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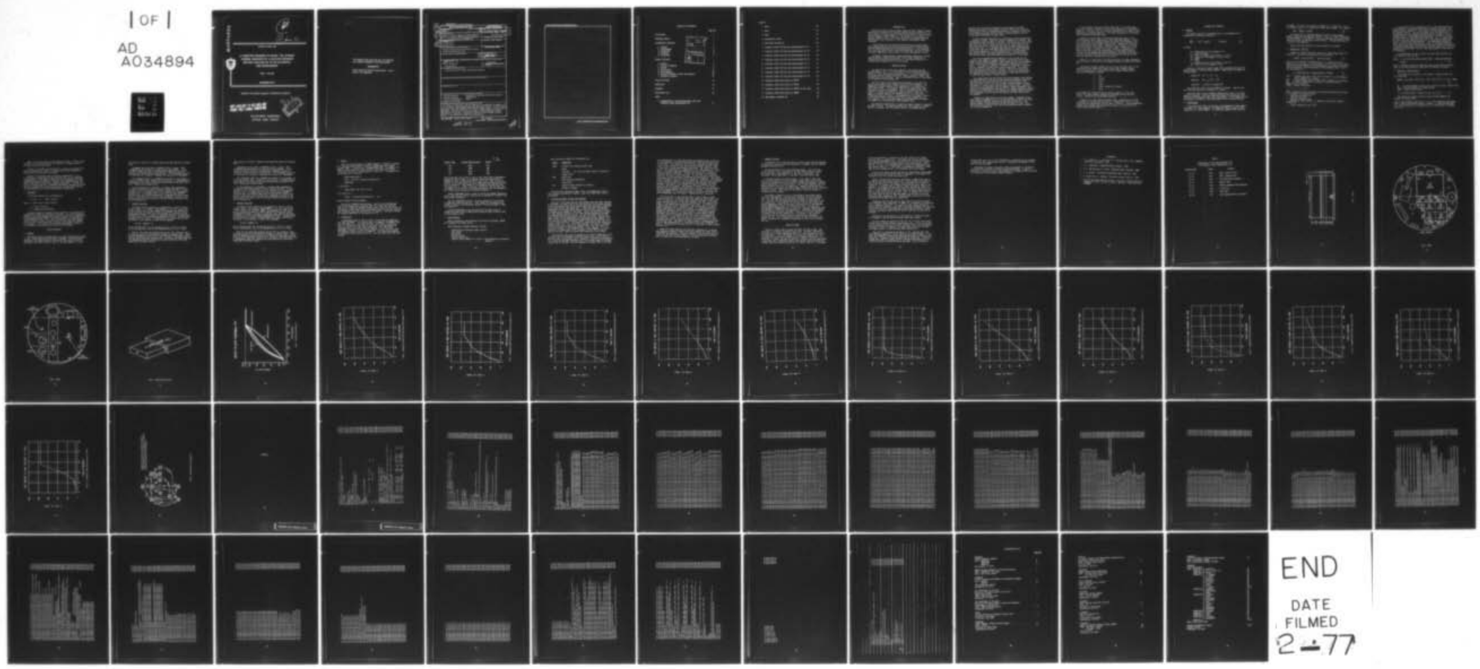

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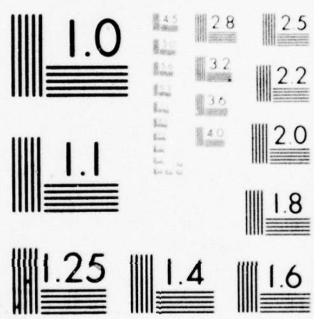

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TECHNICAL REPORT 5015

A COMPUTER PROGRAM TO MODEL THE DYNAMIC THERMAL BEHAVIOR OF A NUCLEAR WARHEAD SECTION ADAPTION KIT IN AN ACCIDENTAL FIRE ENVIRONMENT

FRED A. MULLER

DECEMBER 1976

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PICATINNY ARSENAL
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A method for modeling the thermal behavior of a warhead section adaption kit in an accidental fire environment has been described in detail. A Control Data Corporation Model 6600 computer operating under SCOPE version 3.4.2 and utilizing the dynamic simulator called CSSL 3 is used. The model permits study of the temperature versus time of a few points within a three-dimensional system. The effects of radiation, conduction and convection are included, as well as changes in heat paths due to melting of some parts.

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INTRODUCTION

Picatinny Arsenal Technical Report #4831 entitled "Dynamic Thermal Modeling of the Behavior of a Nuclear Warhead Section Adaption Kit in an Accidental Fire Environment" treated the problem of a safety analysis based on dynamic thermal modeling. The purpose of this report is to provide potential users with a description of the thermal modeling method itself and the details of the computer programming method developed.

It was pointed out in Picatinny Arsenal Technical Report #4831 that unknown effective emissivities and convective film coefficients would be determined empirically by performing one or a few simulated fire tests run under closely controlled conditions, and then fitting the model temperatures versus time to the test thermocouple results.

The general lumped-constant (lumped-parameter) method for solving complex dynamic engineering problems is well known (Reference 1). The method of analysis developed here for the thermal behavior of a warhead section adaption kit is of this type.

MODELING METHOD

The specific device which was modeled is the Spartan Warhead Section Adaption Kit. It is comprised of some 26 different types of mechanical parts and electrical components. It is three-dimensional, involving several different materials, complex geometric shapes, and multipath heat flow patterns. Time is an essential part of the problem so the model must be a dynamic one.

The first step in the lumped-constant method is to divide the device to be modeled into a number of pieces called elements. The temperature of each element is the temperature of a single point within the element. In the model, there are no temperatures other than that of each of the elements. Heat is transferred from one element to another by conduction, radiation and/or convection. The model is a network made of the elemental points with heat paths between some pairs of points. The temperature of an element rises at a rate which depends on the net heat flow to that element and its heat capacity. All of the heat capacity associated with an element is assumed to be concentrated at the elemental point.

The simulation modeled here is based on a mental image of a possible accident scenario. If, before attaching the first stage to a Spartan missile, an organic fuel fire were to start, the Warhead Section

Adaption Kit cover could be exposed to the flames but its base, being mounted against the warhead, would not. Under worst case conditions such a fire is considered equivalent to exposure of the cover to an 1850° F black body source of heat. Average organic fire conditions would correspond to about 1450° F.

In this situation the cover will quickly heat up and radiate heat to components inside. There will also be conduction to the base and through the upright brackets to the deck. Convection will also convey heat from the cover to cooler surfaces inside. Dense smoke will be generated when plastic insulation and paint overheats and this may affect heat flow. It is expected that some of the aluminum and magnesium parts may melt since their melting points are well below the heat source temperature. If the exposed part of the deck melts, a new radiation path is created through the hole to the base below. Each of the effects described above was accounted for in the model.

The Spartan Warhead Section Adaption Kit was divided into 74 elements. (The number of elements chosen is arbitrary, but a large number becomes unwieldy whereas a small number may not include enough detail to accurately distinguish temperatures between the crucial points. The number of elements is limited by the number of representation statements required, which cannot exceed 685. The program described here has about 600.) The way in which the division was done was dictated by the results desired. In the case treated here, the temperature versus time was required for eight critical points in order to study several "thermal races".

In a region where two such points are close together, the division has been made fairly fine while other regions are coarsely sectioned. The propellant activated battery has two critical points, a gas generator which turns it on, and a thermal release connector which disconnects it electrically from the rest of the circuit. (Actually, there are two gas generators and two thermal release connectors, but attention is concentrated on the set which is known to be most critical.) Because of the importance of the thermal race between these two points and the geometry in this region, the battery has been divided into 27 elements.

Elements are identified by a two digit number. Elements of the base plate are numbered 01 to 45, of the deck plate 50 to 64, uprights (which support the deck plate on the base plate) 80 to 89. The warhead thermal release connector 90 and the cover 97 to 99. The shroud which was used as a heat source surrounding the whole adaption kit is called element SH.

In the computer program to be described TC22 is a variable name, the value of which at any given time is the temperature of thermocouple number 22. Similarly, T56 is a variable name the value of which is the temperature of element number 56. All other thermocouples and elements have corresponding variable names.

Figures 1, 2 and 3 show in outline the important parts of the Spartan Warhead Section Adaption Kit which have been modeled. Figure 1 is a side view of a section through the center of the adaption kit. The cover and its three elements can be seen. Element 99 is the part of the cover below the flange. Element 98 is that part of the cover above the flange to the level of the deck plate. Element 97 is the rest of the cover. Elements 98 and 99, instead of representing a point within the cover, are represented by a line going around the cylinder halfway between the top and bottom of that part of the cover. Figure 1 also shows the base plate at the bottom and the deck plate part way between it and the top of the cover.

Figure 2 is a plan view of the base plate with its major components. The base plate is divided into 12 elements numbered as shown (01 through 12).

The battery (element numbers 19-45) occupies the major part of the lower half of the figure and a Burst Delay Timer (element numbers 13-18) the upper part. The prefixes to the element numbers (used only on the diagram) designate:

T - Top

B - Bottom

U - Upper

L - Lower

M - Match (Propellant Element)

S - Side

The elements 80 through 89 are the upright supports for the deck plate. The outer supports (80-86) are fastened to the cover with screws. Element 90 is the warhead connector.

Figure 3 is a plan view of the deck plate. Mounted on it are the IC Box and two arm-safe devices (ASD's). Element 56 is ASD Nr. 1 and corresponds to thermocouple TC22 as shown in Figure 3. The correspondence between other elements and thermocouple numbers in the heat test is given in the table on page 17.

MATHEMATICAL APPROACH

1. General.

The dynamic simulation implemented here is represented by 74 simultaneous differential equations:

$$\frac{dTn}{dt} = 10^{-9} \; QnFn/Vn \qquad {}^{\circ}F/second \qquad (1)$$

in which:

Tn = temperature of n'th element in °F
t = time in seconds
Qn = heat flux toward n'th element in erg/sec
Vn = volume of n'th element in cubic inches
$Fn = \frac{2.63}{C_n D_n}$
Cn = specific heat of n'th element in Cal/g/°C
Dn = density of n'th element in g/cc

Each Qn is the sum of several terms which represent the heat flux toward element n from each other element. These heat flux terms are of three types:

conduction $QC = f_1 (T_1 - T_n)$

radiation $QR = f_2 (T_1^4 - T_n^4)$

convection (similar to conduction)

The conduction terms involve elements in contact. There is one such term for each pair of elements in contact.

Radiation terms involve elements between which there is a direct path for radiation. The only significant ones involve one very hot element and appreciable areas facing one another. Since these criteria also apply to convection, the same element pairs are used for both.

2. Terminology.

The rate of heat flow (in erg/sec) is designated Q in this report. This heat flux from element 01 to element 02, when it results from conduction, is called QC0102. For radiation from 99 to 01, the flux is QR9901. The total flux toward an element 01 is called Q01. It is the algebraic sum of all terms which involve that element. For example:

$$Q01 = QR9901 - QC0102 \quad (2)$$

The second term is negative because the order of the element numbers indicates heat flow away frcm 01. (Eq. (2), which illustrates the terminology, is incomplete. The actual expression includes 12 more conduction terms and two more radiation terms. The complete equation is given in the Appendix.)

There is one such equation for each element of the model.

3. Conduction - (Ref 2).

Elements in contact have heat conduction terms between them (See Figure 4). The heat flux expression is of the form:

QC0102 = KC*(T01-T02)/R (See Note below) (3)

where R is the thermal resistance and KC is a constant for unit conversion (1.411 here). The resistance R in (3) is the sum of three terms, that within element 01 to the boundary, the contact resistance and that within 02 from the boundary to the elemental point. This can be expressed as:

R = D01B/(K01*A01) + D02B/(K02*A02) + R0102C (4)

D01B = Distance heat must travel within element 01 to the boundary within element 01 in inches
A01 = Cross-sectional area for heat flow in element 01 (Sq inches)
K01 = Thermal conductivity of element 01 (erg/cm-sec-deg C)
D02B, A02, K02 similarly
R0102C = Contact resistance

NOTE: Equations in this text and in the computer program are written in the format of Fortran in which:
* signifies multiplication
/ signifies division
** signifies exponentiation
parentheses (multi-nested, if necessary) are used to resolve ambiguities.
3.48E-5 stands for 3.48×10^{-5}

In cases where the two elements are part of the same material, or welded together, the contact resistance is assumed to be zero. The distance within element 01 is the distance from the defined point to the boundary with 02. The cross-sectional area for conduction is an estimated average area between the point and the boundary. For an element which is a rectangular parallelopiped, it is the full cross-sectional normal to the direction of heat flow. This is justified on the basis that the conductive heat flow is not toward the point but rather is practically one dimensional. The temperature gradient is nearly uniform for the whole region. Since all the heat conduction paths (except the three to the battery explosive actuator) are metallic, it becomes evident when analyzing the actual test data that all of the gradients are quite small so the linear approximation is believed to be reasonable.

If we substitute (4) into (3) and use width times thickness for cross-sectional area, we get:

QC0102 = 1.411*(T01-T02)/(D01B/(K01*W01*TH01) + D02B/(K02*W02*TH02) + R0102c) (5)

which is another of the basic equations used in the computer program. There is one such equation for each pair of elements in contact.

4. Radiation - (Ref 3 and 4).

In the terms we are using in this analysis, radiative heat flow is of the form:

QR9901 = KR * ((T99 + 459.7)**4 - (T01 + 459.7)**4) * G * A01 * V9901 (6)

KR = Stefan-Boltzmann constant and a factor for units (3.48E-5 Here)
A01 = Area of element 01 in square inches
V9901 = Effective view factor

G = 1/(1/E01+1/E99-1) (See Ref 4, P74, Eq. (4.7)) (7)

E01 and E99 are effective emissivities and both elements are assumed to be gray bodies.

G has a value between zero and one. It is like a composite emissivity. (Ref 3, P76, Eq at bottom of page is similar. In this case one body is a total enclosure so its emissivity is 1 in which case (7) reduces to G = E).

V9901 is the view factor or configuration factor. It has a value between 0 and 1 which represents the fraction of element 99 which is "seen" by 01 and vice versa.

Equation (7) assumes the absorptivity is equal to the emissivity and all reflection is diffuse. It takes into account radiation, absorption, reflection and reradiation.

Because of the fourth power of absolute temperatures, it is evident that the magnitude of radiative heat flux is very dependent on temperature. Only terms of which one of the elements is at high temperature need be considered. The only ones considered here are those in which one of the cover elements is included. By the time any other element reaches a comparable temperature, some melting occurs. The most exposed areas inside the cover are the deck plate and the IC Box, which melt at 1110 and 1150 degrees, respectively.

5. Convection.

The convective heat flux is expressed as:

$$Q = hA \quad \Delta t \qquad \text{(Ref 5, page 3)} \qquad (8)$$

where h = coefficient of heat transfer

A = Area of Surface

Δt = Temperature Difference

The whole subject of convective heat transfer is very complex and quantitative results are difficult to compute. But for the present purpose, it has been assumed that convective heat flux is proportional to the temperature difference with the constant of proportionality determined empirically. It is also assumed that only those element pairs involved in radiative heat flow may also include the effects of convection. This simplifies the coding considerably, without, it is believed, detracting from the utility of the program.

SYSTEM SIMULATOR

1. General.

The digital computer program used as a system simulator was written in CSSL 3 (Continuous System Simulator Language). A detailed understanding of the program requires familiarity with CSSL 3, which is described in the User's Manual, (Ref 6), and with FORTRAN. A brief description of the CSSL 3 features which have been used will be given here.

Statements may be either in FORTRAN or CSSL 3 syntax. Most statements may be placed in any order within the program. A sort routine arranges the order of replacement statements so that all variables are defined before they are used. The programmer can force a fixed order for a group of statements by the use of a PROCEDURAL.

All statements (CSSL 3 or FORTRAN) are written in free format in which any column, from 1 through 72, may be used. A statement may be continued onto the next line by three periods before the end of the line. Blanks may be added freely.

At the beginning of a statement, a variable name (alphameric) followed by one period denotes a logical control variable. If that variable is true at execution time, the statement will be executed; otherwise not. A statement which starts with the word CONSTANT indicates that the variable names which follow have the value given which is invariable with time (the only independent variable in the program) but which may be given a different value at execution time for a different run.

2. Tabular Functions.

A function may be inputted to the program as a series of points called a TABLE. For example, TABLE SHROUD, 1, 14, etc., means that a Table function has the name SHROUD, one dependent variable and 14 pairs of values (14 points) in which the next 14 values are of the independent variable in order of increasing value and the remaining 14 values are of the corresponding dependent variable. Interpolations between points are linear. Extrapolations are linear from the last two points. This function is used in the statement:

```
NX.TSH = SHROUD  (T)
```

which indicates that, for the present value of T, TSH is to be set to the corresponding value of the SHROUD function (if NX is TRUE).

Data for this table was obtained during the fire simulation test by digitally recording thermocouple voltages on computer tape. Tabular function SHROUD was used as the driving function of temperature versus time for the differential equation set. Similarly, the eight other sets of thermocouple data were inputted as table functions to facilitate comparisons with model results.

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3. Macros.

CSSL 3 allows the usage of a MACRO function. A MACRO is created by a statement MACRO MACRO followed by a MACRO name and a dummy variable name. It ends with a statement MACRO END. In between, the MACRO is defined with the dummy variable subscripted with digits indicating the order of the parameters in the call. An example from our program will illustrate.

```
MACRO MACRO COND Q
Q(1) = 1.411E+7 * (Q(2)-Q(3))/(Q(4) etc
MACRO END
```

if called by -

```
COND QC0102, T01, T02, 4.9 etc.
```

will result in -

```
QC102 = 1.411E+7*(T01-T02)/(4.9,··· etc
```

being inserted into the program.

Three CSSl 3 MACRO's were written. The first called COND and used in the example above produces heat flux values at each time step due to conduction between elements pairs using the form of Eq. (5). The second, called, RAD, similarly produces heat flux due to radiation and convection using the form of Eqs. (6) and (8). The third, called DT, produces equations of the form of Eq. (1).

4. Procedurals.

A PROCEDURAL BLOCK is used to force a fixed order of execution for some statements. This begins with, for example, PROCEDURAL (M52, M58, M19, M56,) etc., and ends with END. This block is sorted so that all variables to the right of the equal sign come before the block and those to the left come afterwards. This particular PROCEDURAL simulates the melting of elements 52, 58, 19 and 56 (see the complete program listing in Appendix). For these four elements, in addition to the variables T52, etc., two more were set up for each element.

Element Temp	Element Melting Point	Melted 0 = no 1 = yes
T52	MP52	M52
T58	MP58	M58
T19	MP19	M19
T56	MP56	M56

Each M-variable such as M52 is set to zero unless the corresponding temperature T52 is equal to or greater than the melting point of element 52, MP52 in which case M52 is set to one. M52 is used as a multiplier for terms which are to be added when melting has occurred, such as radiation from element 97 to element 01 through the void. The expression (1. - M52) is used as a multiplier for the heat flux to element 52 and also for each other term which should be dropped at this time such as conduction to adjacent elements.

Another PROCEDURAL BLOCK is used to switch the SHROUD temperature versus time from the tabular function to an exponential function with controllable parameters.

The third PROCEDURAL BLOCK is for the simulation of the effect of smoke on radiative heat flux. (The reason for introducing this effect is given in the subsequent section "Fitting the Model to Heat Test Results".)

A fourth PROCEDURAL allows switching off the heat input to elements 98 and/or 99 to simulate the situation when the whole cover is not exposed to heat.

5. Data Inputted.

Data is inputted to the program in the form of constants, MACRO call parameters or table values.

Data inputted as program constants include:

Coefficient of Convective Heat Transfer
View Factor
Emissivity
Melting Points
Contact Resistances
Specific Heat & Density via Factor F (See Mathematical Approach General)

Data inputted as MACRO call parameters are:

MACRO	PARAMETERS
COND	Distance for conductive heat flow
	Width
	Thickness For cross-sectional area for conduction
	Conductivity
RAD	Emissivity
	Area Exposed to Radiation
	View Factor
DT	Specific Heat & Density via Factor F
	Volume of Element

The only data inputted by table values are temperatures versus time obtained from physical testing. Nine such tables were used in the program.

6. Fitting the Model to Heat Test Results.

Once all of the known physical and thermal data have been inputted to the model, the next step is to find values for the various unknowns (such as convective heat coefficients) which make the model correspond to the test results reasonably well. There are eight thermocouple temperature versus time curves derived from the test, each of which correspond to an element of the model. Values are arbitrarily chosen for each unknown constant and the eight curves produced by the model are compared with the test curves. On the first guess most of the model curves differ considerably from the test curves. Because some model curves are influenced more by some constants than others, it is not difficult to make the general trend of the curves match the test curves in about 20 runs. (Incidentally, these runs do not require the complete CSSL cycle. The first part produces and compiles a FORTRAN program which takes substantial computer time. But this does not have to be redone if the program itself is not changed. It is only necessary to change some of the "constant" values and this can be done at run time. Each run itself then takes very little time.)

After getting the curves to generally fit overall temperature rise, the next step is to attempt to get the shape of the curves right by balancing the contributions due to radiation, convection and conduction. All curves were matched reasonably well in this way except for thermocouple TC22 in the test which corresponds to element T56 in the model.

This thermocouple is on the deck plate not covered by the IC Box and is thus exposed to radiation and convection from the two upper parts of the cover. The conduction from the cover through the deck plate itself allows the use of only one arbitrary unknown constant which is the cover to deck plate contact resistance. But, even with this at zero, the contribution to temperature rise from conduction is very small. This means that the heating of the deck plate is mainly by radiation and/or convection. To find out how much of each may be required, two sets of runs were made. In the first set, convection was set at zero and radiation increased and decreased until the latest significant point (the occurrence of melting) is matched. The resultant curve is shown on Figure 5. In the second set radiation was eliminated to the deck plate and with only convection the end point was again matched. That curve is also shown on Figure 5, together with the curve for the test result. The problem is evident in the Figure. Combinations of radiation and convection can only give curves between the two extremes whereas the test curve is outside. Therefore, the actual phenomenon is not merely heating by radiation and convection (with conduction, too, of course). Something else is going on.

During the test it was observed that a large volume of dense smoke was evolved. It was felt that this smoke may affect heat flow. If so, it would have an effect which changes with time. This could affect the heating curve in the way observed, with the heating rate higher in the beginning and decreasing with time. To simulate this a smoke function (S) was introduced. The precise manner in which smoke is generated is, of course, unknown. It seemed reasonable to assume that smoke will begin to form when the temperature is high enough for some materials to start burning. Four hundred degrees Fahrenheit was chosen as the temperature at which smoking begins. The value chosen is probably not critical since the temperatures rise rapidly. It was also felt that the rate of smoke generation increases more rapidly than proportional to temperature so a square function was used. The amount of smoke present is cumulative so the rate-of-smoke generation DS is integrated outside the PROCEDURAL to give S. The effective net emissivity GV is then made a simple inverse function of S.

Using this smoke function the arbitrary constants K1, K2 and K3 were adjusted to make T56 match TC22 while keeping all other curves reasonably well-matched. Figures 6 through 13 are the eight pairs of curves for the model output compared with the thermocouple readings when the empirical curve-matching was concluded.

7. Computer Program.

The Appendix has a complete source listing of both the main program, which must be run once each time the model is changed, and of a typical parameter-alteration run.

The main program is in three contiguous parts. The first part (lines 100-230) is the control deck for the SCOPE operating system. The second part (lines 250-7030) is the CSSL 3 source deck. The third part (lines 7050-7180) is the CSSL 3 run time control deck.

Execution proceeds in several steps. First, CSSL 3 reads the CSSL 3 source deck, sorts the statements, makes MACRO substitutions, interprets statements which are in CSSL 3 format and produces a FORTRAN source program on a file called TAPE7. This is then compiled with the machine code written on a file named LGO. Compiled subroutines on a permanent file are loaded into central memory along with LGO for execution as the last step. Total time for execution of the main program is typically 250 CPU seconds.

A parameter alteration run is illustrated by the second source listing in the Appendix. Any defined constants in the main program (see lines 430-520) may have new values assigned for this type of run. The time step and ending time may be reset by redefining CI and TE respectively. The constant XX, initially set to zero, makes the shroud temperature equal to the table function which is the measured shroud thermocouple values as a function of time. If reset to 1 an exponential temperature rise is used with a maximum temperature and time constant of TMAX and TAU respectively. Similarly, the constants X98 and TBC can be used as switches to turn on or off the radiation to elements T98 and T99 respectively. The values of any variable versus time may be outputted and/or plotted during a parameter alteration run. This allows detailed study of heat flow within the model. Execution of a parameter alteration run uses 5 to 10 seconds CPU time.

USING THE MODEL

There are several ways in which the model can now be used. One of these is to assume a different heat input. The most interesting heat input is a shroud temperature which is a fast exponential rise to a steady 1850°F. This corresponds to a worst-case organic fuel fire. The result of using such an input on T52 is shown in Figure 14. As expected, of course, the rate of heating is greater than was experienced in the test, but in addition, details such as the time of melting can probably best be estimated by the use of a model like this. The change to the program which is required to get this result is to input a value for XX of 1 instead of 0. This makes the logical variable X true through PROCEDURAL (X,NX = XX) which acts as a switch to change the definition of TSH, the temperature of the shroud versus time. With XX = 0, TSH is the SHROUD tabular function of thermocouple readings whereas when XX = 1, TSH equals an exponential function of time. TMAX is set to 1850° and TAU is 10 (seconds) within the program.

Figure 15 was gotten in the same way but the maximum shroud temperature (TMAX) was set to 1450°F which is considered to be typical of an organic fuel fire rather than worst-case.

Another configuration which was considered is 1850°F heat only to the top of the cover, which could occur if the missile were lying on the ground with a fuel fire nearby. The resulting T52 is shown in Figure 16. To simulate this condition two switches were reset in the program. The constant TBC was reset to 2000, and X98 was reset to 1. TBC is in the program as the time at which the missile ballistic case melts. Prior to TBC there is no heat input to element T99 because of the shielding effect of the ballistic case. By setting TBC = 0, we have heat input to T99 all the time whereas by setting it high the heat never gets inputted to T99. Constant X98 is used only to allow switching off the heat input to element T98.

Temperature T52 for the case of heat input to the whole top and with a maximum input temperature of 5500°F to correspond to a propellant fire is given in Figure 17. In a case like this, which differs so widely from the conditions under which the model parameters were derived, the results must be interpreted with a great deal of caution. Nevertheless, such results may be better than a simplified calculation or estimate.

Another use for the model is in the analysis of heat flow paths. As an example, consider how the battery match gets heated.

T45 gets heated by conduction from T32, T34, and T42, which three elements form a bottom corner of the battery case. Since any variable can be outputted (not only the state variables used in the integration routines) all that is needed is to output some of the QC's and QR's and compare these to find the main heat flow patterns.

Figure 18 is a diagram of all major (> 10^7 erg/sec) heat flow paths feeding elements 32, 34 and 42 at the time 240 seconds. It is seen that elements 32 and 34 are receiving more heat by radiation than conduction. Element 42 receives heat only by conduction. There are several more heat flow paths, such as radiative and conductive flux from 98 to 99 to 01 and 02 which are not shown. Also, everything changes with time. All of this information is available to use, keeping in mind that the interpretation must be a reasonable consequence of the data put into the model.

Knowledge of the heat flow paths allows the designer to incorporate conductors and insulators to obtain desired performance. It may be desirable to insulate a battery gas generator for example while increasing the conduction to the thermal release connector.

REFERENCES

1. T. H. Naylor, J. L. Balintfy, D. S. Burdick and K. Chu, "Computer Simulation Techniques", 1968

2. P. J. Schneider, "Conduction Heat Transfer", 1955

3. E. M. Sparrow and R. D. Cess, "Radiation Heat Transfer", 1966

4. J. A. Weibelt, "Engineering Radiation Heat Transfer", 1966

5. M. Jakob and G. A. Hawkins, "Elements of Heat Transfer", 1957

6. Control Data 6000 Computer Systems, "Continuous System Simulation Language III (CSSL 3), User's Guide", Version 1, Publication No. 17304400

Table 1

Designations of test thermocouples (TC)
and computer model temperatures (T)

Thermocouple	Model	Location
TC 25	T50	Deck, under IC Box
TC 24	T52	Deck, exposed part
TC 22	T56	Arm Safe Device Number 1
TC 27	T19	Battery TRC
TC 12	T45	Battery explosive gas generator
TC 15	T58	IC Box top
TC 21	T90	WHD TRC
TC 26	T07	Base between BDT and battery

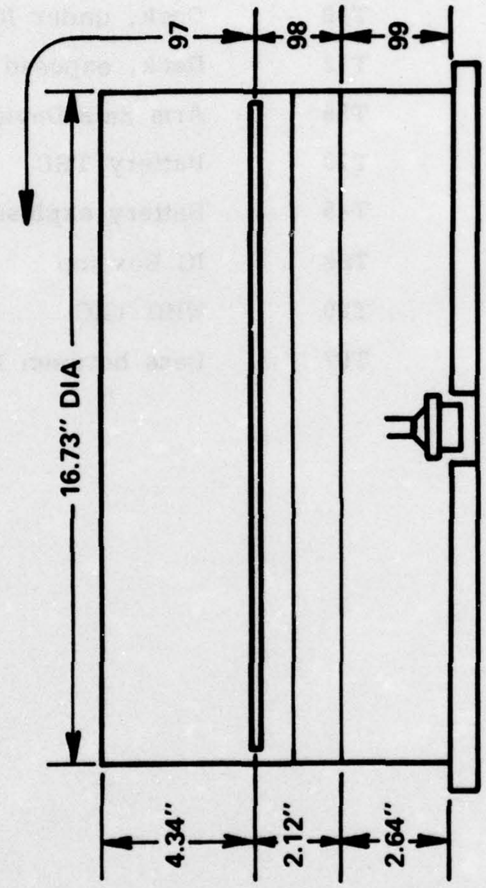


Fig 1 Cover

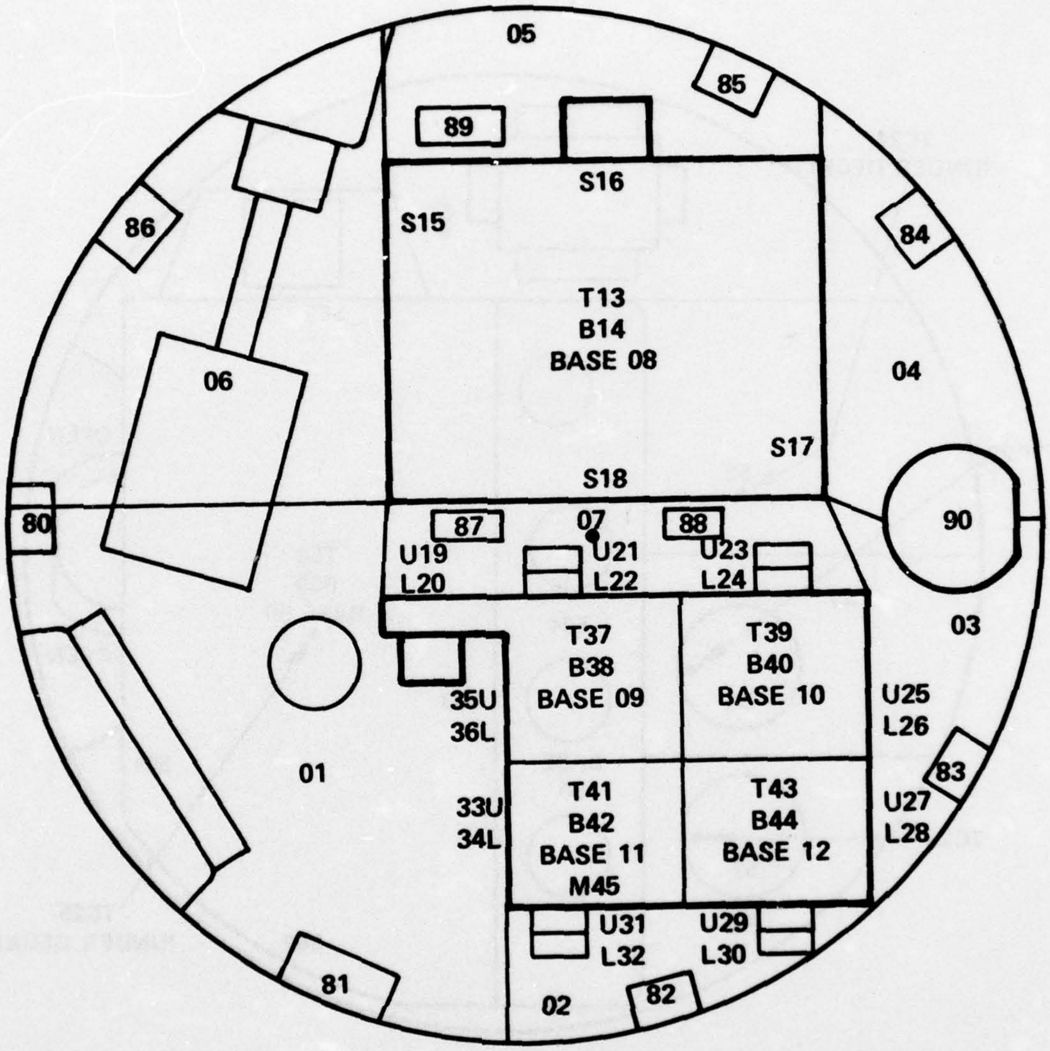

05
85
89
S16
86
S15
84
T13
B14
BASE 08
06
04
S17
S18
80
87
07
88
90
U19
L20
U21
L22
U23
L24
03
T37
B38
BASE 09
T39
B40
BASE 10
35U
36L
U25
L26
01
83
33U
34L
T41
B42
BASE 11
M45
T43
B44
BASE 12
U27
L28
U31
L32
U29
L30
81
02
82
(M45 = MATCH)

Fig 2 Base

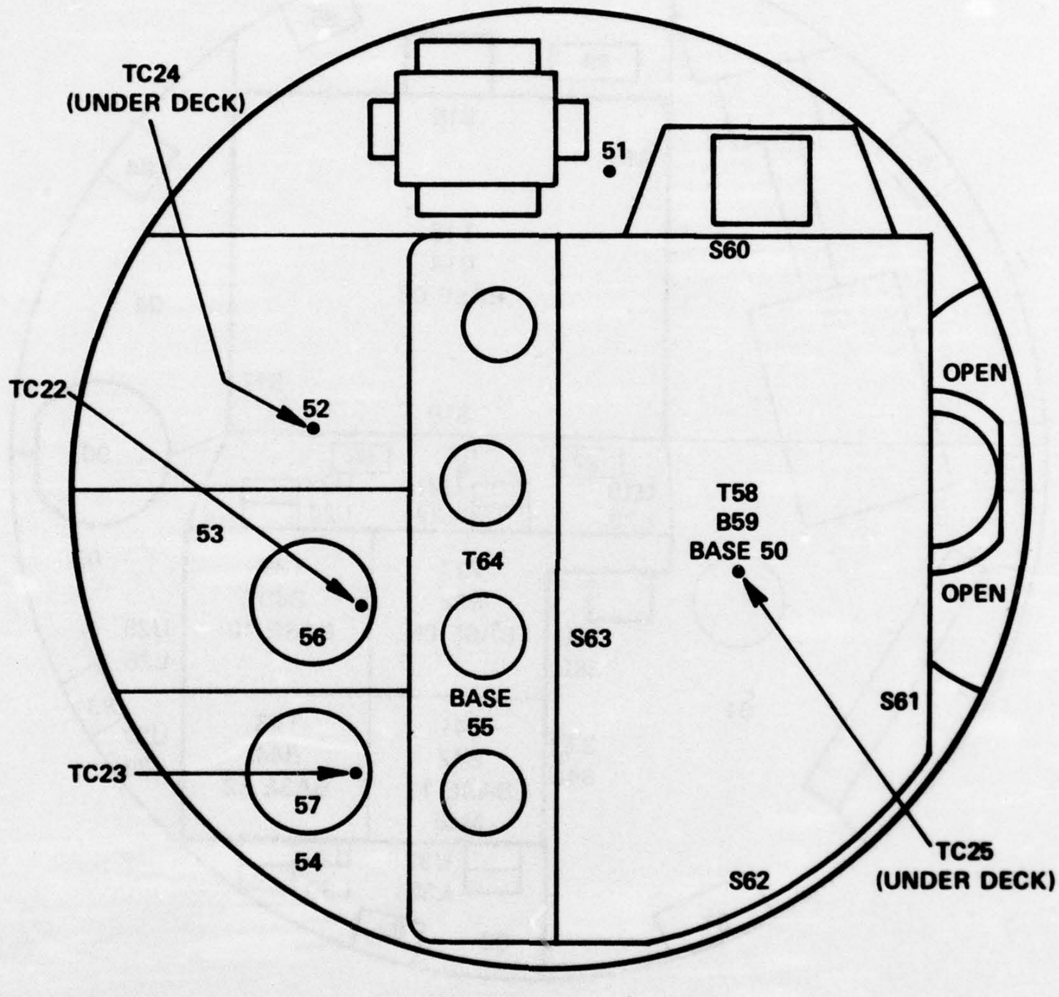

TC24
(UNDER DECK)
51
S60
OPEN
TC22
52
53
T58
B59
BASE 50
T64
OPEN
56
S63
BASE
55
S61
TC23
57
54
S62
TC25
(UNDER DECK)

Fig 3 Deck

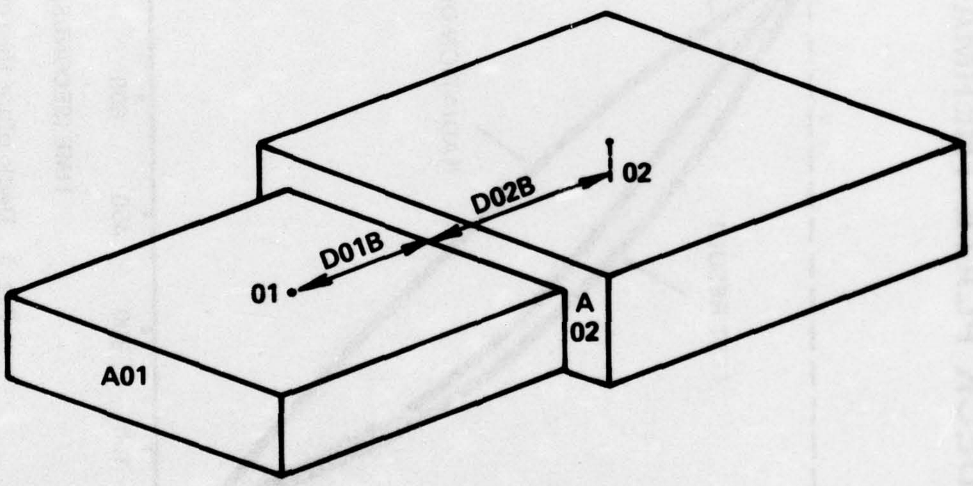


Fig 4 Conductivity model

DECK PLATE THERMAL FIT

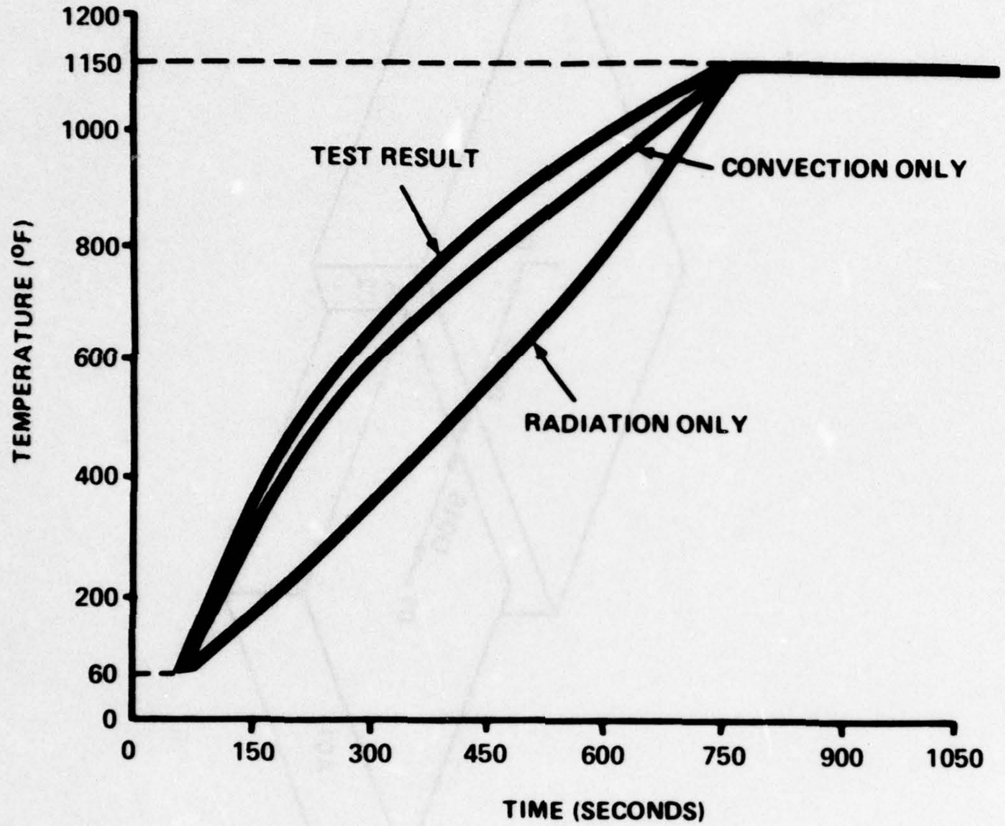


Fig 5 Deck plate thermal fit

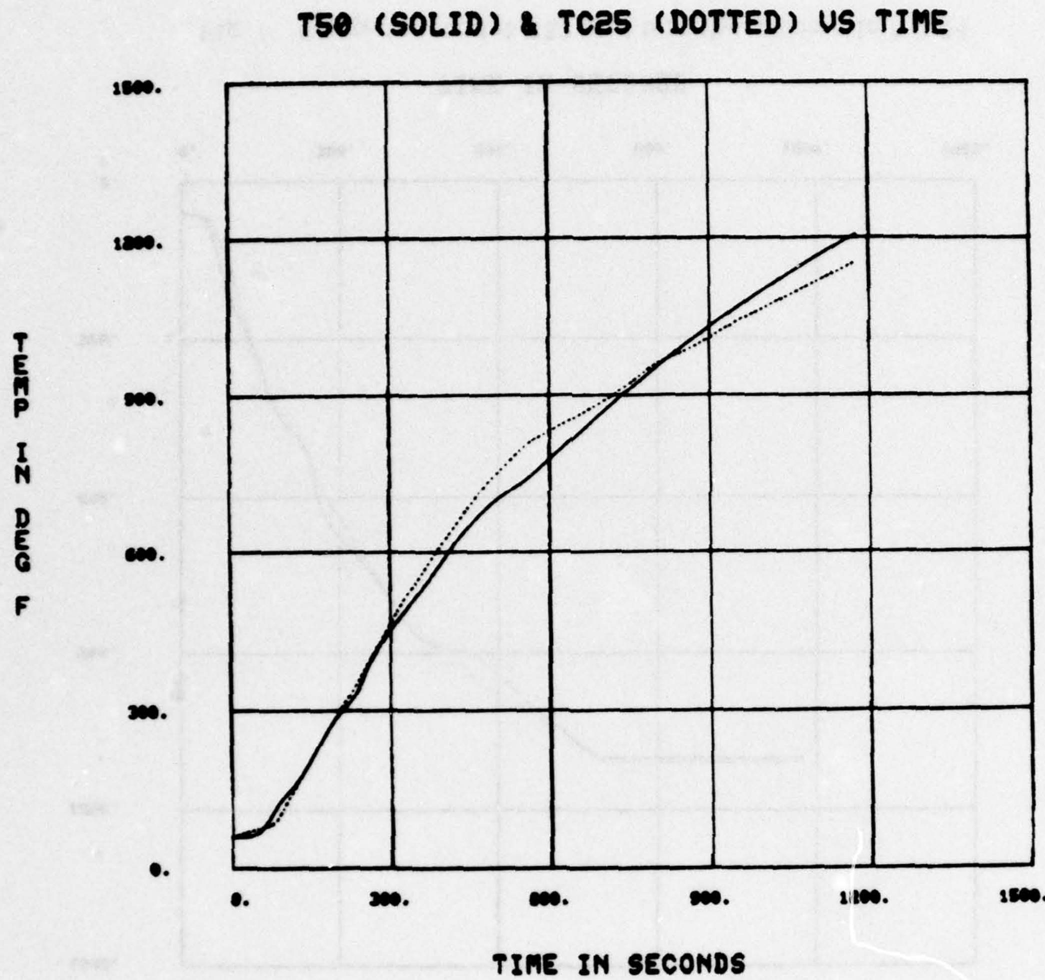


Fig 6 Computer model T50 and test thermocouple TC 25

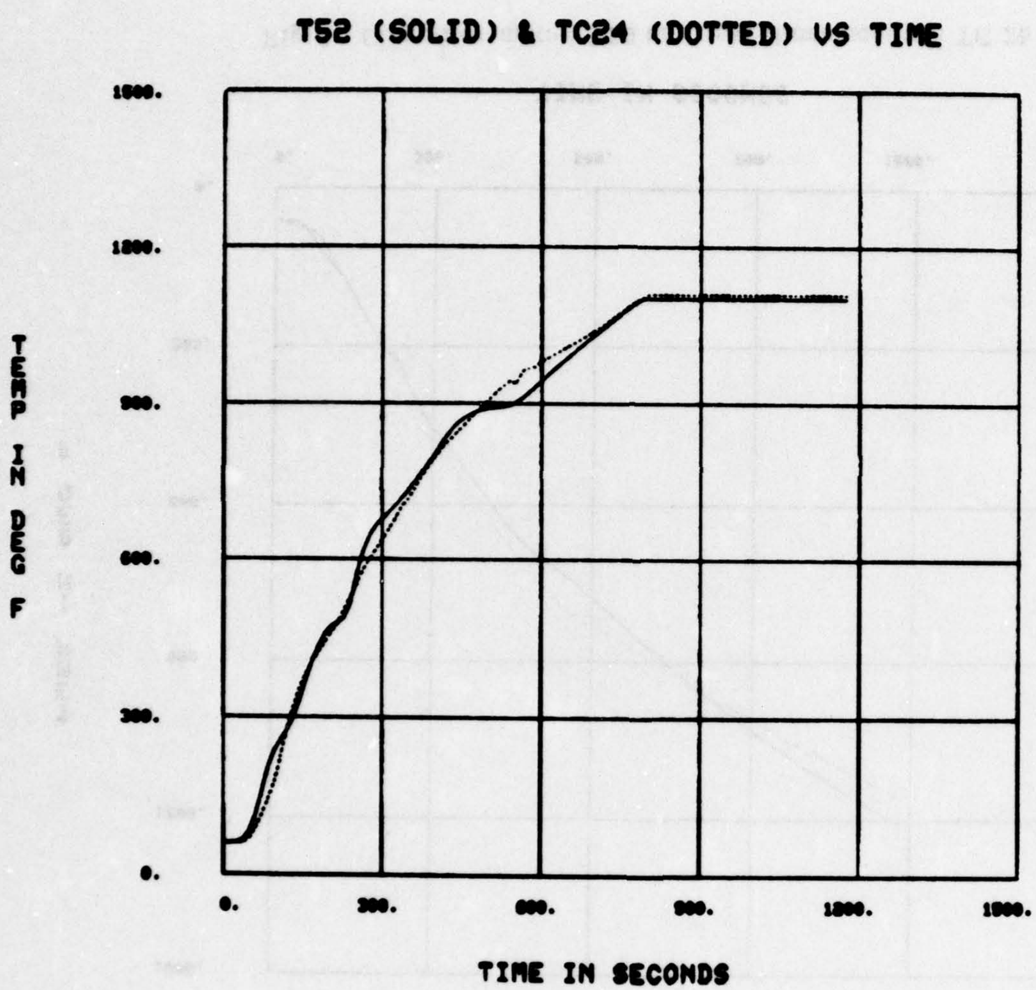


Fig 7 Computer model T52 and test thermocouple TC 24

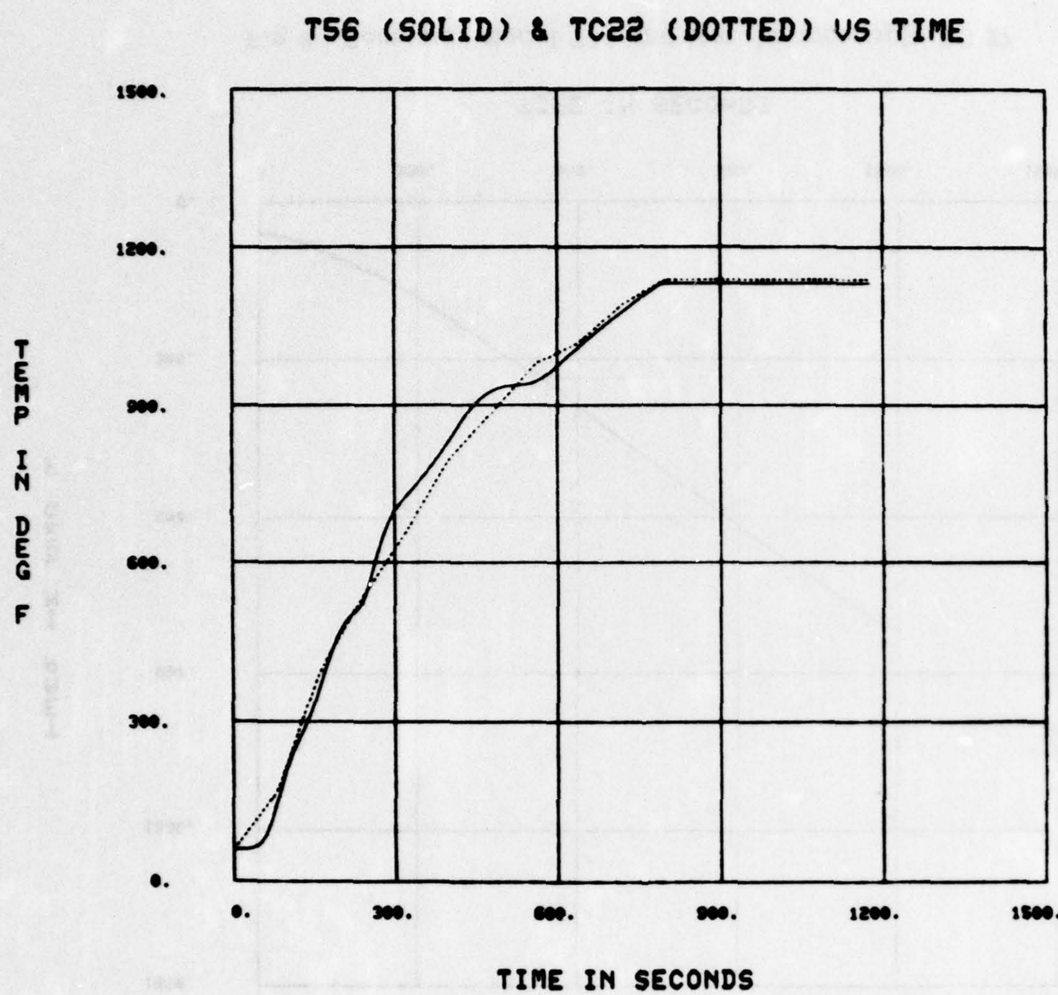


Fig 8 Computer model T56 and test thermocouple TC 22

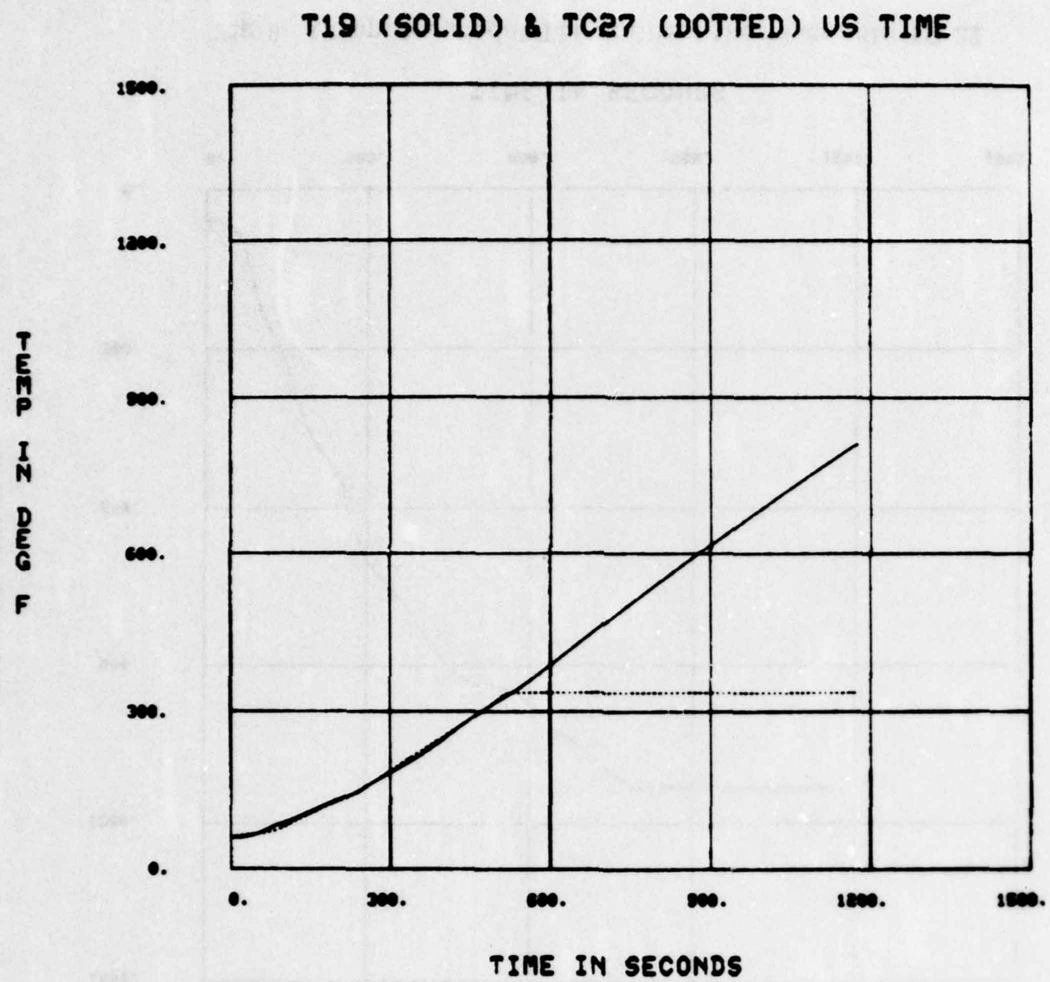


Fig 9 Computer model T19 and test thermocouple TC 27

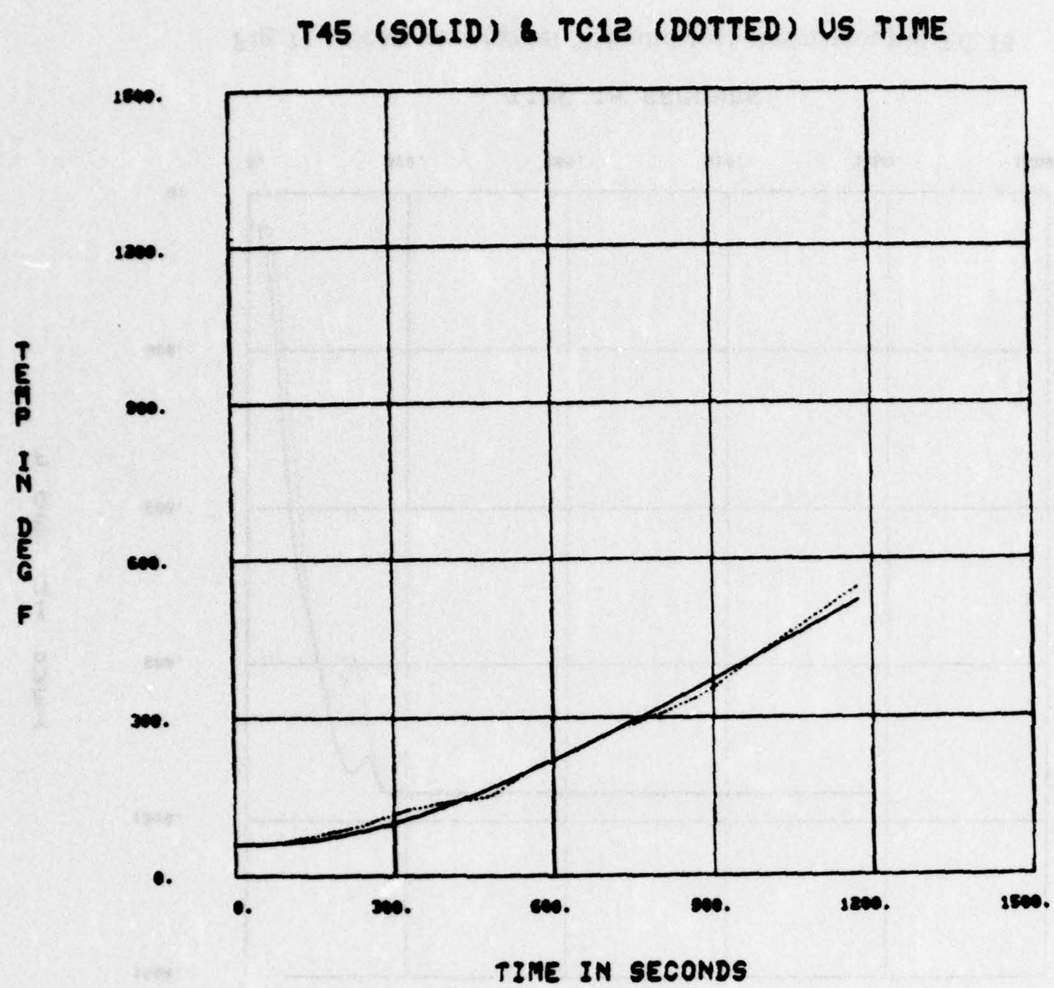


Fig 10 Computer model T45 and test thermocouple TC 12

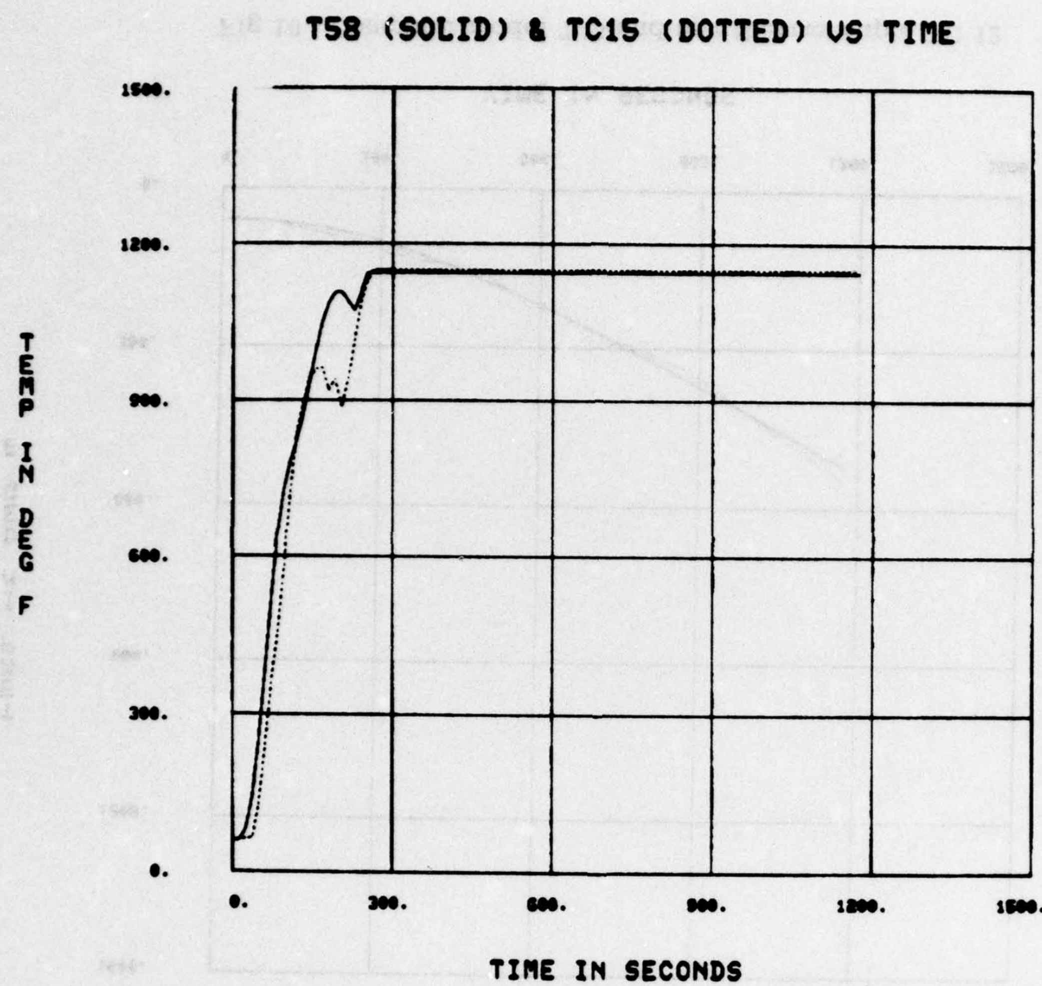


Fig 11 Computer model T58 and test thermocouple TC 15

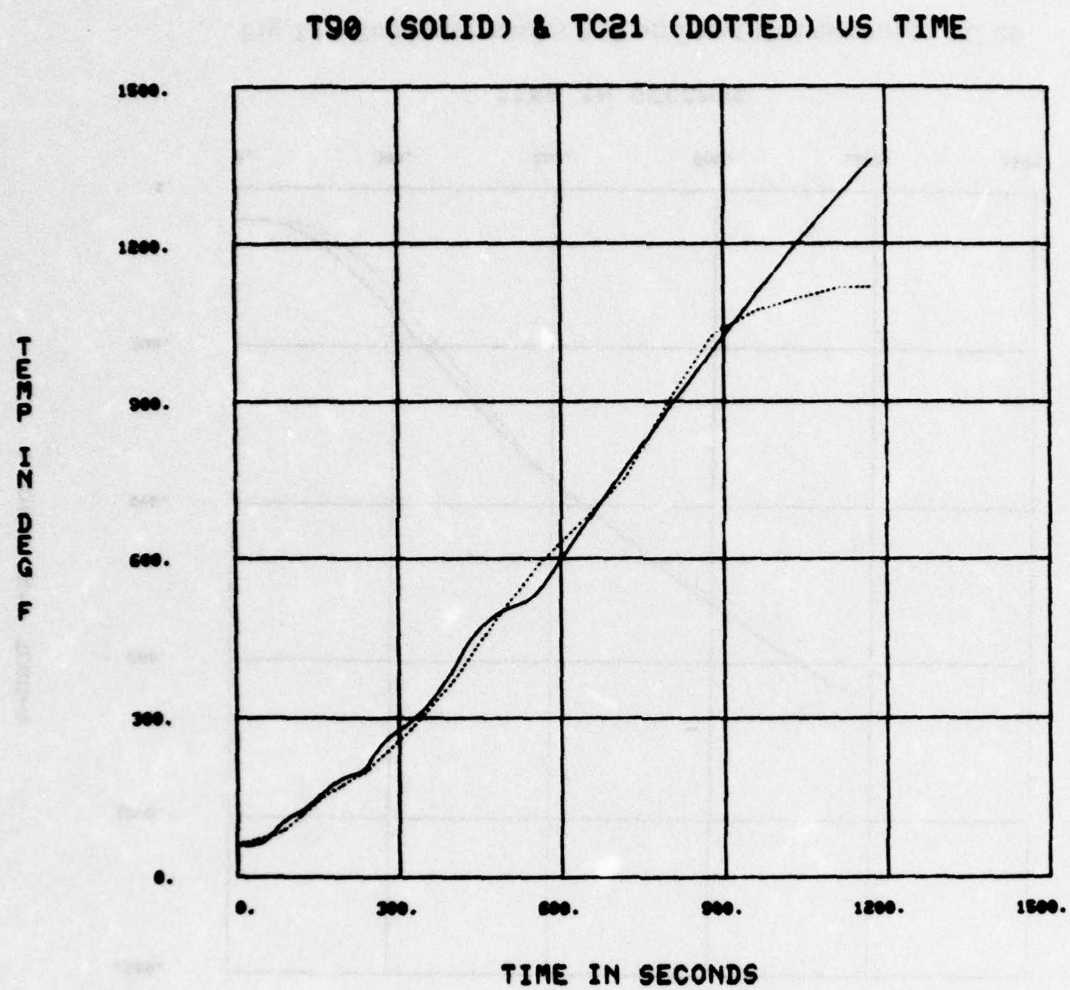


Fig 12 Computer model T90 and test thermocouple TC 21

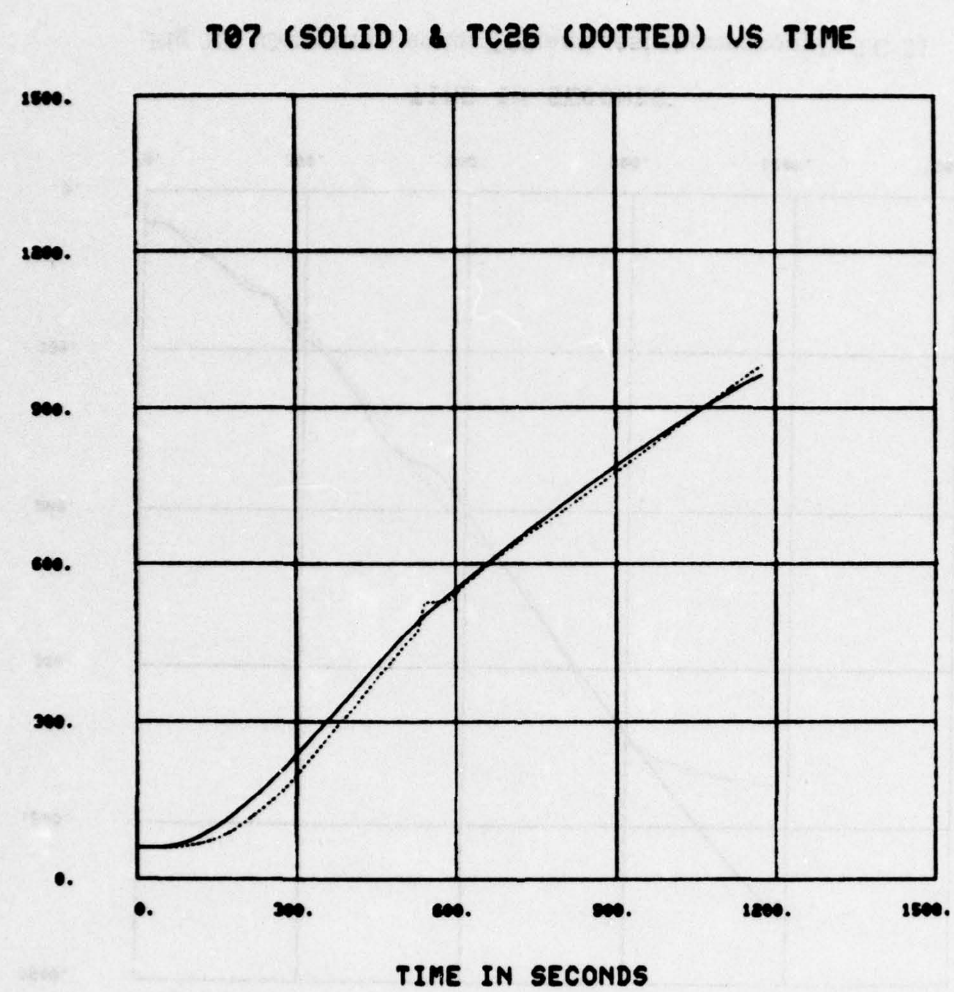


Fig 13 Computer model T07 and test thermocouple TC 26

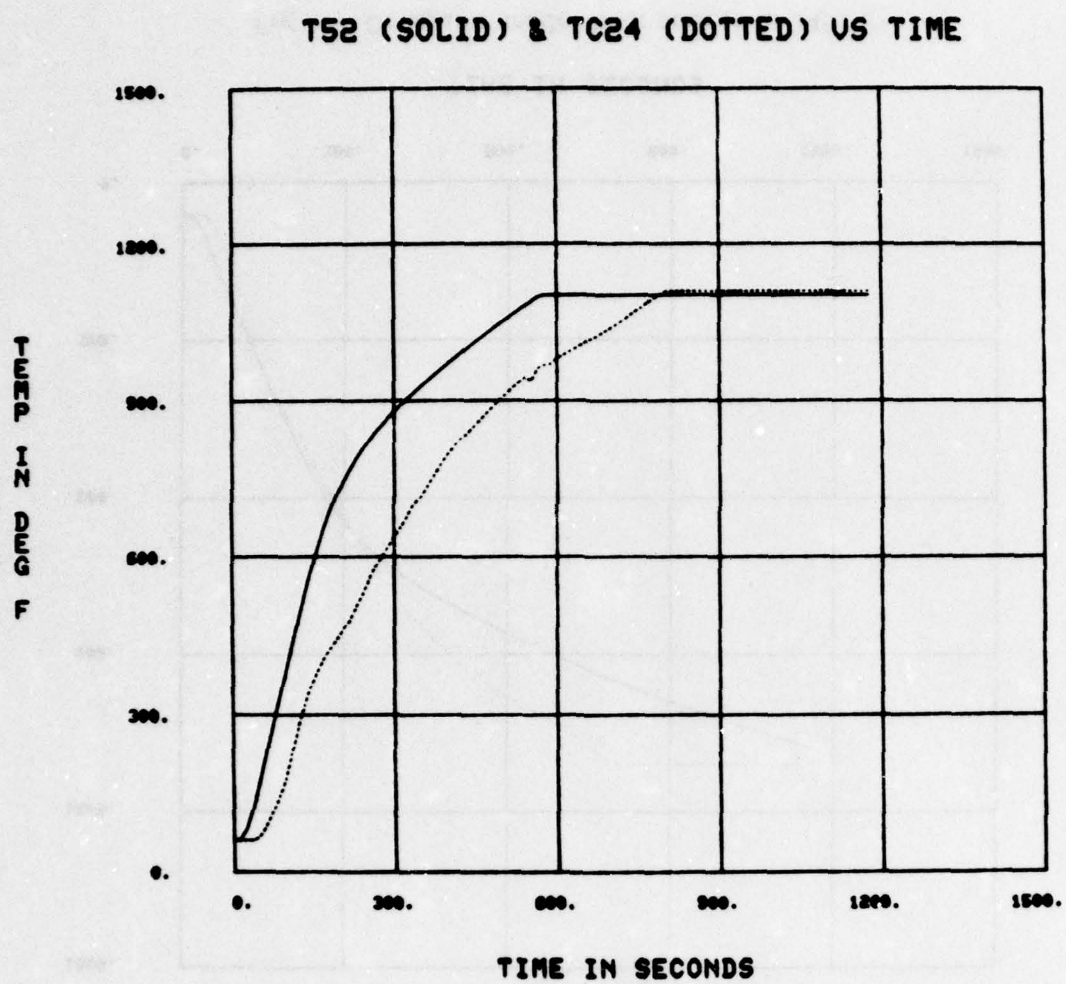


Fig 14 Computer model heat source at 1800°F

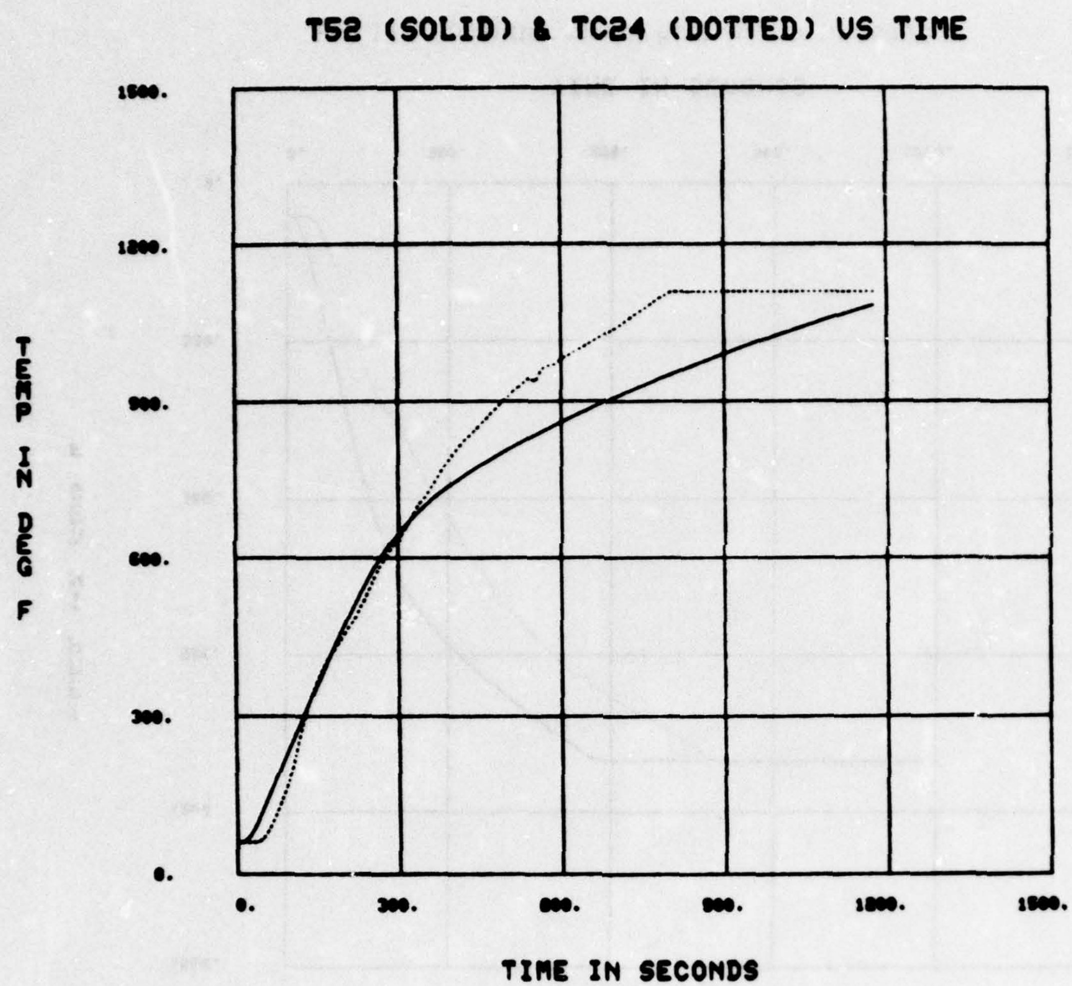


Fig 15 Computer model heat source at 1450°F

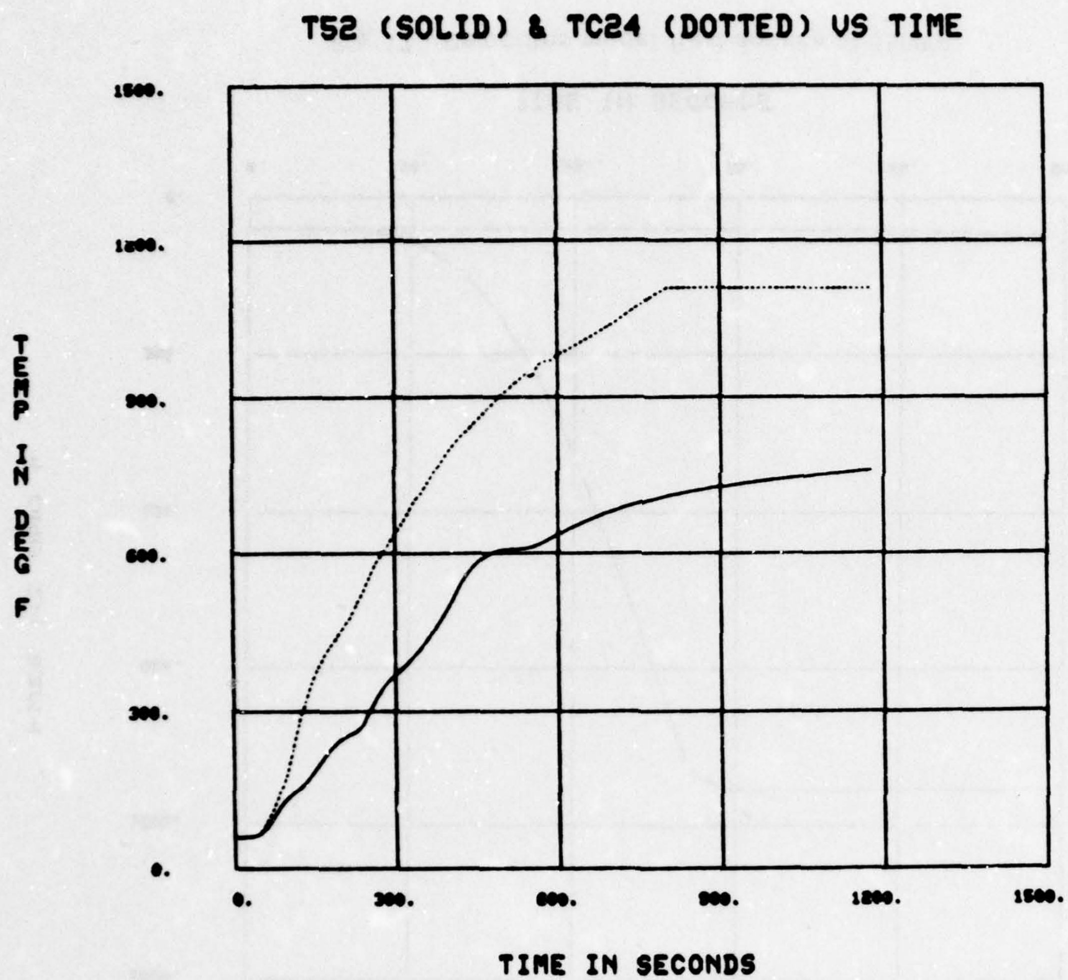


Fig 16 Computer model heat source at 1800°F (to top only)

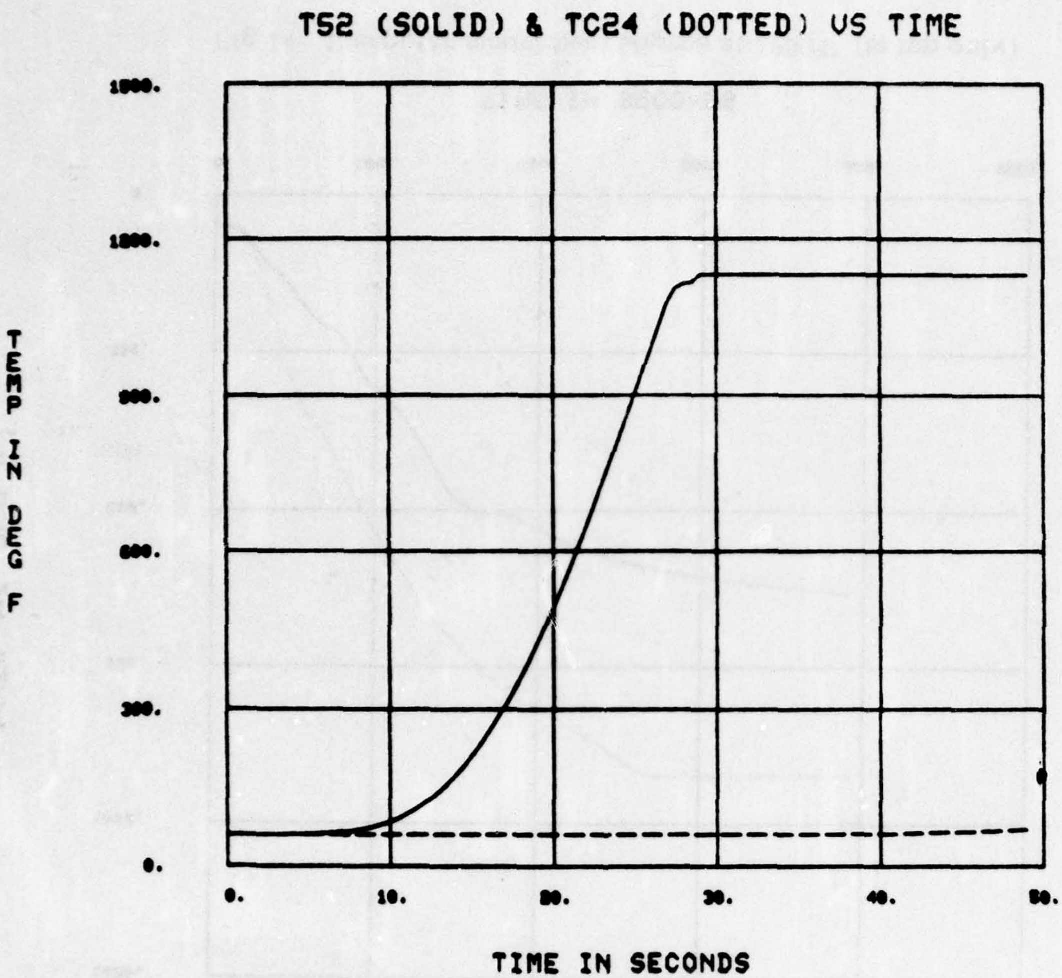
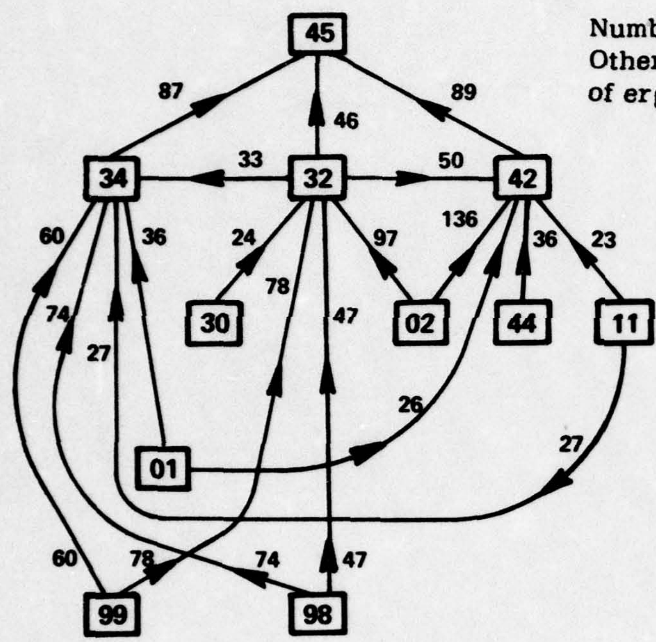


Fig 17 Computer model heat source at 5500°F



Numbers in boxes are element numbers.
Other numbers are heat values in millions
of ergs per second at 240 seconds.

Fig 18 Heat paths to element 45

APPENDIX

```
FREDM,CM150000,T300,IC83.
COMMENT.(XXX-XXX,010REF).MULLER THERMAL ANALYSIS
ATTACH,71,CSL,CY=1,ID=MULLERFA.
RFL,150000.
71.
REWIND,TAPE7.
REQUEST,LGO,*PF.
RFL,150000.
FTN,I=TAPE7,OPT=0,L=0.
CATALOG,LGO,LGO,CY=15,ID=MULLERFA.
ATTACH,72,CSL,CY=2,ID=MULLERFA.
RFL,150000.
LOAD,72.
LGO.
7/8/9
 PROGRAM HEAT CALCULATIONS
 COMMENT...
 ...
         WRITTEN BY -  FRED A MULLER          ...
 ...
                        JULY 1976             ...
 ...
 ...
 COMMENT 3-D HEAT ANALYSIS OF SPARTAN A K
 COMMENT TSH = TEMP OF SHROUD (DEG F)
 COMMENT ALL DIMENSIONS ARE IN INCHES
 MERROR T97=.01, T98=.01, T99=.01
 XERROR T97=1., T98=1., T99=1.
 TABLE SHROUD,1,14,0.,8.,48.,72.,104.,144.,184.,216.,240.. ...
 288.,408.,512.,568.,600.. ...
 60.,60.,1505.,1820.,1144.,1696.,1369.,870.,2010.. ...
 1354.,1922.,1117.,1800.,1800.
 CONSTANT ...
 H   =.05 , VB =.18, GSC=.20   , AA=   0., FASD=2.3,    ...
 HB  =.00 , V07=.00, GCA=.00   , MA=100., F45 =1.5,     ...
 HD  =.020, V50=.08, GCS=.00   , MC=   0., FT  =0.1,    ...
 HIC =.15 , V51=.05, GCT=.60   , MM=   0., KP=.00167,   ...
 HS  =2.0 , V52=.15, MP19=2000., MS= 10., TF  =1188.,   ...
```

```
H19 =5.0 . K1 =.25. MP52=1100.. SS= 10.. TMAX=2000..  ...
H50 =.00 . K2 =.44. MP56=1130.. A107=5.. TAU = 10..   ...
H56 =.000. K3 =.09. MP58=1135.. XX =  0..THIC=.062.   ...
TBC =.000. CC =.200.X98 =.00
PROCEDURAL(X.NX=XX)
X=.FALSE.
IF(XX.GT.0.5)X=.TRUE.
NX=.NOT.X
END
PROCEDURAL(DS=T52.K1)
DTS=(T52-400.)/1000.
IF(DTS.LT.0.)DTS=0.
DS=K1*DTS**2
END
S=INTEG(DS.0.)
GV=K2/(1.+S)+K3
NX.TSH=SHROUD(T)
X.TSH=EXPF(0..TAU.T.1.)*(TMAX-60.)+60.
MACRO MACRO COND Q
Q(1)=1.41E+7*(Q(2)-Q(3))/(Q(4)/(Q(5)*Q(6)*Q(7))+Q(8)/(Q(9)*Q(10)*...
Q(11))+Q(12))
MACRO END
MACRO MACRO RAD R
R(1)=(3.49E-5*((R(2)+459.7)**4-(R(3)+459.7)**4)*R(4)...
*1.E6*(R(2)-R(3))*R(8))*R(5)*R(6)*R(7)
MACRO END
MACRO MACRO DT P
P(1)=1.E-9*P(2)*P(3)/(P(4)*P(5)*P(6))
MACRO END
PROCEDURAL(M52.M58.M19.M56=T52.MP52.T58.MP58.T19.MP19. ...
T56.MP56)
M52=0.
M58=0.
M19=0.
M56=0.
IF(T52.GE.MP52)M52=1.
IF(T58.GE.MP58)M58=1.
IF(T19.GE.MP19)M19=1.
IF(T56.GE.MP56)M56=1.
```

```
END
RAD QRSHS9.TS9.T99.GSC.3.1416*16.73.2.64.1.,HS
RAD QRSHS7.TSH.T97.GSC.3.1416*16.73.16.73/4.+4.34. 1..HS
RAD QRSHS8.TS8.T98.GSC.3.1416*16.73.2.12. 1..HS
PROCEDURAL(TS8.TS9=TSH.T98.T99.T.TBC.X98)
TS8=TSH
TS9=TSH
IF(T.LE.TBC)TS9=T99
IF(X98.GE. 0.5)TS8=T98
END
 Q99=QRSH99+QC0199+QC0299+QC0399+QC0499+QC0599+QC0699 ...
-QR9901-QR9902-QR9903-QR9904-QR9905-QR9906-QR9915-QR9916...
-QR9917-QR9919-QR9920-QR9925-QR9926-QR9927-QR9928-QR9929...
-QR9930-QR9931-QR9932-QR9933-QR9934-QR9935-QR9936-QR9937...
-QR9939-QR9941-QR9943-QR9950-QR9951-QR9952-QR9953-QR9954...
-QR9955-QR9980-QR9981-QR9982-QR9983-QR9984-QR9985-QR9986...
-QR9989-QR9990
COND QC0102.T01.T02.4.90..46.3.0..5.2.44..46.2.0..500 .0.
COND QC0106.T01.T06.4.12..46.4.0..5.2.74..46.6.0..500 .0.
COND QC0107.T01.T07.4.20..46.2.5..5.3.70..46.1.4..500 .0.
COND QC0109.T01.T09.4.10..46.3.0..5.1.45..46.2.5..220 .0.
COND QC0111.T01.T11.3.84..46.3.0..5.1.47..46.2.5..220 .0.
COND QC0120.T01.T20.3.85..46.3.0..5.0.95.1.42.2.0..050 .MS
COND QC0134.T01.T34.3.85..46.3.0..5.0.95.1.42.2.5..025 .MS
COND QC0136.T01.T36.4.10..46.3.0..5.0.95.1.42.2.5..025 .MS
COND QC0138.T01.T38.4.10..46.3.0..5.1.45.1.42.2.5..025 .MS
COND QC0142.T01.T42.3.84..46.3.0..5.1.47.1.42.2.5..025 .MS
COND QC0180.T01.T80.5.3..46.2.0..5.1.60..46.1.90.0.53. MM
COND QC0181.T01.T81.3.3..46.2.0..5.1.60..46.2.50.0.53. MM
COND QC0199.T01.T99.2.43..46.6.0..5.1.39..54.14.0..040 .MC
COND QC0211.T02.T11.1.2..46.2.9..5.1.2..46.2.9..220 .0.
COND QC0212.T02.T12.2.2..46.2.9..5.1.2..46.2.9..220 .0.
COND QC0230.T02.T30.2.2..46.1.0..5..95.1.42.2.9..025 .MS
COND QC0232.T02.T32.1.2..46.2.0..5..95.1.42.2.9..025 .MS
COND QC0242.T02.T42.1.2..46..95..5.1.2.1.42.2.9..025 .MS
COND QC0244.T02.T44.2.2..46..95..5.1.2.1.42.2.9..025 .MS
COND QC0282.T02.T82.0.5..46.1.0..5.1.35..46.1.76.0.39. MM
COND QC0299.T02.T99.1.0..46.5.0..5.1.39..54.5.0..040 .MC
COND QC0304.T03.T04.3.0..46.1.0..5.2.7..46.1.0..500 .0.
```

```
COND QC0307.T03.T07.2.6..46.0.7..5.3.5..46.1.3..500 .0.
COND QC0310.T03.T10.1.0..46.2.0..5.1.5..46.2.0..220 .0.
COND QC0312.T03.T12.2.3..46.1.5..5.1.5..46.1.5..220 .0.
COND QC0326.T03.T26.1.0..46.2.0..5..95.1.42.2.0..025 .MS
COND QC0328.T03.T28.2.3..46.1.5..5..95.1.42.1.5..025 .MS
COND QC0340.T03.T40.1.0..46.2.0..5.1.5.1.42.2.0..025 .MS
COND QC0344.T03.T44.2.3..46.1.5..5.1.5.1.42.1.5..025 .MS
COND QC0383.T03.T83.1.0..46.1.5..5.1.60..46.1.90.0.53. MM
COND QC0399.T03.T99.1.2..46.6.5..5.1.4..54.6.5..040 .MC
COND QC0405.T04.T05.3.5..46.1.3..5.4.0..46.1.0..500 .0.
COND QC0407.T04.T07.3.2..46.0.7..5.3.5..46.1.3..500 .0.
COND QC0408.T04.T08.1.3..46.5.3..5.3.5..46.5.3..220 .0.
COND QC0414.T04.T14.1.3..46.5.3..5.3.5.1.42.5.3..063 .MS
COND QC0417.T04.T17.1.3..46.5.3..5.3.5.1.38.5.3..063 .MS
COND QC0484.T04.T84.1.0..46.1.5..5.1.60..46.1.90.0.53. MM
COND QC0499.T04.T99.1.6..46.5.0..5.1.4..54.5.0..040 .MC
COND QC0506.T05.T06.3.2..46.2.2..5.4.0..46.2.5..500 .0.
COND QC0508.T05.T08.1.3..46.7.0..5.2.7..46.7.0..220 .0.
COND QC0514.T05.T14.1.3..46.7.0..5.2.7.1.38.7.0..063 .MA
COND QC0516.T05.T16.1.3..46.7.0..5.2.1.1.38.7.0..063 .MA
COND QC0585.T05.T85.2.5..46.1.5..5.1.35..46.1.76.0.39. MM
COND QC0589.T05.T89.2.0..46.1.5..5.1.90..46.1.76.0.27. MM
COND QC0599.T05.T99.1.2..46.7.0..5.1.4..54.7.0..04 .MC
COND QC0608.T06.T08.2.2..46.5...50.3.50..46.5...220 .0.
COND QC0614.T06.T14.2.2..46.5...50.3.50.1.38.5...063 .MS
COND QC0615.T06.T15.2.2..46.5...50.2.05.1.38.5...063 .MS
COND QC0686.T06.T86.2.5..46.2.0..5.1.60..46.1.90.0.53. MM
COND QC0699.T06.T99.3.0..46.9...50.1.39..54.9...040 .MC
COND QC0708.T07.T08.0.7..46.7.0..5.2.70..46.7.0..22 .0.
COND QC0709.T07.T09.0.7..46.2.9..5.1.25..46.2.9..22 .0.
COND QC0710.T07.T10.2.5..46.1.5..5.1.25..46.2.9..22 .0.
COND QC0714.T07.T14.0.7..46.7.0..5.2.70.1.38.7.0..063 .MS
COND QC0718.T07.T18.0.7..46.7.0..5.2.05.1.38.7.0..063 .MA
COND QC0720.T07.T20.2.8..46.1.5..5.0.95.1.42.1.9..050 .MS
COND QC0722.T07.T22.0.7..46.2.9..5.0.95.1.42.2.9..025 .MS
COND QC0724.T07.T24.2.5..46.1.5..5.0.95.1.42.2.9..025 .MS
COND QC0728.T07.T28.0.7..46.1.5..5.1.25.1.42.2.9..025 .MS
COND QC074 .T07.T40.2.5..46.1.5..5.1.25.1.42.2.9..025 .MS
COND QC0787.T07.T87.4.0..46.1.4..5.1.90..46.2.26.0.27. MM
```

```
COND QC0708,T07,T08,0.5,.46,1.4,.5,1.90,.46,1.76,0.27, MM        001660
COND QC0814,T08,T14,3.0,.46,12.,.22,3.0,1.38,12.,.063 ,MA        001670
COND QC0815,T08,T15,3.5,.46,5.4,.22,2.05,1.38,5.4,.063 ,MA       001680
COND QC0816,T08,T16,2.7,.46,7.0,.22,2.05,1.38,7.0,.063 ,MA       001690
COND QC0817,T08,T17,3.5,.46,5.4,.22,2.05,1.38,5.4,.063 ,MA       001700
COND QC0818,T08,T18,2.7,.46,7.0,.22,2.05,1.38,7.0,.063 ,MA       001710
COND QC0910,T09,T10,1.45,.46,2.5,.22,1.45,.46,2.5,.220 ,0.       001720
COND QC0911,T09,T11,1.25,.46,2.9,.22,1.25,.46,2.9,.220 ,0.       001730
COND QC0922,T09,T22,1.25,.46,2.9,.22,0.95,1.42,2.9,.025 ,MS      001740
COND QC0936,T09,T36,1.45,.46,2.5,.22,0.95,1.42,2.5,.025 ,MS      001750
COND QC0938,T09,T38,1.30,.46,3.0,.22,1.30,1.42,3.0,.025 ,MS      001760
COND QC1012,T10,T12,1.25,.46,2.9,.22,1.25,.46,2.9,.220 ,0.       001770
COND QC1024,T10,T24,1.25,.46,2.9,.22,0.95,1.42,2.9,.025 ,MS      001780
COND QC1026,T10,T26,1.45,.46,2.5,.22,0.95,1.42,2.5,.025 ,MS      001790
COND QC1040,T10,T40,1.30,.46,3.0,.22,1.30,1.42,3.0,.025 ,MS      001800
COND QC1112,T11,T12,1.45,.46,2.5,.22,1.45,.46,2.5,.220 ,0.       001810
COND QC1132,T11,T32,1.25,.46,2.9,.22,0.95,1.42,2.9,.025 ,MS      001820
COND QC1134,T11,T34,1.45,.46,2.5,.22,0.95,1.42,2.5,.025 ,MS      001830
COND QC1142,T11,T42,1.30,.46,3.0,.22,1.30,1.42,3.0,.025 ,MS      001840
COND QC1228,T12,T28,1.45,.46,2.5,.22,0.95,1.42,2.5,.025 ,MS      001850
COND QC1230,T12,T30,1.25,.46,2.9,.22,0.95,1.42,2.9,.025 ,MS      001860
COND QC1244,T12,T44,1.30,.46,3.0,.22,1.30,1.42,3.0,.025 ,MS      001870
COND QC1315,T13,T15,3.5,1.38,5.4,.063,2.05,1.38,5.4,.063 ,AA     001880
COND QC1316,T13,T16,2.7,1.38,7.0,.063,2.05,1.38,7.0,.063 ,AA     001890
COND QC1317,T13,T17,3.5,1.38,5.4,.063,2.05,1.38,5.4,.063 ,AA     001900
COND QC1318,T13,T18,2.7,1.38,7.0,.063,2.05,1.38,7.0,.063 ,AA     001910
COND QC1415,T14,T15,3.5,1.38,5.4,.063,2.05,1.38,5.4,.063 ,AA     001920
COND QC1416,T14,T16,2.7,1.38,7.0,.063,2.05,1.38,7.0,.063 ,AA     001930
COND QC1417,T14,T17,3.5,1.38,5.4,.063,2.05,1.38,5.4,.063 ,AA     001940
COND QC1418,T14,T18,2.7,1.38,7.0,.063,2.05,1.38,7.0,.063 ,AA     001950
COND QC1516,T15,T16,2.7,1.38,4.1,.063,3.50,1.38,4.1,.063 ,AA     001960
COND QC1518,T15,T18,2.7,1.38,4.1,.063,3.50,1.38,4.1,.063 ,AA     001970
COND QC1617,T16,T17,3.5,1.38,4.1,.063,2.70,1.38,4.1,.063 ,AA     001980
COND QC1718,T17,T18,2.7,1.38,4.1,.063,3.5,1.38,4.1,.063 ,AA      001990
COND QC1920,T19,T20,0.95,1.42,1.9,.050,0.95,1.42,1.9,.050,0.     002000
COND QC1921,T19,T21,0.95,1.42,1.9,.050,1.45,1.42,1.9,.025,0.     002010
COND QC1935,T19,T35,0.95,1.42,1.9,.050,1.25,1.42,1.9,.025,SS     002020
COND QC2022,T20,T22,0.95,1.42,1.9,.050,1.65,1.42,1.9,.025,0.     002030
COND QC2036,T20,T36,0.95,1.42,1.9,.050,1.25,1.42,1.9,.025,SS     002040
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COND QC2122,T21,T22,0.95,1.42,2.9,.025,0.95,1.42,2.9,.025,0.          002050
COND QC2123,T21,T23,1.45,1.42,1.9,.025,1.45,1.42,1.9,.025,0.          002060
COND QC2137,T21,T37,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002070
COND QC2224,T22,T24,1.45,1.42,1.9,.025,1.45,1.42,1.9,.025,0.          002080
COND QC2238,T22,T38,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002090
COND QC2324,T23,T24,0.95,1.42,2.9,.025,0.95,1.42,2.9,.025,0.          002100
COND QC2325,T23,T25,1.45,1.42,1.9,.025,1.25,1.42,1.9,.025,SS          002110
COND QC2339,T23,T39,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002120
COND QC2426,T24,T26,1.45,1.42,1.9,.025,1.25,1.42,1.9,.025,SS          002130
COND QC2440,T24,T40,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002140
COND QC2526,T25,T26,0.95,1.42,2.5,.025,0.95,1.42,2.5,.025,0.          002150
COND QC2527,T25,T27,1.25,1.42,1.9,.025,1.25,1.42,1.9,.025,0.          002160
COND QC2539,T25,T39,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002170
COND QC2628,T26,T28,1.25,1.42,1.9,.025,1.25,1.42,1.9,.025,0.          002180
COND QC2640,T26,T40,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002190
COND QC2728,T27,T28,0.95,1.42,2.5,.025,0.95,1.42,2.5,.025,0.          002200
COND QC2729,T27,T29,1.25,1.42,1.9,.025,1.45,1.42,1.9,.025,SS          002210
COND QC2743,T27,T43,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002220
COND QC2830,T28,T30,1.25,1.42,1.9,.025,1.45,1.42,1.9,.025,SS          002230
COND QC2844,T28,T44,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002240
COND QC2930,T29,T30,0.95,1.42,2.9,.025,0.95,1.42,2.9,.025,0.          002250
COND QC2931,T29,T31,1.45,1.42,1.9,.025,1.45,1.42,1.9,.025,0.          002260
COND QC2943,T29,T43,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002270
COND QC3032,T30,T32,1.45,1.42,1.9,.025,1.45,1.42,1.9,.025,0.          002280
COND QC3044,T30,T44,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002290
COND QC3132,T31,T32,0.95,1.42,2.9,.025,0.95,1.42,2.9,.025,0.          002300
COND QC3133,T31,T33,1.45,1.42,1.9,.025,1.25,1.42,1.9,.025,SS          002310
COND QC3141,T31,T41,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002320
COND QC3234,T32,T34,1.45,1.42,1.9,.025,1.25,1.42,1.9,.025,SS          002330
COND QC3242,T32,T42,0.95,1.42,2.9,.025,1.25,1.42,2.9,.025,SS          002340
COND QC3245,T32,T45,0.00,1.42,1.0,1.00,.25,KP,1.0,1.00 ,0.            002350
COND QC3334,T33,T34,0.95,1.42,2.5,.025,0.95,1.42,2.5,.025,0.          002360
COND QC3335,T33,T35,1.25,1.42,1.9,.025,1.25,1.42,1.9,.025,0.          002370
COND QC3341,T33,T41,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002380
COND QC3436,T34,T36,1.25,1.42,1.9,.025,1.25,1.42,1.9,.025,0.          002390
COND QC3442,T34,T42,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002400
COND QC3445,T34,T45,0.00,1.42,1.0,1.00,.10,KP,1.0,1.00 ,0.            002410
COND QC3536,T35,T36,0.95,1.42,2.5,.025,0.95,1.42,2.5,.025,0.          002420
COND QC3537,T35,T37,0.95,1.42,2.5,.025,1.45,1.42,2.5,.025,SS          002430
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COND QC3638.T36.T38.0.55.1.42.2.5..025.1.45.1.42.2.5..025.SS          002440
COND QC3733.T37.T39.1.45.1.42.2.5..025.1.45.1.42.2.5..025.0.           002450
COND QC3741.T37.T41.1.25.1.42.2.9..025.1.25.1.42.2.9..025.0.           002460
COND QC3840.T38.T40.1.45.1.42.2.5..025.1.45.1.42.2.5..025.0.           002470
COND QC3842.T38.T42.1.25.1.42.2.9..025.1.25.1.42.2.9..025.0.           002480
COND QC3943.T39.T43.1.25.1.42.2.9..025.1.25.1.42.2.9..025.0.           002490
COND QC4044.T40.T44.1.25.1.42.2.9..025.1.25.1.42.2.9..025.0.           002500
COND QC4143.T41.T43.1.45.1.42.2.5..025.1.45.1.42.2.5..025.0.           002510
COND QC4244.T42.T44.1.45.1.42.2.5..025.1.45.1.42.2.5..025.0.           002520
COND QC4245.T42.T45.0.00.1.42.1.0.1.00..10.KP.1.0.1.00 .0.             002530
COND QC5051.T50.T51.6.2..46.6.3..25.2.00..46.3.0..250. 0.              002540
COND QC5055.T50.T55.3.2..46.12...25.1.20..46.12...250. 0.              002550
COND QC5059.T50.T59..75..46.10...25.0.75.1.38.10...063. MA             002560
COND QC5060.T50.T60.6.1..46.6.3..25.1.76.1.38.6.3..063. MA             002570
COND QC5061.T50.T61.3.1..46.6.0..25.1.76.1.38.8.5..063. MA             002580
COND QC5063.T50.T63.3.1..46.9.0..25.1.76.1.38.12...063. MA             002590
COND QC5082.T50.T82.5.5..46.5.0..25.1.35..46.1.76..39. MM              002600
COND QC5083.T50.T83.3.7..46.5.0..25.1.60..46.1.90..53. MM              002610
COND QC5084.T50.T84.7.0..46.4.0..25.1.60..46.1.90..53. MM              002620
COND QC5088.T50.T88.1.7..46.2.0..25.1.90..46.1.76..27. MM              002630
COND QC5152.T51.T52.5.5..46.3.0..25.2.90..46.4.0..250. 0.              002640
COND QC5155.T51.T55.2.5..46.3.0..25.6.00..46.2.5..250. 0.              002650
COND QC5159.T51.T59.2.5..46.2.0..25.6.20.1.38.6.2..063. MA             002660
COND QC5160.T51.T60.2.5..46.2.0..25.1.76.1.38.6.2..063. MA             002670
COND QC5185.T51.T85.2.8..46.2.0..25.1.35..46.1.76..39. MM              002680
COND QC5186.T51.T86.7.0..46.2.0..25.1.60..46.1.90..53. MM              002690
COND QC5189.T51.T89.1.3..46.2.0..25.1.90..46.1.76..27. MM              002700
COND QC5253.T52.T53.1.4..46.4.0..25.2.00..46.4.0..250. 0.              002710
COND QC5255.T52.T55.1.6..46.3.0..25.3.00..46.2.0..250. 0.              002720
COND QC5354.T53.T54.1.3..46.3.5..25.1.50..46.3.5..250. 0.              002730
COND QC5355.T53.T55.1.7..46.3.3..25.1.40..46.3.3..250. 0.              002740
COND QC5356.T53.T56.0.0.1..1..1..0.0.1..1..1..1.                       002750
COND QC5380.T53.T80.4.0..46.2.0..25.1.60..46.1.90..53. MM              002760
COND QC5455.T54.T55.1.7..46.3.0..25.3.5..46.2.0..250. 0.               002770
COND QC5457.T54.T57.0.0.1..1..1..0.0.1..1..1..1.                       002780
COND QC5481.T54.T81.2.5..46.2.0..25.1.60..46.2.50..53. MM              002790
COND QC5559.T55.T59.1.2..46.11...250.3.30.1.38.11...063. MA            002800
COND QC5563.T55.T63.1.2..46.11...250.1.76.1.38.11...063. MA            002810
COND QC5564.T55.T64.0.6..46.11...250.0.60.1.38.11...063. MA            002820
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COND QC5587.T55.T87.2.0..46.2.0..25.1.90..46.2.26..27. MM                002830
COND QC5860.T58.T60.6.2.1.38.6.3..063.1.76.1.38.6.3..063. AA              002840
COND QC5861.T58.T61.3.5.1.38.8.0..063.1.76.1.38.8.0..063. AA              002850
COND QC5863.T58.T63.3.2.1.38.12...063.1.76.1.38.12...063. AA              002860
COND QC5960.T59.T60.6.2.1.38.6.3..063.1.76.1.38.6.3..063. AA              002870
COND QC5961.T59.T61.3.5.1.38.8.0..063.1.76.1.38.8.0..063. AA              002880
COND QC5963.T59.T63.3.2.1.38.12...063.1.76.1.38.12...063. AA              002890
COND QC6061.T60.T61.3.0.1.38.3.5..063.4.2.1.38.3.5..063. AA               002900
COND QC6063.T60.T63.3.0.1.38.3.5..063.6.0.1.38.3.5..063. AA               002910
COND QC6364.T63.T64.1.76.1.38.12...063.1.2.1.38.12...063. AA              002920
COND QC8098.T80.T98..5..46.1..1..1...54.1...04. MC                        002930
COND QC8198.T81.T98..5..46.1..1..1...54.1...04.MC                         002940
COND QC8298.T82.T98..5..46.1..1..1...54.1...04.MC                         002950
COND QC8398.T83.T98..5..46.1..1..1...54.1...04.MC                         002960
COND QC8498.T84.T98..5..46.1..1..1...54.1...04.MC                         002970
COND QC8598.T85.T98..5..46.1..1..1...54.1...04.MC                         002980
COND QC8698.T86.T98..5..46.1..1..1...54.1...04.MC                         002990
COND QC9798.T97.T98.12...54.3.1416*16.73..04.1...54.3.1416*16.73..04.0.003000
COND QC9899.T98.T99.12...54.3.1416*16.73..04.1...54.3.1416*16.73..04.0.003010
RAD QR9701.T97.T01.GV.3..4...4.H                                          003020
RAD QR9706.T97.T06.GV.3..4...4.H                                          003030
RAD QR9751.T97.T51.GV.10..3..V51.HD                                       003040
RAD QR9752.T97.T52.GV.3..4..V52.HD                                        003050
RAD QR9753.T97.T53.GV.3.2.3.2..8.HD                                       003060
RAD QR9754.T97.T54.GV.3..4...8.HD                                         003070
RAD QR9756.T97.T56.GC.A107.1...8.H56                                      003080
RAD QR9757.T97.T57.GC.A107.1...8.H56                                      003090
RAD QR9758.T97.T58.GCA.6.3.10..1..HIC                                     003100
RAD QR9760.T97.T60.GCA.6.4.3.53..8.HIC                                    003110
RAD QR9761.T97.T61.GCA.8.7.3.53.1..HIC                                    003120
RAD QR9763.T97.T63.GCA.12..3.53..8.HIC                                    003130
RAD QR9764.T97.T64.GCA.2.3.12...8.H                                       003140
RAD QR9801.T98.T01.GV.3.1416*4.14**2.1..VR.HR                             003150
RAD QR9802.T98.T02.GV.5.8.1.4. VR.HR                                      003160
RAD QR9803.T98.T03.GV.2..4.. VR.HR                                        003170
RAD QR9804.T98.T04.GV.2..4.. VR.HR                                        003180
RAD QR9805.T98.T05.GV.2..7.. VR.HR                                        003190
RAD QR9806.T98.T06.GV.4.3.7.6. VR.HR                                      003200
RAD QR9807.T98.T07.GV.7.2.1.4.V07.HR                                      003210
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RAD QR9815.T98.T15.GCA.5.4.4.1..05.H                           003220
RAD CR9816.T98.T16.GCA.7.0.4.1. .25.H                          003230
RAD CR9817.T98.T17.GCA.5.4.4.1. .25.H                          003240
RAD CR9819.T98.T19.GCS.1.9.1.0. .01.H19                        003250
RAD CR9820.T98.T20.GCS.1.9.1.0. .01.H                          003260
RAD CR9825.T98.T25.GCS.2.5.1.9. .25.H                          003270
RAD CR9826.T98.T26.GCS.2.5.1.9. .15.H                          003280
RAD CR9827.T98.T27.GCS.2.5.1.9. .25.H                          003290
RAD CR9828.T98.T28.GCS.2.5.1.9. .15.H                          003300
RAD CR9829.T98.T29.GCS.2.9.1.9. .25.H                          003310
RAD CR9830.T98.T30.GCS.2.9.1.9. .15.H                          003320
RAD CR9831.T98.T31.GCS.2.9.1.9. .25.H                          003330
RAD QR9832.T98.T32.GCS.2.9.1.9. .15.H                          003340
RAD CR9833.T98.T33.GCS.2.5.1.9. .05.H                          003350
RAD CR9834.T98.T34.GCS.2.5.1.9. .02.H                          003360
RAD QR9835.T98.T35.GCS.2.5.1.9. .02.H                          003370
RAD QR9836.T98.T36.GCS.2.5.1.9. .02.H                          003380
RAD QR9837.T98.T37.GCS.2.9.2.5. .05.H                          003390
RAD QR9839.T98.T39.GCS.2.9.2.5. .05.H                          003400
RAD QR9841.T98.T41.GCS.2.9.2.5. .05.H                          003410
RAD QR9843.T98.T43.GCS.2.9.2.5. .15.H                          003420
RAD QR9850.T98.T50.GV.6.3.10.. V50.H50                         003430
RAD QR9851.T98.T51.GV.10..3.. V51.HD                           003440
RAD QR9852.T98.T52.GV.3..4.. V52.HD                            003450
RAD QR9853.T98.T53.GV.3.2.3.2. .05.H                           003460
RAD QR9854.T98.T54.GV.3..4.. .05.H                             003470
RAD QR9855.T98.T55.GV.2.3.12.. .02.H                           003480
RAD QR9880.T98.T80.GV.1.9.5.. 1..H                             003490
RAD QR9881.T98.T81.GV.2.5.5.. 1..H                             003500
RAD QR9882.T98.T82.GV.1.76.5.. 1..H                            003510
RAD QR9883.T98.T83.GV.1.9.5.. 1..H                             003520
RAD QR9884.T98.T84.GV.1.9.5.. 1..H                             003530
RAD QR9885.T98.T85.GV.1.76.5.. 1..H                            003540
RAD QR9886.T98.T86.GV.1.9.5.. 1..H                             003550
RAD QR9889.T98.T89.GV.1.76.5.. 1..H                            003560
RAD QR9890.T98.T56.GCT.1.7.1.7..15.0.                          003570
RAD QR9901.T99.T01.GV.3.1416*4.14**2.1..VR.HR                  003580
RAD QR9902.T99.T02.GV.5.8.1.4. VR.HR                           003590
RAD QR9903.T99.T03.GV.2..4.. VR.HR                             003600
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RAD QR9904.T99.T04.GV.2..4.. VR.HR                                003610
RAD QR9905.T99.T05.GV.2..7.. VR.HR                                003620
RAD QR9906.T99.T06.GV.4.3.7.6. VR.HR                              003630
RAD QR9907.T99.T07.GV.7.2.1.4.V07.HR                              003640
RAD QR9915.T99.T15.GCA.5.4.4.1. .25.H                             003650
RAD QR9916.T99.T16.GCA.7.0.4.1. .4.H                              003660
RAD QR9917.T99.T17.GCA.5.4.4.1. .4.H                              003670
RAD QR9919.T99.T19.GCS.1.9.1.0. .02.H19                           003680
RAD QR9920.T99.T20.GCS.1.9.1.0. .02.H                             003690
RAD QR9925.T99.T25.GCS.2.5.1.9. .4.H                              003700
RAD QR9926.T99.T26.GCS.2.5.1.9. .4.H                              003710
RAD QR9927.T99.T27.GCS.2.5.1.9. .4.H                              003720
RAD QR9928.T99.T28.GCS.2.5.1.9. .4.H                              003730
RAD QR9929.T99.T29.GCS.2.9.1.9. .4.H                              003740
RAD QR9930.T99.T30.GCS.2.9.1.9. .4.H                              003750
RAD QR9931.T99.T31.GCS.2.9.1.9. .25.H                             003760
RAD QR9932.T99.T32.GCS.2.9.1.9. .25.H                             003770
RAD QR9933.T99.T33.GCS.2.5.1.9. .25.H                             003780
RAD QR9934.T99.T34.GCS.2.5.1.9. .25.H                             003790
RAD QR9935.T99.T35.GCS.2.5.1.9. .15.H                             003800
RAD QR9936.T99.T36.GCS.2.5.1.9. .15.H                             003810
RAD QR9937.T99.T37.GCS.2.9.2.5. .01.H                             003820
RAD QR9939.T99.T39.GCS.2.9.2.5. .02.H                             003830
RAD QR9941.T99.T41.GCS.2.9.2.5. .02.H                             003840
RAD QR9943.T99.T43.GCS.2.9.2.5. .05.H                             003850
RAD QR9950.T99.T50.GV.6.3.10.. V50.H50                            003860
RAD QR9951.T99.T51.GV.10..3.. V51.HD                              003870
RAD QR9952.T99.T52.GV.3..4.. V52.HD                               003880
RAD QR9953.T99.T53.GV.3.2.3.2. .15.H                              003890
RAD QR9954.T99.T54.GV.3..4.. .15.H                                003900
RAD QR9955.T99.T55.GV.2.3.12.. .15.H                              003910
RAD QR9980.T99.T80.GV.1.9.5.. 1..H                                003920
RAD QR9981.T99.T81.GV.2.5.5.. 1..H                                003930
RAD QR9982.T99.T82.GV.1.76.5.. 1..H                               003940
RAD QR9983.T99.T83.GV.1.9.5.. 1..H                                003950
RAD QR9984.T99.T84.GV.1.9.5.. 1..H                                003960
RAD QR9985.T99.T85.GV.1.76.5.. 1..H                               003970
RAD QR9986.T99.T86.GV.1.9.5.. 1..H                                003980
RAD QR9989.T99.T89.GV.1.76.5.. 1..H                               003990
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RAD QR9990,T99,T90,GCT,1,7,1,7,.25,0.
Q01=-QC0103-QC0106-QC0107-QC0109-QC0111-QC0120-QC0134-QC0136...
-QC0138-QC0142-QC0199-QC0180-QC0181+QR9801+QR9901+M52*QR9701
Q02=-QC0211-QC0212-QC0230-QC0232-QC0242-QC0244-QC0299+QC0102...
-QC0282+QR9802+QR9902
Q03=-QC0304-QC0307-QC0310-QC0312-QC0326-QC0328-QC0340-QC0344...
-QC0399-QC0383+QR9803+QR9903
Q04=-QC0405-QC0407-QC0408-QC0414-QC0417-QC0499+QC0304-QC0484...
+QR9804+QR9904
Q05=-QC0506-QC0508-QC0514-QC0516-QC0599+QC0405-QC0585-QC0589...
+QR9805+QR9905
Q06=-QC0608-QC0614-QC0615-QC0699+QC0106+QC0506-QC0686+QR9806...
+QR9906+M52*QR9706
Q07=-QC0708-QC0709-QC0710-QC0714-QC0718-QC0720-QC0722-QC0724...
-QC0738-QC0740+QC0107+QC0307-QC0787-QC0788+QR9807+QR9907
Q08=-QC0814-QC0815-QC0816-QC0817-QC0818+QC0408+QC0508+QC0608 ...
+QC0708
Q09=-QC0910-QC0911-QC0922-QC0936-QC0938+QC0109+QC0709
Q10=-QC1012-QC1024-QC1026-QC1040+QC0310+QC0710+QC0910
Q11=-QC1112-QC1132-QC1134-QC1142+QC0111+QC0211
Q12=-QC1228-QC1230-QC1244+QC0212+QC0312+QC1012+QC1112
Q13=-QC1315-QC1316-QC1317-QC1318
Q14=-QC1415-QC1416-QC1417-QC1418+QC0414+QC0514+QC0614+QC0714+QC0814
Q15=-QC1516-QC1518+QC0615+QC0815+QC1315+QC1415+QR9815+QR9915
Q16=-QC1617+QC0516+QC0816+QC1316+QC1416+QC1516+QR9816+QR9916
Q17=-QC1718+QC0417+QC0817+QC1317+QC1417+QC1617+QR9817+QR9917
Q18= QC0718+QC0818+QC1318+QC1418+QC1518+QC1718
Q19=(-QC1922-QC1921-QC1935+QR9819+QR9919)*(1.-M19)
Q20=-QC2022-QC2036+QC0120+QC0720+QC1920+QR9820+QR9920
Q21=-QC2122-QC2123-QC2137+QC1921
Q22=-QC2224-QC2238+QC0722+QC0922+QC2022+QC2122
Q23=-QC2324-QC2325-QC2339+QC2123
Q24=-QC2426-QC2440+QC0724+QC1024+QC2224+QC2324
Q25=-QC2526-QC2527-QC2539+QC2325+QR9825+QR9925
Q26=-QC2628-QC2640+QC0326+QC1026+QC2426+QC2526+QR9826+QR9926
Q27=-QC2728-QC2729-QC2743-QC2527+QR9827+QR9927
Q28=-QC2830-QC2844+QC0328+QC1228+QC2628+QC2728+QR9828+QR9928
Q29=-QC2931-QC2943+QC2729+QR9829+QR9929
Q30=-QC3032-QC3044+QC0230+QC1230+QC2830+QC2930+QR9830+QR9930
```

```
Q31=-QC3132-QC3133-QC3141+QC2931+QR9831+QR9931
Q32=-QC3234-QC3242-QC3245+QC0232+QC1132+QC3032+QC3132+QR9832+QR9932
Q33=-QC3334-QC3335-QC3341+QC3133+QR9833+QR9933
Q34=-QC3436-QC3442-QC3445+QC0134+QC1134+QC3234+QC3334+QR9834+QR9934
Q35=-QC3536-QC3537+QC1935+QC3335+QR9835+QR9935
Q36=-QC3638+QC0136+QC0936+QC2036+QC3436+QC3536+QR9836+QR9936
Q37=-QC3739-QC3741+QC2137+QC3537+QR9837+QR9937
Q38=-QC3840-QC3842+QC0138+QC0738+QC0938+QC2238+QC3638
Q39=-QC3943+QC2339+QC2539+QC3739+QR9839+QR9939
Q40=-QC4044+QC0340+QC0740+QC1040+QC2440+QC2640+QC3840
Q41=-QC4143+QC3141+QC3341+QC3741+QR9841+QR9941
Q42=-QC4244-QC4245+QC0142+QC0242+QC1142+QC3242+QC3442+QC3842
Q43= QC2743+QC2943+QC3943+QC4143+QR9843+QR9943
Q44= QC0244+QC0344+QC1244+QC2844+QC3044+QC4044+QC4244
Q45=-QC3245+QC3445+QC4245
Q50=-QC5051-QC5055-QC5059-QC5060-QC5061          -QC5063...
-QC5082-QC5083-QC5084-QC5088+QR9850+QR9950
Q51=(-QC5152)*(1.-M52)-QC5155-QC5159-QC5160-QC5185-QC5186-QC5189...
+QC5051+QR9851+QR9951+QR9751
Q52=(-QC5253-QC5255+QC5152+QR9852+QR9952+QR9752)*(1.-M52)
Q53=-QC5354-QC5355-QC5356+QC5253*(1.-M52)+QR9853+QR9953+QR9753
Q54=-QC5455-QC5457-QC5481+QC5354+QR9854+QR9954+QR9754
Q55=-QC5559-QC5563-QC5564-QC5587+QC5055+QC5155+QC5255*(1.-M52)...
+QC5355+QC5455+QR9855+QR9955
Q56= (QC5356+QR9756)*(1.-M56)
Q57= QC5457+QR9757
Q58=(-QC5860-QC5861          -QC5863+QR9758)*(1.-M58)
Q59=-QC5960-QC5961          -QC5963+QC5059+QC5159+QC5559
Q60=-QC6061-QC6063+QC5060+QC5160+QC5860+QC5960+QR9760
Q61=        +QC5061+QC5861+QC5961+QC6061+QR9761
Q63=-QC6364+QC5063+QC5563+QC5863+QC5963+QC6063          +QR9763
Q64= QC6364+QC5564+QC6364+QR9764
Q80= QC0180+QC5380-QC8098+QR9880+QR9980
Q81= QC0181+QC5481-QC8098+QR9881+QR9981
Q82= QC0282+QC5082-QC8098+QR9882+QR9982
Q83= QC0383+QC5083-QC8098+QR9883+QR9983
Q84= QC0484+QC5084-QC8098+QR9884+QR9984
Q85= QC0585+QC5185-QC8098+QR9885+QR9985
Q86= QC0686+QC5186-QC8098+QR9886+QR9986
```

```
Q87= QC0787+QC5587
Q88= QC0788+QC5088
Q89= QC0589+QC5189+QR9889+QR9989
Q90=QR9990+QR9890
Q97=-QC9798+QRSH97-QR9751-QR9752-QR9753-QR9754-QR9756-QR9757 ...
-QR9758-QR9760-QR9761      -QR9763-QR9764-WS2*(QR9701+QR9706)
Q98= QC9798-QC9899+7.*QC8098-QR9890+QRSH98 ...
-QR9801-QR9802-QR9803-QR9804-QR9805-QR9806-QR9815-QR9816...
-QR9817-QR9819-QR9820-QR9825-QR9826-QR9827-QR9828-QR9829...
-QR9830-QR9831-QR9832-QR9833-QR9834-QR9835-QR9836-QR9837...
-QR9839-QR9841-QR9843-QR9850-QR9851-QR9852-QR9853-QR9854...
-QR9855-QR9880-QR9881-QR9882-QR9883-QR9884-QR9885-QR9886...
-QR9889-QR9890-QR9807
Q99= QC9899+QC0199+QC0299+QC0399+QC0499+QC0599+QC0699-QR9990...
-QR9901-QR9902-QR9903-QR9904-QR9905-QR9906-QR9915-QR9916...
-QR9917-QR9919-QR9920-QR9925-QR9926-QR9927-QR9928-QR9929...
-QR9930-QR9931-QR9932-QR9933-QR9934-QR9935-QR9936-QR9937...
-QR9939-QR9941-QR9943-QR9950-QR9951-QR9952-QR9953-QR9954...
-QR9955-QR9980-QR9981-QR9982-QR9983-QR9984-QR9985-QR9986...
-QR9989-QR9990-QR9907
DT DT01,Q01,6.06,3.1416*8.28**2.1./4...5
DT DT02,Q02,6.06,5.8,2.8/2...5
DT DT03,Q03,6.06,2.0,4.0,.5
DT DT04,Q04,6.06,2.0,4.0,.5
DT DT05,Q05,6.06,2.0,7.0,.5
DT DT06,Q06,6.06,4.3,7.6,.5
DT DT07,Q07,6.06,7.2,1.4,.5
DT DT08,Q08,6.06,7.0,5.4,.22
DT DT09,Q09,6.06,2.9,2.5,.22
DT DT10,Q10,6.06,2.9,2.5,.22
DT DT11,Q11,6.06,2.9,2.5,.22
DT DT12,Q12,6.06,2.9,2.5,.22
DT DT13,Q13,4.31,7.0,5.4,.063
DT DT14,Q14,.7,36,9.1,.1.
DT DT15,Q15,4.31,5.4,4.1,.063
DT DT16,Q16,4.31,3.89,1.,1.
DT DT17,Q17,4.31,5.4,4.1,.063
DT DT18,Q18,4.31,7.0,4.1,.063
DT DT19,Q19,FT,1.9,1.0,.050
```

```
DT DT20,C20,3,08,1,9,1,0,.050                                        005170
DT DT21,C21,3,08,2,9,1,9,.025                                        005180
DT DT22,C22,3,08,2,9,1,9,.025                                        005190
DT DT23,C23,3,08,2,9,1,9,.025                                        005200
DT DT24,C24,3,08,2,9,1,9,.025                                        005210
DT DT25,C25,3,08,2,5,1,9,.025                                        005220
DT DT26,C26,3,08,2,5,1,9,.025                                        005230
DT DT27,C27,3,08,2,5,1,9,.025                                        005240
DT DT28,C28,3,08,2,5,1,9,.025                                        005250
DT DT29,C29,3,08,2,9,1,9,.025                                        005260
DT DT30,C30,3,08,2,9,1,9,.025                                        005270
DT DT31,C31,3,08,2,9,1,9,.025                                        005280
DT DT32,C32,3,08,2,9,1,9,.025                                        005290
DT DT33,C33,3,08,2,5,1,9,.025                                        005300
DT DT34,C34,3,08,2,5,1,9,.025                                        005310
DT DT35,C35,3,08,2,5,1,9,.025                                        005320
DT DT36,C36,3,08,2,5,1,9,.025                                        005330
DT DT37,C37,3,08,2,9,2,5,.025                                        005340
DT DT38,C38,3,08,2,9,2,5,.025                                        005350
DT DT39,C39,3,08,2,9,2,5,.025                                        005360
DT DT40,C40,3,08,2,9,2,5,.025                                        005370
DT DT41,C41,3,08,2,9,2,5,.025                                        005380
DT DT42,C42,3,08,2,9,2,5,.025                                        005390
DT DT43,C43,3,08,2,9,2,5,.025                                        005400
DT DT44,C44,3,08,2,9,2,5,.025                                        005410
DT DT45,C45,F45,1,.1,.1.                                             005420
DT DT50,C50,6,06,.25,6,3,10.                                         005430
DT DT51,C51,6,06,.25,10,.3.                                          005440
DT DT52,C52,6,06,.25,3,.4.                                           005450
DT DT53,C53,6,06,.25,3,2,3,2                                         005460
DT DT54,C54,6,06,.25,3,.4.                                           005470
DT DT55,C55,6,06,.25,2,3,12.                                         005480
DT DT56,C56,FASD,1,.1,.1.                                            005490
DT DT57,C57,FASD,1,.1,.1.                                            005500
DT DT58,C58,4,31,.063,6,3,10.                                        005510
DT DT59,C59,4,31,THIC,6,3,10.                                        005520
DT DT60,C60,4,31,.063,6,4,3,53                                       005530
DT DT61,C61,4,31,.063,8,7,3,53                                       005540
DT DT63,C63,4,31,.063,12,.3,53                                       005550
```

```
DT DT64,C64,4.31,.063,2.3,12.
DT DT80,C80,6,.06,.53,1.9,5.
DT DT81,C81,6,.06,.53,2.5,5.
DT DT82,C82,6,.06,.39,1.76,5.
DT DT83,C83,6,.06,.39,1.9,5.
DT DT84,C84,6,.06,.39,1.9,5.
DT DT85,C85,6,.06,.39,1.76,5.
DT DT86,C86,6,.06,.53,1.9,5.
DT DT87,C87,6,.06,.27,2.26,5.
DT DT88,C88,6,.06,.27,1.76,5.
DT DT89,C89,6,.06,.27,1.76,5.
DT DT90,C90,4.31,.2,1.3,3.1416*1.8
DT DT97,C97,4.4,.04,3.1416*16.73,16.73/4.+4.34
DT DT98,C98,4.4,.04,3.1416*16.73,2.12
DT DT99,C99,4.4,.04,3.1416*16.73,2.64
T01=INTEG(DT01,60.)
T02=INTEG(DT02,60.)
T03=INTEG(DT03,60.)
T04=INTEG(DT04,60.)
T05=INTEG(DT05,60.)
T06=INTEG(DT06,60.)
T07=INTEG(DT07,60.)
T08=INTEG(DT08,60.)
T09=INTEG(DT09,60.)
T10=INTEG(DT10,60.)
T11=INTEG(DT11,60.)
T12=INTEG(DT12,60.)
T13=INTEG(DT13,60.)
T14=INTEG(DT14,60.)
T15=INTEG(DT15,60.)
T16=INTEG(DT16,60.)
T17=INTEG(DT17,60.)
T18=INTEG(DT18,60.)
T19=INTEG(DT19,60.)
T20=INTEG(DT20,60.)
T21=INTEG(DT21,60.)
T22=INTEG(DT22,60.)
T23=INTEG(DT23,60.)
T24=INTEG(DT24,60.)
```

```
T25=INTEG(DT25,60.)                                                    005950
T26=INTEG(DT26,60.)                                                    005960
T27=INTEG(DT27,60.)                                                    005970
T28=INTEG(DT28,60.)                                                    005980
T29=INTEG(DT29,60.)                                                    005990
T30=INTEG(DT30,60.)                                                    006000
T31=INTEG(DT31,60.)                                                    006010
T32=INTEG(DT32,60.)                                                    006020
T33=INTEG(DT33,60.)                                                    006030
T34=INTEG(DT34,60.)                                                    006040
T35=INTEG(DT35,60.)                                                    006050
T36=INTEG(DT36,60.)                                                    006060
T37=INTEG(DT37,60.)                                                    006070
T38=INTEG(DT38,60.)                                                    006080
T39=INTEG(DT39,60.)                                                    006090
T40=INTEG(DT40,60.)                                                    006100
T41=INTEG(DT41,60.)                                                    006110
T42=INTEG(DT42,60.)                                                    006120
T43=INTEG(DT43,60.)                                                    006130
T44=INTEG(DT44,60.)                                                    006140
T45=INTEG(DT45,60.)                                                    006150
T50=INTEG(DT50,60.)                                                    006160
T51=INTEG(DT51,60.)                                                    006170
T52=INTEG(DT52,60.)                                                    006180
T53=INTEG(DT53,60.)                                                    006190
T54=INTEG(DT54,60.)                                                    006200
T55=INTEG(DT55,60.)                                                    006210
T56=INTEG(DT56,60.)                                                    006220
T57=INTEG(DT57,60.)                                                    006230
T58=INTEG(DT58,60.)                                                    006240
T59=INTEG(DT59,60.)                                                    006250
T60=INTEG(DT60,60.)                                                    006260
T61=INTEG(DT61,60.)                                                    006270
T63=INTEG(DT63,60.)                                                    006280
T64=INTEG(DT64,60.)                                                    006290
T80=INTEG(DT80,60.)                                                    006300
T81=INTEG(DT81,60.)                                                    006310
T82=INTEG(DT82,60.)                                                    006320
T83=INTEG(DT83,60.)                                                    006330
```

```
TA4=INTEG(DTA4,60.)
TA5=INTEG(DTA5,60.)
TA6=INTEG(DTA6,60.)
TA7=INTEG(DTA7,60.)
TA8=INTEG(DTA8,60.)
TA9=INTEG(DTA9,60.)
T90=INTEG(DT90,60.)
T97=INTEG(DT97,60.)
T98=INTEG(DT98,60.)
T99=INTEG(DT99,60.)
CINTERVAL CI= 12.
TERMT(T.GE.TE)
TABLE TEST15,1,26,0.,40.,48.,56.,64.,72.,80.,88.,96.,104.,...
112.,120.,144.,152.,160.,168.,176.,184.,192.,200.,...
208.,240.,248.,256.,264.,600.0, ...
60.,65.,124.,197.,274.,356.,435.,462.,575.,674.,771.,...
837.,944.,958.,963.,963.,957.,882.,941.,887.,...
889.,1090.,1124.,1135.,1150.,1150.
TC15=TEST15(T)
TABLE TEST24,1,90,0.,40.,48.,56.,64.,72.,80.,88.,96.,104.,...
112.,120.,128.,136.,144.,152.,160.,168.,176.,184.,192.,...
200.,208.,216.,224.,232.,240.,248.,256.,...
264.,272.,280.,288.,296.,304.,312.,320.,328.,336.,344.,...
352.,360.,368.,376.,384.,392.,400.,408.,416.,424.,432.,440.,...
448.,456.,464.,472.,480.,488.,496.,504.,512.,520.,528.,...
536.,544.,552.,560.,568.,576.,584.,592.,600.,608.,616.,...
624.,664.,680.,688.,712.,728.,736.,744.,752.,760.,768.,...
776.,784.,792.,800.,900.,...
60.,61.,68.,80.,96.,114.,135.,152.,177.,210.,242.,275.,...
304.,331.,353.,373.,389.,405.,418.,430.,440.,451.,...
470.,478.,494.,513.,526.,545.,562.,...
580.,592.,607.,619.,631.,645.,657.,672.,683.,701.,709.,...
721.,735.,748.,761.,775.,788.,799.,810.,820.,829.,835.,...
844.,852.,861.,870.,879.,887.,895.,902.,911.,920.,927.,...
934.,940.,947.,939.,959.,966.,969.,963.,978.,982.,986.,...
990.,995.,1018.,1027.,1033.,1047.,1059.,1065.,1071.,1076.,1082.,...
1088.,1094.,1100.,1103.,1110.,1110.
TC24=TEST24(T)
TABLE TEST26,1,27,0.,80.,128.,160.,184.,248.,280.,...
```

```
320.,360.,384.,408.,432.,456.,480.,504.,528.,552....
584.,608.,632.,656.,680.,704.,728.,752.,776.,800.....
60.,60.,69.,81.,94.,144.,176.,223.,272.,300.,327.....
358.,388.,415.,445.,471.,497.,527.,552.,572.,594.....
613.,631.,650.,667.,682.,700.
TC26=TEST26(T)
TABLE TEST21,1,16,0.,80.,160.,240.,320.,400.,480.,560.. ...
640.,720.,800.,880.,960.,1040.,1120.,1200.. ...
60.,83.,153.,202.,277.,368.,485.,589.,671.,756.,903.. ...
1028.,1073.,1097.,1118.,1118.
TC21=TEST21(T)
TABLE TEST22,1,12,0.,80.,160.,240.,320.,400.,480.,560.. ...
640.,720.,800.,900.. ...
60.,168.,393.,534.,657.,797.,887.,980.,1019.,1092.,1139.. ...
1139.
TC22=TEST22(T)
TABLE TEST12,1,15,0.,80.,160.,240.,320.,400.,480.,560.. ...
640.,720.,800.,880.,960.,1040.,1120.. ...
60.,61.,78.,95.,125.,140.,151.,204.,236.,276.,306.,341.. ...
398.,455.,529.
TC12=TEST12(T)
TABLE TEST25,1,14,0.,80.,160.,240.,320.,400.,480.,560.. ...
640.,720.,800.,880.,960.,1006.. ...
60.,85.,226.,356.,501.,620.,730.,810.,853.,899.,960.. ...
997.,1046.,1069.
TC25=TEST25(T)
TABLE TEST27,1,9,0.,80.,160.,240.,320.,400.,480.,518.. ...
600.. ...
60.,71.,111.,147.,201.,252.,305.,335.,335.
TC27=TEST27(T)
END
7/8/9
OUTPUT
PREPAR TC24,TC15,TC26,T52,T58,T07,TC12,TC21,TC22. ...
T45,T90,T56,TC25,TC27,T19,T50,TSH,T51
START
PLOT T,T52,TC24
PLOT T,T56,TC22
PLOT T,T58,TC15
```

```
      PLOT T,T90,TC21                                                   007120
      PLOT T,T10,TC27                                                   007130
      PLOT T,T45,TC12                                                   007140
      PLOT T,T50,TC25                                                   007150
      PLOT T,T07,TC26                                                   007160
      PLOT T,TSH                                                        007170
      STOP                                                              007180
```

```
FRED,CM150000,T16,IC15.                                    000100
COMMENT.(XXX-XXX,IDREF).MULLER THERMAL ANALYSIS            000110
REWIND,INPUT.                                              000120
COPYSBF.                                                   000130
REWIND,INPUT.                                              000140
COPYBR,INPUT,S.                                            000150
ATTACH,72,CSL,CY=2,ID=MULLEREA.                            000160
ATTACH,LGO,LGO,CY=15,ID=MULLEREA.                          000170
RFL,150000.                                                000180
LOAD,72.                                                   000190
LGO.                                                       000200
7/8/9                                                      000210
 INPUT GC=.020                                             000220
 INPUT XX=1.,TMAX=1800.                                    000230
 PREPAR Q32,034,Q42                                        000240
 START                                                     000250
 PLOT T,Q32,034,Q42                                        000260
 STOP                                                      000270
```

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