to heat transmission alone, heat transfer analysis can provide a means for prediction and design.

Since typical building constructions consist of a series of composite layers and intermediate air layers, transient heat transfer is modeled by conduction through solids and by radiation and convection through air spaces. In addition, the program has built-in features for ease of application to building constructions where various combinations of solid-to-solid and solid-to-air interfaces are encountered. For each solid layer, the present program has provisions for phase changes, heat generation and absorption, and thermal property variation with temperature commonly found in building materials. Through the air spaces the modes of heat transfer include radiation and convection with temperature-dependent air properties.

A number of special analog and numerical programs for fire endurance evaluation have been in existence for some time [1-4][1]. A more flexible and general finite difference program was developed by Krokosky as recently as 1970 [5], which also contains a review of the existing thermal analysis programs for fire endurance evaluation.

The present numerical program was also developed to incorporate into fire endurance analyses the following features which are desirable and yet not readily available in existing programs:

1. Options to handle heat exposure on one or both sides of a structure.
2. Allowance for air infiltration, and heat generation and absorption in air spaces.
3. For ease of application to building structures, a single input card, using digits 1 and 0, is sufficient to instruct the computer the specified number of solid layers and air spaces arranged in a given problem.
4. Temperature-dependent thermal properties and known heat effects due to chemical reactions of some common building materials are stored in a subroutine and called by an input card, punched as 2331, indicate coded materials stored in the subroutine.
5. The duration as well as the amount of heat represented by a phase change or chemical reaction can be varied in any material.

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[1] Numbers in brackets refer to the literature references listed at the end of this paper.

2. GOVERNING EQUATION AND BOUNDARY CONDITIONS

The governing equation for one-dimensional transient heat flow is the well known heat diffusion equation. Including a term for internal heat generation, this can be expressed as:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial k}\right) + g = \rho c\,\frac{\partial T}{\partial \theta} \qquad (1)$$

where

- T = absolute temperature in solid
- x = coordinate in direction of heat flow
- k = heat conduction coefficient
- g = time rate of heat generation per unit volume in solid
- ρ = density of solid
- c = specific heat capacity of solid
- θ = time.

Boundary Conditions [6,7]:

The following types of boundary conditions need to be evaluated for the general problem:

(a) solid to air
(b) energy balance in air space
(c) air to solid
(d) solid to surrounding
(e) solid to symmetry plane
(f) solid to solid
(g) furnace gases to first surface layer.

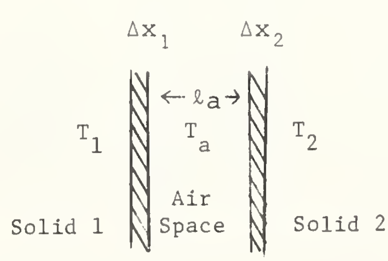


Figure 1. Solid-Air-Solid Interface

(a) Solid to Air (see fig. 1) [7]

$$\frac{\rho_1 c_1 \Delta x}{2} \frac{\Delta T_1}{\Delta \theta} = -k_1 \frac{\Delta T_1}{\Delta x_1} - \sigma \varepsilon_{12} \left(T_1^4 - T_2^4\right) - h(T_1 - T_a)^{5/4} + g_1 \frac{\Delta x_1}{2} \quad (2)$$

(b) Energy Balance in Air Space (see fig. 1)

$$\ell_a c_{pa} \rho_a \frac{\Delta T_a}{\Delta \theta} = h(T_1 - T_a)^{5/4} - h(T_a - T_2)^{5/4} + \mathring{m} c_{pa}(T_1 - T_2) + \ell_a g_a \quad (3)$$

(c) Air to Solid (see fig. 1)

$$\frac{\rho_2 c_2 \Delta x_2}{2} \frac{\Delta T_2}{\Delta \theta} = k_2 \frac{\Delta T_2}{\Delta x} + \sigma \varepsilon_{12} \left(T_a^4 - T_2^4\right) + h(T_a - T_2)^{5/4} + g_2 \frac{\Delta x_2}{2} \quad (4)$$

In the above equations the subscripts 1 and 2 indicate solid 1 and solid 2, respectively, as shown in figure 1, and where

$$\varepsilon_{12} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

and

ε_1, ε_2	are emissivity of surface 1 and of surface 2
T_2, T_1:	surface temperatures as shown in figure 1
Δx_1, Δx_2:	incremental length in x direction in solid 1 and solid 2
σ:	Stefan Boltzmann constant
T_a:	temperature of air
k_1, k_2:	heat conduction coefficient in solid 1, and 2
g_1, g_2:	time rate of heat generation or absorption per unit volume in solid 1 and 2
ℓ_a:	air gap spacing
c_{pa}:	specific heat capacity of air
ρ_a:	density of air

$\overset{\circ}{m}$: rate of mass transfer per unit area due to pressure difference

g_a: rate of heat generation per unit volume in air space due to combustibles

h: an empirical convection heat transfer constant, h = .27 for vertical surface, and h = .38 for horizontal surfaces [8].

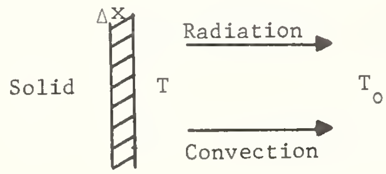


Figure 2. Solid-to-Surrounding Interface

(d) Solid to Ambient (see fig. 2)

$$\frac{\rho c \Delta x}{2} \frac{\Delta T}{\Delta \theta} = -k \frac{\Delta T}{\Delta \theta} - \sigma \varepsilon (T^4 - T_o^4) - h(T - T_o)^{5/4} + g \frac{\Delta x}{2} \qquad (5)$$

where the additional variables are:

T_o: ambient temperature

ε: emissivity of surface

T: surface temperature of solid

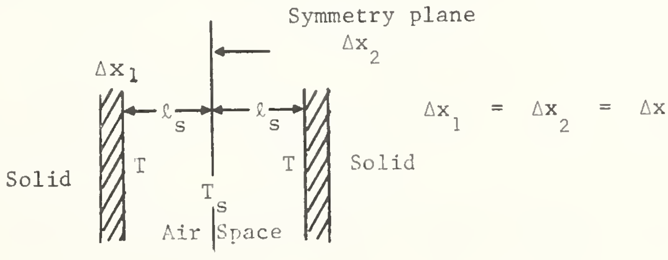


Figure 3. Symmetry Plane

(e) Solid to Symmetry Plane (see fig. 3)

By symmetry, temperature on both solid surfaces that face each other are equal, however $T \geq T_s$. So there will be heat transfer from solid to air. At the interface we have:

$$\frac{\rho c \Delta x}{2} \frac{\Delta T}{\Delta \theta} = -k \frac{\Delta T}{\Delta x} - h(T - T_s)^{5/4} + g \frac{\Delta x}{2} \tag{6a}$$

At the air space we have,

$$\ell_s c_{pa} \rho_a \frac{\Delta T_s}{\Delta \theta} = h(T - T_s)^{5/4} \tag{6b}$$

where

T: surface temperature of solids

T_s: temperature of air in symmetry plane

ℓ_s: distance from solid to symmetry plane

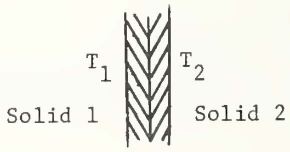


Figure 4. Solid-to-Solid Interface

(f) Solid to Solid (see fig. 4)

Consider interface between Solid 1 and Solid 2 as shown in figure 4. Let T_1 and T_2 be the interface temperature in each solid respectively. A heat balance for the interface node can be expressed as $T_2 = T_1$, and

$$\rho_1 c_1 \frac{\Delta x_1}{2} \frac{\Delta T_1}{\Delta \theta} + \rho_2 c_2 \frac{\Delta x_2}{2} \frac{\Delta T_2}{\Delta \theta} = g_1 \frac{\Delta x_1}{2} + g_2 \frac{\Delta x_2}{2} - k_1 \frac{\Delta T_1}{\Delta x} + k_2 \frac{\Delta T_2}{\Delta x} \tag{7}$$

where subscript indicates conditions in solid layer 1 or 2.

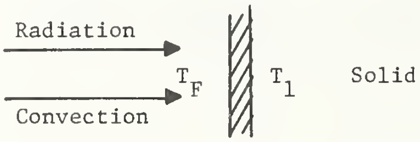


Figure 5. Furnace-to-First-Solid Interface

(g) <u>Furnace Gases to First Solid Surface (see fig. 5)</u>

Consider heat transfer from furnace gases to first solid surface. The main modes of heat transfer will be radiation and convection. A good approximation of ASTM E 119 fire curve is given by the following three formulas:

$$T = 1692 \frac{\theta}{\theta + 4} + 68 \qquad 0 < \theta < 50 \text{ min (error } \pm 2\%)$$

$$T = 1667 + 1.26\theta - 0.0236(120-\theta)^2 \qquad 50 \text{ min} < \theta < 115 \text{ min (no appreciable error)}$$

$$T = 1667 + 1.26\theta \qquad 115 \text{ min} < \theta < 480 \text{ min (linear exact)}$$

Heat balance from furnace to first solid surface,

$$\frac{\rho c \Delta x}{2} \frac{\Delta T_1}{\Delta \theta} = k \frac{\Delta T}{\Delta x} + \sigma \varepsilon (T_F^4 - T_1^4) + h(T_F - T_1)^{5/4} + g \frac{\Delta x}{2} \qquad (8)$$

where T_F is absolute furnace temperature.

3. PROBLEM FORMULTION AND FINITE DIFFERENCE EQUATIONS

Consider general one-dimensional heat transfer problem containing N solid layers and m air spaces in any order. To facilitate formulation and discussion we introduce i, j, and k, three running indices.

Let:

$T_{i,j}$: Temperature of jth node in ith solid

i: 1...N (number of solid layers)

j: 1...n (number of nodes in solid layer

k: 1...m (number of air spaces)

In figure 6, a general multi-layer configuration is shown, where numbers in circles indicate the applicable equation at the given node as discussed in the previous section.

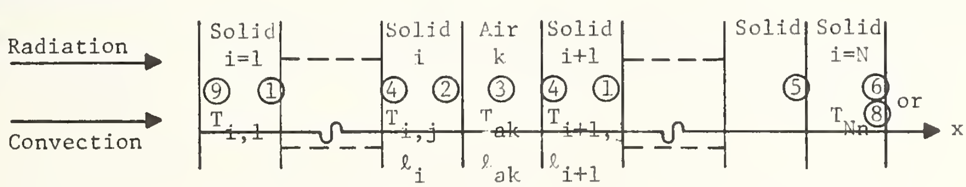


Figure 6. A Composite Wall with N Layers, m Air Spaces (Numbers in circles indicate applicable equation as discussed in section 2.)

To solve our problem numerically with the nonlinear heat diffusion equation and associated complex system of boundary conditions we shall use forward time differencing and central space differencing scheme. Figure 7 shows the finite differencing network inside a solid layer.

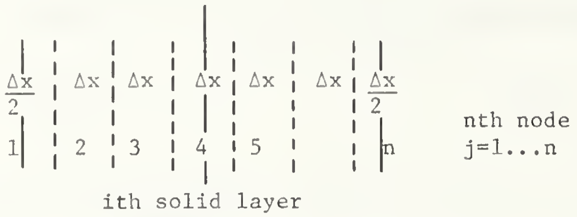


Figure 7. Sketch of Finite Differencing Network in a Solid Layer

Furthermore, let

T_{ak}: Temperature of kth air spacing

θ: Time

$\Delta\theta$: Time increment

$T'_{i,j}$: Temperature at $(\theta + \Delta\theta)$ of jth node in ith solid

ℓ_i: Thickness of ith solid

ℓ_{ak}: Thickness of kth air spacing

$\Delta x_i = \frac{\ell_i}{n-1}$: Difference spacing for ith solid

$g_{i,j}$: Rate of heat generation per unit volume

$k_{i,j}$: Heat conduction coefficient

α_i: Heat diffusion coefficient

g_{ak}: Rate of heat generation per unit volume in air space

$\overset{\circ}{m}_k$: Rate of mass transfer per unit area

Applying our finite differencing scheme we have the following general finite difference expressions corresponding to the previously discussed governing equation and boundary conditions [6,7 and 9].

Governing Equation

$$T'_{i,j} = \frac{1}{M_i}\left(T_{i(j-1)} + T_{i(j+1)}\right) + \left(1 - \frac{2}{M_i}\right) T_{ij} + \frac{g_{ij}\Delta x_i^2}{k_{ij}M_i} \quad (9)$$

where

$$M_i = \frac{\left(\Delta x_i\right)^2}{\alpha_i \Delta\theta}$$

From equation (9) we require $M_i > 2$ for stability.

Solid to Air

$$T'_{i,n} = T_{i,n} + \frac{2}{M_i}\left(T_{i,n-1} - T_{i,n}\right) - R_i \left[(T_{i,n})^4 - (T_{i+1,1})^4\right] \quad (10)$$

$$- H_i(T_{i,n} - T_{ak})^{5/4} + \frac{g_{i,n}\Delta x_i^2}{k_{i,n}M_i}$$

where

$$R_i = \frac{2\Delta\theta\sigma\varepsilon_{12}}{\Delta x_i \rho_i c_i}$$

c_i: Specific heat of ith layer

$$H_i = \frac{2\Delta\theta h}{\rho_i c_i \Delta x_i}$$

Air Space Heat Balance

$$T'_{ak} = T_{ak} + P_k(T_{i,n}-T_{ak})^{5/4} - Q_K (T_{ak} - T_{i+1,1})^{5/4} + S_k(T_{i,n}-T_{i+1,1}) + G_{ak}$$

(11)

where

$$P_k = \frac{h\Delta\theta}{\ell_{ak} c_{pa} \, a}$$

ρ_a: air density function of temperature

c_{pa}: specific heat of air

$$Q_K = \frac{h\Delta\theta}{\ell_{ak} c_{pa} \rho_a}$$

$$S_k = \frac{\overset{\circ}{m}\Delta\theta}{\ell_{ak} \rho_a}$$

$$G_{ak} = \frac{g_{ak}\Delta\theta}{c_{pa}\rho_a}$$

Air to Solid

$$T'_{i+1,1} = T_{i+1,1} + R_i \left[(T_{in})^4 - (T_{i+1,1})^4\right] - \frac{2}{M_{i+1}} (T_{i+1,1} - T_{i+1,2})$$

$$+ H_{i+1} (T_{ak} - T_{i+1,1})^{5/4} \tag{12}$$

R_i, M_{i+1}, H_{i+1} as defined before.

Solid to Ambient

$$T'_{N,n} = T_{N,n} + \frac{2}{M_n} (T_{N,n-1} - T_{N,n}) - R_N(T_{N,n}^4 - T_o^4) - H_N(T_{N,n} - T_o)^{5/4}$$

$$+ \frac{G_{N,n}(\Delta x_N)^2}{k_{N,n} M_N} \tag{13}$$

where

$$R_N = \frac{2\Delta\theta\sigma\varepsilon_N}{\Delta x_N \rho_N c_N}$$

ε_N: emissivity of solid (last node to ambient)

H_N, $k_{N,n}$ and M_N as defined before

T_o: ambient temperature

Solid to Symmetry Plane

$$T'_{N,n} = T_{N,n} + \frac{2}{M_N}(T_{N,n-1} - T_{N,n}) - H_N(T_{N,n} - T_s)^{5/4} + \frac{G_{N,n}(\Delta x_N)^2}{k_{N,n}M_n}$$

$$- R_N(T_{N,n}{}^4 - T_s{}^4) \qquad (14a)$$

$$T'_s = T_s + P_s(T_{N,n} - T_s)^{5/4} + R_N(T_{N,n}{}^4 - T_s{}^4) \qquad (14b)$$

where

T_s: temperature at symmetry plane

$$P_s = \frac{h\Delta\theta}{\ell_s c_{pa}\rho_a}$$

ℓ_s: distance between solid surface and symmetry plane.

Solid to Solid

$$T'_{i+1,1} = T'_{i,n}$$

$$T'_{i,n} = \Big[A_i T_{i,n} + A_{i+1}T_{i+1,1} + B_i g_{i,n} + B_{i+1}g_{i+1,1} + D_{i,n}(T_{i,n-1} - T_{i,n})$$

$$- D_{i+1,1}(T_{i+1,1} - T_{i+1,2})\Big] \quad (A_i + A_{i+1}) \qquad (15)$$

where

$$A_i = \frac{\rho_i c_i \Delta x_i}{2}$$

$$B_i = \frac{\Delta x_i \Delta\theta}{2}$$

$$D_{i,n} = \frac{k_{i,n}\Delta\theta}{\Delta x_i}$$

$$D_{i+1,1} = \frac{k_{i+1,1}\Delta\theta}{\Delta x_{i+1}}$$

$g_{i,j}$: rate of heat generation per unit volume in ith solid.

Furnace Gases to First Solid Surface

$$T'_{1,1} = T_{1,1} + R_1(T_F{}^4 - T_{1,1}{}^4) + H_1(T_F - T_{1,1}) + \frac{G_{1,1}\Delta x_1}{k_{1,1}M_1} - \frac{2}{M_1}(T_{1,1} - T_{1,2}) \quad (16)$$

where

$$R_1 = \frac{2\Delta\theta\sigma\varepsilon_o}{x_1\ _1c_1}$$

ε_o: emissivity of first surface (furnace gases to 1st solid).

T_F: furnace temperature, and

H_1: as defined before

4. DISCUSSION OF NUMERICAL PROGRAM

A flow chart of the main program is presented in figure 16. A listing of the complete numerical program is also presented at the end of this report. The logical sequence of the main program can be grasped readily by first considering the flow chart.

The following is a list of input parameters as read in on data cards (examples of which are shown at section 5.3).

NN: number of solid layers

N: number of nodes in each layer

M: number of air spaces

ID: sequence of numbers 1 or 0, specifying the sequence of solid layers and air spaces, e.g., 101011101 means solid-air-solid-air-solid-solid-solid-air-solid.

IDD: sequence of numbers specifying the material of each solid layer, e.g., 122321 means the six solid layers of the problem are of materials 1, 2, 2, 3, 2, 1 in that order. Various temperature dependent material properties are stored in Subroutine PROP.

AL(i): thickness of ith solid layer in feet

AI(i): thickness of air gap spacing in feet

GA(k): rate of heat generation per unit volume due to combustibles in kth air space, Btu/ft^3-hr.

DTHETA: Time increment in fraction of hour.

AMO: Volume rate of airflow through walls per unit area in ft^3/ft^2-hr ($\mathring{m}/\rho$).

GM1, GM2, GM3, etc: Heat absorption or release due to phase change in material 1, 2 or 3 etc., Btu/ft^{3}hr.

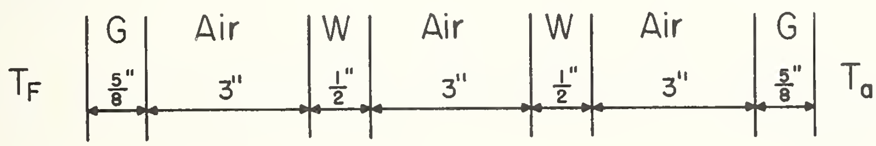
Subroutine PROP stores temperature dependent thermal properties and phase change reactions of some common building materials. This subroutine can be expanded as desired when new materials are encountered. When called from the main program this subroutine supplies the thermal properties for the ith layer of solid currently being calculated.

The function subroutines are self-explanatory. The comment statement at the beginning of each function subroutine properly identifies it with the corresponding equation and boundary conditions in section 3.

5. SAMPLE CASES CALCULATED

5.1. Description of Panels

Case 1: Four solid layers (gypsum, wood, wood, gypsum), three air gaps, heat from one side as shown,

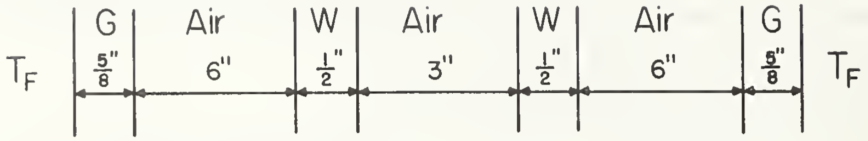


where

G: Gypsum board

W: Plywood

Case 2: Four solid layers (gypsum, wood, wood, gypsum), three air gaps, heating from both sides as shown,

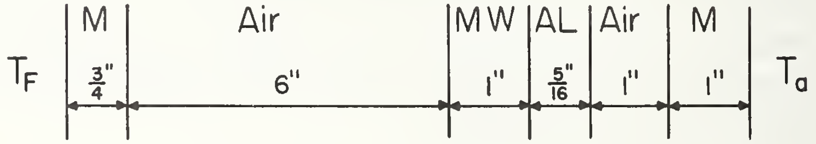


where

G: Gypsum board

W: Plywood

Case 3: Bulkhead 2B[2], four solid layers (marinite, mineral wool, aluminum, marinite), two air gaps, heat from one side as shown,



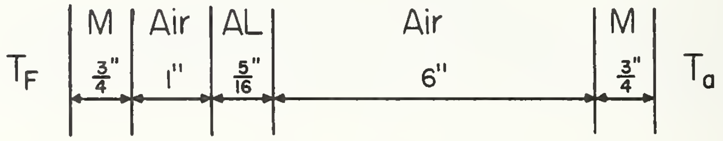
where

M : Marinite

MW: Mineral Wool

AL: Aluminum

Case 4: Bulkhead 3, three solid layers (marinite, aluminum, marinite), two air gaps, heat from one side as shown,



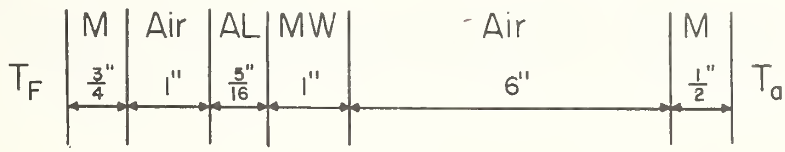
where

M : Marinite

AL: Aluminum

[2]Assembly descriptions and details of the actual ASTM E 119 fire endurance tests of this and following bulkheads are presented in reference [11].

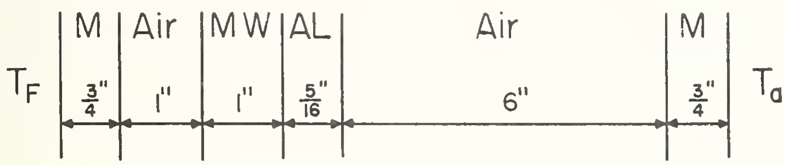
Case 5: Bulkhead 3C, four solid layers (marinate, aluminum, mineral wool, marinite), two air gaps, heat from one side as shown,



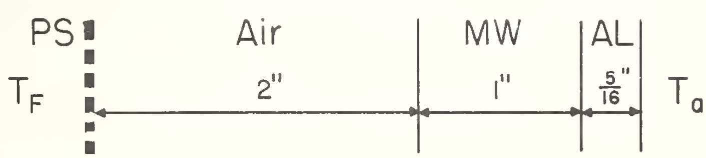
where

M : Marinite
AL: Aluminum
MW: Mineral Wool

Case 6: Bulkhead 3F, four solid layers (marinite, mineral wool, aluminum, marinite), two air gaps, heat from one side as shown,



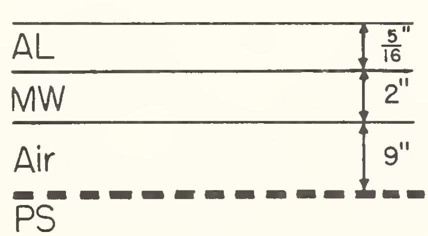
Case 7: Bulkhead 4, three solid layers (perforated steel, mineral wool, aluminum), one air gap, heat from one side as shown,



where

PS: Perforated steel sheet (#16 USCG, 3/16 inch diameter holes, 3/8 inch diameter holes, 3/8 inch center, 23% open area)
MW: Mineral wool
AL: Aluminum

Case 8: Deck 5B1, three solid layers (perforated steel, mineral wool, aluminum), heat from bottom as shown,



5.2. Thermal Properties

The following thermal properties are taken from Ref. [1] and Ref. [10]. NBS property measurements are programmed into subroutine PROPT,

Gypsum Board

ρ	=	60 lb/ft^3	
c	=	.26 Btu/lb °F	
k	=	.125 Btu/hr ft °F	$0 \le T \le 200$ °F
	=	.075 Btu/hr ft °F	200 °F $\le T \le$ 400 °F
	=	$(.05 + \frac{T}{16{,}000})$ Btu/hr ft °F	400 °F $\le T \le$ 2000 °F
ε	=	.9	

Heat of moisture desorption and calcination: 20,740 Btu/ft

Brick

ρ	=	110 lb/ft^3	
c	=	.216 Btu/lb °F	
ε	=	.9	
k	=	1.0 Btu/hr ft °F	$0 \le T \le 200$ °F
	=	(.46 + 2T/10,000) Btu/hr ft °F	200 °F $\le T \le$ 2000 °F

Heat of moisture desorption 5000 Btu/ft^3

Plywood

ρ	=	31 lb/ft^3
c	=	.67 Btu/lb °F
ε	=	.9
k	=	.065 Btu/hr ft °F

Heat of moisture desorption 1500 Btu/ft^3

Mineral Wool

ρ	=	6.04 lb/ft^3	
c	=	.2 Btu/lb °F	
ε	=	.9	
k	=	.02 Btu/hr ft °F	$0 \le T \le 50$ °F
	=	.02167 Btu/hr ft °F	50 °F $\le T \le$ 75 °F
	=	.0229 + 0.517(T-100)/10,000	75 °F $\le T \le$ 2000 °F

Aluminum

α = 3.33 ft^2/hr

ρ = 169 lb/ft^3

c = .208 Btu/lb °F

ε = .09

k = .167 + 1.63 T/10,000 $\quad 0 \le T \le 200$ °F

= 117 + .13 (T-32) $\quad 200 \le T \le 2000$ °F

Marinite

ρ = 36 lb/ft^3

c = .25 Btu/lb °F $\quad 0 \le T \le 200$ °F

= .25 + 3(T-200)/10,000 $\quad 200$ °F $\le T \le 2000$ °F

ε = .9

k = .063 Btu/hr ft °F $\quad 0 \le T \le 200$ °F

= (.76 + 1.1(T-100)/10,000)/12 $\quad 200$ °F $\le T \le 2000$ °F

5.3. Input Data

The following are the complete input data for the sample cases calculated.

Case 1: Four solid layers, 3 air gaps, furnace on one side (gypsum-air-wood-air-wood-air-gypsum)

4531	68.	.0	5380.0	1500.0	1.0
1010101					
1331					
.052	.0417	.0417	.052		
.25	0.	.25	0.	.25	0.

Case 2: Four solid layers, 3 air gaps, furnace on both sides (gypsum-air-wood-air-wood-air-gypsum)

4532	68.0	.0	5380.0	1500.0	1.0
1010101					
1331					
.052	.0417	.0417	.052		
.5	0.	.25	0.	0.	

Case 3: Bulkhead 2B, four solid layers, 2 air gaps, furnace on one side (marinite-air-mineral wool-aluminum-air-marinite)

4321	68.0	.0	.0	.0	1.0
101101					
6456					
.063	.083	0.052	.083		
.5	.00	.083	.00		

Case 4: Bulkhead 3, three solid layers, 2 air gaps, furnace on one side (marinite-air-aluminum-air-marinite)

3321	68.0	.0	.0	.0	1.0
10101					
656					
.063	.052	.063			
.083	.0	.5	.0		

Case 5: Bulkhead 3C, four solid layers, two air gaps furnace on one side (marinite-air-aluminum-mineral wool-air-marinite)

4331	68	.00	.00	.00	1.0
101101					
6546					
.063	.05	.083	.042		
.083	.00	.5	.00		

Case 6: Bulkhead 3F, four solid layers, two air gaps, furnace on one side (marinite-air-mineral wool-aluminum-air-marinite)

4321	68.0	.00	.00	.00	1.0
101101					
6456					
.063	.083	.052	.063		
.083	.00	.5	.00		

6. DISCUSSION OF RESULTS AND CONCLUSIONS

Comparison plots of calculated and measured temperatures from standard fire endurance tests represented by the above sample cases are presented in figures 8-15. Tests were conducted at the NBS large scale fire test center, Washington, D.C. Complete specification of the bulkheads and decks and descriptions of the tests are presented in a separate NBS report [11]. The good agreement between calculations and actual fire endurance test measurements as shown in the comparison plots reflect the success of the mathematical modeling.

In the comparison plots, temperature-time histories were recorded for each individual panel in a given wall construction for comparison with computer calculations. The plots can be examined for details of the heat transfer processes. For the purpose of fire endurance rating generally only the temperature history of the unexposed surface is needed. Table 1 shows a comparison of the fire endurance times by experiment and calculation. The criterion used in this table is the 250 °F average temperature rise condition at the unexposed surface. The agreement of experimental results and theoretical predictions of fire endurance times is good. Based on those calculations one would recommend using the present computer program for the purposes of fire endurance evaluation and design studies. Such applications would result in considerable savings in both money and time. This program could also be used to evaluate the performance of new materials.

Finally a word of caution in the use of a thermal analyzer program with air gap heat balances such as the present program. Due to the low heat capacity of air, one must exercise caution in selecting the incremental $\Delta\theta$. The iteration time, $\Delta\theta$, used in the previous sample calculations are 1/720 or 1/1440 hour for cases which do not involve metal layers and 1/14400 hour for cases involving metals.

7. ACKNOWLEDGMENT

The author wishes to acknowledge the contribution of Mr. Vernon Dantzler, Applications Section, Computer Services Division, for coding the Fortran program, and for his indispensible and cheerful help in modifying and updating the Fortran program.

The author also wishes to thank Mr. J. Newton Breese for his part in preparing the graphs and the flow chart for reproduction.

Table 1. Comparison of Fire Endurance Times by Experiment and Calculations

Case No.	Description	Endurance Time	
		Experiment	Calculation
1	4 layers, Gypsum, Wood, Wood, Gypsum, 3 Air Gaps	Passed 1 hr	Passed 1 hr
2	4 Layers, Gypsum, Wood, Wood, Gypsum, 3 Air Gaps, fire on both sides	Failed at 35 min	Failed at 37 min
3	4 Layers, Marinite, Mineral Wool Aluminum, Marinite, 2 Air Gaps	Passed 1 hr	Passed 1 hr
4	3 Layers, Marinite, Aluminum, Marinite, 2 Air Gaps	Passed 1 hr	Passed 1 hr
5	4 Layers, Marinite, Aluminum, Mineral Wool, marinite, 2 Air Gaps	Passed 1 hr	Passed 1 hr
6	4 Layers, Marinite, Mineral Wool, Aluminum, Marinite, 2 Air Gaps	Passed 1 hr	Passed 1 hr
7	3 Layers, Perforated Steel, Mineral Wool, Aluminum 1 Air Gap	Failed at 38 min	Failed at 36 min
8	3 Layers, Perforated Steel, Mineral Wool, Aluminum, 1 Air Gap	Failed at 30 min	Failed at 34 min

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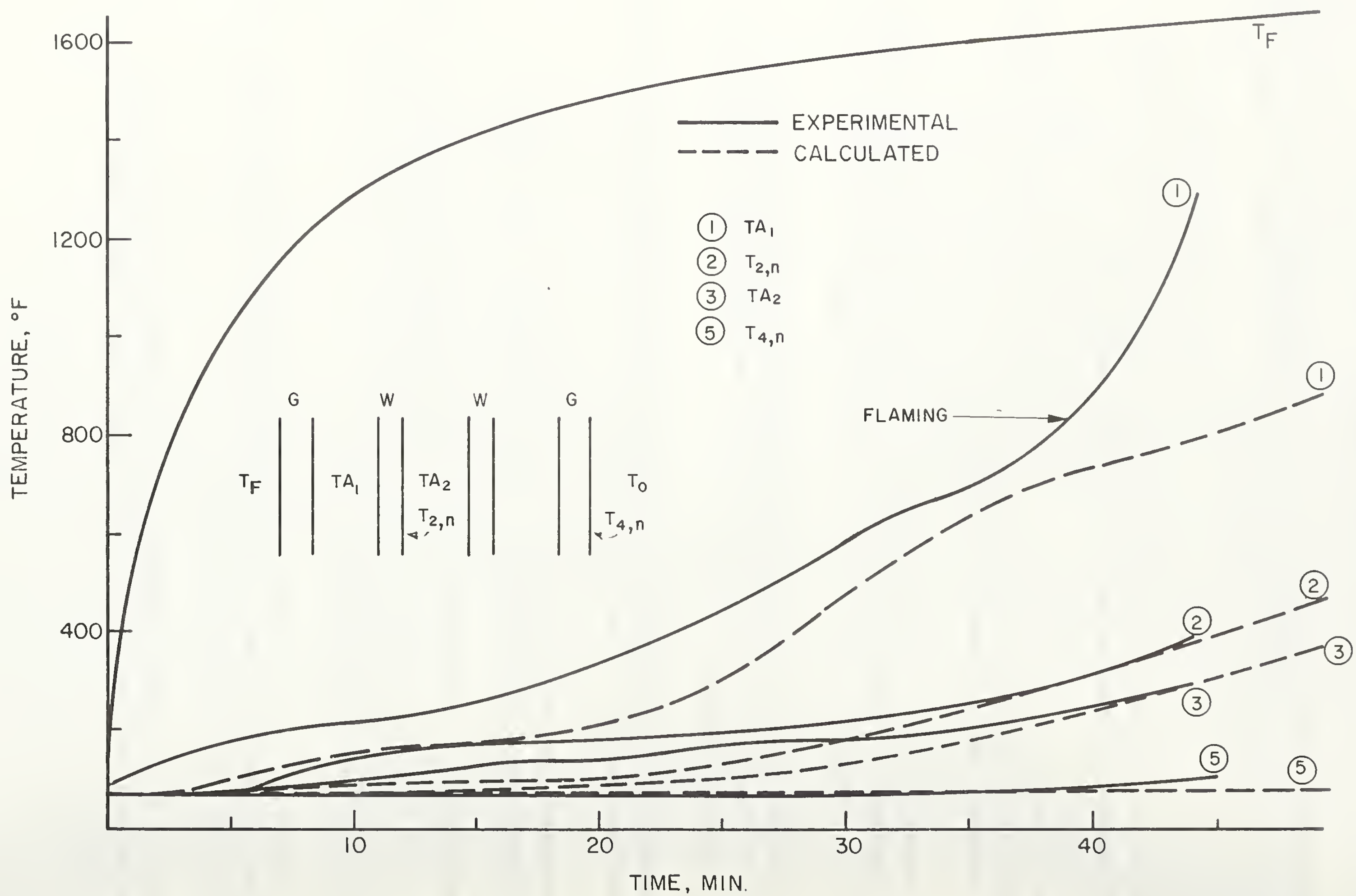

Figure 8. Thermal Response of Gypsum Wood Wall, Case 1

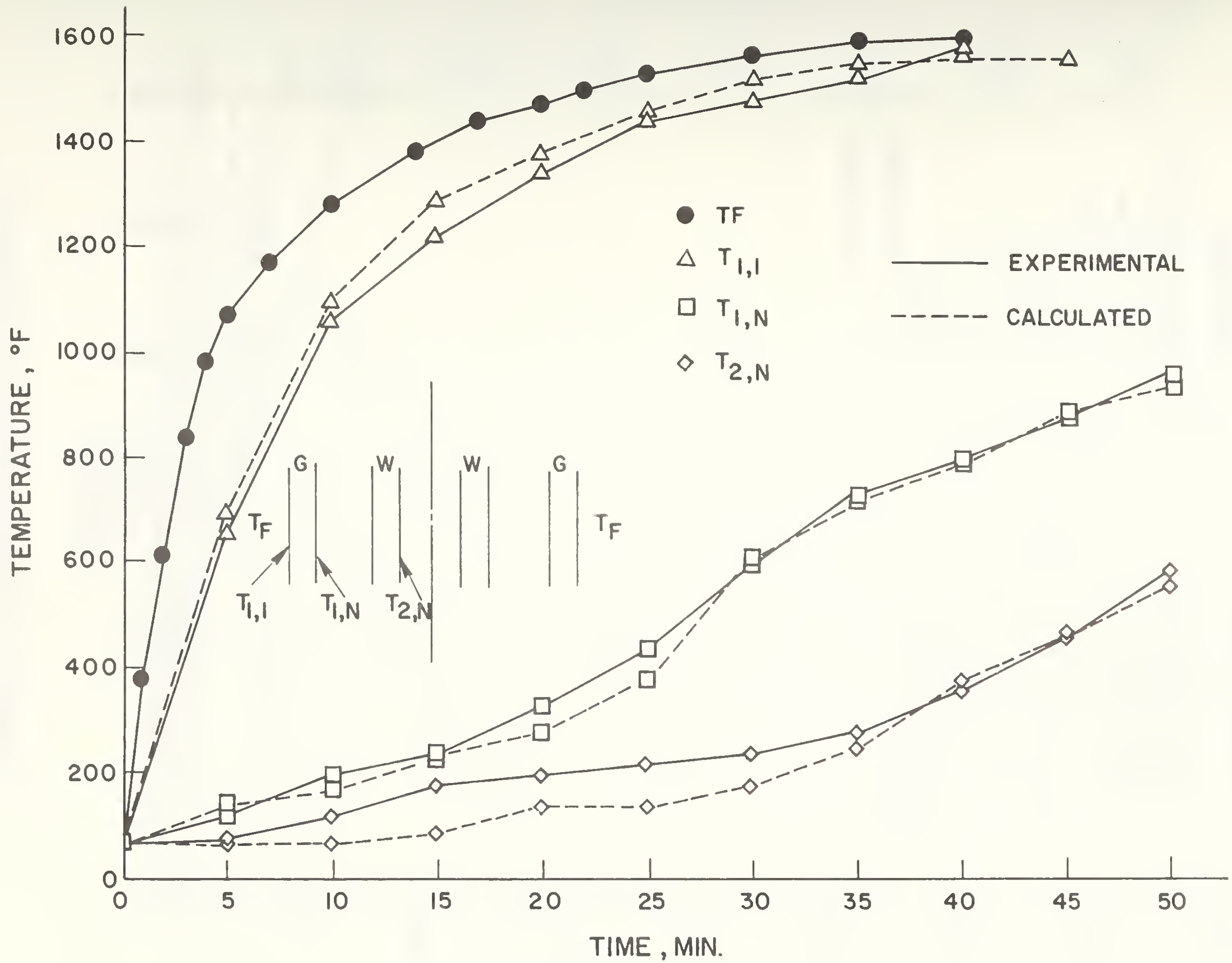

Figure 9. Thermal Response of Gypsum Wood Wall, Case 2.

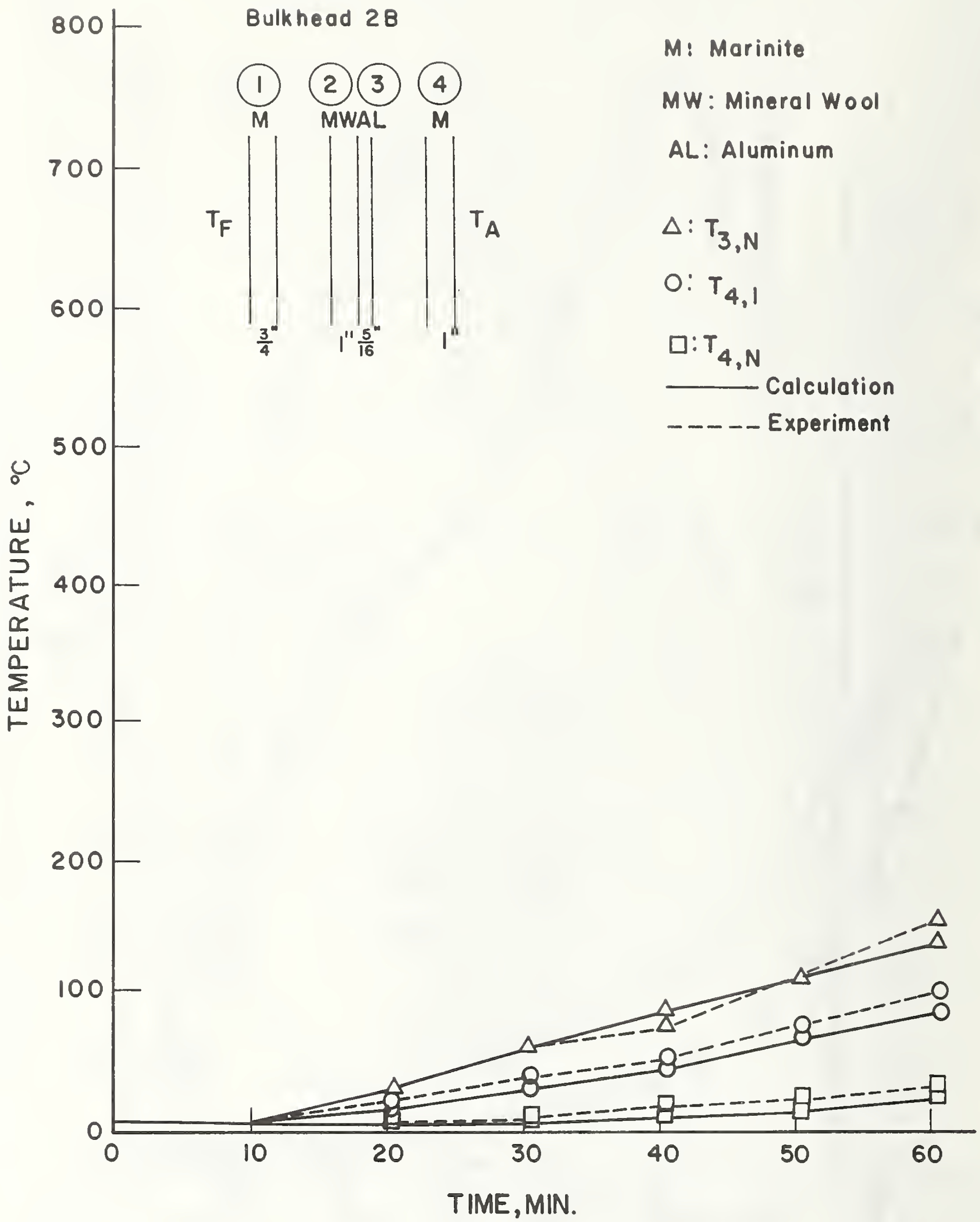

Figure 10. Thermal Response of Bulkhead 2B

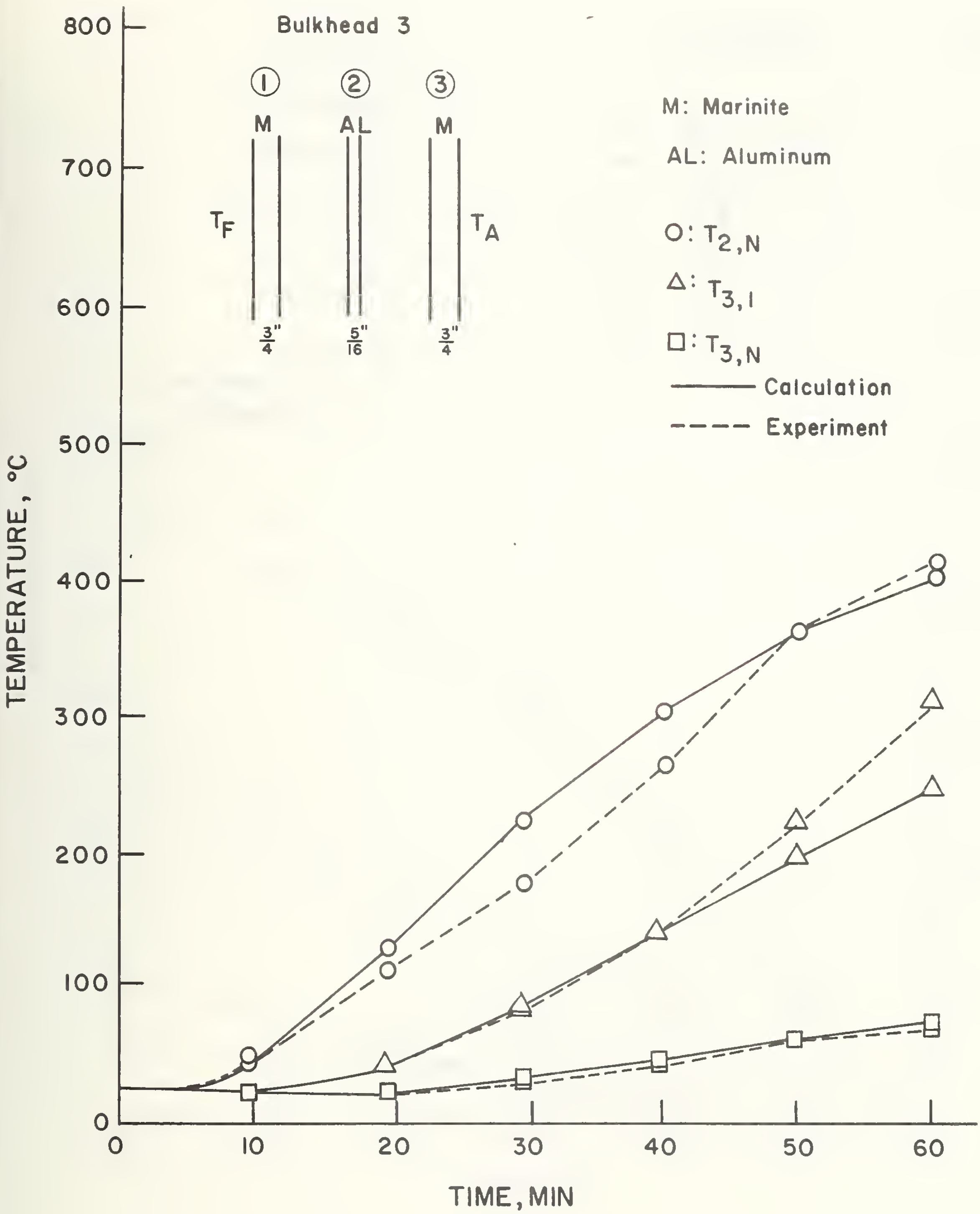

Figure 11. Thermal Response of Bulkhead 3.

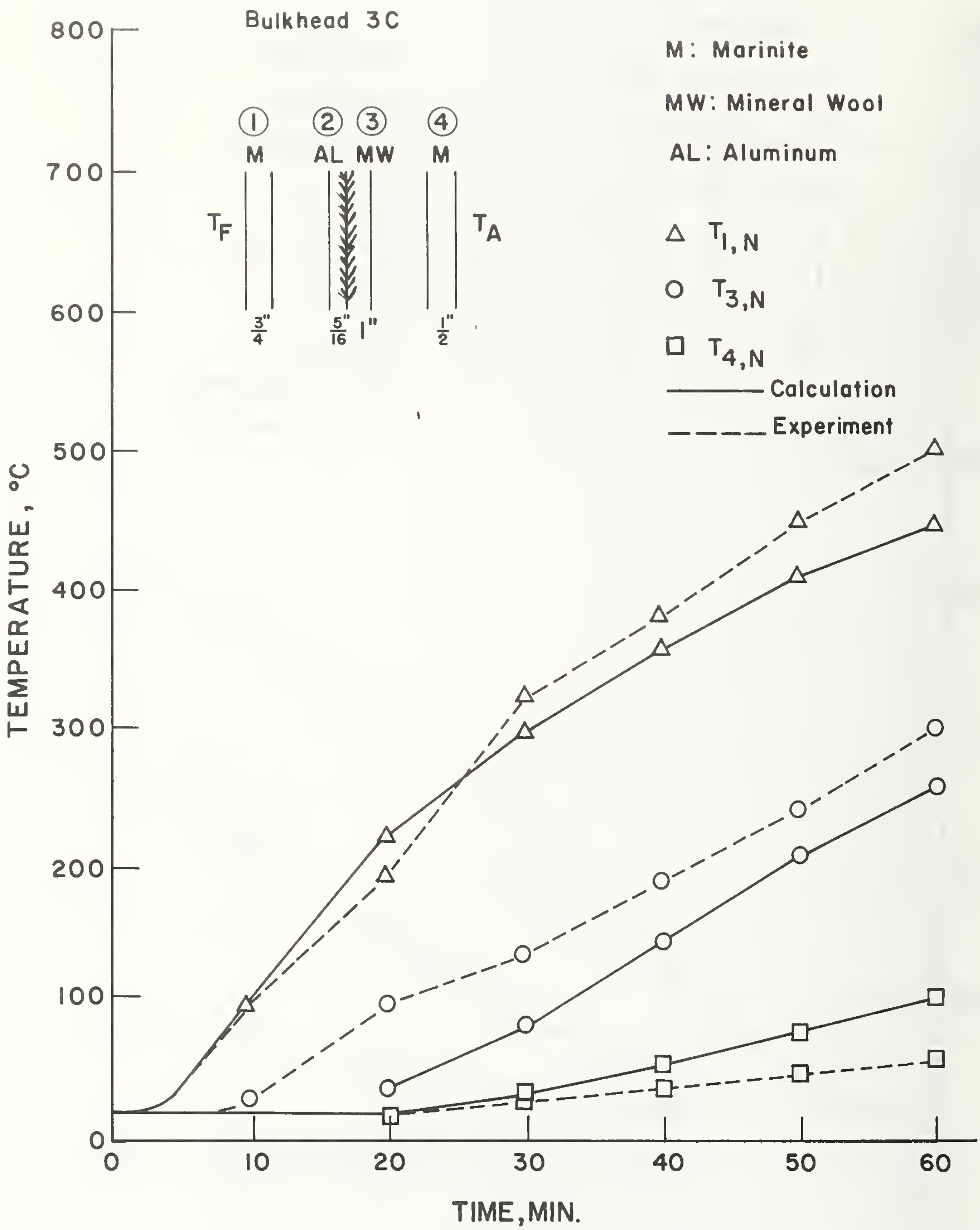

Figure 12. Thermal Response of Bulkhead 3C.

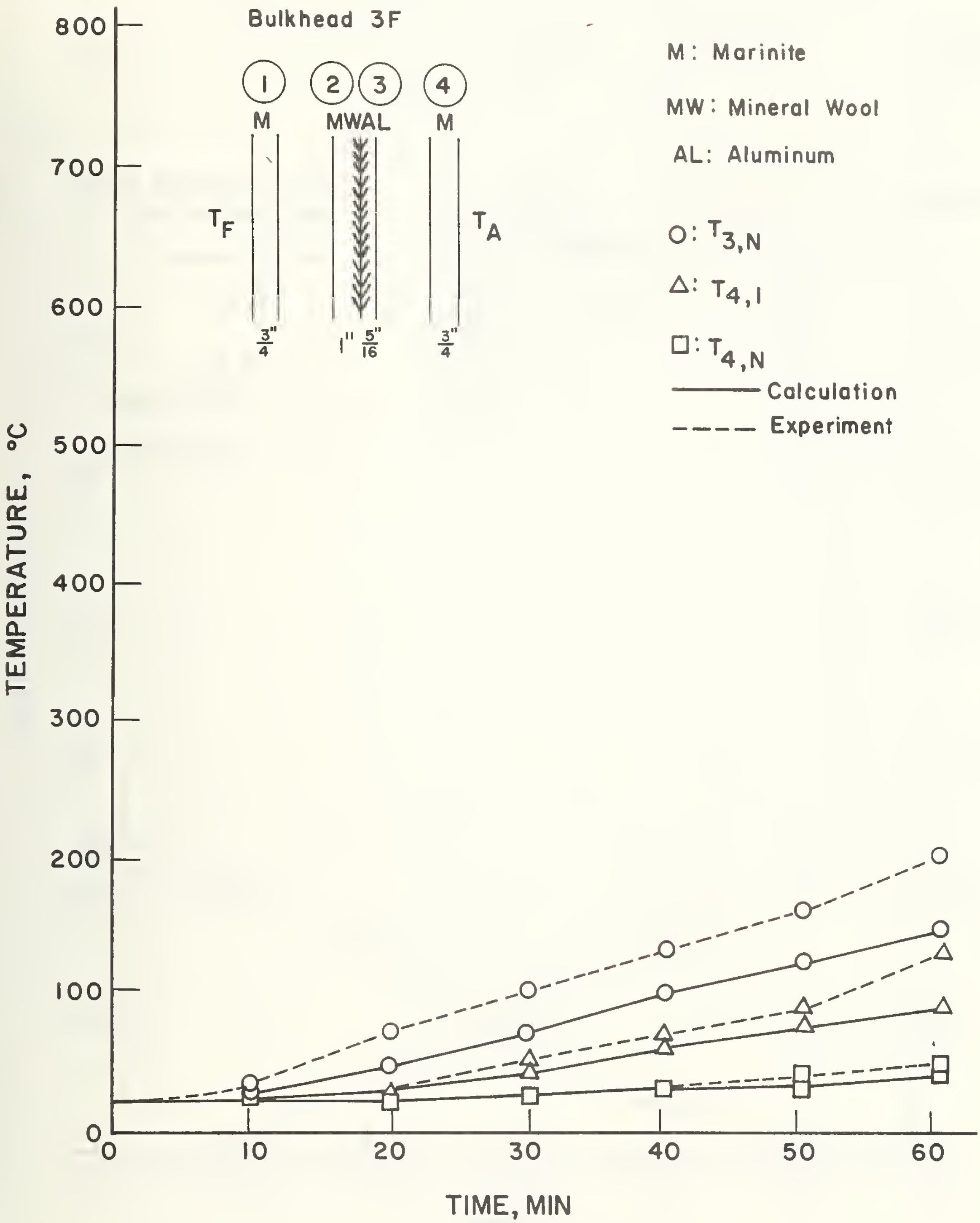

Figure 13. Thermal Response of Bulkhead 3F.

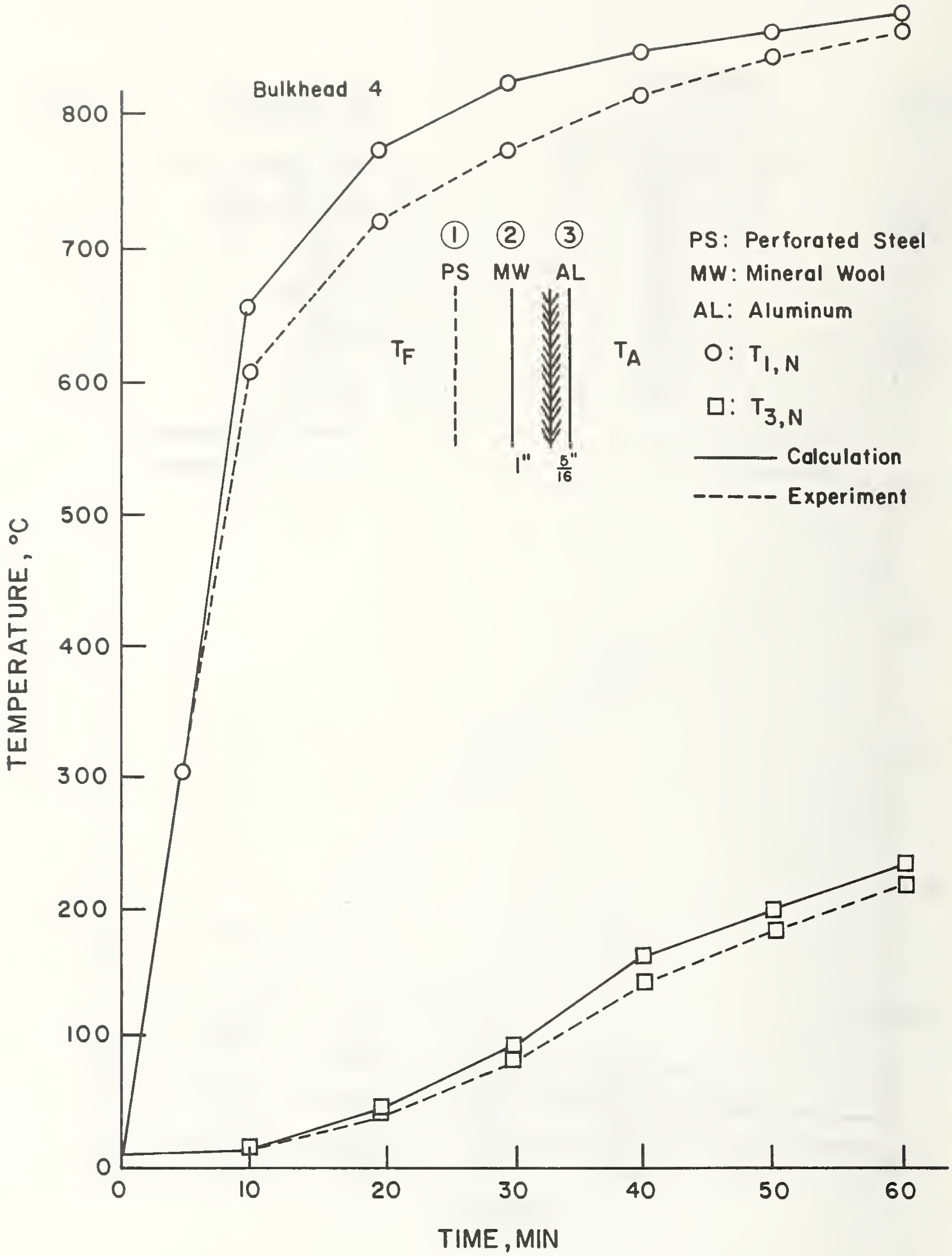

Figure 14. Thermal Response of Bulkhead 4.

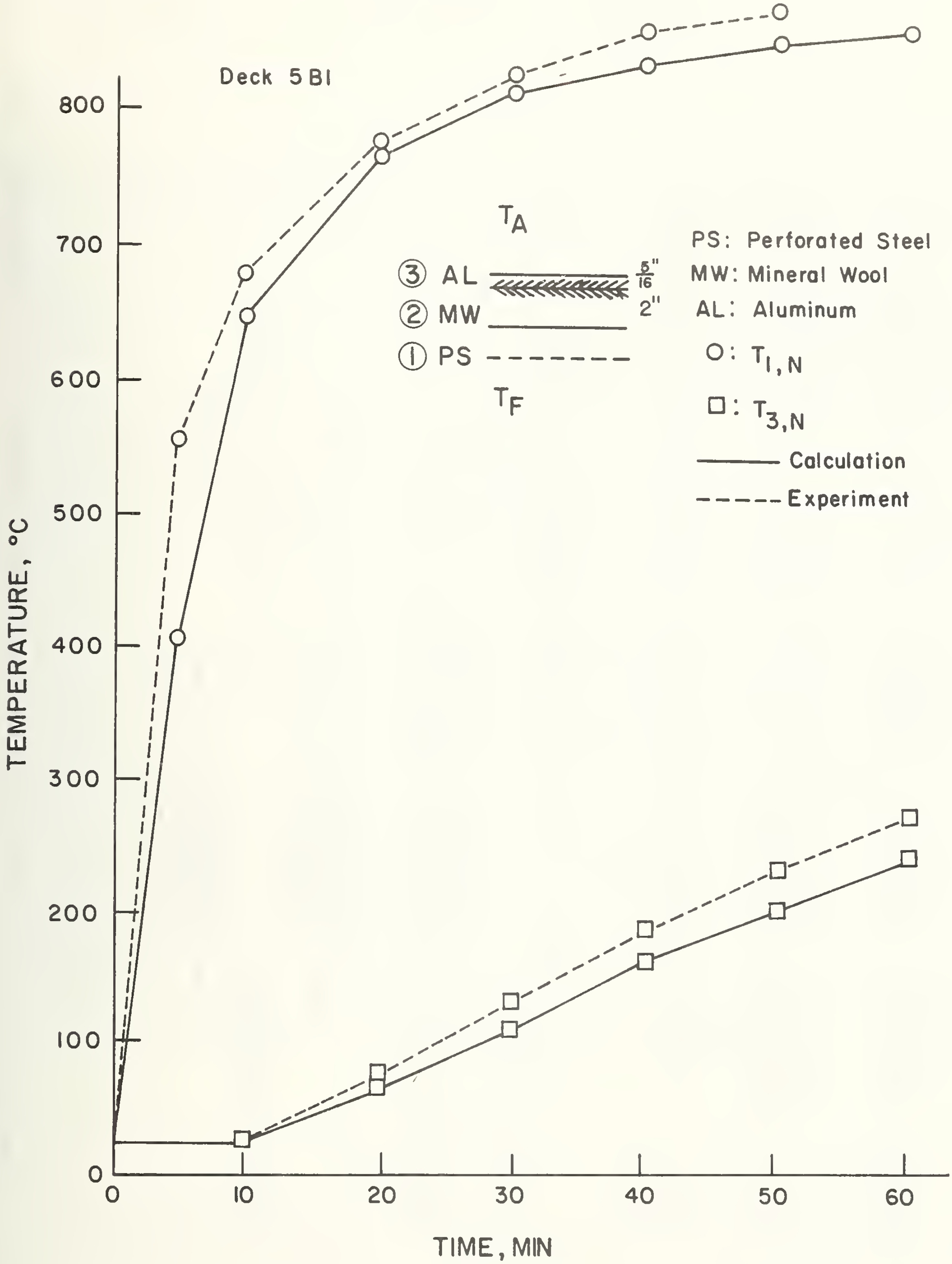

Figure 15. Thermal Response of Bulkhead 5B1.

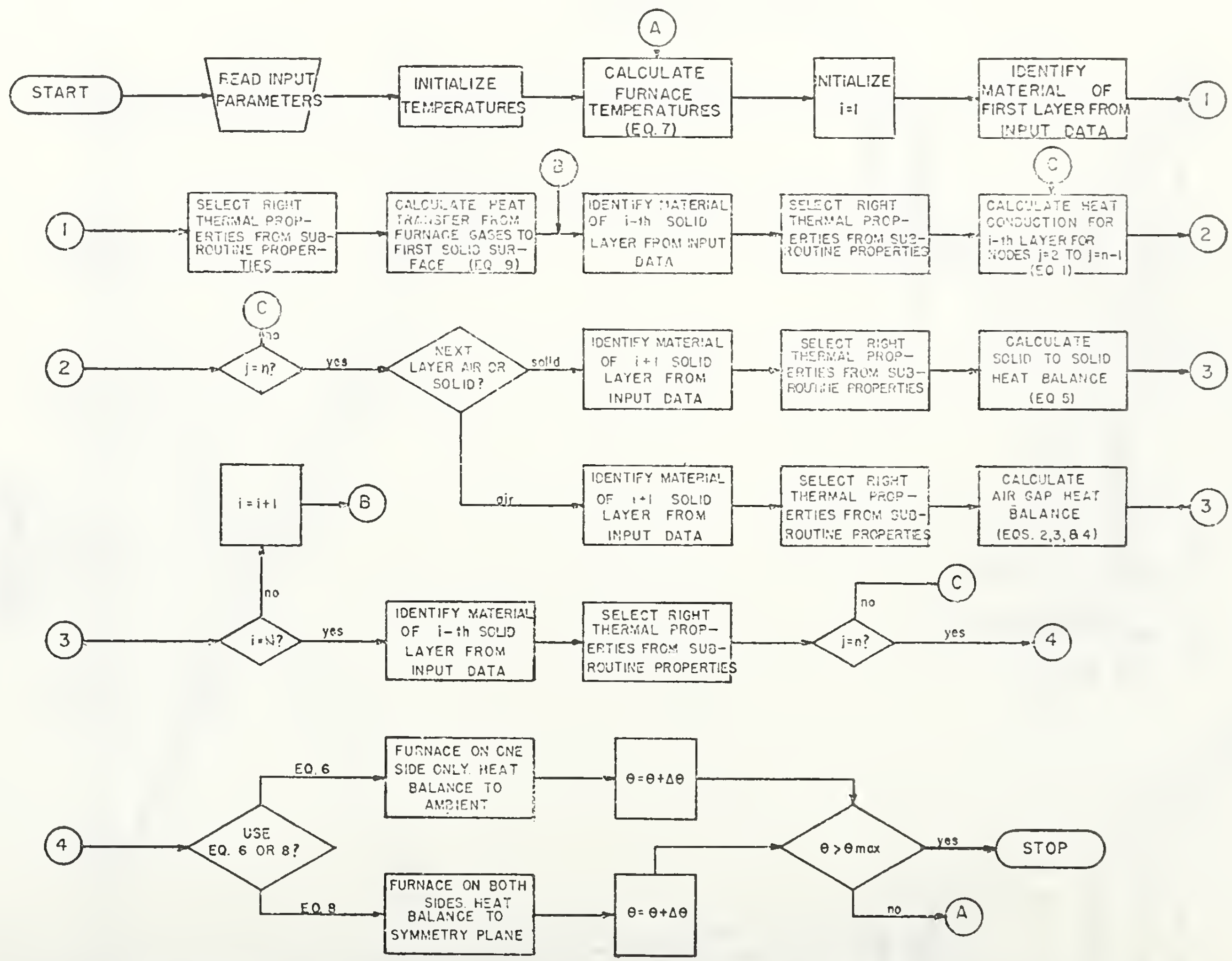

Figure 16. Flow Chart of Transient Heat Transfer Through Composite Walls with Arbitrary Air Gaps.

APPENDIX - PROGRAM LISTING

```
@FOR,IS  MAIN
FOR S0E3-01/25/77-23:18:58 (,0)

    MAIN PROGRAM

    STORAGE USED: CODE(1) 002415; DATA(0) 041117; BLANK COMMON(2) 000000

    EXTERNAL REFERENCES (BLOCK, NAME)

      0003   PROP
      0004   T11
      0005   T55
      0006   T22
      0007   T33
      0010   T44
      0011   T66
      0012   T88
      0013   PLOTS
      0014   NINTR$
      0015   NRDC$
      0016   NIO1$
      0017   NIO2$
      0020   NPRT$
      0021   XPRR
      0022   NSTOP$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

      0001   000413 1L       0000   040735 100F     0000   040734 101F     0000   040771 102F     0001   001235 12L
      0001   000051 132G     0001   000062 140G     0001   000073 146G     0001   000110 156G     0001   000137 167G
      0001   000140 172G     0001   002260 200L     0001   000155 202G     0001   000176 207G     0001   002152 209L
      0001   000204 214G     0000   040746 216F     0001   000231 234G     0001   000242 242G     0001   000257 252G
      0001   000304 261G     0001   000115 307L     0001   000160 308L     0001   000264 310L     0000   040775 311F
      0000   040773 312F     0000   041010 317F     0001   000431 330G     0001   000432 333G     0001   000664 366G
      0001   001773 37L      0001   000016 377L     0001   000460 415L     0001   000502 416L     0001   000510 417L
      0001   001632 45L      0001   000642 5L       0001   002245 57L      0001   002400 75L      0001   002315 76L
      0001   002352 77L      0001   002324 78L      0001   002337 79L      0001   002365 80L      0000   040627 81F
      0000   040637 82F      0000   040647 83F      0000   040657 84F      0000   040667 85F      0000   041000 86F
      0000   040770 87F      0000   040707 88F      0000   040753 89F      0000   040751 90F      0000   040745 91F
      0000   040742 92F      0000   040677 93F      0000   040743 97F      0000   040740 98F      0000 D 025560 A
      0000 R 000037 AI       0000 D 016033 AK       0000 D 040613 AKK      0000 R 000001 AL       0000 D 040603 ALPHA
      0000 D 015547 AM       0000 D 040540 AMO      0000 D 025654 B        0000 D 015737 BH       0000 D 040627 C
      0000 D 040536 CPA      0000 D 026044 D        0000 D 015453 DELTAX   0000 D 040532 DTHETA   0000 D 040611 EPSLON
      0000 D 021443 G        0000 R 000075 GA       0000 D 040617 GAA      0000 R 011743 GM1      0000 R 011744 GM2
      0000 R 011745 GM3      0000 D 040562 G1       0000 D 040564 G2       0000 D 040566 G3       0000 D 015643 H
      0000 D 040534 HH       0000 I 040553 I        0000 I 040576 IA       0000 I 025433 ID       0000 I 031454 IPP
      0000 I 040574 II       0000 I 040602 IJ       0000 I 040551 ITEST    0000 I 040561 J        0000 I 040577 JJ
      0000 I 040601 K        0000 I 040552 KK       0000 I 040600 LL       0000 I 040550 M        0000 I 040575 MM
      0000 I 040547 N        0000 I 040560 NA       0000 I 040626 NARGS    0000 I 040546 NN       0000 I 025553 NMAX
      0000 I 040625 NROW     0000 D 025147 P        0000 D 040623 PS       0000 D 025337 Q        0000 D 040605 RHO
      0000 D 025750 RHOA     0000 D 040542 ROA1     0000 D 025243 R1       0000 D 025053 S        0000 D 040544 SIGMA
      0000 D 011747 T        0000 D 015357 TA       0000 D 040572 TF       0000 D 040554 THETA    0000 D 031512 THETA1
      0000 D 035122 THETA2   0000 R 011746 TMAX     0000 D 040615 TPRIME   0000 D 040570 TS       0000 R 000000 TO
      0000 D 040621 T1       0004 D 000000 T11      0006 D 000000 T22      0007 D 000000 T33      0010 D 000000 T44
      0005 D 000000 T55      0011 D 000000 T66      0012 D 000000 T88      0000 R 000133 X        0000 D 040556 XMAX
      0000 R 005037 Y
```

```
00100   C     ELEMENT HEAT  MAIN PROGRAM                                          000000
00100   C  INPUTS                                                                 000000
00100   C   NN= NUMBER OF SOLIDS                                                  000000
00100   C    N=  NUMBER OF NODES IN SOLID                                         000000
00100   C   M  =  NUMBER OF AIR  SPACES                                           000000
00100   C  ITEST  = AN INTEGER THAT INDICATES WHETHER FORMULA 6 OR FORMULA 8      000000
00100   C  WILL BE USED IN COMPUTATIONS;   1 INDICATES FORMULA 6 ANY OTHER        000000
00100   C  NUMBER INDICATES FORMULA 8                                             000000
00100   C   T0  =  INITIAL TEMPERATURE NOW 68                                     000000
00100   C  GM1 = HEAT RELEASE PER UNIT VOLUME DUE TO MOISTURE VAPORIZATION FOR    000000
00100   C    GYPSUM                                                               000000
00100   C  GM2 = HEAT RELEASE PER UNIT VOLUME DUE TO MOISTURE VAPORIZATION FOR    000000
00100   C    BRICK                                                                000000
00100   C  GM3 = HEAT RELEASE PER UNIT VOLUME DUE TO MOISTURE VAPORIZATION FOR    000000
00100   C    WOOD                                                                 000000
00100   C   ID  AN ARRAY OF INTEGERS THAT INDICATES THE SOLID-AIR CONFIGURATION   000000
00100   C THATS BEING TESTED  0= AN AIR GAP  NON-ZERO = SOLID                     000000
00100   C   A DATA CARD WITH 1010101  WOULD INDICATE 4 SOLIDS AND THREE AIR GAPS  000000
00100   C  IDD AN ARRAY OF INTEGERS THAT INDICATE THE TYPE OF SOLIDS  1=  GYPSUM  000000
00100   C  2=  BRICK  3=  WOOD  SUPPOSE THERE WERE 4 SOLIDS GYPSUM,WOOD,BRICK     000000
00100   C   AND GYPSUM  THEN DATA CARD WOULD BE PUNCHED AS 1321                   000000
00100   C  AL  =  SOLID THICKNESS IN FEET                                         000000
00100   C  ALPHA =  HEAT DIFUSSION COEFFICIENT                                    000000
00100   C   RHO  =  DENSITY OF SOLID IN CUBIT FEET                                000000
00100   C   C=SPECIFIC HEAT CAPACITY OF SOLID                                     000000
00100   C   AI = AIR GAP DISTANCE IN FEET                                         000000
00100   C   GA = HEAT RELEASE PER UNIT VOLUME IN AIR GAP                          000000
00100   C  OUTPUTS                                                                000000
00100   C  T(I,J) PRIME  = TEMPERATURE AT TIME(THETA+DTHETA) OF JTH NODE IN       000000
00100   C  ITH SOLID LAYER                                                        000000
00100   C   TA(I)  =  TEMPERATURE OF MID-POINT OF AIR SPACING BETWEEN ITH AND     000000
00100   C  I+1 LAYER OF SOLID   THETA = TIME                                      000000
00101          IMPLICIT DOUBLE PRECISION(A-H,O-Z)                                 000000
00103          REAL  T0,        AL,             AI,GA,   X,Y ,GM1,GM2,GM3,TMAX    000001
00104          DIMENSION T(30,30),AL(30),AI(30),TA(30),DELTAX(30),AM(30),H(30),   000001
00104        1 BH(30),AK(30,30),G(30,30)                             ,S(30),      000001
00104        2 P(30),R1(30), O(30),ID(80) ,GA(30)                                 000001
00105          DIMENSION X(500,5),Y(500,5),NRMX(5)                 , A(30),B(30), 000001
00105        1 RHOA(30),D(30,30),IDD(30),THETA1(30,30),THETA2(30,30)              000001
00105   C  DTHETA = TIME INCREMENT                                                000001
00106          DTHETA=1.D0/720.D0                                                 000001
00106   C  HH=CHARACTERISTIC HEAT TRANSFER COEFFICIENT                            000001
00107          HH=.2700                                                           000003
00107   C   CPA= SPECIFIC HEAT CAPACITY FOR AIR                                   000003
00110          CPA=0.25D0                                                         000005
00110   C  AMO= VOLUME AIR FLOW THROUGH THE LAYERS, CUBIC FEET PER HOUR           000005
00111          AMO=  0.D0                                                         000007
00111   C  ROA1= DENSITY OF AIR IN LB PER CUBIC FOOT                              000007
00112          ROA1=.05D0                                                         000011
00112   C  SIGMA = BOLTZMAN STEFAN CONSTANT                                       000011
00113          SIGMA=0.1714D-8                                                    000013
00113   C  AK = HEAT CONDUCTION COEFFICIENT                                       000013
00113   C      READ IN DATA THAT DESCRIBE PANELS AND READ IN OTHER DATA           000013
00114   377    READ 90,NN,N,M,ITEST,T0,         GM1,GM2,GM3,TMAX                  000016
00127          KK=NN+M                                                            000035
00130          READ 91,(ID(I),I=1,KK)                                             000040
00136          READ 91,(IDD(I),I=1,NN)                                            000054
```

```
00144              READ 98,(AL(I),I=1,NN)                                                    000065
00152              IF(M.EQ.0)GO TO 307                                                       000076
00154              READ 98,(AI(I),GA(I),I=1,M)                                               000100
00154      C   THETA = TIME IN HOURS                                                         000100
00163      307     THETA=0.0D0                                                               000115
00164              XMAX=TMAX                                                                 000116
00165              NA=0                                                                      000120
00166              DO 301 J=1,N                                                              000140
00171              DO 301  I=1,NN                                                            000140
00174      301     T(I,J)=T0                                                                 000140
00177              IF(M.EQ.0) GO TO 308                                                      000146
00201              DO 302  I=1,M                                                             000150
00204      302     TA(I)=T0                                                                  000155
00206      308     DO 305 I=1,NN                                                             000160
00211      305     H(I)=HH                                                                   000176
00213              DO 104 I=1,NN                                                             000204
00216      104     DELTAY(I)=AL(I)/FLOAT(N-1)                                                000204
00220      309     PRINT 100,NN,N,M,ITFST,T0,          GM1,GM2,GM3                           000207
00232              PRINT 101,(ID(I),I=1,KK)                                                  000223
00240              PRINT 101,(IDD(I),I=1,NN)                                                 000234
00246              IF(M.EQ.0)GO TO 310                                                       000245
00250              PRINT 102,(AI(I),GA(I),I=1,M)                                             000247
00257      310     PRINT 102,(AL(I)                            ,I=1,NN)                      000264
00265              G1=GM1                                                                    000307
00266              G2=GM2                                                                    000311
00267              G3=GM3                                                                    000313
00270              TS=T0                                                                     000315
00271              TF=T0                                                                     000317
00271      C  PLOT VALUES                                                                    000317
00272              X(1,1)=THETA*60.D0                                                        000320
00273              X(1,2)=THETA*60.D0                                                        000322
00274              X(1,3)=THETA*60.D0                                                        000323
00275              X(1,4)=THETA*60.D0                                                        000324
00276              X(1,5)=THETA*60.D0                                                        000325
00277              Y(    1,1)=(T(2,1)-32.D0)/1.8D0                                           000326
00300              Y(    1,2)=(T(3,N)-32.D0)/1.8D0                                           000333
00301              Y(    1,3)=(TA(2)-32.D0)/1.8D0                                            000341
00302              Y(    1,4)=(T(4,1)-32.D0)/1.8D0                                           000346
00303              Y(    1,5)=(T(4,N)-32.D0)/1.8D0                                           000353
00304              II=2                                                                      000360
00305              PRINT 87                                                                  000362
00307              PRINT 88                                                                  000366
00311              PRINT 89,T(1,1),T(1,N),T(2,1),T(2,N),T(3,1),T(3,N),T(4,1),T(4,N),         000372
00311            1 THETA                                                                     000372
00324              MM=N-1                                                                    000407
00325      1       I=1                                                                       000413
00326              IA=1                                                                      000414
00327              DO 106 JJ=1,N                                                             000432
00332              DO 106 LL=1,NN                                                            000432
00335      106     G(LL,JJ)=0.0D0                                                            000432
00340              K=0                                                                       000440
00340      C     COMPUTE TF      FORMULA 7                                                   000440
00341              IF(THETA.GE.1.D0)GO TO 415                                                000441
00343              TF=T0+101520.D0*THETA/(60.D0*THETA+4.D0)                                  000445
00344              GO TO 417                                                                 000456
00345      415     IF(THETA.GE.1.9D0)GO TO 416                                               000460
00347              TF=(926.D0+42.D0*THETA-0.0131D0* (120.D0-60.D0*THETA)**2)*1.8D0           000463
00347            1  +32.D0                                                                   000463
```

```
00350              GO TO 417                                                          000500
00351       416    TF=(926.D0+42.D0*THETA)*1.8D0+32.D0                                000502
00351       C  COMPUTE T(1,1)  AND TPRIME                                             000502
00352       417    IJ=IDD(1)                                                          000510
00352       C   TEST PROPERTIES FOR CURRENT SOLID                                     000510
00353              CALL PROP(T(  1 ,1),AK(  1,1),THETA1(1,1),THETA2(1,1),THETA,       000511
00353            1 DTHETA,G(1,1),G1,G2,G3,ALPHA,RHO,C,EPS LON,IJ)                     000511
00354              AM(1)=DELTAX(1)**2/(ALPHA   *DTHETA)                               000532
00355              BH(1)=(2.*H(1)*DTHETA)/(RHO   *C    *DELTAX(1))                    000540
00356              R1(1)=(2.*DTHETA*SIGMA*EPSLON        )/(DELTAX(1)*RHO    *C    )   000552
00357       924    AKK=AK(1,1)                                                        000567
00360              IF(AM(1).LE.2.D0)GO TO 76                                          000571
00362              TPRIME =T(1,1)+R1(1) *(TF-T(1,1))*(TF+T(1,1)+920.D0)*((TF+460.D0)  000574
00362            1 **2+(T(1,1)+460.D0)**2)+BH(1)*DABS(TF-T(1,1))**.25*(TF-T(1,1))     000574
00362            2 + (G(1,1)+DELTAX(1)**2)/(AKK*AM(1)) -2.D0/AM(I)*(T(1,1)-T(1,2))    000574
00363              T(1,1)=TPRIME                                                      000637
00363       C   COMPUTE TPRIME(I,J)  FORMULA 1                                        000637
00364       5      IJ=IDD(I)                                                          000642
00365              DO 10 J=2,MM                                                       000644
00365       C   TEST PROPERTIES FOR CURRENT SOLID                                     000644
00370              CALL PROP(T(  I ,J),AK( I,J ),THETA1(I,J),THETA2(I,J),THETA,       000664
00370            1 DTHETA,G(I,J),G1,G2,G3,ALPHA,RHO,C,EPS LON,IJ)                     000664
00371              AM(I)=DELTAX(I)**2/(ALPHA   *DTHETA)                               000717
00372              BH(I)=(2.*H(I)*DTHETA)/(RHO   *C    *DELTAX(I))                    000725
00373              R1(I)=(2.*DTHETA*SIGMA*EPSLON        )/(DELTAX(I)*RHO    *C    )   000734
00374       522    AKK=AK(I,J)                                                        000745
00375              IF(AM(I).LE.2.D0)GO TO 77                                          000747
00377              T(I,J)=T11(AM(I),T(I,J-1),T(I,J+1),T(I,J),G(I,J),AKK      ,        000752
00377            1 DELTAX(I))                                                         000752
00400       10     CONTINUE                                                           001002
00402             IF(I.EQ.MM)GO TO 45                                                 001002
00404              IF(ID(IA+I).EQ.0)GO TO 12                                          001005
00404       C   SOLID TO SOLID COMPUTATION                                            001005
00406              IJ=IDD(I)                                                          001020
00406       C   TEST PROPERTIES FOR CURRENT SOLID                                     001020
00407              CALL PROP(T(  I ,N),AK( I,N ),THETA1(I,N),THETA2(I,N),THETA,       001022
00407            1 DTHETA,G(I,N),G1,G2,G3,ALPHA,RHO,C,EPS LON,IJ)                     001022
00410              A(I)=(RHO*C*DELTAX(I))/2.D0                                        001056
00411              B( I)=(DELTAX( I)*DTHETA)/2.D0                                     001063
00412              D( I,N)=(AK( I,N)*DTHETA)/DELTAX( I)                               001067
00413              D( I,1)=(AK( I,1)*DTHETA)/DELTAX( I)                               001074
00414              IJ=IDD(I+1)                                                        001100
00415              CALL PROP(T(I+1,1),AK(I+1,1),THETA1(I+1,1),THETA2(I+1,1),THETA,    001102
00415            1 DTHETA,G(I+1,1),G1,G2,G3,ALPHA,RHO,C,EPS LON,IJ)                   001102
00416              A(I+1)=(RHO*C*DELTAX(I+1))/2.D0                                    001135
00417              B(I+1)=(DELTAX(I+1)*DTHETA)/2.D0                                   001142
00420              D(I+1,N)=(AK(I+1,N)*DTHETA)/DELTAX(I+1)                            001146
00421              D(I+1,1)=(AK(I+1,1)*DTHETA)/DELTAX(I+1)                            001152
00422       932    AKK=AK(I,N)                                                        001156
00423              T(I,N)=T55(A(I),T(I,N),A(I+1),T(I+1,1),B(I),G(I,N),B(I+1),         001160
00423            1 G(I+1,1),D(I,N),T(I,N-1),D(I+1,1),T(I+1,2))                        001160
00424              T(I+1,1)=T(I,N)                                                    001227
00425              I=I+1                                                              001230
00426              GO TO 5                                                            001233
00426       C   COMPUTE TPRIME FORMULA 2  AIR SPACE COMPUTATION                       001233
00427       12     K=K+1                                                              001235
00430              IJ=IDD(I)                                                          001237
00430       C   TEST PROPERTIES FOR CURRENT SOLID                                     001237
```

```
00431          CALL PROP(T(  I  ,N),AK( I,N ),THETA1(I,N),THETA2(I,N),THETA,     001242
00431        1 DTHETA,G(I,N),G1,G2,G3,ALPHA,RHO,C,EPS LON,IJ)                    001242
00432          AM(I)=DELTAX(I)**2/(ALPHA    *DTHETA)                             001304
00433          BH(I)=(2.*H(I)*DTHETA)/(RHO    *C    *DELTAX(I))                   001313
00434          R1(I)=(2.*DTHETA*SIGMA*EPSLON        )/(DELTAX(I)*RHO    *C    )   001323
00435    611   AKK=AK(I,N)                                                       001334
00436          IF(AM(I).LE.2.D0)GO TO 75                                         001336
00440          T(I,N)=T22(AM(I),T(I,N),T(I,N-1),R1(I),T(I+1,1),BH(I),TA(K),      001341
00440        1 G(I,N),AKK,DELTAX(I))                                             001341
00440    C  COMPUTE TAPRIME  FORMULA 3                                           001341
00441          RHOA(K)=39.674D0/(TA(K)+460.D0)                                   001403
00442          P(K)=(H(K)*DTHETA)/(AI(K)*CPA*RHOA(K))                            001411
00443          GA(K)=0.0D0                                                       001422
00444          S(K)=(AMO*DTHETA)/(AI(K))                                         001423
00445          Q(K)=(H(K+1)*DTHETA)/(AI(K)*CPA*RHOA(K))                          001427
00446          GAA=GA(K)                                                         001433
00447          TA(K)=T33(TA(K),P(K),T(I,N), Q(K),T(I+1,1),S(K),GAA   )           001435
00447    C  COMPUTE TPRIME(I+1,1)  FORMULA 4                                     001435
00450          IJ=IDD(I+1)                                                       001463
00450    C   TEST PROPERTIES FOR CURRENT SOLID                                   001463
00451          CALL PROP(T(I+1,1),AK(I+1,1), THETA1(I+1,1),THETA2(I+1,1),        001465
00451        1                    THETA,DTHETA,G(I+1,1),G1,G2,G3,ALPHA,RHO,      001465
00451        1 C,EPSLON,IJ)                                                      001465
00452          AM(I+1)=DELTAX(I+1)**2/(ALPHA*DTHETA)                             001520
00453         BH(I+1)=(2.D0*H(I+1)*DTHETA)/(RHO*C*DELTAX(I+1))                   001526
00454          R1(I+1)=(2.D0*DTHETA*SIGMA*EPSLON)/(DELTAX(I+1)*RHO*C)            001536
00455    412   AKK=AK(I+1,1)                                                     001547
00456          IF(AM(I+1).LE.2.D0)GO TO 80                                       001551
00460         T(I+1,1)=T44(T(I+1,1),R1(I),T(I,N),AM(I+1),BH(I+1),TA(K),T(I+1,2), 001554
00460        1 G(I+1,1),AKK,DELTAX(I+1))                                         001554
00461          IF(K.EQ.M)K=0                                                     001613
00463    39    IF(I.EQ.NN)GO TO 45                                               001617
00465          I=I+1                                                             001622
00466          IA=IA+1                                                           001625
00467          GO TO 5                                                           001630
00467    C     DECIDE BETWEEN FORMULAS 6 AND 8                                   001630
00467    C   COMPUTE T(NN,N)  FORMULA 6                                          001630
00470    45    IF(ITEST.NE.1)GO TO 37                                            001632
00472          T1=T0                                                             001634
00473             IJ=IDD(NN)                                                     001645
00473    C   TEST PROPERTIES FOR CURRENT SOLID                                   001645
00474          CALL PROP(T( NN,N ),AK( NN,N),THETA1( NN,N),THETA2( NN,N),THETA,  001647
00474        1 DTHETA,G( NN,N),G1,G2,G3,ALPHA,RHO,C,EPSLON,IJ)                   001647
00475          AM( NN)=DELTAX( NN)**2/(ALPHA*DTHETA)                             001703
00476         BH( NN)=(2.D0*H( NN)*DTHETA)/(RHO*C*DELTAX( NN))                   001711
00477          R1( NN)=(2.D0*DTHETA*SIGMA*EPSLON)/(DELTAX( NN)*RHO*C)            001721
00500    431   AKK=AK(NN,N)                                                      001732
00501          IF(AM(NN).LE.2.D0)GO TO 78                                        001734
00503          T(NN,N)=T66(T(NN,N),AM(NN),T(NN,N-1),R1(NN),T1,BH(NN),            001737
00503        1 G(NN,N),AKK,DELTAX(NN))                                           001737
00504          GO TO 209                                                         001771
00504    C   COMPUTE T(NN,N)   FORMULA 8                                         001771
00505    37    IJ=IDD(NN)                                                        001773
00505    C   TEST PROPERTIES FOR CURRENT SOLID                                   001773
00506          CALL PROP(T( NN,N ),AK( NN,N),THETA1( NN,N),THETA2( NN,N),THETA,  001775
00506        1 DTHETA,G( NN,N),G1,G2,G3,ALPHA,RHO,C,EPSLON,IJ)                   001775
00507          AM( NN)=DELTAX( NN)**2/(ALPHA*DTHETA)                             002037
00510         BH( NN)=(2.D0*H( NN)*DTHETA)/(RHO*C*DELTAX( NN))                   002046
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00511               R1( NN)=(2.D0*DTHETA*SIGMA*EPSLON)/(DELTAX( NN)*RHO*C)                    002056
00512        432    AKK=AK(NN,N)                                                              002067
00513               IF(AM(NN).LE.2.D0)GO TO 79                                                002071
00515               T(NN,N)=TBB(T(NN,N)  ,T(NN,N-1),TS,AM(NN),BH(NN),                         002074
00515             1 G(NN,N),AKK,DELTAX(NN),R1(NN))                                            002074
00516               PS=0.15D0*DTHETA/(0.5D0*CPA*ROA1)                                         002126
00517               TS=TS+PS*DABS(T(NN,N)-TS)**.25*(T(NN,N)-TS)                               002135
00520        209    IF(MOD(NA,100).NE.0)GO TO 57                                              002152
00522               PRINT 89,T(1,1),T(1,N),T(2,1),T(2,N),T(3,1),T(3,N),T(4,1),T(4,N),         002156
00522             1 THETA                                                                     002156
00522         C  PLOT VALUES                                                                  002156
00535               X(II,1)=THETA*60.D0                                                       002177
00536               X(II,2)=THETA*60.D0                                                       002204
00537               X(II,3)=THETA*60.D0                                                       002205
00540               X(II,4)=THETA*60.D0                                                       002206
00541               X(II,5)=THETA*60.D0                                                       002207
00542               Y(  II,1)=(T(2,1)-32.D0)/1.8D0                                            002210
00543               Y(  II,2)=(T(3,N)-32.D0)/1.8D0                                            002215
00544               Y(  II,3)=(TA(2)-32.D0)/1.8D0                                             002222
00545               Y(  II,4)=(T(4,1)-32.D0)/1.8D0                                            002227
00546               Y(  II,5)=(T(4,N)-32.D0)/1.8D0                                            002234
00547               II=II+1                                                                   002241
00550        57     IF( THETA.GT.XMAX)GO TO 200                                               002245
00552               NA=NA+1                                                                   002250
00552         C   INCREMENT TIME                                                              002250
00553               THETA=THETA+DTHETA                                                        002253
00554               GO TO 1                                                                   002256
00555        200    II=II-1                                                                   002260
00556               PRINT 87                                                                  002262
00560               NROW=500                                                                  002266
00561               NRMX(1)=II                                                                002270
00562               NRMX(2)=II                                                                002272
00563               NRMX(3)=II                                                                002273
00564               NRMX(4)=II                                                                002274
00565               NRMX(5)=II                                                                002275
00566               NARGS=5                                                                   002276
00567               PRINT 87                                                                  002300
00571               CALL PLOTS(NARGS,X,Y,NRMX,NROW)                                           002304
00572               GO TO 377                                                                 002313
00573        76     PRINT 93 ,AM(1)                                                           002315
00576               STOP                                                                      002321
00577        78     PRINT 81,AM(NN)                                                           002324
00602               STOP                                                                      002334
00603        79     PRINT  82,AM(NN)                                                          002337
00606               STOP                                                                      002347
00607        77      PRINT 83,AM(I)                                                           002352
00612               STOP                                                                      002362
00613        80     PRINT 84, AM(I+1)                                                         002365
00616               STOP                                                                      002375
00617        75     PRINT 85, AM(I)                                                           002400
00622               STOP                                                                      002410
00623        81     FORMAT(1X,'M NOT GREATER THAN 2 FORMULA 6 M=',E14.8)                      002414
00624        82     FORMAT(1X,'M NOT GREATER THAN 2 FORMULA 8 M=',E14.8)                      002414
00625        83     FORMAT(1X,'M NOT GREATER THAN 2 FORMULA 1 M=',E14.8)                      002414
00626        84     FORMAT(1X,'M NOT GREATER THAN 2 FORMULA 4 M=',E14.8)                      002414
00627        85     FORMAT(1X,'M NOT GREATER THAN 2 FORMULA 2 M=',E14.8)                      002414
00630        93     FORMAT(1X,'M NOT GREATER THAN 2 T(1,1) M=',F14.8)                         002414
00631        88     FORMAT('     T(1,1)       T(1,N)        T(2,1)       T(2,N)                   002414
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00631    290*        1 T(3,1)       T(3,N)       T(4,1)       T(4,N)       THETA')                   002414
00632    291*    101   FORMAT(20I3)                                                                   002414
00633    292*    100   FORMAT(1X,4I6,5F11.3)                                                          002414
00634    293*    98    FORMAT(10F6.0)                                                                 002414
00635    294*    92    FORMAT(  F6.0)                                                                 002414
00636    295*    97    FORMAT(2F6.0)                                                                  002414
00637    296*    91    FORMAT(20I1)                                                                   002414
00640    297*    216   FORMAT(1X,1X,2I3,3F14.2)                                                       002414
00641    298*    90    FORMAT(4I2,5F6.0)                                                              002414
00642    299*    89    FORMAT(1X,F12.3,1X,F12.3,1X,F12.3,1X,F12.3,1X,F12.3,1X,F12.3,                  002414
00642    300*        1 F12.3,1X,F12.3,7X,F6.3)                                                        002414
00643    301*    87    FORMAT(1H1)                                                                    002414
00644    302*    102   FORMAT(1X,4F14.3)                                                              002414
00645    303*    312   FORMAT(1X,4D26.16)                                                             002414
00646    304*    311   FORMAT(1X,F14.8,4D26.16)                                                       002414
00647    305*    86    FORMAT(1X,F12.3,1X,F12.3,1X,F12.3,1X,F12.3,13X,F12.3)                          002414
00650    306*    317   FORMAT(1X,3F12.3,D26.16,3F12.3)                                                002414
00651    307*          END                                                                            002414

       END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S1
FOR S0E3-01/25/77-23:19:05 (,0)

   FUNCTION T11         ENTRY POINT 000027

   STORAGE USED: CODE(1) 000031; DATA(0) 000015; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000002 2F       0000   000011 INJP$     0000 D 000000 T11

00100      1*      C   ELEMENT TRANS1                                                                 000000
00101      2*          DOUBLE PRECISION FUNCTION T11(AM,T1,T2,T3,G,AK,DELTAX)                         000000
00103      3*          IMPLICIT DOUBLE PRECISION(A-H,O-W)                                             000000
00103      4*      C    FORMULA 1                                                                     000000
00104      5*          T11=(T1+T2)/AM+ (1.D0-2.D0/AM)*T3  +(G*DELTAX**2)/(AK*AM)                      000000
00105      6*      2   FORMAT('  FORMULA 1')                                                          000017
00106      7*          RETURN                                                                         000017
00107      8*          END                                                                            000030

       END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S2
FOR S0E3-01/25/77-23:19:06 (,0)
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FUNCTION T22          ENTRY POINT 000065

STORAGE USED: CODE(1) 000102; DATA(0) 000047; BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

 0003   XPDR
 0004   NEPR3$

STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

 0000   000002 1F       0000   000007 2F       0000   000021 INJP$     0000 D 000000 T22


00100      1*      C    ELEMENT TRANS2                                                        000000
00100      2*      C  FORMULA 2                                                               000000
00101      3*           DOUBLE PRECISION FUNCTION T22(AM,T1,T2,R1,T3,H,TA,G,AK,DELTAX)         000000
00103      4*           IMPLICIT DOUBLE PRECISION(A-H,O-W)                                    000000
00104      5*           T22=T1+2.D0/AM*(T2-T1)-R1*(T1-T3)*(T1+T3+920.D0)*((T1+460.D0)**2+     000000
00104      6*         1(T3+460.D0)**2)-H*DABS(T1-TA)**.25*(T1-TA)+(G*DELTAX**2)/(AK*AM)       000000
00105      7*      1    FORMAT(1X,3F12.3,D26.16,3F12.3)                                       000053
00106      8*      2    FORMAT('  FORMULA 2')                                                 000053
00107      9*           RETURN                                                                000053
00110     10*           END                                                                   000101

     END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S3
FOR S0E3-01/25/77-23:19:08 (,0)

FUNCTION T33          ENTRY POINT 000047

STORAGE USED: CODE(1) 000067; DATA(0) 000036; BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

 0003   XPDR
 0004   NERR3$

STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

 0000   000002 2F       0000   000006 INJP$     0000 D 000000 T33
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```
00100       1*     C   ELEMENT TRANS3                                                              000000
00100       2*     C  FORMULA 3                                                                    000000
00101       3*            DOUBLE PRECISION FUNCTION T33(TA,P,T1,Q,T2,S,GA)                         000000
00103       4*            IMPLICIT DOUBLE PRECISION(A-H,O-W)                                       000000
00104       5*            T33=TA +P*DABS(T1-TA)**.25*(T1-TA)-Q*DABS(TA-T2)**.25*(TA-T2)+           000000
00104       6*          1 S*(T1-T2)+GA                                                             000000
00105       7*     2      FORMAT('  FORMULA 3')                                                    000036
00106       8*            RETURN                                                                   000036
00107       9*            END                                                                      000066

        END OF COMPILATION:       NO  DIAGNOSTICS.

@FOR,IS  S4
FOR S0E3-01/25/77-23:19:09 (,0)

   FUNCTION T44        ENTRY POINT 000065

   STORAGE USED: CODE(1) 000102; DATA(0) 000042; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   XPPR
    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000002 2F        0000   000014 INJP$      0000 D 000000 T44


00100       1*     C   ELEMENT TRANS4                                                              000000
00100       2*     C  FORMULA 4                                                                    000000
00101       3*            DOUBLE PRECISION FUNCTION T44(T1,R1,T2,AM,H,TA,T3,G,AK,DELTAX)           000000
00103       4*            IMPLICIT DOUBLE PRECISION(A-H,O-W)                                       000000
00104       5*            T44=T1 +R1*(T2-T1)*(T2+T1+920.D0)*((T2+460.D0)**2+(T1+460.D0)**2)        000000
00104       6*          1 -2.D0/AM*(T1-T3)+H*DABS(TA-T1)**.25*(TA-T1)+(G*DELTAX**2)/(AK*AM)        000000
00105       7*     2      FORMAT('  FORMULA 4')                                                    000053
00106       8*            RETURN                                                                   000053
00107       9*            END                                                                      000101

        END OF COMPILATION:       NO  DIAGNOSTICS.

@FOR,IS  S5
FOR S0E3-01/25/77-23:19:11 (,0)

   FUNCTION T66        ENTRY POINT 000062

   STORAGE USED: CODE(1) 000076; DATA(0) 000040; BLANK COMMON(2) 000000
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      EXTERNAL REFERENCES (BLOCK, NAME)

        0003   XPDR
        0004   NERR3$

      STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

        0000   000002 2F        0000   000014 INJP$     0000 D 000000 T66


   00100       1*      C   ELEMENT TRANS5                                              000000
   00100       2*      C  FORMULA 6                                                    000000
   00101       3*             DOUBLE PRECISION FUNCTIONT66(T1,AM,T2,R1,T0,H,G,AK,DELTAX)   000000
   00103       4*             IMPLICIT DOUBLE PRECISION(A-H,O-W)                       000000
   00104       5*             T66=T1+2.D0/AM*(T2-T1)-R1*(T1-T0)*(T1+T0+920.D0)*((T1+460.D0)**2   000000
   00104       6*           1 +(T0+460.D0)**2)-H*DABS(T1-T0)**.25*(T1-T0)+(G*DELTAX**2)/(AK*AM)   000000
   00105       7*      2      FORMAT('  FORMULA 6')                                    000051
   00106       8*             RETURN                                                   000051
   00107       9*             END                                                      000075

         END OF COMPILATION:       NO  DIAGNOSTICS.

   @FOR,IS  S6
   FOR S0E3-01/25/77-23:19:13 (,0)

      FUNCTION T88         ENTRY POINT 000046

      STORAGE USED: CODE(1) 000053; DATA(0) 000030; BLANK COMMON(2) 000000

      EXTERNAL REFERENCES (BLOCK, NAME)

        0003   XPDR
        0004   NERR3$

      STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

        0000   000002 2F        0000   000010 INJP$     0000 D 000000 T88


   00100       1*      C   ELEMENT TRANS6                                              000000
   00100       2*      C  FORMULA 8                                                    000000
   00101       3*             DOUBLE PRECISION FUNCTION T88(T1,T2,TS,AM,H,G,AK,DELTAX,R1)   000000
   00103       4*             IMPLICIT DOUBLE PRECISION(A-H,O-W)                       000000
   00104       5*             T88=T1+2.D0/AM*(T2-T1)-H*DABS(T1-TS)**.25 *(T1-TS)+(G*DELTAX**2)/   000000
   00104       6*           1(AK*AM)                                                   000000
   00105       7*      2      FORMAT('  FORMULA 8')                                    000034
   00106       8*             RETURN                                                   000034
   00107       9*             END                                                      000052
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      END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S7
FOR S0E3-01/25/77-23:19:14 (,0)

   FUNCTION T55         ENTRY POINT 000037

   STORAGE USED: CODE(1) 000041; DATA(0) 000006; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000002 INJP$      0000 R 000000 T55


00100      1*      C   ELEMENT TRANS7                                                          000000
00100      2*      C      FORMULA                                                              000000
00101      3*             DOUBLE PRECISION FUNCTION T55(A1,T1,A2,T2,B1,G1,B2,G2,D1,T3,D2,      000000
00101      4*           1 T4)                                                                  000000
00103      5*             IMPLICIT DOUBLE PRECISION (A-H,O-W)                                  000000
00104      6*             T55=(A1*T1+A2*T2+B1*G1+B2*G2+D1*(T3-T1)-D2*(T2-T4))/(A1+A2)          000000
00105      7*             RETURN                                                               000027
00106      8*             END                                                                  000040

      END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S8
FOR S0E3-01/25/77-23:19:16 (,0)

   SUBROUTINE PROP      ENTRY POINT 001033

   STORAGE USED: CODE(1) 001217; DATA(0) 000174; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR2$
    0004   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000013 501L      0001   000172 502L      0001   000325 503L      0001   000417 504L      0001   000600 505L
    0001   000656 506L      0001   001022 522L      0000   000150 INJP$
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00100      C   ELEMENT PROPT                                                                   000000
00101            SUBROUTINE PROP(T1,AK,THETA1,THETA2,THETA,DDTHET,G,GM1,GM2,GM3,              000000
00101          1 ALPHA,RHO,C,EPS LON,IJ)                                                       000000
00103            IMPLICIT DOUBLE PRECISION(A-H,O-W)                                            000000
00103      C  TEST PROPERTIES FOR GYPSUM                                                       000000
00104            GO TO (501,502,503,504,505,506),IJ                                            000000
00105      501   ALPHA=.008D0                                                                  000013
00106            RHO=60.D0                                                                     000014
00107            C=.26D0                                                                       000016
00110            EPS LON=.9D0                                                                  000020
00111            IF(     T1.GE.0.0D0.AND.     T1.LE.200.D0)AK=.5D0                             000022
00113            IF(     T1.GE.200.D0.AND.     T1.LE.400.D0)AK=.3D0                            000042
00115            IF(     T1.GE.400.D0.AND.     T1.LE.2000.D0)AK      =.2D0+T1/4000.D0          000062
00117            AK=AK/4.0                                                                     000104
00120           IF(     T1.GE.212.D0.AND.T1.LE.220.D0     )THETA1=THETA                        000107
00122           IF(     T1.GE.212.D0)THETA2      =THETA-THETA1                                 000127
00124            IF(THETA2.LT.DDTHET)GO TO 522                                                 000136
00126            IF(THETA2      .GE.0.0D0.AND.THETA2     .LE.200.D0*DDTHET)G      =-           000142
00126          1 (GM1+14100.D0)/(200.D0*DDTHET)                                                000142
00130            GO TO 522                                                                     000170
00130      C  TEST PROPERTIES BRICK                                                            000170
00131      502   ALPHA=.028D0                                                                  000172
00132            RHO=110.D0                                                                    000173
00133            C=.216D0                                                                      000175
00134            EPS LON=.9D0                                                                  000177
00135            IF(     T1.GE.0.0D0.AND.     T1.LE.200.D0)AK=1.D0                             000201
00137            IF(     T1.GE.200.D0.AND.     T1.LE.2000.D0)AK      =.46D0+2.D-4*T1           000221
00141           IF(     T1.GE.212.D0.AND.T1.LE.220.D0     )THETA1=THETA                        000243
00143           IF(     T1.GE.212.D0)THETA2      =THETA-THETA1                                 000263
00145            IF(THETA2      .LT.DDTHET)GO TO 522                                           000272
00147            IF(THETA2      .GE.0.0D0.AND.THETA2   .LE. 100.D0*DDTHET)G      =-            000276
00147          1  GM2/(100.D0*DDTHET)                                                          000276
00151            GO TO 522                                                                     000323
00151      C    TEST PROPERTIES FOR WOOD,DOUGLAS FIR                                           000323
00152      503   ALPHA=.0062D0                                                                 000325
00153            RHO=31.D0                                                                     000326
00154            C=.67D0                                                                       000330
00155            EPS LON=.9D0                                                                  000332
00156            AK=.065D0                                                                     000334
00157           IF(     T1.GE.212.D0.AND.T1.LE.220.D0     )THETA1=THETA                        000336
00161           IF(     T1.GE.212.D0)THETA2      =THETA-THETA1                                 000356
00163            IF(THETA2      .LT.DDTHET)GO TO 522                                           000365
00165            IF(THETA2      .GE.0.0D0.AND.THETA2   .LE. 200.D0*DDTHET)G      =-            000371
00165          1  GM3/(200.D0*DDTHET)                                                          000371
00165      C  MATERIAL NO. 4 IS MINERAL WOOL                                                   000371
00167      504   RHO=6.04D0                                                                    000417
00170            C=.2D0                                                                        000420
00171            EPSLON=.9D0                                                                   000422
00172            IF(T1.GE.0.0D0.AND.T1.LE.50.D0)AK=.02D0                                       000424
00174            IF(T1.GE.50.D0.AND.T1.LE.75.D0)AK=.02167D0                                    000444
00176            IF(T1.GE.75.D0.AND.T1.LE.2000.D0)AK=.0229D0+.517D-4*(T1-100.D0)               000464
00200            AK=20.D0*AK                                                                   000507
00201            ALPHA=AK/(RHO*C)                                                              000512
00202            IF(T1.GE.210.D0.AND.T1.LE.220.D0)THETA1=THETA                                 000516
00204            IF(T1.GE.210.D0)THETA2=THETA-THETA1                                           000536
00206            IF(THETA2.LT.DDTHET)GO TO 522                                                 000545
00210            IF(THETA2.GE.0.0D0.AND.THETA2.LE.50.D0*DDTHET)G=-GM1/(50.D0*DDTHE             000551
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00210      58*         1T)                                                          000551
00212      59*           GO TO 522                                                  000576
00212      60*    C    MATERIAL NO. 5 IS ALUMINUM                                   000576
00213      61*    505    ALPHA=3.33D0                                               000600
00214      62*           RHO=169.D0                                                 000601
00215      63*           C=.208D0                                                   000603
00216      64*           IF(T1.GE.0.D0.AND.T1.LE.200.D0) EPSLON=.09D0               000605
00220      65*           IF(T1.GE.200.D0.AND.T1.LE.2000.D0)EPSLON=.167D0+1.63D-4 *T1  000625
00222      66*           AK=117.D0+.13D0*(T1-32.D0)                                 000647
00223      67*           GO TO 522                                                  000654
00223      68*    C    MATERIAL NO. 6 IS MARINITE                                   000654
00224      69*    506    RHO=36.D0                                                  000656
00225      70*           C=.25D0+3.D-4*(T1-200.D0)                                  000657
00226      71*           IF(T1.GE.0.0D0.AND.T1.LE.200.D0)C=.25D0                    000664
00230      72*           EPS LON=.9D0                                               000704
00231      73*           AK=(.76D0+1.1D-4*(T1-100.D0))/12.D0                        000706
00232      74*           IF(T1.GE.0.D0.AND.T1.LE.100.D0)AK=.063D0                   000714
00234      75*           ALPHA=AK/(RHO*C)                                           000734
00235      76*           IF(T1.GE.210.D0.AND.T1.LE.220.D0)THETA1=THETA              000741
00237      77*           IF(T1.GE.210.D0)THETA2=THETA-THETA1                        000761
00241      78*           IF(THETA2.LT.DDTHET)GO TO 522                              000770
00243      79*           IF(THETA2.GE.0.D0.AND.THETA2.LE.1000.D0*DDTHET)G=-GM2/(1000.D0*  000774
00243      80*         1DDTHET)                                                     000774
00245      81*    522    RETURN                                                     001022
00246      82*           END                                                        001216

       END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S9
FOR S0E3-01/25/77-23:19:19 (,0)

     SUBROUTINE PLOTS      ENTRY POINT 000472

     STORAGE USED: CODE(1) 000521; DATA(0) 000313; BLANK COMMON(2) 000000

     EXTERNAL REFERENCES (BLOCK, NAME)

      0003    NWDU$
      0004    NI02$
      0005    NFLR2$
      0006    NI03$
      0007    NERR3$

     STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

      0001    000023 136G      0001    000037 142G      0001    000066 156G      0001    000102 162G      0001    000153 201G
      0001    000163 205G      0001    000166 210G      0001    000174 215G      0001    000213 222G      0001    000243 235G
      0001    000262 240L      0001    000275 244L      0001    000306 250L      0001    000264 253G      0001    000315 260L
      0001    000341 280L      0000    000217 290F      0001    000363 300L      0000    000223 310F      0001    000426 335G
      0001    000373 350L      0001    000377 400L      0000    000227 420F      0000    000232 620F      0000 I  000171 BLANK
      0000 I  000000 BOOL      0000 R  000172 COLX      0000 I  000176 I         0000 I  000160 IDGT      0000    000251 INJP$
      0000 I  000173 IPRINT    0000 I  000174 IX        0000 I  000177 J         0000 I  000206 K         0000 I  000213 KA
      0000 I  000207 KK        0000 I  000214 KKK       0000 I  000175 K2        0000 I  000200 K4        0000 I  000210 K5
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0000 I 000205 L        0000 I 000005 PRINT    0000 R 000202 XDELTA   0000 R 000211 XL     0000 R 000240 XMAX
0000 R 000237 XMIN     0000 R 000152 XP       0000 R 000216 XR       0000 R 000212 XT     0000 R 000237 X0
0000 R 000240 X1       0000 R 000201 YDELTA   0000 R 000203 YL       0000 R 000242 YMAX   0000 R 000241 YMIN
0000 R 000215 YP       0000 R 000204 YT       0000 R 000241 Y0       0000 R 000242 Y1


00100    1*    C   ELEMENT PLOTS                                                              000012
00101    2*          SUBROUTINE PLOTS (NARGS,X,Y, NRMX,NROW)                                  000012
00101    3*    C  PLOTS UP TO 5 PAIRS OF COLUMNS.   THE NOTATION IS AS FOLLOWS.               000012
00101    4*    C                                                                              000012
00101    5*    C     X - A MATRIX HAVING UP TO 5 COLUMNS  AND  NROW ROWS                      000012
00101    6*    C                                                                              000012
00101    7*    C     Y - A MATRIX HAVING UP TO 5 COLUMNS  AND  NROW ROWS                      000012
00101    8*    C                                                                              000012
00101    9*    C          THE FIRST COLUMN OF Y IS PLOTTED VERSUS THE FIRST COLUMN OF X       000012
00101   10*    C              SECOND          Y                      SECOND         X        000012
00101   11*    C                                       ETC                                    000012
00101   12*    C                                                                              000012
00101   13*    C    NROW - THE NUMBER OF ROWS IN  X AND Y IN THEIR DIMENSION STATEMENTS       000012
00101   14*    C           IN THE MAIN PROGRAM.  E.G. IF  X AND Y ARE DIMENSIONED             000012
00101   15*    C           AS   X(130,4) , Y(130,4)  IN THE MAIN PROGRAM THEN SET NROW=130    000012
00101   16*    C                                                                              000012
00101   17*    C    NARGS - THE NUMBER OF PAIRS OF COLUMNS TO BE PLOTTED.                     000012
00101   18*    C                                                                              000012
00101   19*    C    NRMX  - A VECTOR CONTAINING THE LENGTHS OF THE DATA  TO BE                000012
00101   20*    C            PLOTTED IN THE SEVERAL COLUMN PAIRS.  THAT IS,                    000012
00101   21*    C            NRMX(1)  IS NUMBER OF POINTS TO BE PLOTTED IN FIRST COLUMN PAIR   000012
00101   22*    C            NRMX(2)                                   SECOND                  000012
00101   23*    C            NRMX(3)                                   THIRD                   000012
00101   24*    C                                  ETC.                                        000012
00101   25*    C                                                                              000012
00101   26*    C  THE SYMBOLS USED ARE  FIRST  SECOND  THIRD  FOURTH  FIFTH   COLUMN PAIR     000012
00101   27*    C                          .       *       +       ,      -                    000012
00101   28*    C                                                                              000012
00101   29*    C  IF MORE THAN ONE POINT FALLS ON THE SAME POSITION A TALLEY IS KEPT AND      000012
00101   30*    C     THE NUMBER IS PRINTED.                                                   000012
00101   31*    C                                                                              000012
00101   32*    C  LIMITS FOR THE PLOT ARE FIGURED OUT AUTOMATICALLY BASED ON THE SMALLEST     000012
00101   33*    C     AND LARGEST DATA POINTS.                                                 000012
00101   34*    C****                                                                          000012
00101   35*    C****   DOES NOT CALL A NEW PAGE.                                              000012
00101   36*    C                                                                              000012
00101   37*    C**** WRITTEN BY  S. PEAVY    5/1/67                                    0004   000012
00101   38*    C  COMMENTS BY R.L.JOINER   6/4/69                                             000012
00101   39*    C                                                                              000012
00101   40*    C                                                                              000012
00103   41*          DIMENSION NRMX(5),X(NROW,5),Y(NROW,5)                              200   000012
00104   42*          DIMENSION             PRINT(101),XP(6),BOOL(5),IDGT(9)             220   000012
00105   43*          INTEGER PRINT,BLANK                                                240   000012
00106   44*          EQUIVALENCE (X0,XMIN),(X1,XMAX),(Y0,YMIN),(Y1,YMAX)                260   000012
00107   45*          INTEGER BOOL                                                       280   000012
00110   46*          DATA BOOL(1),BOOL(2),BOOL(3),BOOL(4),BOOL(5)/1H.,1H*,1H+,1H,,1H-/,         000012
00110   47*         1COLX/6HCOLUMN/,BLANK/1H       /                                    320   000012
00120   48*          DATA IDGT(1),IDGT(2),IDGT(3),IDGT(4),IDGT(5),IDGT(6),IDGT(7),              000012
00120   49*         1 IDGT(8),IDGT(9)/1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1HX /                     000012
00132   50*          IPRINT=6                                                           860   000012
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C0133              X1=X(1,1)                                                  870    000014
00134              X0=X1                                                      880    000016
C0135              DO 130  IX=1,NARGS                                         884    000023
C0140              K2=NRMX(IX)                                                888    000031
C0141              DO  130 I= 1,K2                                            890    000033
00144              IF(X1.LT.X(I,IX))  X1=X(I,IX)                                     000037
00146              IF(X0.GT.X(I,IX))   X0=X(I,IX)                                    000044
C0150        130   CONTINUE                                                   930    000057
C0153              Y1=Y(1,1)                                                  940    000057
00154              Y0=Y1                                                      945    000061
00155        135   DO 150  J=1,NARGS                                          950    000066
00160              K4=NRMY(J)                                                 970    000074
00161        140   DO 150  I= 1,K4                                            1005   000076
00164              IF(Y1.LT.Y(I,J))     Y1=Y(I,J)                                    000102
00166        150   IF(Y0.GT.Y(I,J))    Y0=Y(I,J)                                     000107
00172              WRITE(IPRINT,620)                                          1110   000122
C0172        C**** DETERMINE X AND Y INCREMENTS FOR PLOT                      1115   000122
00174              YDELTA=(YMAX-YMIN)/50.                                     1120   000127
C0175              XDELTA=(XMAX-XMIN)/100.                                    1160   000133
00176              YL   =YMAX-YDELTA/2.                                       1190   000137
C0177              YT=YMAX                                                    1200   000143
00177        C**** THE I LOOP CONTROLS THE 5 DIVISIONS OF THE Y ORDINATE      1300   000143
C0200              DO 350   I=1,6                                             1400   000153
C0203              L=1                                                        1420   000156
00203        C**** THE J LOOP IS FOR EACH LINE OF PRINT WITHIN THE DIVISIONS  1430   000156
C0204              DO 350   J=1,10                                            1440   000166
C0204        C**** BLANK OUT PRINT BUFFER LINE.                               1450   000166
C0207              DO  200 K=1,101                                            1460   000166
00212        200   PRINT(K)=BLANK                                             1480   000166
C0212        C**** THE KK INDEX IS FOR EACH CURVE.   KK LESS THAN 6.          1490   000165
00214              DO 270 KK=1,NARGS                                          1500   000174
C0217              K4=NRMY(KK)                                                1540   000202
00220              K5= 1                                                      1560   000204
00220        C**** THIS DETERMINES IF Y(K) VALUE IS ON THE PRESENT PRINT LINE 1570   000204
00221              DO 260 K= 1,K4                                             1580   000213
00224              IF(Y(K,KK)-YT) 205,205,260                                        000222
C0227        205   IF(Y(K,KK)-YL) 260,260,210                                        000226
00227        C**** YES. Y(K) BELONGS ON THIS PRINT LINE                       1625   000226
00227        C**** THEREFORE DETERMIND  WHERE ALL THE X(K5) FALL ON THE X-AXIS 1630  000226
00232        210   XL=XMIN                                                    1640   000232
00233              XT=XMIN+XDELTA/2.                                          1660   000234
C0234              DO 255 KA=1,101                                            1680   000243
C0237              IF(X(K5,KK)-XL) 250,215,215                                       000243
C0242        215   IF(X(K5,KK)-XT)  220,250,250                                      000247
C0245        220   IF(PRINT(KA)-BLANK)240,230,240                             1740   000253
00250        230   PRINT(KA)=BOOL(KK)                                         1760   000256
00251              GO TO 260                                                  1762   000260
00251        C**** IF MORE THEN ONE POINT FALLS ON THE PRINT POSITION, TALLY THE NO.  1764   000260
C0251        C**** OF POINTS.                                                 1765   000260
00252        240   DO 242 KKK=1,9                                             1766   000264
C0255              IF(PRINT(KA)-IDGT(KKK)) 242,244,242                        1768   000264
C0260        242   CONTINUE                                                   1770   000271
C0262              PRINT(KA)=IDGT(1)                                          1772   000271
C0263              GO TO 260                                                  1774   000273
00264        244   IF(PRINT(KA).NE.IDGT(9)) PRINT(KA)=IDGT(KKK+1)             1776   000275
C0266              GO TO 260                                                  1778   000304
00267        250   XL=XT                                                      1780   000306
00270        255   XT=XT+XDELTA                                               1800   000307
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00272   109*     260 K5=K5+1                                                                     1820   000315
00274   110*     270 CONTINUE                                                                    1830   000325
00276   111*         YT=YL                                                                       1840   000325
00277   112*         YL=YL-YDELTA                                                                1860   000327
00300   113*         GO TO (280,300),L                                                           1880   000331
00301   114*     280 IF(I-5) 285,285,400                                                         1900   000341
00304   115*     285 L=2                                                                         1920   000343
00304   116*   C**** THIS PATH IS EXECUTED ONCE IN EVERY DIVISION OF THE Y-AXIS. EVERY           1925   000343
00304   117*   C**** TENTH LINE, STARTING WITH ZERO LINE                                         1930   000343
00305   118*         YP=YT+YDELTA/2.                                                             1940   000345
00306   119*         WRITE(IPRINT,290) YP,PRINT                                                  1960   000350
00312   120*     290 FORMAT(1X,E12.5,1H+,101A1,1H+)                                              1980   000361
00313   121*         GO TO 350                                                                   2000   000361
00314   122*     300 WRITE(IPRINT,310) PRINT                                                     2020   000363
00314   123*   C**** PRINTS LINE                                                                 2030   000363
00317   124*     310 FORMAT (13X,1H-,101A1,1H-)                                                  2040   000377
00320   125*     350 CONTINUE                                                                    2060   000377
00323   126*     400 WRITE(IPRINT,290) YMIN,PRINT                                                2090   000377
00323   127*   C**** LAST LINE OF PRINT OUT PLUS X VALUES ALONG X-AXIS.                          2090   000377
00327   128*         WRITE(IPRINT,620)                                                           2100   000407
00331   129*         XP(1)=XMIN                                                                  2120   000414
00332   130*         XP(6)=XMAX                                                                  2140   000416
00333   131*         XR=20.*XDELTA                                                               2160   000420
00334   132*         DO 410 I=2,5                                                                2190   000426
00337   133*     410 XP(I)=XP(I-1)+XR                                                            2200   000426
00341   134*         WRITE(IPRINT,420) XP                                                        2210   000431
00344   135*     420 FORMAT(6(7X,E13.5))                                                         2240   000441
00345   136*         RETURN                                                                      2260   000441
00346   137*     620 FORMAT(14X,1H+,10(10H---------+))                                           2390   000520
00347   138*         END                                                                                000520

       END OF COMPILATION:        NO  DIAGNOSTICS.

GFOR,IS  S.0
FOR S0E3-01/25/77-23:19:22 (,0)

   SUBROUTINE PLOTL      ENTRY POINT 000412

   STORAGE USED: CODE(1) 000440; DATA(0) 000515; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NWDU$
    0004   NIO2$
    0005   NERR2$
    0006   NIO3$
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000412 100F     0001   000045 120L     0001   000036 125G     0001   000053 140L     0001   000116 160G
    0001   000062 160L     0001   000126 164G     0001   000131 167G     0001   000144 176G     0001   000070 180L
    0001   000163 211G     0001   000205 240L     0001   000236 245G     0001   000213 250L     0001   000221 260L
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0001     000250 272L      0001     000253 275L      0001     000255 277L      0001     000264 280L      0000     000435 290F
0001     000306 330L      0000     000441 310F      0001     000351 317G      0001     000316 350L      0001     000322 400L
0000     000445 420F      0000 I 000363 BLANK      0000 I 000364 I          0000 I 000401 IFLAG      0000     000456 INJP$
0000 I 000365 IO          0000 I 000405 ITA        0000 I 000216 ITOTAL     0000 I 000377 J          0000 I 000400 K
0000 I 000404 KA          0000 I 000407 KK         0000 I 000376 L          0000 I 000406 LA         0000 I 000205 NUMB
0000 I 000000 PRINT       0000 I 000153 SYM        0000 R 000373 XDELTA     0000 R 000402 XL         0000 R 000371 XMAX
0000 R 000370 XMIN        0000 R 000145 XP         0000 R 000411 XR         0000 R 000403 XT         0000 P 000372 YDELTA
0000 R 000374 YL          0000 R 000367 YMAX       0000 R 000366 YMIN       0000 R 000410 YP         0000 R 000375 YT

00100    C     ELEMENT PLOTL                                                                        000015
00101           SUBROUTINE PLOTL(N,X,Y,IT)                                                    010  000015
00101    C****    PLOTL  FIGURES  OUT LIMITS FOR THE PLOT BASED ON THE DATA.                        000015
00101    C****    DOES NOT CALL A NEW PAGE.                                                         000015
00101    C****                                                                                      000015
00101    C        THREE VECTORS ARE REQUIRED   X,Y,IT   EACH HAVING  N VALUES.                     000015
00101    C                                                                                          000015
00101    C  PLOTS  Y(I)  VERSUS  X(I)  FOR  I=1,2,...,N                                             000015
00101    C                                                                                          000015
00101    C  THE SYMBOL PLOTTED FOR THE  I'TH POINT IS THE LETTER OF THE ALPHABET                    000015
00101    C  CORRESPONDING TO   IT(I).                                                               000015
00101    C                                                                                          000015
00101    C VALUE OF IT(I)  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24          000015
00101    C SYMBOL PLOTTED  A B C D E F G H I  J  K  L  M  N  O  P  Q  R  S  T  U  V  W  X          000015
00101    C                                                                                          000015
00101    C VALUE  (CONTD)  25 26                                                                    000015
00101    C SYMBOL (CONTD)   Y  Z                                                                    000015
00101    C                                                                                          000015
00101    C      ORIGINAL DATA IS PRESERVED  (THIS ROUTINE SEARCHES                                  000015
00101    C      INSTEAD OF SORTING)                                                                 000015
00101    C                                                                                          000015
00101    C      S. PEAVY       PLOT L      10/13/66                                                 000015
00101    C  LAST UPDATED 3/23/69                                                                    000015
00101    C      COMMENTS BY  B.L. JOINER    6/ 5/69                                                 000015
00101    C                                                                                          000015
00103           DIMENSION X(1),Y(1),IT(1),PRINT(101),XP(6),SYM(26)                                  000015
00104           DIMENSION NUMB(9),ITOTAL(101)                                                       000015
00105           INTEGER PRINT,BLANK,SYM                                                             000015
00105    C      DATA STATEMENTS ARE DIFFERENT FOR DIFFERENT MACHINES                                000015
00105    C  THIS IS IBM 7094 AND UNIVAC 1108 VERSION                                                000015
00106           DATA BLANK/1H  /                                                                    000015
00110           DATA (SYM(I),I=1,26)/1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK                    000015
00110        1   ,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ/                      000015
00112           DATA (NUMB(I),I=1,9)/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                           000015
00112    C                                                                                          000015
00112    C      IO = NUMBER OF PRINT TAPE                                                           000015
00114           IO = 6                                                                              000015
00114    C                                                                                          000015
00115           WRITE(IO,100)                                                                       000017
00117       100 FORMAT(14X,101H+---------+---------+---------+---------+---------+                  000024
00117        1---------+---------+---------+---------+---------+ )                                  000024
00117    C      SEARCH FOR MIN AND MAX OF Y AND X                                                   000024
00120           YMIN=Y(1)                                                                           000024
00121           YMAX=Y(1)                                                                           000026
00122           XMIN=X(1)                                                                           000027
00123           XMAX=X(1)                                                                           000031
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00124    47*         DO 180 I=2,N                                    000036
00127    48*         IF(YMIN-Y(I)) 120,120,110                       000036
00132    49*     110 YMIN=Y(I)                                       000041
00133    50*         GO TO 140                                       000043
00134    51*     120 IF(YMAX-Y(I)) 130,140,140                       000045
00137    52*     130 YMAX=Y(I)                                       000050
00140    53*     140 IF(XMIN-X(I)) 160,160,150                       000053
00143    54*     150 XMIN=X(I)                                       000056
00144    55*         GO TO 180                                       000060
00145    56*     160 IF(XMAX-X(I)) 170,180,180                       000062
00150    57*     170 XMAX=X(I)                                       000065
00151    58*     180 CONTINUE                                    98  000072
00153    59*         YDELTA=(YMAX-YMIN)/50.                     100  000072
00154    60*         XDELTA=(XMAX-XMIN)/100.                    110  000076
00155    61*         YL  =YMAX-YDELTA/2.                        120  000102
00156    62*         YT=YMAX                                    130  000106
00157    63*         DO 350  I=1,6                              140  000116
00162    64*         L=1                                        150  000121
00163    65*         DO 350  J=1,10                             160  000131
00166    66*         DO  200 K=1,101                            170  000131
00171    67*         ITOTAL(K)=1                                     000131
00172    68*     200 PRINT(K)=BLANK                             175  000132
00174    69*         IFLAG=0                                         000135
00175    70*         DO 260 K=1,N                               180  000144
00200    71*         IF(Y(K)-YT) 205,205,260                         000144
00203    72*     205 IF(Y(K)-YL) 260,260,210                         000150
00206    73*     210 XL=XMIN                                    200  000154
00207    74*         XT=XMIN+XDELTA/2.                          210  000156
00210    75*         DO 255 KA=1,101                            220  000163
00213    76*         IF(X(K)-XL) 250,215,215                         000163
00216    77*     215 IF(X(K)-XT) 220,250,250                         000167
00221    78*     220 IF (PRINT(KA)-BLANK) 240,230,240                000173
00224    79*     230 ITA=IT(K )                                 245  000176
00225    80*         PRINT(KA)=SYM(ITA)                         250  000201
00226    81*         GO TO 260                                  260  000203
00227    82*     240 ITOTAL(KA)=ITOTAL(KA)+1                         000205
00230    83*         IFLAG=1                                         000207
00231    84*         GO TO 260                                       000211
00232    85*     250 XL=XT                                           000213
00233    86*     255 XT=XT+XDELTA                                    000214
00235    87*     260 CONTINUE                                        000225
00237    88*         YT=YL                                           000225
00240    89*         YL=YL-YDELTA                                    000227
00241    90*         IF (IFLAG) 265,278,265                          000231
00244    91*     265 DO 275 LA=1,101                                 000236
00247    92*         IF (ITOTAL(LA)-1) 268,275,268                   000236
00252    93*     268 KK=ITOTAL(LA)                                   000240
00253    94*         IF (KK-9) 272,272,270                           000242
00256    95*     270 KK=9                                            000245
00257    96*     272 PRINT(LA)=NUMB(KK)                              000250
00260    97*     275 CONTINUE                                        000255
00262    98*     278 GO TO (280,300),L                               000255
00263    99*     280 IF(I-5) 285,285,400                             000264
00266   100*     285 L=2                                        350  000266
00267   101*         YP=YT+YDELTA/2.                            360  000270
00270   102*         WRITE (IO,290) YP,PRINT                    370  000273
00274   103*     290 FORMAT(1X,E12.4,1H+,101A1,1H+)             380  000304
00275   104*         GO TO 350                                  390  000304
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00276    105*      300 WRITE (IO,310) PRINT                                         400     000306
00301    106*      310 FORMAT (13X,1H-,101A1,1H-)                                   410     000322
00302    107*      350 CONTINUE                                                     420     000322
00305    108*      400 WRITE (IO,290) YMIN,PRINT                                    430     000322
00311    109*          WRITE (IO,100)                                               440     000332
00313    110*          XP(1)=XMIN                                                   450     000337
00314    111*          XP(6)=XMAX                                                   460     000341
00315    112*          XR=20.*XDELTA                                                        000343
00316    113*          DO 410 I=2,5                                                 480     000351
00321    114*      410 XP(I)=XP(I-1)+XR                                             490     000351
00323    115*          WRITE (IO,420) XP                                            500     000354
00326    116*      420 FORMAT(6(7X,E13.5))                                          510     000364
00327    117*          RETURN                                                       520     000364
00330    118*          END                                                          530     000437

      END OF COMPILATION:        NO  DIAGNOSTICS.

@FOR,IS  S11
FOR S0E3-01/25/77-23:19:25 (,0)

   SUBROUTINE PLOTLA     ENTRY POINT 000426

   STORAGE USED: CODE(1) 000462; DATA(0) 000515; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NWDU$
    0004   NIO2$
    0005   NEFR2$
    0006   NIO3$
    0007   NEFR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000412 100F     0001   000045 120L     0001   000036 126G     0001   000053 140L     0001   000062 160L
    0001   000132 172G     0001   000142 176G     0001   000070 180L     0001   000101 191L     0001   000107 196L
    0001   000145 201G     0001   000160 210G     0001   000177 223G     0001   000221 240L     0001   000227 250L
    0001   000252 257G     0001   000235 260L     0001   000264 272L     0001   000267 275L     0001   000271 278L
    0001   000300 280L     0000   000435 290F     0001   000322 300L     0000   000441 310F     0001   000365 332G
    0001   000332 350L     0001   000336 400L     0000   000445 420F     0000 I 000363 BLANK    0000 I 000364 I
    0000 I 000401 IFLAG    0000   000456 INJP$    0000 I 000365 IO       0000 I 000405 ITA      0000 I 000205 ITOTAL
    0000 I 000377 J        0000 I 000400 K        0000 I 000404 KA       0000 I 000407 KK       0000 I 000376 L
    0000 I 000406 LA       0000 I 000352 NUMB     0000 I 000000 PRINT    0000 I 000153 SYM      0000 R 000373 XDELTA
    0000 R 000402 XL       0000 R 000371 XMAX     0000 R 000370 XMIN     0000 R 000145 XP       0000 R 000411 XR
    0000 R 000403 XT       0000 R 000372 YDELTA   0000 R 000374 YL       0000 R 000367 YMAX     0000 R 000366 YMIN
    0000 R 000410 YP       0000 R 000375 YT

00100       1*     C    ELEMENT PLOTA                                                      000015
00101       2*          SUBROUTINE PLOTLA(N,X,Y,IT,YMINS,YMAXS)                            000015
00101       3*     C****   PLOTLA FIGURES  OUT LIMITS FOR THE  X-AXIS (ABSCISSA) FROM THE DATA,   000015
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00101    C****          AND USES THE Y-AXIS LIMITS PROVIDED, UNLESS POINTS ARE OUTSIDE      000015
00101    C****          THE SPECIFIED LIMITS IN WHICH CASE THEY ARE STRETCHED TO INCLUDE    000015
00101    C****          ALL POINTS.                                                         000015
00101    C****   DOES NOT CALL A NEW PAGE.                                                  000015
00101    C****                                                                              000015
00101    C        THREE VECTORS ARE REQUIRED   X,Y,IT   EACH HAVING  N VALUES.              000015
00101    C                                                                                  000015
00101    C  PLOTS  Y(I)  VERSUS  X(I)  FOR  I=1,2,...,N                                     000015
00101    C                                                                                  000015
00101    C  THE SYMBOL PLOTTED FOR THE  I'TH POINT IS THE LETTER OF THE ALPHABET            000015
00101    C  CORRESPONDING TO   IT(I).                                                       000015
00101    C****                                                                              000015
00101    C VALUE OF IT(I)  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24   000015
00101    C SYMBOL PLOTTED  A B C D E F G H I  J  K  L  M  N  O  P  Q  R  S  T  U  V  W  X   000015
00101    C                                                                                  000015
00101    C VALUE  (CONTD)  25 26                                                            000015
00101    C SYMBOL (CONTD)   Y  Z                                                            000015
00101    C                                                                                  000015
00101    C     ORIGINAL DATA IS PRESERVED  (THIS ROUTINE SEARCHES                           000015
00101    C     INSTEAD OF SORTING)                                                          000015
00101    C                                                                                  000015
00101    C     WRITTEN BY  S. PEAVY    10/13/66                                             000015
00101    C     ALTERATIONS AND COMMENTS   R.L. LOIMER  10/13/66 AND 6/5/69                  000015
00101    C****                                                                              000015
00103          DIMENSION X(1),Y(1),IT(1),PRINT(101),XP(6)                        020        000015
00104          DIMENSION SYM(26)                                                 030        000015
00105          DIMENSION ITOTAL(101),NUMB(9)                                                000015
00106          INTEGER PRINT,BLANK,SYM                                                      000015
00106    C                                                                                  000015
00106    C     DATA STATEMENTS ARE DIFFERENT FOR DIFFERENT MACHINES                         000015
00106    C  THIS IS IBM 7094 VERSION                                                        000015
00107          DATA BLANK /1H  /                                                            000015
00111          DATA (SYM(I),I=1,26)/1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK             000015
00111         1  ,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ/              000015
00113          DATA (NUMB(I),I=1,9)/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                    000015
00113    C                                                                                  000015
00113    C     IO = NUMBER OF PRINT TAPE                                                    000015
00115          IO=6                                                                         000015
00115    C                                                                                  000015
00116          WRITE(IO,100)                                                                000017
00120     100 FORMAT(14X,101H+---------+---------+---------+---------+---------+            000024
00120         1---------+---------+---------+---------+---------+ )                         000024
00120    C     SEARCH FOR MIN AND MAX OF Y AND X                                            000024
00121          YMIN=Y(1)                                                                    000024
00122          YMAX=Y(1)                                                                    000026
00123          XMIN=X(1)                                                                    000027
00124          XMAX=X(1)                                                                    000031
00125          DO 190 I=2,N                                                                 000036
00130          IF(YMIN-Y(I)) 120,120,110                                                    000036
00133     110 YMIN=Y(I)                                                                     000041
00134          GO TO 140                                                                    000043
00135     120 IF(YMAX-Y(I)) 130,140,140                                                     000045
00140     130 YMAX=Y(I)                                                                     000050
00141     140 IF(XMIN-X(I)) 160,160,150                                                     000053
00144     150 XMIN=X(I)                                                                     000056
00145          GO TO 190                                                                    000060
00146     160 IF(XMAX-X(I)) 170,180,180                                                     000062
00151     170 XMAX=X(I)                                                                     000065
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00152    62*       180 CONTINUE                                                     98   000072
00152    63*     C     FOLLOWING  ONLY  FOR  VERSION    -A-                              000072
00154    64*           IF (YMINS-YMIN) 190,191,191                                       000072
00157    65*      190  YMIN=YMINS                                                        000076
00160    66*      191  IF (YMAXS-YMAX) 196,196,195                                       000101
00163    67*      195  YMAX=YMAXS                                                        000104
00164    68*      196  CONTINUE                                                          000107
00165    69*           YDELTA=(YMAX-YMIN)/50.                                      100   000107
00166    70*           XDELTA=(XMAX-XMIN)/100.                                     110   000112
00167    71*           YL  =YMAX-YDELTA/2.                                         120   000116
00170    72*           YT=YMAX                                                     130   000122
00171    73*           DO 350  I=1,6                                               140   000132
00174    74*           L=1                                                         150   000135
00175    75*           DO 350  J=1,10                                              160   000145
00200    76*           DO  200 K=1,101                                             170   000145
00203    77*           ITOTAL(K)=1                                                       000145
00204    78*       200 PRINT(K)=BLANK                                              175   000146
00206    79*           IFLAG=0                                                           000151
00207    80*           DO 260 K=1,N                                                180   000160
00212    81*           IF(Y(K)-YT) 205,205,260                                           000160
00215    82*       205 IF(Y(K)-YL) 260,260,210                                           000164
00220    83*       210 XL=XMIN                                                     200   000170
00221    84*           XT=XMIN+XDELTA/2.                                           210   000172
00222    85*           DO 255 KA=1,101                                             220   000177
00225    86*           IF(X(K)-XL) 250,215,215                                           000177
00230    87*       215 IF(X(K)-XT) 220,250,250                                           000203
00233    88*       220 IF (PRINT(KA)-BLANK) 240,230,240                                  000207
00236    89*       230 ITA=IT(K )                                              245   000212
00237    90*           PRINT(KA)=SYM(ITA)                                      250   000215
00240    91*           GO TO 260                                               260   000217
00241    92*      240  ITOTAL(KA)=ITOTAL(KA)+1                                       000221
00242    93*           IFLAG=1                                                       000223
00243    94*           GO TO 260                                               280   000225
00244    95*       250 XL=XT                                                   290   000227
00245    96*       255 XT=XT+XDELTA                                            300   000230
00247    97*       260 CONTINUE                                                305   000241
00251    98*           YT=YL                                                   310   000241
00252    99*           YL=YL-YDELTA                                            320   000243
00253   100*           IF (IFLAG) 265,278,265                                        000245
00256   101*      265  DO 275  LA=1,101                                              000252
00261   102*           IF (ITOTAL(LA)-1) 268,275,268                                 000252
00264   103*      268  KK=ITOTAL(LA)                                                 000254
00265   104*           IF (KK-9) 272,272,270                                         000256
00270   105*      270  KK=9                                                          000261
00271   106*      272  PRINT (LA)=NUMB(KK)                                           000264
00272   107*      275  CONTINUE                                                      000271
00274   108*      278  CONTINUE                                                      000271
00275   109*           GO TO (280,300),L                                       330   000271
00276   110*       280 IF(I-5) 285,285,400                                           000300
00301   111*       285 L=2                                                     350   000302
00302   112*           YP=YT+YDELTA/2.                                         360   000304
00303   113*           WRITE (IO,290) YP,PRINT                                 370   000307
00307   114*       290 FORMAT(1X,E12.4,1H+,101A1,1H+)                          380   000320
00310   115*           GO TO 350                                               390   000320
00311   116*       300 WRITE (IO,310) PRINT                                    400   000322
00314   117*       310 FORMAT (13X,1H-,101A1,1H-)                              410   000336
00315   118*       350 CONTINUE                                                420   000336
00320   119*       400 WRITE (IO,290) YMIN,PRINT                               430   000336
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00324      120*          WRITE (IO,100)                                    440     000346
00326      121*          XP(1)=XMIN                                        450     000353
00327      122*          XP(6)=YMAX                                        460     000355
00330      123*          XR=20.*XDELTA                                             000357
00331      124*          DO 410 I=2,5                                      480     000365
00334      125*      410 XP(I)=XP(I-1)+XR                                  490     000365
00336      126*          WRITE (IO,420) XP                                 500     000370
00341      127*      420 FORMAT(6(7X,E13.5))                               510     000400
00342      128*          RETURN                                            520     000400
00343      129*          END                                               530     000461

     END OF COMPILATION:       NO  DIAGNOSTICS.

@FOR,IS  S12
FOR S0E3-01/25/77-23:19:28 (,0)

   SUBROUTINE PLOTLF    ENTRY POINT 000410

   STORAGE USED: CODE(1) 000446; DATA(0) 000536; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NWDU$
    0004   NIO2$
    0005   NERR2$
    0006   NIO3$
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000411 100F     0001   000073 109L     0001   000076 110L     0001   000053 132G     0001   000103 154G
    0001   000113 160G     0001   000116 163G     0001   000131 172G     0001   000150 205G     0001   000172 240L
    0001   000223 241G     0001   000200 250L     0001   000206 260L     0001   000235 272L     0001   000240 275L
    0001   000242 278L     0001   000251 280L     0001   000434 290F     0001   000273 300L     0000   000440 310F
    0001   000336 314G     0001   000303 350L     0001   000307 400L     0000   000444 420F     0000   000447 550F
    0001   000363 600L     0000 I 000363 BLANK    0000 I 000364 I        0000 I 000401 IFLAG    0000   000473 INJP$
    0000 I 000365 IO       0000 I 000375 IOUT     0000 I 000404 ITA      0000 I 000205 ITOTAL   0000 I 000377 J
    0000 I 000400 K        0000 I 000403 KA       0000 I 000406 KK       0000 I 000376 L        0000 I 000405 LA
    0000 I 000352 NUMB     0000 I 000000 PRINT    0000 I 000153 SYM      0000 R 000367 XDELTA   0000 R 000374 XHIGH
    0000 R 000373 XL       0000 R 000145 XP       0000 R 000410 XP       0000 R 000402 XT       0000 R 000366 YDELTA
    0000 R 000370 YL       0000 R 000372 YLOW     0000 R 000407 YP       0000 R 000371 YT


00100        1*     C   ELEMENT PLOTLF                                                          000002
00101        2*          SUBROUTINE PLOTLF (N,X,Y,IT,XMIN,XMAX,YMIN,YMAX)                010    000002
00101        3*     C****   PLOTLF OMITS ANY POINTS OUTSIDE THE USER SPECIFIED LIMITS XMIN,XMAX,ETC.  000002
00101        4*     C****           A COUNT OF THE NUMER OMITTED IS GIVEN.                     000002
00101        5*     C****   DOES NOT CALL A NEW PAGE.                                           000002
00101        6*     C       THREE VECTORS ARE REQUIRED   X,Y,IT   EACH HAVING  N VALUES.        000002
00101        7*     C                                                                           000002
00101        8*     C  PLOTS  Y(I)  VERSUS  X(I)  FOR  I=1,2,...,N                              000002
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00101    C                                                                          000002
00101    C  THE SYMBOL PLOTTED FOR THE  I'TH POINT IS THE LETTER OF THE ALPHABET    000002
00101    C  CORRESPONDING TO   IT(I).                                               000002
00101    C****                                                                      000002
00101    C VALUE OF IT(I)  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24   000002
00101    C SYMBOL PLOTTED  A B C D E F G H I  J  K  L  M  N  O  P  Q  R  S  T  U  V  W  X   000002
00101    C                                                                          000002
00101    C VALUE  (CONTD)  25 26                                                    000002
00101    C SYMBOL (CONTD)   Y  Z                                                    000002
00101    C                                                                          000002
00101    C BY C. MESSINA,S.PEAVY,AND B.JOINER      NATIONAL BUREAU OF STANDARDS     000002
00101    C LAST UPDATED 1/30/67                                                     000002
00101    C      ORIGINAL DATA IS PRESERVED  (THIS ROUTINE SEARCHES                  000002
00101    C      INSTEAD OF SORTING)                                                 000002
00103           DIMENSION X(1),Y(1),IT(1),PRINT(101),XP(6)                   020    000002
00104           DIMENSION SYM(26)                                            030    000002
00105           DIMENSION ITOTAL(101),NUMB(9)                                       000002
00106           INTEGER PRINT,BLANK,SYM                                             000002
00106    C                                                                          000002
00106    C      DATA STATEMENTS ARE DIFFERENT FOR DIFFERENT MACHINES                000002
00106    C  THIS IS IBM 7094 AND UNIVAC 1108 VERSION                                000002
00107           DATA BLANK/1H  /                                                    000002
00111           DATA (SYM(I),I=1,26)/1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK    000002
00111          1  ,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ/     000002
00113           DATA (NUMB(I),I=1,9)/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/           000002
00113    C                                                                          000002
00113    C      IO = NUMBER OF PRINT TAPE                                           000002
00115           IO=6                                                                000002
00115    C                                                                          000002
00116           WRITE(IO,100)                                                       000004
00120     100 FORMAT(14X,101H+---------+---------+---------+---------+---------+    000011
00120          1---------+---------+---------+---------+---------+ )                000011
00121           YDELTA=(YMAX-YMIN)/50.                                       100    000011
00122           XDELTA=(XMAX-XMIN)/100.                                      110    000015
00123           YL  =YMAX-YDELTA/2.                                          120    000021
00124           YT=YMAX+ YDELTA/2.                                           130    000025
00125           YLOW=YMIN-YDELTA/2.                                                 000030
00126           XL=XMIN-XDELTA/2.                                                   000033
00127           XHIGH=XMAX+XDELTA/2.                                                000037
00130           IOUT=0                                                              000044
00131           DO 110 I=1,N                                                        000053
00134           IF(Y(I)-YT) 101,101,109                                             000053
00137     101 IF(Y(I)-YLOW) 109,109,102                                             000056
00142     102 IF(X(I)-YL) 109,103,103                                               000062
00145     103 IF(X(I)-XHIGH) 110,109,109                                            000066
00150     109 IOUT=IOUT+1                                                           000073
00151     110 CONTINUE                                                              000103
00153           DO 350  I=1,6                                                140    000103
00156           L=1                                                          150    000106
00157           DO 350  J=1,10                                               160    000116
00162           DO  200 K=1,101                                              170    000116
00165           ITOTAL(K)=1                                                         000116
00166     200 PRINT(K)=BLANK                                                 175    000117
00170           IFLAG=0                                                             000122
00171           DO 260 K=1,N                                                 180    000131
00174           IF(Y(K)-YT) 205,205,260                                             000131
00177     205 IF(Y(K)-YL) 260,260,210                                               000135
00202     210 XL=XMIN-XDELTA/2.                                              200    000141
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00203     67*           XT=XMIN+XDELTA/2.                                                 210    000143
00204     68*           DO 255 KA=1,101                                                   220    000150
00207     69*           IF(X(K)-XL) 250,215,215                                                  000150
00212     70*       215 IF(X(K)-XT) 220,250,250                                                  000154
00215     71*       220 IF (PRINT(KA)-BLANK) 240,230,240                                         000160
00220     72*       230 ITA=IT(K )                                                        245    000163
00221     73*           PRINT(KA)=SYM(ITA)                                                250    000166
00222     74*           GO TO 260                                                         260    000170
00223     75*      240  ITOTAL(KA)=ITOTAL(KA)+1                                                  000172
00224     76*           IFLAG=1                                                                  000174
00225     77*           GO TO 260                                                         280    000176
00226     78*       250 XL=XT                                                             290    000200
00227     79*       255 XT=XT+YDELTA                                                      300    000201
00231     80*       260 CONTINUE                                                          305    000212
00233     81*           YT=YL                                                             310    000212
00234     82*           YL=YL-YDELTA                                                      320    000214
00235     83*           IF (IFLAG) 265,278,265                                                   000216
00240     84*      265  DO 275  LA=1,101                                                         000223
00243     85*           IF (ITOTAL(LA)-1) 268,275,268                                            000223
00246     86*      268  KK=ITOTAL(LA)                                                            000225
00247     87*           IF (KK-9) 272,272,270                                                    000227
00252     88*      270  KK=9                                                                     000232
00253     89*      272  PRINT (LA)=NUMB(KK)                                                      000235
00254     90*      275  CONTINUE                                                                 000242
00256     91*      278  CONTINUE                                                                 000242
00257     92*           GO TO (280,300),L                                                 330    000242
00260     93*       280 IF(I-5) 285,285,400                                                      000251
00263     94*       285 L=2                                                               350    000253
00264     95*           YP=YT+YDELTA/2.                                                   360    000255
00265     96*           WRITE (IO,290) YP,PRINT                                           370    000260
00271     97*       290 FORMAT(1X,E12.4,1H+,101A1,1H+)                                    380    000271
00272     98*           GO TO 350                                                         390    000271
00273     99*       300 WRITE (IO,310) PRINT                                              400    000273
00276    100*       310 FORMAT (13X,1H-,101A1,1H-)                                        410    000307
00277    101*       350 CONTINUE                                                          420    000307
00302    102*       400 WRITE (IO,290) YMIN,PRINT                                         430    000307
00306    103*           WRITE (IO,100)                                                    440    000317
00310    104*           XP(1)=XMIN                                                        450    000324
00311    105*           XP(6)=XMAX                                                        460    000326
00312    106*           XR=20.*XDELTA                                                            000330
00313    107*           DO 410 I=2,5                                                      480    000336
00316    108*       410 XP(I)=XP(I-1)+XR                                                  490    000336
00320    109*           WRITE (IO,420) XP                                                 500    000341
00323    110*       420 FORMAT(6(7X,F13.5))                                               510    000351
00324    111*           IF(IOUT) 600,600,500                                                     000351
00327    112*       500 WRITE (IO,550) IOUT                                                      000354
00332    113*       550 FORMAT (/20X,9H**NOTE.  I4,60H POINTS FELL OUTSIDE THE SPECIFIED L       000363
00332    114*          1IMITS AND WERE OMITTED.  )                                               000363
00333    115*       600 CONTINUE                                                                 000363
00334    116*           RETURN                                                            520    000363
00335    117*           END                                                               530    000445

      END OF COMPILATION:       NO  DIAGNOSTICS.

@FOR,IS  S13
FOR S0L3-01/25/77-23:19:31 (,0)
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SUBROUTINE PLOT        ENTRY POINT 000337

STORAGE USED: CODE(1) 000361; DATA(0) 000277; BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

 0003   NWDU$
 0004   NIO2$
 0005   NIO3$
 0006   NERR3$

STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

 0000   000177 100F      0001   000045 120L      0001   000036 121G      0001   000053 140L      0001   000116 154G
 0001   000125 160G      0001   000062 160L      0001   000130 163G      0001   000137 170G      0001   000070 180L
 0001   000156 203G      0001   000172 250L      0001   000200 260L      0001   000300 263G      0000   000222 290F
 0001   000235 300L      0000   000226 310F      0001   000245 350L      0001   000251 400L      0000   000232 420F
 0000 I 000162 I         0000   000243 INJP$     0000 I 000155 IOUT      0000 I 000002 IPRINT    0000 I 000000 ISYMB
 0000 I 000001 ISYMO     0000 I 000170 J         0000 I 000171 K         0000 I 000174 KA        0000 I 000167 L
 0000 R 000164 XDELTA    0000 R 000172 XL        0000 R 000161 XMAX      0000 R 000160 XMIN      0000 R 000147 XP
 0000 R 000176 XR        0000 R 000173 XT        0000 R 000163 YDELTA    0000 R 000165 YL        0000 R 000157 YMAX
 0000 R 000156 YMIN      0000 R 000175 YP        0000 R 000166 YT


 00100      1*     C   ELEMENT PLOT                                                                  000015
 00101      2*           SUBROUTINE PLOT(N,X,Y)                                                      000015
 00101      3*     C  PLOTS  Y(I) VERSUS  X(I)  FOR  I=1,2,...,N                                     000015
 00101      4*     C     TWO VECTORS ARE REQUIRED  X AND Y, EACH HAVING  N  VALUES.                  000015
 00101      5*     C THE VECTORS X AND Y ARE NOT MODIFIED IN ANY MANNER.                             000015
 00101      6*     C****   DOES NOT CALL A NEW PAGE.                                                 000015
 00101      7*     C****                                                                             000015
 00101      8*     C                                                                                 000015
 00101      9*     C C.MESSINA,S.PEAVY,B.L.JOINER                                                    000015
 00101     10*     C                                                                                 000015
 00101     11*     C HOPEFULLY THIS SUBROUTINE IS ALMOST UNIVERSALLY MACHINE COMPATIBL .             000015
 00101     12*     C FOR FORTRAN IV COMPILERS,  EXCEPT FOR DATA STATEMENT.                           000015
 00101     13*     C                                                                                 000015
 00103     14*           DATA ISYMB /1H   /                                                          000015
 00105     15*           DATA ISYMO /1H* /                                                           000015
 00105     16*     C                                                                                 000015
 00107     17*           DIMENSION  X(1),Y(1),IPRINT(101),XP(6)                                      000015
 00107     18*     C                                                                                 000015
 00107     19*     C  IOUT=NUMBER OF PRINT TAPE                                                      000015
 00110     20*           IOUT=6                                                                      000015
 00111     21*           WRITE (IOUT,100)                                                            000017
 00113     22*       100 FORMAT(14X,101H+---------+---------+---------+---------+---------+----- ---+   000024
 00113     23*          1---------+---------+---------+---------+---------+ )                      000024
 00113     24*     C    SEARCH FOR MIN AND MAX ON Y AND Y                                            000024
 00114     25*          YMIN=Y(1)                                                                    000024
 00115     26*          YMAX=Y(1)                                                                    000026
 00116     27*          XMIN=X(1)                                                                    000027
 00117     28*          XMAX=X(1)                                                                    000031
 00120     29*          DO 180 I=2,N                                                                 000036
```

```
00123             IF(YMIN-Y(I)) 120,120,110                                  000036
00126         110 YMIN=Y(I)                                                  000041
00127             GO TO 140                                                  000043
00130         120 IF(YMAX-Y(I)) 130,140,140                                  000045
00133         130 YMAX=Y(I)                                                  000050
00134         140 IF(XMIN-X(I)) 160,160,150                                  000053
00137         150 XMIN=X(I)                                                  000056
00140             GO TO 180                                                  000060
00141         160 IF(XMAX-X(I)) 170,180,180                                  000062
00144         170 XMAX=X(I)                                                  000065
00145         180 CONTINUE                                         98        000072
00147             YDELTA=(YMAX-YMIN)/50.                           100       000072
00150             XDELTA=(XMAX-XMIN)/100.                          110       000076
00151             YL  =YMAX-YDELTA/2.                              120       000102
00152             YT=YMAX                                          130       000106
00153             DO 350  I=1,6                                    140       000116
00156             L=0                                                        000121
00157             DO 350  J=1,10                                   160       000130
00162             DO  200 K=1,101                                  170       000130
00165         200 IPRINT(K)=ISYMB                                            000130
00167             DO 260 K=1,N                                     180       000137
00172             IF(Y(K)-YT) 205,205,260                                    000137
00175         205 IF(Y(K)-YL) 260,260,210                                    000143
00200         210 XL=XMIN                                                    000147
00201             XT=XMIN+XDELTA/2.                                210       000151
00202             DO 255 KA=1,101                                  220       000156
00205             IF(X(K)-XL) 250,215,215                                    000156
00210         215 IF(X(K)-XT) 220,250,250                                    000162
00213         220 IPRINT(KA)=ISYMO                                           000166
00214             GO TO 260                                                  000170
00215         250 XL=XT                                            290       000172
00216         255 XT=XT+XDELTA                                     300       000173
00220         260 CONTINUE                                         305       000203
00222             YT=YL                                            310       000203
00223             YL=YL-YDELTA                                     320       000205
00224             IF(L) 280,280,300                                          000207
00227         280 IF(I-5) 285,285,400                                        000212
00232         285 L=1                                                        000215
00233             YP=YT+YDELTA/2.                                  360       000217
00234             WRITE (IOUT,290) YP,IPRINT                                 000222
00240         290 FORMAT(1X,E12.4,1H+,101A1,1H+)                   380       000233
00241             GO TO 350                                        390       000233
00242         300 WRITE (IOUT,310) IPRINT                                    000235
00245         310 FORMAT (13X,1H-,101A1,1H-)                       410       000251
00246         350 CONTINUE                                         420       000251
00251         400 WRITE (IOUT,290) YMIN,IPRINT                               000251
00255             WRITE (IOUT,100)                                           000261
00257             XP(1)=XMIN                                       450       000266
00260             XP(6)=XMAX                                       460       000270
00261             XR=20.*XDELTA                                              000272
00262             DO 410 I=2,5                                     480       000300
00265         410 XP(I)=XP(I-1)+XR                                 490       000300
00267             WRITE(IOUT,420) XP                                         000303
00272         420 FORMAT(6(7X,E13.5))                              510       000313
00273             RETURN                                           520       000313
00274             END                                              530       000360
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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A general one-dimensional transient heat and mass transfer numerical program has been developed for composite building constructions. Since typical building constructions consist of a series of composite layers and intermediate air layers transient heat transfer is modeled by conduction through solids and by radiation and convection through air spaces. In addition the program has built-in features for ease of application to building constructions where various combinations of solid-to-solid and solid-to-air interfaces are encountered. The complete Fortran language program as used on the NBS Univac 1108 computer is given. A discussion of the program and instruction for its use are facilitated by the aid of examples. Numerical solutions using the present program compare favorably with experimental data in standard fire endurance tests.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Composite building constructions; convection; experimental data; fire endurance; heat generation or absorption; numerical solutions; radiation; one-dimensional; thermal conduction; transient heat transfer.

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