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REPORT

**K-III, A THREE REGION KINETICS CODE
IN FORTRAN-IV**

W. W. Little, Jr.

June, 1966

D. E. Simpson 32445 713 SEP 20 1966
J. E. Baird Jr. 30854 306 DEC 1 1967
J. Kleichman 31476 MATH MAR 1 1968
Dale Dutt 37633 3702 JAN 22 1968
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UC-80, Reactor Technology

K-III, A THREE REGION KINETICS CODE
IN FORTRAN-IV

By

W. W. Little, Jr.

Nuclear Analysis Section
Reactor Physics Department

June, 1966

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ABSTRACT

This paper describes a coupled neutronics-heat transfer kinetics code written in FORTRAN-IV. The power variation is computed using a lumped parameter model with up to six precursor groups. The spatial temperatures distribution in three regions is computed in plane, cylindrical, or spherical geometry. Up to 30 spatial nodes can be employed. Both linear and Doppler ($1/T$) reactivity feedback mechanisms are available. Although running time is highly problem dependent, a "typical" case requires about two minutes of UNIVAC-1107 time.

Input information, a sample case, and a FORTRAN-IV source deck listing are given in the appendices.

ABSTRACT

This paper describes a coupled neutronics-heat transfer kinetics code written in FORTRAN-IV. The power variation is computed using a lumped parameter model with up to six precursor groups. The spatial temperatures distribution in three regions is computed in plane, cylindrical, or spherical geometry. Up to 30 spatial nodes can be employed. Both linear and Doppler (1/T) reactivity feedback mechanisms are available. Although running time is highly problem dependent, a "typical" case requires about two minutes of UNIVAC-1107 time.

Input information, a sample case, and a FORTRAN-IV source deck listing are given in the appendices.

I. INTRODUCTION

In reactor transients, the spatial temperature distribution in a fuel element can depart significantly from its steady state profile. This variation in the temperature profile can sometimes be quite important. For example, if reactivity shutdown depends only on clad expansion, a rapid power excursion in a low conductivity fuel may seriously damage the fuel before any appreciable heat enters the clad.

The K-III code described in this report is designed to compute the radial and time dependent temperature distribution in a two region fuel element. The two fuel regions can be divided into a total of 30 spatial nodes. A third region is used to simulate a coolant heat sink. Calculations can be performed in spherical (fuel bead), cylindrical (fuel rod), or plane (fuel plate) geometry.

The neutronics model in K-III is a lumped parameter calculation with up to six precursor groups.^(1,2) Step, ramp, and quadratic reactivity insertions can be employed. These insertion rates can be varied with time. Reactivity feedback is specified by linear and Doppler temperature coefficients in each of the three regions.

II. NEUTRONICS MODEL

Consider the lumped parameter kinetics equations,

$$\frac{dP}{dt} = \frac{\rho - \beta}{\Lambda} P + \sum_{i=1}^G \lambda^i C^i \quad (2.1)$$

$$\frac{dC^i}{dt} = \frac{\beta^i P}{\Lambda} - \lambda^i C^i, \quad (2.2)$$

where:

P = Power density (W/cm^3)

C^i = Precursor density for group i (W/cm^3)

λ^i = Decay constant for group i (sec^{-1})

β^i = Delayed neutron fraction for group i

β = Total delayed neutron fraction

Λ = Neutron generation time (sec)

G = Number of precursor groups.

$-\omega_j P(t)$ is now added to both sides of Equation (2.1). Integration from t_j to t_{j+1} yields

$$P_{j+1} = e^{\omega_j h} \left[P_j + \int_0^h d\xi \left\{ \frac{\rho(\xi) - \rho_j}{\Lambda} P(\xi) e^{-\omega_j \xi} + \sum_{i=1}^G \lambda_j^i \left(C_j^i(\xi) - C_j^i \frac{P(\xi)}{P_j} \right) e^{-\omega_j \xi} \right\} \right], \quad (2.3)$$

where:

h = mesh spacing

j = time index

$$\omega_j = \frac{\rho_j - \beta}{\Lambda} + \frac{1}{P_j} \sum_{i=1}^G \lambda^i C_j^i.$$

In a similar manner, $-\gamma_j^i C^i(t)$ is added to both sides of Equation (2.2) and then integrated. Therefore,

$$C_{j+1}^i = e^{\gamma_j^i h} \left[C_j^i + \int_0^h d\xi e^{-\gamma_j^i \xi} \left\{ \frac{\beta^i}{\Lambda} \left(P(\xi) - \frac{P_j}{C_j^i} C^i(\xi) \right) \right\} \right], \quad (2.4)$$

where

$$\gamma_j^i = \frac{\beta^i P_j}{\Lambda C_j^i} - \lambda^i$$

Clearly, ω_j and γ_j^i 's are merely approximations to the instantaneous period at time mesh j for the power density and precursor densities, respectively.

To evaluate the integrals in Equations (2.3) and (2.4), the first approximations,

$$P(\xi) = e^{\omega_j \xi} P_j \quad (2.5)$$

and

$$C^i(\xi) = e^{\gamma_j^i \xi} C_j^i, \quad (2.6)$$

are placed in the integrals; and the integration is performed using the trapezoidal rule. This leads to the final march-out algorithm

$$P_{j+1} = e^{\omega_j h} \left\{ P_j \left(1 + \frac{h}{2\Lambda} \left\{ \rho_{j+1} - \rho_j \right\} \right) + \sum_1^G \lambda^i C_j^i \left[\frac{e^{h(\gamma_j^i - \omega_j)} - 1}{\gamma_j^i - \omega_j} - h \right] \right\} \quad (2.7)$$

$$C_{j+1}^i = e^{\gamma_j^i h} \left[C_j^i + \frac{P_j \beta^i}{\Lambda} \left\{ \frac{e^{h(\omega_j - \gamma_j^i)} - 1}{\omega_j - \gamma_j^i} - h \right\} \right]. \quad (2.8)$$

The variable time step, h , is determined by the requirement that the first approximation for P_{j+1} , Equation (2.5), agree with the second approximation, Equation (2.7), within a prescribed tolerance. That is,

$$\frac{P_{j+1}^{(2)} - P_{j+1}^{(1)}}{P_{j+1}^{(1)}} \leq \epsilon,$$

where epsilon is an input parameter.

III. HEAT TRANSFER MODEL

A schematic diagram of the heat transfer model is shown in Figure 3.1. In the first two regions, the time dependent temperature is computed using the equation

$$V_i (\rho C_p)_j \frac{\partial T_i}{\partial t} = \gamma_j P V_i + (hA)_{i-1} (T_{i-1} - T_i) - (hA)_i (T_i - T_{i+1}) \quad (3.1)$$

FIGURE 3.1. Schematic Diagram of Heat Transfer Model

where:

i = Interval index

j = Region index

T_i = Temperature of interval i ($^{\circ}\text{K}$)

V_i = Volume of interval i (cm^3)

$(\rho C_p)_j$ = Heat capacity in region j ($\text{joules}/\text{cm}^3 - ^{\circ}\text{K}$)

$\gamma_j P$ = Power density in region j (W/cm^3)

$(hA)_i$ = Heat transfer coefficient x area for interval i ($\text{W}/^{\circ}\text{K}$)

t = Time (sec).

The energy balance equation for the coolant, or third region, is more complex. Let K denote the internal number for Region 3 ($K = I1 + I2 + 1$).

An energy balance yields the equation

$$V_K(\rho C_p)_3 \frac{\partial T_K}{\partial t} = \gamma_3 P V_K + (hA)_{K-1} (T_{K-1} - T_K) - \omega C_p (T_{\text{out}} - T_{\text{in}}) \quad (3.2)$$

where:

ωC_p = Flow rate x C_p ($\text{W}/^{\circ}\text{K}$)

T_{in} = Inlet coolant temperature ($^{\circ}\text{K}$)

T_{out} = Outlet coolant temperature ($^{\circ}\text{K}$).

If we now assume that

$$T_K = \frac{1}{2}(T_{\text{out}} + T_{\text{in}}) \quad (3.3)$$

Equation (3.2) can be rewritten in the form

$$V_K(\rho C_p)_3 \frac{\partial T_K}{\partial t} = \gamma_3 P V_K + (hA)_{K-1} (T_{K-1} - T_K) - (hA)_K (T_K - T_{\text{in}}) \quad (3.4)$$

where $(hA)_K$ is defined as

$$(hA)_K = 2\omega C_p. \quad (3.5)$$

The code computes the time variation in T_K using Equation (3.5). $(hA)_K$ and T_{in} are input parameters. The quantity $V_K(\rho C_p)_3/(hA)_K$ can be considered simply as the time constant for Region 3.

A few words on the constants used in Equations (3.1) and (3.2) are in order. In the interior of each region, the heat transfer coefficient from interval to interval is assumed to be the conductivity divided by the mesh width. The heat transfer coefficients from region to region are input parameters. Observe that the thermal properties, such as conductivity and heat capacity, are assumed to be independent of temperature.

IV. REACTIVITY FEEDBACK EQUATIONS

After the new temperatures in each interval are obtained, region averaged values are computed using the equations

$$\bar{T}^1(t) = \frac{\sum_{i=1}^{I1} T_i(t) V_i}{\sum_{i=1}^{I1} V_i} \quad (4.1)$$

and

$$\bar{T}^2(t) = \frac{\sum_{i=I1+1}^{I1+I2} T_i(t) V_i}{\sum_{i=I1+1}^{I1+I2} V_i} \quad (4.2)$$

where:

$\bar{T}^1(t)$ = Average temperature in Region 1 ($^{\circ}\text{K}$)

$\bar{T}^2(t)$ = Average temperature in Region 2 ($^{\circ}\text{K}$).

The reactivity associated with each of the three regions is then computed from the equation

$$\frac{d\rho_j(t)}{dt} = \frac{1}{(RTC)_j} \left[R_1^j (\bar{T}^j - \bar{T}_O^j) + R_2^j \ln \left(\frac{\bar{T}^j}{\bar{T}_O^j} \right) - \rho_j(t) \right] \quad (4.3)$$

if $(RTC)_j > 0$, or

$$\rho_j(t) = R_1^j (\bar{T}^j - \bar{T}_O^j) + R_2^j \ln \left(\frac{\bar{T}^j}{\bar{T}_O^j} \right) \quad (4.4)$$

if $(RTC)_j = 0$. In the above equations,

$\rho_j(t)$ = Reactivity of region j

$(RTC)_j$ = Time delay (relaxation time) associated with ρ_j (sec)

R_1^j = Linear temperature coefficient region j ($^{\circ}\text{K}^{-1}$)

R_2^j = Doppler coefficient ($T dk/dT$) in region j

$\bar{T}_O^j$ = Initial temperature in region j.

Finally, the total reactivity is obtained by combining the input drive terms with the three feedback terms. Thus,

$$\rho(t) = a + bt + ct^2 + \sum_{i=1}^3 \rho_i(t), \quad (4.5)$$

where a, b, and c are input parameters.

V. REMARKS ON CODE OPERATION

The running time depends largely on the:

- (1) Neutron generation time,
- (2) Number of spatial nodes,
- (3) Time constant of most responsive node.

In some cases, the execution time is completely controlled by the neutronics calculation, in others, the computation time is governed by the temperature calculations.

Although the code automatically selects time steps that ensure a stable neutronics march-out, instabilities can occur in the temperature equations if large time steps are permitted. However, these instabilities can be avoided by specifying a short maximum time step.

REFERENCES

1. K. F. Hansen, B. V. Koen, and W. W. Little, Jr., "Stable Numerical Solutions to the Reactor Kinetics Equations," Nucl. Sci. and Eng., vol. 22, pp. 51-59 (May, 1965).
2. W. W. Little, Jr., "Kinetics I - A Neutron Kinetics Code in FORTRAN IV," BNWL-111 (July, 1965).

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APPENDIX A
INPUT INFORMATION

<u>Card</u>	<u>Columns</u>	<u>Symbol</u>	<u>Definition</u>
*1	2-72	HOL(I)	Identification card.
2	1-6	M	Number of precursor groups ($1 \leq M \leq 6$).
2	7-12	NMAX	Maximum number of time steps (NMAX $\leq 99,999$).
2	13-18	NPRT	Number of time steps between each print (e.g., NPRT = 1, print every step; NPRT = 2, print every second step).
2	19-24	NSTART	=0, code computes initial precursor densities (equilibrium); =1, precursor densities read into code (see card 5).
2	25-30	NTEQ	=0, code computes initial temperature distribution; =1, temperature distribution read into code (see card 11').
2	31-36	NCYC	Number of time zones (NCYC ≥ 1).
2	37-42	IG	Geometry: = 1, sphere; = 2, cylinder; = 3, plane.
2	43-48	I1	Number of intervals in Region 1 (I1 ≥ 1).
2	49-54	I2	Number of intervals in Region 2 (I2 ≥ 1 , I1 + I2 ≤ 30).
3	1-12	B(1)	Delay fraction for first precursor group.
3	13-24	B(2)	Delay fraction for second precursor group.
4	1-12	AL(1)	Decay constant for first precursor group (sec ⁻¹).
4	13-24	AL(2)	Decay constant for second precursor group (sec ⁻¹).

<u>Card</u>	<u>Columns</u>	<u>Symbol</u>	<u>Definition</u>
5	1-12	AN(1)	Initial power density (W/cm^3).
5	13-24	RI	Initial reactivity (absolute units).
5	25-36	ALIFE	Neutron generation time (sec).
5	37-48	HMAX	Maximum allowable time step (sec). If HMAX = 0.0, code computes HMAX.
5	49-60	EPS	Convergence criterion on march-out algorithm (~ 0.001).
5' (opt.)	1-12	C(1)	Initial concentration of first precursor group (W/cm^3).
5'	13-24	C(2)	Initial concentration of second precursor group.
:			
6	1-12	RC(1,1)	Linear temperature coefficient (dk/dt) for Region 1 ($^{\circ}\text{K}^{-1}$).
6	13-24	RC(1,2)	Doppler coefficient ($T dk/dt$) for Region 1.
6	25-36	RTC(1)	Time delay associated with reactivity feedback in Region 1 (sec).
6	37-48	PGAM(1)	Power density deposition fraction for Region 1 (i.e., power density = AN x PGAM).
7	Same as Card 6 for Region 2.		
8	Same as Card 6 for Region 3.		
9	1-12	RCP(1)	Heat capacity (ρC_p) for Region 1 ($\text{joules}/\text{cm}^3 \text{ } ^{\circ}\text{K}$).
9	13-24	COND(1)	Conductivity for Region 1 ($\text{J}/\text{cm}\text{-sec-}^{\circ}\text{K}$).
9	25-36	HAI(1)	Heat transfer coefficient (h) across outside boundary of Region 1 ($\text{J}/\text{cm}^2\text{-sec-}^{\circ}\text{K}$).
9	37-48	RADI(1)	Radius of Region 1 (cm).
10	Same as Card 6 for Region 2.		
11	1-12	RCP(3)	Heat capacity for Region 3 ($\text{joules}/\text{cm}^3 \text{ } ^{\circ}\text{K}$).
11	13-24	HA(3)	Coefficient for heat removal in Region 3. See Equation (3.5).
11	25-36	TZERO	Inlet coolant temperature ($^{\circ}\text{K}$).
11	37-48	VOL(3)	Volume of Region 3 (cm^3).
11' (opt.)	1-12	TP(1)	Initial temperature of Interval 1 ($^{\circ}\text{K}$).

<u>Card</u>	<u>Columns</u>	<u>Symbol</u>	<u>Definition</u>
11'	13-24	TP(2)	Initial temperature of Interval 2, (I1 + I2 + 1 terms).
⋮			
12	1-12	TMAX	Terminal time for Time Zone 1 (sec.)
12	13-24	R2	Reactivity ramp (dk/dT) in Time Zone 1 (sec ⁻¹).
12	25-36	R3	Quadratic coefficient for reactivity in Time Zone 1 (sec ⁻²).
13 (opt.)	Same as Card 12 for Time Zone 2.		
⋮			

* To run a series of cases, repeat from Card 1.

APPENDIX B
SAMPLE CASE

Input data and computer print-out for a sample problem are given on the following pages.

SAMPLE CASE		5 DOLLAR PER SECOND RAMP					
6	10000	50	0	0	1	0	
.00008	.000588	.000454	.00069	.000214	.000074		49
.0129	.0311	.134	.331	1.26	3.21		49
10000.	.0	.0000003	.0	.001			
.0	.0005	.0	.98				
-.00001	.0	.0	.02				
-.00001	.0	.0	.0				
3.0	.03	.56	.0075				
4.0	.21	.65	.0128				
1.09	.00018	600.	.000018				
.5	.0105	.0					

***** K - 3 A T H R E E N O D E K I N E T I C S M O D E L *****

SAMPLE CASE 5 DOLLAR PER SECOND RAMP

NUMBER OF PRECURSOR GROUPS 6
 MAXIMUM NUMBER OF TIME STEPS 10000
 NUMBER OF INTERVALS BETWEEN PRINT OUT 50
 THE NUMBER OF REACTIVITY ZONES 1
 GEOMETRY(0/1/2=SPHERE/CYLINDER/PLANE) 0
 INITIAL NEUTRON DENSITY(PER CC) 1.0000+04
 INITIAL REACTIVITY (CENTS) 0.0000
 GENERATION TIME(SEC) 3.0000+07
 MAXIMUM TIME STEP(SEC) 0.0000
 CONVERGENCE CRITERION 1.0000+03
 TOTAL PRECURSOR FRACTION 2.1000+03

GROUP	B(I)	LAMBDA(I)	C(I)
1	8.0000-05	1.2900-02	2.0672+08
2	5.8800-04	3.1100-02	6.3023+08
3	4.5400-04	1.3400-01	1.1294+08
4	6.9000-04	3.3100-01	6.9486+07
5	2.1400-04	1.2600+00	5.6614+06
6	7.4000-05	3.2100+00	7.6843+05

REACTIVITY AND HEAT TRANSFER COEFFICIENTS FOR THE THREE REGIONS

PARAMETER	REGION 1	REGION 2	REGION 3
LINEAR TEMP COEF(PER DEG K)	0.0000	-1.0000-05	-1.0000-05
DOPPLER COEFFICIENT (T DK/DT)	5.0000-04	0.0000	0.0000
REACTIVITY DELAY(SEC)	0.0000	0.0000	0.0000
INITIAL TEMP(DEG K)	7.6523+02	7.1811+02	7.0401+02
ENERGY DEPOSITION FRACTION	9.8000-01	2.0000-02	0.0000
VOLUME (CC)	1.7671-06	7.0174-06	1.8000-05
HEAT CAPACITY (JOULES/CC-DEGK)	3.0000+00	4.0000+00	1.0900+00
H.T.C. X AREA (JOULES/SEC-DEGK)	3.9584-04	1.3383-03	1.8000-04
K(J/CM-SEC-DEGK) AND T(INLET)	3.0000-02	2.1000-01	6.0000+02

SAMPLE CASE 5 DOLLAR PER SECOND RAMP

GEOMETRY SPECIFICATIONS AND TEMPERATURE DISTRIBUTION LISTED BELOW

I	ZONE	RADIUS(CM)	AVG RADIUS(CM)	AREA(CM2)	VOLUME(CC)	TEMPERATURE(DEG K)
1	1	7.500-03	3.750-03	7.069-04	1.767-06	7.652+02
2	2	1.280-02	1.015-02	2.059-03	7.017-06	7.181+02
3	3	0.000	0.000	0.000	1.800-05	7.040+02

SAMPLE CASE 5 DOLLAR PER SECOND RAMP

REACTIVITY INPUT DATA LISTED BELOW . . .

THE CURRENT TIME (SEC) = 0.0000

THE CURRENT REACTIVITY (CENTS) = 0.0000

LINEAR COEFFICIENT (CENTS/SEC) = 5.0000+02

QUADRATIC COEFFICIENT (CENTS/SEC²) = 0.0000

SAMPLE CASE 5 DOLLAR PER SECOND RAMP
SOLUTION OF KINETICS EQUATIONS BELOW

I	TIME(SEC)	POWER	RHO(CENTS)	RHO 1/C1	RHO 2/C2	RHO 3/C3	TEMP 1/C4	TEMP 2/C5	TEMP 3/C6
1	0.000	1.000+04	0.000	0.000	0.000	0.000	7.652+02	7.181+02	7.040+02
50	1.435-02	1.077+04	7.163+00	2.067+08	6.302+06	1.129+08	6.949+07	5.681+06	7.684+05
100	3.030-02	1.176+04	1.491+01	2.067+08	6.302+08	1.129+08	6.950+07	5.665+06	7.697+05
150	4.790-02	1.301+04	2.301+01	1.518-01	-2.830-01	-1.073-01	7.701+02	7.187+02	7.042+02
200	6.772-02	1.465+04	3.142+01	2.067+08	6.304+08	1.130+08	6.954+07	5.679+06	7.745+05
250	8.976-02	1.675+04	3.976+01	3.277-01	-8.479-01	-4.192-01	7.758+02	7.199+02	7.049+02
300	1.154-01	1.952+04	4.793+01	5.846-01	-1.915+00	1.130+08	6.964+07	5.708+06	7.841+05
350	1.454-01	2.297+04	5.522+01	2.068+08	6.305+08	1.131+08	7.843+02	7.221+02	7.063+02
400	1.800-01	2.658+04	6.062+01	1.453+00	-6.668+00	-4.546+00	6.981+07	5.760+06	8.012+05
450	2.185-01	2.952+04	6.371+01	2.068+08	6.312+08	1.136+08	7.057+07	5.985+06	8.733+05
500	2.593-01	3.170+04	6.532+01	2.155+00	-1.142+01	-8.203+00	8.377+02	7.421+02	7.212+02
550	3.016-01	3.373+04	6.649+01	2.069+08	6.318+08	1.142+08	7.153+07	6.209+06	9.431+05
600	3.450-01	3.585+04	6.755+01	3.028+00	-1.851+01	-1.389+01	8.690+02	7.570+02	7.332+02
650	3.900-01	3.807+04	6.847+01	2.071+08	6.328+08	1.149+08	7.248+07	6.544+06	1.045+06
700	4.357-01	4.030+04	6.926+01	3.950+00	-2.782+01	-2.169+01	9.053+02	7.765+02	7.496+02
750	4.850-01	4.282+04	6.993+01	2.073+08	6.342+08	1.160+08	7.404+07	6.990+06	1.175+06
769	5.000-01	4.344+04	7.015+01	4.812+00	-3.835+01	-3.080+01	9.366+02	7.986+02	7.687+02
				2.075+08	6.558+08	1.172+08	7.590+07	7.509+06	1.320+06
				5.636+00	-4.942+01	-4.052+01	9.696+02	8.219+02	7.891+02
				2.077+08	6.377+08	1.186+08	7.800+07	8.060+06	1.472+06
				6.454+00	-6.085+01	-5.057+01	1.004+03	8.459+02	8.102+02
				2.080+08	6.398+08	1.202+08	8.034+07	8.698+06	1.628+06
				7.260+00	-7.277+01	-6.104+01	1.039+03	8.709+02	8.322+02
				2.083+08	6.422+08	1.220+08	8.295+07	9.372+06	1.791+06
				8.093+00	-8.495+01	-7.175+01	1.075+03	8.965+02	8.547+02
				2.087+08	6.447+08	1.240+08	8.579+07	1.009+07	1.958+06
				8.908+00	-9.761+01	-9.288+01	1.112+03	9.231+02	8.751+02
				2.091+08	6.476+08	1.262+08	8.893+07	1.036+07	2.151+06
				9.194+00	-1.022+02	-8.689+01	1.126+03	9.326+02	8.865+02
				2.092+08	6.487+08	1.270+08	9.011+07	1.115+07	2.193+06

SAMPLE CASE 5 DOLLAR PER SECOND RAMP

GEOMETRY SPECIFICATIONS AND TEMPERATURE DISTRIBUTION LISTED BELOW

I	ZONE	RADIUS(CM)	AVG RADIUS(CM)	AREA(CM2)	VOLUME(CC)	TEMPERATURE(DEG K)
1	1	7.500-03	3.750-03	7.069-04	1.767-06	1.126+03
2	2	1.280-02	1.015-02	2.059-03	7.017-06	9.326+02
3	3	0.000	0.000	0.000	1.800-05	8.865+02

APPENDIX CLISTING OF FORTRAN-IV SOURCE DECK


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-R ASG A=U0365
-IL PDP INCL
ABC* FCOPY
  DIMENSION B(6),AL(6),GAM(6),ALPH(6),T(2),AN(2),RH(2),C(6,2),
1  HOL(12)          ,RTC(3),PGAM(3),VOL(3),RCP(3),HA(3),RNOR(3),
2  TEMP(3,2),RC(3,2)      ,RCNT(3,2),HHA(30),TP(31,2),ZC(31,3)
3  , RAD(30),RADA(30),RADI(2),AR(30),VR(30)      ,HAI(2),COND(2)
  COMMON M,NSTART,NMAX,NPRT,NCYC,J, NIT, NOT,NTEQ,IG,I1,I2,IT
  COMMON ERROR,BB,STEPM,TMAX,HMAX,ALIFE  ,ANZ,H,W,R1,R2,R3,TZERO
  COMMON B,AL,GAM,ALPH,T,AN,RH,C,HOL, ZC,RTC,PGAM,VOL,RCP,HA,RNOR,
1  TEMP, RC,RCNT
2  ,RAD,RADA,RADI,AR,VR,TP,HAI,COND,HHA
  END
```

```
-ITC FOR MAIN,MAIN
  INCLUDE ABC
  NIT = 5
  NOT = 6
  STEPM = 1.5
1  CONTINUE
  CALL INPUT
  CALL INPUT2
  CALL TEMDIS
  CALL SETUP
  DO 4 IJK = 1, NCYC
  CALL CONST
  CALL CALC
  CALL TEMDIS
  IF (NMAX) 2,2,4
2  KK = IJK + 1
  IF (KK - NCYC) 20,20,1
20 DO 3 K = KK,NCYC
3  CALL CONST
  GO TO 1
4  CONTINUE
  GO TO 1
END
```

```

-ITC FOR INPUT,INPUT
SUBROUTINE INPUT
  INCLUDE ABC
  READ      (NIT,2)(HOL(I),I=1,12)
2  FORMAT (12A6)
  WRITE (NOT, 1)
1  FORMAT (1H1,20X,86H * * * * * K - 3 A T H R E E N O D E
1K I N E T I C S M O D E L * * * * *)
  WRITE      (NOT,4)(HOL(I),I=1,12)
4  FORMAT (1H0//12A6///)
  READ      (NIT,6)M,NMAX,NPRT,NSTART, NTEQ,NCYC ,IG,I1,I2
6  FORMAT (9I6)
  I7 = I1 + I2
  WRITE      (NOT,8)M,NMAX,NPRT,NCYC,IG
8  FORMAT (29H0NUMBER OF PRECURSOR GROUPS ,25X,I2//
131H MAXIMUM NUMBER OF TIME STEPS ,20X,I5//
2 40H NUMBER OF INTERVALS BETWEEN PRINT OUT ,13X,I3//
336H THE NUMBER OF REACTIVITY ZONES ,17X,I3//
4 38H GEOMETRY(0/1/2=SPHERE/CYLINDER/PLANE),15X,I3/)
10 FORMAT (6E12.4)
  READ      (NIT,10)(B(I),I=1,M)
  READ      (NIT,10)(AL(I),I=1,M)
  READ (NIT,10) AN(1), R1, ALIFE, HMAX, ERROR
  BR = .0
  DO 11 I = 1, M
11 BR = BR + B(I)
  R1 = 100.*R1/BR
  IF(NSTART -1) 14,14,12
12 READ      (NIT,10)(C(I,1),I=1,M)
  GO TO 20
14 DO 15 I=1,M
15 C(I,1) = AN(1)*B(I)/(ALIFE* AL(I))
20 CONTINUE
  WRITE (NOT,22) AN(1), R1, ALIFE ,HMAX,ERROR ,BB
22 FORMAT (35H INITIAL NEUTRON DENSITY(PER CC) , 5X,1PE16.4//
130H INITIAL REACTIVITY (CENTS) ,10X,1PE16.4//
3 23H GENERATION TIME(SEC) ,17X,1PE16.4//
2 25H MAXIMUM TIME STEP(SEC) ,15X,1PE16.4//
125H CONVERGENCE CRITERION ,15X,1PE16.4//
5 27H TOTAL PRECURSOR FRACTION ,13X,1PE16.4///
6 48H GROUP B(I) LAMBDA(I) C(I)///
  DO 24 I=1,M
  WRITE      (NOT,26)I,B(I),AL(I),C(I,1)
24 WRITE      (NOT,25)
25 FORMAT (1H )
26 FORMAT (13,1P3E16.4)
  H = 100.* ALIFE
  T(1) = .0
  RH(1) = .01*BB*R1
  RETURN
  END

```

```

-1TC FOR INPUT2,INPUT2
  SUBROUTINE INPUT2
    INCLUDE ABC
  C    READS AND PRINTS HEAT TRANSFER AND REACTIVITY COEFFICIENTS
    DO 10 I = 1,3
      READ (NIT,12) RC(I,1), RC(I,2), RTC(I), PGAM(I)
10    CONTINUE
12    FORMAT (6E12.4)
    DO 20 I = 1,2
      READ (NIT,12) RCP(I), COND(I), HAI(I), RADI(I)
20    CONTINUE
      READ (NIT,12) RCP(3), HA(3), TZERO, VOL(3)
      CALL ADDINP
      CALL CIT
  C    BEGIN PRINT
      WRITE (NOT, 400)
400    FORMAT (64H1REACTIVITY AND HEAT TRANSFER COEFFICIENTS FOR THE THREE
1E REGIONS///11H PARAMETER 28X,39H REGION 1          REGION 2          R
2E GION 3///)
      WRITE (NOT,410) ((RC(I,1), I = 1,3), (RC(I,2), I=1,3), (RTC(I), I
1 = 1,3), (TEMP(I,1), I=1,3), (PGAM(I), I=1,3), (VOL(I), I=1,3),
2 (RCP(I), I =1,3), (HA(I), I=1,3),(COND(I), I=1,2), TZERO)
410    FORMAT (28H LINEAR TEMP COEF(PER DEG K), 6X, 1P3E15.4//
1 30H DOPPLER COEFFICIENT (T DK/DT), 4X, 1P3E15.4//
2 22H REACTIVITY DELAY(SEC),12X, 1P3E15.4//
3 20H INITIAL TEMP(DEG K), 14X, 1P3E15.4//
4 28H ENERGY DEPOSITION FRACTION , 6X, 1P3E15.4//
5 12H VOLUME (CC), 22X, 1P3E15.4//
6 31H HEAT CAPACITY (JOULES/CC-DEGK), 3X, 1P3E15.4//
3 32H H.T.C. X AREA (JOULES/SEC-DEGK), 2X, 1P3E15.4//
7 30H K(J/CM-SEC-DEGK) AND T(INLET), 4X, 1P3E15.4////)
    DO 455 I = 1,3
      RC(I,1) = 100.*RC(I,1)/BB
      RC(I,2) = 100.*RC(I,2)/BB
      RNOR(I) = - ( RC(I,1) * TEMP(I,1) + RC(I,2) * ALOG(TEMP(I,1)))
      RCNT(I,1) = .0
      RCNT(I,2) = .0
455    CONTINUE
    RETURN
  END

```

```

-ITC FOR ADDINP,ADDINP
  SUBROUTINE ADDINP
    INCLUDE ABC
  C    THIS SUBROUTINE COMPUTES INITIAL CONSTANTS
    G = I1
    DEL = RAD(1)/G
    RAD(1) = DEL
    RADA(1) = DEL/2.
    IF (I1 - 1) 5,5,3
  3    DO 4 I = 2,I1
      RAD(I) = RAD(I-1) + DEL
  4    RADA(I) = RADA(I-1) + DEL
  5    CONTINUE
    G = I2
    DEL = (RAD(2) - RAD(1))/G
    KG = I1 + 1
    RAD(KG) = RAD(I1) + DEL
    RADA(KG) = RAD(I1) + DEL/2.
    IF (I2 - 1) 10,10,8
  8    KG = I1 + 2
    DO 9 I = KG,IT
      RAD(I) = RAD(I-1) + DEL
  9    RADA(I) = RADA(I-1) + DEL
  10   CONTINUE
    PI = 3.141592
    IF (IG - 1) 20,30,40
  20   AR(1) = 4.*PI*RAD(1)**2
      VR(1) = 1.33333*PI*RAD(1)**3
      DO 25 I = 2,IT
        AR(I) = 4.*PI*RAD(I)**2
  25   VR(I) = 1.33333*PI*(RAD(I)**3 - RAD(I-1)**3)
      GO TO 100
  30   AR(1) = 2.*PI*RAD(1)
      VR(1) = PI*RAD(1)**2
      DO 35 I = 2,IT
        AR(I) = 2.*PI*RAD(I)
  35   VR(I) = PI*(RAD(I)**2 - RAD(I-1)**2)
      GO TO 100
  40   AR(1) = 1.0
      VR(1) = RAD(1)
      DO 45 I = 2,IT
        AR(I) = 1.0
  45   VR(I) = RAD(I) - RAD(I-1)
  100  CONTINUE
      VOL(1) = .0
      DO 110 I = 1,I1
        VOL(1) = VOL(1) + VR(I)
  110  HA(1) = AR(I1) * HAI(1)
      VOL(2) = .0
      KG = I1 + 1
      DO 120 I = KG,IT
        VOL(2) = VOL(2) + VR(I)
  120  HA(2) = AR(IT) * HAI(2)
      DEL = .5*(RAD(I1+1) - RAD(I1))
      G = 1./HAI(1) + RADA(1)/COND(1) + DEL/COND(2)

```

```

      HHA(I1) = AR(I1)/G
      G = 1.0/HAI(2) + DEL/COND(2)
      HHA(IT) = AR(IT)/G
      IF (I1 - 1) 230,230,200
200    KG = I1 - 1
      DO 210 I = 1, KG
210    HHA(I) = AR(I)*COND(1)/RAD(1)
230    IF (I2 - 1) 260,260,240
240    KG = I1 + 1
      KGG = IT - 1
      DO 250 I = KG,KGG
250    HHA(I) = AR(I) * COND(2)/(RAD(I1+1) - RAD(I1))
260    CONTINUE
      RETURN
      END
-ITC FOR CIT,CIT
      SUBROUTINE CIT
      INCLUDE ABC
C      THIS SUBROUTINE COMPUTES THE INITIAL TEMPERATURE DISTRIBUTION
      IF (NTEQ) 50,50,10
10     CONTINUE
      KG = IT + 1
      READ (NIT,20)(TP(I,1),I=1,KG)
      TEMP(3,1) = TP(KG,1)
20     FORMAT (6E12.4)
      GO TO 200
50     G = .0
      DO 60 I = 1,3
60     G = G + VOL(I) * PGAM(I)
      TEMP(3,1) = TZERO + AN(1) * G/HA(3)
      KG = IT + 1
      TP(KG,1)=TEMP(3,1)
      G = AN(1)*(VOL(1)*PGAM(1) + VOL(2)*PGAM(2))
      TP(IT,1) = TP(KG,1) + G/HHA(IT)
      DO 100 K = 2,IT
      I = IT - K + 1
      IF (I - I1) 66,68,68
66     GG = PGAM(1)
      GO TO 90
68     GG = PGAM(2)
90     G = G - GG*AN(1)*VR(I+1)
100    TP(I,1) = TP(I+1,1) + G/HHA(I)
200    CONTINUE
      TEMP(1,1) = .0
      DO 210 I = 1,I1
210    TEMP(1,1) = TEMP(1,1) + VR(1)*TP(I,1)
      TEMP(1,1) = TEMP(1,1)/VOL(1)
      KG = I1 + 1
      TEMP(2,1) = .0
      DO 220 I = KG,IT
220    TEMP(2,1) = TEMP(2,1) + VR(1)*TP(I,1)
      TEMP(2,1) = TEMP(2,1)/VOL(2)
      RETURN
      END

```



```

-ITC FOR TEMDIS,TEMDIS
  SUBROUTINE TEMDIS
    INCLUDE ABC
  C    THIS SUBROUTINE PRINTS GEOMETRY SPECIFICATIONS AND TEMP DIST
    WRITE (NOT,1) (HOL(I), I=1,12)
  1    FORMAT (1H1,12A6/// 66H GEOMETRY SPECIFICATIONS AND TEMPERATURE DI
1    STRIBUTION LISTED BELOW///94H  I      ZONE      RADIUS(CM)      AVG RA
2    DIUS(CM)      AREA(CM2)      VOLUME(CC)      TEMPERATURE(DEG K)///)
  3    FORMAT (15,I6, 1P5E15.3)
    JK = 1
    DO 6 I = 1,I1
      WRITE (NOT,3) I,JK,RAD(I),RADA(I),AR(I),VR(I),TP(I,1)
  6    CONTINUE
    JK = 2
    JKP = I1 + 1
    DO 8 I = JKP,IT
      WRITE (NOT,3) I,JK,RAD(I),RADA(I),AR(I),VR(I),TP(I,1)
  8    CONTINUE
    JK = 3
    G = .0
    JKP = IT + 1
    WRITE (NOT,3) JKP,JK,G,G,G,VOL(3),TP(JKP,1)
    RETURN
  END

```

```

-ITC FOR CONST,CONST
  SUBROUTINE CONST
    INCLUDE ABC
    WRITE (NOT,1) (HOL(I), I=1,12)
1    FORMAT (1H1//12A6////)
    READ (NIT,10) TMAX, R2, R3
10   FORMAT (6E12.4)
    RH(1) = 100.*RH(1)/BB
    R2 = 100.*R2/BB
    R3 = 100.*R3/BB
    WRITE (NOT,12) T(1), RH(1), R2, R3
12   FORMAT (41HUREACTIVITY INPUT DATA LISTED BELOW . . .////
126H THE CURRENT TIME (SEC) = 1PE16.4//
134H THE CURRENT REACTIVITY (CENTS) = 1PE16.4//
234H LINEAR COEFFICIENT (CENTS/SEC) = 1PE16.4//
338H QUADRATIC COEFFICIENT (CENTS/SEC2) = 1PE16.4//)
    WRITE (NOT,2) (HOL(I), I=1,12)
2    FORMAT (1H1//12A6// 37H SOLUTION OF KINETICS EQUATIONS BELOW//
1112H 1   TIME(SEC)      POWER      RHO(CENTS)  RHO 1/C1    RHO 2/C
22   RHO 3/C3    TEMP 1/C4    TEMP 2/C5    TEMP 3/C6////)
    I = 1
    WRITE (NOT,6) I, T(I), AN(I), RH(I), (RCNT(J,I), J=1,3),
2    (TEMP(J,I), J = 1,3), (C(J,I), J=1,M)
6    FORMAT (15, 1P9E12.3/41X,1P6E12.3)
    RH(1) = .01*BB*RH(1)
    R2 = .01*BB*R2
    R3 = .01*BB*R3
    RETURN
  END

```

```

-ITC FOR SETUP, SETUP
  SUBROUTINE SETUP
    INCLUDE ABC
    ZC(1,1) = PGAM(1)/RCP(1)
    ZC(1,2) = .0
    ZC(1,3) = HHA(1)/(VR(1)*RCP(1))
    IF (I1 - 1) 40,40,10
10    DO 30 I = 2,I1
      ZC(I,1) = PGAM(1)/RCP(1)
      ZC(I,2) = HHA(I-1)/(VR(I)*RCP(1))
30    ZC(I,3) = HHA(I)/(VR(I)*RCP(1))
40    KG = I1 + 1
      DO 50 I = KG,IT
        ZC(I,1) = PGAM(2)/RCP(2)
        ZC(I,2) = HHA(I-1)/(VR(I)*RCP(2))
50    ZC(I,3) = HHA(I)/(VR(I)*RCP(2))
      KG = IT + 1
      ZC(KG,1) = PGAM(3)/RCP(3)
      ZC(KG,2) = HHA(IT)/(VOL(3)*RCP(3))
      ZC(KG,3) = HA(3)/(VOL(3)*RCP(3))
      IF (HMAX) 80,80,90
80    G = .0
      DO 86 I = 1,KG
        IF (G - ZC(I,2)) 82,84,84
82    G = ZC(I,2)
84    IF (G - ZC(I,3)) 85,86,86
85    G = ZC(I,3)
86    CONTINUE
      HMAX = .5/G
90    CONTINUE
      IF (H - HMAX) 100,100,95
95    H = HMAX
100   CONTINUE
      RETURN
      END

```

```

-ITC FOR SUBRHO,SUBRHO
  SUBROUTINE SUBRHO
    INCLUDE ABC
  C    CALCULATION OF NEW TEMPERATURES
    G = AN(1)
    GG = TP(1,1) - TP(2,1)
    TP(1,2) = TP(1,1) + H*(ZC(1,1)*G - ZC(1,3)*GG)
    DO 3 I = 2,IT
      GG = TP(I-1,1) - TP(I,1)
      GGG = TP(I,1) - TP(I+1,1)
3     TP(I,2) = TP(I,1) + H*(ZC(I,1)*G + ZC(I,2)*GG - ZC(I,3)*GGG)
      KG = IT + 1
      GG = TP(KG,1) - TZERO
      GGG = TP(IT,1) - TP(KG,1)
      TP(KG,2) = TP(KG,1) + H*(ZC(KG,1)*G + ZC(KG,2)*GGG - ZC(KG,3)*GG)
      G = .5*(AN(1) + ANZ)
      DO 8 K = 1,3
        GG = .5*(TP(1,1) + TP(1,2) - TP(2,1) - TP(2,2))
        TP(1,2) = TP(1,1) + H*(ZC(1,1)*G - ZC(1,3)*GG)
        DO 6 I = 2,IT
          GG = .5*(TP(I-1,1) + TP(I-1,2) - TP(I,1) - TP(I,2))
          GGG = .5*(TP(I,1) + TP(I,2) - TP(I+1,1) - TP(I+1,2))
6         TP(I,2) = TP(I,1) + H*(ZC(I,1)*G + ZC(I,2)*GG - ZC(I,3)*GGG)
          GG = .5*(TP(KG,1) + TP(KG,2)) - TZERO
          GGG = .5*(TP(IT,1) + TP(IT,2) - TP(KG,1) - TP(KG,2))
          TP(KG,2) = TP(KG,1) + H*(ZC(KG,1)*G + ZC(KG,2)*GGG - ZC(KG,3)*GG)
8        CONTINUE
  C    CALCULATION OF AVERAGE TEMPERATURES
    TEMP(1,2) = .0
    DO 9 I = 1,I1
      TEMP(1,2) = TEMP(1,2) + VR(I)*TP(I,2)
      TEMP(1,2) = TEMP(1,2)/VOL(1)
      TEMP(2,2) = .0
      KG = I1 + 1
      DO 91 I = KG,IT
        TEMP(2,2) = TEMP(2,2) + VR(I)*TP(I,2)
        TEMP(2,2) = TEMP(2,2)/VOL(2)
        TEMP(3,2) = TP(IT + 1,2)
  C    CALCULATION OF REACTIVITY
    DO 16 I = 1,3
      IF (RTC(I) - .000001) 15,15,10
10     CONTINUE
      G = RNOR(I) + RC(I,1)*TEMP(I,1) + RC(I,2)*ALOG(TEMP(I,1))-RCNT(I,1)
      RCNT(I,2) = RCNT(I,1) + H*G/RTC(I)
      DO 12 KKL = 1,3
        GG=RNOR(I) +RC(I,1)*TEMP(I,2) +RC(I,2)*ALOG(TEMP(I,2))-RCNT(I,2)
        RCNT(I,2) = RCNT(I,1) + .5*H*(G + GG)/RTC(I)
12     CONTINUE
      GO TO 16
15     RCNT(I,2) = RNOR(I) + RC(I,1)*TEMP(I,2) +RC(I,2)*ALOG(TEMP(I,2))
16     CONTINUE
  C    CALCULATION OF TOTAL REACTIVITY
    G = .0
    DO 24 I = 1,3

```

```
24  G = G + RCNT(I,2) - RCNT(I,1)
    RH(2) = RH(1) + R2*H + R3*( 2.*T(1)*H + H*H) +.01*G*BB
    RETURN
    END
```

```

-ITC FOR SUBNEU,SUBNEU
SUBROUTINE SUBNEU
  INCLUDE ABC
  THIS SUBROUTINE COMPUTES THE NEW POWER USING THE OLD AND NEW REACTIVITY
  G = .0
  DO 6 I=1,M
    IF (ABS (ALPH(I)*H) - .01) 1,2,2
1    G = G + AL(I)*C(I,1 )*.5*H*H*(-ALPH(I) + H*ALPH(I)**2/3. -
    1 H*H*ALPH(I)**3/12.)
    GO TO 6
2    G = G + AL(I)*C(I,1 )*((1.-EXP (-H*ALPH(I)))/ALPH(I) - H)
6    CONTINUE
    AN(2) = EXP (W*H)*(AN(1 )*(1.+ .5*H*(RH(2)-RH(1 ))/ALIFE) + G )
    RETURN
  END

```

```

-ITC FOR PRECUR,PRECUR
  SUBROUTINE PRECUR
    INCLUDE ABC
  C    THIS SUBROUTINE COMPUTES PRECURSOR DENSITILS AND SETS INDICIES
    DO 15 I=1,M
      IF (ABS (ALPH(I)*H) - .4) 7,5,5
  5    C(I,2) = EXP (GAM(I)*H)*(C(I,1 ) + AN(1 )*B(I)*((EXP (H*ALPH(I))
      1 - 1.)/ALPH(I) - H)/ALIFE)
      GO TO 15
  7    C(I,2) = EXP (H*GAM(I))*(C(I,1 ) + AN(1 )*B(I)*H*H*ALPH(I)*
      1 (1. + ALPH(I)*H/3. + (ALPH(I)*H)**2/12. + (ALPH(I)*H)**3/60.)
      2 /(2.*ALIFE))
  15  CONTINUE
      RH(1) = RH(2)
      AN(1) = AN(2)
      T(1) = T(2)
      DO 20 I = 1,3
        TEMP(I,1) = TEMP(I,2)
        RCNT(I,1) = RCNT(I,2)
  20  CONTINUE
      DO 25 K = 1,M
  25  C(K,1) = C(K,2)
        KG = IT + 1
        DO 30 I = 1,KG
  30  TP(I,1) = TP(I,2)
      RRETURN
      END

```

```

-ITC FOR CALC,CALC
SUBROUTINE CALC
  INCLUDE ABC
  IEND = 0
  JKL = 1
  JIG = 0
  NWWL = 1
  DO 500 J = 2,NMAX
    GC = .0
    DO 3 I=1,M
      3 GC = GC + AL(I)*C(I,1)
      W = (RH(1) - B6)/ALIFE + GC/AN(1)
      DO 4 I=1,M
        GAM(I) = B(I)*AN(1)/(ALIFE*C(I,1)) - AL(I)
      4 ALPH(I) = W - GAM(I)
      5 G = W*H
      8 ANZ = AN(1)*EXP(G)
      9 T(2) = T(1) + H
      CALL SUBRHO
      CALL SUBNEU
      JIG = JIG + 1
      IF (JIG -150) 6,999,999
      6 IF (ABS (ANZ - AN(2))/ANZ - ERROR) 12,12,17
      12 IF (H - HMAX) 666, 20,22
      666 IF (JIG -1) 13,13,14
      13 NNS = 1
      HSTO = H
      ANSTO = AN(2)
      RHSTO = RH(2)
      H = H*STPM
      GO TO 5
      14 IF (NNS) 20,20,13
      17 IF (JIG - 1) 18,18,19
      18 NNS = 0
      H = H/STPM
      GO TO 5
      19 IF (NNS) 18,18,301
      999 WRITE (NOT,1112)H
      1112 FORMAT (23HNO CONVERGENCE H = 1PE16.4)
      GO TO 501
      22 H = HMAX
      CALL SUBRHO
      CALL SUBNEU
      GO TO 20
      301 H = HSTO
      AN(2) = ANSTO
      ANZ = AN(2)
      T(2) = T(1) + H
      CALL SUBRHO
      20 JIG = 0
      IF (AN(2) - 10.**22) 23,23,21
      21 IEND = 1
      23 T(2) = T(1) + H
      IF (T(2) - TMAX) 25,25,24
      24 T(2) = TMAX

```



```

      IEND = 1
      H = TMAX - T(1)
      CALL SUBRHO
      CALL SUBNEU
25     CONTINUE
      CALL PRECUR
35     IF(IEND) 501,40,501
40     JKL = JKL + 1
43     IF(JKL - NPRT) 500,45 ,45
45     JKL = 0
      RH(1) = 100.*RH(1)/BB
      JZ = J
      I = 1
      WRITE(NOT,510)JZ,T(1), AN(1), RH(1), (RCNT(K,I), K=1,3),
2 (TEMP(K,I), K = 1,3), (C(K,I), K=1,M)
      RH(1) = .01*RH(1)*BB
      NWWL = NWWL + 1
      IF (NWWL - 17) 500,500,46
46     NWWL = 0
      WRITE (NOT,47) (HOL(I), I= 1,12)
47     FORMAT (1H1/12A6///
1112H  I   TIME(SEC)      POWER      RHO(CENTS)  RHO 1/C1    RHO 2/C
22      RHO 3/C3    TEMP 1/C4    TEMP 2/C5    TEMP 3/C6///)
500    CONTINUE
      NMAX = 0
501    CONTINUE
      RH(1) = 100.*RH(1)/BB
      JZ = J
      I = 1
      WRITE(NOT,510)JZ,T(1), AN(1), RH(1), (RCNT(K,I), K=1,3),
2 (TEMP(K,I), K = 1,3), (C(K,I), K=1,M)
      RH(1) = .01*RH(1)*BB
510    FORMAT (I5, 1P9E12.3/41X,1P6E12.3)
      RETURN
      END

```


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