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REPORT

COMPUTER CALCULATION OF
REACTOR GRAPHITE OXIDATION

R. C. GIBERSON and C. A. OSTER

APRIL 1967

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UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

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BNWL-331

C-44a, Nuclear Technology
(M-3679, 48th Edition)

COMPUTER CALCULATION OF
REACTOR GRAPHITE OXIDATION

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*Exempt from CCRP Re-review Requirements
(per 7/22/82 Duff/Caudle memorandum)
X-Phase 2-1-12
Classification of Atomic International Review
(T/D 1369-52)
10/19/74*

April 1967

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COMPUTER CALCULATION OF
REACTOR GRAPHITE OXIDATION
R. C. Giberson and C. A. Oster

INTRODUCTION

Graphite oxidation in a graphite-moderated reactor depends on the composition and flow rate of the gas atmosphere, graphite temperature, and geometry of the system. Graphite oxidation, by water vapor or carbon dioxide, in a given system is complicated because of possible inhibition of the oxidation reactions by species such as H_2 and CO and also because gas-phase reactions affect the concentrations of the various gases. Furthermore, diffusion effects in gas-solid reactions must be considered.

A computer program is described in which the rate of graphite oxidation is calculated for a variety of geometrical configurations, and temperature profiles. Chemical reactions involving the gaseous species H_2O , CO_2 , CO , H_2 , and O_2 are treated. Other chemical reactions involving additional species, such as CH_4 , can readily be added to the program, which is limited primarily by the lack of knowledge of reaction mechanisms and rate constants.

The program will be illustrated by its application to a low flow, atmospheric pressure oxidation system. However, with relatively minor modifications the program can be adapted to a high flow, high pressure system as in the HTGR.

SUMMARY

The computer program described calculates graphite oxidation in a variety of geometrical arrangements. Reactions involving the gaseous species CO_2 , CO , H_2 , H_2O , and O_2 have been included.

DESCRIPTION OF PROBLEM

The problem, for which the computer solution was developed, can be divided into two parts:

- The chemical problem
- The geometrical problem.

CHEMISTRY

In a reactor using helium as a gas coolant, a number of impurities may be present. In the present analysis the following gas impurities are considered: H_2O , CO_2 , CO , H_2 , and O_2 . The computer program can easily be modified to consider other possible gases, for example, CH_4 .

With a complicated gas mixture in contact with graphite, several chemical reactions are possible; and in a nuclear reactor both thermal and radiation processes take place. The reactions currently included in the program are:

Thermal:

Radiation:

To calculate the extent of graphite oxidation, mathematical equations are necessary to define the rate of each reaction under the variety of conditions encountered. Appendix B lists the rate expressions for each of the reactions. The nomenclature is given in Appendix A.

While a number of other reactions are possible, those chosen are considered to be of most significance. Lack of information on rate constants and mechanisms prohibits the addition of other reactions such as the reverse of Reaction 1 and 2.

GEOMETRY

The flexibility of the computer system for calculating graphite oxidation is illustrated in Figures 1 and 2. In the Hanford reactors, oxidation of the graphite is monitored

FIGURE 1. Cross Section View of Graphite Moderator Showing Graphite Burnout Channel

FIGURE 2. Longitudinal View of Graphite Containing Channel

with small graphite samples contained in graphite boats, and placed in empty process tube channels of the reactor. Figure 1 shows a cross-sectional view of a typical graphite moderated reactor showing gas passages and a channel containing graphite. A longitudinal view of the channel containing graphite is shown in Figure 2.

The graphite boats are of two types, referred to as "open" or "closed." The open boats (Figure 3) permit direct access of the gas to the small samples. The closed boats (Figure 4) contain both an open and closed section. In the closed section, the gas must diffuse through approximately 1/4 in. of graphite before contacting the samples. Using both types of boats permits measurement of the diffusion effect for the gas-graphite reactions.

The program calculates the oxidation of the boats, samples, and the surrounding moderator along the length of the channel. This calculation requires a knowledge of the concentrations of the various gases and the graphite temperature at any position along the channel. A correction for in-pore gaseous diffusion must be made for all of the gas-graphite reactions.

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FIGURE 3. Open Graphite Boat (units in inches)

FIGURE 4. Closed Graphite Boat (units in inches)

The concentration of gases entering a particular channel depends on the partial pressures of the gases entering the whole reactor system, the total volume flow rate of gas in the system, and the cross-sectional area of the various gas passages. Appendix C shows the detailed calculation of the relative concentrations.

A wide variety of temperature profiles can easily be programmed. In the present case, a simple sine function is used as shown in Appendix D.

The diffusion correction calculations for circular geometry are presented in Appendix E.

MATHEMATICAL MODEL

The information desired from the computer program is the rate of graphite oxidation at any distance along a graphite channel. This rate of reaction depends on the temperature and gas composition at a given point. The net gas composition is obtained by solving a single differential equation for each gaseous species involved. To illustrate for water vapor:

$$\frac{d(H_2O)}{dt} = -R_1 - R_3 + R_4 - R_6 + R_7$$

where R_i is the appropriate kinetic expression for the i^{th} chemical equation listed previously.

In a reactor it is convenient to convert from time dependency to dependence on distance down the channel; thusly,

$$\frac{d(P_{H_2O})}{dx} = \frac{K d(H_2O)}{dt}$$

where K is the conversion factor.

Finally, in the case of the change of water vapor (or CO_2 or O_2), the diffusion correction must be applied for the gas-solid reaction. This correction also depends on the geometry (Appendix E).

The differential equation for the change in partial pressure of water vapor versus distance as a result of the water-graphite reaction is:

$$\frac{d(P_{H_2O})}{dx} = \frac{10^{-5}}{24 \times 3600} \frac{(\rho R T R_h)}{M} \sum \left(\frac{n A g}{V} \right)_i \quad (8)$$

where the summation depends on the particular geometrical pattern involved. Appendix A contains an extensive list of nomenclature.

To Equation 8 must be added (or subtracted), the contribution from Reactions 3, 4, 6, and 7. A conversion to the appropriate units of Equation 8 must be made.

These differential equations are solved by a numerical procedure described in Appendix F.

DESCRIPTION OF PROGRAM

INPUT

The computer program is adaptable to a variety of inputs. Figure 5 shows a flow chart of the program illustrating the various paths of execution. It is possible, for a given geometrical setup, to run various rate constants and/or temperature profiles and, for each set of rate and temperature constants, to run various gas compositions and flow rates. Reactions can be excluded from the program by substituting zeros (or blank cards) for their rate constants. This makes it possible, for example, to separate the effects of thermal and radiation reactions and permits the program to be used for a wide variety of systems.

FIGURE 5. G. O. P. Computer Flow Logic

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The geometrical factors of the program make it possible, by appropriate choice of constants, to simulate a system as simple as a small cylinder hanging in a quartz tube or an empty channel surrounded by graphite up to a complex reactor system involving burnout boats, chamfer channels, and annular gas passages.

A description of the input deck follows:

<u>Card No.</u>	<u>Format</u>	<u>Contents of Card</u>
1	(12A6)	Run identification.
2	(I5)	Print frequency. One line of output will be printed each time the number of integration steps is a multiple of this number, e.g., if print frequency is 1, every step will be printed; if it is 3, then steps 3, 6, 9, would be printed. In addition the conditions at each XM (See card 7+N) will be printed.
3	(3(6XA6), 4A6)	Reactor identification, channel identification, oxidation test number, date charged, date discharged.
4	(3I5)	No. of chamfer channels, No. of annular channels, No. of burnout channels.
5	(6E12.8)	CE - Edge measurement of a chamfer flow channel. DE - Diameter of empty burnout channel. DPT - Outside diameter of process tube. ODB - Outside diameter of boat. DOBI - Inside diameter of boat. DS - Outside diameter of sample. (All of these measurements are in inches).

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<u>Card No.</u>	<u>Format</u>	<u>Contents of Card</u>
6	(E12.8)	Lattice spacing (SPACE) in inches. (See Figure 1 for a drawing showing the various geometrical factors of cards 5 and 6.)
7	(3E12.8)	XZERO - Distance from origin to the point where calculation is to start (feet). DELTX - Integration step size to be used provided DXDD is not specified (feet). Active Zone Length - Length over which calculation is to be done (feet).
7+1 to 7+N	(I5,2E12.8)	NSA, XM, DXDD NSA - Integer denoting the kind of channel obstruction present from the last XM (or XZERO) to this XM. NSA = 1 if channel is empty; = 2 if closed boat and sample; = 3 if open boat and sample. XM - End point of type of flow channel given by NSA on this card (inches). DXDD - Integration step size to be used for this portion of the burn-out channel. If omitted (i.e., blank - not zero), then DELTX is used.
8+N	(5X)	Blank card.
9+N	(3E12.8)	Density of moderator, boat and sample (g/cm^3).

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This completes the first section of the input deck. The next section is all under an E12.8 format (maximum of 6E12.8 per card) except for card No. 21. Cards 10+N through 19+N are rate constant cards. Card 20+N is the temperature card and card 21 (3I5) is a switching card.

<u>Card No.</u>	<u>Reaction</u>	<u>Contents of Card</u>
10+N	$\text{CO} + \text{H}_2\text{O}$	First activation energy, first frequency factor, second activation energy, second frequency factor, inhibition factor.
11+N	$\text{CO}_2 + \text{H}_2$	Same as card 10+N
12+N	$\text{C} + \text{H}_2\text{O}$	First, second and third activation energies.
13+N	$\text{C} + \text{CO}_2$	Same as card 12+N
14+N	$\text{C} + \text{H}_2\text{O}$	First, second and third frequency factors, diffusion factor, temperature coefficient for diffusion factor.
15+N	$\text{C} + \text{CO}_2$	Same as card 14+N.
16+N	$\text{CO} + \text{H}_2\text{O}$ (Gamma)	G-value, activation energy, dose rate, efficiency factors one and two.
17+N	$\text{CO}_2 - \text{H}_2$ (Gamma)	G-value, activation energy, efficiency factors one and two.
18+N	$\text{C} + \text{O}_2$	Frequency factor, activation energy, order of reaction, diffusion factor, temperature coefficient of diffusion.
19+N	$\text{C} + \text{O}_2$ (Gamma)	Frequency factor, activation energy, order of reaction.

<u>Card No.</u>	<u>Reaction</u>	<u>Contents of Card</u>
20+N	Temperature Card	Inlet temperature (i.e., room temperature), initial graphite temperature, maximum graphite temperature, extrapolation distance (feet). Temperatures are given in degrees Centigrade.
21+N	Switching Card	IPLOT - If negative or zero, no plot is made. If positive, a plot is made on the printer. IEXIT - If negative or zero, return is to beginning of input deck. If positive, return is to second section of input deck making it possible to run multiple rate constant variations and/or temperature variations for the same geometrical setup. IETA - If zero or negative, no effect. If positive, the values of <u>eta</u> are printed out.

Third Section - Input concentrations and flow rates.

22+N	(6E12.8)	PH ₂ O, PCO, PCO ₂ , PH ₂ , V, PO ₂ .
22+N+M	Last card must be blank or all zeros. As many partial pressure cards as desired may be used. The pressures are given in millimeters mercury. The V is volume flow in cubic feet per minute - total for the system.	

A detail listing of the program is found in Appendix G and a sample input-output using hypothetical conditions is shown in Appendix H.

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FUTURE WORK

The program will be quantitatively tested by a controlled temperature and gas composition experiment conducted in a furnace 8 in. in diameter by 9 ft. long.

The current program is limited by a knowledge of rate constants and mechanism for other possible reactions. As this type of information becomes available the program can be expanded.

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APPENDIX A
NOMENCLATURE

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APPENDIX A
NOMENCLATURE

General

Ag	cross-sectional area of graphite
C	gas concentration
D	flow channel diameter
I_n	modified Bessel Function of the 1st kind, order n
K_n	modified Bessel Function of the 2nd kind, order n
k_v	rate constant
ℓ	flow channel length
L	oxidation depth
M	molecular weight of carbon
N	number of flow channels (or boats)
P	atmosphere pressure
p	partial pressure
R	reaction rate if subscripted, universal gas constant otherwise
r	radius measurement
T	temperature
V	volume flow rate
X	distance measurement
Z	diffusion coefficient

Other Notation

Δ	used to indicate an increment
δ	reactor extrapolation distance
η	diffusion factor
ρ	graphite density
∇	The Laplacian differential operator

Subscripts

Subscripts are used to identify individual quantities within a given class. The following subscripts and their meaning are used.

A	annular flow channel
B	burnout flow channel
b	boat
C	chamfer flow channel
c	closed boat
E	reactor lattice edge measurement
e	empty flow channel (void of boats)
eff	"effective" relationship or quantity
ex	exterior quantity
h	homogeneous
i	interior quantity
m	moderator
o	open boat
p	process tube
s	sample
T	total or composite quantity for system

Superscripts

In relation to the closed and open boats there are two gas concentrations. In this case the superscripts i and ex are used to indicate interior and exterior quantities respectively.

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APPENDIX B
KINETIC RATE EXPRESSIONS

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APPENDIX B

KINETIC RATE EXPRESSIONS

$$R_h = \frac{k_1 P_{\text{H}_2\text{O}}}{1 + k_2 P_{\text{H}_2}^{1/2} + k_3 P_{\text{H}_2\text{O}}}$$

$$R_h = \frac{k_1 P_{\text{CO}_2}}{1 + k_2 P_{\text{CO}} + k_3 P_{\text{CO}_2}}$$

$$R = \frac{k P_{\text{CO}}^{1/2} P_{\text{H}_2\text{O}}}{(T + a P_{\text{H}_2\text{O}})^{1/2}}$$

$$R = k_1 P_{\text{CO}_2} P_{\text{H}_2}^{1/2} + k_2 P_{\text{CO}_2} P_{\text{H}_2}^{1/3}$$

$$R_h = k P_{\text{O}_2}^n$$

The k's in the above reactions are exponential functions of temperature:

$$k = k_0 e^{-E/RT}$$

Radiation Reactions - The yields of radiation-induced reactions are commonly expressed as G values (molecules reacted or formed per 100 eV of energy absorbed). Reactions 6 and 7 have been studied by G. L. Tingey.^(5,6) The rate expression is:

$$R = G e^{-E/RT} g F$$

where g is the radiation dose rate in Roentgens per hour and F is a constant containing appropriate conversion factors as well as gas pressure terms to correct for energy absorbed in the various gases and E is the activation energy for the radiation-induced process.

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APPENDIX C
FLOW CALCULATIONS

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APPENDIX C

FLOW CALCULATIONS

To calculate graphite weight loss in a given location, it is necessary to determine what portion of the total gas flow, V , flows in the channel of interest.

Assumptions used in deriving the relationships in the program are as follows:

- I. The mass flow is conservative, i.e., for a given time increment the same quantity of gas flows into the system as flows out.
- II. The mass flow rate is proportional to the fourth power of the flow channel diameter.
- III. The mass flow rate is directly proportional to the product of the pressure drop ΔP over the flow channel and the fourth power of the flow channel diameter divided by the flow channel length.
- IV. The effective radius of a flow channel is taken to be the so-called hydraulic radius or twice the ratio of the area of flow to the wetted perimeter of the flow channel.
- V. The mass flow rate between two surfaces is assumed to be split into two channels by a fictitious surface between the two actual surfaces in such a manner that half the total mass flow rate is in each channel.

Consider the boat loaded channel as shown in Figure 2, where all open boats are contiguous as are the closed boats.

Let $D_{o \text{ eff}}$ denote the effective diameter of the open boat-sample combination. ($D_{o \text{ eff}}$ is defined in Equation C-8 below.)

From Assumption I, we have

$$V_B = V_C = V_O = V_e;$$

and from Assumption II,

$$V_B = \frac{K D_B^4 \Delta P_B}{l_B} = \frac{K D_C^4 \Delta P_C}{l_C} = \frac{K D_O^4 \text{eff} \Delta P_O}{l_O} = \frac{K D_e^4 \Delta P_e}{l_e} \quad (C-1)$$

Now

$\Delta P_B = \Delta P_C + \Delta P_O + \Delta P_e$, which by using Equation C-1 leads to

$$\Delta P_B = \frac{V_B}{K} \left\{ \frac{l_C}{D_C^4} + \frac{l_O}{D_O^4 \text{eff}} + \frac{l_e}{D_e^4} \right\}.$$

Thus

$$\frac{V_B}{D_B^4 \text{eff}} = \frac{K \Delta P_B}{l_B} = \frac{V_B}{l_B} \left\{ \frac{l_C}{D_C^4} + \frac{l_O}{D_O^4 \text{eff}} + \frac{l_e}{D_e^4} \right\}.$$

Or on solving for the effective diameter of a boat loaded channel we have

$$D_B^4 \text{eff} = l_B \left\{ \frac{l_C}{D_C^4} + \frac{l_O}{D_O^4 \text{eff}} + \frac{l_e}{D_e^4} \right\}^{-1}$$

Now from Assumption II it follows that

$$\frac{V_C}{D_C^4} = \frac{V_A}{D_A^4} = \frac{V_B}{D_B^4 \text{eff}}$$

which leads to

$$V_B = \frac{V_C}{D_C^4} = D_B^4 \text{eff} \quad (C-2)$$

and

$$V_A = \frac{V_C}{D_C^4} D_A^4. \quad (C-3)$$

Assumption I gives the relationship

$$V_T = N_C V_C + N_A V_A + N_B V_B$$

which from Equations C-2 and C-3 yields

$$V_C = V_T [N_C + \frac{1}{D_C^4} (N_A D_A^4 + N_B D_B^4 \text{ eff})]^{-1}. \quad (C-4)$$

In the case of the annular channel, Assumption IV implies that

$$D_A = 2(r_e - r_{p \text{ ex}}).$$

The chamfer flow channels are assumed to have cross sections which are right isosceles triangles. Here the flow area is $E_C^2/2$ and the wetted perimeter is $(2 + \sqrt{2})E_C$. Hence, by Assumption IV,

$$D_C = \frac{2}{2 + \sqrt{2}} E_C.$$

In treatment of flow within the burnout channel, the channel is assumed to have the form shown in Figure 2. Using Assumption IV, we have

$$D_{b \text{ i eff}} = 2(r_{b \text{ i}} - r_s)$$

$$D_{b \text{ ex eff}} = 2(r_e - r_{b \text{ ex}}). \quad (C-5)$$

If the boat is closed, then there is only one flow channel, in which case

$$D_{c \text{ eff}} = D_{b \text{ ex eff}} \quad (C-6)$$

Consider the open boat and sample case. Here, by Assumption V,

$$V_o = V_{o \text{ ex}} + V_{o \text{ i}} = 1/2 V_B \quad (\text{C-7})$$

and, from Assumption II,

$$V_{o \text{ i}} = V_{o \text{ ex}} \left(\frac{D_{b \text{ i eff}}^4}{D_{b \text{ ex eff}}^4} \right)$$

which with Equation C-7 leads to

$$V_{o \text{ ex}} = V_B \left(\frac{D_{b \text{ ex eff}}^4}{D_{b \text{ ex eff}}^4 + D_{b \text{ i eff}}^4} \right) .$$

Equation C-6 may also be written as

$$\frac{V_{o \text{ ex}}}{D_{b \text{ ex eff}}^4} = \frac{V_B}{D_{b \text{ ex eff}}^4 + D_{b \text{ i eff}}^4} .$$

Using Assumption II again and Equation C-5, we have

$$\frac{V_B}{D_{b \text{ ex eff}}^4} = \frac{V_B}{D_{o \text{ eff}}^4}$$

or by solving for $D_{o \text{ eff}}$

$$D_{o \text{ eff}} = (D_{b \text{ ex eff}}^4 + D_{b \text{ i eff}}^4)^{1/4} . \quad (\text{C-8})$$

Calculation of burnout rates for the moderator, boat, and sample requires Assumption V which gives

Case 1. Empty channel

$$V_{me} = V_B$$

Case 2. Closed boat

$$V_{mc} = 1/2 V_B$$

$$V_{bc} = 1/2 V_B$$

Case 3. Open boat

$$V_{mo} = V_{o\ ex}$$

$$V_{so} = V_{oi}$$

$$V_{bo} = V_{mo} + V_{so} .$$

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APPENDIX D
TEMPERATURE DISTRIBUTION

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APPENDIX D

TEMPERATURE DISTRIBUTION

A temperature distribution of the following form has been programmed.

$$T = a + b \sin[(X + \delta)s] + 273.16$$

where:

$$s = \frac{\pi}{2(\ell' + \delta)}$$

$$b = \frac{T_{MAX} - T_{IN}}{1 - \sin(\delta s)}$$

$$a = T_{MAX} - b$$

ℓ' = active zone length

δ = extrapolation length

T_{IN} = inlet temperature ($^{\circ}\text{C}$)

T_{MAX} = maximum graphite temperature ($^{\circ}\text{C}$).

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APPENDIX E
DIFFUSION FACTORS

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APPENDIX E

DIFFUSION FACTORS

In gas-solid reactions, it is necessary to account for the diffusion of the gas into and away from the solid. The effect of diffusion is taken into account through the so-called depth of oxidation L :

$$L = \left(\frac{Z}{k_v} \right)^{1/2} \quad (E-1)$$

Z is the effective diffusion coefficient:

$$Z = m D_{12}$$

where D_{12} is the actual gaseous diffusion coefficient and m is a variable that depends on the type of material. Graphite values of m from 0.004 to 0.01 have been determined.

The variable k_v is the specific volume rate constant (i.e., volume of carbon removed per volume of graphite present per unit time) for the reaction. It is defined for the water graphite reaction:

$$k_v = \bar{K} \frac{R_h T_p}{P_{H_2O}} \text{ sec}^{-1}$$

The constant $\bar{K}$ is for unit conversion and is given by

$$\bar{K} = 6.01019 \times 10^{-7} \left(\frac{\text{mm Hg}}{\text{atm}} \right) \left(\frac{\text{cm}^3}{\text{g}} \right) \left(\frac{\text{KOD}}{\%} \right) \left(\frac{1}{\text{sec}} \right).$$

The solution of the diffusion equation for circular geometry is shown below. The assumptions involved in the solution are:

- I. A gas concentration, C , in contact with a material diffuses into that material according to the diffusion equation, i.e.,

$$\nabla^2 C = \frac{1}{L^2} C. \quad (E-2)$$

Two sets of coefficients must be determined for the closed boat case: one set for the exterior and one set for the interior. Let

$$\Omega = \left(\frac{L^{\text{ex}}}{L^{\text{i}}} \right) I_1(r_{\text{ex}}^{\text{i}}/L^{\text{i}}) K_0(r_{\text{i}}^{\text{ex}}/L^{\text{ex}}) + I_0(r_{\text{ex}}^{\text{i}}/L^{\text{i}}) K_1(r_{\text{i}}^{\text{ex}}/L^{\text{ex}})$$

$$\chi = I_0(r_{\text{ex}}^{\text{i}}/L^{\text{i}}) I_1(r_{\text{i}}^{\text{ex}}/L^{\text{ex}}) - \left(\frac{L^{\text{ex}}}{L^{\text{i}}} \right) I_1(r_{\text{ex}}^{\text{i}}/L^{\text{i}}) I_0(r_{\text{i}}^{\text{ex}}/L^{\text{ex}})$$

$$\psi = \Omega I_0(r_{\text{ex}}^{\text{ex}}/L^{\text{ex}}) + \chi K_0(r_{\text{ex}}^{\text{ex}}/L^{\text{ex}})$$

and

$$\zeta = \frac{I_0(r_{\text{ex}}^{\text{i}}/L^{\text{i}})}{(r_{\text{i}}^{\text{ex}}/L^{\text{ex}})\psi} \quad (\text{E-5})$$

then,

$$A^{\text{ex}} = \frac{C_{\text{ex}}^{\text{ex}}}{\psi} \Omega$$

$$B^{\text{ex}} = \frac{C_{\text{ex}}^{\text{ex}}}{\psi} \chi$$

$$A^{\text{i}} = \zeta C_{\text{ex}}^{\text{ex}}/I_0(r_{\text{ex}}^{\text{i}}/L^{\text{i}})$$

$$B^{\text{i}} = 0$$

The effective reaction rate R_{eff} is the volume integral of $q = k_v C$. For a cylinder of unit length, we have

$$R_{\text{eff}} = k_v \int_0^1 \int_0^{2\pi} \int_{r_i}^{r_{\text{ex}}} C r dr d\theta dx$$

Under Assumption II, this expression reduces to

$$R_{\text{eff}} = 2\pi k_v \int_{r_i}^{r_{\text{ex}}} C(r) r dr \quad (\text{E-6})$$

Now Equation E-1 is used with Equation E-4 and E-6 to obtain

$$R_{\text{eff}} = \frac{2\pi Z}{L} \left\{ r_{\text{ex}} [A I_1(r_{\text{ex}}/L) - B K_1(r_{\text{ex}}/L)] - r_i [A I_1(r_i/L) - B K_1(r_i/L)] \right\}.$$

Notice that

$$R_{\text{eff}} = 2 Z \left[\left(r \frac{dC}{dr} \right) \Big|_{r=r_{\text{ex}}} - \left(r \frac{dC}{dr} \right) \Big|_{r=r_i} \right]$$

The homogeneous reaction rate, R_h , is defined in a similar manner except that C is further assumed to be independent of r ;

$$\begin{aligned} R_h &= k_v C_{\text{ex}} \int_0^1 \int_0^{2\pi} \int_{r_i}^{r_{\text{ex}}} r \, dr \, d\theta \, dx \\ &= \pi k_v C_{\text{ex}} (r_{\text{ex}}^2 - r_i^2). \end{aligned}$$

The diffusion factor, η , is defined to be the ratio of R_{eff} to R_h ;

$$\eta = \frac{R_{\text{eff}}}{R_h}. \quad (\text{E-7})$$

In the case of the closed boat, Equation E-7 gives η under the condition of $C_{\text{ex}} = C_i$; however, Equation E-5 is simply the ratio C_1/C_{ex} . Therefore, we use the following relationship to obtain

$$\eta_{\text{CS}} = \zeta \frac{R_{\text{eff}}}{R_h}$$

Hence, there are from one to four diffusion factors to calculate depending on the geometry of the flow channel.

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APPENDIX F
METHOD OF INTEGRATION

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APPENDIX F

METHOD OF INTEGRATION

Vector notation will be used to describe the numerical integration procedure. Let y^i denote the solution of the i^{th} differential equation $\frac{dy^i}{dx} = f^i(x, y^i)$. Now let

$$\vec{y} = \begin{pmatrix} y_1^i \\ y_2^i \\ y^i \\ \vdots \\ y^s \end{pmatrix} \text{ and } \vec{f}(x, \vec{y}) = \begin{pmatrix} f_1^i(x, \vec{y}) \\ f_2^i(x, \vec{y}) \\ \vdots \\ f^s(x, \vec{y}) \end{pmatrix}$$

Other vectors are similarly defined. The initial conditions are denoted by the subscript 0. If h is a constant, let $x_i = x_{i-1} + h$ and let $\vec{y}_i$ denote the solution vector $\vec{y}$ at the point $x = x_i$. Similarly let $\vec{f}_i = \vec{f}(x_i, \vec{y}_i)$.

The numerical procedure used is a combination of Runge-Kutta and predictor-corrector methods. The Runge-Kutta method is used to obtain starting data required by the predictor-corrector procedure. The Runge-Kutta scheme utilized may be described as follows:⁽⁷⁾

$$\begin{aligned} \vec{k}_1 &= h \vec{f}_0 \\ \vec{k}_2 &= h \vec{f}\left(x_0 + \frac{h}{2}, \vec{y}_0 + \frac{\vec{k}_1}{2}\right) \\ \vec{k}_3 &= h \vec{f}\left(x_0 + \frac{h}{2}, \vec{y}_0 + \frac{\vec{k}_2}{2}\right) \\ \vec{k}_4 &= h \vec{f}(x_0 + h, \vec{y}_0 + \vec{k}_3) \\ \vec{y}_1 &= \vec{y}_0 + \frac{1}{6} (\vec{k}_1 + 2 \vec{k}_2 + 2 \vec{k}_3 + \vec{k}_4) \end{aligned}$$

This algorithm is repeated three times giving $\vec{y}_1, \vec{f}_1, \vec{y}_2, \vec{f}_2, \vec{y}_3$ and $\vec{f}_3$. After the points $\vec{y}_0, \vec{y}_1, \vec{y}_2$, and $\vec{y}_3$ have been

determined, subsequent points are obtained by the following predictor-corrector method.⁽⁸⁾

Milnes predictor formula is

$$\vec{y}_4 = \vec{y}_0 + \frac{4h}{3} (2\vec{f}_1 - \vec{f}_2 + 2\vec{f}_3)$$

and Hamming's corrector formula

$$\vec{y}_4 = 1/8 [9\vec{y}_3 - \vec{y}_1 + 3h (\vec{f}_4 + 2\vec{f}_3 - \vec{f}_2)] \quad (F-1)$$

Equation (F-1) is used repeatedly until successive iterates agree to 7 significant figures. The solution at x_5 is obtained by adjusting the subscripts and applying the predictor equation again, followed by repeated applications of the corrector equation. If it is necessary to change the value of h , the Runge-Kutta procedure is repeated again at that point.

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APPENDIX G
FORTTRAN LISTING OF COMPUTER PROGRAM

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```
C000 GRAPHITE OXIDATION PROGRAM                                0000000
DIMENSION PO2(5),DRVCO2(5)                                    0000010
DIMENSION A1(5,3),B1(5),C1(5),D1(5,3),X(5),DRVH2O(5),DRVCO(5), 0000020
1DRVCO2(5),PH2O(5),PCO(5),PCO2(5),PH2(5),                    0000030
2DENT(12),TYPE(2),NSAI(50),XMI(50),DXDDI(50),TYP(2,50)      0000040
COMMON ZUH2O , ABH2O , NSAMPL , ZUCO2 , ABCO2 , YI          0000050
COMMON S , EXT , VKODC , VKODB , VKODS , AVS                0000060
COMMON AVC , AVB , TY , UGC , R , RE                        0000070
COMMON RD , RB , RS , H2OK10 , H2OK20 , H2OK30              0000080
COMMON H2OX1 , H2OX2 , H2OX3 , CO2K10 , CO2K20 , CO2K30      0000090
COMMON CO2X1 , CO2X2 , CO2X3 , TA , TB , AKRK1              0000100
COMMON AKRK2 , AKRK3 , AKRK4 , ALRK1 , ALRK2 , ALRK3          0000110
COMMON ALRK4 , AMRK1 , AMRK2 , AMRK3 , AMRK4 , KRK           0000120
COMMON DRVH2O , DRVCO , DRVCO2 , PH2O , PH2 , PCO           0000130
COMMON PCO2 , A1 , B1 , C1 , D1 , B1EX1                    0000140
COMMON B1EX2 , C1EX1 , C1EX2 , B1FFC1 , B1FFC2 , C1FFC1      0000150
COMMON C1FFC2 , B1IFA , C1IFA , HALFVB , VCO , RBT           0000160
COMMON VB , X , Y , TYI , TKV , TK                          0000170
COMMON ZCO2 , ZH2O , B1CON , C1CON1 , DENM , DENS           0000180
COMMON DENB , R1 , R3 , EH2O1 , EH2O2 , EH2O3              0000190
COMMON ECO21 , ECO22 , ECO23 , NSAI , XMI , DXDDI           0000200
COMMON H2OK1 , H2OK2 , H2OK3 , CO2K1 , CO2K2 , CO2K3        0000210
COMMON DENT , TYPE , TYP , RBSQ , RDSQ , ZCTK               0000220
COMMON AM , AB , AS , RATIOI , EH2OT , ECO2T                0000230
COMMON PCKOD , TIN , TMAX , BORC , BORB , BORS              0000240
COMMON H2OL , CO2L , H2OKV , CO2KV , ANRK1 , ANRK2           0000250
COMMON ANRK3 , ANRK4 , DRVU2 , PO2 , O2K1 , O2K2             0000260
COMMON APW , BPW , O2KV , O2L , EO21 , EO23                  0000270
COMMON EO22 , EO2T , ZO2 , ABO2 , ZO22 , O2X1               0000280
COMMON O2X2 , O2K10 , O2K20 , GE , DELE , XKRAD             0000290
COMMON ACON , GVALUE , REXP , VFAC , TEFAC , WWA            0000300
COMMON ECAREA , CBAREA , OBAREA , TIK , RGE , RDELE         0000310
COMMON RACON , RGVAL , C1CON2 , WI                           0000320
COMMON /ANN/CFICM,IQ,JQ,KQ,RQOCH(450),RQOOS(450),RQOCS(450),DQOCH( 0000330
1450),DQOOS(453),DQOCS(450)                                  0000340
COMMON /JAN/ EH2OCH(450),EH2OSA(450),ECO2CH(450),ECO2SA(450),EO2CH0000350
X(450),EO2SA(450),H2OLP(450),CO2LP(450),O2LPR(450),PRTYP1(450),PRTY0000360
XP2(450),TYIPR(450),WIP(450)                                 0000370
COMMON /JOKLS/ JOPH2,JOUXY,JUCU,JUHYU,JUSH2U,JUSCU2,JOCO2    0000380
1 FORMAT(1H1//////////22X12A6,///18X11HREACTOR KEY10XA6,10X16HDATE0000390
1 CHARGED 2A6,///18X14HCHANNEL NUMBER7XA6,10X16HDATE DISCHARGED 2A0000400
26,///18X21HBURNOUT TEST NUMBER A6)                          0000410
2 FORMAT(3(6XA6),4A6)                                         0000420
3 FORMAT(1H+117X,I4,I1)                                       0000430
4 FORMAT(1H 2A6,F9.2,5F10.4,F10.0,1P3E12.3)                  0000440
5 FORMAT(12A6)                                                 0000450
6 FORMAT(14I5)                                                 0000460
7 FORMAT(15,2E12.8)                                           0000470
9 FORMAT(6E12.8)                                               0000480
201 FORMAT(28HUFLOW PERCENTAGES CHAMFERF8.3,9H ANNULARF8.3,9H BUR0000490
1NOUTF8.3//)                                                  0000500
202 FORMAT(110HU CHANNEL DISTANCE PARTIAL PRESSU R0000510
1 E S BURNOUT RATE S/60H PROF10000520
2LE INCHES H2O CO H2 CO2,8X,2HO2,4X,80000530
3HTEMP.-C.,5X,7HCHANNEL,6X,4HBOAT,7X,6HSAMPLE//)           0000540
203 FORMAT(34HUNO. OF BOATS ETC. EXCEEDS LIMITS.)             0000550
204 FORMAT(1HUF8.4,1X2A6,F9.4,1X2A6,F9.4,1X2A6,F9.4,1X2A6,F9.4,1X2A6, 0000560
1F9.4/(10X2A6,F9.4,1X2A6,F9.4,1X2A6,F9.4,1X2A6,F9.4,1X2A6,F9.4)) 0000570
205 FORMAT(45HUNO. OF CHAMFER FLOW CHANNELS.....15,18X39HED0000580
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1GE OF CHAMFER FLOW CHANNEL.....F7.4/45H NO. OF ANNULAR FLOW 0000590
2CHANNELS.....15,18X39HDIAETER OF EMPTY FLOW CHANNEL...0000600
3.....F7.4/45H NO. OF BURNOUT FLOW CHANNELS.....15,18X30000610
49HOUTSIDE DIAMETER OF PROCESS TUBE.....F7.4/68X39HOUTSIDE DIAMET0000620
5ER OF BOAT.....F7.4/43H REACTOR LATTICE SPACING.....0000630
6.....F7.4,18X39HINSIDE DIAMETER OF BOAT.....F7.4/40C000640
73H ACTIVE ZONE LENGTH (FEET).....F7.4,18X39HDIAETER 00000650
8F SAMPLE.....F7.4) 0000660
206 FORMAT(1H125X27H RATE CALCULATION PARAMETERS//26X8HCO + H2O17X8HCO20000670
1 + H238X16H CARBON DENSITIES/24X1H110X1H214X1H110X1H2/18H ACTIVATIO0000680
2N ENERGY1P2E11.3,4X2E11.3,30X9HMODERATOROPF9.4/18H FREQUENCY FACT0000690
3R 1P2E11.=,4X2E11.3,30X4HBOAT5X OPF9.4/18H INHIBITION FACTOR7XF9.0000700
44,17XF9.4,36X9HSAMPLE F9.4//) 0000710
207 FORMAT(21HUTEMPERATURES GASF6.1,3X15HGRAPHITE INLET F8.2, 9H 0000720
1MAXIMUM F6.2, 12X22HEXTRAPOLATION DISTANCE F7.3) 0000730
208 FORMAT(27H INITIAL CONDITIONS FLOW =F7.2,6H PH2O =F8.3,7H PFO =0000740
1F8.3,8H PCO2 =F8.3,7H PH2 =F8.3,7H PO2 =F8.3//) 0000750
200 FORMAT(1H1,22X12A6/) 0000760
209 FORMAT(1H032XA3,11H + GRAPHITE23X9HDIFFUSION/24X1H114X1H214X1H316X0000770
17HFACTORS//18H ACTIVATION ENERGY1PE11.3,2E15.3,9X2HZOE10.3/18H FRE0000780
2QUENCY FACTOR E11.3,2E15.3,9X3HATZOPF9.4//) 0000790
210FORMAT(1H0,47HDATA FOR THE CO + H2O REACTION IN A GAMMA FIELD//1H0000800
1,3HGE=,1PE10.3,5X,5HDELE=,E10.3,5X,6HXKRAD=,E10.3,5HACON=,E10.3,250000810
2X,6HIPILOT=,I3,2X,6HIEXIT=,I3,2X,5HIETA=,I3//) 0000820
2120FORMAT(1H0,29X,35HDATA FOR OXYGEN - GRAPHITE REACTION/12X,36HFREQU0000830
1ENCY FACTOR ACTIVATION ENERGY,10X,5HORDER,17X,17HDIFFUSION FACT0000840
2RS/8H THERMAL,5X,7H02K10=,1PE10.3,10H 02E1=,E10.3,10H APW0000850
3=,E10.3,10H 0202=,E10.3,10H ABO2=,E10.3/20H RADIATION 0000860
42K20=,E10.3,10H 02E2=,E10.3,10H BPW=,E10.3//) 0000870
2130FORMAT(1H0,47HDATA FOR THE CO2 + H2 REACTION IN A GAMMA FIELD,47X,0000880
113HPRINT FREQ. =,I5//1H0,4HRGE=1PE10.3,5X,6HRDELE=,E10.3,5X,7HRAC0000890
2N=,E10.3,37X,11HSTEP SIZE =,E10.4//) 0000900
2140FORMAT(1H1,46X,25HDEPTH OF OXIDATION VALUES//42X,10HETA VALUES,35X0000910
1,15HL(DEPTH) VALUES//32H CHANNEL DISTANCE WATER,8X,14HCAR0000920
2BON DIOXIDE,8X,6HOXYGEN,13X,26HWATER CARBON OXYGEN,8X,4HTEM0000930
3P/71H PROFILE INCHES CHAN. SAMP. CHAN. SAMP. CH0000940
4AN. SAMP.,22X,7HDIOXIDE,18X,2HC.//1H,2A6,F9.4,2F7.4,4X,2F7.4,4X0000950
5,2F7.4,8X,1P3E10.3,5X,OPF5.0)) 0000960
2160FORMAT(1H0,110HIF THE CONSTANTS BELOW HAVE A VALUE OF 1 THE INDICA0000970
1TED REACTION WAS SHUT DOWN BECAUSE OF LOW GAS CONCENTRATION//8H JO0000980
2PH2 =,I5,48H HYDROGEN INHIBITION OF WATER GRAPHITE REACTION/8H JO0000990
3OXY =,I5,26H OXYGEN-GRAPHITE REACTION/8H JOCO =,I5,18H CO + H20001000
4 THERMAL/8H JOHYD =,I5,18H CO2 + H2 THERMAL/8H JOH2O=,I5,20H CO0001010
5 + H2O RADIATION/8H JOSCO2=,I5,20H CO2 + H2 RADIATION/8H JOCO2 =,0001020
6I5,45H C5 + H2O RADIATION HYDROGEN WENT 0 OR MINUS ) 0C01030
C CFICM IS THE CONVERSION FACTOR FOR INCHES TO CENTIMETERS 0001040
C SEE NAT. BUREAU OF STAND. HANDBOOK OF MATH. FUNCTIONS, APP. MATH. 0001050
C SERIES NO. 55, JUNE 64, PP 7-8 0001060
C ATJ IS A CONVERSION CONSTANT (JOULES/(ATMOS*CM**3)) 0001070
C CAJ IS A CONVERSION CONSTANT (JOULES/CALORIE) 0001080
C RGC IS THE UNIVERSAL GAS CONSTANT (JOULES/(DEG K*MOLE)) 0001090
C CATMW IS THE GRAM ATOMIC WT OF CARBON (GM/MOLE) 0001100
C ATMOS IS ATMOSPHERIC PRESSURE AT SEA LEVEL (MM OF HG) 0001110
C ZCTK IS 0 DEG K EXPRESSED IN DEG C ABSOLUTE ZERO. 0001120
C TIMEPC IS THE BASIC TIME UNIT RATIO (0/0*SEC/KOD) 0001130
C MAXLIN IS THE NUMBER OF LINES PER PAGE OF OUTPUT 0001140
DATA PI/3.14159265/,FOROPI/1.27323954/,CFICM/2.540005/,
1ATJ/,1013250/,CAJ/4.1840/,RGC/8.3143/,CATMW/12.01/,ATMOS/760./, 0001150
2ZCTK/273.16/,TIMEPC/8.64E+9/,MAXLIN/45/ 0001170

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```
DATA H2O/6HH2O /,CO2/6HCO2 /,OC1,OC2/12HOPEN CHANNEL/, 0001180
1CB1,CB2/12HCLOSED BOAT /,OB1,OB2/12HOPEN BOAT / 0001190
C TK IS THE DIFFUSION COEFF. CONVERSION FACTOR 0001200
C ((MMHG/DEG)*(CM**3/GM)*(KOD/0/0)/SEC) 0001210
TK=ATMOS/TIMEPC*RG/ATJ/CATMT 0001220
C UGC IS THE UNIVERSAL GAS CONSTANT (CALORIES/(DEG*MOLE)) 0001230
UGC=RG/CAJ 0001240
CALL SETIO (2,1) 0001250
CALL SETIO(3,2) 0001260
C DENT IS RUN IDENTIFICATION (HOLLERITH) 0001270
100 READ (2,5)DENT 0001280
C KRITE IS PRINT FREQUENCY 0001290
READ (2,6)KRITE 0001300
C RKEY IS REACTOR IDENTIFICATION (HOLLERITH) 0001310
C CHNO IS CHANNEL IDENTIFICATION (HOLLERITH) 0001320
C BOTNO IS BURNOUT CHANNEL IDENTIFICATION (HOLLERITH) 0001330
C DCHD IS DATE CHARGED (HOLLERITH) 0001340
C DDCHD IS DATE DISCHARGED (HOLLERITH) 0001350
READ (2,2)RKEY,CHNO,BOTNO,DCHD1,DCHD2,DDCHD1,DDCHD2 0001360
C NC IS THE NO. OF CHAMFER FLOW CHANNELS 0001370
C NA IS THE NO. OF ANNULAR FLOW CHANNELS 0001380
C NB IS THE NO. OF BOAT LOADED FLOW CHANNELS 0001390
READ (2,6)NC,NA,NB 0001400
C CE IS THE EDGE OF THE CHAMFER FLOW CHANNELS (INCHES) 0001410
C DPT IS THE DIAMETER OF THE PROCESS TUBE (INCHES) 0001420
C DE IS DIAMETER OF EMPTY FLOW CHANNEL (INCHES) 0001430
C ODB IS OUTSIDE DIAMETER OF BOAT (INCHES) 0001440
C DOBI IS INSIDE DIAMETER OF BOAT (INCHES) 0001450
C DS IS DIAMETER OF SAMPLE (INCHES) 0001460
READ (2,9)CE,DE,DPT,ODB,DOBI,DS 0001470
C SPACE IS THE REACTOR LATTICE SPACING (INCHES) 0001480
READ (2,9)SPACE 0001490
C XZERO IS DISTANCE OF 1-ST POINT IN BURNOUT FLOW CHANNEL FROM ORIGIN 0001500
C (FEET) 0001510
C DELTX IS THE OVERALL STEP SIZE (WILL BE USED UNLESS OVERRIDDEN BY 0001520
C INDIVIDUAL LOCAL STEP SIZE. SEE DXDD BELOW) (FEET) 0001530
C TOX IS THE DISTANCE OF LAST POINT ON THE BURNOUT CHANNEL FROM 0001540
C THE ORIGIN. (FEET) 0001550
. READ (2,9)XZERO,DELTX,TOX 0001560
C CONVERT LENGTH TO INCHES 0001570
XZERO=12.*XZERO 0001580
DELTX=12.*DELTX 0001590
TOTALX=12.*TOX 0001600
C ELE IS LENGTH OF EMPTY CHANNEL 0001610
C ELC IS LENGTH OF CLOSED BOATS 0001620
C ELO IS LENGTH OF OPEN BOATS 0001630
ELE=0. 0001640
ELC=0. 0001650
ELO=0. 0001660
X0=XZERO 0001670
ITOTSA=0 0001680
C NSA = 1 FLOW CHANNEL IS OPEN TO XM. 0001690
C NSA = 2 FLOW CHANNEL IS CLOSED BOAT TO XM. 0001700
C NSA = 3 FLOW CHANNEL IS OPEN BOAT TO XM. 0001710
C XM IS THE DISTANCE TO THE NEXT CHANGE OF CHANNEL (INCHES) 0001720
C DXDD IS INDIVIDUAL STEP SIZE TO BE USED HERE. IF NOT GIVEN DELX 0001730
C IS USED. (INCHES) 0001740
C WHEN RUNNING A BURNOUT CHANNEL ONLY CASE IT IS NECESSARY TO HAVE 0001750
C CE WITH A VALUE 0001760
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```
IF(NC)51,51,30
51 CE= 1.0
30 READ (2,7)NSA,XM,DXDD
IF(NSA) 31,31,130
130 ITOTSA=ITOTSA+1
IF(ITOTSA-50) 230,230,330
230 XM=AMIN1(XM,TOTALX)
DIFL=XM-X0
X0=XM
XMI(ITOTSA)=XM
DXDDI(ITOTSA)=DXDD
NSA=MIN0(MAX0(NSA,1),3)
NSAI(ITOTSA)=NSA
GO TO (730,830,930),NSA
730 ELE=ELE+DIFL
TYP(1,ITOTSA)=OC1
TYP(2,ITOTSA)=OC2
GO TO 30
830 ELC=ELC+DIFL
TYP(1,ITOTSA)=CB1
TYP(2,ITOTSA)=CB2
GO TO 30
930 ELO=ELO+DIFL
TYP(1,ITOTSA)=OB1
TYP(2,ITOTSA)=OB2
GO TO 30
330 WRITE (3,203)
430 CALL EXIT
C RHOMOD IS MODERATOR DENSITY (GM/CC)
C RHOBOT IS BOAT DENSITY (GM/CC)
C RHOSAM IS SAMPLE DENSITY (GM/CC)
31 READ (2,9)RHOMOD,RHOBOT,RHOSAM
WRITE (3,1)DENT,RKEY,DCHD1,DCHD2,CHNO,DDCHD1,DDCHD2,BOTNO
WRITE (3,204)XZERO,(TYP(1,I),TYP(2,I),XMI(I),I=1,ITOTSA)
WRITE (3,205)NC,CE,NA,DE,NB,DPT,ODB,SPACE,DOBI,TOX,DS
ICAN = 0
GO TO 1010
1011 ICAN = 1
C AE - S ARE ACTIVATION ENERGIES
C FFC - S ARE FREQUENCY FACTORS
C IFA - S ARE INHIBITION FACTORS
1010 READ (2,9)H2OAE1,B1FFC1,H2OAE2,B1FFC2,B1IFA
READ (2,9)CO2AE1,C1FFC1,CO2AE2,C1FFC2,C1IFA
C E - S ARE ACTIVATION ENERGIES
READ (2,9)H2OE1 , H2OE2 , H2OE3
READ (2,9)CO2E1 , CO2E2 , CO2E3
C K - S ARE FREQUENCY FACTORS
C K10 (0/0/KOD/MMHG)
C K20,K30 (1/MMHG)
C Z0,AB ARE DIFFUSION FACTORS
C Z0 (CM**2/(SEC*DEG**AB))
C AB DIMENSIONLESS
READ (2,9)H2OK10,H2OK20,H2OK30,Z0H20,ABH20
READ (2,9)CO2K10,CO2K20,CO2K30,Z0CO2,ABCO2
READ (2,9)GE,DELE,XKRADE,ACON
READ (2,9)RGE,RDELE,RACON
READ (2,9)O2K10,O2E1,APW,Z0O2,ABO2
READ (2,9)O2K20,O2E2,BPW
C RMT = GAS TEMP (CENTIGRADE)
```

0001770
0001780
0001790
0001800
0001810
0001820
0001830
0001840
0001850
0001860
0001870
0001880
0001890
0001900
0001910
0001920
0001930
0001940
0001950
0001960
0001970
0001980
0001990
0002000
0002010
0002020
0002030
0002040
0002050
0002060
0002070
0002080
0002090
0002100
0002110
0002120
0002130
0002140
0002150
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0002170
0002180
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0002200
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0002240
0002250
0002260
0002270
0002280
0002290
0002300
0002310
0002320
0002330
0002340
0002350

```
C    TIN = INLET TEMP (CENTIGRADE)                                0002360
C    TMAX = MA( TEMP (CENTIGRADE)                                0002370
C    EXT = EXTRAPOLATION DISTANCE (FEET)                          0002380
      READ (2,9)RMT,TIN,TMAX,EXT                                  0002390
      READ (2,6)IPLT,IEXIT,IETA                                  0002400
      WRITE (3,206)H2OAE1,H2OAE2,CO2AE1,CO2AE2,RHOMOD,B1FFC1,B1FFC2,F1FF0002410
1C1,C1FFC2,RHOBOT,B1IFA,C1IFA,RHOSAM                             0002420
      WRITE (3,209)H2O,H2OE1,H2OE2,H2OE3,ZOH2O,H2OK10,H2OK20,H2OK30,ABH20002430
10                                                                    0002440
      WRITE (3,209)CO2,CO2E1,CO2E2,CO2E3,ZOCO2,CO2K10,CO2K20,CO2K30,ABC0002450
12                                                                    0002460
      WRITE (3,211)GE,DELE,XKRAD,ACON,IPLT,IEXIT,IETA           0002470
      WRITE (3,213) KRITE,RGE,RDELE,RACON,DELTX                 0002480
      WRITE (3,212)O2K10,O2E1,APW,ZOO2,ABO2,O2K20,O2E2,BPW      0002490
      WRITE (3,207)RMT,TIN,TMAX,EXT                             0002500
      TIK=RMT+ZCTK                                               0002510
C    PCKOD IS A BURNOUT RATE FACTOR ((W/G/KOD)*GM*SEC/(MMHG*CM**3)) 0002520
      PCKOD=1./(TK*TIK)                                          0002530
C    SET UP EXPONENTS USED IN REACTION RATES                     0002540
C    SEE SUBROUTINE T                                            0002550
      H2OX1=H2OE1/UGC                                           0002560
      H2OX2=H2OE2/UGC                                           0002570
      H2OX3=H2OE3/UGC                                           0002580
      CO2X1=CO2E1/UGC                                           0002590
      CO2X2=CO2E2/UGC                                           0002600
      CO2X3=CO2E3/UGC                                           0002610
      B1EX1=H2OAE1/UGC                                           0002620
      B1EX2=H2OAE2/UGC                                           0002630
      C1EX1=CO2AE1/UGC                                           0002640
      C1EX2=CO2AE2/UGC                                           0002650
      O2X1= O2E1/UGC                                           0002660
      O2X2= O2E2/UGC                                           0002670
      EXT = CFICM*EXT*12.                                         0002680
      IF(ICAN)1012,1012,1013                                     0002690
1012 AN=NA                                                       0002700
      BN=NB                                                       0002710
      CN=NC                                                       0002720
C    CALCULATE FACTORS FOR L (SEE SUBROUTINE ETA)               0002730
      DENM=1./SQRT(RHOMOD)                                       0002740
      DENS=1./SQRT(RHOSAM)                                       0002750
      DENB=1./SQRT(RHOBOT)                                       0002760
      RATIOI=DENB/DENS                                           0002770
C    CONVERT UNITS                                              0002780
      CE =CFICM*CE                                               0002790
      DE =CFICM*DE                                               0002800
      DPT =CFICM*DPT                                             0002810
      ODB =CFICM*ODB                                             0002820
      DOBI =CFICM*DOBI                                           0002830
      DS =CFICM*DS                                               0002840
      SPACE=CFICM*SPACE                                          0002850
      XZERO=CFICM*XZERO                                          0002860
      DDXD =CFICM*DELTX                                          0002870
      ELE =CFICM*ELE                                             0002880
      ELC =CFICM*ELC                                             0002890
      ELO =CFICM*ELO                                             0002900
      TOTALX=TOTALX*CFICM                                         0002910
C    ELB IS THE LENGTH OF THE BURNOUT CHANNEL                   0002920
      ELB=ELE+ELC+ELO                                           0002930
C    DETERMINE TEMPERATURE PARAMETERS                           0002940
```

```
S=PI/(2.*(EXT+TOTALX))                                0002950
1013 TB = (TMAX-TIN)/(1.-SIN(EXT*S))                    0002960
      TA=TMAX-TB                                         0002970
      IF(ICAN)1014,1014,530                             0002980
C      OBTAIN EFFECTIVE CHAMFER DIAMETER (ASSUME CHAMFER CROSSECTION 0002990
C      TO BE A RIGHT ISOSELES TRIANGLE.                 0003000
1014 DC = .585786437*CE                                  0003010
C      R IS THE EFFECTIVE RADIUS OF MODERATOR GRAPHITE    0003020
      R=SPACE/.177245385E+01                             0003030
      DC2=DC**2                                           0003040
      DC4=DC2**2                                           0003050
C      DA IS THE DIAMETER OF THE ANNULAR FLOW CHANNELS   0003060
      DA=DE-DPT                                           0003070
      DA2=DA**2                                           0003080
      DA4=DA2**2                                           0003090
C      EMPTY CHANNEL                                     0003100
      RE=DE/2.                                             0003110
      AEC=PI*RE**2                                         0003120
      DE2=DE**2                                           0003130
C      BOATS                                              0003140
C      INTERIOR RADIUS                                    0003150
      RB=DOBI/2.                                           0003160
C      OUTSIDE RADIUS                                     0003170
      RD=ODB/2.                                           0003180
      ODB2=ODB**2                                          0003190
      ODB4=ODB2**2                                          0003200
C      SAMPLE                                             0003210
      RS=DS/2.                                             0003220
C      SET UP GAS CHANNEL CROSS-SECTIONAL AREAS UNITS CM**2 0003230
      ECAREA= PI * RE**2                                   0003240
      CBAREA= ECAREA - PI * RD**2                         0003250
      OBAREA= CBAREA +PI*(RB**2 - RS**2)                  0003260
C      R1 IS USED TO CALC ETA1                           0003270
      R1=R **2-RE**2                                       0003280
      RDSQ=RD**2                                           0003290
      RBSQ=RB**2                                           0003300
C      R3 IS USED TO CALC ETA3                           0003310
      R3=RDSQ-RBSQ                                         0003320
C      EFFECTIVE RADIUS OF CLOSED BOAT SAMPLE USED IN SUBROUTINE ETA. 0003330
      RBT=SQRT(R3+RHOSAM/RHOBOT*RS**2)                    0003340
C      EFFECTIVE DIAMETER (CLOSED BOATS)                 0003350
      DCBO=DE-ODB                                           0003360
      DCBO2=DCBO**2                                         0003370
      DCBO4=DCBO2**2                                       0003380
C      EFFECTIVE DIAMETER (OPEN BOATS)                   0003390
      DBI=DOBI-DS                                           0003400
      DBI2=DBI**2                                           0003410
      DBI4=DBI2**2                                           0003420
      DOB4=DCBO4+DBI4                                       0003430
      DOB2=SQRT(DOB4)                                       0003440
      DOB=SQRT(DOB2)                                       0003450
C      EFFECTIVE DIAMETER FOR OVER-ALL BOAT LOADED CHANNEL 0003460
      DBT4=ELB/(ELC/DCBO4+ELO/DOB4+ELE/(DE2**2))          0003470
      DBT2=SQRT(DBT4)                                       0003480
C      CALCULATE CROSSECTIONAL AREAS OF GRAPHITE         0003490
      AM = SPACE**2-AEC                                     0003500
      AB = (ODB2-DOBI**2)/FOROPI                           0003510
      AS = DS**2/FOROPI                                     0003520
C      CALCULATE THE WEIGHT OF GRAPHITE IN MODERATOR,BOAT,AND SAMPLE 0003530
```

```
WGAM=AM*RHOMOD 0003540
WGAB=AB*RHOBOT 0003550
WGAS=AS*RHOSAM 0003560
PARTVC=CN+(AN*DA4+BN*DBT4)/DC4 0003570
53~ READ (2,9)PH205 ,PC05 ,PC025 ,PH25 ,VI ,PO25 0003580
IF(PH205 +PC05 +PC025 +PH25 +VI +PO25 ) 1000,1000,630 0003590
1000 IF(IEXIT)100,100,1011 0003600
630 PH20(5)=PH205 0003610
PC0(5)=PC05 0003620
PC02(5)=PC025 0003630
PO2(5)=PO25 0003640
PH2(5)=PH25 0003650
JOPH2 = 0 0003660
JOOPY = 0 0003670
JOCO = 0 0003680
JOHYD = 0 0003690
JOSH20 = 0 0003700
JOSCO2 = 0 0003710
JOCO2 = 0 0003720
IQ = 1 0003730
JQ = 1 0003740
KQ = 1 0003750
IJK = 0 0003760
CONST=PH25+PH205 0003770
C CONVERT CU FT PER MIN TO CC PER SEC 0003780
VT=VI*471.9502 0003790
C FLOW VOLUMES 0003800
VC=VT/PARTVC 0003810
PVC=VC/DC4 0003820
VB=PVC*DBT4 0003830
VA=PVC*DA4 0003840
C VOLUME OUTSIDE CLOSED BOAT 0003850
VCBO=VB/2. 0003860
C VOLUME OUTSIDE OPEN BOAT 0003870
VBO=VB/DOB4*DCB04/2. 0003880
C VOLUME INSIDE OPEN BOAT 0003890
VBI=VBO/DCB04*DBI4 0003900
VOBT=VBO+VBI 0003910
C FACORS USED IN DERIV 0003920
C OPEN BOAT 0003930
VASO=VBI/WGAS*PCKOD 0003940
VABO=VOBT/WGAB*PCKOD 0003950
VAMO=VBO/WGAM*PCKOD 0003960
C CLOSED BOAT 0003970
VABC=VCBO/(WGAS+WGAB)*PCKOD 0003980
VAMC=VCBO/WGAM*PCKOD 0003990
C EMPTY CHANNEL 0004000
VAME=VB/WGAM*PCKOD 0004010
C FLOW PERCENTAGES 0004020
VPC=100./VT 0004030
VAOVT=VA*VPC*AN 0004040
VBOVT=VB*VPC*BN 0004050
VCOVT=VC*VPC*CN 0004060
ASSIGN 440 TO IGO 0004070
ASSIGN 244 TO IAM 0004080
X(5)=XZERO 0004090
YI=XZERO 0004100
CALL T(YI) 0004110
LINE=12 0004120
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WRITE (3,200)DENT                                0004130
WRITE (3,201)VCOVT,VAOVT,VBOVT                    0004140
WRITE (3,208)VI,PH205,PC05,PC025,PH25,PO25        0004150
WRITE (3,202)                                       0004160
TYPE(1)=TYP(1,1)                                   0004170
TYPE(2)=TYP(2,1)                                   0004180
WI=YI/CFICM                                         0004190
OWRITE (3,4)TYPE,WI,PH20(5),PC0(5),PH2(5),PC02(5),PO2(5),TYI 0004200
DO 241 INSA=1,ITOTSA                               0004210
KOUT= U                                             0004220
NSAMPL=NSAI(INSA)                                  0004230
XN=XMI(INSA)*CFICM                                  0004240
DXDD=DXDDI(INSA)                                    0004250
ASSIGN 48 TO IPC                                    0004260
DATA Q008CT/0000000000000/                         0004270
DATA Q009CT/077777777777/                          0004280
IF(BOOL(OR(AND(DXDD,Q008CT),AND(COMPL(DXDD),Q009CT))))43,44,43 0004290
C DXDD CHANGED FOR THIS INTERVAL                    0004300
43 DDXD=DXDD*CFICM                                  0004310
44 ISTEP=U                                           0004320
X0 = X(5)                                           0004330
NOSTEP=(XN-X0)/DDXD+.5                             0004340
344 DELX=(XN-X0)/FLOAT(NOSTEP)                     0004350
GO TO IAM,(144,244)                                0004360
144 IF(ABS((DELX-DELTAX)/DELTAX)-.5E-7) 46,46,45   0004370
244 IF(NOSTEP-4) 145,444,444                        0004380
444 ASSIGN 144 TO IAM                               0004390
GO TO 245                                           0004400
C INTERVAL OF INTEGRATION CHANGED                  0004410
45 IF(NOSTEP-4) 145,245,245                         0004420
145 NOSTEP=4                                         0004430
GO TO 344                                           0004440
245 DELTAX=DELX                                      0004450
DX0304=DELTAX/.75                                  0004460
DX02=DELTAX/2.                                      0004470
DX3=DELTAX*3.                                       0004480
X(1)=X(5)                                           0004490
PH20(1)=PH20(5)                                     0004500
PC0(1)=PC0(5)                                       0004510
PC02(1)=PC02(5)                                    0004520
PO2(1)=PO2(5)                                       0004530
PH2(1)=PH2(5)                                       0004540
DRVH20(1)=DRVH20(5)                                0004550
DRVCO(1)=DRVCO(5)                                  0004560
DRVCO2(1)=DRVCO2(5)                                0004570
2000 DRVO2(1)=DRVO2(5)                             0004580
ASSIGN 240 TO IWENT                                0004590
GO TO 48                                             0004600
C INTERVAL OF INTEGRATION REMAINS THE SAME         0004610
46 ASSIGN 210 TO IWENT                              0004620
146 DO 47 I=1,4                                     0004630
X(I)=X(I+1)                                         0004640
PH20(I)=PH20(I+1)                                  0004650
PC0(I)=PC0(I+1)                                    0004660
PC02(I) = PC02(I+1)                                0004670
PO2(I)=PO2(I+1)                                    0004680
PH2(I)=PH2(I+1)                                    0004690
DRVH20(I)=DRVH20(I+1)                              0004700
DRVCO(I)=DRVCO(I+1)                                0004710
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```
DRVCO2(I)=DRVCO2(I+1)                                0004720
2001 DRVO2(I)=DRVO2(I+1)                                0004730
47 CONTINUE                                             0004740
GO TO IPC,(210,48)                                     0004750
48 GO TO ( 20, 21, 22 ) , NSAMPL                      0004760
C EMPTY CHANNEL                                         0004770
20 AVC=VAME                                             0004780
TYPE(1)=OC1                                             0004790
TYPE(2)=OC2                                             0004800
GO TO 40                                                0004810
C CLOSED BOAT                                           0004820
21 AVB=VABC                                             0004830
AVC=VAMC                                                0004840
TYPE(1)=CB1                                             0004850
TYPE(2)=CB2                                             0004860
GO TO 40                                                0004870
C OPEN BOAT.                                             0004880
22 AVC=VAMO                                             0004890
AVB=VABO                                                0004900
AVS=VASO                                                0004910
TYPE(1)=OB1                                             0004920
TYPE(2)=OB2                                             0004930
40 GO TO IGO,(340,440)                                  0004940
340 GO TO IWENT,(240,210)                              0004950
440 ASSIGN 340 TO IGO                                  0004960
C USE RUNGES METHOD TO GET STARTED                      0004970
YI=X(1)                                                 0004980
CALL T(YI)                                              0004990
KRK = 4                                                 0005000
CALL DERIV(1)                                           0005010
240 CONTINUE                                             0005020
AKRK4          = DELTAX*( DRVH2O( 1 ) )                0005030
ALRK4          = DELTAX*( DRVCO ( 1 ) )                0005040
AMRK4          = DELTAX*( DRVCO2 (1 ) )                0005050
2002 ANRK4      = DELTAX*( DRVO2(1))                   0005060
140 KOUNT=1                                             0005070
DO 10 I = 1 , 3                                       0005080
ISTEP=ISTEP+1                                         0005090
AKRK1=AKRK4                                           0005100
ALRK1=ALRK4                                           0005110
AMRK1=AMRK4                                           0005120
ANRK1=ANRK4                                           0005130
KRK = 1                                               0005140
YI=YI+DXO2                                           0005150
CALL T(YI)                                           0005160
CALL DERIV(I+1)                                       0005170
AKRK2=DELTAX*DRVH2O(I+1)                             0005180
ALRK2=DELTAX*DRVCO (I+1)                             0005190
AMRK2=DELTAX*DRVCO2(I+1)                             0005200
2003 ANRK2=DELTAX*DRVO2(I+1)                         0005210
KRK = 2                                               0005220
CALL DERIV(I+1)                                       0005230
AKRK3=DELTAX*DRVH2O(I+1)                             0005240
ALRK3=DELTAX*DRVCO (I+1)                             0005250
AMRK3=DELTAX*DRVCO2(I+1)                             0005260
2004 ANRK3=DELTAX*DRVO2(I+1)                         0005270
YI=YI+DXO2                                           0005280
CALL T(YI)                                           0005290
KRK = 3                                               0005300
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```
CALL DERIV(I+1)                                0005310
AKRK4=DELTAX*DRVH2O(I+1)                        0005320
ALRK4=DELTAX*DRVCO (I+1)                        0005330
AMRK4=DELTAX*DRVCO2(I+1)                        0005340
ANRK4=DELTAX*DRVO2(I+1)                        0005350
PH2O(I+1) = PH2O(I)+(AKRK1+2.*(AKRK2+AKRK3)+AKRK4)/6. 0005360
PCO (I+1) = PCO (I)+(ALRK1+2.*(ALRK2+ALRK3)+ALRK4)/6. 0005370
PCO2(I+1) = PCO2(I)+(AMRK1+2.*(AMRK2+AMRK3)+AMRK4)/6. 0005380
2005 PO2(I+1) = PO2 (I)+(ANRK1+2.*(ANRK2+ANRK3)+ANRK4)/6. 0005390
PO2(I+1)= AMAX1(PO2(I+1),0.)                    0005400
PH2(I+1)=CONST-PH2O(I+1)                       0005410
X( I+1 ) = YI                                   0005420
IF(KOUNT-KRITE) 10,110,110                      0005430
110 KOUNT=0                                      0005440
IF(LINE-MAXLIN) 410,310,310                     0005450
310 LINE=8                                       0005460
WRITE (3,200)DENT                               0005470
WRITE (3,208)VI,PH2O5,PCO5,PCO25,PH25,PO25      0005480
WRITE (3,202)                                    0005490
410 LINE=LINE+1                                  0005500
C CALCULATE BURNOUT RATES                       0005510
KRK=4                                             0005520
CALL DERIV(I+1)                                  0005530
WI=YI/CFICM                                       0005540
WRITE (3,4)TYPE,WI,PH2O(I+1),PCO(I+1),PH2(I+1), PCO2(I+1),PO2(I+1) 0005550
1, TYI, BORC, BORB, BORS                        0005560
IJK = IJK + 1                                    0005570
EH2OCH(IJK) = EH2O1                              0005580
EH2OSA(IJK) = EH2O2                              0005590
ECO2CH(IJK) = ECO21                              0005600
ECO2SA(IJK) = ECO22                              0005610
EO2SA(IJK) = EO22                                0005620
H2OLP(IJK) = H2OL                                0005630
CO2LP(IJK) = CO2L                                0005640
O2LPR(IJK) = O2L                                 0005650
PRTYP1(IJK) = TYPE(1)                           0005660
PRTYP2(IJK) = TYPE(2)                           0005670
TYIPR(IJK) = TYI                                 0005680
WIP(IJK) = WI                                    0005690
10 KOUNT=KOUNT+1                                 0005700
KRK = 4                                           0005710
ASSIGN 210 TO IPC                               0005720
210 I=1                                           0005730
ISTEP=ISTEP+1                                    0005740
X( I+4 ) = X( I+3 ) + DELTAX                    0005750
C PREDICTOR - CORRECTOR FORMULAE                 0005760
C SEE RALSTON AND WILF, MATH METHODS FOR DIGITAL COMP. PP 99-100 0005770
C MILNES PREDICTOR FORMULA                       0005780
PH2O( I+4 ) = PH2O( I ) + DXO304*( 2.0*DRVH2O( I+1 ) - DRVH2O 0005790
1( I+2 ) + 2.0*DRVH2O( I+3 ))                    0005800
PCO ( I+4 ) = PCO ( I ) + DXO304*( 2.0*DRVCO ( I+1 ) - DRVCO 0005810
1( I+2 ) + 2.0*DRVCO ( I+3 ))                    0005820
PCO2( I+4 ) = PCO2( I ) + DXO304*( 2.0*DRVCO2( I+1 ) - DRVCO2 0005830
1( I+2 ) + 2.0*DRVCO2( I+3 ))                    0005840
PO2( I+4 ) = PO2( I ) + DXO304*( 2.0*DRVO2(I+1) - DRVO2(I+2) + 0005850
12.0*DRVO2(I+3))                                0005860
PO2(I+4)= AMAX1(PO2(I+4),0.)                    0005870
PH2(I+4)=CONST-PH2O(I+4)                        0005880
YI = X( I + 4 )                                  0005890
```



```

      CALL T(YI)
      N = 1
C      CORRECTOR FORMULAE
C      HAMMINGS METHOD
15  CONTINUE
      CALL DERIV(I+4)
      PH2OA=(9.*PH2O(I+3)-PH2O(I+1)+DX3*(DRVH2O(I+4)+2.*DRVH2O(I+3)-
1DRVH2O(I+2)))/8.
      PCOA=(9.*PCO(I+3)-PCO(I+1)+DX3*(DRVCO(I+4)+2.*DRVCO(I+3)-
1DRVCO(I+2)))/8.
      PCO2A=(9.*PCO2(I+3)-PCO2(I+1)+DX3*(DRVCO2(I+4)+2.*DRVCO2(I+3)-
1DRVCO2(I+2)))/8.
      PH2(I+4)=CONST-PH2OA
2006 PO2A=(9.*PO2(I+3)-PO2(I+1)+DX3*(DRVO2(I+4)+2.*DRVO2(I+3)-
1DRVO2(I+2)))/8.
      PO2A=AMAX1(PO2A,0.)
      IF( N - 2 )12,14,14
12  N = N + 1
      PH2O(I+4)=PH2OA
      PCO(I+4)=PCOA
      PCO2(I+4)=PCO2A
2007 PO2(I+4)=PO2A
C      TEST TO HALVE THE INTERVAL SIZE
      IF(N-5)15,15,301
301  DDXD=DDXD/2.
      KOUT=KOUT+1
      X(5)=X(4)
      PH2O(5)=PH2O(4)
      PCO(5)=PCO(4)
      PCO2(5)=PCO2(4)
      PO2(5)=PO2(4)
      PH2(5)=PH2(4)
      DRVH2O(5)=DRVH2O(4)
      DRVCO(5)=DRVCO(4)
      DRVCO2(5)=DRVCO2(4)
      DRVO2(5)=DRVO2(4)
      GO TO 44
14  TEST1=(PH2OA - PH2O(I+4))/PH2OA
      TEST2=(PCOA - PCO(I+4))/PCOA
      TEST3=(PCO2A - PCO2(I+4))/PCO2A
2008 TEST4=(PO2A - PO2(I+4))/PO2A
      IF(ABS(TEST1) - .5E-7) 16,16,12
16  IF(ABS(TEST2) - .5E-7) 17,17,12
17  IF(ABS(TEST3) - .5E-7) 18,18,12
18  IF(ABS(TEST4) - .5E-7) 19,19,12
19  PH2O(I+4)=PH2OA
      PCO(I+4)=PCOA
      PCO2(I+4)=PCO2A
2009 PO2(I+4)=PO2A
      IF(KOUNT - KRITE)41,42,42
42  KOUNT=0
      IF(LINE-MAXLIN) 242,142,142
142 LINE=8
      WRITE(3,200)DENT
      WRITE(3,208)VI,PH2O5,PCO5,PCO25,PH25,PO25
      WRITE(3,202)
242 LINE=LINE+1
      WI=YI/CFICM
      OWRITE(3,4)TYPE,WI,PH2O(5),PCO(5),PH2(5),PCO2(5),PO2(5),TYI,BORC,B0006480

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10RB,BORS	0006490
WRITE (3,3)KOUT,N	0006500
IJK = IJK + 1	0006510
EH20CH(IJK) = EH201	0006520
EH20SA(IJK) = EH202	0006530
EC02CH(IJK) = EC021	0006540
EC02SA(IJK) = EC022	0006550
EO2CH(IJK) = EO21	0006560
EO2SA(IJK) = EO22	0006570
H20LP(IJK) = H20L	0006580
CO2LP(IJK) = CO2L	0006590
O2LPR(IJK) = O2L	0006600
PRTYP1(IJK) = TYPE(1)	0006610
PRTYP2(IJK) = TYPE(2)	0006620
TYIPR(IJK) = TYI	0006630
WIP(IJK) = WI	0006640
41 KOUNT = KOUNT + 1	0006650
IF(ISTEP-NOSTEP) 146,141,141	0006660
141 IF(KOUNT-1) 42,241,42	0006670
241 CONTINUE	0006680
JOKE = JOPH2 + JOOXY + JOCO + JOHYD + JOSH20 + JOSCO2 + JOCO2	0006690
IF(JOKE)302,302,304	0006700
304 WRITE (3,216) JOPH2,JOOXY,JOCC,JOHYD,JOSH20,JOSCO2,JOCO2	0006710
302 IF(IETA)251,251,243	0006720
243 NCOUNT = IJK	0006730
JWRITE (3,214) (PRTYP1(IX),PRTYP2(IX),WIP(IX),EH20CH(IX),EH20SA(IX),	0006740
1,EC02CH(IX),EC02SA(IX),EO2CH(IX),EO2SA(IX),H20LP(IX),CO2LP(IX),O2L	0006750
2PR(IX),TYIPR(IX), IX=1,NCOUNT)	0006760
251 IF(IPL0T) 1020,1020,1030	0006770
1030 CALL GOPLOT	0006780
1020 GO TO 530	0006790
END	0006800-

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C010 SUBROUTINE DERIV(J)                                0100000
      SUBROUTINE DERIV(J)                                0100010
C      THIS ROUTINE CALCULATES THE DERIVATIVES AT NODE I  0100020
      DIMENSION PO2(5),DRV02(5)                          0100030
      DIMENSION A1(5,3),B1(5),C1(5),D1(5,3),X(5),DRVH20(5),DRVCO(5), 0100040
      1DRVCO2(5),PH20(5),PCO(5),PCO2(5),PH2(5),          0100050
      2DENT(12),TYPE(2),NSAI(50),XMI(50),DXDDI(50),TYP(2,50) 0100060
      COMMON ZOH20 , ABH20 , NSAMPL , ZOC02 , ABC02 , YI    0100070
      COMMON S , EXT , VKODC , VKODB , VKODS , AVS         0100080
      COMMON AVC , AVB , TY , UGC , R , RE                0100090
      COMMON RD , RB , RS , H2OK10 , H2OK20 , H2OK30       0100100
      COMMON H2OX1 , H2OX2 , H2OX3 , CO2K10 , CO2K20 , CO2K30 0100110
      COMMON CO2X1 , CO2X2 , CO2X3 , TA , TB , AKRK1       0100120
      COMMON AKRK2 , AKRK3 , AKRK4 , ALRK1 , ALRK2 , ALRK3   0100130
      COMMON ALRK4 , AMRK1 , AMRK2 , AMRK3 , AMRK4 , KRK    0100140
      COMMON DRVH20 , DRVCO , DRVCO2 , PH20 , PH2 , PCO    0100150
      COMMON PCO2 , A1 , B1 , C1 , D1 , B1EX1             0100160
      COMMON B1EX2 , C1EX1 , C1EX2 , B1FFC1 , B1FFC2 , C1FFC1 0100170
      COMMON C1FFC2 , B1IFA , C1IFA , HALFBV , VCB0 , RBT   0100180
      COMMON VB , X , Y , TYI , TKV , TK                  0100190
      COMMON ZC02 , ZH20 , B1CON , C1CON1 , DENM , DENS    0100200
      COMMON DENB , R1 , R3 , EH201 , EH202 , EH203        0100210
      COMMON ECO21 , ECO22 , ECO23 , NSAI , XMI , DXDDI     0100220
      COMMON H2OK1 , H2OK2 , H2OK3 , CO2K1 , CO2K2 , CO2K3  0100230
      COMMON DENT , TYPE , TYP , RBSQ , RDSQ , ZCTK        0100240
      COMMON AM , AB , AS , RATIO , EH20T , ECO2T         0100250
      COMMON PCKOD , TIN , TMAX , BORC , BORB , BORS       0100260
      COMMON H2OL , CO2L , H2OKV , CO2KV , ANRK1 , ANRK2    0100270
      COMMON ANRK3 , ANRK4 , DRV02 , PO2 , O2K1 , O2K2      0100280
      COMMON APW , BPW , O2KV , O2L , EO21 , EO23          0100290
      COMMON EO22 , EO2T , ZO2 , ABO2 , ZO2 , O2X1         0100300
      COMMON O2X2 , O2K10 , O2K20 , GE , DELE , XKRAD     0100310
      COMMON ACON , GVALUE , REXP , VFACT , TEFAC , WWA    0100320
      COMMON ECAREA , CBAREA , OBAREA , TIK , RGE , RDELE  0100330
      COMMON RACON , RGVAL , C1CON2 , WI                  0100340
      COMMON /ANN/CFICM,IQ,JQ,KQ,RQOCH(450),RQOOS(450),RQOCS(450),DQOCH( 0100350
      1450),DQOOS(450),DQOCS(450)                        0100360
      COMMON /JAN/ EH2OCH(450),EH2OSA(450),ECO2CH(450),ECO2SA(450),EO2CH( 0100370
      X(450),EO2SA(450),H2OLP(450),CO2LP(450),O2LPR(450),PRTYP1(450),PRTY 0100380
      XP2(450),TYIPR(450),WIP(450)                        0100390
      COMMON /JOKES/ JOPH2,JOOXY,JOCO,JOHYD,JOSH20,JOSCO2,JOCO2 0100400
      I=J                                                    0100410
      GO TO ( 5 , 6 , 7 , 4 ) , KRK                       0100420
4 PH2OI=PH20(I)                                           0100430
  PH2I=PH2(I)                                             0100440
  PCOI=PCO(I)                                             0100450
  PCO2I=PCO2(I)                                           0100460
  PO2I= PO2(I)                                           0100470
  GO TO 8                                                 0100480
5 AKO2=AKRK1/2.                                           0100490
  PH2OI=PH20(I-1) + AKO2                                0100500
  PH2I = PH2(I-1) - AKO2                                0100510
  PCOI = PCO(I-1) + ALRK1/2.                             0100520
  PCO2I = PCO2(I-1) + AMRK1/2.                          0100530
  PO2I = PO2(I-1) + ANRK1/2.                             0100540
  GO TO 8                                                 0100550
6 AKO2=AKRK2/2.                                           0100560
  PH2OI = PH20(I-1 ) + AKO2                             0100570
  PH2I = PH2(I-1) - AKO2                                0100580

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PCO1 = PCO(I-1) + ALRK2/2.      0100590
PCO2I = PCO2(I-1) + AMRK2/2.    0100600
PO2I = PO2(I-1) + ANRK2/2.      0100610
GO TO 8                          0100620
7 AKO2=AKRK3                     0100630
PH2O1 = PH2O(I-1) + AKO2        0100640
PH2I = PH2(I-1) - AKO2          0100650
PCO1 = PCO(I-1) + ALRK3         0100660
PCO2I = PCO2(I-1) + AMRK3       0100670
PO2I = PO2(I-1) + ANRK3         0100680
C TK=6.01019E-7                 0100690
C TKV=TK*TY                      0100700
C SEE SUBROUTINE T               0100710
C K1=K10*EXPF(X1/T)             0100720
C K2=K20*EXPF(X2/T)             0100730
C K3=K30*EXPF(X3/T)             0100740
C SEE SUBROUTINE T               0100750
C RH IS THE HOMOGENEOUS REACTION RATE 0100760
8 IF (PH2I)82,82,84             0100770
82 PH2IX = 0.00001              0100780
   JOPH2 = 1                    0100790
   GO TO 83                     0100800
84 PH2IX = PH2I                 0100810
83 RHH2O = H2OK1*PH2O1/(1.+H2OK2*SQR(TPH2IX)+H2OK3*PH2O1) 0100820
   RH CO2=CO2K1*PCO2I/(1.+CO2K2*PCO1+CO2K3*PCO2I) 0100830
   IF(O2K1)91,91,93             0100840
93 IF(PO2I-.00076)88,88,86      0100850
88 JOOXY = 1                    0100860
91 RH02 = 0.                    0100870
   GO TO 89                     0100880
86 RH02 = O2K1*PO2I**APW        0100890
89 PKH2O = RHH2O*TKV            0100900
   PKCO2=RH CO2*TKV             0100910
   PKO2= RH02 * TKV             0100920
C KV IS THE VOLUME RATE CONSTANT IN THE REACTION /GRAPHITE DENSITY 0100930
   H2OKV=PKH2O/PH2O1            0100940
   CO2KV=PKCO2/PCO2I            0100950
   O2KV= PKO2/PO2I              0100960
C Z IS THE EFFECTIVE DIFFUSION COEFFICIENT 0100970
C L IS THE DEPTH OF OXIDATION*SQR(TF(GRAPHITE DENSITY)) 0100980
   H2OL=SQR(TZH2O/H2OKV)        0100990
   CO2L=SQR(TZCO2/CO2KV)       0101000
   O2L = SQR(TZO2/O2KV)        0101010
C ETA CALCULATES THE DIFFUSION FACTOR 0101020
   CALL ETA(H2OL,EH2O1,EH2O3,EH2O2,EH2OT) 0101030
   CALL ETA(CO2L,ECO21,ECO23,ECO22,ECO2T) 0101040
   CALL ETA(O2L,EO21,EO23,EO22,EO2T)      0101050
C T A1 IS THE C + H2O REACTION RATE TERM 0101060
C T D1 IS THE C + CO2 REACTION RATE TERM 0101070
C TF1 IS THE C + O2 REACTION RATE TERM (THERMAL) 0101080
C TF2 IS THE C + O2 REACTION RATE TERM (RADIATION) 0101090
   IF(PO2I)23,23,24             0101100
23 TF2= 0.                      0101110
   GO TO 25                     0101120
24 TF2= O2K2 * PO2I**BPW        0101130
25 BORC=-(EH2O1*RH H2O+ECO21*RH CO2 + EO21*RH02 + TF2) 0101140
   RQOCH(IQ) = BORC             0101150
   DQOCH(IQ) = YI/CFICM         0101160
   IQ = IQ + 1                  0101170

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      TA1=EH201/AVC                                0101180
      TD1=ECO21/AVC                                0101190
      TF1= EO21/AVC                                0101200
      IF(NSAMPL-2) 9,10,11                          0101210
C     EMPTY CHANNEL                                0101220
      9 BORB=0.                                       0101230
      BORS=0.                                       0101240
      GO TO 12                                       0101250
C     CLOSED BOAT                                  0101260
      10 BORB=-(EH203*RH H2O+ECO23*RH CO2 + EO23*RH02 + TF2) 0101270
      BORS=-(EH202*RH H2O+ECO22*RH CO2 + EO22*RH02 + TF2) 0101280
      RQOCS(KQ) = BORS                             0101290
      DQOCS(KQ) = YI/CFICM                          0101300
      KQ = KQ + 1                                    0101310
      TA1=TA1+EH20T/AVB                             0101320
      TD1=TD1+ECO2T/AVB                             0101330
      TF1= TF1+EO2T/AVB                             0101340
      GO TO 12                                       0101350
C     OPEN BOAT                                    0101360
      11 BORB=-(EH203*RH H2O+ECO23*RH CO2 + EO23*RH02 + TF2) 0101370
      BORS=-(EH202*RH H2O+ECO22*RH CO2 + EO22*RH02 + TF2) 0101380
      RQOOS(JQ) = IORS                             0101390
      DQOOS(JQ) = YI/CFICM                          0101400
      JQ = JQ + 1                                    0101410
      TA1=TA1+EH203/AVB+EH202/AVS                   0101420
      TD1=TD1+ECO23/AVB+ECO22/AVS                   0101430
      TF1= TF1+EO23/AVB + EO22/AVS                  0101440
      12 CONTINUE                                   0101450
      TA1=TA1*RH H2O                                0101460
      TD1=TD1*RH CO2                                0101470
      TF1= TF1*RH02                                  0101480
C     THE REACTIONS WHICH FOLLOW DO NOT INVOLVE GRAPHITE 0101490
C     WATER GAS SHIFT REACTION - THERMAL             0101500
C     B1 IS THE CO + H2O REACTION RATE TERM          0101510
C     C1 IS THE CO2 + H2 REACTION RATE TERM          0101520
      IF(PCOI-.0076)62,62,64                         0101530
      62 B1(I) =0.0                                  0101540
      JOCO = 1                                       0101550
      GO TO 66                                       0101560
      64 IF(PH2I)68,68,69                            0101570
      68 B1IFA = 0.                                  0101580
      JOCO2 = 1                                      0101590
      69 B1(I) = B1CON*SQRT(PCOI/(TY+B1IFA*PH2I))*PH2OI*TIK 0101600
      66 IF(PH2I-.0076)72,72,74                     0101610
      72 C1(I) = 0.0                                 0101620
      JOHYD = 1                                      0101630
      GO TO 76                                       0101640
      740C1(I)= C1CON1 * PCO2I * SQRT(PH2I/TY)/TY + C1CON2 * PCO2I * ((PH2I
      1/TY)**0.33333)/TY                             0101650
      76 IF(NSAMPL - 2 )26,27,28                    0101660
C     EMPTY CHANNEL                                0101670
      26 B1(I)= B1(I)*ECAREA                         0101680
      C1(I)= C1(I)*ECAREA                         0101690
      GO TO 29                                       0101700
C     CLOSED BOAT                                  0101710
      27 B1(I)= B1(I)*CBAREA                         0101720
      C1(I)= C1(I)*CBAREA                         0101730
      GO TO 29                                       0101740
C     OPEN BOAT                                    0101750
      0101760
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28 B1(I)= B1(I)*OBAREA                                0101770
   C1(I)= C1(I)*OBAREA                                0101780
29 C1MB1= C1(I) - B1(I)                                0101790
C   CO + H2O REACTION IN A RADIATION FIELD            0101800
C   WWA IS THE REACTION RATE TERM                    0101810
   IF(PH2OI - .0076)14,14,16                          0101820
16 IF(PCOI - .0076)14,14,18                            0101830
14 WWA= 0.                                              0101840
   JOSH2O = 1                                          0101850
   GO TO 20                                           0101860
18 TEFAC = ACON                                         0101870
   OPRESTE=83.7*(PCOI*28.+(760.-(PCOI+ PCO2I + PH2OI + PH2I + PO2I)
   1)*4.0) + 93.0 * PH2OI * 18.0                     0101880
   1)*4.0) + 93.0 * PH2OI * 18.0                     0101890
C   CONST1= 2.87785E-18 = 6.24E11(EV/ERG)/100(EV/100EV)*6.023E23(MOLE-0101900
C   CULES PER MOLE) * 3600 (SECS/HR)                 0101910
   CONST1 = 2.87785E-18                               0101920
   WWA= GVALUE * REXP * CONST1 * PRESTE * TEFAC * VFACT 0101930
   IF(NSAMPL-2)30,31,32                               0101940
C   EMPTY CHANNEL                                     0101950
30 WWA = WWA * ECAREA                                  0101960
   GO TO 20                                           0101970
C   CLOSED BOAT                                       0101980
31 WWA= WWA * CBAREA                                   0101990
   GO TO 20                                           0102000
C   OPEN BOAT                                         0102010
32 WWA= WWA * OBAREA                                   0102020
C   CO2 + H2 REACTION IN A RADIATION FIELD           0102030
C   REWWA IS THE REACTION RATE TERM                  0102040
20 IF(PCO2I - .0076) 41,41,42                         0102050
42 IF(PH2I - .0076)41,41,43                          0102060
41 REWWA= 0.                                           0102070
   JOSCO2 = 1                                          0102080
   GO TO 40                                           0102090
43 RTEFAC= RACON                                        0102100
   URPREST= 83.7*(PCO2I * 44. + (760.-(PCOI + PCO2I + PH2OI + PH2I +
   1PO2I))* 4.0) + 167.4 * PH2I * 2.0                0102110
   REWWA= RGVAL * REXP * CONST1 * RPREST * RTEFAC * VFACT 0102120
   IF(NSAMPL-2)50,51,52                               0102130
C   EMPTY CHANNEL                                     0102140
50 REWWA = REWWA * ECAREA                              0102150
   GO TO 40                                           0102160
C   CLOSED BOAT                                       0102170
51 REWWA = REWWA * CBAREA                              0102180
   GO TO 40                                           0102190
C   OPEN BOAT                                         0102200
52 REWWA = REWWA * OBAREA                              0102210
40 WWA= WWA - REWWA                                    0102220
   DRVH2O( I )= - TA1 + C1MB1 - WWA                  0102230
   DRVCO(I)= TA1 + C1MB1 + TD1*2. - WWA + 0.5*(TF1 + TF2) 0102240
   DRVCO2(I)= - C1MB1 - TD1 + WWA + 0.5*(TF1 + TF2 )    0102250
   DRVO2(I)= -TF1-TF2                                 0102260
13 RETURN                                              0102270
   END                                                0102280
                                                    0102290-
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C020 SUBROUTINE T(YI)                                0200000
      SUBROUTINE T(YI)                                0200010
      DIMENSION PO2(5),DRVO2(5)                      0200020
      DIMENSION A1(5,3),B1(5),C1(5),D1(5,3),X(5),DRVH2O(5),DRVCO(5), 0200030
      1DRVCO2(5),PH2O(5),PCO(5),PCO2(5),PH2(5),      0200040
      2DENT(12),TYPE(2), NSAI(50),XMI(50),DXDDI(50),TYP(2,50) 0200050
      COMMON ZOH2O , ABH2O , NSAMPL , ZOCO2 , ABCO2 , YI    0200060
      COMMON S , EXT , VKODC , VKODB , VKODS , AVS         0200070
      COMMON AVC , AVB , TY , UGC , R , RE                0200080
      COMMON RD , RB , RS , H2OK10 , H2OK20 , H2OK30       0200090
      COMMON H2OX1 , H2OX2 , H2OX3 , CO2K10 , CO2K20 , CO2K30 0200100
      COMMON CO2X1 , CO2X2 , CO2X3 , TA , TB , AKRK1       0200110
      COMMON AKRK2 , AKRK3 , AKRK4 , ALRK1 , ALRK2 , ALRK3   0200120
      COMMON ALRK4 , AMRK1 , AMRK2 , AMRK3 , AMRK4 , KRK     0200130
      COMMON DRVH2O , DRVCO , DRVCO2 , PH2O , PH2 , PCO     0200140
      COMMON PCO2 , A1 , B1 , C1 , D1 , B1EX1             0200150
      COMMON B1EX2 , C1EX1 , C1EX2 , B1FFC1 , B1FFC2 , C1FFC1 0200160
      COMMON C1FFC2 , B1IFA , C1IFA , HALFBV , VCBO , RBT    0200170
      COMMON VB , X , Y , TYI , TKV , TK                 0200180
      COMMON ZCO2 , ZH2O , B1CON , C1CON1 , DENM , DENS     0200190
      COMMON DENB , R1 , R3 , EH201 , EH202 , EH203        0200200
      COMMON ECO21 , ECO22 , ECO23 , NSAI , XMI , DXDDI     0200210
      COMMON H2OK1 , H2OK2 , H2OK3 , CO2K1 , CO2K2 , CO2K3  0200220
      COMMON DENT , TYPE , TYP , RBSQ , RDSQ , ZCTK        0200230
      COMMON AM , AB , AS , RATIO , EH20T , ECO2T         0200240
      COMMON PCKOD , TIN , TMAX , BORC , BOR3 , BORS       0200250
      COMMON H2OL , CO2L , H2OKV , CO2KV , ANRK1 , ANRK2    0200260
      COMMON ANRK3 , ANRK4 , DRVO2 , PO2 , O2K1 , O2K2      0200270
      COMMON APW , BPW , O2KV , O2L , EO21 , EO23          0200280
      COMMON EO22 , EO2T , ZO2 , AB02 , ZO02 , O2X1        0200290
      COMMON O2X2 , O2K10 , O2K20 , GE , DELE , XKRAD      0200300
      COMMON ACON , GVALUE , REXP , VFAC , TEFAC , WWA     0200310
      COMMON ECAREA , CBAREA , OBAREA , TIK , RGE , RDELE  0200320
      COMMON RACON , RGVAL , C1CON2 , WI                 0200330
      TYI=TA+TB*SIN((2.*YI+EXT)*S)                     0200340
C      CONVERT TO KELVIN FOR COMPUTATION                0200350
      TY=TYI+ZCTK                                       0200360
C      CALCULATE THE TEMPERATURE DEPENDENT PARTS OF THE EQUATIONS 0200370
C      SEE SUBROUTINE DERIV                            0200380
      H2OK1 = H2OK10 *EXP( H2OX1/TY)                  0200390
      H2OK2 = H2OK20 *EXP( H2OX2/TY)                  0200400
      H2OK3 = H2OK30 *EXP( H2OX3/TY)                  0200410
      CO2K1 = CO2K10 *EXP( CO2X1/TY)                  0200420
      CO2K2 = CO2K20 *EXP( CO2X2/TY)                  0200430
      CO2K3 = CO2K30 *EXP( CO2X3/TY)                  0200440
      ZH2O = ( ZOH2O)*( TY **ABH2O )                 0200450
      ZCO2 = ( ZOCO2)*(TY **ABCO2 )                   0200460
C      CO + H2O IN A GAMMA FIELD                        0200470
      GVALUE= GE * EXP(+DELE/(UGC*TY))                0200480
C      CO2 + H2 IN A RADIATION FIELD                    0200490
      RGVAL = RGE * EXP(RDELE/(UGC*TY))              0200500
      REXP= XKRDH * SIN((2.*YI + EXT)*S)              0200510
      VFAC = TIK/(VB * TY )                          0200520
      O2K1= O2K10 * EXP(O2X1/TY)                      0200530
      O2K2= O2K20 * EXP(O2X2/TY)                      0200540
      ZO2 = ZO02*(TY**ABO2)                          0200550
      1 TKV=TK*TY                                       0200560
      B1CON=(B1FFC1*EXP(B1EX1/TY)+B1FFC2*EXP(B1EX2/TY))/(VB*TY) 0200570
      C1CON1= C1FFC1 * EXP(C1EX1/TY) * TIK/VB        0200580
      C1CON2= C1FFC2 * EXP(C1EX2/TY) * TIK/VB        0200590
      RETURN                                           0200600
      END                                           0200610-
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C030  SUBROUTINE ETA(ALL,ETAM,ETAB,ETAS,ETABS)          03000000
      SUBROUTINE ETA(ALL,ETAM,ETAB,ETAS,ETABS)          03000010
C      THIS ROUTINE CALCULATES THE REACTION RATE FACTORS 03000020
C      ALL IS THE DEPTH OF OXIDATION*SQRTF(GRAPHITE DENSITY) 03000030
C      ETAM IS DIFFUSION FACTOR FOR MODERATOR             03000040
C      ETAB IS DIFFUSION FACTOR FOR BOAT                   03000050
C      ETAS IS DIFFUSION FACTOR FOR SAMPLE                 03000060
      DIMENSION PO2(5),DRVO2(5)                          03000070
      DIMENSION A1(5,3),Z1(5),C1(5),D1(5,3),X(5),DRVH2O(5),DRVCO(5), 03000080
      1DRVCO2(5),PH2O(5),PCO(5),PCO2(5),PH2(5),          03000090
      2DENT(12),TYPE(2),NSAI(50),XMI(50),DXDDI(50),TYP(2,50) 03000100
      COMMON ZOH2O , ABH2O , NSAMPL , ZO2CO2 , ABCO2 , YI    03000110
      COMMON S , EXT , VKODC , VKODB , VKODS , AVS          03000120
      COMMON AVC , AVB , TY , UGC , R , RE                 03000130
      COMMON RD , RB , RS , H2OK10 , H2OK20 , H2OK30        03000140
      COMMON H2OX1 , H2OX2 , H2OX3 , CO2K10 , CO2K20 , CO2K30 03000150
      COMMON CO2X1 , CO2X2 , CO2X3 , TA , TB , AKRK1        03000160
      COMMON AKRK2 , AKRK3 , AKRK4 , ALRK1 , ALRK2 , ALRK3   03000170
      COMMON ALRK4 , AMRK1 , AMRK2 , AMRK3 , AMRK4 , KRK     03000180
      COMMON DRVH2O , DRVCO , DRVCO2 , PH2O , PH2 , PCO     03000190
      COMMON PCO2 , A1 , Z1 , C1 , D1 , B1EX1              03000200
      COMMON B1EX2 , C1EX1 , C1EX2 , B1FFC1 , B1FFC2 , C1FFC1 03000210
      COMMON C1FFC2 , B1IFA , C1IFA , HALFB , VCBO , RBT     03000220
      COMMON VB , X , Y , TYI , TKV , TK                   03000230
      COMMON ZCO2 , ZH2O , B1CON , C1CON1 , DENM , DENS     03000240
      COMMON DENB , R1 , R3 , EH2O1 , EH2O2 , EH2O3         03000250
      COMMON ECO21 , ECO22 , ECO23 , NSAI , XMI , DXDDI     03000260
      COMMON H2OK1 , H2OK2 , H2OK3 , CO2K1 , CO2K2 , CO2K3   03000270
      COMMON DENT , TYPE , TYP , RBSQ , RDSQ , ZCTK         03000280
      COMMON AM , AB , AS , RATIOI , EH2OT , ECO2T          03000290
      COMMON PCKOD , TIN , TMAX , BORC , BORB , BORS        03000300
      COMMON H2OL , CO2L , H2OKV , CO2KV , ANRK1 , ANRK2     03000310
      COMMON ANRK3 , ANRK4 , DRVO2 , PO2 , O2K1 , O2K2       03000320
      COMMON APW , BPW , O2KV , O2L , EO21 , EO23           03000330
      COMMON EO22 , EO2T , ZO2 , ABO2 , ZO2 , O2X1          03000340
      COMMON O2X2 , O2K10 , O2K20 , GE , DELE , XKRAD       03000350
      COMMON ACON , GVALUE , REXP , VFACT , TEFAC , WWA     03000360
      COMMON ECAREA , CBAREA , OBAREA , TIK , RGE , RDELE   03000370
      COMMON RACON , RGVAL , C1CON2 , WI                   03000380
C      Z1 HAS THE SAME LOCATION AS B1 IN THE REST OF PROGRAM 03000390
C      B0 IS MODIFIED BESSEL FUNCTION, FIRST KIND, ORDER 0. 03000400
C      B1 IS MODIFIED BESSEL FUNCTION, FIRST KIND, ORDER 1. 03000410
C      OK IS MODIFIED BESSEL FUNCTION, SECOND KIND, ORDER 0. 03000420
C      SK IS MODIFIED BESSEL FUNCTION, SECOND KIND, ORDER 1. 03000430
C      DEN IS 1./SQRTF(GRAPHITE DENSITY)                   03000440
C      RATIOI=BL/SL                                         03000450
      AL=ALL                                                 03000460
      IF(AL)9,9,8                                           03000470
8      CL=AL*DENM                                           03000480
C      R1=R **2-RE**2                                       03000490
      RUN1=R1/CL                                           03000500
      IF(NSAMPL-1) 1,1,2                                    03000510
C      EMPTY CHANNEL CASE                                  03000520
1      E2=0.                                                 03000530
      E3=0.                                                 03000540
      GO TO 6                                                03000550
2      SL=AL*DENS                                           03000560
      BL=AL*DENB                                           03000570
      X1=RS/SL                                              03000580

```



```
X2=RB/BL                                0300590
X3=RD/BL                                0300600
BIOX1=BO(X1)                            0300610
BIOX2=BO(X2)                            0300620
BIOX3=BO(X3)                            0300630
BI1X1=B1(X1)                            0300640
BI1X2=B1(X2)                            0300650
BI1X3=B1(X3)                            0300660
BKX2=OK(X2)                             0300670
BKX3=OK(X3)                             0300680
BK1X2=SK(X2)                            0300690
BK1X3=SK(X3)                            0300700
SAMR=BI1X1/BIOX1                        0300710
IF(NSAMPL-2) 3,3,4                      0300720
C   CLOSED BOAT CASE                    0300730
3   RLSI1=RATIO1*BI1X1                  0300740
    SCRIPA=RLSI1*BKX2+BIOX1*BK1X2       0300750
    PSI=BI1X3*SCRIPA+(BKX3*BI1X2)*BIOX1-(BKX3*RLSI1)*BIOX2 0300760
    SCRIPC=BI1X1/(X2*PSI)                0300770
C   BOAT                                0300780
    ET3 = 2.*(RD*(SCRIPA*BI1X3-((BK1X3*BIOX1)*BI1X2-(BK1X3*BIOX2)* 0300790
1RLSI1))-RB*(SCRIPA*BI1X2-((BK1X2*BIOX1)*BI1X2-(BK1X2*BIOX2)*RLSI1 0300800
2)))/PSI                                0300810
    SAMR=SAMR*SCRIPC                    0300820
C   CALCULATE ETA FOR BOAT SAMPLE COMBINATION 0300830
    X6=RB/BL                             0300840
    BIOX6=BO(X6)                         0300850
    BI1X6=B1(X6)                         0300860
    ETABS=2./X6*(BI1X6/BIOX6)            0300870
    GO TO 5                              0300880
C   OPEN BOAT CASE                      0300890
C   BOAT                                0300900
4   ET3 = 2.*((BKX3-BKX2)/(BIOX2*BKX3-BIOX3*BKX2)*(RD*BI1X3- 0300910
1RB*BI1X2)+(BIOX3-BIOX2)/(BIOX2*BKX3-BIOX3*BKX2)*(RD*BK1X3-RB* 0300920
2BK1X2))                                0300930
    R3=RD**2-RB**2                      0300940
C   5 RUN3=R3/BL                        0300950
    E3=ET3/RUN3                          0300960
C   SAMPLE                              0300970
    E2=2./X1*SAMR                        0300980
C   CHANNEL                             0300990
6   X4=RE/CL                             0301000
    X5=R /CL                             0301010
    BIOX4=BO(X4)                         0301020
    BI1X4=B1(X4)                         0301030
    BI1X5=B1(X5)                         0301040
    BKX4=OK(X4)                         0301050
    BK1X4=SK(X4)                         0301060
    BK1X5=SK(X5)                         0301070
    ET1 = 2.*RE*((BK1X4*BI1X5-BI1X4*BK1X5)/(BIOX4*BK1X5+BI1X5* 0301080
1BKX4))                                0301090
    ETAM=ET1/RUN1                        0301100
    ETAS=E2                              0301110
    ETAB=E3                              0301120
9   RETURN                              0301130
    END                                  0301140-
```

```
C040 FUNCTION BO(Y)                                0400000
      FUNCTION BO(Y)                                0400010
C      BO IS MODIFIED BESSEL FUNCTION, FIRST KIND, ORDER 0. 0400020
C      ONLY GOOD FOR X GREATER THAN -3.75              0400030
C                                                        0400040
C      SEE E E ALLEN, POLYNOMIAL APPROXIMATIONS TO SOME MODIFIED BESSEL 0400050
C      FUNCTIONS, MTAC V 10, 1956, PP 162-164.          0400060
C                                                        0400070
C      HANDBOOK OF MATH FUNCTIONS, N.B.S. APPLIED MATH SERIES, 55 0400080
C      JUNE 1964, PP 378-379                            0400090
C                                                        0400100
      X=Y                                              0400110
      IF (X-3.75)2,2,3                                0400120
2     Z=(X/3.75)**2                                    0400130
      BIO=1.0+Z*(3.5156229+Z*(3.0899424+Z*(1.2067492+
1     Z*(.2659732+Z*(.0360768+Z*(.0045813))))))      0400140
      0400150
4     BO= BIO                                          0400160
      RETURN                                           0400170
3     Z=3.75/X                                         0400180
      BIO=(EXP(X)/SQRT(X))*(.39894228+Z*(.013285917+ Z*(.002253187+Z*(-.0400190
1     001575649+Z*(.009162808+Z*(-.020577063+Z*(.026355372+Z*(-.01647630400200
2     229+Z*(.003923767)))))))*X                    0400210
      GO TO 4                                          0400220
      END                                              0400230
```

```
C050 FUNCTION B1(Y)                                0500000
      FUNCTION B1(Y)                                0500010
C      B1 IS MODIFIED BESSEL FUNCTION, FIRST KIND, ORDER 1. 0500020
C      ONLY GOOD FOR X GREATER THAN -3.75              0500030
C                                                        0500040
C      SEE E E ALLEN, POLYNOMIAL APPROXIMATIONS TO SOME MODIFIED BESSEL 0500050
C      FUNCTIONS, MTAC V 10, 1956, PP 162-164.          0500060
C                                                        0500070
C      HANDBOOK OF MATH FUNCTIONS, N.B.S. APPLIED MATH SERIES, 55 0500080
C      JUNE 1964, PP 378-379                            0500090
C                                                        0500100
      X=Y                                              0500110
      IF (X-3.75)2,2,3                                0500120
2     Z=(X/3.75)**2                                    0500130
      B11=(.5+Z*(.87890594+Z*(.51498869+Z*(.15084934+
1     Z*(.02658733+Z*(.00301532+Z*(.00032411))))))*X 0500140
      0500150
4     B1= B11                                          0500160
      RETURN                                           0500170
3     Z=3.75/X                                         0500180
      B11=(EXP(X)/SQRT(X))*(.39894228+Z*(-.039880242+Z*(-.003620183+ Z*(.0500190
1     001638014+Z*(-.01031555+Z*(.022829673+Z*(-.028953121+ Z*(.01787650500200
2     235-Z*(.004200587)))))))*X                    0500210
      GO TO 4                                          0500220
      END                                              0500230-
```

```
C060 FUNCTION OK(Y)                                0600000
      FUNCTION OK(Y)                                0600010
C      OK IS MODIFIED BESSEL FUNCTION, SECOND KIND, ORDER 0. 0600020
C      ONLY GOOD FOR X NON-NEGATIVE                  0600030
C                                                     0600040
C      SEE E E ALLEN, POLYNOMIAL APPROXIMATIONS TO SOME MODIFIED BESSEL 0600050
C      FUNCTIONS, MTAC V 10, 1956, PP 162-164.      0600060
C                                                     0600070
C      HANDBOOK OF MATH FUNCTIONS, N.B.S. APPLIED MATH SERIES, 55 0600080
C      JUNE 1964, PP 378-379                        0600090
C                                                     0600100
      X=Y                                             0600110
      IF (X-2.0)2,2,3                               0600120
2     Z=(X/2.0)**2                                   0600130
      SERIES=-.57721566+Z*(.4227842+Z*(.23069756+
1     Z*(.0348859+Z*(.00262698+Z*(.0001075+Z*
2     .0000074))))))                               0600150
      BKO =SERIES- ALOG(.5*X) *BO(X)                 0600160
4     OK= BKO                                        0600170
      RETURN                                         0600180
3     Z=2.0/X                                       0600190
      BKO=(1.25331414+Z*(-.07832358+ Z*(.02189568+Z*(-.01062446+Z*(.0058
1     17872+Z*(-.0025154+Z*.00053208)))))) / (SQRT(X)*EXP(X)) 0600210
      GO TO 4                                       0600220
      END                                           0600230
                                                    0600240
```

```
C070 FUNCTION SK(Y)                                0700000
      FUNCTION SK(Y)                                0700010
C      SK IS MODIFIED BESSEL FUNCTION, SECOND KIND, ORDER 1. 0700020
C      ONLY GOOD FOR X NON-NEGATIVE                  0700030
C                                                     0700040
C      SEE E E ALLEN, POLYNOMIAL APPROXIMATIONS TO SOME MODIFIED BESSEL 0700050
C      FUNCTIONS, MTAC V 10, 1956, PP 162-164.      0700060
C                                                     0700070
C      HANDBOOK OF MATH FUNCTIONS, N.B.S. APPLIED MATH SERIES, 55 0700080
C      JUNE 1964, PP 378-379                        0700090
C                                                     0700100
      X=Y                                             0700110
      IF (X-2.0)2,2,3                               0700120
2     Z=(X/2.0)**2                                   0700130
      SERIES=1.0+Z*(.15443144+Z*(-.67278579+Z*(-.18156897
1     1+Z*(-.01919402+Z*(-.00110404-Z*.00004686)))))) 0700140
      BK1= SERIES/X+ ALOG(.5*X) *B1(X)               0700150
4     SK= BK1                                        0700160
      RETURN                                         0700170
3     Z=2.0/X                                       0700180
      BK1=(1.25331414+Z*(.23498619+Z*(-.0365562+Z*(.01504268+Z*(-.00780
1     1353+Z*(.00325614-Z*.00068245)))))) / (SQRT(X)* EXP(X)) 0700190
      GO TO 4                                       0700200
      END                                           0700210
                                                    0700220
                                                    0700230-
```

```
C080 SUBROUTINE GOPLOT                                0800000
      SUBROUTINE GOPLOT                                0800010
      DIMENSION NY(3),XX(450),YY(450,3),TEMP(450),XTITLE(19),YTITLE(8,200800020
1) ,CHAR(5)                                           0800030
      INTEGER XTITLE,YTITLE,CHAR                     0800040
      COMMON /A*N/CFICM,IQ,JQ,KQ,RQOCH(450),RQOOS(450),RQOCS(450),DQOCH(0800050
1450),DQOOS(453),DQOCS(450)                          0800060
      COMMON /JUDY/ Z(3600)                           0800070
      COMMON /BPL0T1/ YTITLE,XTITLE,CHAR             0800080
      NY(1) = IQ - 1                                   0800090
      NY(2) = JQ - 1                                   0800100
      NY(3) = KQ - 1                                   0800110
      NX = IQ - 1                                       0800120
      K = 0                                              0800130
      NOYST= 3                                          0800140
      N1 = IQ - 1                                       0800150
      N2 = JQ - 1                                       0800160
      N3 = KQ - 1                                       0800170
      NQ = N1 + N2 + N3                                0800180
      N4 = NQ + N1                                       0800190
      N5 = N4 + N2                                       0800200
      IF(N1)2,2,4                                       0800210
4 DO 100 I=1,N1                                       0800220
      K = K + 1                                         0800230
100 Z(K + NQ) = RQOCH(I)                               0800240
      K = 0                                              0800250
      2 IF(N2)6,6,8                                    0800260
      8 DO 105 I=1,N2                                  0800270
      K = K + 1                                         0800280
105 Z(K + N4) = RQOOS(I)                               0800290
      K = 0                                              0800300
      6 IF(N3)12,12,14                                 0800310
      14 DO 110 I=1,N3                                 0800320
      K = K + 1                                         0800330
110 Z(K + N5) = RQOCS(I)                               0800340
      K=0                                                0800350
      12 IF(N1) 16,16,18                               0800360
      18 DO 115 I=1,N1                                 0800370
115 Z(I) = DQOCH(I)                                    0800380
      K = 0                                              0800390
      16 IF(N2)22,22,24                                0800400
      24 DO 120 I=1,N2                                 0800410
      K = K + 1                                         0800420
120 Z(K + N1) = DQOOS(I)                               0800430
      K = 0                                              0800440
      22 IF(N3)26,26,28                                0800450
      28 DO 125 I=1,N3                                 0800460
      K = K + 1                                         0800470
125 Z(K + N1 + N2) = DQOCS(I)                         0800480
      26 WRITE (6,1)                                    0800490
      1 FORMAT(1H1)                                    0800500
      IF(N1)32,32,34                                    0800510
      32 NOYST=NOYST - 1                                0800520
      34 IF(N2)36,36,38                                0800530
      36 NOYST= NOYST - 1                                0800540
      38 IF(N3)42,42,44                                0800550
      42 NOYST= NOYST - 1                                0800560
      44 CALL PLOT (3,2,41,NX,NOYST,NY,XX,YY,TEMP)    0800570
      RETURN                                           0800580
      END                                              0800590-
```

```
C090 SUBROUTINE PLOT ( MODE, KRID, NUML, NX, NOYS, NY, XX, YY, TEMP ) 0900000
SUBROUTINE PLOT ( MODE, KRID, NUML, NX, NOYS, NY, XX, YY, TEMP ) 0900010
C PLOT SUBROUTINE REQUIRES MSORT AND LSORT SUBROUTINES. 0900020
C ALSO A BLOCK DATA SUBROUTINE TO DEFINE OCTAL CONSTANTS PLUS AND 0900030
C BLANK. 0900040
C THESE THREE ROUTINES ARE PRE-WRITTEN. 0900050
C USER MUST WRITE MAIN CALLING PROGRAM AND HAS OPTION OF DEFINING 0900060
C TITLES AND PLOTTING SYMBOLS IN A BLOCK DATA PROGRAM OR READING 0900070
C THEM AS DATA. 0900080
C USER SHOULD ADVANCE PRINTER IN MAIN PROGRAM AS PLOT WILL START ON 0900090
C THE NEXT LINE. 0900100
C 0900110
C SPECIFICATION STATEMENTS 0900120
C USER MUST MAINTAIN CORRESPONDENCE BETWEEN VARIABLE TYPES IN 0900130
C MAIN AND SUB PROGRAMS. 0900140
C LABELED COMMON BLOCKS MUST HAVE THE SAME NAMES. 0900150
C 0900160
DIMENSION XX(NX), YY(NX,NOYS), NY(NOYS), TEMP(NX), IFULL(20), 0900170
1YTITLE(8,20),XTITLE(30),CHAR(20), 0900180
2 YSCALE(11),SFY(20),YMIN(20),JSUM(20),LINE(101) 0900190
COMMON /JUDY/ Z(3600) 0900200
COMMON /BLOT1/ YTITLE,XTITLE,CHAR 0900210
COMMON /BLOT2/PLUS,BLANK 0900220
LOGICAL SLINE 0900230
INTEGER XTITLE, YTITLE, CHAR, PLUS, BLANK, XLINE 0900240
C 0900250
C INITIALIZE. ENSURE CONSISTENCY OF INPUT. 0900260
C MAKE A REASONABLE DECISION WHERE POSSIBLE TO ALLOW EXECUTION. 0900270
C IS MODE VALID. 0900280
100 IF( MODE.EQ.1 .OR. MODE.EQ.2 .OR. MODE.EQ.3 ) GO TO 110 0900290
WRITE(6,190) MODE 0900300
RETURN 0900310
190 FORMAT( 30H1PLOTING MODE IS INVALID. 0900320
- // 30H RETURN TO CALLING PROGRAM. 0900330
A // 7H MODE = I5 /// ) 0900340
C ENSURE NUMBER OF LINES IS A MULTIPLE OF TEN PLUS ONE. 0900350
110 NUML = 1 + 10 * ( ( NUML - 1 ) / 10 ) 0900360
C IS GRID STYLE VALID. IF NOT CHOOSE OPEN STYLE. 0900370
IF( .NOT.( KRID.EQ.1 .OR. KRID.EQ.2 ) ) KRID = 2 0900380
C IF MODE = 1 COMPLETE THOSE TABLES MAIN PROGRAM IS ALLOWED TO 0900390
C IGNORE. 0900400
IF( MODE.NE.1 ) GO TO 200 0900410
DO 120 J = 1, NOYS 0900420
NY(J) = NX 0900430
120 IFULL(J) = J 0900440
C SET UP AIDS FOR SEARCHING ARRAYS. 0900450
C JSUM SERVES AS SUBSCRIPT ORIGIN AND IS SUM OF NUMBER OF 0900460
C PRECEDING ELEMENTS OF YY IN COLUMN ORDER. NYSUM IS TOTAL NUMBER 0900470
C OF POINTS TO BE PLOTTED. 0900480
200 JSUM(1) = 0 0900490
DO 210 J = 2, NOYS 0900500
210 JSUM(J) = JSUM(J-1) + NY(J-1) 0900510
NYSUM = JSUM(NOYS) + NY(NOYS) 0900520
C 0900530
C BRANCH TO SORTING ROUTINE APPROPRIATE TO FORM OF DATA. 0900540
IF( MODE - 2 )221,222,223 0900550
C MODE = 1. ONE X COLUMN, ALL Y COLUMNS SAME LENGTH. 0900560
C SORT X COLUMN AND KEEP ALL Y COLUMNS IN CORRESPONDENCE. 0900570
221 CALL LSORT ( XX, NX, YY, NY, NOYS, IFULL, NOYS ) 0900580
```

C	COPY SORTED Y S FROM COMMON INTO YY.	0900590
C	AND COPY X S FROM XX INTO COMMON NOYS TIMES.	0900600
	K = 0.	0900610
	DO 230 J = 1, NOYS	0900620
	DO 230 I = 1, NX	0900630
	K = K + 1	0900640
	YY(I,J) = Z(K)	0900650
230	Z(K) = XX(I)	0900660
	XMIN = XX(1)	0900670
	XMAX = XX(NX)	0900680
	GO TO 350	0900690
C	MODE = 2. ONE X COLUMN, Y COLUMNS VARY IN LENGTH.	0900700
C	INITIALIZE SEARCH FOR XMAX, XMIN.	0900710
222	XMAX = XX(1)	0900720
	XMIN = XMAX	0900730
C	SORT EACH PARTIAL X COLUMN CORRESPONDING TO A Y COLUMN.	0900740
	DO 240 J = 1, NOYS	0900750
	CALL MSORT (XX, NX, YY, NY, NOYS, J, TEMP)	0900760
C	COPY SORTED J-TH Y COLUMN FROM COMMON INTO YY	0900770
C	AND CORRESPONDING X S FROM TEMP INTO COMMON FOLLOWING Y S.	0900780
	LL = NY(J)	0900790
	DO 241 I = 1, LL	0900800
	K = JSUM(J) + I	0900810
	KZ = NYSUM + K	0900820
	YY(I,J) = Z(K)	0900830
241	Z(KZ) = TEMP(I)	0900840
	XMAX = AMAX1(XMAX, TEMP(LL))	0900850
240	XMIN = AMIN1(XMIN, TEMP(1))	0900860
C	NOW COPY X S INTO SECTION OF COMMON THAT CONTAINED Y S.	0900870
	DO 245 K = 1, NYSUM	0900880
	KZ = NYSUM + K	0900890
245	Z(K) = Z(KZ)	0900900
	GO TO 350	0900910
C		0900920
C	MODE = 3. AS MANY X COLUMNS AS Y COLUMNS.	0900930
C	LENGTH MAY VARY.	0900940
C	INITIALIZE SEARCH FOR XMAX, XMIN.	0900950
223	XMAX = Z(NYSUM + 1)	0900960
	XMIN = XMAX	0900970
C	SORT EACH X COLUMN IN TURN.	0900980
	DO 250 J = 1, NOYS	0900990
C	COPY J-TH X COLUMN FROM COMMON INTO TEMP.	0901000
	KK = NYSUM + JSUM(J)	0901010
	LL = NY(J)	0901020
	DO 251 I = 1, LL	0901030
	K = KK + I	0901040
251	TEMP(I) = Z(K)	0901050
C	SORT THIS X COLUMN.	0901060
	CALL MSORT (TEMP, NX, YY, NY, NOYS, J, TEMP)	0901070
C	COPY SORTED J-TH Y COLUMN FROM COMMON INTO YY	0901080
C	AND CORRESPONDING X S FROM TEMP INTO SAME COMMON	0901090
	LL = NY(J)	0901100
	DO 252 I = 1, LL	0901110
	K = JSUM(J) + I	0901120
	KZ = NYSUM + K	0901130
	YY(I,J) = Z(K)	0901140
252	Z(KZ) = TEMP(I)	0901150
	XMAX = AMAX1(XMAX, TEMP(LL))	0901160
250	XMIN = AMIN1(XMIN, TEMP(1))	0901170

```
C      NOW COPY X S INTO SECTION OF COMMON THAT CONTAINED Y S.      0901180
      DO 255 K = 1, NYSUM      0901190
      KZ = NYSUM + K      0901200
255    Z(K) = Z(KZ)      0901210
C      0901220
C      CALCULATE SCALING FACTOR FOR X.      0901230
350    SFX = ( XMAX - XMIN ) / FLOAT ( NUML - 1 )      0901240
      SFXPR = 10.0 * SFX      0901250
C      0901260
C      FIND MAX AND MIN FOR EACH Y COLUMN.      0901270
      J=1      0901280
      512 YMIN(J) = 0.0      0901290
C      CALCULATE SCALING FACTORS FOR EACH Y COLUMN.      0901300
      SFY(J) = 4.0      0901310
360    SFYPR = 10.0 * SFY(J)      0901320
C      0901330
C      WRITE SCALES AND TITLES FOR EACH CURVE.      0901340
500    YSCALE(1) = YMIN(J)      0901350
      LAM = 2      0901360
      505 YSCALE(LAM)=YSCALE(LAM-1)+SFYPR      0901370
      LAM = LAM+1      0901380
      IF (LAM-12) 505, 510, 510      0901390
510    WRITE(6,550) CHAR(J), CHAR(J), CHAR(J), (YTITLE(KK,J),KK=1,8),      0901400
      - (YSCALE(L), L = 1, 11 )      0901410
      IF (J-NOYS) 511,600,600      0901420
511    J=J+1      0901430
      GO TO 512      0901440
C      0901450
C      SET UP FOR LOOP TO PRINT ONE LINE OF GRAPH ON EACH PASS.      0901460
C      CALCULATE LIMITS OF FIRST LINE.      0901470
600    TOP = XMIN      0901480
      BOT = TOP + SFX      0901490
C      IFULL IS USED HERE TO STORE STOPPING POINT ON EACH Y COLUMN SCAN.      0901500
      DO 601 KK = 1, NOYS      0901510
601    IFULL(KK) = 1      0901520
C      START LOOP FOR EACH LINE.      0901530
      DO 810 KLINE = 1, NUML      0901540
C      CLASSIFY KIND OF LINE.      0901550
C      CLEAR LINE IMAGE TO BARE GRID OF USER S CHOICE.      0901560
      IF( MOD( KLINE, 10) .EQ. 1 ) GO TO 610      0901570
C      THIS LINE CONTAINS NO SCALE INFORMATION.      0901580
      IF( KRID .EQ. 1 ) GO TO 620      0901590
      DO 630 KK = 1, 91, 10      0901600
      LINE(KK) = PLUS      0901610
      DO 630 KJ = 1, 9      0901620
      KKJ = KK + KJ      0901630
630    LINE(KKJ) = BLANK      0901640
      GO TO 640      0901650
620    DO 621 KK = 1, 99, 2      0901660
      LINE(KK) = PLUS      0901670
621    LINE(KK+1) = BLANK      0901680
640    LINE(101) = PLUS      0901690
C      RECORD TYPE OF LINE.      0901700
      SLINE = .FALSE.      0901710
      GO TO 650      0901720
C      THIS LINE CONTAINS SCALE INFORMATION.      0901730
610    DO 611 KK = 1, 101      0901740
611    LINE(KK) = PLUS      0901750
C      RECORD TYPE OF LINE.      0901760
```

```
      SLINE = .TRUE.                                0901770
C                                           0901780
C   GENERATE CHARACTER FOR VERTICAL TITLE, IF REQUIRED. 0901790
650 IF ( KLINE .GT. 30 ) GO TO 655                0901800
      XLINE = XTITLE(KLINE)                        0901810
      GO TO 700                                    0901820
655 XLINE = BLANK                                  0901830
C                                           0901840
C   FIND POINTS FOR THIS LINE AND ENTER IN IMAGE OF GRAPH LINE. 0901850
C   SCAN X COLUMN FOR EACH CURVE.                  0901860
700 DO 710 J = 1, NOYS                             0901870
C   SCAN EACH ELEMENT OF THE X COLUMN.              0901880
C   IFULL IS STOPPING POINT IN X COLUMN FROM PREVIOUS LINE, THEREFORE 0901890
C   START AT THAT POINT AND SCAN UNTIL X VALUES AGAIN EXCEED LIMITS OF 0901900
C   LINE.                                           0901910
      IF( IFULL(J))710,706,705                      0901920
706 IFULL(J) = - 1                                  0901930
      KLOOK = NY(J)                                  0901940
      KWORD = 1 + IFIX((YY(KLOOK,J) - YMIN(J) ) / SFY(J) ) 0901950
      GO TO 710                                      0901960
705 KK = IFULL(J)                                   0901970
      LL = NY(J)                                     0901980
      DO 715 KLOOK = KK, LL                          0901990
C   TEST AN X FOR BEING ON THIS LINE.               0902000
C   X(I,J) IS IN Z( I + JSUM(J) )                  0902010
      KKK = KLOOK + JSUM(J)                          0902020
      IF( Z(KKK) .LT. BOT ) GO TO 711                0902030
C   THERE ARE NO MORE POINTS ON THIS LINE FROM THIS CURVE. 0902040
      IFULL(J) = KLOOK                               0902050
      GO TO 710                                      0902060
C   THIS POINT GOES IN CURRENT LINE. FIND POSITION IN LINE. 0902070
711 KWORD = 1 + IFIX( ( YY(KLOOK,J) - YMIN(J)) / SFY(J) ) 0902080
      IF( KLOOK .EQ. NY(J) ) IFULL(J) = 0           0902090
715 LINE(KWORD) = CHAR(J)                           0902100
710 CONTINUE                                         0902110
C                                           0902120
C   LINE IMAGE IS COMPLETE. WRITE THIS LINE WITH ANY SCALE AND TITLE 0902130
C   INFORMATION REQUIRED.                            0902140
C   WRITE STATEMENT DEPENDS ON TYPE OF LINE.        0902150
800 IF( SLINE ) GO TO 801                           0902160
      WRITE(6,851) XLINE, ( LINE(NN), NN=1,101 )    0902170
      GO TO 802                                      0902180
801 WRITE(6,850) XLINE, TOP, ( LINE(NN), NN=1,101 ) 0902190
C   STEP LINE LIMITS FOR NEXT PASS , IF ANY.        0902200
802 TOP = BOT                                        0902210
810 BOT = BOT + SFX                                  0902220
      RETURN                                         0902230
850 FORMAT( 1X, A1, 1PE9.2, 101A1 )                 0902240
851 FORMAT( 1X, A1, 9X, 101A1 )                     0902250
550 FORMAT( 11X, 3A1, 3X, 8A6 / 6X 1P11E10.2 )     0902260
      END                                           0902270-
```


C100	BLOCK DATA		1000000
	BLOCK DATA		1000010
C	DEFINE TITLES AND PLOTTING SYMBOLS		1000020
	DIMENSION YTITLE(8,20), XTITLE(30), CHAR(5)		1000030
	COMMON/BPLOT1/YTITLE, XTITLE, CHAR		1000040
	COMMON /BPLOT2/PLUS,BLANK		1000050
	INTEGER PLUS,BLANK		1000060
C			1000070
	CDATA (YTITLE(K,1),K=1,8)/		1000080
	X 48H DISTANCE INCHES	/,	1000090
	2(YTITLE(K,2),K=1,8)/		1000100
	X 48H DISTANCE INCHES	/,	1000110
	4(YTITLE(K,3),K=1,8)/		1000120
	X 48H DISTANCE INCHES	/,	1000130
	X (XTITLE(K),K=1,30)/		1000140
	X66H		1000150
	X ,1HB,1HU,1HR,1HN,1HO,1HU,1HT,1H ,1HR,1HA,1HT,1HE,1H ,1H(,1H/,		1000160
	X1HK,1HO,1HD,1H /,		1000170
	XCHAR(1)/1H*/ ,CHAR(2)/1H(/,CHAR(3)/1H*/		1000180
	DATA PLUS/1H+/,BLANK/1H /		1000190
C			1000200
	END		1000210-

```
C110 SUBROUTINE LSORT ( X, NX, Y, NY, NOYS, IFULL, NXY )      1100000
      SUBROUTINE LSORT ( X, NX, Y, NY, NOYS, IFULL, NXY )      1100010
C     SORTS FULL X COLUMN AND ALL FULL Y COLUMNS              1100020
C     SORT IS ON X COLUMN USING PAIR INTERCHANGE.              1100030
C     BRANCH OUT ONLY WHEN NO INTERCHANGE ON LAST PASS.        1100040
      DIMENSION X(NX), Y(NX,NOYS), IFULL(NOYS), NY(NOYS)        1100050
      COMMON /JUDY/ Z(3600)                                       1100060
      LOGICAL IND                                                  1100070
C     LOAD Y FROM COMMON                                         1100080
      K = 0                                                         1100090
      DO 101 J = 1, NOYS                                           1100100
      LL = NY(J)                                                    1100110
      DO 101 I = 1, LL                                             1100120
      K = K + 1                                                    1100130
101  Y(I,J) = Z(K)                                                  1100140
C     SET RANGE OF X COLUMN TO BE EXAMINED.                    1100150
      INDEX = NX- 1                                                1100160
C     SET NO INTERCHANGE FLAG TO TRUE.                          1100170
      IND = .TRUE.                                                 1100180
C     START LOOP.                                               1100190
      DO 5 I = 1, INDEX                                           1100200
      IF( X(I+1) - X(I) )6,5,5                                       1100210
C     INTERCHANGE THIS PAIR OF X VALUES.                      1100220
      SAVE = X(I+1)                                                1100230
      X(I+1) = X(I)                                                1100240
      X(I) = SAVE                                                  1100250
C     INTERCHANGE CORRESPONDING Y PAIRS IN ALL FULL Y COLUMNS. 1100260
      DO 10 K = 1, NXY                                             1100270
      L = IFULL(K)                                                 1100280
      SAVE = Y(I+1,L)                                              1100290
      Y(I+1,L) = Y(I,L)                                           1100300
10  Y(I,L) = SAVE                                                  1100310
C     AFTER EXIT FROM LOOP IHOLD IS POSITION OF LAST INTERCHANGE. 1100320
      IHOLD = I                                                    1100330
C     SET NO INTERCHANGE FLAG TO FALSE.                        1100340
      IND = .FALSE.                                               1100350
      5 CONTINUE                                                  1100360
C     IF NO INTERCHANGE SORT IS COMPLETE.                      1100370
      IF( IND ) GO TO 8                                           1100380
C     OTHERWISE ADJUST RANGE OF X COLUMN TO BE EXAMINED AND REPEAT. 1100390
      INDEX = IHOLD                                               1100400
      GO TO 3                                                      1100410
C     LOAD Y INTO COMMON                                         1100420
      8 K = 0                                                         1100430
      DO 100 J = 1, NOYS                                           1100440
      LL = NY(J)                                                    1100450
      DO 100 I = 1, LL                                             1100460
      K = K + 1                                                    1100470
100  Z(K) = Y(I,J)                                                  1100480
      RETURN                                                       1100490
      END                                                           1100500-
```

C120	SUBROUTINE MSORT (X, NX, Y, NY, NOYS, NI, TEMP)	1200000
	SUBROUTINE MSORT (X, NX, Y, NY, NOYS, NI, TEMP)	1200010
C	SORTS PARTIAL X COLUMN IN TEMP AND ONE SHORT Y COLUMN.	1200020
C	SORT IS ON TEMP USING PAIR INTERCHANGE.	1200030
C	BRANCH OUT WHEN NO INTERCHANGE ON LAST PASS.	1200040
	DIMENSION X(NX), Y(NX,NOYS), TEMP(NX), NY(NOYS)	1200050
	COMMON /JUDY/ Z(3600)	1200060
	LOGICAL IND	1200070
C	LOAD Y FROM COMMON	1200080
	K = 0	1200090
	DO 51 J = 1, NOYS	1200100
	LL = NY(J)	1200110
	DO 51 I = 1, LL	1200120
	K = K + 1	1200130
51	Y(I,J) = Z(K)	1200140
C	LOAD FIRST NNY X VALUES INTO TEMP.	1200150
	NNY = NY(NI)	1200160
	DO 100 I = 1, NNY	1200170
100	TEMP(I) = X(I)	1200180
C	SORT TEMP	1200190
C	SET RANGE OF TEMP TO BE EXAMINED.	1200200
	INDEX = NNY - 1	1200210
C	SET NO INTERCHANGE FLAG TO TRUE.	1200220
3	IND = .TRUE.	1200230
C	START LOOP.	1200240
	DO 5 I = 1, INDEX	1200250
	IF(TEMP(I+1) - TEMP(I))6,5,5	1200260
C	INTERCHANGE THIS PAIR OF TEMP VALUES.	1200270
6	SAVE = TEMP(I+1)	1200280
	TEMP(I+1) = TEMP(I)	1200290
	TEMP(I) = SAVE	1200300
C	INTERCHANGE CORRESPONDING PAIR IN Y COLUMN NI.	1200310
	SAVE = Y(I+1,NI)	1200320
	Y(I+1,NI) = Y(I,NI)	1200330
	Y(I,NI) = SAVE	1200340
C	AFTER EXIT FROM LOOP IHOLD IS POSITION OF LAST INTERCHANGE.	1200350
	IHOLD = I	1200360
C	SET NO INTERCHANGE FLAG TO FALSE.	1200370
	IND = .FALSE.	1200380
5	CONTINUE	1200390
C	IF NO INTERCHANGE SORT IS COMPLETE.	1200400
	IF(IND) GO TO 8	1200410
C	OTHERWISE ADJUST RANGE OF TEMP TO BE EXAMINED AND REPEAT.	1200420
	INDEX = IHOLD	1200430
	GO TO 3	1200440
C	LOAD Y INTO COMMON	1200450
8	K = 0	1200460
	DO 50 J = 1, NOYS	1200470
	LL = NY(J)	1200480
	DO 50 I = 1, LL	1200490
	K = K + 1	1200500
50	Z(K) = Y(I,J)	1200510
	RETURN	1200520
	END	1200530-

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APPENDIX H
SAMPLE COMPUTER INPUT AND OUTPUT

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GOP TEST CASE - PARAMETER STUDY

1	TEST-X	PLOTS	TRYOUT	3-2-66	3-2-66		
10600	1991	1					1
389		1788	1625	1125	875	426	2
8375							3
0		5	28				4
1 35							5
3 55							6
1 79							7
3 108							7+ 1
2 118							7+ 2
3 147							7+ 3
2 156							7+ 4
3 185							7+ 5
2 195							7+ 6
3 215							7+ 7
1 266							7+ 8
3 286							7+ 9
1 300							7+10
3 320							7+11
1 336							7+12
							7+13
							7+14
							7+15
							8+15
							9+15
166	166	166					10+15
-655000000+4	319000000+11	000000000+0	000000000+0	350000000+1			11+15
-780000000+4	303000000+13	392000000+4	962000000+3	000000000+0			12+15
-327000000+4	608000000+4	793000000+4					13+15
-668000000+4	295000000+4	000000000+0					14+15
304000000+8	124000000-10	651000000-18	106000000-6	158000000+0			15+15
192200000+14	415000000-7	350000000-3	160000000-7	184000000+0			16+15
000000000+0	000000000+0	000000000+0	000000000+0				17+15
000000000+0	000000000+0	000000000+0					18+15
000000000+0	000000000+0	000000000+0	000000000+0	000000000+0			19+15
000000000+0	000000000+0	000000000+0					20+15
156	350	820	1				21+15
1 0	1						22+15+ 1
600000000-1	207500000+1	361760000+2	760000000-2	285000000+2	000000000-0		22+15+ 1

60P TEST CASE - PARAMETER STUDY

REACTOR KEY	TEST-X	DATE CHARGED	3-2-66
CHANNEL NUMBER	PLOTS	DATE DISCHARGED	3-2-66
BURNOUT TEST NUMBER	TRYOUT		
.0000 OPEN CHANNEL	35.0000 OPEN BOAT	55.0000 OPEN CHANNEL	79.0000 OPEN BOAT
OPEN BOAT	147.0000 CLOSED BOAT	156.0000 OPEN CHANNEL	168.0000
108.0000 CLOSED BOAT	118.0000		
NO. OF CHAMFER FLOW CHANNELS.....	10600	EDGE OF CHAMFER FLOW CHANNEL.....	.3890
NO. OF ANNULAR FLOW CHANNELS.....	1995	DIAMETER OF EMPTY FLOW CHANNEL.....	1.7880
NO. OF BURNOUT FLOW CHANNELS.....	9	OUTSIDE DIAMETER OF PROCESS TUBE.....	1.6250
REACTOR LATTICE SPACING.....	8.3580	OUTSIDE DIAMETER OF BOAT.....	1.1250
ACTIVE ZONE LENGTH (FEET).....	14.0000	INSIDE DIAMETER OF BOAT.....	.8750
		DIAMETER OF SAMPLE.....	.4260

1

 RATE CALCULATION PARAMETERS

	CO + H2O		CO2 + H2	
	1	2	1	2
ACTIVATION ENERGY	-0.000	-0.000	-0.000	-0.000
FREQUENCY FACTOR	-0.000	-0.000	-0.000	-0.000
INHIBITION FACTOR		-0.0000		-0.0000

CARBON DENSITIES

MODERATOR	1.6600
BOAT	1.6600
SAMPLE	1.6600

	1	H2O + GRAPHITE 2	3	DIFFUSION FACTORS
ACTIVATION ENERGY	-3.270+04	6.080+04	7.930+04	ZO 1.060-06
FREQUENCY FACTOR	3.040+08	1.240-11	6.510-19	ATZ 1.5800

	1	CO2 + GRAPHITE 2	3	DIFFUSION FACTORS
ACTIVATION ENERGY	-6.680+04	2.950+04	0.000	ZO 1.600-07
FREQUENCY FACTOR	1.922+13	4.150-07	3.500-03	ATZ 1.8400

DATA FOR THE CO + H2O REACTION IN A GAMMA FIELD

GE= -0.000 DELE= -0.000 XKRAD= -0.000 ACON= -0.000

IPL0T= 1 IEXIT= 0 IETA= 1

DATA FOR THE CO2 + H2 REACTION IN A GAMMA FIELD

RGE= -0.000 RDELE= -0.000 RACON= -0.000

PRINT FREQ. = 1

STEP SIZE = 6.0000+00

DATA FOR OXYGEN - GRAPHITE REACTION

	FREQUENCY FACTOR	ACTIVATION ENERGY	ORDER
THERMAL	O2K10= -0.000	O2E1= -0.000	APW= -0.000
RADIATION	O2K20= -0.000	O2E2= -0.000	BPW= -0.000

DIFFUSION FACTORS

Z002= -0.000	AB02= -0.000
--------------	--------------

TEMPERATURES GAS 15.6 GRAPHITE INLET 500.00 MAXIMUM 1000.00

EXTRAPOLATION DISTANCE 1.000

GOP TEST CASE - PARAMETER STUDY

FLOW PERCENTAGES CHAMFER 85.482 ANNULAR 4.212 BURNOUT 10.306

INITIAL CONDITIONS FLOW = 285.00 PH2O = .500 PCO = 20.750 PCO2 = 361.760 PH2 = .076 PO2 = .000

CHANNEL PROFILE	DISTANCE INCHES	P A R T I A L P R E S S U R E S				O2	TEMP.-C.	B U R N O U T R A T E S		
		H2O	CO	H2	CO2			CHANNEL	BOAT	SAMPLE
OPEN CHANNEL	.00	.5000	20.7500	.0760	361.7600	.0000	500.			
OPEN CHANNEL	5.83	.5000	20.7500	.0760	361.7600	.0000	556.	-4.372-05	0.000	0.000
OPEN CHANNEL	11.67	.5000	20.7500	.0760	361.7600	.0000	611.	-1.603-03	0.000	0.000
OPEN CHANNEL	17.50	.5000	20.7500	.0760	361.7600	.0000	664.	-3.456-02	0.000	0.000
OPEN CHANNEL	23.33	.5000	20.7505	.0760	361.7598	.0000	715.	-4.549-01	0.000	0.000
OPEN CHANNEL	29.17	.4998	20.7544	.0762	361.7579	.0000	763.	-3.692+00	0.000	0.000
OPEN CHANNEL	35.00	.4992	20.7793	.0768	361.7458	.0000	808.	-2.051+01	0.000	0.000
OPEN BOAT	40.00	.4972	20.9660	.0788	361.6534	.0000	843.	-6.318+01	-9.411+01	-9.388+01
OPEN BOAT	45.00	.4934	21.4615	.0826	361.4076	.0000	876.	-1.351+02	-2.680+02	-2.667+02
OPEN BOAT	50.00	.4875	22.3625	.0885	360.9600	.0000	905.	-2.147+02	-6.264+02	-6.217+02
OPEN BOAT	55.00	.4792	23.6828	.0968	360.3040	.0000	930.	-2.880+02	-1.242+03	-1.230+03
OPEN CHANNEL	61.00	.4747	24.6824	.1013	359.8064	.0000	956.	-3.710+02	0.000	0.000
OPEN CHANNEL	67.00	.4712	25.6941	.1048	359.3023	.0000	976.	-4.468+02	0.000	0.000
OPEN CHANNEL	73.00	.4673	26.8761	.1087	358.7133	.0000	990.	-5.075+02	0.000	0.000
OPEN CHANNEL	79.00	.4632	28.1800	.1128	358.0634	.0000	998.	-5.439+02	0.000	0.000
OPEN BOAT	84.80	.4457	31.4910	.1303	356.4167	.0000	1000.	-5.435+02	-6.465+03	-6.370+03
OPEN BOAT	90.60	.4266	35.0684	.1494	354.6375	.0000	996.	-5.136+02	-5.642+03	-5.563+03
OPEN BOAT	96.40	.4094	38.3093	.1666	353.0257	.0000	987.	-4.602+02	-4.291+03	-4.237+03
OPEN BOAT	102.20	.3945	41.0705	.1815	351.6525	.0000	972.	-3.911+02	-2.824+03	-2.792+03
OPEN BOAT	108.00	.3825	43.2898	.1935	350.5489	.0000	952.	-3.140+02	-1.588+03	-1.573+03
CLOSED BOAT	110.50	.3797	43.9496	.1963	350.2204	.0000	941.	-2.795+02	-1.161+03	-1.132+03
CLOSED BOAT	113.00	.3774	44.5036	.1986	349.9446	.0000	930.	-2.438+02	-8.342+02	-8.148+02
CLOSED BOAT	115.50	.3753	44.9780	.2007	349.7084	.0000	918.	-2.066+02	-5.783+02	-5.660+02
CLOSED BOAT	118.00	.3736	45.3709	.2024	349.5128	.0000	905.	-1.680+02	-3.859+02	-3.788+02
OPEN BOAT	123.80	.3695	46.0722	.2065	349.1642	.0000	871.	-8.142+01	-1.289+02	-1.284+02
OPEN BOAT	129.60	.3671	46.3652	.2089	349.0189	.0000	832.	-2.542+01	-3.278+01	-3.274+01
OPEN BOAT	135.40	.3659	46.4417	.2101	348.9813	.0000	790.	-5.252+00	-6.175+00	-6.173+00
OPEN BOAT	141.20	.3653	46.4564	.2107	348.9742	.0000	744.	-7.791-01	-8.330-01	-8.329-01
OPEN BOAT	147.00	.3651	46.4599	.2109	348.9725	.0000	695.	-7.689-02	-7.766-02	-7.766-02
CLOSED BOAT	149.25	.3651	46.4600	.2109	348.9725	.0000	675.	-2.764-02	-2.775-02	-2.775-02
CLOSED BOAT	151.50	.3651	46.4600	.2109	348.9725	.0000	655.	-9.274-03	-9.287-03	-9.287-03
CLOSED BOAT	153.75	.3651	46.4600	.2109	348.9725	.0000	635.	-2.900-03	-2.902-03	-2.902-03
CLOSED BOAT	156.00	.3651	46.4600	.2109	348.9725	.0000	614.	-8.430-04	-8.431-04	-8.431-04
OPEN CHANNEL	159.00	.3651	46.4600	.2109	348.9725	.0000	586.	-1.439-04	0.000	0.000

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60P TEST CASE - PARAMETER STUDY

INITIAL CONDITIONS FLOW = 285.00 PH2O = .500 PCO = 20.750 PCO2 = 361.760 PH2 = .076 PO2 = .000

CHANNEL PROFILE	DISTANCE INCHES	P A R T I A L P R E S S U R E S				O2	TEMP.-C.	B U R N O U T R A T E S		SAMPLE
		H2O	CO	H2	CO2			CHANNEL	BOAT	
OPEN CHANNEL	162.00	.3651	46.4600	.2109	348.9725	.0000	558.	-2.119-05	0.000	0.000
OPEN CHANNEL	165.00	.3651	46.4600	.2109	348.9725	.0000	529.	-2.661-06	0.000	0.000
OPEN CHANNEL	168.00	.3651	46.4600	.2109	348.9725	.0000	500.	-2.809-07	0.000	0.000

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DEPTH OF OXIDATION VALUES

		ETA VALUES						L(DEPTH) VALUES				
CHANNEL PROFILE	DISTANCE INCHES	WATER		CARBON DIOXIDE		OXYGEN		WATER	CARBON DIOXIDE	OXYGEN	TEMP C.	
		CHAN.	SAMP.	CHAN.	SAMP.	CHAN.	SAMP.					
OPEN CHANNEL	5.8333	1.0000	.0000	1.0000	.0000	.0000	.0000	2.075+03	2.847+04	0.000	556.	
OPEN CHANNEL	11.6667	.9991	.0000	1.0000	.0000	.0000	.0000	3.620+02	4.780+03	0.000	611.	
OPEN CHANNEL	17.5000	.9826	.0000	.9999	.0000	.0000	.0000	8.136+01	1.046+03	0.000	664.	
OPEN CHANNEL	23.3333	.8181	.0000	.9986	.0000	.0000	.0000	2.278+01	2.884+02	0.000	715.	
OPEN CHANNEL	29.1667	.3669	.0000	.9879	.0000	.0000	.0000	7.790+00	9.782+01	0.000	763.	
OPEN CHANNEL	35.0000	.1213	.0000	.9318	.0000	.0000	.0000	3.240+00	3.991+01	0.000	808.	
OPEN BOAT	40.0000	.0585	.9817	.7950	.9999	.0000	.0000	1.798+00	2.113+01	0.000	843.	
OPEN BOAT	45.0000	.0348	.9570	.5825	.9996	.0000	.0000	1.154+00	1.249+01	0.000	876.	
OPEN BOAT	50.0000	.0242	.9223	.3845	.9991	.0000	.0000	8.370-01	8.119+00	0.000	905.	
OPEN BOAT	55.0000	.0188	.8836	.2532	.9982	.0000	.0000	6.641-01	5.733+00	0.000	930.	
OPEN CHANNEL	61.0000	.0151	.0000	.1648	.0000	.0000	.0000	5.438-01	4.107+00	0.000	956.	
OPEN CHANNEL	67.0000	.0130	.0000	.1201	.0000	.0000	.0000	4.746-01	3.215+00	0.000	976.	
OPEN CHANNEL	73.0000	.0119	.0000	.0976	.0000	.0000	.0000	4.348-01	2.729+00	0.000	990.	
OPEN CHANNEL	79.0000	.0113	.0000	.0874	.0000	.0000	.0000	4.146-01	2.499+00	0.000	998.	
OPEN BOAT	84.8000	.0112	.7560	.0870	.9903	.0000	.0000	4.112-01	2.490+00	0.000	1000.	
OPEN BOAT	90.6000	.0115	.7645	.0945	.9915	.0000	.0000	4.219-01	2.659+00	0.000	996.	
OPEN BOAT	96.4000	.0123	.7842	.1119	.9935	.0000	.0000	4.488-01	3.041+00	0.000	987.	
OPEN BOAT	102.2000	.0137	.8148	.1461	.9957	.0000	.0000	4.978-01	3.743+00	0.000	972.	
OPEN BOAT	108.0000	.0163	.8553	.2121	.9976	.0000	.0000	5.824-01	4.991+00	0.000	952.	
CLOSED BOAT	110.5000	.0179	.5882	.2569	.9922	.0000	.0000	6.361-01	5.799+00	0.000	941.	
CLOSED BOAT	113.0000	.0201	.6406	.3158	.9944	.0000	.0000	7.058-01	6.855+00	0.000	930.	
CLOSED BOAT	115.5000	.0230	.6976	.3916	.9962	.0000	.0000	7.978-01	8.255+00	0.000	918.	
CLOSED BOAT	118.0000	.0270	.7569	.4845	.9974	.0000	.0000	9.215-01	1.013+01	0.000	905.	
OPEN BOAT	123.8000	.0445	.9713	.7326	.9998	.0000	.0000	1.427+00	1.770+01	0.000	871.	
OPEN BOAT	129.6000	.0925	.9912	.9134	1.0000	.0000	.0000	2.615+00	3.503+01	0.000	832.	
OPEN BOAT	135.4000	.2536	.9982	.9820	1.0000	.0000	.0000	5.741+00	8.000+01	0.000	790.	
OPEN BOAT	141.2000	.6676	.9997	.9975	1.0000	.0000	.0000	1.509+01	2.149+02	0.000	744.	
OPEN BOAT	147.0000	.9511	1.0000	.9998	1.0000	.0000	.0000	4.766+01	6.929+02	0.000	695.	
CLOSED BOAT	149.2500	.9813	1.0000	.9999	1.0000	.0000	.0000	7.846+01	1.152+03	0.000	675.	
CLOSED BOAT	151.5000	.9935	1.0000	1.0000	1.0000	.0000	.0000	1.333+02	1.979+03	0.000	655.	
CLOSED BOAT	153.7500	.9979	1.0000	1.0000	1.0000	.0000	.0000	2.341+02	3.519+03	0.000	635.	
CLOSED BOAT	156.0000	.9994	1.0000	1.0000	1.0000	.0000	.0000	4.258+02	6.488+03	0.000	614.	
OPEN CHANNEL	159.0000	.9999	.0000	1.0000	.0000	.0000	.0000	1.002+03	1.558+04	0.000	586.	
OPEN CHANNEL	162.0000	1.0000	.0000	1.0000	.0000	.0000	.0000	2.533+03	4.027+04	0.000	558.	
OPEN CHANNEL	165.0000	1.0000	.0000	1.0000	.0000	.0000	.0000	6.920+03	1.128+05	0.000	529.	
OPEN CHANNEL	168.0000	1.0000	.0000	1.0000	.0000	.0000	.0000	2.058+04	3.444+05	0.000	500.	

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