NASA TECHNICAL MEMORANDUM

NASA TM X-72677

NASA TM X- 72677

(NASA-TM-X-72677) A USERS MANUAL FOR A REVISED VERSION OF THE LANGLEY CHARRING ABLATOR PROGRAM (NASA) 121 p HC $5.25 CSCI 20M G3/34

N75-23881

Unclas 20782

A USERS MANUAL FOR A REVISED VERSION OF THE LANGLEY CHARRING ABLATOR PROGRAM

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TM X-72677		

4. Title and Subtitle	5. Report Date
A Users Manual for A Revised Version of the Langley Charring Ablator Program	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
C. W. Stroud and Kay L. Brinkley	10. Work Unit No. 506-16-21-01

9. Performing Organization Name and Address	11. Contract or Grant No.
NASA Langley Research Center Hampton, VA 23665	13. Type of Report and Period Covered Technical Memorandum

12. Sponsoring Agency Name and Address	14. Sponsoring Agency Code
National Aeronautics & Space Administration Washington, DC 20546	

15. Supplementary Notes

16. Abstract

A computer program is described that will compute the transient response of a thermal protection material to a prescribed heat input at the surface. The program has the capability of analyzing pyrolysis gas chemical kinetics in detail and treating pyrolysis reactions-in-depth. Deposition of solid products produced by chemical reactions in the gas phase is included in the analysis. This paper outlines the theory and gives detailed operating instructions for the computer program.

17. Key Words (Suggested by Author(s)) (STAR category underlined)	18. Distribution Statement
ABLATION, Computer Program, chemical kinetics, reactions-in-depth	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	115	$5.25

*Available from { The National Technical Information Service, Springfield, Virginia 22151
STIF/NASA Scientific and Technical Information Facility, P.O. Box 33, College Park, MD 20740

INTRODUCTION

The computer program to be described is entitled "Advanced Investigation of Thermal Protection Systems for Atmospheric Entry-Modification Number 2" (CHAP III). CHAP III is programed in FORTRAN language and is used to compute the transient response of a thermal protection material to a prescribed heat input at the surface. The original version of the program, CHAP I, was developed (ref. 1) to deal with ablation materials but has been applied to a wide class of thermal protection problems. CHAP III has been developed primarily to add the capability to analyze chemical kinetics in detail.

The purpose of this note is to provide a user's manual for the revised computer program. Use of CHAP III should not be attempted without familiarity with the mathematical development of CHAP I. Lengthy mathematical developments are avoided since they are included in the references. However, this manual does provide a brief description of the mathematical model around which CHAP III is built. The emphasis herein is on those points that represent changes in the mathematical model that was the basis for CHAP I.

This manual contains a set of tables which provide: (1) a definition of physical symbols and a list of FORTRAN symbols, (2) a list of input and output FORTRAN variables in the order they appear in the I/O lists of CHAP III and, (3) an alphabetical list of FORTRAN symbols and their location in (1) and (2). Cross reference features in these tables should permit straight-forward use of CHAP III.

SYMBOLS

The computer program is normally used with English Units shown in parentheses below. A consistent set of SI units can be used if PREHE = 2 and YDEL is set equal to the Stefan-Boltzmann constant in the units chosen.

A	frequency factors in Arrhenius constants (units vary with reaction order)
A_i	chemical specie identification symbols for reactants
B_i	chemical specie identification symbol for products
C	concentration of a component, gm-moles/cm^3 (gm-moles/cm^3)
C_{solid_i}	mass fraction converted to carbon by pyrolysis

E	activation energy, J/kg (Btu/lbm)
h	enthalpy, J/kg (Btu/lbm)
k	reaction rate constant for pyrolysis reactions or for oxidation of char (units vary with order)
L	total thickness, m (ft)
M	molecular weight
m	number of chemical reactions
$\dot{m}$	mass flow rate, kg/m^2s (lbm/ft^2s)
n	reaction order
$\dot{w}$	rate of deposition kg/m^3s (lbm/ft^3s)
N	number of reacting specie
R	universal gas constant, J/kg-K (Btu/lbmR)
P_w	pressure at the wall, atmospheres
P_i	rate of production of chemical specie by chemical reaction, kg/m^3s (gm/cm^3s)
$q_{c,net}$	net aerodynamic heating rate to the surface, W/m^2 (Btu/ft^2s)
S	power on the temperature in the rate equation
t	time, s
T	temperature, K (^oR)
V	velocity of surface due to surface recession, m/s (ft/s)
α_{ij}	stoichiometric coefficients of reactants
β_{ij}	stoichiometric coefficients of products
σ	order of reaction for reactants
δ	order of reaction for products
κ	char permeability, m^2 (ft^2)
μ	viscosity coefficient, $N-s/m^2$ ($lbf\ s/ft^2$)

$\S$	dimensionless coordinate normal to surface
λ	weight of char removed per unit weight of oxygen diffusing to the surface
ρ	density, kg/m^3 (lbm/ft^3)
ψ_{bl}	parameter equal to $\frac{M_{bl}\kappa}{ZRT\mu}$, m^2s/N (ft^2s/lbf)
ψ_p	parameter equal to $\frac{M_p\kappa}{ZRT\mu}$, m^2s/N (ft^2s/lbf)

Subscripts:

c	char
e	external to the boundary layer
f	forward
i	integers
o	initial values
p	pyrolysis or constant pressure
r	reverse
s	surface
w	wall

MATHEMATICAL ANALYSIS

The Model

The physical model of an ablation material as used herein is shown schematically in figure 1. More complex models have been described (see, for example, ref. 2). However, the physical model used herein can approximate a wide range of ablation problems. Moreover, this model is described adequately by a mathematical model whose computer solution is feasible. The general form of the energy equation for CHAP III is shown below:

(Storage) + (Pyrolysis solid reactions) + (Pyrolysis gas reactions) + (Convection) + (Conduction) + (Work) + (Kinetic energy) + (Viscous dissipation) = 0 (1)

The mathematical model differs in some respects from CHAP I. The areas of the analysis where major changes have been made in the terms of the energy equation are outlined in the following sections. In addition, a set of density equations has been added to account for a pyrolysis reaction zone rather than the reaction plane used in CHAP I.

The Pyrolysis Gas Kinetic Reactions

CHAP III can compute the solution to the generalized chemical kinetics problem. The kinetics analysis is necessary when neither chemical equilibrium nor chemically frozen pyrolysis gas flow provides an adequate approximation. In addition, simplified analyses are included to provide the bounding conditions: gases that are chemically frozen or gases that are in chemical equilibrium.

The general kinetic solution.- The kinetic solution must be approached from a general standpoint to have broad applicability. The chemical reactions involved in a generalized reaction can be written in the following form:

$$\sum_{i=1}^{N} \alpha_{ij} A_j \underset{k_{r_j}}{\overset{k_{f_j}}{\rightleftharpoons}} \sum_{i=1}^{N} \beta_{ij} B_j \qquad (2)$$

Each value of i in equation (2) corresponds to one chemical specie and j takes on values from 1 to the number of chemical reactions involved. Once the equation set has been established by equation (2), the rate of production of the i^{th} specie can be written as:

$$P_i = \sum_{j=1}^{m} (\alpha_{ji} - \beta_{ji}) \left(k_{f_j} \prod_{\ell=1}^{N} [C_\ell]^{\gamma_{\ell_j}} - k_{r_j} \prod_{\ell=1}^{N} [C_\ell]^{\delta_{\ell_j}}\right) \qquad (3a)$$

where the values k_f and k_r are of the form

$$k = AT^{-S} e^{-E/RT} \qquad (3b)$$

for each chemical reaction.

The generality of the above equations makes them very useful. The price paid for this generality is increased computing time. The chain multiplications involved in the π terms of equation (3) are the main contributors to large computing times.

The above equations are included as a sub-routine that can be inserted into CHAP III to model a generalized set of chemical reactions. However, the generalized approach is not recommended except under unusual conditions.

Explicit kinetic solutions.- A more practical approach to the kinetic solution is to write out explicitly the rate of production terms defined by equation (3). This approach constrains the set of chemical reactions that can be modeled. This constraint will be minimal if judicious choices are made for the set of chemical reactions. For example, a system of chemical reactions for ablation materials has been programed explicitly and used with excellent results by the authors for a number of ablation materials. This explicit equation set is included in the program as the standard option for modeling gas kinetics.

Simple systems should almost always be modeled by writing a new explicit expression to describe the unique system being modeled. This explicit expression is programed and inserted at statement number 10 in the KINET subroutine. The appropriate changes can be made in the comment cards in the INOUT subroutine so they describe the set of chemical reactions currently being used. An example is shown below to demonstrate the simplicity of the explicit approach. A simple set of chemical reactions is shown in equation (4)

$$CH_4 \rightleftharpoons CH_3 + H \qquad (4a)$$

$$H_2 \rightleftharpoons 2H \qquad (4b)$$

The 4 species are:

1 - CH_4

2 - CH_3

3 - H_2

4 - H

From equation (3a), an explicit expression for the rate of production of specie 1 (CH_4) contains only one term since CH_4 appears only in equation (4a). Using FORTRAN symbols:

$$XMULTP = C_{H}^{\gamma_{4_1}} \; C_{CH_3}^{\gamma_{2_1}} = C(4)**NPEX(4,1)*C(2)**NPEX(2,1) \qquad (5)$$

$$XMULTR = C_{CH_4}^{\delta_{1_1}} = C(1)**NREX(1,1) \quad (6)$$

$$P_1 = RATE\ (1) = (PSC\ (1,1) - RSC(1,1))*(FK(1)*XMULTP - RK(1)*XMULTR) \quad (7)$$

The expression for RATE(2) is equal in magnitude to RATE (1) since CH_3 appears only in equation (4a) and the stoichiometric coefficients are equal. This is programed as:

$$P_2 = RATE\ (2) = -RATE\ (1) \quad (8)$$

The expression for RATE (3) also contains only one set of terms.

$$XMULTP = C_H^{\gamma_{4_2}} = C(4)**NPEX(4,2) \quad (9)$$

$$XMULTR = C_{H_2}^{\delta_{3_2}} = C(3)**NREX(3,2) \quad (10)$$

$$P_3 = RATE(3) = (PSC(2,3) - RSC(2,3))*(FK(2)*XMULTP-RK(2)*XMULTR) \quad (11)$$

The production rate for specie 4 contains two sets of terms since it appears in both equations (4a) and (4b).

$$RATE(4) = (PSC(2,4) -RSC\ (2,4))*(FK(2)*XMULTP-RK(2)*XMULTR) \quad (12)$$

$$+(PSC(1,4) - RSC(1,4))*(FK1)*XMULTP-RK(1)*XMULTR) \quad (13)$$

It should be noted that the expression for specie 4 can also be written as:

$$P_4 = RATE(4) = -RATE(1) - 2*RATE(2) \quad (14)$$

If equations (5), (6), (7), (8), (9), (10), (11), and (14) are used, the computer time is approximately 6% of that required by the generalized equation (3a). Larger systems of chemical reactions can be programed in an equally simple fashion. The approach to a kinetic solution in this section has followed closely the development in reference 3.

The bounding solutions.- It is frequently desirable to establish the boundaries within which a solution will lie. With respect to chemical reactions, these boundaries are defined by: (1) the solution when the pyrolysis gases are chemically frozen and (2) the solution when

the pyrolysis gases are in chemical equilibrium. The frozen solution requires no elaboration. The equilibrium solution contained in CHAP III is based on the assumption that the pyrolysis gases are in local thermal and chemical equilibrium within the porous solid. This assumption makes it possible to compute the enthalpy and chemical composition of the gas as a function of temperature and pressure. The equilibrium solution for a given chemical system is readily obtained by use of the computer program described in reference 4. The output of that program is compatible with the input required by CHAP III.

Chemical reactions between pyrolysis gases and boundary layer gases.- CHAP III has provisions for incorporating the effects of boundary layer combustion into the surface recession rates. The model used to develop the combustion analysis was a carbon bearing gas being injected into a boundary layer that contains oxygen. When the combustion of pyrolysis gases is included, the expression for first order oxidation of the surface becomes:

$$\dot{m}_c = KP_w \left[C_e - \frac{\dot{m}_{carbon}\,(h_e - h_w)}{\lambda N_{Le}^{0.6}\, q_{c,net}} \right] \Bigg/ \left[1 + \frac{KP_w\,(h_e - h_w)}{\lambda N_{Le}^{0.6}\, q_{c,net}} \right] \tag{15}$$

Here $\dot{m}_{carbon}$ includes all carbon injected into the boundary layer, either as a result of pyrolysis or as a result of sublimation, except carbon in the form CO. Also, the assumption is made that any oxygen in the pyrolysis gases is in the form CO. The computer program has been made flexible enough so that other material systems, exposed to more generalized atmopsheres, can be analyzed.

The Density Equation

The chemically reacting components of the solid are allowed to vary as a function of position and time in CHAP III. Pyrolysis reaction-in-depth has been incorporated into the transient analysis in a fashion similar to that used in the quasi-steady solution described in reference 5. This analysis is not included in reference 1, so it is outlined here. The differential equation for the densities of the irreversible pyrolysis reactions are:

$$\frac{D\rho_i}{Dt} = \frac{\partial \rho_i}{\partial t} + \frac{\partial \rho_i}{\partial \S}\,\frac{\partial \S}{\partial t} \tag{16a}$$

where there is one density equation for each component in the solid. The rate of mass loss $\partial\rho/\partial t$ of each component is given by a pseudo-order classical rate expression (refs. 6, 7).

$$\frac{\partial \rho}{\partial t} = \rho^{n} A e^{-\Delta E/RT} \tag{16b}$$

Solid carbon is formed both by the irreversible pyrolysis reactions and by deposition from the gas phase. The differential equation for the density of carbon is:

$$\frac{D\rho_c}{Dt} = \sum_{i=1}^{NTYR} \left[\frac{\partial \rho_i}{\partial t} (C_{solid})_i\right] + \dot{w} + \frac{\partial \rho_c}{\partial \S} \frac{\partial \S}{\partial t} \tag{16c}$$

The rate of deposition of solid, $\dot{w}$, is calculated from the gas phase kinetics solution. The expression for the derivative $\frac{\partial \S}{\partial t}$ is:

$$\frac{\partial \S}{\partial t} = \frac{\dot{m}_s}{\rho_s L} (1 - \S) \tag{17}$$

where $\dot{m}_s$ is the surface mass loss rate and $\rho_s L$ is the local density at the current surface location. The remaining derivative in equation (16), $\frac{\partial \rho}{\partial \S}$, is obtained with standard finite difference techniques.

NUMERICAL ANALYSIS

The physical model in figure 1 has been approximated in one-dimension by a finite difference network. A coarse grid illustrated in figure 2 is used with an implicit-finite difference formulation of the energy equation to generate a set of simultaneous algebraic equations. These algebraic equations are readily transformed to a tri-diagonal form whose solution is rapid and accurate. Within the coarse grid of the energy equation is a finer grid whose spacings vary with chemical composition. This finer gridwork is used to integrate the non-linear ordinary differential equations that describe the chemical reactions that occur in the pyrolysis gas. The mass-density equations use the results of both the energy equation and chemical kinetics in conjunction with the pyrolysis rate to generate instantaneous density values for all components at each coarse grid location. The coarse grid is more than adequate for approximating the energy equation. The finer gridwork is required to give adequate approximations to the highly non-linear chemical-kinetics equations. The accuracy to be expected using this

numerical approach is indicated by the following examples.

Comparisons with Exact Solutions

Two problems for which exact solutions exist were modeled with the ablation program and solved numerically. The resulting numerical solutions were then compared with the exact solutions. The first problem selected was to find the temperature response of a heat sink, with constant material properties, that had a constant-heating rate applied to one face and was perfectly insulated on the other face. A comparison of numerical and exact solutions to this problem is shown in figure 3. The percent error in the numerical solution is plotted for three points within the solid: near the surface, the mid-point of the slab, and the back surface of the slab. Since the exact solution has a discontinuity at time equal zero, the comparison is started at a non-dimensional time ($kt/L^2\rho C_p$) of 0.025. This figure shows that errors in the numerical solution are negligible.

The second problem was to find the temperature response of an ablation material undergoing quasi-steady ablation when pyrolysis reactions- in-depth are present, and the heat of pyrolysis is zero. The zero heat of pyrolysis decouples the mass and energy equations thus permitting exact solutions (ref. 8). The resulting exact temperature equation is an exponential function of distance. This problem was modeled on the computer by imposing constant environmental conditions and allowing the quasi- steady conditions to develop as they would in a semi-infinite slab. After about 140 seconds, the numerical solution approached a quasi- steady condition by oscillating about the exact solution. In the exact solution, the surface recedes at a constant velocity, and the temperature and density profiles do not change with time. The transient numerical solution oscillated slowly about the exact solution. Figure 4 shows the temperature profile, obtained numerically after 140 seconds at constant conditions, compared with the exact solution. Agreement between the solutions is good. Similar agreement is obtained at all greater times investigated.

COMPUTER PROGRAM

Using the Program

To assist the user, three tables are included in this paper. Table I contains two sections. The first section is in alphabetical order according to physical symbols. These symbols were used in the mathematical modeling of the physical system. Each physical symbol is defined in section one and the equivalent FORTRAN symbol is given. A number is also assigned to each symbol for use as cross-reference to the

other tables. The second section of Table I contains the same information about items that are important enough to require definition but were not assigned a physical symbol.

Table I should be used to go from the mathematical formulation in reference 1 to symbols used in this computer program. This table can obviously be used as an updated symbol list.

Table II contains a list of input and output variables in the order of appearance in the I/O lists of the computer program. This table can be used as a reference when preparing inputs. Two columns of numbers are included in this table. The first column, in parenthesis, is the item number of that FORTRAN variable. The third column is the number assigned to the FORTRAN symbol in Table I.

The primary method of input is by use of the namelist entitled NAME1. The remainder of the inputs are made by individual FORMAT. The appropriate FORMAT to use for each input is listed under comments. The latter inputs, not included in NAME1, are those that will be changed infrequently when working with a particular material system.

Table III is an alphabetical listing by FORTRAN symbol. The majority of these symbols are used internally and have no physical significance. When appropriate, the corresponding symbols are listed opposite the FORTRAN symbol. The location of the FORTRAN symbols in Tables I and II are listed for cross-reference purposes. Table III will be of use when working internally with the program. Internal items will only be known by FORTRAN symbol.

A brief description of the table look-up subroutines used in the program is included as Appendix A. The inputs for these sub-routines are input in standard Namelist form in NAME1.

Experience has shown that computing time is virtually unaffected by the number of finite difference stations used as long as the total (I+J+M) is 100 or below. Consequently, it is recommended that I+J be greater than 50 and M greater than 10. It does not save computing time to use a smaller number of stations but it will increase truncation errors.

Example Case

The example case included herein is moderately complex so that a number of the more commonly used factors of the program are demonstrated. A copy of the actual output is printed in Appendix B. The ablation material in this case contains seven solid pyrolysis reactions, all of which leave a solid residue upon pyrolyzing. The ablation material is modeled by 51 finite-difference stations spaced at 1/n-1 or 1/50 = 0.02 distance apart. The computer automatically calculates the number of fine grid points used in integrating the chemical reaction equations. The

material is subjected to an environment that is typical of entry at lunar return velocity.

The first section of printout in Appendix B is a list of the NAMELIST entitled NAME1. This list continues for 14 1/2 pages and is terminated by $END. The values input in this section are typical for epoxy ablation materials and can be used where specific data are not available. Immediately following NAME1 is a list of the inputs required by the pyrolysis-gas kinetics sub-program. The reading and printing for this section are done in subroutine INØUT. The values listed in this section are for the chemical species and kinetic equations listed in the subroutine. The last section of input is a tabular listing of selected data from NAME1. These tabulated items are frequently referred to and are relisted for convenience.

The results of calculations are headed by the title "Beginning of Output." The output is keyed to the current computed value of time designated as TAU. The first cycle of output occurs after only one time step or DELTAU. The first print, in this case, occurs after only .0078125 second. As would be expected after such a brief time interval, the temperature of the ablator, T, is virtually unchanged from the initial condition. Even the surface temperature has risen only 3.84 degrees. All points of the ablator are at such a low temperature that no pyrolysis is occurring. Consequently, the gas flow past all points within the solid, WWPDOT, is zero and the density of all reacting components of the solid, RHO, remain at initial values.

One more print sequence is shown at a time of 80.023437. The surface temperature has increased to 5400.83 R. Pyrolysis has proceeded to a point that the density of all seven solid components has been reduced to zero at the surface. Deposition of carbon has proceeded to a point that the density at the surface is 23.5441 pounds per cubic foot. The average molecular weight of the pyrolysis gases as they enter the boundary layer is 11.114. This value is much lower than the average molecular weight of 37.815 as produced by pyrolysis. The temperatures are so high that a large percentage of the pyrolysis gas should be converted to solid carbon. An examination of the rates of deposition of carbon confirms this assumption. The sum of the rate of deposition, WDEP, of carbon represents 44% of the mass formation rate of pyrolysis gas.

CONCLUDING REMARKS

The computer program which has been described (CHAP III) has the capability of computing the response of a material to a prescribed heat input at the surface. This program is a modification to an existing program (CHAP I). This manual contains a brief explanation of the modification that was made to the original program. Use of CHAP III should not be attempted without familiarity with the mathematical formulation of CHAP I. The tables in the appendix are complete and

contain all FORTRAN symbols used in the program. A brief explanation is included for each symbol used in input or output.

APPENDIX A

LIBRARY SUBROUTINES

The following are instructions on the use of library TABLE LOOKUP subroutines contained in the computer program. These sheets are copies of pages from the computer programing manual used at the Langley Research Center.

SUBROUTINE FTLUP

NOTE: This subroutine is a special case of MTLUP (E1.5) and is included to provide continuity of existing programs. New programs should use MTLUP instead of FTLUP.

LANGUAGE: FORTRAN

PURPOSE: Computes y = F(x) from a table of values using first or second order interpolation. An option to give y a constant value for any x is also provided.

USE: CALL FTLUP (X, Y, M, N, VARI, VARD)

X - The name of the independent variable x.

Y - The name of the dependent variable, y = F(x)

M- The order of interpolation (an integer)

M = 0 for y a constant as explained in the NOTE below.

M = 1 or 2. First or second order if VARI is strictly increasing (not equal)

M = -1 or -2. First or second order if VARI is strictly decreasing (not equal)

N - The number of points in the table (an integer).

VARI - The name of a one-dimensional array which contains the N values of the independent variable.

VARD - The name of a one-dimensional array which contains the N values of the dependent variable.

NOTE: VARD(I) corresponds to VARI(I) for I = 1, 2, . . . , N. For M = 0 or N $\leq$ 1, y = F(VARI(1)) for any value of x. The program extrapolates.

RESTRICTIONS: All the numbers must be floating point. The values of the independent variable x in the table must be strictly increasing or strictly decreasing.

FTLUP

The following arrays must be dimensioned by the calling program as indicated: VARI(N), VARD(N).

ACCURACY: A function of the order of interpolation used.

REFERENCES: Nielson, K.L.; METHODS IN NUMERICAL ANALYSIS, pp. 87-91.

Milne, NUMERICAL ANALYSIS, pp. 69-73.

STORAGE: 430_8 locations

ERROR CONDITION: If the VARI values are not in order, the subroutine will print TABLE BELOW OUT OF ORDER FOR FTLUP AT POSITION xxx TABLE IS STORED IN LOCATION xxxxxx (absolute). It then prints the contents of VARI and VARD, and STOPS the program.

SOURCE: NASA, LRC, Edward C. Polhamus, Jr.

RESPONSIBLE PERSON: Vivian P. Adair

SUBROUTINE DISCOT

LANGUAGE: FORTRAN

PURPOSE: SINGLE OR DOUBLE INTERPOLATION SUBROUTINE FOR CONTINUOUS OR DISCONTINUOUS FUNCTIONS

Given some function with two independent variables, x and z, this subroutine performs K_xth and K_zth order interpolation to calculate the dependent variable. In this subroutine all single line functions are read in as two separate arrays and all multi-line functions are read is as three separate arrays, i.e.

X_i $\quad i = 1, 2, \ldots L$

Y_j $\quad j = 1, 2, \ldots M$

Z_k $\quad k = 1, 2, \ldots N$

USE: CALL DISCOT (XA, ZA, TABX, TABY, TABZ, NC, NY, NZ, ANS)

XA - The X argument.

ZA - The Z argument (may be the same name as X on single lines).

TABX - A one-dimensional array of X's.

TABY - A one-dimensional array of Y's.

TABZ - A one-dimensional array of Z's.

NC - A control word that consists of a sign and three digits. The control word is formed as follows:

(1) If NX = NY, the sign is -. If NX ≠ NY, NX is computed by DISCOT as NX = NY/NZ. The sign is + and may be omitted if desired.

(2) A 1 in the hundreds position of the word indicates that no extrapolation occurs

above Z max. With a zero in this position extrapolation occurs when Z > Z max. The zero may be omitted if desired.

(3) 1-7 in the tens position of the word indicates the order of interpolation in the X direction.

(4) 1-7 in the units position of the word indicates the order of interpolation in the Z direction.

NY - The number of points in the Y array

NZ - The number of points in the Z array.

ANS - The dependent variable Y.

The following programs will illustrate various ways to use DISCOT.

Case I. Given Y = f(x)

NY = 50
NX (number of points in X array) = NY
Extrapolation when Z > Z max
Second order interpolation in X direction
No interpolation in Z direction
Control word = -020

```
1.      DIMENSION TABX (50), TABY (50)
      1 FORMAT (8E 9.5)
        READ (5, 1) TABX, TABY
        READ (5, 1) XA
        CALL DISCOT (XA, XA, TABX, TABY, TABY,
        -020, 50, 0, ANS)
```

Case II Given Y = f(x, z)

NY = 800
NZ = 10
NX = NY/NZ (computed by DISCOT)
Extrapolation when Z > Z max
Linear interpolation in X direction
Linear interpolation in Z direction
Control word = 11

```
      DIMENSION TABX (800), TABY (800), TABZ (10)
    1 FORMAT (8E 9.5)
      READ (5, 1) TABX, TABY, TABZ
      READ (5, 1) XA, ZA
      CALL DISCOT ( XA, ZA, TABX, TABY, TABZ,
      11, 800, 10, ANS)
```

Case III. Given Y = f(x, z)

```
NY = 800
NZ = 10
NX = NY
Extrapolation when Z > Z max
Seventh order interpolation in X direction
Third order interpolation in Z direction
Control word = -73

      DIMENSION TABX (800), TABY(800), TABZ (10)
    1 FORMAT (8E 9.5)
      READ (5, 1) TABX, TABY, TABZ
      READ (5, 1) XA, ZA
      CALL DISCOT (XA, ZA, TABX, TABY, TABZ,
      -73, 800, 10, ANS)
```

Case IV. Same as Case III with no extrapolation above Z max. Control word = -173

```
      CALL DISCOT (XA, ZA, TABX, TABY, TABZ, -173,
      800, 10, ANS)
```

RESTRICTIONS: See 4c of METHOD for restrictions on tabulating arrays and discontinuous functions. The order of interpolation in the X and Z directions may be from 1-7.

The following subprograms are used by DISCOT: UNS, DISSER, LAGRAN.

METHOD: Lagrange's interpolation formula is used in both the X and Z direction for interpolation. This method is explained in detail in Methods in Numerical Analysis by Nielsen. The search in both the X and Z direction observe the following rules:

1. $X < X_1$ the routine chooses the following points for extrapolation.

$X_1, X_2, \ldots . X_{k+1} \quad Y_1, Y_2, \ldots . Y_{k+1}$

2. $X > X_n$ the routine chooses the following points for extrapolation.

$X_{n-k}, X_{n-k+1}, \ldots . X_n \quad Y_{n-k}, Y_{n-k+1}, \ldots Y_n$

3. $X \leq X_n$ the routine chooses the following points for interpolation.

k is odd $X_{i-\frac{k+1}{2}}, X_{i-\frac{k+1}{2}+1}, \ldots X_{i-\frac{k+1}{2}+k}$

$Y_{i-\frac{k+1}{2}}, Y_{i-\frac{k+1}{2}+1}, \ldots . Y_{i-\frac{k+1}{2}+k}$

k is even $X_{i-\frac{k}{2}}, X_{i-\frac{k}{2}+1}, \ldots . X_{i-\frac{k}{2}+k}$

$Y_{i-\frac{k}{2}}, Y_{i-\frac{k}{2}+1}, \ldots . Y_{i-\frac{k}{2}+k}$

4. If any of the subscripts in Rule 3 become negative or greater than n (number of points), Rules 1 and 2 apply. When discontinuous functions are tabulated, the independent variable at the point of discontinuity is repeated, i.e.

$k = 2 \ (X_1, X_2, X_3, X_3, X_4, X_5, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6)$.

The subroutine will automatically examine the points selected before interpolation and if there is a discontinuity, the following rules apply. Let X_d and X_{d+1} be the point of discontinuity.

a. $X \leq X_d$ points previously chosen are modified for interpolation as shown

$X_{d-k}, X_{d-k+1}, \ldots . X_d$

$Y_{d-k}, Y_{d-k+1}, \ldots . Y_d$

b. $X > X_d$ points previously chosen are modified for interpolation as shown

$X_{d+1}, X_{d+2}, \ldots . X_{d+k}$

$Y_{d+1}, Y_{d+2}, \ldots . Y_{d+k}$

c. When tabulating discontinuous functions, there must always be k+1 points above and below the discontinuity in order to get proper interpolation.

When tabulating arrays for this subroutine, both independent variables must be in ascending order.

In some engineering programs with many tables, it is quite desirable to read in one array of x's that could be used for all lines of a multi-line function or different functions.

The above not only saves much time in preparing tabular data, but can also save many locations previously used when every y coordinate had to have a corresponding x coordinate. Even though the above is not always applicable, the subroutine has been written to handle this situation.

Another additional feature that may be useful is the possibility of a multi-line function with no extrapolation above the top line.

DISCOT

ACCURACY: A function of the order of interpolation used.

REFERENCE: Nielsen, K.L.; Methods in Numerical Analysis

STORAGE: DISCOT - 555_8 locations

SUBPROGRAMS USED:
UNS 40_8 locations
DISSER 110_8 locations
LAGRAN 55_8 locations

OTHER CODING INFORMATION: NONE

SOURCE: SHARE Library, General Motors Corp., Allison Div.

RESPONSIBLE PERSON: Vivian P. Adair

APPENDIX B

EXAMPLE CASE

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***** EXAMPLE CASE *****

```
$NAME1
 T      = 0.54E+03,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,
          0.54E+03,  0.54E+03,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+03,
          0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+03,  0.54E+03,
          0.54E+03,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,
          0.54E+C3,  0.54E+03,  0.54E+03,  0.54E+03,  0.54E+03,  0.54E+03,
          0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,
          0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,
          0.54E+03,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+03,  0.54E+03,
          0.54E+C3,  0.54E+03,  0.54E+C3,  0.54E+03,  0.54E+03,  0.54E+03,
          0.54E+C3,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 Z      = 0.3188E+00,  C.3021E+00,  C.2771E+00,  0.2521E+00,  0.1625E+00,
          0.0,  0.0,  C.0,  0.0,  0.C,

 TZ     = 0.0,  C.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 MCP    = 1,

 NCP    = 8,

 TTABCP = 0.72E+03,  0.1C8E+04,  0.144E+04,  0.18E+04,  0.216E+04,  0.252E+04,
          0.2574E+04,  C.7E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.C,  0.0,  0.C,  0.0,  0.0,  0.0,  0.C,  0.0,

 CPTAB  = 0.2504E+00,  C.2991E+00,  0.3478E+00,  0.3965E+00,  0.4452E+00,
          0.4939E+00,  0.5012E+00,  C.5E+00,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,

 MCPP   = 0,

 NCPP   = 0,

 TTBCPP = 0.0,  0.56E+03,  0.66E+03,  0.76E+03,  0.86E+C3,  0.96E+03,
          0.10CE+04,  0.116E+04,  0.121E+04,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

 CPPTAB = 0.3E+00,  0.329E+00,  0.364E+00,  0.397E+0C,  0.406E+00,  0.418E+00,
          0.424E+00,  0.425E+00,  0.425E+00,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
                0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MCPDP       0,

NCPDP    =  0,

TTCPDP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,

CPDPTB   =  0.11E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,

MCPBAR   =  1,

NCPBAR   =  2,

TTBCPB   =  0.1E+04,  0.2E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,

CPBTAB   =  0.1E+04,  0.2E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,

MK       =  1,

NK       =  8,

TTABK    =  0.5E+03,  0.1E+04,  0.15E+04,  0.2E+04,  0.25E+04,  0.3E+04,
            0.35E+04,  0.4E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

CKTAB    =  0.14E-04,  0.14E-04,  0.388E-04,  0.813E-04,  0.117E-03,  0.167E-03,
            0.2E-03,  0.2E-03,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MCKNP    =  0,

NCKNP    =  8,

TTCKNP   =  0.5E+03,  0.1E+04,  0.15E+04,  0.2E+04,  0.25E+04,  0.3E+04,
```

```
          0.35E+04,  0.4E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

CKNPTB  = 0.14E-04,  0.14E-04,  0.388E-04,  0.813E-04,  0.117E-03,  0.167E-03,
          0.2E-03,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MCKNDP  = 0,

NCKNDP  = 0,

TCKNDP  = 0.0,  0.0,  0.0,  0.0,  0.0,

CKNDPT  = 0.417E-04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MHW     = 1,

NHW     = 14,

TTABHW  = 0.5E+03,  0.1E+04,  0.15E+04,  0.2E+04,  0.25E+04,  0.3E+04,
          0.35E+04,  0.4E+04,  0.45E+04,  0.5E+04,  0.55E+04,  0.6E+04,
          0.65E+04,  0.7E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,

HWTAB   = -0.1E+02,  0.111E+03,  0.239E+03,  0.375E+03,  0.517E+03,  0.665E+03,
          0.818E+03,  0.98E+03,  0.1173E+04,  0.1384E+04,  0.17E+04,
          0.206E+04,  0.255E+04,  0.3E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,

MALPHA  = 0,

NALPHA  = 0,

TALPHA  = 0.0,  0.0,  0.0,  0.0,  0.0,

ALPHAT  = 0.1159E+01,  0.0,  0.0,  0.0,  0.0,

MALPH1  = 0,
```

```
NALPH1  =  0,

TTAL1   =  0.0,  0.0,  0.0,  0.0,  0.0,

AL1TAB  =  0.5E+00,  0.0,  0.0,  0.0,  0.0,

MALPH2  =  0,

NALPH2  =  0,

TTAL2   =  0.0,  0.0,  0.0,  0.0,  0.0,

AL2TAB  =  0.1E+01,  0.0,  0.0,  0.0,  0.0,

MHE     =  0,

NHE     =  0,

TTABHE  =  0.0,  0.29E+02,  0.39E+02,  0.49E+02,  0.59E+02,  0.79E+02,
           0.99E+02,  0.119E+03,  0.139E+03,  0.149E+03,  0.159E+03,
           0.179E+03,  0.199E+03,  0.219E+03,  0.239E+03,  0.259E+03,
           0.299E+03,  0.329E+03,  0.369E+03,  0.399E+03,  0.419E+03,
           0.449E+03,  0.489E+03,  0.509E+03   0.529E+03,  0.549E+03,
           0.569E+03,  0.599E+03,  0.11E+04,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

HETAB   =  0.1922E+05,  0.1922E+05,  0.1922E+05,  0.1934E+05,  0.1934E+05,
           0.1922E+05,  0.1873E+05,  0.1764E+05,  0.1565E+05,  0.1318E+05,
           0.1104E+05,  0.94E+04,  0.808E+04,  0.7046E+04,  0.6188E+04,
           0.5478E+04,  0.488E+04,  0.4375E+04,  0.3948E+04,  0.3575E+04,
           0.3256E+04,  0.2977E+04,  0.2724E+04,  0.2491E+04,  0.2273E+04,
           0.206E+04,  0.1855E+04,  0.1649E+04,  0.1438E+04,  0.1232E+04,
           0.1025E+04,  0.832E+03,  0.6567E+03,  0.504E+03,  0.3767E+03,
           0.2768E+03,  0.2112E+03,  0.1404E+03,  0.1404E+03,  0.9768E+02,
           0.5771E+02,  0.4682E+02,  0.3277E+02,  0.229E+02,  0.162E+02,
           0.120E+02,  0.98E+01,  0.72E+01,  0.5E+01,  0.8E-02,  0.8E-02,
```

```
                0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,
                0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.8E-02,  0.0,
                0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
                0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
                0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
                0.0,  0.0,

MQC     =  1,

NCC     =  64,

TTABQC  =  0.0,  0.1E+02,  0.2E+02,  0.3E+02,  0.4E+02,  0.5E+02,  0.6E+02,
           0.7E+02,  0.8E+02,  0.9E+02,  0.1E+03,  0.11E+03,  0.12E+03,
           0.13E+03,  0.14E+03,  0.15E+03,  0.16E+03,  0.17E+03,  0.18E+03,
           0.19E+03,  0.2E+03,  0.21E+03,  0.22E+03,  0.23E+03,  0.24E+03,
           0.25E+03,  0.26E+03,  0.27E+03,  0.28E+03,  0.29E+03,  0.3E+03,
           0.31E+03,  0.32E+03,  0.33E+03,  0.34E+03,  0.35E+03,  0.36E+03,
           0.37E+03,  0.38E+03,  0.39E+03,  0.4E+03,  0.41E+03,  0.42E+03,
           0.43E+03,  0.44E+03,  0.45E+03,  0.46E+03,  0.47E+03,  0.48E+03,
           0.49E+03,  0.5E+03,  0.51E+03,  0.52E+03,  0.53E+03,  0.54E+03,
           0.55E+03,  0.56E+03,  0.57E+03,  0.58E+03,  0.59E+03,  0.6E+03,
           0.61E+03,  0.13E+04,  0.2E+04,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

QCTAB   =  0.365E+01,  0.75E+01,  0.168E+02,  0.406E+02,  0.961E+02,
           0.1927E+03,  0.3177E+03,  0.4385E+03,  0.4901E+03,  0.4344E+03,
           0.3337E+03,  0.2618E+03,  0.1698E+03,  0.1397E+03,  0.1163E+03,
           0.979E+02,  0.831E+02,  0.712E+02,  0.615E+02,  0.533E+02,
           0.472E+02,  0.422E+02,  0.382E+02,  0.349E+02,  0.321E+02,
           0.295E+02,  0.271E+02,  0.246E+02,  0.218E+02,  0.187E+02,
           0.154E+02,  0.122E+02,  0.92E+01,  0.67E+01,  0.47E+01,  0.33E+01,
           0.22E+01,  0.22E+01,  0.14E+01,  0.1E+01,  0.6E+00,  0.4E+00,
           0.3E+00,  0.2E+00,  0.15E+00,  0.1E+00,  0.8E-01,  0.6E-01,
           0.5E-01,  0.4E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.2E-01,  0.2E-01,
           0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.1E-01,  0.1E-01,  0.1E-02,
           0.1E-02,  0.1E-02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MQR     =  0,
```

```
NQR      =  0,

TTABQR   =  0.0,  0.31E+02,  0.36E+02,  0.41E+02,  0.46E+02,  0.51E+02,
            0.56E+02,  0.59E+02,  0.61E+02,  0.63E+02,  0.65E+02,  0.79E+02,
            0.81E+02,  0.85E+02,  0.91E+02,  0.261E+03,  0.291E+03,  0.441E+03,
            0.461E+03,  0.491E+03,  0.541E+03,  0.11E+04,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

QRTAB    =  0.5E-01,  0.2E+00,  0.7E+00,  0.34E+01,  0.148E+02,  0.481E+02,
            0.1099E+03,  0.1779E+03,  0.1837E+03,  0.1279E+03,  0.676E+02,
            0.376E+02,  0.218E+02,  0.132E+02,  0.82E+01,  0.53E+01,  0.35E+01,
            0.23E+01,  0.16E+01,  0.11E+01,  0.8E+00,  0.6E+00,  0.4E+00,
            0.3E+00,  0.2E+00,  0.2E+00,  0.2E+00,  0.1E+00,  0.9E+00,  0.6E+00,
            0.4E+00,  0.2E+00,  0.1E+00,  0.5E-01,  0.2E+01,  0.3E-01,  0.3E-01,
            0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,
            0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,
            0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,
            0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.3E-01,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,

MCDOT    =  0,

NCDOT    =  0,

TTMCDT   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,

WCDOTT   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,

MX       =  0,
```

```
NX     = 0,

TTABX  = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0,

XTAB   = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0,

MDUM1  = 0,

NDUM1  = 0,

TTDUM1 = 0.0,

DUM1TB = 0.0,

MCS    = 0,

NCS    = 0,

TTABQS = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

QSTAB  = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

F1     = 0.0,

RC     = 0.0,

RCP    = 0.0,

RODP   = 0.55E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
```

```
DELHF  = 0.0,
DELHP  = 0.0,
EIPJ   = 0.0,
CIPJ   = 0.0,
EIJM   = 0.0,
CIJM   = 0.0,
BETA   = 0.0,
ETA    = 0.6E+00,
EPSONE = 0.75E+00,
TNSTCP = 0.0,
X      = 0.1E+00,
MHC    = 0,
NHC    = 0,
TTABHC = 0.2E+04, 0.4E+04, 0.6E+04, 0.8E+04, 0.1E+05,
HCTAB  = 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05,
         0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05,
         0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05,
         0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05, 0.12E+05,
         0.12E+05,
MTB    = 0,
NTB    = 0,
TTABTB = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TBTAB  = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
```

```
XP      = 0.64666E-01,
XDP     = 0.1625E+00,
TNBAR   = 0.1E+05,
I       = 26,
J       = 25,
M       = 0,
TAUO    = 0.0,
WCDOTC  = 0.0,
WPDOTO  = 0.0,
DELWFO  = 0.0,
FREO    = 0.1E+02,
ENDTAU  = 0.1E+04,
XOPT    = 0.1E+02,
IOPT    = 1,
NXOPT   = 1,
XMIN    = 0.8E-04,
XFMIN   = 0.1E-03,
NUMZ    = 5,
TCPT    = 0.1E+05,
NTOPT   = 2,
AEXP    = 0.1E+13,
```

```
BEXP    = 0.765E+05,
APEXP   = 0.0,
BPEXP   = 0.0,
XCRDER  = 0.1E+01,
CE      = 0.23E+00,
ELAM    = 0.0,
HCOMB   = 0.0,
REFF    = 0.1E+01,
PCOEF   = 0.2024E+02,
MPRAT   = 0,
NPRAT   = 0,
TTPRAT  = 0.0,  0.0,  0.0,  0.0,  0.0,
PRATT   = 0.82E+00,  0.0,  0.0,  0.0,  0.0,
MXPRES  = 1,
NXPRES  = 2,
TTXPRE  = 0.0,  0.5E+01,  0.1E+03,  0.39E+02,  0.49E+02,  0.59E+02,  0.79E+02,
          0.99E+02,  0.119E+03,  0.139E+03,  0.149E+03,  0.159E+03,
          0.179E+03,  0.199E+03,  0.219E+03,  0.239E+03,  0.259E+03,
          0.299E+03,  0.329E+03,  0.369E+03,  0.399E+03,  0.419E+03,
          0.449E+03,  0.489E+03,  0.509E+03,  0.529E+03,  0.549E+03,
          0.569E+03,  0.599E+03,  0.629E+03,  0.649E+03,  0.679E+03,
          0.709E+03,  0.759E+03,  0.11E+04,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,

XPREST  =   0.3883E-02,  0.7945E-02,  0.1779E-01,  0.4287E-01,  0.1015E+00,
            0.2044E+00,  0.3453E+00,  0.5074E+00,  0.6397E+00,  0.6729E+00,
            0.6161E+00,  0.5665E+00,  0.5271E+00,  0.4923E+00,  0.4615E+00,
            0.4343E+00,  0.4099E+00,  0.3882E+00,  0.3689E+00,  0.3511E+00,
            0.3352E+00,  0.3248E+00,  0.3168E+00,  0.3135E+00,  0.3141E+00,
            0.3185E+00,  0.3261E+00,  0.3374E+00,  0.3508E+00,  0.3646E+00,
            0.375E+00,  0.3812E+00,  0.3824E+00,  0.3813E+00,  0.3696E+00,
            0.3575E+00,  0.3567E+00,  0.3354E+00,  0.3354E+00,  0.3256E+00,
            0.3207E+00,  0.3212E+00,  0.3289E+00,  0.3424E+00,  0.362E+00,
            0.395E+00,  0.4272E+00,  0.4595E+00,  0.4899E+00,  0.4633E+00,
            0.5093E+00,  0.5456E+00,  0.5836E+00,  0.6231E+00,  0.6643E+00,
            0.7071E+00,  0.7516E+00,  0.7978E+00,  0.8458E+00,  0.8621E+00,
            0.9124E+00,  0.9E-01,  0.9E-01,  0.9E-01,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

MQRAT   =   0,

NQRAT   =   0,

TTQRAT  =   0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

QRATT   =   0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

WCSDOO  =   0.0,

WCCDOO  =   0.0,

AL      =   0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,
            0.2E-01,  0.2E-01,  0.2E-01,  0.2E-01,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,
```

```
MTAU    =  0,
NTAU    =  4,
TTAU    =  0.0,  0.6E+01,  0.1E+02,  0.4E+03,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,
TAUTAB  =  0.78125E-02,  0.15625E-01,  0.625E-01,  0.1E+01,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,
TCHAN   =  0.0,
MAXIT   =  5,
ERRCR   =  0.1E-02,
ICEBUG  =  0,
THETA   =  0.1E+01,
ABEXP   =  0.0,
BBEXP   =  0.0,
ICPT1   =  1,
PREFE   =  0.1E+01,
ABUT    =  0.0,
GAM1TB  =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
GAM2TB  =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
           0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
XRTAB  = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

PHIPTB = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

PHIETB = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

MXR    = 0,

NXR    = 0,

TTBPHI = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

MPHI   = 0,

NPHI   = 0,

PERM   = 0.0,

R      = 0.0,

CCN    = 0.0,

ACOEF  = 0.0, 0.0, 0.0,

YDEL   = 0.0,
```

```
ELAMTB = 0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,
         0.75E+00,  0.75E+00,  0.75E+00,  0.75E+00,

TTELAM = 0.5E+03,  0.5E+03,  0.5E+03,  0.5E+03,  0.5E+03,  0.5E+03,  0.5E+03,
         0.5E+03,  0.5E+03,  0.1E+05,

PELAM  = 0.1E-01,  0.5E-01,  0.1E+01,  0.2E+01,

IPRINT = 0,

KTXDP  = 0,

ICPBAR = 2,

CPPT7  = 0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

TTHCCMB = 0.18E+04,  0.27E+04,  0.36E+04,  0.45E+04,  0.54E+04,  0.63E+04,
          0.72E+04,

HCCMBTB = 0.411E+04,  0.4266E+04,  0.4454E+04,  0.4871E+04,  0.6265E+04,
          0.1022E+05,  0.1354E+05,  0.411E+04,  0.4266E+04,  0.4447E+04,
          0.4697E+04,  0.5295E+04,  0.6995E+04,  0.1305E+05,  0.411E+04,
          0.4266E+04,  0.4446E+04,  0.4656E+04,  0.4983E+04,  0.5679E+04,
          0.7134E+04,  0.411E+04,  0.4266E+04,  0.4445E+04,  0.4643E+04,
          0.4884E+04,  0.5245E+04,  0.5869E+04,

PHCOMB = 0.1E+00,  0.1E+01,  0.1E+02,  0.1E+03,

NHCCMB = 56862409532376811,

NPHCCMB = 56862409532376E34,

MCP7   = 0,

NCP7   = 0,

T7CPP  = 0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
CMASSF  =  0.52E+C0,

CHANGE  =  C.2E+01,

DDELPP  =  0.125E+03,  0.125E+03,  0.125E+03,  0.164E+03,  0.164E+03,
           0.164E+03,  0.27E+03,

CSOLID  =  0.25E+CC,  0.25E+C0,  0.25E+00,  0.25E+00,  0.25E+00,  0.25E+00,
           0.25E+00,

RHOZ    =  0.6006E+00,  C.7854E+00,  0.10164E+02,  0.80025E+00,  0.136125E+01,
           0.60885E+01,  0.132E+02,

NPYR    =  7,

AP      =  0.5166666E+09,  0.25E+06,  0.21666667E+08,  0.21666667E+06,
           0.966666E+07,  0.13E+11,  0.8333333E+15,

BP      =  0.4947185E+05,  0.4344919E+05,  0.602266E+05,  0.301133E+05,
           0.5248318E+05,  0.7399268E+C5,  0.99804089E+05,

RHO     =  0.60C6E+00,  0.6006E+00,  C.6006E+00,  0.6006E+00,  0.6006E+00,
           C.60C6E+00,  0.6006E+00,  C.6006E+00,  0.6006E+00,  0.6006E+00,
           0.60C6E+00,  C.6006E+00,  C.60C6E+00,  C.6006E+00,  0.6006E+00,
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 RHOC     =         0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
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 ORDER    =         0.1E+01,  0.1E+01,  0.1E+01,  0.1E+01,  0.1E+01,  0.1E+01,  0.1E+01,

 WPSUM    =         0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
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                    0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
                    0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
                0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP1    =  0,
NCP1    =  0,
T1CPP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPPT1   =  0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP2    =  0,
NCP2    =  0,
T2CPP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPPT2   =  0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP3    =  0,
NCP3    =  0,
T3CPP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPPT3   =  0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP4    =  0,
NCP4    =  0,
T4CPP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPPT4   =  0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP5    =  0,
T5CPP   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
CPPT5   =  0.3E+00,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
MCP6    =  0,
NCP6    =  0,
```

T6CPP = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

CPPT6 = 0.3E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

NCP5 = 0,

$END

PYROLYSIS GAS KINETICS INPUT

NUMBER OF EQUATIONS 20

EXPONENTS OF RATE EQUATIONS

1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	2	2	2	1	0	0	0	1	1	0	2	0	0	1	0	0	0	0	0
1	0	1	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0

AF	SF	AEF	I
7.60000000E+14	0.	1.03000000E+02	1
1.00000000E-32	0.	0.	
1.50000000E+11	0.	1.62000000E+01	2
1.00000000E-32	0.	1.00000000E+00	
3.14000000E+15	0.	6.01000000E+01	3
1.00000000E-32	0.	1.00000000E+00	
2.57000000E+08	0.	2.30000000E+01	4
1.00000000E-30	0.	0.	
2.14000000E+10	0.	4.00000000E+01	5
1.00000000E-30	0.	0.	
1.40000000E+11	0.	5.20000000E+01	6
1.00000000E-30	0.	0.	
2.40000000E+19	8.60000000E-01	1.03200000E+02	7
2.00000000E+18	1.00000000E+00	0.	
2.80000000E+21	1.50000000E+00	2.25000000E+02	8
1.60000000E+20	1.50000000E+00	0.	
2.50000000E+16	5.00000000E-01	1.18000000E+04	9
2.20000000E+13	1.00000000E+00	0.	
3.00000000E+12	-5.00000000E-01	9.92000000E+01	10
3.00000000E+13	0.	6.00000000E+03	
3.00000000E+12	0.	4.80000000E+00	11
1.00000000E-30	0.	0.	
2.86000000E+06	0.	6.08000000E+01	12
1.00000000E-30	0.	1.80000000E+00	
8.78000000E+06	0.	7.71000000E+01	13
1.00000000E-30	0.	0.	
7.80000000E+11	0.	4.54000000E+01	14
2.10000000E+12	0.	0.	
1.00000000E+20	0.	5.40000000E+01	15

1.00000000E+17	0.	0.	
2.00000000E+14	0.	2.80000000E+01	16
2.60000000E+12	0.	6.38000000E+01	
1.20000000E+12	-1.00000000E+00	8.50000000E+01	17
1.00000000E-30	0.	0.	
9.25500000E+03	0.	7.00000000E+01	18
1.00000000E-30	0.	0.	
1.70000000E+22	1.30000000E+00	1.18000000E+02	19
4.50000000E+21	1.50000000E+00	0.	
6.90000000E+13	0.	1.80000000E+01	20
7.60000000E+12	0.	1.00000000E+00	

NG=23 NS= 1 MM= 4
S1

1.36325000E+00	1.85605000E-03	-7.66750000E-07	1.51040000E-10	-1.13900000E-14
-7.12440000E-01	7.34065000E-03	-5.52620000E-06	1.51400000E-09	-2.38200000E-14
3.04369000E+00	6.11870000E-04	-7.39900000E-09	-2.03000000E-11	2.45900000E-15
2.84680500E+00	4.19320000E-03	-9.61190000E-06	9.51230000E-09	-3.30900000E-12
2.85457600E+00	1.59760000E-03	-6.25660000E-07	1.13160000E-10	-7.69000000E-15
3.69161500E+00	-1.33330000E-03	2.65031000E-06	-9.76900000E-10	-9.97700000E-14
3.59761300E+00	7.81456000E-04	-2.23870000E-07	4.24900000E-11	-3.34600000E-15
3.71899500E+00	-2.51670000E-03	8.58374000E-06	-8.29990000E-09	2.70820000E-12

XFW

1.000E+00	H	0	5.2098E+04
2.000E+00	H2	0	0.
1.500E+01	CH3	0	3.3491E+04
1.600E+01	CH4	0	-1.7889E+04
2.600E+01	C2H2	0	5.4194E+04
2.800E+01	C2H4	0	1.2496E+04
3.000E+01	C2H6	0	-2.0317E+04
7.800E+01	C6H6	0	1.9779E+04
2.800E+01	N2	0	0.
1.400E+01	N	0	1.1302E+05
1.700E+01	NH3	0	-1.1040E+04
3.000E+01	NO	0	2.1600E+04
4.600E+01	NO2	0	8.0075E+03
6.200E+01	NO3	0	8.0075E+03
4.400E+01	N2O	0	1.9490E+04
2.700E+01	HCN	0	3.1189E+04
1.600E+01	O	0	5.9557E+04
3.200E+01	O2	0	0.
4.800E+01	O3	0	5.2098E+04

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                    1.8000E+01           H2O     0      -5.7798E+04
                    1.7000E+01            OH     0       9.3125E+03
                    4.4000E+01           CO2     0      -9.4052E+04
                    2.8000E+01            CO     0      -2.6416E+04
                    1.2000E+01             C     1       0.


        COMPOSITION OF GASES PRODUCED BY NPYR PYROLYSIS REACTIONS


          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          1.0400E-01       1.0400E-01      1.0400E-01      1.0400E-01      1.0400E-01      1.0400E-01      1.0400E-01
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          9.2000E-02       9.2000E-02      9.2000E-02      9.2000E-02      9.2000E-02      9.2000E-02      9.2000E-02
          6.0000E-03       6.0000E-03      6.0000E-03      6.0000E-03      6.0000E-03      6.0000E-03      6.0000E-03
          4.2400E-01       4.2400E-01      4.2400E-01      4.2400E-01      4.2400E-01      4.2400E-01      4.2400E-01
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          0.              -0.             -0.             -0.             -0.             -0.             -0.
          1.7600E-01       1.7600E-01      1.7600E-01      1.7600E-01      1.7600E-01      1.7600E-01      1.7600E-01
          1.9800E-01       1.9800E-01      1.9800E-01      1.9800E-01      1.9800E-01      1.9800E-01      1.9800E-01
          0.              -0.             -0.             -0.             -0.             -0.             -0.
```

AA

46

0.	1.00000E+00	0.	0.			
2.50000E+00	0.	0.	0.	0.	2.54705E+04	-4.60010E-01
2.50000E+00	0.	0.	0.	0.	2.54705E+04	-4.60010E-01
0.	2.00000E+00	0.	0.			
3.04369E+00	6.11870E-04	-7.39900E-09	-2.03000E-11	2.45900E-15	-8.54910E+02	-1.64800E+00
2.84609E+00	4.19320E-03	-9.61190E-06	9.51230E-09	-3.30900E-12	-9.67254E+02	-1.41180E+00
1.00000E+00	3.00000E+00	0.	0.			
2.80277E+00	6.25045E-03	-2.28920E-06	3.89930E-10	-2.52800E-14	1.57875E+04	5.68412E+00
3.39551E+00	4.26783E-03	2.03327E-07	-1.15480E-09	4.12880E-13	1.56498E+04	2.70375E+00
1.00000E+00	4.00000E+00	0.	0.			
1.18000E+00	1.09500E-02	-4.06200E-06	7.13700E-10	-4.74900E-14	-9.85560E+03	1.25060E+01
4.24577E+00	-6.91270E-03	3.16020E-05	-2.97150E-08	9.51030E-12	-1.01866E+04	-9.17550E-01
2.00000E+00	2.00000E+00	0.	0.			
4.49660E+00	5.26980E-03	-1.84000E-06	3.10540E-10	-2.00000E-14	2.56370E+04	-3.14481E+00
7.90333E-01	2.34660E-02	-3.55420E-05	2.79510E-08	-8.44800E-12	2.62550E+04	1.40050E+01
2.00000E+00	4.00000E+00	0.	0.			
3.50230E+00	1.15900E-02	-4.47450E-06	7.94500E-10	-5.32300E-14	4.54390E+03	2.46670E+00
1.12024E+00	1.39060E-02	2.65680E-06	-1.15600E-08	5.23870E-12	5.33289E+03	1.58378E+01
2.00000E+00	6.00000E+00	0.	0.			
6.39154E+00	-0.	-0.	-0.	-0.	-1.21017E+04	-0.
6.39154E+00	-0.	-0.	-0.	-0.	-1.21017E+04	-0.
6.00000E+00	6.00000E+00	0.	0.			
7.54906E+00	-0.	-0.	-0.	-0.	7.29743E+03	-0.
7.54906E+00	-0.	-0.	-0.	-0.	7.29743E+03	-0.
0.	0.	2.00000E+00	0.			
2.85458E+00	1.59760E-03	-6.25660E-07	1.13160E-10	-7.69000E-15	-8.90174E+02	6.39029E+00
3.69161E+00	-1.33330E-03	2.65031E-06	-9.76900E-10	-9.97700E-14	-1.06283E+03	2.28750E+00
0.	0.	1.00000E+00	0.			
2.44223E+00	1.22761E-04	-8.49920E-08	2.14010E-11	-1.25100E-15	5.61488E+04	4.49257E+00
2.51479E+00	-1.12430E-04	2.96475E-07	-3.24600E-10	1.25950E-13	5.61278E+04	4.11930E+00
0.	3.00000E+00	1.00000E+00	0.			
2.14940E+00	6.49285E-03	-2.26550E-06	3.73940E-10	-2.36100E-14	-6.40196E+03	9.23891E+00
3.77162E+00	-4.86210E-04	9.87420E-06	-9.56790E-09	3.13130E-12	-6.72810E+03	1.46540E+00
0.	0.	1.00000E+00	1.00000E+00			
3.15294E+00	1.46000E-03	-5.76780E-07	1.06280E-10	-7.37200E-15	9.85221E+03	6.94465E+00
4.14695E+00	-4.11970E-03	9.69224E-06	-7.86340E-09	2.23100E-12	9.74479E+03	2.56943E+00
0.	0.	1.00000E+00	2.00000E+00			
4.61293E+00	2.63866E-03	-1.09490E-06	2.08180E-10	-1.46500E-14	2.34038E+03	1.36764E+00
3.43446E+00	2.22343E-03	6.71490E-06	-9.74280E-09	3.72130E-12	2.85477E+03	8.40846E+00
0.	0.	1.00000E+00	3.00000E+00			
4.62655E+00	3.02168E-03	-1.21560E-06	2.28560E-10	-1.58500E-14	8.13566E+03	-1.14636E+00
2.38212E+00	1.03505E-02	-1.11670E-05	6.95832E-09	-1.87800E-12	8.72300E+03	1.02270E+02
0.	0.	2.00000E+00	1.00000E+00			
4.62655E+00	3.02168E-03	-1.21560E-06	2.28560E-10	-1.58500E-14	8.13566E+03	-1.14636E+00
2.38212E+00	1.03505E-02	-1.11670E-05	6.95832E-09	-1.87800E-12	8.72300E+03	1.02270E+02

```
 1.00000E+00   1.00000E+00   1.00000E+00   0.
 3.65380E+00   3.44363E-03  -1.25850E-06   2.16920E-10  -1.43000E-14   1.44218E+04   2.37260E+00
 2.16812E+00   1.07290E-02  -1.50880E-05   1.19330E-08  -3.70000E-12   1.46829E+04   9.28102E+00
 0.            0.            0.            1.00000E+00
 2.53726E+00  -1.84220E-05  -8.80180E-09   5.96430E-12  -5.57400E-16   2.92300E+04   4.94679E+00
 3.02189E+00  -2.17370E-03   3.75422E-06  -2.99470E-09   9.07770E-13   2.91372E+04   2.64601E+00
 0.            0.            0.            2.00000E+00
 3.59761E+00   7.81456E-04  -2.23870E-07   4.24900E-11  -3.34600E-15  -1.19279E+03   0.
 3.71900E+00  -2.51670E-03   8.58374E-06  -8.29990E-09   2.70820E-12  -1.05767E+03   0.
 0.            0.            0.            3.00000E+00
 2.53726E+00  -1.84220E-05  -8.80180E-09   5.96430E-12  -5.57400E-16   2.92300E+04   4.94679E+00
 3.02189E+00  -2.17370E-03   3.75422E-06  -2.99470E-09   9.07770E-13   2.91372E+04   2.64601E+00
 0.            2.00000E+00   0.            1.00000E+00
 2.67075E+00   3.03170E-03  -8.53500E-07   1.17900E-10  -6.19700E-15  -2.98890E+04   6.88383E+00
 4.15650E+00  -1.72440E-03   5.69820E-06  -4.59300E-09   1.42340E-12  -3.02888E+04  -6.86160E-01
 0.            1.00000E+00   0.            1.00000E+00
 2.88555E+00   9.98350E-04  -2.18800E-07   1.98030E-11  -3.84500E-16   3.88118E+03   5.55970E+00
 3.82347E+00  -1.11870E-03   1.24668E-06  -2.10300E-10  -5.25400E-14   3.58528E+03   5.82530E-01
 1.00000E+00   0.            0.            2.00000E+00
 4.41290E+00   3.19230E-03  -1.29800E-06   2.41500E-10  -1.67400E-14  -4.89440E+04  -7.28760E-01
 2.17010E+00   1.03780E-02  -1.07340E-05   6.34592E-09  -1.62800E-12  -4.83526E+04   1.06644E+01
 1.00000E+00   0.            0.            1.00000E+00
 2.95120E+00   1.55260E-03  -6.19110E-07   1.13500E-10  -7.78800E-15  -1.42320E+04   6.53140E+00
 3.78713E+00  -2.17100E-03   5.07573E-06  -3.47380E-09   7.72170E-13  -1.43635E+04   2.63355E+00
 1.00000E+00   0.            0.            0.
 1.36325E+00   1.85605E-03  -7.66750E-07   1.51040E-10  -1.13900E-14  -6.49670E+02  -7.98900E+00
-7.12440E-01   7.34065E-03  -5.52620E-06   1.51400E-09  -2.38200E-14  -6.80533E+01   2.79326E+00
LAST DATA CARD READ
```

TABULAR LIST OF SELECTED DATA FROM TAPE1

CP TABLE SPECIFIC HEAT OF CHAR

TEMPERATURE	CP
7.20000000E+02	2.50400000E-01
1.08000000E+03	2.99100000E-01
1.44000000E+03	3.47800000E-01
1.80000000E+03	3.96500000E-01

2.16000000E+03	4.45200000E-01
2.52000000E+03	4.93900000E-01
2.57400000E+03	5.01200000E-01
7.00000000E+03	5.00000000E-01

CPP TABLE SPECIFIC HEAT OF UNCHARRED MATERIAL

TEMPERATURE	CPP
0.	3.00000000E-01

CPBAR TABLE SPECIFIC HEAT OF GASEOUS PRODUCTS OF PYROLYSIS

TEMPERATURE	CPBAR
1.00000000E+03	1.00000000E+03
2.00000000E+03	2.00000000E+03

CK TABLE THERMAL CONDUCTIVITY OF CHAR

TEMPERATURE	CK
5.00000000E+02	1.40000000E-05
1.00000000E+03	1.40000000E-05
1.50000000E+03	3.88000000E-05
2.00000000E+03	8.13000000E-05
2.50000000E+03	1.17000000E-04
3.00000000E+03	1.67000000E-04
3.50000000E+03	2.00000000E-04
4.00000000E+03	2.00000000E-04

CKP TABLE THERMAL CONDUCTIVITY OF UNCHARRED MATERIAL

TEMPERATURE	CKP
5.00000000E+02	1.40000000E-05
1.00000000E+03	1.40000000E-05
1.50000000E+03	3.88000000E-05

HW TABLE LOCAL ENTHALPY OF FLUID AT WALL

TEMPERATURE	HW
5.00000000E+02	-1.00000000E+01
1.00000000E+03	1.11000000E+02
1.50000000E+03	2.39000000E+02
2.00000000E+03	3.75000000E+02
2.50000000E+03	5.17000000E+02
3.00000000E+03	6.65000000E+02
3.50000000E+03	8.18000000E+02
4.00000000E+03	9.80000000E+02
4.50000000E+03	1.17300000E+03
5.00000000E+03	1.38400000E+03
5.50000000E+03	1.70000000E+03
6.00000000E+03	2.06000000E+03
6.50000000E+03	2.55000000E+03
7.00000000E+03	3.00000000E+03

TB TABLE TEMPERATURE TO WHICH BACK SURFACE RADIATES

TIME	TB
0.	0.

HE TABLE LOCAL ENTHALPY EXTERNAL TO BOUNDARY LAYER

TIME	HE
0.	1.922000C0E+C4

HC TABLE HEAT OF SUBLIMATION OF CHAR

TIME	HC
2.0CCC00000E+03	1.20000C00E+04

QC TABLE CONVECTIVE HEATING RATE

TIME	QC
0.	3.650000C0E+C0
1.00000000E+01	7.500000C0E+C0
2.0CC000C0E+01	1.680000C0E+01
3.000000C0E+01	4.C50C00C0E+C1
4.0CCC00000E+01	9.610000C0E+01
5.0CC000C0E+01	1.927C00C0E+02
6.000000000E+01	3.177000C0E+02
7.0CC000C0E+01	4.385000C0E+02
8.000000000E+01	4.901C0000E+C2
9.CCCC0CC0E+01	4.344C0000E+02
1.0C0C00C0E+02	3.337000C0E+02
1.1CCCC0C0E+02	2.618000C0E+02
1.2CCC00C0E+02	1.698C0000E+C2
1.300000000E+02	1.397000C0E+C2
1.4CC000C0E+02	1.163000C0E+02
1.5C0000000E+02	9.790000C0E+C1
1.[illegible]CCC000E+02	8.310000C0E+01
1.700000000E+02	7.130000000E+C1
1.8CC000000E+02	6.150000C0E+C1
1.9CCC00000E+02	5.330000000E+01
2.000000C0E+02	4.720000C0E+01
2.1CC000000E+02	4.220000000E+C1
2.200000000E+02	3.820000000E+01
2.3CC000000E+02	3.490000000E+01
2.4CCCC0C0E+02	3.210000000E+01
2.500000C0E+02	2.950C0C0C0E+01
2.6CCCCC C0E+02	2.710000C0E+01
2.700000000E+02	2.460000C0E+01
2.8CC000000E+02	2.180000C0E+01
2.900000000E+02	1.870000000E+01
3.0C000000E+02	1.540000000E+C1
3.1C0C00C0E+02	1.220000C0E+01
3.2CCCCC0C0E+02	9.200000C0E+C0
3.3CCCC0C0E+02	6.700000C0E+00
3.4CCCC0C0E+02	4.700000C0E+00
3.5CCCC000E+02	3.300000C0E+CC
3.600000000E+02	2.200000C0E+C0
3.7C0C00C0E+02	2.200C0C0E+00
3.8C0CC0C0E+02	1.400000C0E+C0
3.9C0CCC0CE+02	1.000000C0E+00
4.0CCC00000E+02	6.000000C0E-C1

4.1C000000E+02	4.00000000E-01
4.2CC000C0E+02	3.00000000E-01
4.3CCC00C0E+02	2.000000C0E-01
4.4CCC0000E+02	1.5C000000E-01
4.5CCC0000E+02	1.C00000C0E-01
4.6CCOC000E+02	8.000J0000E-02
4.7CCCCCC0E+02	6.00000C00E-02
4.8CCCC000E+02	5.000C000CE-02
4.900C0000E+02	4.00000000E-02
5.00C00000E+02	3.00000000E-02
5.10000000E+02	3.000C0000E-02
5.20C00000E+02	3.000000C0E-02
5.3CC00000E+02	2.0000C000E-02
5.40C00000E+02	2.000000C0E-02
5.50000C0CE+02	2.000000C0E-02
5.60C00000E+C2	2.00000000E-02
5.7CCC00C0E+02	2.00000000E-02
5.8CCC0000E+02	2.000000C0E-02
5.9CC00000E+02	1.C0000000E-02
6.C0C00000E+02	1.00000000E-02
6.1CC00000E+C2	1.00000000E-03
1.30C00000E+03	1.00000000E-03
2.000000C0E+03	1.00000000E-03

QR TABLE RADIANT HEATING RATE

TIME	QR
0.	5.C0000000E-02

P-RATIO TABLE

TIME	PRAT
0.	1.00000000E+00

Q-RATIO TABLE

TIME	QRAT
0.	1.00000000E+00

PRESSURE TABLE

TIME	PRESSURE
0.	3.88300000E-03
5.C0C00000E+00	7.94500000E-03

ALPHA TABLE ABSORPTIVITY OF CHAR SURFACE

TIME	ALPHA
0.	1.19900000E+00

ALPHA1 TABLE

TIME	ALPHA1
0.	5.00000000E-01

ALPHA2 TABLE

TIME	ALPHA2

0.	1.00000000E+00

MCDOT TABLE RATE OF CHAR LOSS-OPTICA 2

TIME	MCDOT
0.	0.

X TABLE CHAR THICKNESS-CPTION 3

TIME	X
0.	C.

DELTAU TABLE

TIME	DELTAU
0.	7.8125000CE-03
6.0C000000E+00	1.5625C00CE-02
1.00C00000E+01	6.25000C00E-02
4.00C00000E+02	1.00000000E+00

HCOMB TABLE PRESSURE

	1.00000000E-01	1.00000000E+00	1.00000000E+01	1.00000000E+02
TEMPERATURE				
1.8GCC0000E+03	4.13000000E+03	4.11000000E+03	4.11000000E+03	4.11000000E+03
2.7CC00C0E+03	4.26600000E+03	4.266C0000E+03	4.26600000E+03	4.26600000E+03
3.6C000000E+03	4.45400000E+03	4.44400000E+03	4.44600000E+03	4.44500000E+03
4.5CCC0000E+03	4.87100000E+03	4.65700000E+03	4.65600000E+03	4.64300000E+03
5.4000000E+03	6.26500000E+03	5.24500000E+03	4.98400000E+03	4.88400000E+03
6.3000000E+03	1.02200000E+04	6.99500000E+03	5.67900000E+03	5.24500000E+03
7.2CCC0000E+03	1.35400000E+04	1.30500000E+04	7.13400000E+03	5.86900000E+03

XDP	=1.6250J0E-01	PO	= 0.0000	ROP	= 0.0000	RODP = 5.5000
BETA	= 0.0000	ETA	= .6000	REFF	= 1.00000000	COEF = 2.02400000E+01
TC	= 0.	DELHP	= 0.	DELHF	= 0.	EPSONE = 7.50000000E-01
EIPJ	= 0.	EIJM	= 0.	CIPJ	= 0.	CIJM = 0.
AEXP	= 1.0000000CE+10	BEXP	= 7.65000000E+04	APEXP	= 1.28000000E+05	BPEXP = 1.96000000E+04
ORDER	= 1.0	CE	= 2.32000000E-01	ELAM	= 0.	HCOMB = 0.
ABEXP	= 0.	BBEXP	= 0.	IOPT	= 1	IOPT1 = 1
I	= 26	J	= 25	M	= 0	ERROR = 1.00000000E-03

L DISTANCES

2.0CCCCCC0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.CC0000C0E-02	2.000000C0E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.0C0CC0C0E-02	2.000000C0E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.C0000000E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.00000000E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.000000C0E-02	2.000000C0E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.000000C0E-02	2.000000C0E-02	2.000000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.0C0CCC0E-02	2.000000C0E-02	2.0C0000C0E-02	2.00000000E-02	2.00000000E-02	2.00000000E-02	
2.CC0000C0E-02	2.000000C0E-02					
6.CC6000E-01	7.8540C0E-01	1.016400E+01	8.002500E-01	1.361250E+00	6.088500E+00	1.320000E+01
6.CC6000E-01	7.8540C0E-01	1.016400E+01	8.002500E-01	1.361250E+00	6.088500E+00	1.320000E+01
6.CC6000E-01	7.8540C0E-01	1.016400E+01	8.002500E-01	1.361250E+00	6.088500E+00	1.320000E+01

6.CC6000E-01	7.854000E-01	1.016400E+01	8.002500E-01	1.361250E+00	6.088500E+00	1.320000E+01

ORIGINAL PAGE IS
OF POOR QUALITY

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6.006000E-01    7.854000E-01    1.016400E+01    8.002300E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
6.006000E-01    7.854000E-01    1.016400E+01    8.002500E-01    1.361250E+00    6.088500E+00    1.320000E+01
```

**********BEGINNING OF OUTPUT**********

TAU= .007813 DELTAU= .00781250

T	WMPDOT	RHOC	RHO						
543.84	0.	.0000	.6006	.7854	10.1640	.8002	1.3612	6.0885	13.2000
540.01	0.	.0000	.6006	.7854	10.1640	.8002	1.3612	6.0885	13.2000
540.00

```
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.               .0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
     540.00     0.              0.0000      .6006      .7854     10.1640       .8002       1.3612       6.0885      13.2000
Z(N)       3.18800000E-01  3.02100000E-01  2.77100000E-01  2.52100000E-01  1.62500000E-01
T(ZN)      5.40000000E+02  5.40000000E+02  5.40000000E+02  5.40000000E+02  5.40000000E+02
T(1) =     543.8417        T(I) =     540.0000        TIJ  =     540.0000        TIJM =    540.0000
MCDOT=  0.00000000         MPDOT=  0.00000000         DELWF=  0.00000000         MSDOT=  0.00000000       SQ. RT. PRESSURE=   .00388935
X     =  1.00000000E-01    XP    =  6.46660000E-02    WFSUM=  0.
HW    =  6.09896671E-01    HC    =  1.20000000E+04    TNBAR=  1.00000000E+03
TB    =  0.                HE    =  1.52200000E+04    QC    =  3.65300781E+00    QR    =  5.00000000E-02    QAERO=  3.71284189E+00
QCOMB=  0.                 QRR   =  3.06747745E-02    MSCDOT=  0.                RATIO=            IIIII    XTOTAL=  1.97599200E+00
DELZ=  0.
      OVERALL MASS FLUX=    0.0000
      AVERAGE MOLECULAR WEIGHT OF GAS=     0.000


WPDOTS= 0.              WCGDOT=-7.17383055E+57   ALPHA2= 1.00000000E+00
ENTHALPY
    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01
    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01
    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01    3.000000E-01
    3.000000E-01    3.000000E-01
```

	ENTHALPY	MOLE FRACTION	RATE(I)	FLUXMA(I)
H	0.	-4.04315003-174	0.	0.
H2	0.	-2.49845402+134	0.	0.
CH3	0.	-2.49844370+134	0.	0.
CH4	0.	-8.50176095E-43	0.	0.
C2H2	0.	1.26808035+285	0.	0.
C2H4	0.	-1.94908099-106	0.	0.
C2H6	0.	-2.74706376+146	0.	0.
C6H6	0.	-3.29010697-185	0.	0.
N2	0.	-2.74708317+146	0.	0.
N	0.	-1.09589647-193	0.	0.
NH3	0.	3.24321747-232	0.	0.
NO	0.	2.69113142-275	0.	0.
NO2	0.	-5.96603428E-13	0.	0.
NO3	0.	-3.00714764-126	0.	0.
N2O	0.	2.69113403-275	0.	0.
HCN	0.	-4.51166854E-13	0.	0.
O	0.	-4.04315003-174	0.	0.
O2	0.	-2.04336369+134	0.	0.
O3	0.	-1.52793455E-10	0.	0.
H2O	0.	2.68972372-275	0.	0.
OH	0.	-4.04315003-174	0.	0.
CO2	0.	-2.49845756+134	0.	0.
CO	0.	-8.50171421E-43	0.	0.
C	0.	1.26808035+285	0.	0.

WDEP							
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.						

NUMBER OF ITERATIONS FOR THIS STEP= 2

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TAU=   80.023437          DELTAU=   .06250000

        T            WWPDOT          RHOC        RHO
     5400.83     8.97449E-03      23.5441      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
     4223.34     8.97449E-03      14.9110      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
     3228.37     8.97449E-03       8.2934      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
     2343.84     8.97449E-03       8.2500      0.0000       .0000       .0000      0.0000       .0000      0.0000      0.0000
     1571.65     8.97449E-03       5.3569       .0000       .4309      8.5280       .0000       .4665      2.1449       .0000
     1121.94     5.09598E-04        .1563       .4719       .7839     10.1633       .3084      1.3597      6.0881     13.1996
      861.43     1.33289E-05        .0033       .6004       .7854     10.1640       .7871      1.3612      6.0885     13.2000
      714.61     3.82676E-07        .0001       .6006       .7854     10.1640       .7998      1.3612      6.0885     13.2000
      633.92     3.03069E-08        .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      590.10     6.65554E-09        .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      566.46     2.64672E-09        .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      553.78     1.27446E-09        .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      547.04     5.30883E-10        .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      543.52     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      541.71     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.81     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.37     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.17     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.07     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.03     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.01     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
      540.00     0.                 .0000       .6006       .7854     10.1640       .8002      1.3612      6.0885     13.2000
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         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                  .0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
         540.00     0.                 0.0000        .6006        .7854     10.1640       .8002      1.3612      6.0885      13.2000
Z(N)        3.18800000E-01  3.02100000E-01  2.77100000E-01  2.52100000E-01  1.62500000E-01
T(ZN)       4.36400392E+05  3.55649196E+05  2.50232008E+05  1.63361385E+05  4.36835016E+03
T(1) =    5400.8299         T(I) =     540.0000        TIJ  =     540.0000          TIJN =     540.0000
MCDOT=   0.00000000         MPDOT=    .00697449        DELWF=  0.00000000           MSDOT=  0.00000000     SQ. RT. PRESSURE=   .06889404
X    =   1.00000000E-01     XP    =  6.46660000E-02    WFSUM=  0.
HW   =   1.63826924E+03     HC    =  1.20000000E+04    TNBAR=  1.00000000E+03
To   =   0.                 HE    =  1.92200000E+04    QC   =  4.89969453E+02     QR    =  5.00000000E-02    QAERO=  3.83204383E+02
QCOMB=   0.                 QRR   =  3.07192361E+02    MSCDOT=  0.                RATIO=              IIIII   XTOTAL=  1.97599200E+00
DELZ=    5.40678511E-02
      OVERALL MASS FLUX=      .0025
      AVERAGE MOLECULAR WEIGHT CF GAS=    11.114


WPDOTS= 5.07345556E-03   WCGDOT= 6.905867 62E-04   ALPHA2= 1.25986034E+00
ENTHALPY
    4.268209E+03     3.259259E+03     2.635369E+02    -6.125521E+01    -6.473156E+02    -7.985335E+02    -7.967937E+02    -5.208392E+02
    0.               3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01
    3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01
    3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01
    3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-01     3.000000E-C1     3.000000E-01     3.000000E-01
    3.000000E-01
```

	ENTHALPY	MOLE FRACTION	RATE(I)	FLUXMA(I)
H	6.55167622E+04	1.26069100E-01	3.58530818E-09	2.80981567E-05
H2	2.12119228E+04	4.35523593E-01	2.55530005E-09	2.03053298E-04
CH3	7.62926574E+04	1.26045476E-01	-8.90722989E-08	4.21393371E-04
CH4	3.68731127E+04	-4.58874129E-30	-1.89153469E-32	-1.63637461E-32
C2H2	1.02562314E+05	9.37210378E-07	4.34795414E-09	5.43099764E-09
C2H4	8.03747344E+04	-9.58831941E-07	-4.34795414E-09	-5.98369849E-09
C2H6	1.40651662E+04	1.08C39508E-05	4.45361495E-08	7.22392170E-08
C6H6	5.95131621E+04	-1.41226698E-27	-6.45096458E-30	-2.45516444E-29
N2	2.21619877E+04	-6.06488226E-28	-3.89143880E-31	-1.78485794E-30
N	1.26446287E+05	5.73032989E-47	1.27232958E-49	1.78803838E-49
NH3	3.03448182E+04	8.41901607E-27	2.67817916E-30	1.18991740E-29
NO	4.47905178E+04	-3.60304515E-27	-1.00000000E-30	-2.40912945E-29
NO2	4.3135714JE+04	1.C3949172E-27	2.26919900E-30	1.08623696E-29
NO3	5.67C347c3E+04	-1.05949172E-27	-2.26919900E-30	-1.46405852E-29
N2O	5.67C34743E+04	-6.08718148E-57	-1.07422231E-59	-5.96950203E-59
HCN	6.66C2J143E+04	-3.60299447E-27	-9.99891398E-31	-2.16818601E-29
O	7.30730365E+04	1.0C671046E-26	4.76919900E-30	3.58999415E-29
O2	2.34541744E+04	1.37443122E-52	5.76475804E-57	9.80262002E-55
O3	7.30730365E+04	3.695d6275E-67	8.17391376E-70	3.94320699E-69
H2O	-2.74669672E+04	-1.80152250E-27	-4.99999715E-31	-7.22738805E-30
OH	3.07176979E+04	-7.272604d2E-35	-2.85271104E-37	-2.75554868E-37
CO2	-5.75009034E+04	-3.51994438E-27	-2.33827662E-30	-3.45189562E-29
CO	-4.053223e9E+03	2.92351049E-01	3.67655323E-30	1.92444958E-03
C	1.47025432E+04	0.	3.71649107E-29	0.

%DEP

4.928362E-04	3.230302E-03	5.921402E-05	2.472234E-09	2.069195E-14	9.680931E-20	2.622437E-24	7.044432E-28
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.							

NUMBER OF ITERATIONS FOR THIS STEP= 1

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3. April, Gary C.; Pike, Ralph W.; DeValle, Edwardo G.: Modeling Reacing Gas Flow in the Char Layer of an Ablator. AIAA Journal, vol. 9, no. 6, 1971.

4. Stroud, C. W.; and Brinkley, Kay L.: Chemical Equilibrium of Ablation Materials Including Condensed Species. NASA TN D-5391, 1969.

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TABLE I

DEFINITION OF SYMBOLS

The following table contains definitions of important symbols used in the program. The first section is in alphabetical order by physical symbol. The second section contains those items requiring definition but not assigned a physical symbol. The latter section is in alphabetical order by FORTRAN symbol.

SECTION I

Physical Symbol	Number	FORTRAN Symbol	Definition
A	10	AEXP	Pre-exponential factor of Arrhenius expression for calculating MCDØT. Corresponds to specific reaction rate.
A'	20	AP	Pre-exponential factors of Arrhenius expression for calculating pyrolysis rate of each pyrolysis reaction.
B	40	BEXP	Power of the exponential term in the Arrhenius expression for MCDØT. Corresponds to activation energy divided by the gas constant. Calculates K in equation (15) as follows: $K = AEXPe^{-BEXP/T(1)}$ Also used for oxidation calculation.
B'	50	BP	Pre-exponential factors of Arrhenius expression for calculating pyrolysis rate of each pyrolysis reaction.
C	80	--	Concentrations of a specie in the pyrolysis gas.
C_e	90	CE	Oxygen concentration in the external flow.
C_p	91	CPTAB	Specific heat of char as a function of temperature.

Physical Symbol	Number	FORTRAN Symbol	Definition
C_{p_N}'	100	CPPT1 CPPT2 -- CPPT7	Specific heat of each specie in ablation material as a function of temperature
C_p''	110	CPDPTB	Specific heat of insulation layer as a function of temperature
$\overline{C}_p$	120	CPBAR	Enthalpy of pyrolysis gas as a function of temperature.
C_{i+j}	130	CIPJ	Concentrated heat sink at back of ablation material
C_{i+j+m}	140	CIJM	Concentrated heat sink at back of insulation layer
ΔE	150	--	Activation energy. Appears in computer program only in the form $\Delta E/R$
F	160	F1	Constant heat generation function per unit volume
G	180	$(PC\emptyset EFF)^2$	The constant used in the hypersonic pressure term. See equation (9) in reference 1.
H_c	190	HCTAB	Latent heat of process which removes material from the front surface as a function of temperature and pressure
H_e	200	HETAB	Enthalpy of the gas stream external to the boundary layer. Zero point in table should correspond to temperature on which cold wall heating rate is based.
H_w	210	HWTAB	Enthalpy of gas stream at the surface temperature. Zero point in table should correspond to temperature on which cold wall heating rate is based.
Δh_p	220	DDELHP	Heat of pyrolysis for each reacting specie.

Physical Symbol	Number	FORTRAN Symbol	Definition
Δh_c	230	HCØMBTB	Heat of combustion of char as a function of temperature and pressure.
Δh_f	240	DELHF	Heat absorbed by coolant behind third layer.
i	241	I	Number of stations in first layer ($I \geq 26$ is recommended)
j	242	J	Number of stations in second layer ($J \geq 25$ is recommended)
k	250	CKTAB	Thermal conductivity of char as a function of temperature
k'	260	CKNPTB	Thermal conductivity of virgin ablation material as a function of temperature
k''	270	CKNDPT	Thermal conductivity of insulation material as a function of temperature and location
l	280	AL	Non-dimensional distance between stations $\sum_{n=1}^{i+j-1} AL_n = 1.0$. If AL(1) = 0. then AL(n) are all equal to $AL(n) = \frac{1.0}{i+j-1}$
M	290	XFW	Molecular weight of each reacting specie in pyrolysis gas
m	300	M	Number of stations in the insulation layer ($M \geq 10$ is recommended)
$\dot{m}_c$	310	WCCDØT	Surface mass loss rate by combustion
$\dot{m}_p$	320	WPDØT	Local mass flow rate of pyrolysis products
n	330	XØRDER	Order of oxidation reaction. Use value of 0.5 or 1.0

Physical Symbol	Number	FORTRAN Symbol	Definition
N	340	NG	Number of chemically reacting species in pyrolysis gas
$\lambda N_{Le}^{0.6}$	350	ELAMTB	Product of Lewis number to the 0.6 power and λ where λ is the weight of char removed from the outer surface per unit weight of oxygen diffusing to the surface
P_w	360	$(EXPRESS)^2$	Pressure at the wall as a function of time
q_{aero}	380	QAERØ	Net aerodynamic heating rate to the surface after correction for hot wall and blocking
q_c	390	QCTAB	Reference convective heating rate. Stagnation values usually used as reference. (QRATT specifies ratio of local to reference heating rate.)
q_r	400	QRTAB	Reference radiant heating rate. Absorptance, ALPHAT, is altered to account for ratio of local to reference heating rate.
q_s	410	QSTAB	Stagnation heating rate
R	420	RR R	Gas constant or Maximum radius of ablating body. Required when IØPT=5.
R_j	430	RATE	Effective reaction rate for gas or solid species in pyrolysis gas reaction
T	460	T	The initial temperatures of the finite difference stations. Stations are numbered from the front surface.
T_B	470	TBTAB	Temperature as a function of time to which back surface is radiating

Physical Symbol	Number	FORTRAN Symbol	Definition
T_{i+j}	480	TIPJ	Back surface temperature at which coolant becomes active (TNSTØP=0.) When TNSTØP =1, program stops when back surface temperature reaches TNBAR.
T_{i+j+m}			Same as T_{i+j} when there is another material behind ablator
t_o	490	TAUØ	Starting time
t_f	500	ENDTAU	Stop time if TNSTØP = 0. If TNSTØP is 1, set ENDTAU very large and program stops when back surface temperature reaches TNBAR
U	510	--	Velocity of pyrolysis gas
V	520	V1	Surface recession velocity
ΔW_f	530	DELWF	Coolant consumption rate back surface
x	540	X	Thickness of the char layer
x'	550	XP	Thickness of the virgin ablation material
x''	560	XDP	Thickness of the insulation layer
y	570	--	Coordinate normal to the surface
Z	580	Z	Location of fixed stations measured from the back surface
α	590	ALPHA	Name assigned internally to absorptance of the surface. Value of ALPHA is obtained by program from table entitled ALPHAT
α_c	600	AL1	Name assigned internally to factor used to correct blocking effectiveness of mass loss from outer surface for molecular weight effects and/or turbulent flow. Values of AL1 obtained by program from table entitled AL1TAB.

Physical Symbol	Number	FORTRAN Symbol	Definition
α_p	610	AL2	Name assigned internally to factor used to correct blocking effectiveness of pyrolysis gas due to molecular weight effects and/or turbulent flow. Calculated automatically when pyrolysis gas reactions kinetics are treated in detail (ICPBAR = 2)
β	620	BETA	Determine if ablation or transpiration theory will be used. If ablation theory, BETA = 1; if transpiration theory, BETA = 0. In the former case, a transpiration factor ETA must be specified
γ_1, γ_2	621	--	Approximate geometric coefficients
ε_1	630	EPSØNE	Emittance of the heated surface
ε_{i+j}	640	EIPJ	Emittance of back surface when no insulation layer is present
ε_{i+j+m}	650	EIJM	Emittance of back surface when an insulation layer is present
η	660	ETA	Transpiration factor. A value of 0.6 is frequently used for laminar flow. A value of .2 is used for turbulent flow.
μ	--	--	Viscosity of gas flowing through char
ρ	665	RHØ	Density of solids that undergo pyrolysis at each finite difference station
ρ_c	670	RHØC	Density of char at each finite difference station
ρ''	680	RØDP	Density of insulation
Δt	690	DELTAU	Time step obtained from table entitled TAUTAB by zero order interpolation
ψ_{bl}	700	PHIETB	Parameter equal to $\frac{M_{bl}\kappa}{2RT\mu}$

Physical Symbol	Number	FORTRAN Symbol	Definition
ψ_p	710	PHIPTB	Parameter equal to $\frac{M_p \kappa}{2RT\mu}$

SECTION II

FORTRAN SYMBOLS

FORTRAN SYMBOL	NUMBER	Definition
AA	720	Gram atoms of element J in specie I. This two-dimensional array defines the chemical formula of the individual species. For example, if the order of the elements are assigned as follows: J = 1 Carbon J = 2 Hydrogen J = 3 Oxygen J = 4 Nitrogen Then, for this 4 element system (mm = 4) if the specie methane (CH_4) is designated specie number 1. AA (1, 1) = 1.0 AA (1, 2) = 4.0 AA (1, 3) = 0. AA (1, 4) = 0. The resulting array for the species H, H_2, CH_4, N_2, NH_3, NO, H_2O and CO is as follows:

	C	H	O	N
CH_4	1.0	4.0	0.	0.
H	0.	1.	0.	0.
H_2	0.	2.	0.	0.
NH_3	0.	3.	0.	1.
NO	0.	0.	1.	1.
H_2O	0.	2.	1.	0.
CO	1.	0.	1.	0.

ABEXP	722	Pre-exponential factor for computing surface mass loss rate by sublimation
ABUT	724	Initial value of the square root of pressure

FORTRAN SYMBOL	NUMBER	Definition
ACØEF	726	Negative blocking coefficients when boundary layer flow through porous char is considered
AEF	728	Activation energy of the forward reaction of pyrolysis gas kinetics
AER	730	Activation energy of the reverse reaction of pyrolysis gas kinetics
AF	732	Frequency factor of the foreward reaction of pyrolysis gas kinetics
AI,BI,CI, DI,EI,FI,	733	Empirical constants for the enthalpy of the chemical specie of the pyrolysis gas above 1000 K by the equation AI*T+BI*T**2/(2*1.987) + CI*T**3/(3*1.987) + DI*T**4/(4*1.987) + EI*T**5/(5*1.987) + 1.987*FI
AII,BII, CII,DII, EII, FII	734	Empirical constants for the enthalpy of the chemical specie of the pyrolysis gas below 1000 K as shown in AI, BI, CI, DI, EI, FI
AR	745	Frequency factor of the reversed reaction of pyrolysis gas kinetics
A11--A55	746	Empirical constants of heat capacity of elements below 1000 K.
BBEXP	750	Power of the exponential term for computing surface mass loss rate by sublimation
CHANGE	760	A computing time saving device. Chemical reaction rates are not calculated until T(1) has changed more than CHANGE
CMASSF	770	The mass fraction of the original material that is carbon
CØN	780	Normalyzing constant for flow through porous media
CSØLID	790	The mass fraction of a pyrolysis specie that is converted to char upon pyrolyzing
DELH	810	Enthalpy of formation at 298.15 K
DELWFØ	820	Initial coolant flow rate

FORTRAN SYMBOL	NUMBER	Definition
DUM1TB	821	Blank table (not used)
EQN	840	Alphanumeric input of pyrolysis chemical reaction equation, for example, the reaction $CH_4 = C + 2H_2$ would be input as CH4 = C + 2H2
ERRØR	850	The test of T(1) for convergence from one iteration to the next. Convergence is assumed to have occurred when $\frac{T(1) - T(1)'}{T(1)} \leq$ ERRØR Where T(1) is from the previous iteration
FREØ	851	Cyclic printing interval
IDEBUG	853	When this input is greater than zero, extra printing will be done each iteration to aid debugging
IØPT	854	Initial option for computing surface recession. There are 5 options available. These may be selected by assigning values to IØPT of 1, 2, 3,4, or 5. When a value of 1 is assigned, surface recession is removed by (1) an exponential function of temperature or (2) by oxidation. Both forms are achieved by determining values for AEXP and BEXP. When a value of 2 is assigned, the mass loss rate is computed as a function of time from table WCDØTT.If NCDØT is a negative number, the table WCDØTT can be used to compute surface recession as a function of surface temperature. When a value of 3 is assigned, the thickness of the ablator is specified as a function of time in XTAB. When a value of 4 is assigned, surface removal is by sublimation and IØPT1=1. When a value of 5 is assigned, the surface recession is computed taking into account internal flow through porous media. (See ref. 9.) If option 5 (IØPT=5) is not used, the following inputs are not required: GAM1TB, GAM2TB, XRTAB, PHIPTB, PHIETB, MXR, NXR, TTBPHI, MPHI, NPHI, PERM, R, CON, and ACØEF.

FORTRAN SYMBOL	NUMBER	Definition
IØPT1	855	Option for computing sublimation IØPT1 = 1 for sublimation at the outer surface
ICPBAR	857	Option for simplified treatment of pyrolysis gas kinetics. ICPBAR = 1. Enthalpy of pyrolysis gas must be supplied in CPBTAB
ICØDE	858	Phase identification of pyrolysis gas components ICØDE = 0 - specie is a gas ICØDE = 1 - specie is a solid
IPRINT	860	Option for printing contents of NAMELIST entitled NAME1. When no value is input or when IPRINT = 0, NAME1 is printed.
KTXDP	870	Option for variable density and conductivity of the third layer KTXDP = 0 Density constant and equal to RØDP(1) KTXDP ≠ 0. RØDP and CKNDPT are input as a function of position
MALPHA	880	Order of interpolation for ALPHA table
MALPH1	890	Order of interpolation for AL1 table
MALPH2	900	Order of interpolation for AL2 table
MAXIT	910	Maximum number of interations performed before time step reduced to one-half current value
MCDØT	920	Order of interpolation in WCDØT table
MCKNDP	930	Order of interpolation in KDP table
MCKNP	940	Order of interpolation in KP table
MCP	950	Order of interpolation for CP table
MCPBAR	960	Order of interpolation for CPBAR table
MCPDP	970	Order of interpolation for CPDP table
MCP1	980	Order of interpolation in CPPT1 table
MCP2	981	Order of interpolation in CPPT2 table
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MCP7	987	Order of interpolation in CPPT7 table
MDUM1	990	Order of interpolation for DUM1 table

FORTRAN SYMBOL	NUMBER	Definition
MHC	1000	Order of interpolation in HCTAB table
MHE	1010	Order of interpolation in HETAB table
MHW	1020	Order of interpolation in HW table
MK	1030	Order of interpolation in K table
MM	1040	Number of elements in pyrolysis gas species
MPHI	1050	Order of interpolation in PHIETB table
MPRAT	1060	Order of interpolation in PRATT table
MQC	1070	Order of interpolation in QC table
MQR	1071	Order of interpolation in QR table
MQRAT	1072	Order of interpolation in QRATT table
MQS	1080	Order of interpolation in QS table
MSMIN	1090	Minimum value of sublimation for which sublimation program STAT1 is used to decrease computing time when sublimation is occuring
MTAU	1100	Order of interpolation in TAUTAB table
MTB	1110	Order of interpolation in TB table
MX	1120	Order of interpolation in X table
MXPRES	1130	Order of interpolation in XPRESS table
MXR	1140	Order of interpolation in XRTAB table
NALPHA	1150	Number of entries in TALPHA and ALPHAT
NALPH1	1160	Number of entries in TTAL1 and AL1TAB
NALPH2	1170	Number of entries in TTAL2 and AL2TAB
NCCDØT	1180	Number of entries in TTMCDT and WCDØTT. Negative value required by program logic
NCDØT	1190	Number of entries in TTMBCT and NCDØTT
NCKNDP	1210	Number of entries in TCKNP and CKNDPT

FORTRAN SYMBOL	NUMBER	Definition
NCKNP	1220	Number of entries in TTCKNP and CKNPTB
NCP	1230	Number of entries in TTABCP and CPTAB
NCPBAR	1240	Number of entries in TTBCPB and CPBTAB
NCPDP	1250	Number of entries in TTCPDP and CPDPTB
NCP1	1260	Number of entries in T1CPP and CPPT1
NCP2	1261	Number of entries in T2CPP and CPPT2
---	--	-
NCP7	1267	Number of entries in T7CPP and CPPT7
NDUM1	1270	Number of entries in vacant table
NEQ	1280	Number of chemical reactions in pyrolysis gas kinetics
NHC	1300	Number of entries in TTABHC and HCTAB
NHCØMB	1310	Number of entries in TTHCØMB and HCØMBTB
NPHCØMB	1311	Number of entries in PHCØMB
NHE	1320	Number of entries in TTABHE and HETAB
NHW	1330	Number of entries in TTABHW and HWTAB
NK	1340	Number of entries in TTABK and CKTAB
NPEX	1350	Power to which the concentration of the products is raised in pyrolysis gas kinetics reactions
NPHI	1360	Number of entries in TTBPHI, PHIPTB and PHIETB
NPYR	1370	Number of pyrolysis reactions
NPRAT	1380	Number of entries in TTPRAT and PRATT
NQC	1400	Number of entries in TTABQC and QCTAB
NQR	1410	Number of entries in TTABQR and QRTAB
NQRAT	1420	Number of entries in TTQRAT and QRATT
NQS	1430	Number of entries in TTABQS and QSTAB
NREX	1440	Power to which concentrations of reactants is raised in pyrolysis gas kinetics reactions

FORTRAN SYMBOL	NUMBER	Definition
NS	1390	Number of solids in kinetic equations of pyrolysis gas
NTAU	1450	Number of entries in TTAU and TAUTAB
NTB	1460	Number of entries in TTABTB and TBTAB
NTOPT	1470	New surface recession option changed to at TØPT
NUMZ	1480	Number of Z values used
NX	1490	Number of entries in TTABX and XTAB
NXØPT	1500	New surface recession option changed to at XØPT
NXPRES	1510	Number of entries in TTXPRE and XPREST
NXR	1520	Number of entries in XRTAB, GAM1TB and GAM2TB
ØRDER	1530	Order of pyrolysis reaction $m_p = (\rho)^{ORDER}(AP) \exp(-BP/T)$
PELAM	1550	Pressure in ELAM table
PERM	1551	Permeability of char
PHCØMB	1560	Pressures in HCØMBTB
PRATT	1570	The ratio of the local pressure to the stagnation pressure
PREHE	1580	Option for using punched input from program ØPTUM (PREHE = 1.)
PSC	1581	Stoichiometric coefficients of the products of pyrolysis gas kinetics equations. This array in conjunction with RSC (Stoichiometric coefficients of the reactants) and SNAME (specie identification and ordering) define the chemical reactants as they are used in calculation. The equations are written symbolically as:

FORTRAN SYMBOL	NUMBER	Definition

$$[RSC]\begin{bmatrix}S\\N\\A\\M\\E\end{bmatrix} = [PSC]\begin{bmatrix}S\\N\\A\\M\\E\end{bmatrix}$$

to use a simple example, if a system of only 4 species are considered: H, H_2, CH_4 and C
The equations

$$CH_4 \rightleftharpoons C + 2\,H_2$$

$$H_2 \rightleftharpoons 2H$$

are written as:

$$\begin{bmatrix}0 & 0 & 1 & 0\\ 0 & 1 & 0 & 0\end{bmatrix}\begin{bmatrix}H\\H_2\\CH_4\\C\end{bmatrix} = \begin{bmatrix}0 & 2 & 0 & 1\\ 2 & 0 & 0 & 0\end{bmatrix}\begin{bmatrix}H\\H_2\\CH_4\\C\end{bmatrix}$$

P5	1585	Pressure table for HCTAB
QRATT	1620	The ratio of local convective heating rate to stagnation convective heating rate. If QRATT set to zero, the pressure is computed using QS from QSTAB as follows: P_w = RHOF*PCØEF*PRAT*QS/HE
QSTAB	1625	Stagnation heating rate table used to obtain hypersonic pressure when QRATT=0.
R	1630	Maximum radius of ablating body. Required only when flow through porous media effects are considered (IØPT = 1)
REFF	1700	Effective nose radius
RHØZ	1640	Initial density of each component of material that will pyrolyze
RØDP	1641	Density of insulation layer
RSC	1650	Stoichiometric coefficients of the reactants of pyrolysis gas kinetics equations. See explanation of PSC

FORTRAN SYMBOL	NUMBER	Definition
SF	1660	Power on the temperature in the forward rate constant in pyrolysis gas reaction
SNAME	1670	Alphanumeric input of specie names in pyrolysis gas kinetics. See explanation of PSC
SR	1680	Power on the temperature in the reversed rate constants in pyrolysis gas reactions
S1--S5	1690	Empirical constants for heat capacity of elements below 1000 K
TALPHA	1710	Temperature table corresponding to values in ALPHAT
TAUØ	1720	Starting time
TAUTAB	1730	Table of time steps
TBTAB	1740	Temperature to which back surface is radiating
TCHAN	1750	Temperature change required before pyrolysis gas composition is recomputed
TCKNDP	1760	Temperature table for CKNDPT
TNBAR	1770	Back surface temperature at which coolant becomes active (TNSTØP = 0). When TNSTØP = 1, TNBAR is back surface temperature at which program will stop
TNSTØP	1780	Controls point at which computation stops. If TNSTØP =0, program stops at ENDTAU. If TNSTØP = 1, program stops when back surface temperature reaches TNBAR
TØPT	1790	Time at which surface removal option may be changed using NTØPT
TTABCP	1800	Temperature table for CPTAB
TTABHE	1810	Time table for HETAB
TTABHC	1820	Temperature table for HCTAB
TTABHW	1830	Temperature table for HWTAB
TTABK	1840	Temperature table for CKTAB
TTABQC	1850	Time table for QCTAB

FORTRAN SYMBOL	NUMBER	Definition
TTABQR	1860	Time table for QRTAB
TTABQS	1870	Time table for QSTAB
TTABTB	1880	Time table for TBTAB
TTABX	1900	Time table for XTAB
TTAL1	1910	Time table for AL1TAB
TTAB2	1920	Time table for AL2TAB
TTAU	1930	Time table for TAUTAB
TTBCPB	1940	Temperature table for CPPTAB
T1CPP	1950	Temperature table for CPPT1
T2CPP	1951	Temperature table for CPPT2
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T7CPP	1957	Temperature table for CPPT7
TTBPH1	1960	Temperature table for PHIPTB and PHIETB
TTCPDP	1970	Temperature table for CKNDPT
TTCKNP	1980	Temperature table for CKNPTB
TTDUM1	1990	Blank table
TTELAM	2000	Temperature table for ELAMTB
TTHCØMB	2010	Temperature table for HCØMBTB
TTMCDT	2020	Time table for WCDØTT
TTPRAT	2030	Time table for PRATT
TTQRAT	2040	Time table for QRATT
TTXPRE	2050	Time table for XPREST
TZ	2060	Temperature at fixed locations (Z)
WCCDØØ	2070	Initial value of WCCDØT
WCDØTØ	2080	Initial value of WCDØT

FORTRAN SYMBOL	NUMBER	Definition
WCDØTT	2090	Table used with option 2
WCSDØØ	2100	Initial value of WCSDØT
WCSDØT	2101	Surface mass loss rate by sublimation
WPDØTØ	2110	Initial value of WPDØT
WPSUM	2120	Total mass flow past a given point (one value for each station)
XFW	2141	Molecular weight of each specie in pyrolysis gas
XMIN	2150	X<XMIN, program stops
XØPT	2160	Thickness of X at which surface removal option will change using NXØPT
XØRDER	2170	Order of oxidation reaction
XPMIN	2180	XP<XPMIN, program stops
XPREST	2190	Square root of the total stream pressure in atmospheres, when considering subsonic or supersonic flow. Set to zero for computed pressure
XRTAB	2200	Table to input radius of curvature as a function of time when option 5 is used.
XTAB	2210	Table to input char thickness as a function of time when option 3 is used
YDEL	2220	Stefan Boltzmann constant in appropriate units.
YI	2230	The mole fraction of gas species produced by each pyrolyzable component
Z	2240	Location of fixed stations measured from back surface

TABLE II

This table contains a list of input and output FORTRAN variables in the order they appear in the I/O lists. Instructions for use of library subroutines related to I/O are included in Appendix A. All tables use subroutine FTLUP for table look-up unless otherwise noted below under comments.

The following inputs are entered by namelist entitled NAME1:

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(10) T	460	T	I+J+M	Used to initialize temperature distribution
(20) Z	580	y-yo	NUMZ	
(30) TZ	2060	T	NUMZ	Used to initialize temperatures at fixed locations within solid (e.g. thermocouple locations)
(40) MCP	950	NA	1	
(50) NCP	1230	NA	1	Table to input specific
(60) TTABCP	1800	T	NCP	heat of char
(70) CPTAB	91	C_p	NCP	
(80) MCP1	980	NA	1	
(81) MCP2	981	NA	1	
-----	--	--	-	
(86) MCP7	986	NA	1	
(90) NCP1	1260	NA	1	
(91) NCP2	1261	NA	1	Table to input specific heat of each componert in the virgin state
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(96) NCP7	1266	NA	1	
(100) T1CPP	1950	T	NCP1	
(101) T2CPP	1951	T	NCP2	
---	--	--	-	
(106) T7CPP	1956	T	NCP7	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(110) CPPT1	100	C_p'	NCP1	
(111) CPPT2	101	$C_{p'}$	NCP2	
---	--	-	-	
(116) CPPT7	106	$C_{p'}$	NCP7	
(120) MCPDP	970	NA	1	
(130) NCPDP	1250	NA	1	Table to input specific
(140) TTCPDP	1970	T	NCPDP	heat of insulation layer
(150) CPDPTB	110	C_p''	NCPDP	
(160) MCPBAR	960	NA	1	
(170) NCPBAR	1240	NA	1	Table to input enthalpy of pyrolysis gas as a function of temp. when kinetic treatment of pyrolysis gas is not calculated internally. This table not required when pyrolysis gas kinetics are treated in detail (ICPBAR≠1)
(180) TTBCPB	1940	T	NCPBAR	
(190) CPBTAB	120	$\bar{C}_p$	NCPBAR	
(200) MK	1030	NA	1	
(210) NK	1340	NA	1	Table to input thermal conductivity of char as a function of temperature.
(220) TTABK	1840	T	NK	
(230) CKTAB	250	k	NK	
(240) MCKNP	940	NA	1	
(250) NCKNP	1220	NA	1	Table to input composite thermal conductivity of virgin material as a function of temperature
(260) TTCKNP	1980	T	NCKNP	
(270) CKNPTB	260	k'	NCKNP	
(280 MCKNDP	930	NA	1	Table to input thermal conductivity of insulation layer as a function of temperature and position
(290) NCKNDP	1210	NA	1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(300) TCKNDP	1760	T	NCKNDP	
(310) CKNDPT	270	k''	NCKNDP	
(320) MHW	1020	NA	1	Table to input enthalpy of external gas stream at the surface temperature as a function of temperature
(330) NHW	1330	NA	1	
(340) TTABHW	1830	T	NHW	
(350) HWTAB	210	H_w	NHW	
(360) MALPHA	880	NA	1	Table to input absorptivity
(370) NALPHA	1150	NA	1	of the surface as a function of temperature
(380) TALPHA	1710	T	NALPHA	
(390) ALPHAT	590	α_T	NALPHA	
(400) MALPH1	890	NA	1	Table to input blocking factor of surface reaction products as a function of time
(410) NALPH1	1160	NA	1	
(420) TTAL1	1910	T	NALPH1	
(430) AL1TAB	600	c	NALPH1	
(440) MALPH2	900	NA	1	Table to input blocking factor of pyrolysis reaction products as a function of time
(450) NALPH2	1170	NA	1	
(460) TTAL2	1920	T	NALPH2	
(470) AL2TAB	610	α_p	NALPH2	
(480) MHE	1010	NA	1	Table to input enthalpy of gas external to boundary layer as a function of time
(490) NHE	1320	NA	1	
(500) TTABHE	1810	t	NHE	
(510) HETAB	200	H_e	NHE	
(520) MQC	1070	NA	1	Table to input convective heating rate as a function of time
(530) NQC	1400	NA	1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(540) TTABQC	1850	t	NQC	
(550) QCTAB	390	q_c	NQC	
(560) MQR	1071	NA	1	Table to input radiant heating rate to the surface as a function of time
(570) NQR	1410	NA	1	
(580) TTABQR	1860	t	NQR	
(590) QRTAB	400	q_r	NQR	
(600) MCDØT	920		1	Table of surface recession rate as a function of time when option 2 is used & NCCDØT is greater than or equal to zero. When NCCDØT is less than zero, this table is used to input surface recession as a function of surface temperature.
(610) NCDØT	1190		1	
(620) TTMCDT	2020	t, T_s	NCDØT	
(630) WCDØTT	2090	m_c	NCDØT	
(640) MX	1120	NA	1	Table to input char thickness as a function of time when option 3 is used
(650) NX	1490	NA	1	
(660) TTABX	1900	t	NX	
(670) XTAB	2210	X	NX	
(680) MDUM1	990		1	
(690) NDUM1	1270		1	Table for expansion (not used)
(700) TTDUM1	1990		NDUM1	
(710) DUM1TB	821		NDUM1	
(720) MQS	1080	NA	1	Table of stagnation heating rate as a function time
(730) NQS	1430	NA	1	
(740) TTABQS	1870	T	NQS	
(750) QSTAB	410	q_s	NQS	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(760) F1	160	F	1	
(770) RO	--			Calculated internally
(780) ROP	--			Calculated internally
(790) RODP	680	ρ''	1	can have 10 values which are specified for 10 equally spaced thicknesses of insulation numbered from the back surface of the ablator. Either one value or 10 values required.
(800) DELHF	240	ΔH_f	1	
(810) DELHP	--	ΔH_p	1	Calculated internally
(820) EIPJ	640	ε_{i+j}	1	
(830) CIPJ	130	C_{i+j}	1	
(840) EIJM	650	ε_{j+m}	1	
(850) CIJM	140	C_{i+j+m}	1	
(860) BETA	620	β	1	
(870) ETA	660	η	1	
(880) EPSONE	630	ε_1	1	
(890) TNSTØP	1780	NA	1	
(900) X	540	X	1	
(910) MHC	1000	NA	0	Not used for input.
(920) NHC	1300	NA	0	
(930) TTABHC	1820	T	5	A value of 5 is assigned internally. Not used for input.
(935) P5	1585		5	A value of 5 is assigned internally. Not used for input.

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(940) HCTAB	190	Hc	25	Not used for input. A value of 25 is assigned internally. Table to input latent heat of surface removal process as a function of temperature and pressure. Uses subroutine DISCOT for table look-up.
(950) MTB	1110	NA	1	Table to input temperature to which back surface is radiating as a function of time
(960) NTB	1460	NA	1	
(970) TTABTB	1880	t	NTB	
(980) TBTAB	470	T_B	NTB	
(990) XP	550	X'	1	
(1000) XDP	560	X''	1	
(1010) TNBAR	1770	T_{i+j} or T_{i+j+m}	1	
(1020) I	241	i	1	
(1030) J	242	j	1	
(1040) M	300	m	1	
(1050) TAUØ	490	t_o	1	
(1060) WCDØTØ	2080		1	
(1070) WPDØTØ	2110		1	
(1080) DELWFØ	820		1	
(1090) FREØ	851		1	
(1100) ENDTAU	500	t_f	1	
(1110) XØPT	2160		1	
(1120) IØPT	854		1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(1130) NXØPT	1500		1	
(1140) XMIN	2150		1	
(1150) XPMIN	2180		1	
(1160) NUMZ	1480		1	
(1170) TØPT	1790		1	
(1180) NTØPT	1470		1	
(1190) AEXP	10		1	
(1200) BEXP	40		1	
(1210) APEXP			0	Do not use
(1220) BPEXP			0	Do not use
(1230) XØRDER	330		1	
(1240) CE	90	C_e	1	
(1250) ELAM	--		0	Do not use
(1260) HCØMB	--		1	Do not use
(1270) REFF	1700			
(1280) PCØEF	180	$\sqrt{G}$	1	square root of constant in hypersonic pressure term A value of 7.5 in SI units and 20.27 in English units is recommended.
(1290) MPRAT	1060	NA	1	Table to input ratio of local pressure to stagnation pressure as a function of time
(1300) NPRAT	1380	NA	1	
(1310) TTPRAT	2030	t	NPRAT	
(1320) PRATT	1570	P/P_s	NPRAT	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(1330) MXPRES	1130	NA	1	Table to input square root of the total stream pressure as a function of time
(1340) NXPRES	1510	NA	1	
(1350) TTXPRE	2050	t	NXPRES	
(1360) XPREST	2190	$\sqrt{P'_s}$	NXPRES	
(1370) MQRAT	1072	NA	1	Table to input the ratio of local laminar to stagnation convective heating as a function of time
(1380) NQRAT	1420	NA	1	
(1390) TTQRAT	2040	t	NQRAT	
(1400) QRATT	1620	q/q_s	NQRAT	
(1410) WCSDØØ	2100		1	
(1420) WCCDØØ	2070		1	
(1430) AL	280	1	1	
(1440) MTAU	1100		0	Make no entry
(1450) NTAU	1450	NA	1	Table to input time step as a function of time with zero order interpolation (time step remains constant at TAUTAB value until time equals or exceeds next TTAU value.) All entries in this table should be powers of 2, e.g. 1/32, 1/16, 1/2, 1, 2, etc.
(1460) TTAU	1930	t	NTAU	
(1470) TAUTAB	1730	Δt	NTAU	
(1480) TCHAN	1750		1	A value of 25 is recommended.
(1490) MAXIT	910		1	A value of 3 is recommended
(1500) ERRØF	850		1	
(1510) IDEBUG	853		1	
(1520) THETA	--		0	Do not use
(1530) ABEXP	722		1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(1535) BBEXP	750		1	
(1540) IØPT1	855		1	
(1550) PREHE	1580		1	
(1560) ABUT	724		1	
(1570) MXR	1140	NA	1	Table to input approximate geometric coefficients as a function of position (see reference 9)
(1580) NXR	1520	NA	1	
(1590) XRTAB	2200	x/r	NXR	
(1600) GAM1TB	621	ξ_1	NXR	Uses (1570), (1580), and (1590) above to input approximate geometric coefficient as a function of position
(1610) GAM2TB	621	ξ_2	NXR	
(1620) NPHI	1360			Table to input parameter as a function of temperature (see reference 9)
(1630) MPHI	1050			
(1640) TTBPHI	1960		NPHI	
(1650) PHIPTB	710	$\frac{M_p \psi}{M}$	NPHI	
(1660) PHIETB	700	ψ	NPHI	Use (1620), (1630), and (1640) above to input parameter as a function of temperature
(1670) PERM	1551	k	1	See reference 9
(1680) R	420			See reference 9
(1690) CØN	780			See reference 9
(1700) ACØEF	726		3	
(1710) YDEL	2220		1	
(1720) ELAMTB	350	λ	40	Table to input $\lambda N_{le}^{0.6}$ as a function of surface temp. and pressure
(1730) TTELAM	2000	T	10	Uses DISCOT for table look-up

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(1740) PELAM	1550	P	4	
(1750) IPRINT	860			
(1760) KTXDP	870			
(1770) ICPBAR	857			
(1780) MSMIN	1090			
(1790)TTHCØMB	2010	T	28	Table to input heat of combustion of the char
(1800)HCØMBTB	841	ΔH_{comb}	7	as a function of temperature and
(1810) PHCØMB	1560	P	4	pressure. Uses DISCOT for table look-up.
(1820) NHCØMB	1310	NA	0	Set internally to a value of 28
(1830) NPHCØMB	1311	NA	0	Set internally to a value of 4
(1840) CMASSF	770		1	
(1850) CHANGE	760		1	
(1860) DDELHP	220	ΔH_p	NPYR	
(1870) CSØLID	790		NPYR	
(1880) RHØZ	1640	ρ_z	NPYR	
(1890) NPYR	1370		1	
(1900) AP	20		NPYR	
(1910) BP	50		NPYR	
(1920) RHØ	665	ρ		
(1930) RHØC	670	ρ_c	I+J	
(1940) ØRDER	1530		NPYR	
(1950) WPSUM	2120	$\dot{m}_p$	I+J	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
THE FOLLOWING INPUTS ARE ENTERED BY INDIVIDUAL FORMAT IN SUBROUTINE INØUT				
(1960) NG	340		1	FØRMAT (4I6)
(1970) NS	1390		1	
(1980) MM	1040		1	
(1990) NEQ	1280		1	
(2000) EQN	840		12	FØRMAT (12A6)
(2010) RSC	1650		Variable	FORMAT (6F4.0) input required for each term in chemical reaction e.g. for the chemical reaction $CH_4 = C_{(s)} + 2H_2$, 1 RSC and 2 PSC are required
(2020) PSC	1581		Variable	
(2030) NREX	1440		Same as PSC	FØRMAT (5I4.0)
(2040) NPEX	1350		Same as PSC	
(2050) AF	732		1	FØRMAT (E8.0,1X,2F6.0)
(2060) SF	1660		1	
(2070) AEF	728		1	
(2080) AR	745		1	FØRMAT (E8.0,1X, 2F6.0)
(2090) SR	1680		1	
(2100) AER	730		1	
REPEAT THE SEQUENCE OF ITEMS 2000 THROUGH 2100 FOR EACH CHEMICAL REACTION				
(2110) S1	1690		1	FØRMAT (7E10.5) One set of inputs for each element in the system (i.e. MM cards)
(2120) S2	1690		1	
(2130) S3	1690		1	
(2140) S4	1690		1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(2150) S5	1690		1	
(2160) A11	746		1	FØRMAT (7E10.5) One set of inputs for each element in the system (i.e. MM cards)
(2170) A22	746		1	
(2180) A33	746		1	
(2190) A44	746		1	
(2200) A55	746		1	
(2210) XFW	290		1	FØRMAT (20X, E10.4, 10X, A6, I6, E15.4) KSPI sets of input
(2220) SNAME	1670		1	
(2230) ICØDE	858		1	
(2240) DELH	810		1	
(2250) YI	2230		NPYR*KSP1	FØRMAT (7E10.4) KSP1 cards with NPYR inputs per card
(2260) AA	720		MM*KSP1	FØRMAT (7E10.5)
(2270) AI	733		1	FØRMAT (7E10.5)
(2280) BI	733		1	
(2290) CI	733		1	
(2300) DI	733		1	
(2310) EI	733		1	
(2320) FI	733		1	
(2330) GI	733		1	
(2340) AII	734		1	FØRMAT (7E10.5)
(2350) BII	734		1	
(2360) CII	734		1	
(2370) DII	734		1	

FORTRAN NAME	ITEM NUMBER IN TABLE I	PHYSICAL SYMBOL	NO. OF INPUTS REQ'D	COMMENTS
(2380) EII	734		1	
(2390) FII	734		1	
(2400) GII	734		1	

THE SEQUENCE OF ITEMS 2260 THROUGH 2400 IS REPEATED KSP1 TIMES

Preliminary Printing Before Computation Begins

Output from NAMELIST entitled NAME1: This list is printed automatically unless IPRINT is different from zero. The list is headed by $NAME1 and contains each entry in NAME1 followed by the actual data contained in the locations reserved for that variable. If all locations reserved are not input, the remaining ones will be filled with zeros. This list is followed by $END.

Title card: The contents of the title card are printed next and followed by the title "INPUT DATA." Some selected tables with titles are printed. These tables are followed by some items that remain constant during computation.

Cyclic Printing

Printing interval: Cyclic printing of values that change with time are printed at intervals of FREØ.

Items printed each cycle: The number of iterations needed to converge during the last time step is printed last. The current time TAU and the last time step DELTAU used in the computation are printed first. These items are followed by 10 columns of numbers. The first column on the left is the temperature of each finite difference station from the surface inward. The second column (WWPDØT) is the mass flow rate of pyrolysis gas past each station. The third column RHØC is the char density at each station. The next seven columns are the local density of each of the solid components that make up the original ablation material (some columns may have all zero entries for a simple material).

These 10 columns are followed by a list of current values of variables that are individually titled.

Additional printing (1) when IDEBUG ≠ 0., there is additional printing that is done to aid debugging. The following items are printed each iteration: TAU, WCDØT, WCCDØT, WCSDØT, WPDØT, X, XP, QCNET, TEMPERATURES of each station during current and previous iterations. (2) When ICPBAR ≠ 1, and the pyrolysis reactions are treated in detail, the following items are printed each interval of FREØ. A group of items dealing with front surface conditions. This group is followed by a list entitled ENTHALPY. This list contains the enthalpy of the pyrolysis gas at each finite difference station where gas flow is large enough to be significant. The next list contains information about each reacting specie in the pyrolysis gas. The final list in this group is entitled WDEP and gives the current rate of deposition of carbon from the gas phase that occurs at each finite-difference station.

TABLE III

ALPHABETICAL LISTING OF FORTRAN SYMBOLS

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
AA		720	2260
AAL			
ABEXP		722	1530
ABIT			
ABUT		724	1560
ACØEF		726	1700
ACØN1			
ACØN4			
ACØN9			
AEF		728	2070
AER		730	2100
AEXP	A	10	1190
AF		732	2050
AI		733	2270
AII		734	2340
AL	1	280	1430
ALAM			
ALPHA	α	590	
ALPHAN			
ALPHAT		590	390
ALPHA1			
ALPHA2			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
AL1TAB	α_c	600	430
AL2TAB	α_p	610	470
AMUT			
AM1			
AP	A'	20	1900
AR		745	2080
ASQ			
APEXP			121
AVGX			
AZ			
AZETA			
A1			
A11		746	2160
A22		746	2170
A33		746	2180
A44		746	2190
A55		746	2200
A2			
B			
BAT			
BB			
BC			
BBEXP		750	1535

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
BETA	β	620	860
BEXP	B	40	1200
BII		734	2350
BLØCK			
BLØCK1			
BN			
BØX			
BP	B'	50	1910
BPEXP			1220
C		80	
CAT			
CC			
CE	Ce	90	1240
CELL			
CELL1			
CHANGE		760	1850
CI		733	2290
CII		734	2360
CIJM	C_{i+j+m}	140	850
CIPJ	C_{i+j}	130	830
CK			
CKDP			
CKNDPT	k''	270	310
CKNPTB	k'	260	270

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FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
CKP			
CKTAB	k	250	230
CMASSF		770	1840
CØLL			
CØN			
CØNST			
CP			
CPBAR			
CPBTAB	$\bar{C}_p$	120	190
CPB1			
CPB2			
CPDP			
CPDT			
CPDT1			
CPDPTB	$C_{p''}$	110	150
CPP			
CPPT1	$C_{p'}$	100	110
CPPT2			

CPPT7			
CPTAB	C_p	91	70
CSØLID		790	1870
CUE			
CZ			
D			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
DABC			
DABUT			
DB2KSQ			
DBLØCK			
DCALL			
DCELL1			
DCOLL			
DC			
DDD			
DDELHP		220	1860
DELH		810	2240
DELHF		240	800
DELHP			810
DELSUM			
DELTAU	$\Delta\tau$	690	
DELWF	Δw_f	530	
DELWFO		820	1080
DELWFS			
DELWF1			
DELY			
DELZ			
DELZA			
DELZB			
DELZBS			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
DELZS			
DHRODZ			
DI		733	2300
DII		734	2370
DIV			
DIV1			
DIV2			
DPDØT			
DSAVE			
DTAU1			
DTAU2			
DTEST			
DTDY			
DTT1			
DUMMY			
DUM1TB		821	710
DWCCDT			
E			
EI		733	2310
EII		734	2380
EIJM	ε_{i+j+m}	650	840
EIPJ	ε_{i+j}		1250
ELAM			
ELAMTB	$\lambda N_{Le}^{0.6}$	350	1720

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
EL1			
EL2			
EL3			
EN			
ENDTAU	τ_f	500	1100
ENT			
ENTH			
EPS			
EPSØNE	ϵ_1	630	880
EQN		840	2000
ERRØR		850	1500
ETA	η	660	870
EXPRESS	$\sqrt{P_w}$	360	
EXTRA			
EYE1			
EYE2			
EYE3			
FI		733	2320
FII		734	2390
FK			
FLUXMA			
FLUXMAP			
FLUXMØ			
FREØ		851	1090

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
FXTAB			
F1	F	160	760
GAMMA1			
GAMMA2			
GAM1TB		621	1600
GAM2TB		621	1610
GENTH			
GI		733	2330
GII		734	2400
HC			
HCØMB			1260
HCØMBTB		841	1800
HCTAB	H_c	190	
HE			
HETAB	H_e	200	510
HØLE			
HW			
HWTAB	H_w	210	350
I	i	241	1020
ICØDE		858	2230
ICPBAR		857	1770
IDEBUG		853	1510
IERRØR			
IFIRST			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
III			
IJM			
IJP1			
IK			
IKINET			
IM1			
INEQ			
INØ			
IØPT		854	1120
IØPT1		855	1540
IPJ			
IPJM1			
IPRINT		860	1750
IP1			
ISQ			
ISQ1			
IT			
ITIME			
ITT			
I1			
J		242	1030
JET			
K			
KEYB1			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
KEYT3			
KFRE			
KN			
KKK			
KSP			
KSP1			
KSP2			
KTXDP		870	1760
KØØFX			
K3			
L			
L1			
LLL			
M	m	300	1040
MALPHA		880	360
MALPHA1		890	400
MALPHA2		900	440
MAT			
MAXIT		910	1490
MCDØT		920	600
MCKNDP		930	280
MCKNP		940	240
MCP		950	40
MCPBAR		960	160

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
MCPDP		970	120
MCPP		980	80
MDUM1		990	680
MHC		1000	910
MHE		1010	480
MHW		1020	320
MK		1030	200
MM		1040	1980
MPHI		1050	1630
MPRAT		1060	1290
MQC		1070	520
MQR		1071	560
MQRAT		1072	1370
MQS		1080	720
MSMIN		1090	1780
MTAU		1100	1440
MTB		1110	
MX		1120	640
MXPRES		1130	1330
MXR		1140	1570
M1			
M1J			
M11			
N			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
NALPHA		1150	370
NALPHA1		1160	410
NALPHA2		1170	450
NCCDØT		1180	
NCDØT		1190	610
NCKNDP		1210	290
NCKNP		1220	250
NCP		1230	50
NCPBAR		1240	170
NCPDP		1250	130
NCP1		1260	90
NCP2		1261	91
----	--	--	-
NCP7		1266	96
NDUM1		1270	690
NEQ		1280	1990
NFRE			
NG	N	340	1960
NHC		1300	920
NHCØMB		1310	1820
NHE		1320	490
NHW		1330	330
NK		1340	210
NLIM			
NMI			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
NN			
NNN			
NPEX		1350	
NPHCØMB		1311	1830
NPHI		1360	1620
NPRAT		1380	1300
NPEX		1350	2040
NPYR		1370	1890
NQC		1400	530
NQR		1410	570
NQRAT		1420	1380
NQS		1430	730
NREX		1440	2030
NS		1390	1970
NTAU		1450	1450
NTB		1460	960
NTI			
NTIM1			
NTIM2			
NTØPT		1470	1180
NTOTAL			
NUMZ		1480	1160
NUMZ1			
NX		1490	650

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
NXØPT		1500	1130
NXPRES		1510	1340
NXR		1520	1580
N1			
ØMØRD			
ØMT			
ØRDER		1530	1940
P			
PART			
PART1			
PART2			
PERCE			
PCØEF	$\sqrt{G}$	180	1280
PELAM		1550	1740
PERM		1551	1670
PHCØMB		1560	1810
PHCTAB			
PHIE			
PHIETB	ψ_{b1}	700	1660
PHIP			
PHIPTB	ψ_{p}	710	1650
POW			
PRAT			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
PRATT		1570	1320
PREHE		1580	1550
PSC	P	1581	2020
P2			
P5	p	1585	935
Q			
QAERØ	q_{aero}	380	
QAERØØ			
QBAR			
QBARØ			
QCNET			
QCTAB	q_c	390	550
QR			
QRAT			
QRATT		1620	1400
QRR			
QRTAB	q_r	400	590
QRZ			
QS			
QSTAB	q_s	410	750
R	R	420	1680
R1			
R2			
RATE	R_j	430	

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
RATIØ			
RC			
RCØN			
REFF		1700	1270
RESID			
RHØ	ρ	665	1920
RHØC	ρ_c	670	1930
RHØCØ			
RHØLD			
RHØZ		1640	1880
RØ			
RØDD			
RØDP	ρ''	680	79ᴄ
RØDRØ			
RØP			780
RØPDP			
RØPDRØ			
RØPE			
RØS			
RØTAB			
RØX			
RR			
RRR			
RSC	γ_{ij}	1650	2010

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
SAVE1			
SAVE2			
SAVE3			
SB			
SC			
SELL			
SF	S	1660	2060
SIG			
SIGMA			
SNAME		1670	2220
SR		1680	2090
STUMP			
SUB			
SUM			
SUMN			
SUMP			
SUMW			
S1		1690	2110
S2		1690	2120
S3		1690	2130
S4		1690	2140
S5		1690	2150
T	T	460	10
TALPHA		1710	380

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
TAU			
TAUØ	t_o	490	1050
TAUØØ			
TAUSQ			
TAUTAB		1730	1470
TAVE			
TB			
TBTAB	T_B	470	980
TEMP			
TCHAN		1750	1480
TCKNDP			
TEST			
TEST1			
TEST3			
TG			
TG2			
THETA			1520
TIPJ	T_{i+j}	480	
TKINET			
TNBAR		1770	1010
TNSTØP		1780	890
TØPT		1790	1170
TP1			
TT			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
TTABCP		1800	60
TTABHC		1820	930
TTABHE		1810	500
TTABHW		1830	340
TTABK		1840	220
TTABQC		1850	540
TTABQR		1860	580
TTABQS		1870	740
TTABTB		1880	970
TTABX		1900	660
TTAL1		1910	420
TTAL2		1920	460
TTAU		1930	1460
TTBCPB		1940	180
T1CPP		1950	100
TTBPH1		1960	1640
TTCKNP		1980	260
TTCPDP		1970	140
TTDUM1		1990	700
TTELAM		2000	1730
TTF			
TTHCØMB		2010	1790
TTMCDT		2020	620
TTPRAT		2030	1310

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
TTQRAT		2040	1390
TTXPRE		2050	1350
TUM			
TWØJ			
TZ		2060	30
TZERØ			
TZERØ1			
TZERØ2			
TZERØ3			
TZERØ4			
TZERØ5			
VV			
V1	V	520	
V2			
W			
WCCDØØ		2070	1420
WCCDØT	$\dot{m}_c$	310	
WCDØT			
WCDØTB			
WCDØTØ		2080	1060
WCDØTT		2090	630
WCGDØT			
WCSDØØ		2100	1410

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
WCSDØT		2101	
WDEP			
WDIF			
WNEW			
WPDØT	$\dot{m}_p$	320	
WPDØTØ		2110	1070
WPDØTS			
WPDØTT			
WPR			
WPSUM		2120	1950
WP1			
WSDØT			
WWPDØT			
X	x	540	900
XCTAB			
XDP	x''	560	1000
XDR			
XFW	M	290	2210
XMAT			
XMIN		2150	1140
XMULTP			
XMULTR			
XNEW			
XØNE			

FORTRAN SYMBOL	PHYSICAL SYMBOL	LOCATION IN TABLE I	LOCATION IN TABLE II
XØNEØ			
XØPT		2160	1110
XØRDER	n	330	1230
XP	x'	550	990
XPMIN		2180	1150
XPRESS			
XPREST		2190	1360
XRTAB		2200	1590
XT			
XTAB		2210	670
XTWØ			
XX			
XXEXP			
Y			
YI			
YCTAB			
YDEL		2220	1710
YI		2230	2250
Z	z	580	20
ZEE			
ZETA			
ZI			
ZTABLE			
Z1			
Z2			

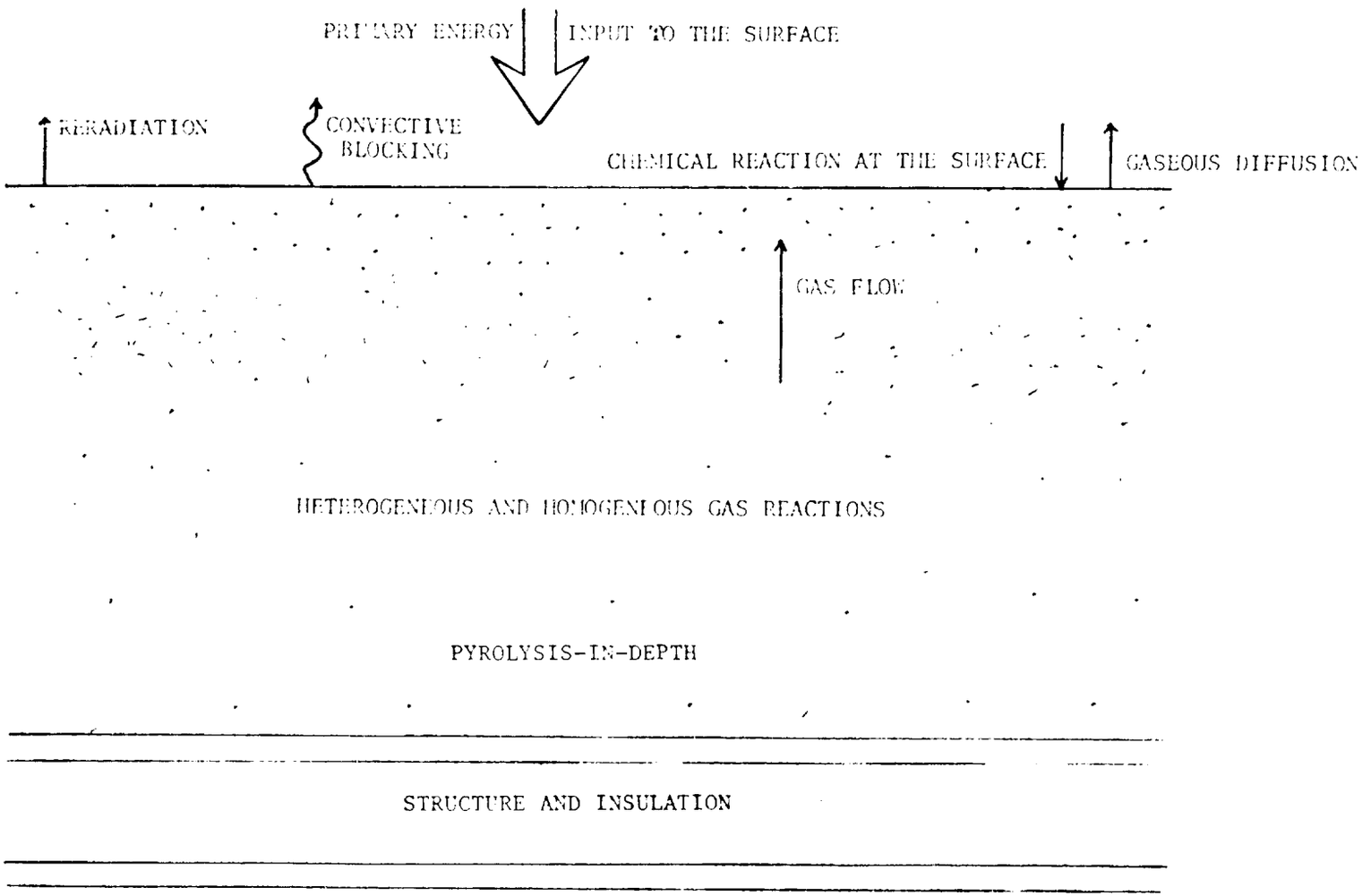

Figure 1. - Schematic of ablation material.

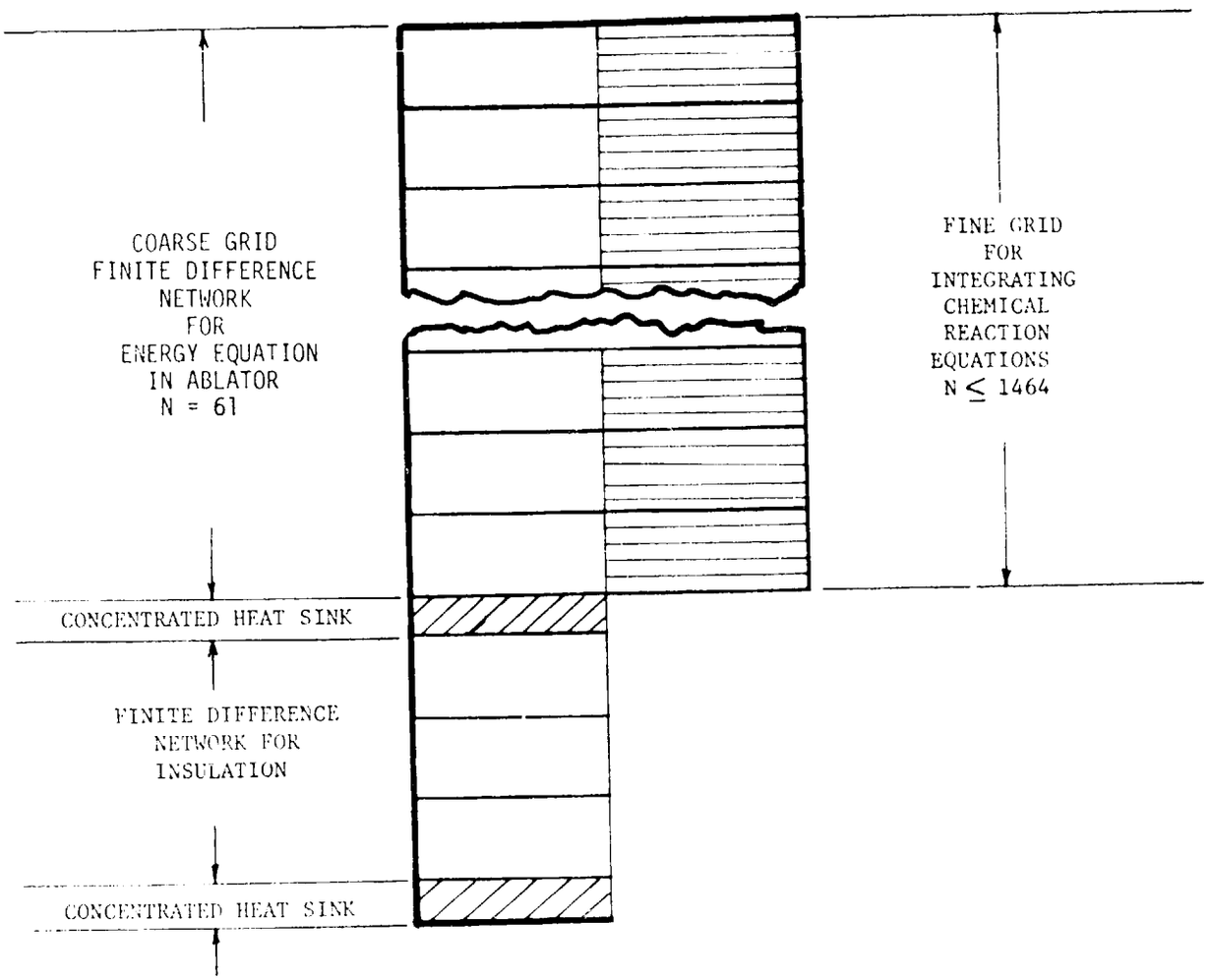

Figure 2.- Schematic of finite difference network.

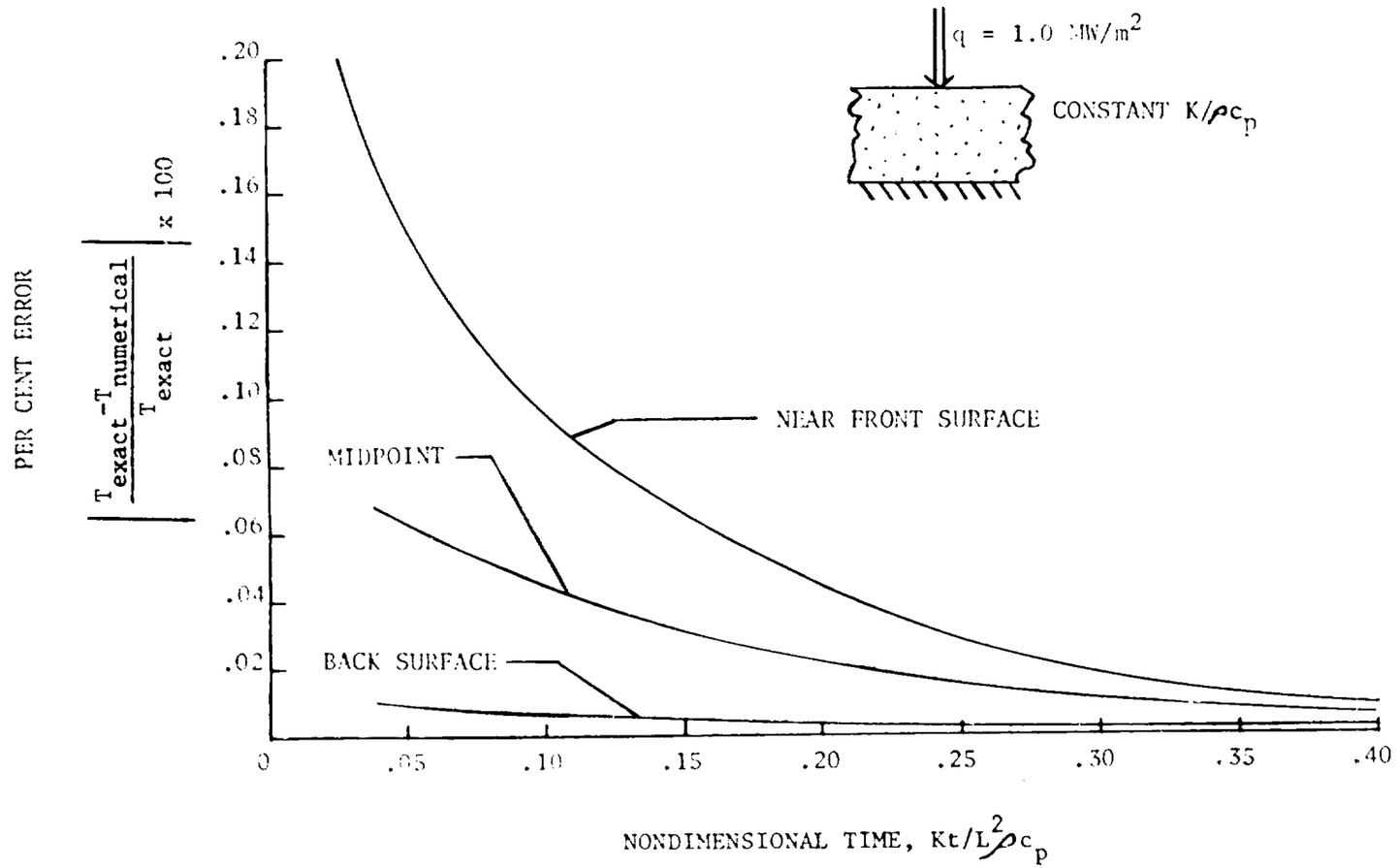

Figure 3.- Comparison of numerical and exact solutions for slab heated at constant rate.

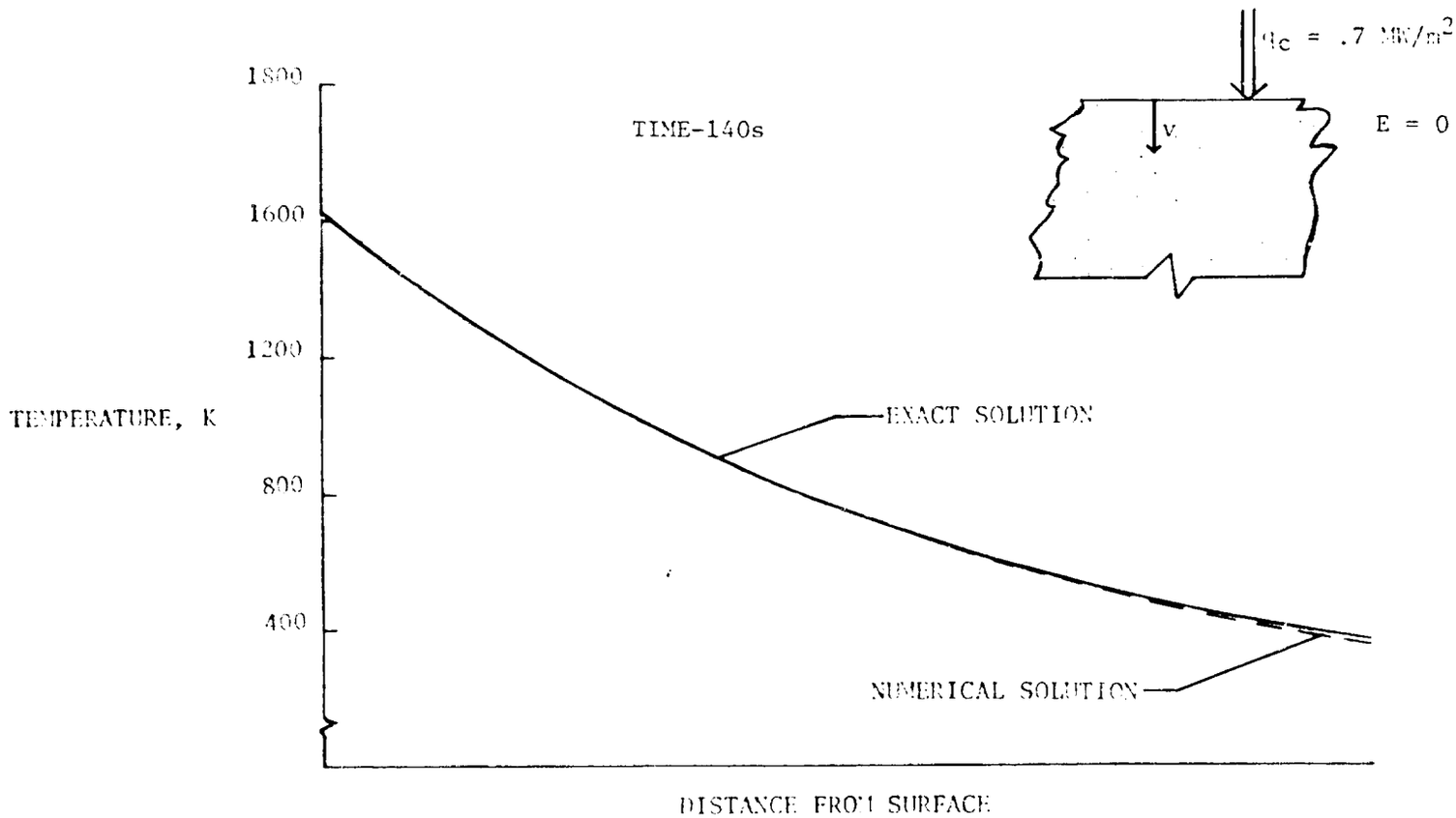

Figure 4.- Comparison of numerical and exact solutions during quasi-steady ablation.