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HTFLO - A COMPUTER MODEL OF A RESISTIVELY-
HEATED UO_2 PIN WITH A RATE-DEPENDENT HEAT
CAPACITY

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CONTENTS

INTRODUCTION.	5
DESCRIPTION OF THE PROGRAM.	6
General Equations.	6
Cylindrical Geometry Case.	6
Boundary and Source Terms.	10
Dynamic Heat Capacity Model.	12
SAMPLE CALCULATION.	16
HTFLO Input Data	16
Output	17
APPENDIX A - Thermal Properties of UO_2 Used in HTFLO.	18
APPENDIX B - FORTRAN Listing of HTFLO for CDC7600	20
APPENDIX C - Sample Calculation Using HTFLO	26
REFERENCES.	39

LIST OF FIGURE;

Figure 1. Cylindrical geometry and indexing convention	7
Figure 2. Two models for the heat capacity of solid UO_2	13
Figure 3. Illustration of temperature/enthalpy history for one zone during a single time step	14
Figure 4. Input data cards for the sample HEPLO calculation.	27

INTRODUCTION

A one-dimensional model, HTFLO, has been developed to describe the thermal behavior of a uranium dioxide (UO_2) rod that is heated resistively and cooled by surface radiation. The heat transfer portion of the program is a forward differencing scheme based on ONEDIM.⁽¹⁾ The major differences are that HTFLO incorporates a dynamic heat capacity model, the sample's temperature-dependent electrical properties are calculated for each time step and corrections are included for the cylindrical geometry. The dynamic heat capacity model used in HTFLO is empirical with an adjustable relaxation time constant. A more detailed theoretical model which treats the dynamic heat capacity on a microscopic scale based on real physical considerations has also been developed recently.⁽²⁾

This model was developed to aid in designing an experiment to measure the heat capacity of UO_2 during rapid resistive heating. A major limitation to this technique arises from the increase in electrical conductivity as the temperature rises. This can lead to an unstable heating mode in which a hot filament builds up in the sample's interior. HTFLO has been used to assess the feasibility of a series of experimental configurations.

This report describes the finite difference equations used, the treatment of the source and boundary terms, and the dynamic enthalpy model. Detailed input instructions are provided and a sample calculation is shown.

DESCRIPTION OF THE PROGRAM

General Equations

The program solves the general heat conduction equation for the case in which the modeled pin is divided into many concentric zones, the temperature for each of which is governed by the following equation: (5)

$$\nabla \cdot (k\nabla T) + \dot{q} = \rho c \frac{\partial T}{\partial t} \quad (1)$$

T is the temperature of the zone and $\dot{q}$ is the heat generation rate per unit volume, and k , ρ and c are the thermal conductivity, density and specific heat, respectively.

The boundary conditions imposed on Equation (1) are the continuity of temperature and heat flux at the boundaries of each zone. The initial condition is the sample's temperature profile at zero time.

Cylindrical Geometry Case

The one-dimensional form of equation (1) can be written in cylindrical coordinates as

$$k \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right) + \dot{q} = \rho c \frac{\partial T}{\partial t} \quad (2)$$

where k is assumed to be a slowly varying function of r .

To solve this equation using a finite difference technique, the sample is divided into N , equally spaced, radial zones. The sample's length and diameter are L and D , respectively. For the one-dimensional problem there is no variation of temperature, properties or geometry in the axial or angular dimensions. Figure 1 illustrates the geometry and zone numbering convention. Note that the outermost zone is labeled $I = 1$.

The first term in equation (2) is the net rate heat is conducted into a given zone. Applying the Divergence Theorem yields Fourier's Law:

$$-k \frac{\partial T}{\partial r} = \dot{q}_s \quad (3)$$

Figure 1. Cylindrical geometry and indexing convention. To simplify the figure, only a segment of the entire cylinder is shown.

where $\dot{q}_s$ is the surface heat flux. For a hollow cylinder of inner radius a and outer radius b , equation (3) is solved by

$$T = \frac{T_a - T_b}{\ln(\frac{a}{b})} \ln r + \text{const.} \quad (4)$$

Using this expression for T , equation (3) becomes:

$$\dot{q}_s = - \frac{k}{r \ln \frac{a}{b}} (T_a - T_b) \quad (5)$$

Equation (5) is expressed in terms of the zone boundary temperatures. A more convenient form for calculations would be in terms of the node temperatures. To do this, first consider the heat flux through the right half (as depicted in figure (1)) of zone n :

$$\dot{q}_s = - \frac{k_n}{r \ln \frac{b}{r_n}} (T_n - T_b) \quad (6)$$

The thermal conductivity is subscripted since it can have different values in each zone.

Next, consider the heat flux through the left half of zone $n-1$:

$$\dot{q}_s = - \frac{k_{n-1}}{r \ln \frac{r_{n-1}}{b}} (T_b - T_{n-1}) \quad (7)$$

$\dot{q}_s$ is the same in equations (6) and (7) as required by the boundary condition of continuous heat flux. These equations can be solved for the surface temperature (T_b) at $r = b$:

$$T_b = \frac{\frac{k_n T_n}{\ln\left(\frac{b}{r_n}\right)} + \frac{k_{n-1} T_{n-1}}{\ln\left(\frac{r_{n-1}}{b}\right)}}{\frac{k_n}{\ln\left(\frac{b}{r_n}\right)} + \frac{k_{n-1}}{\ln\left(\frac{r_{n-1}}{b}\right)}} \quad (8)$$

Substituting this expression for T_b into equation (6) and rearranging gives

$$\dot{q}_s = -\frac{1}{r} \left(\frac{\ln\left(\frac{b}{r_n}\right)}{k_n} + \frac{\ln\left(\frac{r_{n-1}}{b}\right)}{k_{n-1}} \right)^{-1} (T_n - T_{n-1}) \quad (9)$$

Multiplying equation (9) by the surface area ($2\pi rL$) gives the net rate heat is conducted from zone n into zone n-1:

$$\dot{Q}_R = - \left(\frac{\ln\left(\frac{b}{r_n}\right)}{2\pi L k_n} + \frac{\ln\left(\frac{r_{n-1}}{b}\right)}{2\pi L k_{n-1}} \right)^{-1} (T_n - T_{n-1}) \quad (10)$$

In a similar manner, the heat conducted into zone n from zone n+1 is

$$\dot{Q}_L = - \left(\frac{\ln\left(\frac{a}{r_{n+1}}\right)}{2\pi L k_{n+1}} + \frac{\ln\left(\frac{r_n}{a}\right)}{2\pi L k_n} \right)^{-1} (T_n - T_{n+1}) \quad (11)$$

The net heat gain per unit volume for zone n becomes

$$\frac{\dot{Q}_R + \dot{Q}_L}{\pi(b^2 - a^2)L} \quad (12)$$

Next, the time derivative of temperature in equation (2) is approximated by the following standard difference operator: (1)

$$\frac{\partial T_n}{\partial t} = \frac{T_n^{t+\Delta t} - T_n^t}{\Delta t} \quad (13)$$

The superscripts refer to time and the subscript refers to position.

Finally, the expressions in equations (10), (11), (12), and (13) can be combined in equation (2) and rearranged to give

$$T_n^{t+\Delta t} = T_n^t + \frac{\Delta t}{\rho c} \frac{1}{\pi(b^2 - a^2)} \left(\frac{\ln\left(\frac{a}{r_{n+1}}\right)}{2\pi k_{n+1}} + \frac{\ln\left(\frac{R}{a}\right)^{-1}}{2\pi k_n} \right) (T_{n+1} - T_n) \\ + \frac{\Delta t}{\rho c} \frac{1}{\pi(b^2 - a^2)} \left(\frac{\ln\left(\frac{b}{r_n}\right)}{2\pi k_n} + \frac{\ln\left(\frac{r_{n-1}}{b}\right)^{-1}}{2\pi k_{n-1}} \right) (T_{n-1} - T_n) + \frac{\dot{q}\Delta t}{\rho c} \quad (14)$$

Equation (14) can now be used to calculate the temperature of zone n at time $t + \Delta t$. The solutions will be stable if the following condition is satisfied: (3)

$$\Delta t < \frac{(\Delta x)^2}{2 \frac{k}{\rho c}} \quad (15)$$

In addition, accuracy is improved as Δt is reduced.

Boundary and Source Terms

The source term, $\dot{q}$, in equation (10) can be calculated for each zone. It is assumed that each zone has the same voltage, V , applied across it during a given time step. The heat generated per unit time is given by

$$\dot{q} \text{ VOL} = \frac{V^2}{R} \quad (16)$$

where R is the resistance of the zone and VOL is the volume of the zone. R can be calculated from

$$R = \frac{1}{\sigma} \frac{L}{A} \quad (17)$$

where σ , L and A are the conductivity, length, and cross-sectional area in the axial direction, respectively. If Equation (17) is substituted into Equation (16), the source term becomes

$$\dot{q} \text{ VOL} = \left(\frac{V}{L}\right)^2 \sigma \text{ VOL} \quad (18)$$

In HTFLO, the applied voltage may be calculated in one of three ways. If the heating mode is by capacitive discharge, V is the capacitor voltage. The total energy drained during a time step is used to calculate the voltage at the beginning of the next time step. Heating is terminated when the voltage falls below a predetermined value.

In the constant current mode, the sample's total resistance is calculated at each time step and the voltage determined from the product of current and resistance. In the voltage mode, a fixed resistor is assumed in series with the sample. As in the current mode, the sample's resistance is calculated at each time step. The result is used to determine the fraction of the applied voltage dropped across the sample. In the current and voltage modes, heating is terminated after a specified time has elapsed or the surface temperature reaches a set value.

The surface boundary term is radiation at a fixed emissivity to a fixed heat sink temperature. The surface temperature is calculated from the boundary condition of continuous heat flux. First, the radiated power is given by the Stefan-Boltzmann equation:

$$\dot{Q} = A\epsilon\sigma (T^4 - T_{sk}^4) \quad (19)$$

where A is the external surface area of the pin, ϵ is the emissivity, σ the Stefan-Boltzmann constant, T is the surface temperature and T_{sk} is the heat sink temperature. Following the technique of Gabrielson et al.⁽¹⁾, equation (19) can be factored to give

$$\dot{Q} = A\epsilon\sigma (T^2 + T_{sk}^2)(T + T_{sk})(T - T_{sk}) \quad (20)$$

This expression is made a linear function of the temperature difference between the surface and the heat sink for a given time step by defining a surface heat transfer coefficient, H_R :

$$H_R = A\epsilon\sigma (T^2 + T_{sk}^2)(T + T_{sk}) \quad (21)$$

Second, the rate heat is conducted from the outermost zone to the surface is given by

$$\dot{Q} = U_1 (T_1 - T) \quad (22)$$

where T_1 is the temperature of zone 1. U_1 is defined by

$$U_1 = \frac{2\pi L k_1}{\ln\left(\frac{\frac{D}{2}}{\frac{D}{2} - \frac{\Delta r}{2}}\right)} \quad (23)$$

where T_1 is the temperature of zone 1. The boundary condition requires the two powers be equal.

$$H_R (T - T_{sk}) = U_1 (T_1 - T) \quad (24)$$

Solving Equation (24) for the surface temperature gives

$$T = \frac{U_1 T_1 + H_R T_{sk}}{U_1 + H_R} \quad (25)$$

The boundary condition between zones is the continuity of heat flux. At the center of the pin the heat flux is zero.

Dynamic Heat Capacity Model

Two heat capacity models for UO_2 are shown in Figure (2). Model 2 is based on measurements by standard calorimetry methods with long heating and cooling times.⁽⁴⁾ Some recent transient vaporization experiments⁽⁵⁾ suggest that model 1, a linear extrapolation of the 1000-1500K data from model 2, applies to rapid heating and cooling processes.

HTFLO incorporates a dynamic heat capacity model in which the instantaneous temperature rise in response to a heat input is calculated using the linear heat capacity of model 1. Then, the temperature is relaxed exponentially at constant enthalpy to the value given by the heat capacity of model 2.

Figure 2. Two Models for the Heat Capacity of Solid UO_2 .

H_1 : INSTANTANEOUS ENTHALPY/TEMPERATURE CURVE FOR MODEL 1

H_2 : EQUILIBRIUM ENTHALPY/TEMPERATURE CURVE FOR MODEL 2

Figure 3. Illustration of temperature/enthalpy history for one zone during a single time step.

This process is illustrated in Figure 3. H_1 and H_2 are the temperature-enthalpy curves corresponding to heat capacity models 1 and 2, respectively; T_1 and H_1 are the temperature and enthalpy of a given zone at the start of a time step. A quantity of heat is added raising the enthalpy to H_f . T_1 is the instantaneous temperature. T_2 is the equilibrium temperature at enthalpy H_f . T_f is the final temperature for the time step and is calculated by

$$T_f = T_1 - (T_1 - T_2)(1 - e^{-\Delta t/\tau}) \quad (26)$$

where Δt is the length of the time step and τ is the relaxation time.

SAMPLE CALCULATION

As the introduction stated, HTFLO was developed to help assess the feasibility of a resistive heating experiment by simulating various proposed configurations. The program is arranged, therefore, to set the sample geometry, emissivity, initial temperature and heat sink temperature at the beginning of each calculation. Then, during the calculation, various heating modes can be set up to simulate the switching on of several different power supplies separated by periods of pure heat conduction (no heating). Each of these periods is called a separate heating period.

HTFLO Input Data

The first card of the data deck contains the geometric information for the sample. The sample length (in cm), diameter (in cm) and number of zones are required. The read statement is in free format. This card is included only once regardless of the number of calculations to be performed in any given job.

The next card, also in free format, gives the following data:

1. The number of heating periods in the calculation.
2. The surface emissivity of the sample.
3. The heat sink temperature (in °K).
4. The initial sample temperature--assumed spatially uniform (in °K).
5. The heat capacity relaxation time (in msec).

Then, each heating period in the calculation requires a separate data card using the format

FORMAT (2I5, 2F10.4, 2I5, 2F10.4).

The details of each input variable are as follows:

1. HTFLAG - defines whether there is resistive heating during the period:
 - 0, No heating
 - 1, Heating
2. LFLAG - defines the limiting condition for terminating the period:
 - 1, Time Limit
 - 0, Surface Temperature Limit
 - 1, Capacitor Voltage Limit

3. LIMIT - defines the limit specified by LFLAG (in msec, °K, or volts).
4. DELT - the length of the time step (in msec).
5. ITER - the number of time steps per line of printed output.
6. IFLAG - defines the type of power supply for heating:
 - 1, Constant Current
 - 0, Constant Voltage
 - 1, Discharging Capacitor
7. CURVOL - the power supply output for the current and voltage heating modes or the initial capacitor voltage for the discharging capacitor heating mode.
8. RESCAP - the resistor in series with the sample for the current and voltage modes or the value of the capacitor for the discharging capacitor heating mode.

If HTFLAG = 0 (i.e., no resistive heating), inputs 6, 7 and 8 are left blank.

HTFLO is currently dimensioned for up to 10 heating periods per calculation. Up to 24 calculations can be performed in one job by adding the appropriate data cards. The last card in the data deck must have 1000 punched on it (free format).

Output

HTFLO generates both tabulated output and plots. The tabulated output lists the temperatures at selected points in the sample at the end of the specified number of time steps. The total heat deposited in the sample since the start of the most recent heating period (HTFLAG = 1) is also listed. This is followed by the heat capacity calculated from the total heat added and the change in surface temperature. Then, the heat capacities of models 1 and 2 at the given surface temperature are shown. The final outputs compare the calculated and modeled heat capacities.

There are two plots generated for each calculation. The first shows the sample's temperature profile at the end of each heating period and the second shows the surface temperature as a function of time during the calculation.

APPENDIX A - THERMAL PROPERTIES OF UO_2 USED IN HTFLO

1. Property: Thermal Conductivity

$$\text{Model: } k = (4.0 + 2.57 \times 10^{-2} T)^{-1} + .72 \times 10^{-12} T^3$$

$$\text{Units: } k = \text{W/cm}^\circ\text{K}$$

Source: Reference 4

2. Property: Density

$$\text{Model: } \rho = 10.97 (1.0 + 2.04 \times 10^{-5} T + 8.7 \times 10^{-9} T^2)^{-1}$$

$$\text{Units: } \rho = \text{gm/cm}^3$$

$$T = ^\circ\text{C}$$

Source: Reference 4

3. Property: Specific Heat - Model 1

$$\text{Model: } C_p = .2762 + 3.78 \times 10^{-5} T$$

$$\text{Units: } C_p = \text{J/gm}^\circ\text{K}$$

$$T = ^\circ\text{K}$$

Source: Linear extrapolation of specific heat from the range of 1000°K to 1500°K in Reference 4

4. Property: Electrical Conductivity

$$\text{Model: } \ln \sigma = -3 \times 10^{-9} - 2011.8/T; T < 1400^\circ\text{K}$$

$$\ln \sigma = 9.58 - 15235/T; T > 1400^\circ\text{K}$$

$$\text{Units: } \sigma = \Omega^{-1} \text{ cm}^{-1}$$

$$T = ^\circ\text{K}$$

Source: Reference 6

5. Property: Enthalpy - Equilibrium Model

$$\begin{aligned} \text{Model: } H = & 32.6897 + \frac{158.718}{e^{535/T} - 1} + 1.21675 \times 10^{-5} T^2 \\ & + 87420 e^{-18939.7/T} \end{aligned}$$

$$\text{Units: } H = \text{J/gm}$$

$$T = ^\circ\text{K}$$

Source: Reference 4

6. Property: Equilibrium Temperature

Model:
$$T = -53.9406 + 4.66449H - 2.08141 \times 10^{-3}H^2 + 3.52908 \times 10^{-7}H^3$$

Units: $T = ^\circ K$

$H = J/gm$

Source: Polynomial fit to enthalpy in Reference 4

7. Property: Specific Heat - Model 2

Model:
$$C_p = .22999 - .153147 \times 10^{-3}T + .494536 \times 10^{-7}T^2$$

Units: $C_p = J/gm \ ^\circ K$

$T = ^\circ K$

Source: Reference 4

APPENDIX B - FORTRAN LISTING OF HTFLO FOR CDC 7600.

```

1      PROGRAM HTFLC(INPUT,OUTPUT,TAPE4C)
      REAL L,LIMIT1
      DIMENSION VCL(200),TEMP(200),ARA(200),ARB(200),TCOIN(200)
      DIMENSION SFCHT(200),RHO(200),SIGMA(200)
5      DIMENSION CAP(200),U(200),DTH(200),DT(200),RAD(10)
      DIMENSION A1(20),A2(20),B1(20),B2(20),C1(20),C2(20),C3(20)
      DIMENSION T(5),A(5),DT5(5),XTIME(955),YTSUR(999)
      DIMENSION TITLE(5),ARSC(5),ORD(5),XPOS(200)
10     DIMENSION H(200),CURVOL(10),RESCAP(10)
      DATA T/1H,10H,SURFACE TE,10H,TEMPERATURE,10HOF UO2 PIN,1H /
      DATA A/2*1H,10H,TIME(MSEC),2*1H /
      DATA C/1H,1CM SURFAC,10H,TEMPERAT,10HURE(K),1H /
      DATA TITLE/1H,10H,TEMPERATUR,10H,PROFILE,10HOF UO2 PIN,1H /
      DATA ARSC/1H,10H,RADIAL POS,10H,ITION (CM),2*1H /
15     DATA ORD/1H,10H,TEMPERATUR,SHE (K),2*1H /
      CALL HCCOPY(40)
      CALL EXTFLM(40)
      READ *,L,DIA,N
      NM1=N-1
20     M1=N/5
      M2=N*4/5
      PI=3.14159265
      F=2*PI*L
      DO 100 J=1,N
      ROUT=(N-I+1.5)/(N-I+1)
      RIN=(N-I+1)/(N-I+5)
      ARA(I)=F/ALCG(RCUT)
      ARB(I)=F/ALCG(RIN)
      VOL(I)=PI*DIA*DIA*(2.*N-2.*I+1.)*L/(4.*N+N)
30     XPOS(I) = (N-I+5)*DIA/(2.*N)
      ARSURF=PI*DIA*L
      VOLUME=PI*DIA*DIA*L/4.
      RAD(1)=1*DIA
35     RAD(2)=2*DIA
      RAD(3)=3*DIA
      RAD(4)=4*DIA
      RAD(5)=5*DIA
110    READ *,NEW,EMISS,TEMPSK,TI,RELAXT

      IF (NEW.EQ.1000) CALL EXTFLM(40)
      IF (NEW.EQ.1000) CALL EXIT
      INDEX = 0
      TIME=0.0
45     K=0
      NF = 1
      CLEFF=1./RELAXT

      VZERO=TI-300.
      PRINT C20
      PRINT C10,"SAMPLE LENGTH",*,L," CM"
      PRINT C10,"SAMPLE DIAMETER",*,DIA," CM"
55     PRINT C20,"NUMBER OF NODES",*,N
      PRINT C10,"SAMPLE EMISSIVITY",*,EMISS
      PRINT C10,"FEAT SINK TEMPERATURE",*,TEMPSK," K"

```

```

115      PRINT 700
      PRINT 620,TIME,TEMP(N),(TEMP(N-I),I=M1,M2,M1),TEMPSUR
      XTIME(K)=TIME
      YTSUR(K)=TEMPSUR

120      C
      C      CALCULATE THERMAL PROPERTIES
      C
      160 M=0
      170 M=M+1
      SUM=0.
      DO 210 I=1,N

125      C
      C      THERMAL CONDUCTIVITY (TCN)      (W/CM K)
      TCN(I)=1./Z(4.+2.57E-2*TEMP(I))+.73E-12*TEMP(I)**3.

130      C      DENSITY (RHC)      (GM/CC)
      T1=TEMP(I)-273.
      R1=1.+2.04E-5*T1+8.7E-9*T1*T1
      RHO(I)=10.97/R1

135      C
      C      SPECIFIC HEAT (SPCHT) - MODEL 1      (J/CM K)
      SPCHT(I)=.276E+1.78E-5*TEMP(I)

      C
      C      HEAT CAPACITY (CAP)      (J/K)
      CAP(I)=VOL(I)*SPCHT(I)*RHO(I)

140      C
      C      ELECTRICAL CONDUCTIVITY      (1/CM CM)
      IF (TEMP(I)-1400.) 190,190,200
      190 ELNSIG=3.E-9-2011.8/TEMP(I)
      SIGMA(I)=EXP(ELNSIG)
      GO TO 210

145      200 ELNSIG=9.58-15235./TEMP(I)
      SIGMA(I)=EXP(ELNSIG)

150      210 SUM=SUM+SIGMA(I)*VOL(I)

      C
      C      CALCULATE HEAT TRANSFER COEFFICIENTS
      C
      HR=ARSLRF*EMISS+5.67E-12*(TEMPSK+TEMPSUR)*(TEMPSK**2+TEMPSUR**2)
      DO 220 I=2,N
      C1=1./((ARA(I)+TCN(I-1))
      C2=1./((ARB(I)+TCN(I))
155      220 U(I)=1./(C1+C2)
      U(I)=ARB(I)+TCN(I)

      C
      C      CALCULATE HEAT INPUT FROM RESISTIVE HEATING
160      C
      IF (HTFLAG) 340,340,230
      230 IF (IFLAG) 250,235,260
      250 RES=L*L/SUM
      V1 = CLRVOL(INDEX)*RES
      165 V2=V1*V1
      GO TO 270
      255 RES = L*L/SUM
      V1 = CLRVOL(INDEX)*RES/(RESCAP(INDEX)+RES)
      V2 = V1*V1
      GO TO 270
170      260 V2 = 2.*E/(RESCAP(INDEX)+1.E-6)

```

```

      PRINT 510,"RELAXATION TIME          ",RELAXT," MSEC"
      PRINT 700
50    PRINT 700
      DO 120 I=1,N
      TEMP(I)=T1
      F(I)=EXP(535./TEMP(I))-1.
      H(I)=158.718/H(I)+1.21675E-5*TEMP(I)*TEMP(I)
      W(I)=F(I)+B7420.*EXP(-18940./TEMP(I))
      TEMPSLR=TEMP(I)
      125 INDEX = INDEX + 1
      READ E,HTFLAG,LFLAG,LIMIT,DELT,ITER,IFLAG,CURVOL(INDEX),
      1 RESCAP(INDEX)
      IF (HTFLAG) 127,127,130
      127 A1(INDEX)=" "
      DO 128 J=1,N
      128 CTH(J)=0.
      GO TO 150
      75    130 DO = 0.
      TD1=TEMPSUR
      IF (IFLAG) 135,140,145
      135 A1(INDEX)="CLRRNT "
      A2(INDEX)=" AMPS"
      B1(INDEX)="RESISTOR "
      B2(INDEX)=" CMPS"
      GO TO 150
      140 A1(INDEX)="VOLTAGE "
      A2(INDEX)=" VOLTS"
      B1(INDEX)="RESISTOR "
      B2(INDEX)=" CMPS"
      GO TO 150
      85    145 A1(INDEX)="INITIAL "
      A2(INDEX)=" VOLTS"
      B1(INDEX)="CAPACITOR "
      B2(INDEX)=" PFC"
      90    150 C2(INDEX)=LIMIT
      IF (LFLAG) 155,156,157
      155 C1(INDEX)="TIME LIMIT"
      95    C3(INDEX)=" MSEC"
      LIMIT = TIME+LIMIT
      GO TO 159
      156 C1(INDEX)="TEMP LIMIT"
      C3(INDEX)=" "
      GO TO 159
      100    157 C1(INDEX)="PIN. VOLTS"
      C3(INDEX)=" VOLTS"
      LIMIT = LIMIT+LIMIT
      E=.5E-6*RESCAP(INDEX)*CURVOL(INDEX)+CLRVOL(INDEX)
      105    159 PRINT 520,"PERIOD NUMBER          ",INDEX
      IF (HTFLAG) 152,152,151
      151 PRINT 530,A1(INDEX),CLRVOL(INDEX),A2(INDEX)
      PRINT 540,B1(INDEX),RESCAP(INDEX),B2(INDEX)
      110    152 PRINT 530,C1(INDEX),C2(INDEX),C3(INDEX)
      PRINT 510,"TIME STEP          ",DELT," MSEC"
      PRINT 520,"NUMBER OF ITERATIONS ",ITER
      PRINT 700
      PRINT 600
      PRINT 610,(RAC(I),I=1,5)

```

```

      IF (V2-LIMIT) 470,470,270
270 DO 280 I=1,N
      DTH(I)=V2*(SIGMA(I)+VOL(I))/(L*L)
175 DE=DTH(I)*DELT*1.E-3
      E=E-DE
280 DG=DG+DE
      C
      C CALCULATE HEAT FLOW
180 C
      340 TEMPSUR=(HR*TEMPSK+U(1)*TEMP(1))/(HR+U(1))
      DT(1)=L(1)*(TEMPSUR-TEMP(1))+U(2)*(TEMP(2)-TEMP(1))
      DO 350 I=2,N+1
285 350 DT(I)=L(I)*(TEMP(I-1)-TEMP(I))+U(I+1)*(TEMP(I+1)-TEMP(I))
      DT(N)=U(N)*(TEMP(N-1)-TEMP(N))
      C
      C CALC. NEW TEMP. DUE TO RESISTIVE HEATING AND HEAT FLOW
      C
      DO 380 I=1,N
190 TEMP(I)=TEMP(I)+(DTH(I)+DT(I))*DELT*1.E-3/CAP(I)
      IF (TEMP(I)-1500.) 370,370,360
      C
      C DYNAMIC ENTHALPY EFFECT
      C
195 360 DH=(CT(I)+DTH(I))*DELT*1.E-3/(VOL(I)*RHO(I))
      H(1)=H(1)+DH
      H2=H(1)*H(1)
      H3=H2*H(1)
      TEMPREL=-53.5466+4.66449*H(1)-.208141E-2*H2+.352908E-6*H3
200 C
      C CALC. NEW TEMP. DUE TO DYNAMIC ENTHALPY EFFECT
      C
      C
205 FACTOR = EXP(-COEFF*DELT)
      TEMP(1)=(TEMP(1)-TEMPREL)*FACTOR+TEMPREL
      370 IF (TEMP(1)-1138.) 380,380,420
      380 CONTINUE
      TIME=TIME+DELT
210 IF (LFLAG) 440,450,460
      440 IF (TIME-LIMIT*DELT) 460,470,470
      450 IF (TEMPSUR-LIMIT) 460,470,470
      460 IF (N-ITER) 170,475,475
      420 PRINT 700
215 PRINT 510," SAMPLE MELTED AT R = ",XPOS(I)," CM"
      470 FLAG = 1.
      IF (INCEX.EC.NEW) GO TO 472
      IF (TEMP(1).GT.3138.) GO TO 472
      FLAG = 0.
220 472 CALL PLOTFR (0.0,XPOS,TEMP,N+1,0.1H ,TITLE,ABSC,ORC,NF,1,0.,
      1 RAD(5),1,YZERO,3200.)
      NF=0
      GO TO 480
      475 FLAG=-1.
225 480 CP=DG/(TEMPSUR-T01)
      CPCALC=SPCHT(1)+VOLUME*RHO(1)
      DC=(CP-CPCALC)*100./CPCALC
      ANLCP=-.22999-.153147E-3*TEMPSUR+.49463EE-7*TEMPSUR*TEMPSUR

```

```

      ANLOC=(CP-ANLCP)*100./ANLCP
230  PRINT 620,TIME,TEMP(N),TEMP(N-I),I=M1,M2,M1,TEMPSLR,CQ
      1,CP,CP*CALC,ANLCP,OC,ANLOC
      K=K+1
      XTIME(K)=TIME
      YTSUR(K)=TEMPSLR
235  IF (FLAG) 160,485,490
      485 PRINT 705
      GO TO 125
      490 PRINT 710,"INITIAL TEMP. ",TI," K"
      PRINT 730,"EMISSIVITY ",EMISS
240  PRINT 720,"HEAT SINK TEMP. ",TEMPSK," K"
      DO 495 I=1,INDEX
      PRINT 740,"FERICO NUMBER ",I
      PRINT 750,C1(I),C2(I),C3(I)
      IF (A1(I)-EG," ") GO TO 495
245  PRINT 750,A1(I),CURVOL(I),A2(I)
      PRINT 750,B1(I),RESCAP(I),B2(I)
      495 CONTINUE
      PRINT 710
      CALL FLOTPR(0,0,XTIME,YTSU,"K",1,1,0,1H,"T",A,0,1,I,0,XTIME(K),
250  1,1,YZERO,32CC)
      IF (INDEX-EG,NEW) GO TO 110
      NX=INDEX+1
      495 READ 6,HTFLA,EG,LFLAG,LIMIT,DELT,ITER,IFLAG,CURVOL(NX),RESCAP(NX)
255  GO TO 110
      6 FORMAT (2(21E,2F10.4))
      500 FORMAT (1H1,40X,25H          INITIAL CONDITIONS      )
      510 FORMAT (40X,2A10,A2,F9.3,A6)
      520 FORMAT (40X,2A10,A2,I9,A6)
260  530 FORMAT (40X,A10,12X,F9.3,A6)
      600 FORMAT(9H  TIME ,20H,20HRAIDIAL POSITION (CM),21X,12H  HEAT INPLY
      1,3X,24H---HEAT CAPACITY (J/K)---,6X,21H---ERROR (PERCENT)---)
      610 FORMAT (9H  MSEC , 9X,2HCL,5F9.2,8X,9H(JOULES) ,3X,
      1 24HMEASURED  LINEAR  ANL ,8X,1E1,LINEAR  ANL)
265  620 FORMAT (F9.3,3X,5F9.1,4X,F12.4,3X,3F8.4,3X,2F12.4)
      700 FORMAT (1H )
      705 FORMAT (1H1)
      710 FORMAT (1H1,104X,A10,A5,F9.3,A6)
      720 FORMAT (1H ,104X,A10,A5,F9.3,A6)
270  730 FORMAT (1H0,104X,A10,A5,F9.3,A6)
      740 FORMAT (1H0,104X,A10,A5,I9,A6)
      750 FORMAT (1H ,104X,A10,5X,F9.3,A6)
      END

```


APPENDIX C - SAMPLE CALCULATION USING HTFLO.

The sample calculation was done for a total of six heating periods: three active and three passive. The first period warmed the sample to 2000°K with a high voltage power supply, followed by a 150 msec period with no active heat input. The third period held the sample's surface temperature at a fairly constant value for 1 second with a low voltage power supply. The fourth period was another period without active heating which lasted for 500 msec. The fifth period heated the sample rapidly with a discharging capacitor as the power source. The final period, lasting for 1.5 seconds, had no active heating and the sample cooled by surface radiation.

The data cards for this calculation are listed in Figure 4. The computer output listing is shown following the figure.

C DATA CARDS FOR SAMPLE HTFLO CALCULATION

11111111112222222222333333333344444444445555555555666666666677777777778
1234567890123456789012345678901234567890123456789012345678901234567890

C SAMPLE	SAMPLE	NUMBER
C LENGTH	DIAMETER	OF ZONES
C CM.	CM.	
1.	.2	50

CARD 1

C NUMBER OF	SURFACE	HEAT SINK	INITIAL	RELAXATION
C PERIODS	EMISSIVITY	TEMPERATURE	TEMPERATURE	TIME
C		DEG K	DEG K	MSEC
6	.2	300.	300.	100.

CARD 2

C HTFLAG	LFLAG	LIMIT	DELT	ITER	IFLAG	CURVOL	RESCAP
1	0	2000.	.2	500	0	1000.	50.
0	-1	150.	.2	200			
1	-1	1000.	.02	500	0	12.	1.272
0	-1	500.	.05	200			
1	1	10.	.02	50	1	400.	800.
0	-1	1500.	.05	200			

CARD 3

CARD 4

CARD 5

CARD 6

CARD 7

CARD 8

C LAST DATA CARD
1000

LASTCARD

11111111112222222222333333333344444444445555555555666666666677777777778
1234567890123456789012345678901234567890123456789012345678901234567890

Figure 4. Input data cards for the sample HTFLO calculation. Column numbers are shown to illustrate the required format.

INITIAL CONDITIONS

SAMPLE LENGTH 1.000 CM
 SAMPLE DIAMETER .200 CM
 NUMBER OF NODES 50
 SAMPLE EPISISTIVITY .200
 HEAT SINK TEMPERATURE 300.000 K
 RELAXATION TIME 100.000 MSEC

PERIOD NUMBER 1
 VOLTAGE 1000.000 VOLTS
 RESISTOR 50.000 OHMS
 TEMP LIMIT 2000.000 K
 TIME STEP .020 MSEC
 NUMBER OF ITERATIONS 500

TIME MSEC	RADIAL POSITION (CM)						HEAT INPUT (J/CM)		HEAT CAPACITY (J/K)			ERROR (PERCENT)	
	CL	.02	.04	.06	.08	.10	MEASURED	LINEAR	ANL	LINEAR	ANL	LINEAR	ANL
0.000	200.0	300.0	300.0	300.0	300.0	300.0							
10.000	204.0	304.0	304.0	304.0	304.0	304.0	4.002	.0593	.0991	1000	1000	1.0921	1.071252
20.000	208.5	308.5	308.5	308.5	308.5	308.5	.0288	.0592	.0991	1075	1075	.0659	1.071252
30.000	213.5	313.5	313.5	313.5	313.5	313.5	1.3228	.0592	.0991	1075	1075	1.0712	1.071252
40.000	218.0	318.0	318.0	318.0	318.0	318.0	1.8595	.0592	.0991	1075	1075	1.0712	1.071252
50.000	224.0	324.0	324.0	324.0	324.0	324.0	2.4605	.0592	.0991	1075	1075	1.0712	1.071252
60.000	231.6	331.6	331.6	331.6	331.6	331.6	3.1394	.0593	.0991	1075	1075	1.0712	1.071252
70.000	239.4	339.4	339.4	339.4	339.4	339.4	3.9145	.0593	.0991	1075	1075	1.0712	1.071252
80.000	248.4	348.4	348.4	348.4	348.4	348.4	4.8104	.0594	.0996	1075	1075	1.0712	1.071252
90.000	259.0	359.0	359.0	359.0	359.0	359.0	5.8616	.0594	.0997	1075	1075	1.0712	1.071252
100.000	271.6	371.6	371.6	371.6	371.6	371.6	7.1171	.0595	.0999	1075	1075	1.0712	1.071252
110.000	286.9	386.9	386.9	386.9	386.9	386.9	8.6874	.0596	.1000	1075	1075	1.0712	1.071252
120.000	406.1	406.1	406.1	406.1	406.1	406.1	10.5706	.0597	.1002	1075	1075	1.0712	1.071252
130.000	430.9	430.9	430.9	430.9	430.9	430.9	13.0612	.0598	.1005	1075	1075	1.0712	1.071252
140.000	464.4	464.4	464.4	464.4	464.4	464.4	16.4291	.1000	.1008	1075	1075	1.0712	1.071252
150.000	511.9	511.9	511.9	511.9	511.9	511.9	21.2285	.1003	.1013	1075	1075	1.0712	1.071252
160.000	583.4	583.4	583.4	583.4	583.4	583.4	28.5014	.1006	.1021	1075	1075	1.0712	1.071252
170.000	697.2	697.2	697.2	697.2	697.2	697.2	40.1786	.1015	.1032	1075	1075	1.0712	1.071252
180.000	880.2	880.2	880.2	880.2	880.2	880.2	59.2226	.1022	.1050	1075	1075	1.0712	1.071252
190.000	1151.4	1151.4	1151.2	1151.2	1151.0	1149.7	88.0345	.1036	.1075	1123	1123	1.0712	1.071252
200.000	1510.0	1510.0	1509.6	1509.3	1508.7	1505.6	127.5398	.1058	.1106	1115	1115	1.0712	1.071252
210.000	1715.2	1715.0	1713.6	1712.1	1710.2	1704.5	169.2085	.1174	.1169	1115	1115	1.0712	1.071252
220.000	1924.4	1922.5	1916.0	1902.8	1876.8	1852.4	195.5225	.1291	.1132	1115	1115	1.0712	1.071252
230.000	2137.2	2032.5	2017.7	1987.8	1940.9	1908.1	214.2670	.1532	.1136	1179	1179	1.0712	1.071252
240.000	2406.2	2170.7	2101.5	2048.6	1980.2	1940.7	249.3068	.1798	.113	1191	1191	1.0712	1.071252
250.000	2743.1	2226.1	2176.4	2095.0	2006.5	1961.0	292.0328	.1457	.1141	1199	1199	1.0712	1.071252
260.000	2949.0	2351.0	2281.5	2181.8	2029.2	1979.3	351.0224	.151	.1141	1204	1204	1.0712	1.071252
270.000	2957.0	2414.5	2352.2	2161.7	2037.2	1982.5	262.7533	.1561	.1101	1208	1208	1.0712	1.071252
280.000	2564.0	2504.9	2360.9	2186.7	2047.2	1990.0	271.4510	.1606	.1142	1211	1211	1.0712	1.071252
290.000	2665.9	2589.6	2411.2	2208.4	2055.6	1995.7	279.5051	.1647	.1142	1214	1214	1.0712	1.071252
297.020	2739.7	2650.5	2447.1	2223.9	2061.4	2000.0	284.9533	.1676	.1143	1216	1216	1.0712	1.071252

PERIOD NUMBER 2
 TIME LIMIT 150.000 MSEC
 TIME STEP .050 MSEC
 NUMBER OF ITERATIONS 200

TIME MSEC	CL	RADIAL POSITION (CM)					HEAT INPUT (J/DOULES)	--HEAT CAPACITY (J/K)--			---ERROR (PERCENT)---	
		.02	.04	.06	.08	.10		MEASURED	LINEAR	ANL	LINEAR	ANL
297.820	2734.3	2650.5	2447.1	2222.9	2061.9	2000.0	284.9533	-1695	-1141	-1202	48.5086	48.3899
307.820	2645.1	2570.1	2392.5	2189.9	2039.2	1981.2	284.9533	-1712	-1140	-1200	50.1452	42.6192
317.820	2544.9	2479.5	2342.2	2158.3	2018.9	1964.6	284.9533	-1727	-1139	-1194	51.6196	44.6876
327.820	2495.1	2437.0	2296.1	2129.1	2000.6	1949.9	284.9533	-1741	-1138	-1189	52.9510	46.3868
337.820	2433.5	2381.3	2254.2	2102.2	1984.1	1936.8	284.9533	-1753	-1137	-1185	54.1965	47.9826
347.820	2378.6	2331.4	2216.1	2077.6	1969.2	1925.2	284.9533	-1765	-1137	-1181	55.2522	49.4212
357.820	2326.5	2284.9	2181.4	2055.1	1956.7	1914.8	284.9533	-1775	-1136	-1178	56.2494	50.7216
367.820	2285.2	2245.9	2150.0	2034.8	1943.4	1905.4	284.9533	-1784	-1135	-1175	57.1593	51.8799
377.820	2245.3	2209.2	2121.5	2016.0	1932.4	1897.0	284.9533	-1793	-1135	-1172	57.9906	52.9699
387.820	2209.1	2176.0	2095.6	1999.0	1922.2	1889.3	284.9533	-1801	-1134	-1170	58.7511	53.9431
397.820	2176.3	2145.9	2072.1	1985.6	1913.2	1882.4	284.9533	-1808	-1134	-1168	59.4474	54.8294
407.820	2146.5	2118.5	2050.7	1969.6	1904.9	1876.1	284.9533	-1815	-1133	-1166	60.0854	55.6379
417.820	2119.4	2093.6	2031.4	1956.9	1897.3	1870.4	284.9533	-1821	-1133	-1164	60.6784	56.3758
427.820	2094.7	2071.0	2013.7	1945.4	1890.5	1865.2	284.9533	-1826	-1133	-1163	61.2071	57.0588
437.820	2072.2	2053.4	1997.7	1934.9	1884.2	1860.5	284.9533	-1831	-1133	-1163	61.6798	57.6466
447.820	2051.8	2031.6	1983.2	1925.3	1878.6	1856.1	284.9533	-1833	-1132	-1161	61.6798	57.6466

PERIOD NUMBER											
3											
12.000 VOLTS											
1.272 OHMS											
1000.000 MSEC											
0.200 MSEC											
NUMBER OF ITERATIONS											
500											
TIME	RACIAL POSITION (CM)					HEAT INPUT	--HEAT CAPACITY (J/K)---			--ERROR (PERCENT)---	
MSEC	CL	.02	.04	.06	.08	(JOULES)	MEASURED	LINEAR	ANL	LINEAR	ANL
447.820	2051.8	2031.6	1983.2	1925.3	1878.6	1856.1					
457.820	2035.3	2016.6	1971.6	1911.5	1874.6	1853.3	-1.684	-0.0558	.1132	-1161	-149.2865
467.820	2020.3	2002.9	1961.2	1911.5	1871.0	1850.7	-3.177	-0.0991	.1132	-1160	-152.1836
477.820	2006.6	1990.4	1951.8	1905.7	1867.9	1848.6	-4.722	-0.0624	.1132	-1153	-159.1693
487.820	1994.1	1979.1	1943.3	1900.5	1865.2	1846.7	-6.243	-0.0660	.1132	-1159	-158.2843
497.820	1982.7	1968.8	1935.6	1895.8	1862.7	1845.0	-7.751	-0.0697	.1132	-1158	-161.3761
507.820	1972.4	1959.5	1928.6	1891.6	1860.4	1841.6	-9.220	-0.0736	.1132	-1158	-165.0487
517.820	1962.9	1951.0	1922.3	1887.8	1858.8	1842.4	-1.0680	-0.0777	.1131	-1157	-168.7127
527.820	1954.4	1943.3	1916.6	1884.4	1857.1	1841.4	-1.2126	-0.0821	.1131	-1157	-172.3785
537.820	1946.6	1936.3	1911.5	1881.4	1855.7	1840.5	-1.3557	-0.0867	.1131	-1157	-176.0555
547.820	1939.5	1929.9	1906.8	1878.6	1854.7	1839.8	-1.4976	-0.0916	.1131	-1157	-179.7462
557.820	1932.1	1924.2	1902.7	1876.4	1853.5	1839.2	-1.6383	-0.0967	.1131	-1156	-183.4589
567.820	1927.3	1919.0	1898.5	1874.3	1852.6	1838.7	-1.7781	-0.1021	.1131	-1156	-187.2726
577.820	1922.0	1914.3	1895.5	1872.4	1851.9	1838.3	-1.9171	-0.1078	.1131	-1156	-191.3115
587.820	1917.2	1910.0	1892.5	1869.8	1851.2	1838.1	-2.0553	-0.1138	.1131	-1156	-195.4821
597.820	1912.9	1906.2	1889.7	1869.9	1850.7	1837.9	-2.1928	-0.1201	.1131	-1156	-200.2190
607.820	1908.0	1902.7	1887.3	1868.1	1850.3	1837.8	-2.3297	-0.1268	.1131	-1156	-215.1170
617.820	1905.5	1899.6	1885.1	1867.0	1850.0	1837.7	-2.4662	-0.1338	.1131	-1156	-218.3321
627.820	1902.3	1896.7	1883.2	1866.0	1849.8	1837.7	-2.6022	-0.1413	.1131	-1156	-222.1987
637.820	1899.4	1894.2	1881.4	1865.2	1849.6	1837.8	-2.7378	-0.1491	.1131	-1156	-231.7282
647.820	1896.8	1891.9	1879.9	1864.5	1849.5	1837.9	-2.8731	-0.1573	.1131	-1156	-239.8717
657.820	1894.5	1889.9	1878.5	1863.9	1849.3	1838.0	-3.0081	-0.1660	.1131	-1156	-248.7511
667.820	1892.4	1888.1	1877.3	1863.4	1849.2	1838.2	-3.1429	-0.1752	.1131	-1156	-254.8531
677.820	1890.6	1886.5	1876.5	1863.0	1849.6	1838.4	-3.2775	-0.1848	.1131	-1156	-261.3885
687.820	1888.9	1885.0	1875.4	1862.7	1849.7	1838.6	-3.4119	-0.1951	.1131	-1156	-272.4345
697.820	1887.4	1883.7	1874.5	1862.1	1849.8	1838.9	-3.5462	-0.2059	.1131	-1156	-280.8234
707.820	1886.1	1882.6	1873.5	1862.2	1850.0	1839.2	-3.6805	-0.2173	.1131	-1156	-292.8627
717.820	1884.9	1881.6	1873.3	1862.1	1850.2	1839.5	-3.8146	-0.2293	.1131	-1156	-302.7353
727.820	1883.9	1880.7	1872.6	1862.0	1850.4	1839.8	-3.9488	-0.2421	.1131	-1157	-314.0364
737.820	1883.0	1880.0	1872.4	1862.0	1850.7	1840.2	-4.0829	-0.2557	.1131	-1157	-326.8180
747.820	1882.2	1879.3	1872.0	1862.0	1850.9	1840.5	-4.2170	-0.2697	.1131	-1157	-339.7278
757.820	1881.5	1878.8	1871.8	1862.1	1851.2	1840.9	-4.3511	-0.2853	.1131	-1157	-352.2171
767.820	1880.9	1878.3	1871.6	1862.2	1851.6	1841.3	-4.4853	-0.3016	.1131	-1157	-364.5781
777.820	1880.5	1877.9	1871.4	1862.3	1851.9	1841.6	-4.6195	-0.3189	.1131	-1157	-381.8826
787.820	1880.0	1877.6	1871.3	1862.4	1852.2	1842.0	-4.7538	-0.3375	.1131	-1157	-398.1886
797.820	1879.7	1877.4	1871.2	1862.6	1852.4	1842.4	-4.8882	-0.3570	.1131	-1157	-415.5562
807.820	1879.4	1877.2	1871.3	1862.8	1852.5	1842.8	-5.0226	-0.3781	.1131	-1157	-434.1802
817.820	1879.2	1877.0	1871.3	1863.1	1853.3	1843.3	-5.1578	-0.4007	.1132	-1158	-454.1487
827.820	1879.1	1877.0	1871.4	1863.3	1853.7	1843.7	-5.2932	-0.4250	.1132	-1158	-475.5993
837.820	1879.0	1876.9	1871.5	1863.6	1854.1	1844.1	-5.4286	-0.4511	.1132	-1158	-498.6288
847.820	1878.9	1876.9	1871.7	1863.9	1854.5	1844.5	-5.5615	-0.4793	.1132	-1158	-523.5973
857.820	1878.9	1877.0	1871.8	1864.2	1854.9	1845.0	-5.6965	-0.5099	.1132	-1158	-548.2786
867.820	1878.9	1877.1	1872.0	1864.5	1855.3	1845.4	-5.8317	-0.5430	.1132	-1158	-579.8286
877.820	1878.7	1877.2	1872.2	1864.9	1855.7	1845.8	-5.9670	-0.5791	.1132	-1158	-611.6931
887.820	1878.1	1877.3	1872.5	1865.2	1856.1	1846.3	-6.1024	-0.6185	.1132	-1158	-643.7822
897.820	1879.2	1877.5	1872.7	1865.6	1856.4	1846.7	-6.2369	-0.6617	.1132	-1159	-684.4963
907.820	1879.4	1877.7	1873.0	1865.9	1857.0	1847.1	-6.3718	-0.7094	.1132	-1159	-726.7605
917.820	1879.6	1877.9	1873.3	1866.3	1857.3	1847.6	-6.5097	-0.7621	.1132	-1159	-773.3137
927.820	1879.7	1878.1	1873.6	1866.7	1857.9	1848.0	-6.6458	-0.8207	.1132	-1159	-825.1054
937.820	1880.0	1878.1	1873.6	1867.1	1858.3	1848.5	-6.7820	-0.8863	.1132	-1159	-881.0624
947.820	1880.3	1878.7	1874.3	1867.5	1858.7	1848.9	-6.9183	-0.9603	.1132	-1159	-942.3455
957.820	1880.6	1879.0	1874.6	1867.9	1859.2	1849.4	-7.0550	-1.0442	.1132	-1159	-1008.4214
967.820	1880.9	1879.3	1875.3	1868.3	1859.6	1849.8	-7.1918	-1.1404	.1132	-1160	-1087.2048
977.820	1881.2	1879.6	1875.5	1868.7	1860.1	1850.1	-7.3287	-1.2411	.1132	-1160	-1200.1474

907.820	1081.5	1079.9	1075.7	1069.1	1060.5	1050.7	7.4659	-1.3807	+1132	+1160	-1319.6271	-1290.4710
997.820	1281.0	1080.3	1076.1	1069.6	1061.0	1051.2	7.6032	-1.5341	+1132	+1160	-1454.1379	-1422.6262
1007.820	1080.2	1080.6	1076.5	1070.9	1061.4	1051.1	7.7406	-1.7107	+1132	+1160	-1610.0775	-1581.5261
1017.820	1082.5	1081.0	1076.9	1070.4	1061.9	1052.1	7.8783	-1.9447	+1132	+1160	-1817.6992	-1776.1933
1027.820	1082.9	1081.4	1077.3	1070.9	1062.2	1052.5	8.0162	-2.2281	+1132	+1160	-2067.9484	-2020.2253
1037.820	1083.3	1081.8	1077.7	1071.3	1062.8	1053.2	8.1542	-2.5538	+1132	+1160	-2390.0682	-2339.1153
1047.820	1083.6	1082.2	1078.1	1071.7	1063.3	1053.5	8.2925	-3.0837	+1132	+1161	-2813.4145	-2756.7512
1057.820	1084.0	1082.6	1078.6	1072.2	1063.7	1053.9	8.4309	-3.7740	+1132	+1161	-3433.0697	-3351.3715
1067.820	1084.4	1083.0	1079.0	1072.6	1064.2	1054.3	8.5695	-4.8194	+1132	+1161	-4356.1820	-4251.4882
1077.820	1084.9	1083.4	1079.4	1073.1	1064.6	1054.8	8.7083	-6.5085	+1132	+1161	-5918.3798	-5724.7422
1087.820	1085.3	1083.8	1079.9	1073.5	1065.1	1055.3	8.8473	-10.2308	+1132	+1161	-9134.6735	-8916.8392
1097.820	1085.7	1084.2	1080.3	1074.0	1065.5	1055.7	8.9865	-22.0583	+1132	+1161	-12907.6527	-12703.1222
1107.820	1086.1	1084.7	1080.8	1074.5	1066.0	1056.2	9.1259	179.1572	+1132	+1161	158102.4666	154515.9188
1117.820	1086.6	1085.1	1081.2	1074.9	1066.5	1056.6	9.2655	18.1788	+1132	+1162	15952.0494	15558.9885
1127.820	1087.0	1085.6	1081.7	1075.4	1066.9	1057.1	9.4053	9.7057	+1133	+1162	8470.0329	8254.6681
1137.820	1087.4	1086.0	1082.1	1075.9	1067.4	1057.6	9.5453	6.6796	+1133	+1162	3797.8480	3649.7491
1147.820	1087.9	1086.5	1082.6	1076.3	1067.9	1058.0	9.6855	5.1257	+1133	+1162	4425.6199	4311.8779
1157.820	1088.3	1086.9	1083.0	1076.8	1068.3	1058.5	9.8259	4.1797	+1133	+1162	3590.3288	3476.5333
1167.820	1088.8	1087.4	1083.5	1077.2	1068.8	1059.0	9.9665	3.5434	+1133	+1162	3028.3865	2948.6436
1177.820	1089.2	1087.8	1084.0	1077.7	1069.3	1059.4	10.1073	3.0860	+1133	+1162	2624.4726	2554.7785
1187.820	1089.7	1088.3	1084.4	1078.2	1069.8	1059.9	10.2483	2.7413	+1133	+1163	2320.1371	2258.0882
1197.820	1090.2	1088.8	1084.9	1078.7	1070.2	1060.3	10.3895	2.4323	+1133	+1163	2082.5917	2026.3617
1207.820	1090.6	1089.2	1085.4	1079.1	1070.7	1060.8	10.5309	2.2565	+1133	+1163	1892.8185	1848.5159
1217.820	1091.1	1089.7	1085.8	1079.6	1071.2	1061.3	10.6725	2.0796	+1133	+1163	1735.7347	1688.1881
1227.820	1091.6	1090.2	1086.3	1080.1	1071.6	1061.7	10.8143	1.9318	+1133	+1163	1685.2460	1648.8441
1237.820	1092.1	1090.7	1086.8	1080.6	1072.1	1062.2	10.9563	1.8066	+1133	+1163	1649.6588	1622.2884
1247.820	1092.6	1091.2	1087.3	1081.1	1072.6	1062.7	11.0986	1.6991	+1133	+1163	1599.7171	1568.3091
1257.820	1093.0	1091.6	1087.8	1081.5	1073.1	1063.1	11.2410	1.6028	+1133	+1164	1517.3376	1489.8379
1267.820	1093.5	1092.1	1088.2	1082.0	1073.6	1063.6	11.3836	1.5241	+1133	+1164	1465.1727	1429.6476
1277.820	1094.0	1092.6	1088.7	1082.5	1074.0	1064.1	11.5265	1.4519	+1133	+1164	1413.9362	1377.5715
1287.820	1094.5	1093.1	1089.2	1083.0	1074.5	1064.5	11.6696	1.3877	+1133	+1164	1324.7037	1292.1480
1297.820	1095.0	1093.6	1089.7	1083.5	1075.0	1065.0	11.8128	1.3302	+1133	+1164	1073.5386	1042.8937
1307.820	1095.5	1094.1	1090.2	1084.0	1075.5	1065.5	11.9563	1.2784	+1133	+1164	1020.1949	997.9743
1317.820	1096.0	1094.6	1090.7	1084.5	1076.0	1066.0	12.1000	1.2315	+1133	+1164	966.7762	952.5619
1327.820	1096.4	1095.1	1091.2	1084.9	1076.4	1066.4	12.2439	1.1888	+1133	+1165	949.8957	928.7943
1337.820	1096.9	1095.6	1091.7	1085.4	1076.9	1066.9	12.3880	1.1498	+1133	+1165	913.6681	887.1783
1347.820	1097.4	1096.1	1092.2	1085.9	1077.4	1067.4	12.5324	1.1141	+1133	+1165	883.0886	856.3794
1357.820	1097.9	1096.6	1092.7	1086.4	1077.9	1067.9	12.6769	1.0812	+1133	+1165	856.8178	828.8938
1367.820	1098.4	1097.1	1093.2	1086.9	1078.4	1068.3	12.8217	1.0508	+1133	+1165	827.1651	801.7964
1377.820	1098.9	1097.6	1093.7	1087.4	1078.9	1068.8	12.9666	1.0226	+1133	+1165	802.2879	777.3119
1387.820	1099.4	1098.1	1094.2	1087.9	1079.4	1069.3	13.1118	.9965	+1133	+1166	779.1731	754.9467
1397.820	1000.0	1098.6	1094.7	1088.4	1079.8	1069.8	13.2572	.9721	+1133	+1166	757.6486	733.9238
1407.820	1000.5	1099.1	1095.2	1088.9	1080.3	1070.2	13.4028	.9493	+1133	+1166	737.5523	714.2495
1417.820	1001.0	1099.6	1095.7	1089.4	1080.8	1070.7	13.5486	.9280	+1133	+1166	718.7189	695.8977
1427.820	1001.5	1000.1	1096.2	1089.9	1081.3	1071.2	13.6947	.9080	+1134	+1166	701.8561	678.6677
1437.820	1002.0	1000.6	1096.7	1090.4	1081.8	1071.7	13.8409	.8892	+1134	+1166	689.4624	662.4681
1447.820	1002.5	1001.1	1097.2	1090.9	1082.3	1072.2	13.9874	.8716	+1134	+1166	668.8365	647.1759

PERIOD NUMBER
TIME LIMIT 500.000 MSEC
TIME STEP .050 MSEC
NUMBER OF ITERATIONS 200

TIME MSEC	RADIAL POSITION (CM)						HEAT INPUT (J/CM ²)	HEAT CAPACITY (J/K)		ERROR (PERCENT)	
	CL	.02	.04	.06	.08	.10		MEASURED	LINEAR	LINEAR	ANL
1447.820	1502.5	1901.1	1897.2	1890.9	1882.5	1872.2					
1457.820	1501.7	1898.4	1896.4	1890.3	1881.5	1871.4	13.9874	9.2130	1133	1166	785.4319
1467.820	1500.8	1899.4	1895.4	1889.3	1880.8	1870.7	13.9874	9.2899	1133	1165	745.3983
1477.820	1500.0	1898.6	1894.7	1888.2	1880.0	1870.0	13.9874	1.0096	1133	1166	730.7738
1487.820	1899.1	1897.8	1893.5	1887.7	1879.2	1869.2	13.9874	1.0659	1133	1166	840.4863
1497.820	1898.3	1896.9	1893.1	1887.0	1878.5	1868.5	13.9874	1.1285	1133	1165	835.7128
1507.820	1897.5	1896.1	1892.2	1886.2	1877.8	1867.8	13.9874	1.1587	1133	1165	957.7184
1517.820	1896.7	1895.3	1891.4	1885.4	1877.1	1867.1	13.9874	1.2280	1133	1165	1027.7181
1527.820	1895.9	1894.5	1890.8	1884.7	1876.2	1866.3	13.9874	1.3682	1133	1165	1187.3691
1537.820	1895.1	1893.7	1890.0	1883.9	1875.6	1865.6	13.9874	1.4717	1133	1164	1198.8228
1547.820	1894.3	1893.0	1889.2	1883.1	1874.8	1864.9	13.9874	1.5519	1133	1164	1304.9238
1557.820	1893.5	1892.2	1888.4	1882.3	1874.1	1864.2	13.9874	1.7130	1133	1165	1425.5113
1567.820	1892.7	1891.4	1887.7	1881.6	1873.4	1863.5	13.9874	1.9010	1133	1164	1571.8746
1577.820	1891.9	1890.6	1886.8	1880.9	1872.6	1862.8	13.9874	2.1046	1133	1163	1757.6324
1587.820	1891.2	1889.8	1886.2	1880.2	1871.9	1862.1	13.9874	2.3562	1133	1163	1979.8698
1597.820	1890.4	1889.1	1885.4	1879.4	1871.2	1861.4	13.9874	2.6754	1133	1163	2261.6271
1607.820	1889.6	1888.3	1884.6	1878.7	1870.5	1860.7	13.9874	3.0535	1133	1163	2638.0865
1617.820	1888.9	1887.6	1883.9	1877.9	1869.7	1859.9	13.9874	3.6649	1133	1163	3135.5893
1627.820	1888.1	1886.8	1883.2	1877.2	1869.0	1859.2	13.9874	4.4933	1133	1162	3846.9395
1637.820	1887.3	1886.0	1882.4	1876.4	1868.2	1858.4	13.9874	5.4014	1133	1162	5822.5816
1647.820	1886.6	1885.3	1881.7	1875.7	1867.6	1857.8	13.9874	6.4794	1133	1162	7121.9398
1657.820	1885.8	1884.5	1880.9	1875.0	1866.9	1857.1	13.9874	7.8481	1133	1162	8212.8829
1667.820	1885.1	1883.8	1880.2	1874.3	1866.1	1856.4	13.9874	9.4716	1132	1162	99425.6611
1677.820	1884.3	1883.0	1879.4	1873.5	1865.4	1855.7	13.9874	10.3846	1132	1161	122229.8517
1687.820	1883.6	1882.3	1878.7	1872.8	1864.7	1855.0	13.9874	12.9495	1132	1161	145397.7483
1697.820	1882.8	1881.6	1877.8	1871.9	1863.8	1854.1	13.9874	15.8164	1132	1161	17185.5448
1707.820	1882.1	1880.8	1877.2	1871.4	1863.2	1853.7	13.9874	18.6473	1132	1161	20123.2168
1717.820	1881.4	1880.1	1876.5	1870.7	1862.6	1853.0	13.9874	21.4258	1132	1160	23884.3541
1727.820	1880.6	1879.3	1875.8	1869.9	1861.9	1852.3	13.9874	24.3316	1132	1160	27387.3958
1737.820	1879.9	1878.6	1875.0	1869.2	1861.2	1851.6	13.9874	27.3977	1132	1160	30828.2321
1747.820	1879.2	1877.9	1874.3	1868.5	1860.5	1850.9	13.9874	30.6188	1132	1160	34645.8218
1757.820	1878.4	1877.1	1873.6	1867.8	1859.8	1850.2	13.9874	33.9331	1132	1160	37877.8149
1767.820	1877.7	1876.4	1872.5	1866.7	1858.7	1849.5	13.9874	37.3473	1132	1159	41078.4788
1777.820	1877.0	1875.7	1872.1	1866.4	1858.4	1849.8	13.9874	40.8613	1132	1159	44194.3425
1787.820	1876.2	1875.0	1871.4	1865.6	1857.7	1848.1	13.9874	44.4753	1132	1159	46940.0731
1797.820	1875.5	1874.2	1870.7	1864.9	1857.0	1847.5	13.9874	48.1892	1132	1158	49567.7659
1807.820	1874.8	1873.5	1870.0	1864.2	1856.2	1846.8	13.9874	51.9968	1132	1159	51922.4994
1817.820	1874.0	1872.8	1869.2	1863.5	1855.6	1846.1	13.9874	55.8949	1132	1158	54132.5558
1827.820	1873.3	1872.1	1868.5	1862.8	1854.9	1845.4	13.9874	59.8811	1132	1158	56194.7073
1837.820	1872.6	1871.3	1867.7	1862.1	1854.2	1844.7	13.9874	63.9552	1132	1158	58125.5582
1847.820	1871.9	1870.6	1867.1	1861.4	1853.5	1844.1	13.9874	68.1169	1132	1158	60033.7132
1857.820	1871.1	1869.9	1866.4	1860.7	1852.8	1843.4	13.9874	72.4672	1132	1158	61919.6831
1867.820	1870.4	1869.2	1865.7	1860.0	1852.1	1842.7	13.9874	76.9018	1131	1157	63784.8241
1877.820	1869.7	1868.5	1865.0	1859.3	1851.4	1842.0	13.9874	81.4218	1131	1157	65629.5224
1887.820	1869.0	1867.7	1864.2	1858.5	1850.7	1841.3	13.9874	86.0311	1131	1157	67454.3529
1897.820	1868.3	1867.0	1863.5	1857.9	1850.0	1840.7	13.9874	90.7311	1131	1157	69263.7312
1907.820	1867.5	1866.3	1862.8	1857.2	1849.3	1840.0	13.9874	95.5211	1131	1157	71058.2796
1917.820	1866.8	1865.6	1862.1	1856.5	1848.7	1839.3	13.9874	100.4011	1131	1156	72839.8591
1927.820	1866.1	1864.9	1861.4	1855.8	1848.0	1838.6	13.9874	105.3711	1131	1156	74608.1461
1937.820	1865.3	1864.2	1860.7	1855.1	1847.3	1837.9	13.9874	110.4311	1131	1156	76364.0041
1947.820	1864.7	1863.4	1860.0	1854.4	1846.6	1837.3	13.9874	115.5811	1131	1156	78108.4456

PERIOD NUMBER 5
 INITIAL 400.000 VOLTS
 CAPACITOR 800.000 MFD
 MIN. VOLTS 10.000 VOLTS
 TIME STEP .020 MSEC
 NUMBER OF ITERATIONS 50

TIME PSEC	CL	RACIAL POSITION (CM)					HEAT INPUT (J/CM)	HEAT CAPACITY (J/K)			ERROR (PERCENT)	
		.02	.04	.06	.08	.10		MEASURED	LINEAR	ANL	LINEAR	ANL
1947.820	1864.7	1865.4	1860.0	1854.4	1846.6	1837.5						
1948.820	2092.3	2089.3	2081.2	2068.2	2050.6	2026.5	23.8989	.1263	.1144	.1228	10.3523	2.8712
1949.820	2355.9	2349.4	2331.7	2304.0	2268.0	2228.4	20.5232	.1287	.1158	.1303	11.1921	-0.2259
1950.820	2473.7	2465.0	2441.3	2404.7	2358.1	2312.8	61.6766	.1297	.1163	.1404	11.5985	-7.5987
1951.820	2493.9	2484.8	2460.0	2421.6	2373.2	2328.3	63.6931	.1297	.1164	.1416	11.6794	-0.5558
1952.820	2495.4	2486.3	2461.4	2423.1	2374.4	2330.8	63.9610	.1296	.1164	.1416	11.3592	-0.5482

		PERIOD NUMBER					6			
		TIME LIMIT					1500.000 MSEC			
		TIME STEP					.050 MSEC			
		NUMBER OF ITERATIONS					200			
TIME		RACIAL POSITION (CM)					HEAT INPUT	--HEAT CAPACITY (J/K)---	--ERROR (PERCENT)--	
PSEC	CL	.02	.04	.06	.08	.10	(JOULES)	MEASURED LINEAR ANL	LINEAR	ANL
1952.820	2455.4	2406.3	2461.4	2423.1	2374.4	2330.8	63.9610	1193	1163	1118
1962.820	2482.8	2474.0	2450.2	2413.3	2368.0	2322.0	63.9610	1193	1163	1118
1972.820	2471.1	2462.7	2439.8	2404.6	2353.2	2305.6	63.9610	1197	1164	1117
1982.820	2452.3	2450.3	2425.3	2389.4	2335.6	2287.8	63.9610	1196	1164	1116
1992.820	2450.5	2442.7	2421.6	2390.1	2354.8	2308.0	63.9610	1209	1164	1114
2002.820	2441.3	2433.8	2413.7	2384.0	2351.0	2323.0	63.9610	1317	1163	1112
2012.820	2432.9	2425.7	2406.4	2378.5	2347.4	2320.3	63.9610	1224	1163	1109
2022.820	2429.0	2418.2	2400.3	2371.9	2342.5	2314.6	63.9610	1332	1163	1107
2032.820	2418.8	2411.3	2393.2	2364.8	2334.7	2304.6	63.9610	1229	1163	1105
2042.820	2411.2	2404.9	2388.0	2364.5	2337.2	2312.2	63.9610	1347	1163	1103
2052.820	2405.0	2399.1	2383.2	2360.5	2334.6	2304.6	63.9610	1254	1163	1101
2062.820	2393.9	2387.7	2372.4	2350.8	2325.8	2295.7	63.9610	1351	1163	1100
2072.820	2387.2	2380.9	2374.3	2353.4	2329.0	2304.6	63.9610	1268	1162	1098
2082.820	2389.3	2384.0	2370.2	2350.1	2326.4	2302.5	63.9610	1275	1162	1096
2092.820	2384.8	2379.7	2366.2	2347.0	2323.9	2300.2	63.9610	1382	1162	1094
2102.820	2380.0	2375.1	2361.8	2343.1	2320.1	2296.4	63.9610	1288	1162	1093
2112.820	2376.7	2372.0	2359.7	2341.4	2318.3	2294.6	63.9610	1395	1162	1091
2122.820	2373.0	2368.5	2356.6	2338.8	2317.0	2294.0	63.9610	1401	1162	1090
2132.820	2369.6	2365.2	2353.7	2336.3	2314.9	2292.0	63.9610	1407	1162	1088
2142.820	2366.3	2362.1	2350.5	2333.3	2312.9	2290.3	63.9610	1513	1161	1087
2152.820	2362.3	2359.2	2348.2	2331.6	2310.5	2288.0	63.9610	1418	1161	1085
2162.820	2360.4	2356.4	2345.7	2329.5	2309.0	2286.5	63.9610	1424	1161	1083
2172.820	2357.7	2353.8	2343.2	2327.3	2307.1	2284.7	63.9610	1430	1161	1082
2182.820	2355.1	2351.1	2340.5	2325.3	2305.1	2283.0	63.9610	1436	1161	1081
2192.820	2352.6	2348.9	2338.6	2323.3	2303.2	2281.4	63.9610	1440	1161	1080
2202.820	2350.2	2346.6	2336.7	2321.4	2301.8	2279.7	63.9610	1446	1161	1079
2212.820	2347.9	2344.4	2334.6	2319.4	2300.1	2278.1	63.9610	1451	1161	1078
2222.820	2345.7	2342.2	2332.4	2317.4	2298.1	2276.4	63.9610	1457	1161	1077
2232.820	2343.6	2340.2	2330.7	2316.0	2296.5	2275.1	63.9610	1461	1160	1076
2242.820	2341.6	2338.2	2328.9	2314.3	2295.3	2273.5	63.9610	1466	1160	1075
2252.820	2339.6	2336.2	2327.0	2312.6	2293.7	2272.1	63.9610	1471	1160	1074
2262.820	2337.7	2334.3	2325.1	2310.9	2292.2	2270.7	63.9610	1476	1160	1073
2272.820	2335.8	2332.5	2323.5	2309.4	2290.7	2269.2	63.9610	1481	1160	1072
2282.820	2333.9	2330.7	2321.8	2307.8	2289.2	2267.8	63.9610	1486	1160	1071
2292.820	2332.2	2329.0	2320.1	2306.2	2287.7	2266.4	63.9610	1491	1160	1070
2302.820	2330.6	2327.5	2318.6	2304.7	2286.1	2265.0	63.9610	1496	1160	1069
2312.820	2328.7	2325.5	2316.6	2303.2	2284.9	2263.6	63.9610	1500	1160	1068
2322.820	2327.0	2323.9	2315.1	2301.7	2283.4	2262.3	63.9610	1505	1160	1067
2332.820	2325.4	2322.3	2313.5	2300.2	2282.0	2260.9	63.9610	1510	1160	1066
2342.820	2323.7	2320.7	2311.9	2298.7	2280.5	2259.5	63.9610	1515	1160	1065
2352.820	2322.1	2319.1	2310.7	2297.3	2279.3	2258.3	63.9613	1519	1159	1064
2362.820	2320.5	2317.5	2309.2	2295.8	2277.5	2256.9	63.9610	1524	1159	1063
2372.820	2319.0	2316.0	2307.8	2294.4	2276.0	2255.6	63.9610	1529	1159	1062
2382.820	2317.4	2314.4	2306.2	2293.0	2274.5	2254.2	63.9610	1534	1159	1061
2392.820	2315.9	2312.9	2304.7	2291.6	2273.5	2253.1	63.9610	1538	1159	1060
2402.820	2314.4	2311.4	2303.2	2289.2	2272.5	2251.8	63.9610	1543	1159	1059
2412.820	2312.9	2309.9	2301.8	2286.8	2271.2	2250.5	63.9610	1548	1159	1058
2422.82C	2311.4	2308.4	2300.3	2284.7	2270.1	2249.1	63.9613	1553	1159	1057
2432.82C	2309.9	2306.9	2299.0	2282.6	2268.6	2248.0	63.9610	1558	1159	1056
2442.820	2308.4	2305.4	2297.6	2281.1	2267.3	2246.7	63.9610	1562	1159	1055
2452.820	2306.9	2303.9	2296.1	2279.6	2265.9	2245.2	63.9613	1567	1159	1054
2462.820	2305.4	2302.4	2294.6	2278.1	2264.6	2243.0	63.9613	1571	1158	1053
2472.820	2304.1	2301.3	2293.4	2276.7	2263.4	2241.0	63.9610	1576	1158	1052
2482.820	2302.7	2299.9	2292.0	2275.3	2262.1	2241.7	63.9610	1582	1158	1051
2492.820	2301.2	2298.4	2290.5	2273.9	2260.8	2240.5	63.9610	1586	1158	1050
2502.820	2300.0	2297.1	2289.4	2272.7	2259.5	2239.2	63.9610	1591	1158	1049

2512-820	2298-5	2295-7	2287-5	2275-4	2258-3	2238-0	63-9612	-1596	-1158	-1350	37-8207	16-2424
2522-820	2297-1	2294-3	2286-6	2274-1	2257-0	2236-8	63-9610	-1601	-1158	-1349	38-2533	16-6793
2532-820	2296-7	2292-9	2285-5	2272-7	2255-7	2235-6	63-9613	-1616	-1158	-1348	40-6076	19-1178
2542-820	2294-3	2291-6	2283-5	2271-4	2254-5	2234-3	63-9610	-1611	-1158	-1347	39-1235	19-5579
2552-820	2292-9	2290-2	2282-5	2270-1	2253-2	2233-1	63-9610	-1616	-1158	-1347	39-5611	19-9997
2562-820	2291-6	2288-8	2281-2	2268-8	2251-5	2231-9	63-9612	-1621	-1154	-1346	40-0005	20-4333
2572-820	2290-2	2287-5	2279-5	2267-5	2250-7	2230-5	63-9610	-1626	-1158	-1345	40-4417	20-8886
2582-820	2289-9	2286-1	2278-5	2266-2	2249-8	2229-5	63-9610	-1631	-1158	-1344	41-0087	21-3357
2592-820	2287-5	2284-8	2277-2	2265-0	2248-2	2228-3	63-9610	-1636	-1158	-1343	41-3296	21-7846
2602-820	2286-1	2283-4	2275-5	2263-7	2246-9	2227-1	63-9610	-1641	-1157	-1343	41-7768	22-2355
2612-820	2284-8	2282-1	2274-6	2262-4	2245-7	2225-9	63-9610	-1646	-1157	-1342	42-2252	22-6883
2622-820	2283-5	2280-8	2273-2	2261-1	2244-8	2224-7	63-9610	-1651	-1157	-1341	42-6760	23-1507
2632-820	2282-1	2279-4	2272-0	2259-8	2243-2	2223-5	63-9610	-1656	-1157	-1340	43-1287	23-5997
2642-820	2280-8	2278-1	2270-7	2258-6	2242-0	2222-3	63-9610	-1662	-1157	-1339	43-5835	24-0584
2652-820	2279-4	2276-8	2269-4	2257-3	2240-7	2221-1	63-9610	-1667	-1157	-1339	44-0404	24-5192
2662-820	2278-1	2275-5	2268-0	2256-0	2239-5	2219-9	63-9610	-1672	-1157	-1338	44-4994	24-9828
2672-820	2276-8	2274-1	2266-6	2254-7	2238-1	2218-7	63-9610	-1677	-1157	-1337	44-9605	25-4469
2682-820	2275-5	2272-8	2265-5	2253-5	2237-0	2217-5	63-9610	-1682	-1157	-1336	45-4237	25-9139
2692-820	2274-2	2271-5	2264-2	2252-2	2235-8	2216-3	63-9610	-1688	-1157	-1335	45-8891	26-3831
2702-820	2272-8	2270-2	2262-5	2250-9	2234-6	2215-1	63-9610	-1693	-1157	-1335	46-3568	26-8544
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2722-820	2270-2	2267-6	2260-3	2248-8	2232-1	2212-7	63-9610	-1704	-1157	-1333	47-2986	27-8036
2732-820	2268-9	2266-3	2259-0	2247-2	2230-9	2211-6	63-9610	-1709	-1157	-1332	47-7729	28-2815
2742-820	2267-6	2265-0	2257-7	2245-9	2229-7	2210-4	63-9610	-1714	-1156	-1331	48-2495	28-7617
2752-820	2266-3	2263-7	2256-4	2244-7	2228-5	2209-2	63-9610	-1720	-1156	-1331	48-7284	29-2441
2762-820	2265-0	2262-4	2255-1	2243-9	2227-3	2208-0	63-9610	-1725	-1156	-1330	49-2096	29-7295
2772-820	2263-7	2261-1	2253-5	2242-2	2226-1	2206-9	63-9610	-1731	-1156	-1329	49-6932	30-2159
2782-820	2262-4	2259-8	2252-6	2240-9	2224-8	2205-7	63-9610	-1736	-1156	-1328	50-1791	30-7052
2792-820	2261-1	2258-6	2251-4	2239-9	2223-6	2204-5	63-9610	-1742	-1156	-1328	50-6674	31-1969
2802-820	2259-8	2257-3	2250-1	2238-4	2222-4	2203-3	63-9610	-1747	-1156	-1327	51-1580	31-6829
2812-820	2258-6	2256-0	2248-5	2237-2	2221-2	2202-2	63-9610	-1753	-1156	-1326	51-6511	32-1673
2822-820	2257-3	2254-7	2247-6	2236-0	2220-0	2201-0	63-9610	-1759	-1156	-1325	52-1467	32-6562
2832-820	2256-0	2253-4	2246-3	2234-7	2218-8	2199-9	63-9610	-1764	-1156	-1325	52-6446	33-1474
2842-820	2254-7	2252-2	2245-1	2233-5	2217-6	2198-7	63-9610	-1770	-1156	-1324	53-1451	33-6421
2852-820	2253-4	2250-9	2243-8	2232-3	2216-4	2197-5	63-9610	-1776	-1156	-1323	53-6480	34-1371
2862-820	2252-2	2249-6	2242-5	2231-1	2215-2	2196-4	63-9610	-1781	-1156	-1322	54-1535	34-6387
2872-820	2250-9	2248-4	2241-3	2229-8	2214-0	2195-2	63-9610	-1787	-1155	-1322	54-6614	35-1469
2882-820	2249-6	2247-1	2240-1	2228-6	2212-8	2194-1	63-9610	-1793	-1155	-1321	55-1728	35-6583
2892-820	2248-4	2245-8	2238-8	2227-4	2211-7	2192-9	63-9610	-1799	-1155	-1320	55-6850	36-1761
2902-820	2247-1	2244-6	2237-6	2226-2	2210-5	2191-8	63-9610	-1805	-1155	-1319	56-2087	36-6970
2912-820	2245-8	2243-3	2236-3	2224-9	2209-3	2190-6	63-9610	-1810	-1155	-1319	56-7110	37-2263
2922-820	2244-6	2242-1	2235-1	2223-7	2208-1	2189-5	63-9610	-1816	-1155	-1318	57-2399	37-7488
2932-820	2243-3	2240-8	2233-5	2222-5	2206-5	2188-3	63-9610	-1822	-1155	-1317	57-7634	38-2766
2942-820	2242-1	2239-6	2232-6	2221-3	2205-7	2187-2	63-9610	-1828	-1155	-1317	58-2896	38-8050
2952-820	2240-8	2238-3	2231-4	2220-1	2204-6	2186-0	63-9610	-1834	-1155	-1316	58-8185	39-3378
2962-820	2239-6	2237-1	2230-2	2218-9	2203-4	2184-9	63-9610	-1840	-1155	-1315	59-3581	39-8713
2972-820	2238-3	2235-8	2228-5	2217-7	2202-2	2183-7	63-9610	-1846	-1155	-1314	59-8844	40-4043
2982-820	2237-1	2234-6	2227-7	2216-5	2201-0	2182-6	63-9610	-1852	-1155	-1313	60-4213	40-9388
2992-820	2235-8	2233-4	2226-5	2215-3	2199-9	2181-5	63-9610	-1858	-1155	-1313	60-9613	41-4753
3002-820	2234-6	2232-1	2225-3	2214-1	2198-7	2180-3	63-9610	-1863	-1155	-1312	61-5027	42-0155
3012-820	2233-3	2230-9	2224-0	2212-9	2197-5	2179-2	63-9610	-1871	-1154	-1312	62-0493	42-5633
3022-820	2232-1	2229-6	2222-8	2211-7	2196-3	2178-1	63-9610	-1877	-1154	-1311	62-5973	43-1158
3032-820	2230-9	2228-4	2221-6	2210-5	2195-2	2176-9	63-9610	-1883	-1154	-1311	63-1486	43-6774
3042-820	2229-6	2227-2	2220-8	2209-3	2194-6	2175-8	63-9610	-1889	-1154	-1310	63-7025	44-2387
3052-820	2228-4	2226-0	2219-2	2208-1	2192-9	2174-7	63-9610	-1896	-1154	-1309	64-2584	44-8028
3062-820	2227-2	2224-7	2218-0	2206-9	2191-7	2173-6	63-9610	-1902	-1154	-1308	64-8191	45-3688
3072-820	2225-9	2223-5	2216-7	2205-7	2190-5	2172-4	63-9610	-1909	-1154	-1307	65-3817	45-9386
3082-820	2224-7	2222-3	2215-5	2204-5	2189-4	2171-3	63-9610	-1915	-1154	-1307	65-9474	46-5078
3092-820	2223-5	2221-1	2214-3	2203-3	2188-2	2170-2	63-9610	-1921	-1154	-1306	66-5180	47-0880
3102-820	2222-3	2219-9	2213-1	2202-2	2187-1	2169-1	63-9610	-1928	-1153	-1305	67-0976	47-6717
3112-820	2221-0	2218-6	2211-9	2201-0	2185-9	2168-0	63-9610	-1934	-1154	-1305	67-6822	48-2583
3122-820	2219-8	2217-4	2210-7	2199-8	2184-8	2166-8	63-9610	-1941	-1154	-1304	68-2799	48-8579
3132-820	2218-6	2216-2	2209-5	2198-6	2183-7	2165-7	63-9610	-1947	-1154	-1303	68-8827	49-4405
3142-820	2217-4	2215-0	2208-3	2197-4	2182-4	2164-6	63-9610	-1954	-1153	-1302	69-4904	49-9951
3152-820	2216-2	2213-8	2207-1	2196-3	2181-3	2163-5	63-9610	-1961	-1153	-1302	70-1015	50-6198
3162-820	2215-0	2212-6	2205-9	2195-1	2180-2	2162-4	63-9610	-1967	-1153	-1301	70-6416	51-2467

3172.820	2213.6	2211.4	2204.8	2193.9	2179.1	2161.3	63.9610	-1574	-1153	-1300	71.1745	51.8016
3182.820	2212.6	2210.2	2203.4	2190.8	2177.3	2160.2	63.9610	-1581	-1153	-1300	71.7714	52.4996
3192.820	2211.3	2209.0	2202.4	2191.6	2176.8	2159.1	63.9610	-1588	-1153	-1299	72.3711	53.1888
3202.820	2210.1	2207.8	2201.2	2190.4	2175.6	2158.0	63.9610	-1595	-1153	-1298	72.9740	53.6852
3212.820	2208.9	2206.6	2200.0	2189.3	2174.5	2156.9	63.9610	-2001	-1153	-1296	73.5803	54.2128
3222.820	2207.7	2205.4	2198.8	2188.1	2172.4	2155.8	63.9610	-2008	-1153	-1297	74.1898	54.8237
3232.820	2206.5	2204.2	2197.6	2187.0	2172.2	2154.7	63.9610	-2015	-1153	-1296	74.8026	55.4378
3242.820	2205.4	2203.0	2196.5	2185.8	2171.1	2153.6	63.9610	-2022	-1153	-1296	75.4188	56.0552
3252.820	2204.2	2201.8	2195.3	2184.6	2170.0	2152.5	63.9610	-2029	-1153	-1295	76.0383	56.6759
3262.820	2203.0	2200.6	2194.1	2183.5	2168.9	2151.4	63.9610	-2036	-1153	-1295	76.6613	57.2888
3272.820	2201.8	2199.4	2192.5	2182.3	2167.7	2150.3	63.9610	-2043	-1153	-1294	77.2877	57.9274
3282.820	2200.6	2198.3	2191.8	2181.2	2166.6	2149.2	63.9610	-2051	-1153	-1293	77.9176	58.5582
3292.820	2199.4	2197.1	2190.6	2180.0	2165.5	2148.1	63.9610	-2058	-1152	-1293	78.5509	59.1924
3302.820	2198.2	2195.9	2189.4	2178.9	2164.4	2147.1	63.9610	-2065	-1152	-1292	79.1878	59.8381
3312.820	2197.0	2194.7	2188.2	2177.7	2163.3	2146.0	63.9610	-2072	-1152	-1291	79.8282	60.4713
3322.820	2195.9	2193.6	2187.1	2176.6	2162.1	2144.9	63.9610	-2079	-1152	-1291	80.4721	61.1132
3332.820	2194.7	2192.4	2186.0	2175.5	2161.0	2143.8	63.9610	-2087	-1152	-1290	81.1197	61.7682
3342.820	2193.5	2191.2	2184.6	2174.3	2159.9	2142.7	63.9610	-2094	-1152	-1289	81.7709	62.4159
3352.820	2192.3	2190.0	2183.6	2173.2	2158.8	2141.7	63.9610	-2102	-1152	-1289	82.4258	63.0713
3362.820	2191.2	2188.9	2182.5	2172.0	2157.7	2140.6	63.9610	-2109	-1152	-1288	83.0844	63.7383
3372.820	2190.0	2187.7	2181.1	2170.9	2156.6	2139.5	63.9610	-2117	-1152	-1287	83.7467	64.3929
3382.820	2188.8	2186.5	2180.0	2169.8	2155.5	2138.4	63.9610	-2124	-1152	-1287	84.4127	65.0523
3392.820	2187.6	2185.4	2179.0	2168.6	2154.4	2137.4	63.9610	-2132	-1152	-1286	85.0826	65.7293
3402.820	2186.5	2184.2	2177.5	2167.5	2153.3	2136.3	63.9610	-2139	-1152	-1286	85.7562	66.4031
3412.820	2185.3	2183.0	2176.7	2166.4	2152.2	2135.2	63.9610	-2147	-1152	-1285	86.4338	67.0807
3422.820	2184.2	2181.9	2175.6	2165.3	2151.1	2134.1	63.9610	-2155	-1152	-1284	87.1152	67.7628
3432.820	2183.0	2180.7	2174.4	2164.1	2150.0	2133.1	63.9610	-2162	-1151	-1284	87.8005	68.4473
3442.820	2181.8	2179.6	2173.2	2163.0	2148.9	2132.0	63.9610	-2170	-1151	-1283	88.4897	69.1363
3452.820	2180.7	2178.4	2172.1	2161.9	2147.8	2131.0	63.9610	-2178	-1151	-1283	89.1830	69.8294

INITIAL TEMP.	300.000 K
EMISSION	.200
HEAT SINK TEMP.	300.000 K
PERIOD NUMBER	1
TEMP LIMIT	2000.000 K
VOLTAGE	1000.000 VOLTS
RESISTOR	50.000 OHMS
PERIOD NUMBER	2
TIME LIMIT	150.000 MSEC
PERIOD NUMBER	3
TIME LIMIT	1800.000 MSEC
VOLTAGE	12.000 VOLTS
RESISTOR	1.272 OHMS
PERIOD NUMBER	4
TIME LIMIT	500.000 MSEC
PERIOD NUMBER	5
HEAT. VOLTS	10.000 VOLTS
INITIAL	400.000 VOLTS
CAPACITOR	800.000 MFD
PERIOD NUMBER	6
TIME LIMIT	1500.000 MSEC

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