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ABRAC-AN-IBM-704 THREE DIMENSIONAL NUCLEAR-THERMAL DEPLETION PROGRAM WITH DISTRIBUTED VOID EFFECTS

March 1960

CONTRACT AT-11-1-GEN-14

**BETTIS ATOMIC POWER LABORATORY
PITTSBURGH, PENNSYLVANIA**

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DEPLETION PROGRAM WITH DISTRIBUTED VOID EFFECTS

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ABRAC is a three dimensional nuclear-thermal depletion program to study the effects of water moderator density changes, resulting from flow variations and boiling, on neutron flux distribution and depletion. The program requires an IBM-704 with a memory of 32,768 words and ten tape units.

ABRAC - AN IBM-704 THREE DIMENSIONAL NUCLEAR-THERMAL
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W. M. Jacobi, T. J. Lawton, S. H. Meanor and J. R. Parrette

I. INTRODUCTION

ABRAC-01 is an IBM-704 three dimensional program to study the effects of water moderator density changes, resulting from flow variations and boiling, on neutron flux distributions and depletion. Thermal and hydraulic calculations performed within the code, limit its applicability to water cooled and moderated cores, having rectangular coolant channels, and one, upflow, coolant pass. The code was developed as an adjunct to the Bettis Natural Circulation Reactor Study, and special provisions were incorporated to improve the treatment of natural circulation cores; however, the code may be applied to forced circulation designs if they satisfy the restrictions given above.

The calculation may be briefly described as follows:

A water density distribution for the core is assumed, or is taken from a preceding calculation. Using this distribution and the appropriate few-group constants, the diffusion equations are solved in X, Y, Z geometry to obtain a

three-dimensional power distribution for the core. Based upon this power distribution, and a specified power level, a thermal and hydraulic calculation is performed yielding a new water density distribution. This completes one cycle of the nuclear-thermal iteration process. The process is continued (under the requestor's control) until satisfactory agreement between initial and final water density distributions is obtained.

The depletion calculation is then performed in the usual manner. A new nuclear-thermal iteration series can be performed, and the sequence may be repeated throughout the core lifetime.

ABRAC-01 is essentially the program DRACO-1 (Ref 4) to which the thermal and hydraulic calculation is added immediately after the power and flux normalization routine and just prior to the depletion routine.

II. SPATIAL INTEGRATION

The spatial integration routine of ABRAC which was taken directly from DRACO is a modification of TKO (Ref 7). The few-group diffusion equations are solved in X-Y-Z geometry yielding a flux shape and a corresponding power shape.

The following restrictions must be observed:

(a) Variable water density (H_2O) must be carried as a single element number 30. For nonfuel bearing regions or fixed water density, water may also be carried as elements 1 and 2, hydrogen and oxygen.

<u>Element No.</u>	<u>Group</u>	<u>σ_{TR}</u>	<u>σ_f</u>	<u>σ_a</u>
30	1	4.4095	3.1381	.0425
	2	9.1124	4.5145	.0004
	3	16.9331	4.5536	.0284

(b) An axis of symmetry in the X-Y plane must be handled as follows: a rod region is defined for which an extrapolation length would usually be specified by

the relation

$$\frac{D_1}{\phi_1} \frac{\partial \phi_1}{\partial n} = -c, \quad (2.1)$$

we then let $c = 0$, so that $\frac{\partial \phi_1}{\partial n} = 0$ and we have the first interior mesh line as an axis of symmetry. Notice that no mesh points are lost by this procedure.

III. THERMAL AND HYDRAULIC CALCULATIONS

As ABRAC was developed for the analysis of a natural circulation reactor, the thermal and hydraulic calculations are made in a rather complex manner to give adequate solutions for such reactors. While the same solution technique will work with forced circulation designs, the added complexity is probably not required. In particular, natural circulation reactor flow analyses have indicated that use of an "average channel" to determine pressure drops across the core may lead to significant errors, and have also indicated that an assumption of constant total flow regardless of power distribution is poor; these two concepts have been abandoned.

In ABRAC, some portion of the primary coolant loop (including the core) is chosen for flow analysis. Let us say for an example that the region from the core inlet nozzle to the core outlet nozzle is chosen. The assumption is then made that pressure drop for all paths through the core between these two areas is uniform. By use of the "divisions" (described below), it is possible to introduce various resistances external to the core along these paths. The flow through each core "stick" (also described below) is then determined so as to give a uniform overall pressure drop. This uniform overall pressure drop is found for several values of total flow, giving total core flow as a function of pressure drop.

A system characteristic curve (representing the forcing pressure drop available from that portion of the system not included in the ABRAC analysis as a function

of flow) is supplied to the code. At the intersection of these two curves, a total flow solution and ultimately all the individual stick flow solutions are determined.

The calculation procedure is discussed in further detail below.

A thermal stick is formed by any four adjacent DRACO vertical planes, two lying in the X direction; two in the Y direction and bounded in the Z direction by the planes $Z = 0$ and $Z = uu$. A stick is considered only if it encloses fuel and coolant and only the length of the stick between the two horizontal planes which enclose the fuel is considered. A division is defined as an assemblage of adjacent sticks, including nonfuel sticks.

The sticks will be numbered $i = 1, 2, \dots, m$ and the divisions $j = 1, 2, \dots, n$. For any problem, the number of sticks is equal to the number of DRACO mesh cubes per plane.

Each thermal stick is subdivided into rectangular parallelepipeds by the horizontal DRACO planes lying in the fueled region. The DRACO portion of ABRAC calculates a mean normalized power value for each rectangular parallelepiped, which is proportional to the average heat flux. It should be noted that the channel inlet for a stick is considered to be at the first axial mesh rectangle for which the power is not zero. The channel outlet occurs at the next axial mesh rectangle for which the power is zero or at the end of the stick whichever is encountered first.

Using the stick power distributions, the pressure drop routine generates m tables of stick pressure drop versus mass velocity (ΔP_i vs G_i), one for each stick over ranges of mass velocity specified as division dependent input. The method of calculating pressure drop and the correlations used are those customarily applied

to rectangular channel flow. The pressure drop across each stick is calculated as the sum of the entrance and exit pressure drops, the elevation pressure drop, acceleration pressure drop, and the friction pressure drop in the heating, local boiling and bulk boiling regions.

$$\Delta P^i = \Delta P_{in} + \Delta P_{ex} + \Delta P_{acc} + \Delta P_{f_H} + \Delta P_{f_{LB}} + \Delta P_{f_{BB}} \quad (3.2)$$

The calculation of each of these terms is discussed below.

Friction Pressure Drops

Three basic flow regimes are recognized in the channel for pressure drop calculations. They are defined as follows:

1. Bulk boiling regime: if $H(Z) > H_{SAT}$ the channel is in the bulk boiling regime.
2. Local boiling regime: if $T_W > T_{SAT} + \Delta T_{JL}$ and $H(Z) \leq H_{SAT}$ the channel is in the local boiling regime.
3. Heating regime: if $T_W < T_{SAT} + \Delta T_{JL}$ and $H(Z) \leq H_{SAT}$ the channel is in the heating regime.

For pressures less than 1850 psia, the friction pressure drops are calculated in the following manner: (Ref 3)

In the bulk boiling regime,

$$\Delta P_{f_{BB}} = \frac{G^2 f_{SAT} V_f}{2gD_e} \int_{BB} \Phi_{LO_{M-N}}^2 \left[\frac{\Phi_{LO}^2}{\Phi_{LO_{M-N}}^2} \right] dz, \quad (3.3)$$

where $\Phi_{LO_{M-N}}^2$ is obtained by interpolation from the table of quality versus $\Phi_{LO_{M-N}}^2$ at the given pressure,

$$\left[\frac{\Phi_{LO}^2}{\Phi_{LO_{M-N}}^2} \right] = 1.36 + 0.0005 P + 0.1 \left(\frac{G}{10^6} \right) - 0.000714 P \left(\frac{G}{10^6} \right), \quad (3.4)$$

for $G \leq 0.7 \times 10^6$, and

$$\left[\frac{\Phi_{LO}^2}{\Phi_{LO_{M-N}}} \right] = 1.26 - 0.0004 P + 0.119 \left(\frac{10^6}{G} \right) + 0.00028 P \left(\frac{10^6}{G} \right) \quad (3.5)$$

for $G > 0.7 \times 10^6$.

In the local boiling regime,

$$\Delta P_{f_{LB}} = \frac{G^2}{2gD_e} \int_{LB} (f/f_{iso}) f_{iso} V_B dz \quad (3.6)$$

where

$$f/f_{iso} = 1 + \frac{T_B - T_{LB}^*}{T_{SAT} - T_{LB}^*} \left[(f/f_{iso})_{SAT} - 1 \right] \quad (3.7)$$

and

$$T_{LB}^* = T_{SAT} + 60 \frac{\left(\frac{\phi}{10^6} \right)^{0.25}}{P/900} - \frac{\phi}{h} \quad (3.8)$$

and

$$h = 0.03 \frac{k_{mt}}{D_e} (Re)_{mt}^{0.8} (Pr)_{mt}^{0.4} \quad (3.9)$$

$(f/f_{iso})_{SAT}$ is an input quantity. If no value of $(f/f_{iso})_{SAT}$ is specified in the input, the program will use the value of the Martinelli-Nelson multiplier obtained from the library (3000 series).

In the heating regime,

$$\Delta P_{f_H} = \frac{G^2}{2gD_e} \int_H (f/f_{iso}) f_{iso} V_B dz, \quad (3.10)$$

where

$$f/f_{iso} = (1 - 0.001\Delta T_f); \Delta T_f = \frac{\phi}{h}, \quad (3.11)$$

and

$$h = 0.023 k_{mt}/D_e (Re)_{mt}^{0.8} (Pr)_{mt}^{0.4} \quad (3.12)$$

In all cases above, f_{iso} is obtained by interpolation from the table of Reynold's number versus f_{iso} .

Elevation Pressure Drop

$$\Delta P_{el} = \int_{Z_1}^{Z_2} \rho(Z) dZ \text{ where } Z_1 \text{ is the elevation at the channel inlet and } Z_2 \text{ is}$$

the elevation at the channel outlet.

For $H(Z) \leq H_{SAT}$, $\rho(Z)$ is obtained by interpolation from the table of enthalpy versus ρ .

For $H(Z) > H_{SAT}$, $\rho(Z) = R_g \rho_g + (1 - R_g) \rho_f$ where R_g is obtained by interpolation from the table of quality versus R_g .

Acceleration Pressure Drop

Two cases must be considered:

1. $H(Z_2) > H_{SAT}$:

$$\Delta P_{acc} = \frac{G^2}{g} \left\{ \left[\frac{(1 - X)^2 v_f}{1 - R_g} + \frac{X^2 v_g}{R_g} \right]_{outlet} - \frac{1}{\rho(Z)_{inlet}} \right\}. \quad (3.13)$$

2. $H(Z_2) \leq H_{SAT}$:

$$\Delta P_{acc} = \frac{G^2}{g} \left\{ \frac{1}{\rho(Z)_{outlet}} - \frac{1}{\rho(Z)_{inlet}} \right\}. \quad (3.14)$$

Entrance and Exit Pressure Drops

$$\Delta P_{en} = \frac{G^2 V_B}{2g} (1 - \sigma^2 + K_{in}) , \quad (3.15)$$

$$\Delta P_{ex} = \frac{G^2 V_B}{2g_c} (\sigma^2 - 1 + K_{ex}) , \quad (3.16)$$

where σ^2 , K_{in} and K_{ex} are input constants, and $V_B = \frac{1}{\rho(Z)_{inlet}}$ or $\frac{1}{\rho(Z)_{outlet}}$ respectively.

Enthalpy, Temperature, and Water Properties

The enthalpy at Z is given by

$$H(Z) = H_{in} + \frac{1}{G \left(\frac{A_f}{A_{HT}} \right)} \int_{(Z)_{inlet}}^Z \phi(Z) dZ , \quad (3.17)$$

where H_{in} and $\frac{A_f}{A_{HT}}$ are input quantities and $\phi(Z)$ is calculated from

$$\phi(Z) = p(Z) \left(\frac{V_H}{A_{HT}} \right) c \quad (3.18)$$

where p is normalized DRACO power, V_H/A_{HT} is the volume per unit heat transfer area, and c is a unit conversion factor.

T_B is obtained by interpolation from the table of enthalpy versus T_B for $H(Z) < H_{SAT}$.

$$T_B = T_{SAT} \text{ for } H(Z) \geq H_{SAT} , \quad (3.19)$$

$$T_W = T_B + \frac{\phi(Z)}{h} \text{ where } h = 0.03 \frac{k_{mt}}{D_e} (Re)_{mt}^{0.8} (Pr)_{mt}^{0.4} . \quad (3.20)$$

The values of Re , Pr and k are calculated for each thermal stick using the

mean value of T_B for the stick which is defined as

$$T_{B_{mt}} = \frac{T_{SAT} + T_{in}}{2} \text{ or } \frac{T_{max} + T_{in}}{2} \quad (3.21)$$

After the $(\Delta P_i^1 \text{ vs } G_i)$ tables have been generated, the assumption is then made that the stick pressure drops for all sticks in a division are the same (the first application of the parallel channel concept). Using this assumption and the stick flow areas, $G_i A_i$, a table of division flow versus stick pressure drop ($W_j \text{ vs } \Delta P_j^1$) is generated for each division. This is done by interpolating in the $\Delta P_i^1 \text{ vs } G_i$ tables for the mass velocity corresponding to the stick pressure drop (division dependent input) and calculating the division flow by summing the stick flow areas over the sticks in the division. Assuming perfect mixing at the outlet of the sticks and knowing the total division power, Q_j , the division exit enthalpy is computed for each value of division flow in the $W_j \text{ vs } \Delta P_j^1$ tables. Using this data, a plenum pressure drop versus division flow relationship ($\Delta P_{p\ell_j} \text{ vs } W_j$) is developed for each division and tables of overall pressure drop versus division flow ($\Delta P_{T_j} \text{ vs } W_j$) are calculated. The plenum pressure may be significant in cores where withdrawn control rods or other structures affect flow patterns above the core. The equations used in the generation of the above tables are discussed below.

$$\Delta P_{T_j} = \Delta P_j^1 + \Delta P_{p\ell_j} = \Delta P_j^1 + \Delta P_{p\ell_{inlet}} + \Delta P_{p\ell_{outlet}} \quad (3.22)$$

$$\Delta P_{p\ell_{inlet}} = K_0 + K_1 W_j^2 v_j(Z_1) \quad (3.23)$$

$$\Delta P_{p\ell_{outlet}} = K_2 + K_3 W_j^2 v_j(Z_2) + \frac{K_4 L}{v_j(Z_2)} \quad (3.24)$$

where K_0, K_1, K_2, K_3 and K_4 are division dependent input constants and L is the vertical distance from the top of the core to the center line of the outlet nozzle,

or some similar dimension.

The entrance enthalpy for each division is the average entrance enthalpy (input) of the sticks in the division and the exit enthalpy is calculated for each division as follows:

$$\left[H(Z)_j \right]_{\text{outlet}} = \left[H(Z)_j \right]_{\text{inlet}} + \frac{Q_j}{W_j} , \quad (3.25)$$

where

$$Q_j = \sum \varphi(Z) A_i \frac{A_{HT}^*}{A_f} \Delta Z , \quad (3.26)$$

where the sums are taken over all the sticks in the division.

If it is assumed that overall pressure drop across all divisions is the same (the second application of the parallel channel concept), it is possible to generate a single table of total flow versus overall pressure drop (W_T vs ΔP_T). These tables are computed by interpolating in the ΔP_{T_j} vs W_j tables for the division flow corresponding to the overall pressure drop (input) and calculating the total flow by summing the division flows over all the divisions.

If a sufficient range of flows has been considered, it should be possible to find an unique pair of values for total flow and overall pressure drop at the point where the generated curve (W_T vs ΔP_T) intersects an input system characteristic curve (net pressure drop available from the rest of the system as a function of total flow). It is now necessary to find values of mass velocity in each stick corresponding to these values of total flow and overall pressure drop.

First, the overall pressure drop value is modified by the individual division plenum pressure drops to give one value of stick pressure drop for each division. These division values are then applied to the stick tables and a mass velocity is found for each stick.

Using these mass velocities and the stick power information a complete new density distribution is calculated and compared with that which was used as a basis for the DRACO power calculation. If adequate convergence exists, the requested thermal edits are printed out and the problem terminates. If the convergence check is unsatisfactory, the newly calculated density distribution replaces the previous density distribution and a new iteration can be initiated.

In some cases, usually because of an inadequate input range of flow guesses, but possibly because of a severe thermal condition, no solution may be found. This fact is noted on the on-line printer and the program will stop. For two cases additional information will be printed on the on-line printer. If the total flow in the generated total flow versus overall pressure drop table (W_T vs ΔP_T) is not an increasing function of overall pressure drop or if this curve does not intersect the input system characteristic curve, the generated table is printed.

IV. NUCLEAR-THERMAL ITERATION

At the conclusion of a spatial integration and corresponding thermal and hydraulic calculation, there are two alternatives: a depletion of the fissionable materials may be performed if the void distribution is accurate (see V), or a so-called nuclear-thermal iteration may be carried out.

The concept of nuclear-thermal iteration rests on the fact that for a given power shape there is a corresponding water density distribution; on the other hand the water density distribution perturbs the power shape. Thus a power shape and density distribution are calculated alternately until the change in water density becomes very small. Intuitively such a process is expected to converge; there is no theoretical proof that it should.

To perform an iteration, the time-step number is increased by one and the problem resubmitted. The spatial integration is then performed using the new water

densities.

A feeling for the over-all water density change from iteration to iteration may be gleaned from inspection of convergence criteria which are always printed off-line. The first is the integrated change in water content, ϵ_1 ; the second are the ten maximum percentage changes in mesh cubes, ϵ_2 , with their locations:

$$\epsilon_1 = \frac{\int |N_{30}(t) - N_{30}(t-1)| dv}{\int N_{30}(t-1) dv},$$

where v is the volume of a mesh cube,

$$\epsilon_2 = \frac{|N_{30}(t) - N_{30}(t-1)|}{N_{30}(t-1)}.$$

V. DEPLETION

At the conclusion of any thermal calculation, it is possible to perform a nuclear depletion (DRACO) with element 30 held constant by simply initiating a restart. It should be noted that the most recently calculated number densities are destroyed by this procedure. This should not be considered as a limitation, however, since in the case of the nuclear-thermal iteration convergence of the iteration scheme implies that the time step (n-1) number densities are just as good as the time step (n).

VI. INPUT

Card numbers are in fixed point form; i.e., they are punched as a signed integers. The same is true of most control information. All the other input is punched in excess-50 floating point. If

$$N = \pm .xxxx.10^{+y}$$

then N is punched as

+CCxxx

where

$$CC = 50 \pm y$$

A floating point zero is punched as all zeros.

The sample library and test problem should be consulted as a guide to input preparation.

A. Library

Because of the lack of available tape units during an ABRAC calculation and since the quantities contained in the library enjoy a relative permanence, the library is written on the program tape. This implies that it is somewhat time consuming to rewrite the library, as the entire ABRAC program must be copied at the same time. It is advisable, in view of this, to use the card input options if the current library data is inadequate. A listing of the current library may be found in Appendix C.

Caution must be exercised in constructing and using tables extracted from the library, for example:

Let P_1, P_2 be two values of pressure (psia), with corresponding tables of enthalpy versus bulk temperature -

- $$\begin{aligned} \text{(a)} & (H_1)_1, (T_1)_1; (H_2)_1, (T_2)_1; (H_3)_1, (T_3)_1; \dots; (H_f)_1, (T_{\text{SAT}})_1; (H_g)_1, \\ & (T_{\text{SAT}})_1, \\ \text{(b)} & (H_1)_2, (T_1)_2; - - - - - \end{aligned}$$

If the system under consideration has an operating pressure P where $P_1 < P < P_2$, then the table of H versus T for pressure P is constructed as follows:

$$(a) \quad H_1 = \left(\frac{P - P_2}{P_2 - P_1} \right) \left((H_1)_2 - (H_1)_1 \right) + (H_1)_2$$

$$(b) \quad T_i = \left(\frac{P - P_2}{P_2 - P_1} \right) \left((T_i)_2 - (T_i)_1 \right) + (T_i)_2$$

(c) $i = 1, 2, \dots, (k - 1)$ where k is such that either

$$(T_k)_1 = (T_{k+1})_1 \text{ or } (T_k)_2 = (T_{k+1})_2$$

i.e., the linear interpolation is performed point by point until saturation conditions are reached in one of the tables. Then

$$T_{SAT} = T_K = \left(\frac{P - P_2}{P_2 - P} \right) \left((T_{SAT})_2 - (T_{SAT})_1 \right) + (T_{SAT})_2$$

In other words, the interpolation procedure uses whatever values it finds until saturating conditions are reached; then it interpolates between values at saturation. Clearly, if tables with unequal numbers of entries are used, there is a discontinuity introduced at this point.

All other interpolation is done in a completely analogous manner.

N.B. All abscissae in all tables must be strictly increasing. No single set of data may exceed 10,000 numbers in all. No individual table may have more than twenty abscissae.

#10000 Series - Fluid Properties

For a given value of pressure, a table of enthalpy versus bulk temperature, specific volume, thermal conductivity, Prandtl number and viscosity is supplied. All of these are computed at the same enthalpy. Up to 99 values of enthalpy may be supplied for each pressure and up to 99 pressure may be used. There is no restriction on how the tables are constructed except that enthalpy be strictly increasing. For a given pressure the last two temperatures must be equal to T_{SAT} ; the last two enthalpies and specific volumes must be those for saturated liquid and saturated vapor.

Card No.	Quantity	Description
+10001	P_1	Operating pressure
	$n_1 (\leq 99)$	Number of values of enthalpy - fx. pt.
+10002	$(H_1)_1$	Enthalpy
	$(T_1)_1$	Corresponding value of bulk temperature
	$(V_1)_1$	Corresponding value of specific volume
	$(K_1)_1$	Corresponding value of thermal conductivity
	$(Pr_1)_1$	Corresponding value of Prandtl number
	$(\mu_1)_1$	Corresponding value of viscosity
+10003	$(H_2)_1$	
	$(T_2)_1$	
	$(V_2)_1$	
	$(K_2)_1$	
	$(Pr_2)_1$	
	$(\mu_2)_1$	
		
+10101	P_2	
	n_2	
	$(H_1)_2$	
	$\vdots$	

20000 Series - Isothermal Friction Factors

For selected values of relative roughness (RMS/D), tables of Reynolds number versus isothermal friction factor should be supplied.

Up to 250 values of Reynolds number may be supplied for each (RMS/D) and up to 99 values of (RMS/D). Reynolds number is strictly increasing.

<u>Card No.</u>	<u>Quantity</u>	<u>Description</u>
+20001	(RMS/D) ₁ n ₁	Fixed point
+20002	Re f _{iso} Re f _{iso} Re f _{iso}	
+20003	Re f _{iso} Re f _{iso} Re f _{iso}	
+20101	(RMS/D) ₂ n ₂	Fixed point
+20102	<u>etc.</u>	

30000 Series - (f/f_{iso}) SAT

For a selected value of quality, usually 4.2%, one table of pressure versus (f/f_{iso}) SAT is supplied. This is described in Reference 3. Up to 20 values of P may be used.

<u>Card No.</u>	<u>Quantity</u>	<u>Description</u>
+30001	Quality Number of pres- sure values	Fixed point
+30002	P (f/f _{iso}) SAT	

<u>Card No.</u>	<u>Quantity</u>	<u>Description</u>
	P	
	(f/f _{iso})	SAT
	P	
	(f/f _{iso})	SAT
+30003	P	
	(f/f _{iso})	SAT
	P	
	(f/f _{iso})	SAT
	P	
	(f/f _{iso})	SAT
	etc.	

40000 Series - This series is always omitted, insert a card of the following form into the deck,

+99999+000 0.

50000 Series - Martinelli-Nelson Multiplier

Tables of quality versus Φ_{LO}^2 are supplied for selected values of pressure.
M-N

Begin numbering at 50001 and proceed as in the 20000 series.

60000 Series - This series is always omitted, insert a card of the following form into the deck,

+99999+000 0.

70000 Series - Void Fractions

Tables of quality versus void fraction are supplied for selected values of pressure.

Begin numbering at 70001 and proceed as in the 20000 series.

80000 Series - G Dependent Void Fractions

See Appendix E

B. DRACO Input

A DRACO-01 input deck is prepared in accordance with Reference 4. Each iteration corresponds to a full DRACO time step, and time steps must be numbered accordingly.

One additional card is required. The last card processed by DRACO is numbered +13000 and this must be followed by a blank. If this is time step 00, then the blank is followed by a card of the form

$$\begin{array}{c} 0 \\ +14000+ \text{ or } +0 \dots\dots\dots 0 \\ 1 \end{array}$$

The presence of a 1 indicates that immediately following this card is a binary deck prepared by another ABRAC problem giving an initial number density guess. Clearly, the other problem must have had identical geometry. The thermal and hydraulic data immediately follows this card if column 8 is a zero.

For all other time steps, there is no 14000 card; the thermal and hydraulic deck follows the blank card.

C. Thermal and Hydraulic Input

All input data cards are numbered serially, each series corresponding to a different type of input:

- 1000 series - general information
- 2000 series - thermal stick lay-out
- 3000 series - division description
- 4000 series - thermal-stick dependent data
- 5000 series - division dependent data
- 6000 series - R_e versus f_{iso}
- 8000 series - X versus $\Phi^2_{LO_{M-N}}$
- 9000 series - X versus R_g

Series 1000 through 5000 are mandatory. Series 6000 through 9000 are optional, and one or more of these may be omitted. There are five input forms for an ABRAC problem as shown in Appendix C.

Form # 1

Title Card - Anything in columns 1-72.

Library Title Card - This must be the same card used for a title when the library was written. Failure to supply the exact duplicate results in an error stop.

Card 1001

Number of distinct, nonzero, thermal stick types (≤ 50).

Number of divisions (≤ 50).

GDEP = 0*

If S6000 = 0, 6000 series is from cards,

= 1, 6000 series information is obtained from library.

$\left. \begin{array}{l} \text{S8000} \\ \text{S9000} \end{array} \right\}$ similar to S6000

NEDIT = 0 or 1 for no density edit or density edit

GEDIT = 0 or 1 for no mass flow edit or mass flow edit

HEDIT = 0 or 1 for no enthalpy edit or enthalpy edit

T.S. option = 0 normally; when set = 1, the time step number is not increased allowing forced re-entry to the thermal calculation.

Punch option = 0 or 1 for no punch-out or punch-out of number densities for element 30 for subsequent input to other ABRAC problem.

Card 1002 - L, P, θ , surface roughness, $(f/f_{\text{iso}})_{\text{SAT}}$

If $(f/f_{\text{iso}})_{\text{SAT}} = 0$, the appropriate value is obtained from the library.

Card 1003 - α , R_{g1}^i , R_{g2}^i , H_1^i , H_2

If $\alpha = 0$, the local voids calculation is bypassed.

If H_1^i is not at least one BTU/lb less than saturation, then it is set equal to $H_f - 1$. See Appendix B, # 24.

Card 1101-1107 - W_T , ΔP_T , W_T , ΔP_T , W_T , ΔP_T

where the values describe the system characteristic curve. Up to 20 values of W_T may be inserted with W_T strictly increasing. The first flow value must be zero. The unused portion of the last card needed is filled with zeros.

* See Appendix E.

Card 1201-1204 - ΔP_T , ΔP_T , ΔP_T , ΔP_T , ΔP_T , ΔP_T

where the values describe the range of total core pressure drop. Up to 20 values of ΔP_T may be inserted in a strictly increasing fashion. The unused portion of the last card needed is filled with zeros. There must be a zero value to signal termination of the data.

Form # 2

(A) Thermal Stick Classification

The term, thermal stick type is used to describe a region in which the channel parameters K_{in} , K_{out} , σ_{in} , σ_{out} , H_{in} , A , A_f/A_{HT}^* , V_H/A_{HT} , D_e , T_{max} are constant for each stick in the region. Associated with each mesh rectangle in the X-Y plane must be a positive integer - the thermal stick type. Only the X-Y plane is considered as whatever is said of an X-Y mesh rectangle is implied to extend over the entire fueled region in the Z direction.

If the thermal stick type is zero, then this mesh rectangle is excluded from all calculation in the thermal and hydraulic section. Hence, every nonfueled mesh rectangle and rectangles exterior to the axes of symmetry should be classified by zero.

If more than one channel is included in a single mesh rectangle, then they must be averaged into a single channel or the mesh spacing reduced.

The thermal stick type of each mesh rectangle is described by successively overlaying rectangular blocks of specified type on the mesh. Any block may be laid over part or all of the previously specified blocks. Cards are numbered starting at 2001 with 4 blocks defined per card. Five fixed point integers are used to describe a block:

V = thermal stick type ≤ 50

WW = column forming left boundary

$0 \leq WW \leq (ss - 1)$, $WW < XX$

XX = column forming the right boundary

$01 \leq XX \leq ss$

YY = row forming the upper boundary

$00 \leq YY \leq (tt - 1)$, $YY < ZZ$

ZZ = row forming the lower boundary

$01 \leq ZZ \leq tt$

(B) Division Description

To account more adequately for flow redistribution in the plenum chamber, the concept of a flow division improves on the normal parallel channel treatment.* In such codes as ATBAC and ART (Refs 5 and 6) the assumption is made that the same pressure drop is applied across every channel in the reactor. ABRAC allows the reactor to be subdivided into divisions, the pressure drop across all channels in a particular division being the same.

The divisioning of the core is described in exactly the same way as section (A) above. Card numbering starts at 3001. A full set of V, WW, XX, YY, ZZ all set to zero signal the end of the division description.

Form # 3

Thermal Stick Input

For each thermal stick type the following constants are specified:

K_{in} , K_{out} , σ_{in} , σ_{out} , H_{in} , A , A_f/A_{HT}^* , V_H/A_{HT} , D_e , T_{max} , print option.

T_{max} is used only in calculating an average temperature to evaluate the heat transfer coefficient.

* All sticks in each division are assumed to be associated with an identical plenum pressure drop.

$$T_{avg} = \frac{T_{max} + T_{in}}{2}$$

If $T_{max} = 0$ then it is set equal to T_{SAT} . The print option is a fixed point 0 or 1. In the latter case, a table of G_1 vs ΔP_1^i is printed for each stick of the type under consideration.

Two cards are required for each stick type numbered $[4000 + n \times 10]$, $[4001 + n \times 10]$ where n is the type number.

Form # 4

Division Input

For each division the following quantities are specified:

K_0, K_1, K_2, K_3, K_4

up to 20 values of G - the range of mass flow velocity

up to 20 values of ΔP^i - the range of pressure drop over the division in question

Cards are numbered sequentially with each division beginning at $[5000 + n \times 10]$ where n is the division number. Here and wherever table ranges are specified, great care must be taken to prevent too much loss of range by successive failure of tables to overlap. A considerable amount of preliminary study is required to properly specify table limits.

The last value of ΔP^i must be zero to signal the end of this set of input.

Form # 5

Table Input

All input on Form # 5 is optional in that it may be obtained from the library.

If S6000 on card number 1001 is zero, then up to 20 values of Reynolds number with corresponding values of f_{iso} must be entered, 3 pairs/card, with numbering beginning at 6001.

If S8000 on card # 1001 is zero then up to 20 values of quality with corresponding values of the Martinelli-Nelson factor, $\Phi_{LO, M-N}^2$ must be entered, 3 pairs/card,

with numbering beginning at 80001.

If S9000 on card #1001 is zero, then up to 20 values of quality with corresponding values of void fraction, R_g must be entered, 3 pairs/card, with numbering beginning at 90001.

VII. OUTPUT

All DRACO edits are available, the supervisory on-line DRACO edit included.

The following quantities are always edited off-line:

- A picture of the thermal stick lay-out

- A picture of the divisioning

- All input quantities and any data obtained from the library

- The integrated change in water content and the 10 maximum percentage changes

- Total flow and pressure drop, for the core and for each division

- Exit enthalpy for each division

- The total head load

- Mass flow integrated over the core, each thermal stick type, and each division

At requestor's option the following stick may be edited:

- Tables of mass velocity versus stick pressure drop (G_i vs ΔP_i^s)

- Tables of division flow versus stick pressure drop (W_j vs ΔP_j^s)

- Tables of division flow versus plenum pressure (W_j vs $\Delta P_{p/j}$)

- The enthalpy at the center of each mesh cube

- The density (of water) at the center of each mesh cube

- The flow in each stick

In the event that tables of mass velocity versus stick pressure drop (G_i vs ΔP_i^s) are multi-valued, the first ten tables are automatically edited and identified by row and column number. All other multi-valued tables are only identified.

The G_i vs ΔP_i^1 tables are checked for multiple solutions when the W_j vs ΔP_j^1 tables are formed and when the final G_i for each stick is found. After interpolating for the smallest value of G corresponding to a given ΔP , the ΔP_i^1 corresponding to values of G_i greater than the solution, G , are compared with the given ΔP . If any ΔP_i^1 is less or equal to ΔP , the table is considered to be multi-valued. This procedure is followed every time an interpolation is done in the G_i vs ΔP_i^1 tables, hence the same table could be printed several times. Tables may be multi-valued, but will not be recognized as such by the program, unless the multiple solutions occur in the range of the ΔP .

If a binary deck of N_{30} is called for, then it is sequentially numbered in row 9-left and may be identified by the fact that columns 1-21 of 9-left are punched.

VIII. OPERATING INSTRUCTIONS

Card Reader

Use 72-72 card reader board.

On-Line Punch

Use 80-80 card punch board.

On-Line Printer

Use GLOUT-2 board.

Off-Line Printer

Carriage control set to Program.

Tapes

- 1 Program
- 2-5 Blanks
- 6 Blank or flux tape. If column 27 of card 1001 in the DRACO input deck is 3, flux tape is to be used.
- 7 History tape - at time step 0 this is a blank
- 8-10 Blanks

Sense Switches

- 1 Up: normal
 Down: stop iteration at best point
- 2 Up: normal
 Down: restart
- 3,4,5 Up: normal
- 6 Up: normal
 Down: brings in octal dump (NYDS1) for restart failures (must have a blank in card reader).

Starting Procedure

Mount the necessary tapes, ready the input deck followed by at least one blank in the card reader, set the necessary switches, CLEAR and LOAD TAPE.

At program stop (00007)_g enter 0 or 1 into the address portion of the MQ. START. (0 is the routine to continue the history tape after an end of tape is sensed by DRACO-1.)

Restart Procedure

A restart may be initiated at any time providing all tapes have been saved. Tape 1 must be rewound and sense switch 2 down, CLEAR and LOAD TAPE. Proceed as if starting a problem, but there must only be a thermal and hydraulic input deck in the card reader (this is identified by the fact that it begins with two title cards).

At program stop (747)_g, hit start.

In the event of a restart failure, rewind tape 1, depress sense switch 6, and LOAD TAPE. This brings in the octal dump. There should be a blank card in the card reader. Dump core; backspace each tape one record and dump.

Instruction Tape Preparation

Ready a blank tape 1, the DRACO program tape on logical 2, a blank tape 10. Ready the ABRAC deck in the card reader (WBAB1000-WBAB253). The library deck is placed between the WBAB1 and WBAB2 decks. CLEAR and LOAD CARDS. After the tape

written, the computer halts at $(00067)_8$. Any other stops are due to machine failure or library input error.

The contents of the library are printed on tape 10. Any input error on the library cards is indicated on-line before the computer halts.

Program Tape Copy

To copy the ABRAC program tape, place the program on logical 2, a blank on logical 1. Ready the deck (WBABCOOO-WBABC34) in the card reader. CLEAR and LOAD CARDS. The program halts at $(00067)_8$.

Error Steps

All errors in the thermal and hydraulic section are diagnosed on-line with the computer halting in location $(77777)_8$. Save all tapes if the problem has run more than several minutes. In any event, note the diagnostics before taking corrective action.

Most of the following error stops are DRACO stops:

1) Normal stops:

$(1623)_8$ - occurs when the requestor has used a specified flux tape. SEE ON-LINE INSTRUCTIONS.

$(25252)_8$ - occurs when the requestor has asked for a BCD picture edit immediately after the input routine. SEE ON-LINE INSTRUCTIONS. Label and save all tapes except 9, which contains the BCD edit. The problem will be continued at some later time by means of a restart.

$(10000)_8$ - end of time-step calculation

a) SEE ON-LINE INSTRUCTIONS.

b) Edit binary output tape (9) if requested. SAVE TAPE 9.

c) SAVE HISTORY TAPE-TAPE 7 FOR DRACO-1. Upon request, save flux tape. This may be tape 5 or 6 and will be indicated on-line.

d) Clear the card punch. In the event of tape errors which do not result in a program stop, cards indicating the nature of the difficulty are punched according to the format specified by the tape routine WB-RWT5. The address of the 9L word indicates the octal address of the tape in error. Note the number of the tape reel and identify the tape unit.

- e) If there has been a BCD picture edit (indicated on-line) print tape (4 or 9) off-line. Return on-line and off-line edits to requestor.

(77777)g See on-line diagnostics, remove punched cards from hopper.

2) Error stops:

6	Tape loader	Load tape to try again
160	Sigma	Machine error - restart
245	Iteration	Machine error - restart
251	Average	Machine error - hit start to proceed
251	Picture	Machine error - hit start to proceed
267	Sigma	Over or underflow - restart
330	Average	Machine error - restart
330	Picture	Machine error - restart
375	Rest	Tape 1 error - restart
376	Rest	Tape 2 error - restart
377	Rest	Tape 5 error - restart
400	Rest	Tape 7 error - restart
401	Rest	Tape 7 error - restart
402	Rest	Record numbering error on tape 1 - restart
403	Rest	Restart is impossible - quit
407	Rest	Restart is impossible - quit
565	Depletion	MQ overflow light on - restart
645	Depletion	Error checking calc - hit start to try again
674	Coef	Machine error - restart
745	Depletion	Negative isotopic density - restart
747	Rest	Stops in all restart, may fudge values - hit start
764	Rest	Stop for entering rout. no. - load MQ, hit start
771	Depletion	Error checking calc - restart

776	Depletion	MQ overflow light on - restart
1012	Rest	Restart impossible in input routine - hit start to rewind all tapes. Reload data deck and try again
1014	Part. Sums	Tape 2 error - restart
1015	Part. Sums	Tape 3 error - restart
1016	Part. Sums	Tape 4 error - restart
1017	Part. Sums	Tape 7 error - restart
1020	Part. Sums	Tape 8 error - restart
1020	Rest	Routine number incorrect - restart
1021	Part. Sums	Machine error - restart
1022	Part. Sums	Over or underflow - restart
1050	Depletion	Error checking calc - restart
1067	Depletion	Error checking calc - restart
1073	Depletion	Over or underflow - restart
1115	Rest	Error in restart record - restart
1135	Depletion	Error - in return - restart
1143	Depletion	Error checking calc - restart
1152	Depletion	Machine error - restart
1170	Depletion	Negative isotopic density - restart
1174	Depletion	Over or underflow - restart
1205	Depletion	Error - in return - restart
1207	Sigma	Over or underflow - restart
1210	Rest	Problem may be complete - hit start to rewind
1213	Depletion	Error - checking calc - restart
1226	Depletion	Probably machine error - restart
1240	Rest	EOF missing on tape 9 - restart
1254	Depletion	Error - checking calc - restart
1256	Rest	Bad record on tape 9 - hit start to try 3 more times

1274	DRACO-0	Tape 7 positioned incorrectly - start over
1275	DRACO-0	Error - tape 2 - start over
1276	DRACO-0	Error - tape 4 - start over
1277	DRACO-0	Error - tape 7 - start over
1302	Expan	Error copying 6 to 5 - hit start to try again
1311	Depletion	Error - checking calc - restart
1315	Depletion	Over or underflow - restart
1324	Depletion	Probably machine error - restart
1325	Picture	Tape 2 error - restart
1344	Depletion	Error - in return - restart
1351	Picture	Error in requesting picture - restart
1352	Depletion	Error checking calc - restart
1357	Depletion	Probably machine error - restart
1363	Depletion	Over or underflow - restart
1372	Depletion	Machine error - restart
1377	Depletion	Machine error - restart
1413	Picture	Error in requesting picture - restart
1431	Percnt	AC overflow - restart
1434	Percnt	MQ overflow - restart
1443	Depletion	Tape 2 error - restart
1444	Depletion	Tape 3 error - restart
1445	Depletion	Tape 7 error - restart
1450	Depletion	Machine error - restart
1456	Sigma	Tape error - 2, 4 or 5 - read - restart
1471	Sigma	Machine error - restart
1513	Percnt	Drum error - restart
1541	Depletion	Machine error - restart

1566	Flux	Drum error - restart
1576	Rest	Error in time-step no. on rest. rec. - restart
1602	Flux	Incorrect no. of flux tape records - restart
1602	Expan	Calculation does not check - restart
1604	Expan	Impossible end of tape - restart
1605	Expan	Tape 2 error - restart
1606	Expan	Tape 3 error - restart
1607	Expan	Tape 5 error - restart
1610	Expan	Tape 6 error - restart
1611	Expan	Tape 8 error - restart
1611	Iteration	Machine error - sq rt - restart
1612	Expan	Tape 9 error - restart
1614	Iteration	Machine error - in return - restart
1615	Omega	Impossible end of tape - restart
1625	Expan	Flux tape stop - see on-line instructions
1626	Omega	Tape 4 error - restart
1631	Sigma	Machine error - restart
1635	Omega	Drum error - restart
1637	Rest	Too many records in a file of tape 7 - restart
1645	Iteration	Machine error - hyp cos - restart
1653	Iteration	Machine error - hyp cos - restart
1656	Sigma	Tape error - 2, 3, 4, or 5 - write - restart
1657	Sigma	Tape error - 2, 3, 4, or 5 - write - restart
1660	Iteration	Machine error - hyp cos - restart
1700	Rest	Error in no. of files on tape 7 - restart
1707	Omega	Tape EOF error - restart
1710	Omega	Tape 2 error - restart

1733	Depletion	Machine error - restart
1735	Rest	Double end of file missing on tape 7 - restart
1737	Rest	Machine error - restart
1751	Rest	Machine error - restart
2001	Percnt	AC overflow - restart
2004	Percnt	MQ overflow - restart
2026	Rest	End of tape 7 - see on-line instructions
2037	Rest	EOF in wrong plane on tape 7 - restart
2041	Rest	Incorrect tape 7 is mounted - mount 7, restart
2042	Flux	Drum error - restart
2051	Power	Length of KSIG records incorrect - restart
2115	Rest	Incorrect tape 7 is mounted - mount 7 - restart
2201	Coef	Impossible end of tape - restart
2207	Power	Divide error - restart
2211	Iteration	Stop at best point in iteration - save tapes for restart
2223	Average	Tape 2 error - restart
2224	Average	Tape 3 error - restart
2225	Average	Tape 5 error - restart
2226	Average	Tape 6 error - restart
2255	Average	Impossible end of tape - restart
2270	Power	AC overflow - restart
2274	Power	MQ overflow - restart
2353	Coef	Over or underflow - restart
2354	Coef	CKSUM of 1st pass does not check with 2nd pass
2355	Coef	Machine error - restart
2356	Coef	Tape 1 error - restart
2357	Coef	Tape 2 error - restart

2360	Coef	Tape 3 error - restart
2361	Coef	Tape 4 error - restart
2440	Coef	Machine error - restart
2500	Picture	Tape 2 error - restart
2574	Omega	Machine error - restart
2576	Omega	Machine error - restart
2663	Picture	Impossible end of tape - restart
2664	Picture	Tape 3 error - restart
2720	Depletion	Tape 3 error - extra record - restart
2734	Power	Impossible end of tape - restart
2734	Norm	Impossible end of tape - restart
2735	Norm	Tape 3 error - restart
2736	Norm	Tape 2 error - restart
2737	Depletion	Tape 8 error - restart
2757	Depletion	Error - positioning tape 8 - restart
2760	Power	Machine error - restart
2761	Power	Tape 3 error - restart
2762	Power	Tape 8 error - restart
2763	Power	Tape 9 error - restart
3010	Flux	Flux tape (5 or 6) error - restart
3011	Flux	Tape 2 error - restart
3012	Flux	Tape 7 error - restart
3013	Flux	Tape 9 error - restart
3022	Flux	AC overflow - restart
3026	Flux	MQ overflow - restart
3064	Depletion	Machine error - checking count in index 1 - restart
3066	Norm	Drum error - hit start to try 3 more times

3102	Norm	Drum error - hit start to try 3 more times
3103	Percent	Drum error - hit start to try again
3113	Power	Drum error - hit start to try 3 more times
3127	Power	Drum error - hit start to try 3 more times
3251	Percent	Drum error - hit start to try 3 more times
3264	Percent	Drum error - hit start to try 3 more times
3272	Sigma	Tape 2 error - restart
3273	Sigma	Tape 3 error - restart
3276	Sigma	Tape 7 error - restart
3277	Sigma	Tape 8 error - restart
3300	Sigma	Tape 9 error - restart
3300	Norm	AC overflow - restart
3301	Sigma	Diffusion not acceptable - restart (or WSTRE) [*]
3302	Sigma	Total not acceptable - restart (or WSTRE)
3303	Sigma	Removal not acceptable - restart (or WSTRE)
3304	Sigma	Absorption not acceptable - restart (or WSTRE)
3304	Sigma	MQ overflow - restart
3305	Sigma	Fission not acceptable - restart (or WSTRE)
3306	Sigma	Sum weight factors zero for 2 grp - restart
3307	Sigma	Machine error - restart
3310	Sigma	Machine error - restart
3406	Percent	Tape 3 error - restart
3407	Percent	Tape 2 error - restart
3410	Percent	Impossible end of tape - restart
3727	Iteration	Tape 2 error - restart

^{*} Waste time because of requestor error.

3730	Iteration	Tape 4 error - restart
3731	Iteration	Tape 5 error - restart
3732	Iteration	Tape 6 error - restart
3733	Iteration	Impossible end of tape - restart
3734	Iteration	Drum error - restart
3735	Iteration	AC or MQ overflow - restart
3736	Iteration	AC or MQ overflow - restart
3737	Iteration	AC or MQ overflow - restart
3740	Iteration	AC or MQ overflow - restart
3741	Iteration	AC or MQ overflow - restart
7465	Perent	Machine error - restart
10000	Picture	End of time-step calc - see on-line instructions
12563	Part. Sums	Occurs only at T.S. = 0; CK sum error, card out of order or wrong I.D. on binary no. density cards, reload card 14000 and binary deck, try again.
25252	Picture	Picture after input - see on-line instructions
77777	Pwr or Depl	End of tape 7. Load DRACO-0 to continue history tape.

Operating Instructions - DRACO-3 (Edits)

A. Tape Configuration

- 1 All DRACO program tape
- 9 Binary output, tape 9 from specified ABRAC problem
- 10 Blank
- 2-8 Blanks when needed. The tapes required vary with the edits requested and may be determined by comparing the edit numbers on the master control card with the following table.

TABLE I

Tapes Needed for Each Edit

<u>Edit No.</u>	<u>Tape No.</u>
1	5
2	3,5,6,8
3	8
4	2
5	2
6	4
7	2
8	2
9	8
10	8
11	8

B. Sense Switches

1 Up : normal
Down: restart

2-5 Up

6 Up : normal
Down: brings in octal dump (NYDS1) which requires control cards or blank
card in card hopper.

C. Starting Procedure

- 1) Mount tapes as indicated.
- 2) Set proper sense switches.
- 3) GLOUT-2 printer panel in printer.
- 4) 72-72 panels in card reader and card punch.
- 5) Ready card reader with control deck in hopper.
- 6) Clear, load tape.
- 7) At program stop (0007)₈, manually enter the code number, in this case 3,
into the address portion of the MQ. START.
- 8) Always check information printed on-line to determine the progress of the
sort and edits.

D. Program Stops

1) Normal stop:

(4731)₈ Program has been successfully completed. Save tapes 9 and 10.
Print 10, the BCD output tape, off-line.

2) For all other program stops, consult the list of DRACO-3 Program Stops below.

E. Restart Procedure

- 1) In general, a restart cannot be initiated unless EDIT SORT HAS BEEN COMPLETED has been printed on-line, and at least one card has been punched.
- 2) Rewind all tapes except 10.
- 3) Remove the control deck from the card reader and the restart card or cards from the card punch. A restart card is recognized by the 12L word which contains punches in columns 1 through 36. The 9L word will have one or more bits punched.
- 4) Depending on the type of error necessitating the restart, proceed with (a) or (b) as directed by the comments listed with the program stop.
 - a) NORMAL RESTART: Insert the last restart card into the control deck in place of the master control card which follows the title card.
 - b) BY PASS EDIT: Obtain the most recent restart card from the card punch. If there is only one bit punched in the 9L word of this card, remove the edit from the machine. Otherwise, omitting the leftmost bit, punch the 9L word on a blank card. Insert this card into the control deck in place of the master control card (second card of control deck). When all edits have been completed, save tapes pertaining to edits which have been skipped.
- 5) The leftmost punch in the 9L word of the inserted restart card indicates at which edit the restart will begin. Remove all control cards pertaining

to edits preceding this one. An edit control card is identified by its card number which begins in column 12 and is of the form (x000+n) where x indicates the edit number and n refers to sequencing within the set of cards for the edit. The number of the last card for an edit is negative.

- 6) Depress sense switch 1.
- 7) Ready the card reader with the corrected control deck in the hopper.
- 8) Clear, load tape. At program stop (0007)_g enter 3 into the address of the MQ. Start.
- 9) When a restart fails, save all tapes.

F. Program Stops

0351	Cont, Edit 1 -6	GLOUT2 - machine error - normal restart
0356	Sort	GLOUT2 - machine error - if sort has been completed - normal restart; otherwise reload deck, start over
0430	Cont, Edit 1 -6	GLOUT2 - machine error - normal restart
0435	Sort	GLOUT2 - machine error - if sort has been completed - normal restart; otherwise reload deck, start over
1276	Cont, Edit 1 -6	Boundary error - restart - bypass edit
1340	Sort	DBC - machine error - reload deck, start over
1362	Cont, Edit 1 -6	Machine error - normal restart
1407	Sort	DBC - loading or requestor error - reload deck, start over
1411	Cont, Edit 1 -6	Machine error - normal restart
1725	Sort	DBC - loading or requestor error - reload deck, start over
2005	Sort	DBC - machine error - normal restart
2206	Sort	CSH - machine error or illegal punch - reload deck, start over

2472	Sort	Tape 9 error - if sort has been completed - normal restart, otherwise reload deck, start over
2473	Sort	Tape 9 error - if sort has been completed - normal restart, otherwise reload deck, start over
2520	Sort	Title card wrong - remove problem - save all tapes if this is a restart
3617	Cont, Edit 1 -6	DBC - machine error - normal restart
3666	Cont, Edit 1 -6	DBC - loading or requestor error - normal restart
3701	Sort	Tape 2 error - reload deck, start over
3713	Sort	Tape 3 error - reload deck, start over
3725	Sort	Tape 4 error - reload deck, start over
3737	Sort	Tape 5 error - reload deck, start over
3753	Sort	Tape 8 error - reload deck, start over
4204	Cont, Edit 1 -6	DBC - loading or requestor error - reload deck, start over
4256	Sort	End of tape - remove problem - save all tapes
4264	Cont, Edit 1 -6	DBC - machine error - normal restart
4321	Sort	Tape 9 positioned wrong - reload deck, start over
4337	Sort	Tape 9 positioned wrong - reload deck, start over
4465	Control	CSH - machine error or illegal punch - normal restart
4710	Control	Tape 1 error - rewind tape 1 - normal restart
4731	Control	Normal end of program - get off the machine
4746	Control	End of tape - remove problem - save all tapes
5050	Edit 1 -6	Boundary error - restart - bypass edit
5051	Edit 1 -6	Card number error - restart - bypass edit
5052	Edit 1	Machine error - normal restart

	Edit 3,4,5	Element number error - restart - bypass edit
	Edit 6	Error selecting output - restart - bypass edit
5053	Edit 1,6	Group number error - restart - bypass edit
	Edit 2	Machine error - normal restart
5054	Edit 3	Option number error - restart - bypass edit
	Edit 6	Sigma R requested for last group - restart - bypass edit
5055	Edit 11	Tape 3 error - normal restart
5056	Edit 11	Tape 5 error - normal restart
5057	Edit 2	Tape 9 error - normal restart
	Edit 11	Tape 6 error - normal restart
5060	Edit 11	Tape 8 error - normal restart
5061	Edit 1	Tape 9 error - normal restart
	Edit 11	Tape 9 error - normal restart
5062	Edit 4,5	Tape 9 error - normal restart
5064	Edit 6	Tape 9 error - normal restart
5076	Edit 6	Tape 4 error - normal restart
5107	Edit 3	Tape 9 error - normal restart
5174	Edit 3	Tape 8 error - normal restart
5211	Edit 7,8,9	GLOUT2 - machine error - normal restart
5222	Edit 3	Erroneous division - normal restart
5226	Edit 4,5	Tape 2 error - normal restart
5265	Edit	Tape 5 error - normal restart
5270	Edit 7,8,9	GLOUT2 - machine error - normal restart
5315	Edit 2	Tape 5 error - normal restart
5356	Edit 2	Tape 6 error - normal restart
5371	Edit 3	Tape 8 error - normal restart

5414	Edit 3	Tape 8 error - normal restart
5417	Edit 2	Erroneous division - normal restart
5432	Edit 2	Tape 6 error - normal restart
5457	Edit 2	Tape 3 error - normal restart
5562	Edit 10	Over or underflow - normal restart
5563	Edit 10	Machine error - normal restart
5564	Edit 10	Machine error - normal restart
5565	Edit 10	Tape 8 error - normal restart
5566	Edit 10	Tape 9 error - normal restart
5636	Edit 2	Erroneous division - normal restart
5720	Edit 7,8	Tape 9 error - normal restart
5723	Edit 9	Tape 9 error - normal restart
5756	Edit 9	Tape 8 error - normal restart
6025	Edit 7,8	Tape 2 error - normal restart
6031	Edit 7,8	Machine error - normal restart
6173	Sort	Machine error - false EOF - reload deck - start over
6174	Sort	Machine error - false EOF - reload deck - start over
6264	Sort	Tape errors (DRACO-1) and/or requestor error (DRACO-2). May restart as indicated on-line to get available information.
6266	Sort	Tape errors (DRACO-1) and/or requestor error (DRACO-2). Requested edits cannot be done. Tape 9 probably bad.

APPENDIX A

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
A	flow area of stick	ft ²
A_f/A_{HT}^*	ratio of flow area to active heat-transfer	ft
D_e	hydraulic diameter	ft
f	friction factor	dimensionless
G	mass velocity	lb/hr ft ²
g	gravitational constant	ft/hr ²
H	enthalpy	BTU/lb
h	surface heat transfer coefficient	BTU/hr - ft ² - F ^o
k	thermal conductivity	BTU/hr - ft - F ^o
K	plenum constant	dimensionless
L	vertical distance from top of core to center line of outlet nozzle	ft
m	total number of sticks	dimensionless
n	total number of division	dimensionless
Nu	Nusseldt Number	dimensionless
N_{30}	number density of element 30	nuclei/barn-cm
P	absolute pressure	lb/in ²
p	normalized power	watts/cm ³
Pr	Prandtl Number	dimensionless
Re	Reynolds Number	dimensionless
R_g	void fraction	dimensionless
$\frac{RMS}{D}$	relative roughness, <u>root-mean-square roughness</u> $\frac{D_e}{D_e}$	dimensionless

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
T	temperature	F°
$\frac{V_H}{A_{HT}}$	core volume per square foot of heat transfer area	ft
V	specific volume <u>or</u> volume of mesh cube	ft ³ /lb or cm ³
W	flow	lb/hr
X	quality	dimensionless
X,Y,Z	Cartesian coordinates for core	ft or cm
α	constant in local voids calculation	dimensionless
ΔP	pressure drop	lb/ft ²
ΔZ	vertical mesh space	ft or cm
ϕ	extrapolation factor	dimensionless
μ	viscosity	dimensionless
σ	ratio of smaller area to large area	dimensionless
ρ	density	lb/ft ³
ϕ	heat flux	BTU/hr-ft ²
Φ^2	two phase pressure drop multiplier	dimensionless

Subscripts

acc	refers to acceleration
B	refers to bulk fluid
BB	bulk boiling
el	refers to elevation
f	saturated fluid or refers to friction term
fg	change, fluid to vapor
g	saturated vapor
H	heating

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
i	refers to ith stick	
in	inlet	
iso	isothermal conditions	
j	refers to jth division	
JL	derived from Jens and Lottes correlation	
LB	condition at inception of local boiling	
LO	derived from Martinelli-Nelson correlation as modified by Eq 3.4	
LO _{M-N}	derived from Martinelli-Nelson correlation	
max	maximum	
mt, mean, avg	condition at mean temperature for stick	
O	variable is held constant	
out, ex	outlet	
p/	refers to plenum	
SAT	saturation	
T	total (usually with reference to entire core)	
W	wall	

APPENDIX B

Summary of Thermal and Hydraulic Equations

See References 2, 3, 9 and 10.

1) Heat Flux

$$\phi(x,y,z) = p(x,y,z) \left(\frac{V_H}{A_{HT}} \right)_i (96650.)$$

2) Enthalpy

$$H(x_0, y_0, z) = G \left(\frac{1}{\frac{A_f}{A_{HT}}} \right)_i \int_{(Z)_{inlet}}^Z \phi(x_0, y_0, z) dz$$

3) Surface Heat Transfer Coefficient

$$h_i = a \frac{k_i}{(D_e)_i} (Re)_i^8 (Pr)_i^4$$

where $a = .030$ or $.023$ depending on which correlation h is being used. All other quantities on the right are evaluated once in each stick for some mean temperature.

4) Wall Temperature

$$T_W(x,y,z) = T_B(x,y,z) + \frac{\phi(x,y,z)}{h_i}$$

where $a = .030$ in the expression for h_i ,

5) Steam Quality

$$X(x,y,z) = \frac{H(x,y,z) - H_{SAT}}{H_{fg}}$$

6) Core Pressure Drop

$$[\Delta P]_i = [\Delta P_{inlet} + \Delta P_{outlet} + \Delta P_{el} + \Delta P_{acc} + \Delta P_f]_i$$

Appendix B (contd.)

where $\Delta P_f = \Delta P_{f_H} + \Delta P_{f_{LB}} + \Delta P_{f_{BB}}$.

7) Bulk Boiling Friction Pressure Drop

$$\Delta P_{f_{BB}} = \frac{G^2 f_{SAT} V_f}{2gDe} \int_{BB} \Phi_{LO_{M-N}}^2 \left[\frac{\Phi_{LO}^2}{2} \right]_{LO_{M-N}} dZ$$

where $\int_{BB}$ implies the integral is taken over that section of the channel which is in bulk boiling.

8) Correction Factor to Martinelli-Nelson Multiplier

$$G \leq .7 \times 10^6$$

$$\left[\frac{\Phi_{LO}^2}{\Phi_{LO_{M-N}}^2} \right] = 1.36 + .0005P + 0.1 \left(\frac{G}{10^6} \right) - .000714P \left(\frac{G}{10^6} \right)$$

$$G > .7 \times 10^6$$

$$\left[\frac{\Phi_{LO}^2}{\Phi_{LO_{M-N}}^2} \right] = 1.26 - .0004P + 0.119 \left(\frac{10^6}{G} \right) + .00028P \left(\frac{10^6}{G} \right)$$

9) Jens and Lottes Temperature Difference

$$\Delta T_{JL}(x,y,z) = \left(\frac{60}{e^{P/900}} \right) \left(\frac{\varphi(x,y,z)}{10^6} \right)^{.25}$$

10) Water Temperature at Inception of Local Boiling

$$T_{LB}^*(x,y,z) = T_{SAT} + \Delta T_{JL}(x,y,z) - \frac{\varphi(x,y,z)}{h_i}$$

where $a = .030$ in the expression for h_i .

11) Local Boiling Friction Factor

$$(f/f_{iso})_{x,y,z} = 1 + \frac{T_B(x,y,z) - T_{LB}^*(x,y,z)}{T_{SAT} - T_{LB}^*(x,y,z)} \left[(f/f_{iso})_{SAT} - 1 \right]$$

12) Local Boiling Friction Pressure Drop

$$\Delta P_{f_{LB}} = \int_{LB} \frac{G^2}{2gD_e} \left[f/f_{iso} \right] f_{iso} V(x,y,z) dz$$

13) Friction Factor Correction Term in Heating Regime

$$(f/f_{iso})_{x,y,z} = 1 - .001 \frac{\varphi(x,y,z)}{h_i}$$

where $a = .023$ in the expression for h_i .

14) Heating Friction Pressure Drop

$$\Delta P_{f_h} = \frac{G^2}{2gD_e} \int_h (f/f_{iso}) f_{iso} V(x,y,z) dz$$

15) Elevation Pressure Drop

$$\Delta P_{el} = \int_{inlet}^{outlet} \rho(x,y,z) dz$$

16) Acceleration Pressure Drop

$$(H_{exit})_i > H_f$$

$$\Delta P_{acc} = \frac{G^2}{g} \left\{ \left[\frac{(1 - x^2) V_f}{1 - R_g} + \frac{x^2 V_g}{R_g} \right]_{outlet} - \frac{1}{(\rho)_{inlet}} \right\}$$

17) Entrance Pressure Drop

$$\Delta P_{inlet} = \frac{G^2}{2g(\rho)_{inlet}} (1 - \sigma_{inlet}^2 + K_{inlet})$$

18) Exit Pressure Drop

$$\Delta P_{exit} = \frac{G^2}{2g(\rho)_{outlet}} (\sigma_{outlet}^2 - 1 + K_{outlet})$$

19) Mixed Exit Enthalpy (used only in plenum calculations)

$$[H_{out}]_j = [H_{mean}]_j + \frac{Q_j}{W_j}$$

Here $H_{mean,j}$ is the arithmetic mean of all inlet enthalpies to division j and

$$Q_j = \sum_{\text{division } j} \left[\sum_{\text{stick } i} A_i \Delta Z \left(\frac{A_{HT}^*}{A_f} \right)_i \varphi(x,y,Z) \right]$$

20) Inlet Plenum Pressure Drop

$$[\Delta P_{p\ell}]_{inlet} = K_0 + \frac{K_1 W_j^2}{(\rho_j)_{inlet}}$$

21) Outlet Plenum Pressure Drop

$$[\Delta P_{p\ell}]_{outlet} = K_2 + \frac{K_3 W_j^2}{(\rho_j)_{outlet}} + K_4 L (\rho_j)_{outlet}$$

22) Reynolds Number

$$R_e = \frac{D_e G}{\mu}$$

23) Nusselt Number

$$Nu = \frac{h_i D_e}{K}$$

where $a = .030$ in the expression for h_i .

24) Density Equations

a) General

The friction pressure drop correlations used in the local and bulk boiling regimes assume that densities used to find elevation pressure drops are calculated according to the modified Martinelli-Nelson model. For this reason densities for pressure drop calculations are always found in the following manner:

For $H(x,y,z) \leq H_f$,

$\rho(x,y,z)$ is extracted from a table of ρ versus H .

For $H(x,y,z) > H_f$,

$$\rho(x,y,z) = R_g \rho_g + (1 - R_g) \rho_f.$$

Unfortunately, experimental evidence (Ref 10) indicates that for many cases, particularly those having high heat fluxes in relatively thin channels, these expressions provide a rather poor estimate of moderator density in the local boiling and low net quality regions. To provide a more flexible relationship for moderator density calculations in these regions, the model proposed by Maurer in (Ref 10) has been incorporated as a requestor option, and is discussed under b) below.

b) Optional Water Density Calculation for Local Boiling and Low Net Quality Regions

- 1) No void fraction, $H < H_{LB}$ and $H < H_f$.
- 2) The so-called "first region" of boiling, where a film of bubbles is built up until the entire boiling surface is covered by a single thickness bubble layer.
- 3) The "second region" of boiling, where an appreciable portion of the total heat input is used in the formation of vapor, and the void fraction increases at a relatively high rate.
- 4) At some point above the bulk saturation enthalpy, it appears that the dependence of vapor fraction on flow, heat flux, etc. becomes less marked, and that satisfactory correlation can be made on the basis of bulk enthalpy. The portion of the stick with an enthalpy greater than this value constitutes the fourth region.

Based on this model then, density is calculated in the following manner.

For $H(x,y,z) < H_{LB}$, (the enthalpy corresponding to initiation of local boiling),

$\rho(x,y,z)$ is taken from a table of ρ versus H as in a) above.

For $H_{LB} \leq H(x,y,z) < H_1$,

$\rho(x,y,z) = R_g^i(x,y,z)\rho_g + [1 - R_g^i(x,y,z)] \rho[H(x,y,z)]$, where $\rho[H(x,y,z)]$ is the density corresponding to $H(x,y,z)$ in the density versus enthalpy table, and

$$R_g^i(x,y,z) = \frac{\alpha \left\{ \frac{\phi(x,y,z)}{h_i} - T_w(x,y,z) + T_B(x,y,z) \right\} \frac{Pr}{Nu}}{T_{SAT} - T_B(x,y,z)}$$

where $\alpha = .030$ in the expression for h_i .

At an input value of R_g^i , R_{g1}^i , the vapor fraction corresponding to the establishment of a single thickness layer of bubbles is reached, and the corresponding bulk enthalpy is denoted as H_1 . In certain low heat flux cases certain difficulties can arise. If R_g^i has not reached R_{g1}^i when $H(x,y,z) \geq H_1^i$, underflow could occur; and to prevent this, H_1 is set equal to H_1^i . The requestor may supply a value for H_1^i in the input. If a value is not supplied or if the value is not at least one BTU/lb less than saturation, H_1^i it is set equal to $H_f - 1$ BTU/lb. If $T_{LB} > T_{SAT}$ for a mesh cube, the optional water density calculation is bypassed, and density for that mesh cube is calculated as described under a) above.

For $H_1 < H(x,y,z) < H_2$, R_g^i is found from

$$R_g^i(x,y,z) = R_{g1}^i + \left[\frac{H(x,y,z) - H_1}{H_2 - H_1} \right] [R_{g2}^i - R_{g1}^i],$$

that is, a linear interpolation is made between H_1 , R_{g1}^i , and H_2 , R_{g2}^i on the Martinelli-Nelson vapor fraction versus enthalpy curve.

For enthalpies above H_2 , the densities are calculated as described in a) above.

c) Density Averaging Routine

In the mesh cube where the transition from local boiling to net quality generation occurs, the density changes rather rapidly. In all other mesh cubes, it is adequate to assume that the mean density in the mesh cube is the same as the density

at the cube centerpoint. In fact, this assumption is satisfactory for all mesh cubes in elevation pressure drop calculations. However, in the calculation of moderator density, a mesh cube containing the point $H(x,y,z) = H_1$, (or H_f) may show an apparent failure to converge to a constant mean density because a small shift in H changes the mean density from one side to the other of H_1 (or H_f). To prevent this, the averaging routine below is applied.

Say H_a, H_b, H_c , etc., are consecutive enthalpies calculated up a channel (cf. fig. 1)

Let

$$H_a < H_1 < H_b \text{ where } H_1 = H_{SAT} \text{ for no local voids}$$

Then

$$H_{a+} = \frac{\phi(x,y,z)}{G \left(\frac{A_f}{A_{HT}} \right)} \left(\frac{\Delta Z_a}{2} \right) + H_a$$

If

$$H_a < H_1 \leq H_{a+}$$

Then

$$\begin{aligned} H_{a-} &= H_a - \frac{\phi(x,y,z)}{G \left(\frac{A_f}{A_{HT}} \right)} \frac{\Delta Z_a}{2} \\ \rho_a &= \frac{\rho(H_1) + \rho(H_{a-})}{2} \left\{ \frac{H_1 - H_{a-}}{H_{a+} - H_{a-}} \right\} \\ &\quad + \frac{\rho(H_1) + \rho(H_{a+})}{2} \left\{ \frac{H_{a+} - H_1}{H_{a+} - H_{a-}} \right\} \end{aligned}$$

If

$$H_{a+} < H_1 \leq H_b$$

Then

$$H_b^+ = H_b + \frac{\varphi(x, y, b)}{G \left(\frac{A_f}{A_{HT}} \right)} \frac{\Delta Z_b}{2}$$

$$\rho_b = \frac{\rho(H_1) + \rho(H_{a+})}{2} \left\{ \frac{H_1 - H_{a+}}{H_b^+ - H_{a+}} \right\} + \frac{\rho(H_{b+}) + \rho(H_1)}{2} \left\{ \frac{H_{b-} - H_1}{H_b^+ - H_{a+}} \right\}$$

Figure 1

APPENDIX C

Library

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

+99999+00
+50001+53250+15+00
+50002+0000000000+5110000000+4910000000+5126500000+4925000000+5149600000
+50003+4942000000+5168200000+4950000000+5178000000+5010000000+5214400000
+50004+5020000000+5226600000+5030000000+5240000000+5040000000+5250000000
+50005+5050000000+5262000000+5060000000+5273000000+5070000000+5283000000
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+50803+4942000000+5113200000+4950000000+5114200000+5010000000+5117000000
+50804+5020000000+5121300000+5030000000+5125800000+5040000000+5129200000
+50805+5050000000+5132200000+5060000000+5135800000+50700

[illegible]

[illegible]

APPENDIX D
Sample Problem

ABRAC - FORM 2

THERMAL STICK AND DIVISION DESCRIPTION

NOTE : LAST SET OF V,WW,XX,YY AND ZZ MUST ALL BE ZERO

BEGIN NUMBERING AT { 2000 FOR STICKS
3000 FOR DIVISIONS

V = DESCRIPTIVE No.

WW = LEFT BOUNDARY
YY = UPPER BOUNDARY

XX = RIGHT EOUNDARY
ZZ = LOWER BOUNDARY

Input Form

72

$$+3000+0 \quad \text{---} \quad 0$$
[illegible]

ABRAC - FORM 3

THERMAL STICK INPUT

NUMBERING { STICK # 1 = CDS. 4010, 4011 etc.
2 = CDS. 4020, 4021 etc.

Input form

+	4	0	0	0	+	0	0																0
---	---	---	---	---	---	---	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	---

	6	K _{IN}				17	K _{OUT}				28	σ _{IN}				39	σ _{OUT}				50	H _{IN}				61					72					
+	4	0	1	0	+	5028000000				+	5020000000				+	5055500000				+	5055500000				+	5351320000				+	0					0

	6	A				17	A _f /A _{HT} [*]				28	V _H /A _{HT}				39	D _e				50	T _{MAX}				61	PRINT	63					72					
+	4	0	1	1	+	4873178000				+	4841667000				+	4875008000				+	4916666700				+	0000000000				+		+	0					0

	6	K _{IN}				17	K _{OUT}				28	σ _{IN}				39	σ _{OUT}				50	H _{IN}				61					72					
+					+					+					+					+					+					+	0					0

	6	A				17	A _f /A _{HT} [*]				28	V _H /A _{HT}				39	D _e				50	T _{MAX}				61	PRINT	63					72					
+					+					+					+					+					+					+		+	0					0

	6	K _{IN}				17	K _{OUT}				28	σ _{IN}				39	σ _{OUT}				50	H _{IN}				61					72					
+					+					+					+					+					+					+	0					0

	6	A				17	A _f /A _{HT} [*]				28	V _H /A _{HT}				39	D _e				50	T _{MAX}				61	PRINT	63					72					
+					+					+					+					+					+					+		+	0					0

	6	K _{IN}				17	K _{OUT}				28	σ _{IN}				39	σ _{OUT}				50	H _{IN}				61					72					
+					+					+					+					+					+					+	0					0

	6	A				17	A _f /A _{HT} [*]				28	V _H /A _{HT}				39	D _e				50	T _{MAX}				61	PRINT	63					72					
+					+					+					+					+					+					+		+	0					0

ABRAC - FORM 4

DIVISION INPUT

NOTE : LAST G VALUE FOR EACH DIVISION MUST BE ZERO

+5000 CONTROL CARD NEEDED ONLY BEFORE 1st SET OF DIVISION INPUT

NUMBERING { DIVISIONS # 1 = CD 5010, 5011 etc.
2 = CD 5020, 5021 etc.

										72
+	5	0	0	0	+	0				0

CD. No.	6	K ₀	17	K ₁	28	K ₂	39	K ₃	50	K ₄	61	72
+	5	0	1	0	+	0000000000	+	0000000000	+	0000000000	+	0000000000

	6	G	17	G	28	G	39	G	50	G	61	G	71	
+	5	0	1	1	+	5640000000	+	5660000000	+	5680000000	+	5710000000	+	5712000000
+	5	0	1	2	+	5716000000	+	5718000000	+	5720000000	+	5722000000	+	5724000000
+	5	0	1	3	+	5728000000	+	5730000000	+	5732000000	+	5734000000	+	5736000000
+	5	0	1	4	+	5740000000	+	0000000000	+	0000000000	+	0000000000	+	0000000000
+					+		+		+		+		+	

	6	$\Delta P'$	17	$\Delta P'$	28	$\Delta P'$	39	$\Delta P'$	50	$\Delta P'$	61	$\Delta P'$	71	
+	5	0	1	5	+	5330000000	+	5340000000	+	5350000000	+	5355000000	+	5360000000
+	5	0	1	6	+	5370000000	+	5375000000	+	5380000000	+	5390000000	+	0000000000
+					+		+		+		+		+	
+					+		+		+		+		+	
+					+		+		+		+		+	

Input form

Input form

Input form

Input form

Input form

72

72727272

ABRAC - FORM 5 TABLE INPUT OPTION

BEGIN NUMBERING AT $\begin{cases} \text{6000 FOR RE vs fiso} \\ \text{8000 FOR X vs } \phi_{LO}^2 \\ \text{9000 FOR X vs Rg}_{M-N} \end{cases}$

+		0	0	0	+	0																	72
																				0			

CD. No.				6	X	17	Y	28	X	39	Y	50	X	61	Y	71	
+		0	0	1	+			+		+		+		+		+	0
+		0	0	2	+			+		+		+		+		+	0
+		0	0	3	+			+		+		+		+		+	0
+		0	0	4	+			+		+		+		+		+	0
+		0	0	5	+			+		+		+		+		+	0
+		0	0	6	+			+		+		+		+		+	0
+		0	0	7	+			+		+		+		+		+	0

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ABRAC-01 TEST PROBLEM 2 ITERATION1                                DRAC1
+01001+2+03+07+14+0+0+0+3+2+1+1+1+00+5718000000+5724720000+0000000000
+01002+5111800000+4950000000+0000000000+0000000000+0000000000+0000000000
+01003+5111000000+0000000000+0000000000+0000000000+0000000000+0000000000
+01004+4960000000+0000000000+0000000000+0000000000+0000000000+0000000000
+02001+5110000000+02+5135000000+07+0000000000+00+0000000000+00+0000000000
+03001+5210000000+02+5191440000+12+5210000000+14+0000000000+00+0000000000
+04000+0000000000000000000000000000000000000000000000000000000000000000
+04001+00+02+03+00+07+00+07+01+01+06+01+06+00+00+00+00+00+00+00+00+00+00
+04002+02+12+03+00+07+00+07+01+01+06+01+06+02+02+06+02+06+00+00+00+00+00
+04003+12+14+03+00+07+00+07+01+01+06+01+06+00+00+00+00+00+00+00+00+00+00
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+05004+0000000000+0000000000+0000000000+0000000000+0000000000+5343517200
+05005+0000000000+0000000000+0000000000+0000000000+0000000000+0000000000
+05006+0000000000+5574770000+5722630000+5265000000+5426417000+5249099100
+05007+5021840000+4713160000+5011840000+0000000000+0000000000+0000000000
+05008+0000000000+0000000000+0000000000+0000000000+0000000000+0000000000
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+12001+01+03+0000000000000000000000000000000000000000000000000000000000
+12002+0000000000+0000000000+0000000000+0000000000+0000000000+0000000000
+12003+02+03+0000000000000000000000000000000000000000000000000000000000
+12004+0000000000+0000000000+0000000000+0000000000+0000000000+0000000000
+13000+00000000000000000000000000000000000000000000000000000000000000

+14000+0+00000000000000000000000000000000000000000000000000000000000000
TEST PROBLEM 2 ITERATION 1
STANDARD ABRAC LIBRARY TAPE - FEBRUARY 22, 1960
+1000+00000000000000000000000000000000000000000000000000000000000000
+1001+01+03+0+1+1+1+1+1+1+0+1+00000000000000000000000000000000000000000000

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74

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+1002+5130000000+5410000000+0000000000+4541650000+0000000000+0000000000
+1003+5137380000+4980000000+5040000000+5354500000+5356600000+0000000000
+1101+0000000000+5410680000+5610600000+5393000000+5615000000+5383500000+0
+1102+5620000000+5369000000+5625000000+5349000000+5630000000+5326200000+0
+1103+5635000000+5229000000+0000000000+0000000000+0000000000+0000000000+0
+1201+5350000000+5355000000+5360000000+5362500000+5365000000+5367500000+0
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+3002+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00+00
+4000+000000000000000000000000000000000000000000000000000000000000000000
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+4011+4873178000+4841667000+4875008000+4916666700+0000000000+01+00000000
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+5032+5714000000+5716000000+5718000000+5720000000+5722000000+5724000000+0
+5033+5726000000+5728000000+5730000000+5732000000+5734000000+5736000000+0
+5034+5738000000+5740000000+0000000000+0000000000+0000000000+0000000000+0
+5035+5320000000+5325000000+5330000000+5335000000+5340000000+5345000000+0
+5036+5350000000+5360000000+5370000000+5380000000+5390000000+0000000000+0
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ABRAC-01 TEST PROBLEM 2 ITERATION1

DRAC1

TIME STEP NUMBER

00

OPERATORS INSTRUCTIONS-REMOVE TAPES AND SAVE,PUT A BLANK ON 6-HIT START.

COMP	GROUP	DIFFUSION	ABSORPTION	NU FISSION	REMOVAL
1	1	1.8215300	.00060033	.00000000	.03559823
1	2	.2743027	.01081406	.00000000	...
2	1	1.8785356	.00186520	.00220995	.01893621
2	2	.3915273	.06432722	.08681216	...
3	1	.0000000	.00000000	.00000000	.00000000
3	2	.0000000	.00000000	.00000000	...

GROUP	IT. NO.	PI	SHK1	SHK2	SHK3	SHK4	WMIN	OMEGA	WMAX	NMIN	NMAX
1	10	0.95467742	0.95509101	0.95468889	0.95468219	0.95467213	1.54256774	1.64893590	1.68918942	7	15
2	10	0.84033751	0.87655443	0.87224738	0.89594446	0.79119818	1.26031525	1.37273224	1.52732004	4	6

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.	OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
1	30.4573	18	1.1709								
2	24.6534	7	.8232								
1	1.662447	1.242595	1.037974		.251197	.000000	.000000	1.001378			

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.	OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
1	7.2520	15	.3146								
2	6.1890	7	.2741								
2	1.388360	1.219432	1.160502		.093428	.000000	.000000	.996988			

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.	OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
1	2.0168	15	.0972								
2	2.6589	7	.1302								
3	1.282692	1.212546	1.196192		.035669	.000000	.000000	.997031			

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.	OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.	SIGMA
1	.9797	14	.0489									
2	1.4861	8	.0453									
4	1.249730	1.211498	1.203884		.018921	1.353489	.000000	.997499	.522337			

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GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.				
1	.8205	14	.0363				
2	1.2461	7	.0609				
OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
5	1.228971	1.211325	1.207306	.008902	1.443687	.066641	.998516

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.				
1	.5261	14	.0232				
2	.6134	7	.0389				
OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
6	1.219773	1.211323	1.209149	.004386	1.400142	.034469	.999298

GROUP	INITIAL RES.	NO. INNER IT.	FINAL RES.				
1	.2518	14	.0120				
2	.3832	7	.0176				
OUTER IT.	MAX. LAMBDA	LAMBDA	MIN. LAMBDA	EPSILON SQ.	ALPHA	BETA	RENORM.
7	1.216981	1.211304	1.210089	.002474	.000000	.000000	1.000000

1	5 116517	5 179222	5 204060	COMPOSITION-INTEGRATED VOLUME
1	5 132686	5 622473	5 244164	COMPOSITION-INTEGRATED FLUX - GROUP 1
1	1 113877	1 347320	1 119653	COMPOSITION-AVERAGED FLUX - GROUP 1
1	5 114496	5 235869	5 114255	COMPOSITION-INTEGRATED FLUX - GROUP 2
1	982654	1 131607	555906	COMPOSITION-AVERAGED FLUX - GROUP 2

POWER

COMPOSITION PERCENTAGES	18	20	21	23	COMPOSITION TOTAL/REACTOR TOTAL
1	00000	00000	00000	00000	00000
2	1 10000	00000	00000	00000	1 10000
3	00000	00000	00000	00000	00000

NORMALIZATION FACTOR. 14 87711754

0ABRAC WILL OBTAIN INFORMATION FROM THE LIBRARY ENTITLED-
0 STANDARD ABRAC LIBRARY TAPE - FEBRUARY 22, 1960
0MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE
0MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE
0MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE

CHANNEL LOCATED IN ROW	5,COLUMN	4
CHANNEL LOCATED IN ROW	6,COLUMN	5
CHANNEL LOCATED IN ROW	6,COLUMN	6

BEGIN ABRAC OUTPUT

END OF THERMAL CALCULATIONS.

LABEL AND SAVE TAPES 2,3,7,8,9 AND FLUX TAPE IF REQUESTED.

FLUX IS ON TAPE 5. PRINT TAPE 10 OFF LINE.

TEST PROBLEM 2 ITERATION 1

PAGE 1

ABRAC WILL OBTAIN INFORMATION FROM THE LIBRARY ENTITLED-
STANDARD ABRAC LIBRARY TAPE - FEBRUARY 22, 1960

TEST PROBLEM 2 ITERATION 1

PAGE 2

THERMAL STICK CLASSIFICATION LAY-OUT

COLUMN	0	1	2	3	4	5	6	7
ROW	0	1	2	3	4	5	6	7
0	.....	.....	.....	.....	.....	.....	.....	.....
1	.000 000 000 000 000 000 000.							
2	.000 000 000 000 000 000 000.							
3	.000 000.001 001 001 001.000.							
4	.000 000.001 001 001 001.000.							
5	.000 000.001 001 001 001.000.							
6	.000 000.001 001 001 001.000.							
7	.000 000 000 000 000 000 000.							

TEST PROBLEM 2 ITERATION 1

DIVISION DESCRIPTION

COLUMN	0	1	2	3	4	5	6	7
ROW	0	.....	.....	.....	.....	.....	.....	.....
1								
2								
3								
4								
5								
6								
7								

TEST PROBLEM 2 ITERATION 1

PAGE 4

L= 3.0000 FT. P= 1000.00 LB/SG. IN. THETA= .0000 RMS/D= .00000 (F/F-ISO)-SAT= 2.6400

LOCAL VOIDS DATA-

ALFA= 1.3738 R(G1)= -1.8000 F(G2)= 4000 H2= 3.5660

TABLE OF TOTAL FLOW VS. AVAILABLE PRESSURE DROP-

W	DELTA-P	W	DELTA-P	W	DELTA-P
0000	4.1058	6.1000	3.9300	6.1300	3.8350
6.2000	3.6900	6.2500	3.4900	6.3000	3.2620
6.3500	2.2900	0000	0000	0000	0000

ASSUMED RANGE OF CORE TOTAL PRESSURE DROP-

3.5000	3.5500	3.6000	3.6250	3.6500	3.6750
3.7000	3.7500	3.8000	3.9000	0000	0000

TEST PROBLEM 2 ITERATION 1

PAGE 5

THERMAL STICK TYPE 1

AVG. TEMP= 532.91 DEG F. (1.-SIGMA SQD.+K)-INLET= 9720 (-1.+SIGMA SQD.+K)-OUTLET= -4920

H-IN= 513.20 BTU/LB. AREA= .00732 SQ. FT. HYDRAULIC DIAMETER= .01667 FT.

FLOW AREA/HEAT TRANSFER AREA PER FT.= .00417 FT. CORE VOL./HEAT TRANSFER AREA = .00750 FT.

TEST PROBLEM 2 ITERATION 1

PAGE 6

DIVISION NUMBER 1

K(0)= 0000 K(1)= 0000 K(2)= 0000 K(3)= 0000 K(4)= 0000

ASSUMED RANGE OF MASS VELOCITY-

6 4000	6 6000	6 8000	7 1000	7 1200	7 1400
7 1600	7 1800	7 2000	7 2200	7 2400	7 2600
7 2800	7 3000	7 3200	7 3400	7 3600	7 3800
7 4000	0000	-39 0000	6 4000	6 6000	6 8000

ASSUMED RANGE OF CORE PRESSURE DROP FOR THIS DIVISION-

3 3000	3 4000	3 5000	3 5500	3 6000	3 6500
3 7000	3 7500	3 8000	3 9000	0000	0000

DIVISION NUMBER 2

K(0)= 2 7200 K(1)= 0000 K(2)= 2 7300 K(3)= 0000 K(4)= 0000

ASSUMED RANGE OF MASS VELOCITY-

6 4000	6 6000	6 8000	7 1000	7 1200	7 1400
7 1600	7 1800	7 2000	7 2200	7 2400	7 2600
7 2800	7 3000	7 3200	7 3400	7 3600	7 3800
7 4000	0000	-39 0000	6 2000	6 4000	6 6000

ASSUMED RANGE OF CORE PRESSURE DROP FOR THIS DIVISION-

3 2500	3 3000	3 3500	3 4000	3 4500	3 5000
3 5500	3 6000	3 7000	3 8000	3 9000	0000

DIVISION NUMBER 3

K(0)= 3 1440 K(1)= 0000 K(2)= 3 1340 K(3)= 0000 K(4)= 0000

ASSUMED RANGE OF MASS VELOCITY-

6 2000	6 4000	6 6000	6 8000	7 1000	7 1200
7 1400	7 1600	7 1800	7 2000	7 2200	7 2400
7 2600	7 2800	7 3000	7 3200	7 3400	7 3600
7 3800	7 4000	0000	0000	0000	0000

ASSUMED RANGE OF CORE PRESSURE DROP FOR THIS DIVISION-

3 2000	3 2500	3 3000	3 3500	3 4000	3 4500
3 5000	3 6000	3 7000	3 8000	3 9000	0000

TEST PROBLEM 2 ITERATION 1

PAGE 7

FLUID PROPERTIES AND ASSOCIATED DATA-

T-SAT= 544.61 DEG. F. H-F= 542.41 BTU/LB. H-G=1191.80 BTU/LB V-F= .02159CU. FT./LB V-G=.44550CU. FT./LB

ENTHALPY VS. BULK TEMPERATURE

H	T	H	T	H	T	H	T	H	T
291.87	320.00	312.58	340.00	333.46	360.00	354.58	380.00	375.85	400.00
397.35	420.00	419.29	440.00	441.64	460.00	464.43	480.00	487.71	500.00
511.70	520.00	536.54	540.00	542.41	544.61	.00	.00	.00	.00

ENTHALPY VS. SPECIFIC VOLUME

H	V	H	V	H	V	H	V	H	V
291.87	.01758	312.58	.01780	333.46	.01803	354.58	.01828	375.85	.01855
397.35	.01884	419.29	.01917	441.64	.01953	464.43	.01991	487.71	.02035
511.70	.02085	536.54	.02144	542.41	.02159	.00	.00000	.00	.00000

BULK TEMPERATURE VS. THERMAL CONDUCTIVITY

T	K	T	K	T	K	T	K	T	K
320.00	.396900	340.00	.394700	360.00	.391900	380.00	.388500	400.00	.384000
420.00	.378700	440.00	.372800	460.00	.366400	480.00	.359500	500.00	.351000
520.00	.341000	540.00	.330000	544.61	.327400	.00	.000000	.00	.000000

BULK TEMPERATURE VS. PRANDTL NUMBER

T	PR	T	PR	T	PR	T	PR	T	PR
320.00	1.11000	340.00	1.04000	360.00	.99700	380.00	.95800	400.00	.92400
420.00	.89700	440.00	.87800	460.00	.86600	480.00	.86100	500.00	.86100
520.00	.87000	540.00	.89900	544.61	.91100	.00	.00000	.00	.00000

BULK TEMPERATURE VS. VISCOSITY

T	MU	T	MU	T	MU	T	MU	T	MU
320.00	.42600	340.00	.39600	360.00	.37200	380.00	.35100	400.00	.33000
420.00	.31200	440.00	.29600	460.00	.28200	480.00	.27000	500.00	.25700
520.00	.24600	540.00	.23500	544.61	.23300	.00	.00000	.00	.00000

REYNOLDS NUMBER VS. ISOTHERMAL FRICTION FACTOR

RE	F-ISO	RE	F-ISO	RE	F-ISO	RE	F-ISO	RE	F-ISO
10000	.030807	15000	.027309	30000	.023210	60000	.019810	100000	.018110
200000	.016110	300000	.014512	500000	.013213		.000000		.000000

TEST PROBLEM 2 ITERATION 1

PAGE 8

8UA3ITY VS. 4A9TI5E33I 5E3S65 FACT69

X	PQ1-SQ	X	PQR-SQ	X	PHI-SQ	X	PHI-SQ	X	PHI-SQ
.000000	1.0000	.010000	1.4700	.025000	2.0300	.042000	2.6400	.050000	2.9200
.100000	4.9000	.200000	7.9500	.300000	11.0000	.400000	14.1000	.500000	16.9000
.600000	19.8000	.700000	22.0000	.800000	24.0000	.900000	23.8000	1.000000	16.2000

QUALITY VS. VOID FRACTION

X	R	X	R	X	R	X	R	X	R
.000000	.000000	.010000	.170000	.025000	.308000	.042000	.440000	.050000	.477000
.075000	.554000	.100000	.617000	.150000	.678000	.200000	.729000	.250000	.766000
.300000	.797000	.350000	.821000	.400000	.843000	.500000	.878000	.600000	.908000
.700000	.931000	.800000	.956000	.500000	.978000	1.000000	1.000000	.000000	.000000

TEST PROBLEM 2 ITERATION 1

PAGE 9

MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE

CHANNEL LOCATED IN ROW 5 COLUMN 4

PRESSURE DROP	FLOW
3 21932205	6 40000000
3 27703820	6 60000000
3 31702954	6 80000000
3 36001205	7 10000000
3 39328289	7 12000000
3 43530612	7 14000000
3 47931200	7 16000000
3 52021113	7 18000000
3 65880666	7 20000000
3 58271409	7 22000000
3 65357327	7 24000000
3 73331417	7 26000000
3 81731323	7 28000000
3 90683692	7 30000000
4 10013232	7 32000000
4 10998591	7 34000000
4 12022059	7 36000000
4 13081245	7 38000000
4 14173753	7 40000000

TEST PROBLEM 2 ITERATION 1

PAGE 10

MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE

CHANNEL LOCATED IN ROW 6,COLUMN 5

PRESSURE DROP	FLOW
3 21403715	6 40000000
3 26868325	6 60000000
3 30591970	6 80000000
3 34813143	7 10000000
3 38591221	7 12000000
3 41347837	7 14000000
3 45228029	7 16000000
3 49055465	7 18000000
3 60204928	7 20000000
3 57810851	7 22000000
3 65326084	7 24000000
3 73296710	7 26000000
3 81696260	7 28000000
3 90646525	7 30000000
4 10009203	7 32000000
4 10994260	7 34000000
4 12017433	7 36000000
4 13076330	7 38000000
4 14168555	7 40000000

TEST PROBLEM 2 ITERATION 1

PAGE 11

MULTIPLE VALUED PRESSURE DROP VS. FLOW TABLE

CHANNEL LOCATED IN ROW 6, COLUMN 6

PRESSURE DROP	FLOW
3 21307810	6 40000000
3 26714437	6 60000000
3 30391349	6 80000000
3 34603530	7 10000000
3 38751164	7 12000000
3 41979876	7 14000000
3 45834019	7 16000000
3 46306769	7 18000000
3 61382372	7 20000000
3 57805940	7 22000000
3 65320513	7 24000000
3 73290544	7 26000000
3 81690142	7 28000000
3 90639826	7 30000000
4 10008478	7 32000000
4 10993479	7 34000000
4 12016599	7 36000000
4 13075444	7 38000000
4 14167618	7 40000000

TEST PROBLEM 2 ITERATION 1

PAGE 12

BEGIN ABRAC OUTPUT

INTEGRATED CHANGE IN WATER CONTENT= .11654490

MAXIMUM PERCENT CHANGE	AT COLUMN NO.	ROW NO.	PLANE NO.
.46546937	3	4	9
.46883423	4	4	12
.50098802	3	3	8
.51192126	3	4	10
.54684901	3	4	11
.56354421	3	3	9
.57385143	3	4	12
.60155222	3	3	10
.62276487	3	3	11
.64039827	3	3	12

REACTOR-	TOTAL FLOW	TOTAL PRESSURE DROP
6	20745930	3 66016278

CORE CHARACTERISTIC CURVE-

TOTAL FLOW	TOTAL PRESSURE DROP
6 13087458	3 50000000
6 15356231	3 54999999
6 17556307	3 59999999
6 18966348	3 62499999
6 20351974	3 64999999
6 21321089	3 67500000
6 22303745	3 69999999
6 24553064	3 74999999
6 26698348	3 79999999
6 30447360	3 90000000

DIVISION NO.	MIXED EXIT ENTHALPY	TOTAL FLOW	PRESSURE DROP
1	542.0130	6 12048862	3 66016278
2	555.1722	5 61479502	3 51616279
3	606.3751	5 25491177	3 37216278

TOTAL HEAT LOAD= 7.84482666

MASS FLOW RATE INTEGRATED OVER-

TOTAL CORE	=	6 20791893
THERMAL STICK TYPE 1	=	6 20791893
DIVISION NO. 1	=	6 12049432
DIVISION NO. 2	=	5 61897552
DIVISION NO. 3	=	5 25527063

TEST PROBLEM 2 ITERATION 1

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MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 3, COLUMN 3

6	20000000	3	16754098
6	40000000	3	26418718
6	60000000	3	33862724
6	80000000	3	39180084
7	10000000	3	44833728
7	12000000	3	49131237
7	14000000	3	54988030
7	16000000	3	60027883
7	18000000	3	66316981
7	20000000	3	70443870
7	22000000	3	76881204
7	24000000	3	79577517
7	26000000	3	85511872
7	28000000	3	99940825
7	30000000	4	10893418
7	32000000	4	10046181
7	34000000	4	11033165
7	36000000	4	12058136
7	38000000	4	13118752
7	40000000	4	14212722

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 4, COLUMN 3

6	20000000	3	15604769
6	40000000	3	24349609
6	60000000	3	31257986
6	80000000	3	35661609
7	10000000	3	40364454
7	12000000	3	45071378
7	14000000	3	49648138
7	16000000	3	55164700
7	18000000	3	58453601
7	20000000	3	64168323
7	22000000	3	67384001
7	24000000	3	79196443
7	26000000	3	87238766
7	28000000	3	81892790
7	30000000	3	90854075
7	32000000	4	10030959
7	34000000	4	11016938
7	36000000	4	12041397
7	38000000	4	13101790
7	40000000	4	14195482

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 4, COLUMN 4

6	20000000	3	14510864
6	40000000	3	22373389
6	60000000	3	28403026
6	80000000	3	32635072
7	10000000	3	36595392
7	12000000	3	40736863
7	14000000	3	45113333
7	16000000	3	48929244
7	18000000	3	53252136
7	20000000	3	54962234
7	22000000	3	68105068
7	24000000	3	65383124
7	26000000	3	73360096
7	28000000	3	81762696

TEST PROBLEM 2 ITERATION 1

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7	30000000	3	90714284
7	32000000	4	10016548
7	34000000	4	11002157
7	36000000	4	12025868
7	38000000	4	13085291
7	40000000	4	14178032

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 5, COLUMN 3

6	40000000	3	23840743
6	60000000	3	30538073
6	80000000	3	35132519
7	10000000	3	39247833
7	12000000	3	44380209
7	14000000	3	48099552
7	16000000	3	53476112
7	18000000	3	57768375
7	20000000	3	61391542
7	22000000	3	65640162
7	24000000	3	70287383
7	26000000	3	74001765
7	28000000	3	81860280
7	30000000	3	90818706
7	32000000	4	10027165
7	34000000	4	11013080
7	36000000	4	12037537
7	38000000	4	13097689
7	40000000	4	14191144

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 5, COLUMN 4

6	40000000	3	21932205
6	60000000	3	27703820
6	80000000	3	31702954
7	10000000	3	36001205
7	12000000	3	39328289
7	14000000	3	43530612
7	16000000	3	47931200
7	18000000	3	52021113
7	20000000	3	65880666
7	22000000	3	58271409
7	24000000	3	65357327
7	26000000	3	73331417
7	28000000	3	81731323
7	30000000	3	90683692
7	32000000	4	10013232
7	34000000	4	10998591
7	36000000	4	12022059
7	38000000	4	13081245
7	40000000	4	14173753

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 5, COLUMN 5

6	40000000	3	21500018
6	60000000	3	27021603
6	80000000	3	30794041
7	10000000	3	35021399
7	12000000	3	38858025
7	14000000	3	41781469
7	16000000	3	45755148
7	18000000	3	49912642
7	20000000	3	59260066
7	22000000	3	57815764

TEST PROBLEM 2 ITERATION 1

7	24000000	3	65331664
7	26000000	3	73302927
7	28000000	3	81702384
7	30000000	3	90653230
7	32000000	4	10009931
7	34000000	4	10995041
7	36000000	4	12018267
7	38000000	4	13077217
7	40000000	4	14169492

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 6, COLUMN 3

6	40000000	3	23730673
6	60000000	3	30379843
6	80000000	3	34946420
7	10000000	3	38994745
7	12000000	3	44120983
7	14000000	3	47710478
7	16000000	3	53083786
7	18000000	3	57330730
7	20000000	3	60692734
7	22000000	3	66289352
7	24000000	3	71698574
7	26000000	3	73831455
7	28000000	3	81853026
7	30000000	3	90810888
7	32000000	4	10026320
7	34000000	4	11012274
7	36000000	4	12036675
7	38000000	4	13096774
7	40000000	4	14190176

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 6, COLUMN 4

6	40000000	3	21835873
6	60000000	3	27552259
6	80000000	3	31501724
7	10000000	3	35782567
7	12000000	3	38987576
7	14000000	3	43156998
7	16000000	3	47496207
7	18000000	3	51420789
7	20000000	3	54019377
7	22000000	3	58131961
7	24000000	3	65351638
7	26000000	3	73325107
7	28000000	3	81724453
7	30000000	3	90676943
7	32000000	4	10012501
7	34000000	4	10997805
7	36000000	4	12021219
7	38000000	4	13080353
7	40000000	4	14172809

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 6, COLUMN 5

6	40000000	3	21403715
6	60000000	3	26868325
6	80000000	3	30591970
7	10000000	3	34813143
7	12000000	3	38591221
7	14000000	3	41347837
7	16000000	3	45228029

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TEST PROBLEM 2 ITERATION 1

7 18000000	3 49055465
7 20000000	3 60204928
7 22000000	3 57810851
7 24000000	3 65326084
7 26000000	3 73296710
7 28000000	3 81696260
7 30000000	3 90646525
7 32000000	4 10009203
7 34000000	4 10994260
7 36000000	4 12017433
7 38000000	4 13076330
7 40000000	4 14168555

MASS VELOCITY VS. CORE PRESSURE DROP FOR STICK AT ROW 6, COLUMN 6

6 40000000	3 21307810
6 60000000	3 26714437
6 80000000	3 30391349
7 10000000	3 34603530
7 12000000	3 38791164
7 14000000	3 41979876
7 16000000	3 45834019
7 18000000	3 46306769
7 20000000	3 61382372
7 22000000	3 57805940
7 24000000	3 65320513
7 26000000	3 73290544
7 28000000	3 81690142
7 30000000	3 90639826
7 32000000	4 10008478
7 34000000	4 10993479
7 36000000	4 12016599
7 38000000	4 13075444
7 40000000	4 14167618

DIVISION NO. 1 FLOW VS. CORE PRESSURE DROP

5 36151235	3 30000000
5 61889180	3 40000000
5 87144090	3 50000000
5 96627541	3 54999999
6 10534255	3 59999999
6 11900557	3 65000000
6 12630208	3 69999999
6 13508549	3 74999999
6 14126612	3 79999999
6 15287142	3 90000000

DIVISION NO. 2 FLOW VS. CORE PRESSURE DROP

5 17625829	3 25000000
5 24554396	3 30000000
5 32888220	3 35000000
5 42448243	3 40000000
5 50948069	3 45000000
5 59607788	3 50000000
5 65397980	3 54999999
5 72700689	3 59999999
5 90193940	3 69999999
6 10685634	3 79999999
6 10916914	3 90000000

DIVISION NO. 3 FLOW VS. CORE PRESSURE DROP

TEST PROBLEM 2 ITERATION 1

PAGE 17

4	88387462	3	20000000
5	12406762	3	25000000
5	16622534	3	30000000
5	22700623	3	35000000
5	28996208	3	40000000
5	35099776	3	45000000
5	41745990	3	50000000
5	54033133	3	59999999
5	65734541	3	69999999
5	73267634	3	79999999
5	84945959	3	90000000

DIVISION NO. 1 FLOW VS. PLENUM LOSS

5	36151235	00000000
5	61889180	00000000
5	87144090	00000000
5	96627541	00000000
6	10534256	00000000
6	11900557	00000000
6	12630208	00000000
6	13508549	00000000
6	14126612	00000000
6	15287142	00000000

DIVISION NO. 2 FLOW VS. PLENUM LOSS

5	17625829	3	14400000
5	24554396	3	14400000
5	32888220	3	14400000
5	42448243	3	14400000
5	50948069	3	14400000
5	59607788	3	14400000
5	65397980	3	14400000
5	72700689	3	14400000
5	90193940	3	14400000
6	10065634	3	14400000
6	10916914	3	14400000

DIVISION NO. 3 FLOW VS. PLENUM LOSS

4	88387462	3	28800000
5	12406762	3	28800000
5	16822534	3	28800000
5	22700623	3	28800000
5	28996208	3	28800000
5	35099776	3	28800000
5	41745990	3	28800000
5	54033133	3	28800000
5	65734541	3	28800000
5	73267634	3	28800000
5	84945959	3	28800000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY

PLANE 0 PAGE 18

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 1 PAGE 19

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7							

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 2 PAGE 20

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	517.7301	516.6219	515.0813	514.5064	.0000
4	.0000	.0000	516.6219	515.7530	514.6219	514.2457	.0000
5	.0000	.0000	515.0813	514.6299	514.5403	514.2106	.0000
6	.0000	.0000	514.5064	514.2457	514.2106	514.2028	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 3 PAGE 21

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	527.4879	523.8553	519.0386	517.2512	.0000
4	.0000	.0000	523.8558	521.0273	517.5663	516.3900	.0000
5	.0000	.0000	519.0386	517.5663	517.2752	516.2696	.0000
6	.0000	.0000	517.2512	516.3900	516.2696	516.2432	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 5 PAGE 23

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	553.3328	542.6780	529.2848	524.3497	.0000
4	.0000	.0000	542.6780	534.4446	524.9888	521.8025	.0000
5	.0000	.0000	529.2848	524.9888	524.1426	521.4321	.0000
6	.0000	.0000	524.3497	521.8025	521.4321	521.3506	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 6 PAGE 24

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	568.9056	554.0151	535.4555	528.6245	.0000
4	.0000	.0000	554.0151	542.5223	529.4568	525.0603	.0000
5	.0000	.0000	535.4555	529.4568	528.2756	524.5388	.0000
6	.0000	.0000	528.6245	525.0603	524.5388	524.4241	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 7 PAGE 25

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	585.0135	565.7418	541.8383	533.0462	.0000
3	.0000	.0000	565.7418	550.8776	534.0783	528.4301	.0000
4	.0000	.0000	541.8383	534.0783	532.5507	527.7523	.0000
5	.0000	.0000	533.0462	528.4301	527.7523	527.6032	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7							

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 8 PAGE 26

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	600.6453	577.1219	548.0324	537.3373	.0000
3	.0000	.0000	577.1219	558.9859	538.5633	531.7003	.0000
4	.0000	.0000	548.0324	538.5633	535.6995	530.8709	.0000
5	.0000	.0000	537.3373	531.7003	530.8709	520.6884	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7							

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY

PLANE 9 PAGE 27

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	614.8213	587.4426	553.6501	541.2290	.0000
4	.0000	.0000	587.4426	566.3399	542.6310	534.6664	.0000
5	.0000	.0000	553.6501	542.6310	540.4624	533.6995	.0000
6	.0000	.0000	541.2290	534.6664	533.6995	533.4868	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY

PLANE 10 PAGE 28

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	626.7199	586.1116	558.3695	544.4990	.0000
3	.0000	.0000	596.1116	572.5226	546.0520	537.1610	.0000
4	.0000	.0000	558.3599	546.0520	543.6282	536.0794	.0000
5	.0000	.0000	544.4990	537.1610	536.0794	535.3414	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7							

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 11 PAGE 29

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	636.6108	603.4442	562.3813	547.2813	.0000
4	.0000	.0000	603.4442	577.8695	549.0286	539.3348	.0000
5	.0000	.0000	562.3813	549.0286	546.4006	538.1668	.0000
6	.0000	.0000	547.2813	539.3348	538.1668	537.9098	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY

PLANE 12 PAGE 30

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE BULK ENTHALPY PLANE 13 PAGE 31

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 2

POINT-WISE WATER DENSITY

PLANE 0 PAGE 32

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 1 PAGE 33

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY PLANE 2 PAGE 34

	1	2	3	4	5	6	7
	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	47.6172	47.6760	47.7579	47.7885	.0000
3	.0000	.0000	47.6760	47.7221	47.7819	47.8024	.0000
4	.0000	.0000	47.7579	47.7819	47.7867	47.8043	.0000
5	.0000	.0000	47.7885	47.8024	47.8043	47.8047	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7							

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY PLANE 3 PAGE 35

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	44.9874	47.2951	47.5481	47.6426	.0000
4	.0000	.0000	47.2951	47.4433	47.6259	47.6883	.0000
5	.0000	.0000	47.5481	47.6259	47.6413	47.6947	.0000
6	.0000	.0000	47.6426	47.6883	47.6947	47.6961	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY PLANE 4 PAGE 36

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	39.7817	45.8217	47.3028	47.4717	.0000
4	.0000	.0000	45.8217	47.1240	47.4473	47.5576	.0000
5	.0000	.0000	47.3028	47.4473	47.4759	47.5699	.0000
6	.0000	.0000	47.4717	47.5576	47.5699	47.5727	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1.

POINT-WISE WATER DENSITY PLANE 5 PAGE 37

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	33.8740	41.8395	47.0133	47.2693	.0000
4	.0000	.0000	41.8395	45.9287	47.2360	47.4026	.0000
5	.0000	.0000	47.0133	47.2360	47.2801	47.4220	.0000
6	.0000	.0000	47.2693	47.4026	47.4220	47.4263	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 6

PAGE

38

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	27.3358	35.5622	46.2530	47.0474	.0000
4	.0000	.0000	35.5622	42.1297	47.0044	47.2323	.0000
5	.0000	.0000	46.2530	47.0044	47.0654	47.2595	.0000
6	.0000	.0000	47.0474	47.2323	47.2595	47.2655	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 7 PAGE 39

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	23.1763	26.8364	42.7686	46.8199	.0000
4	.0000	.0000	28.8364	37.3618	46.7672	47.0574	.0000
5	.0000	.0000	42.7686	46.7672	46.8453	47.0925	.0000
6	.0000	.0000	46.8199	47.0574	47.0925	47.1002	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY PLANE 9 PAGE 41

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	18.5056	22.6685	35.7715	43.6220	.0000
4	.0000	.0000	22.6685	28.6879	42.3129	46.7372	.0000
5	.0000	.0000	35.7715	42.3129	44.2519	46.7865	.0000
6	.0000	.0000	43.6220	46.7372	46.7865	46.7974	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 10 PAGE 42

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	17.5204	21.0463	33.0645	41.0201	.0000
4	.0000	.0000	21.0463	26.0345	40.1294	46.6073	.0000
5	.0000	.0000	33.0645	40.1294	41.5196	46.6652	.0000
6	.0000	.0000	41.0201	46.6073	46.6652	46.6773	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 11 PAGE 43

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	16.7015	19.7922	30.7638	39.4244	.0000
4	.0000	.0000	19.7922	24.6696	38.4222	46.4869	.0000
5	.0000	.0000	30.7638	38.4222	39.9295	46.5515	.0000
6	.0000	.0000	39.4244	46.4869	46.5515	46.5658	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY

PLANE 12 PAGE

44

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

POINT-WISE WATER DENSITY PLANE 13 PAGE 45

	1	2	3	4	5	6	7
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000

TEST PROBLEM 2 ITERATION 1

STICK-WISE MASS FLOW

PLANE 0 PAGE 46

	1	2	3	4	5	6	7
1	0000	0000	0000	0000	0000	0000	0000
2	0000	0000	0000	0000	0000	0000	0000
3	0000	0000	6 7261	6 8661	7 1531	7 2190	0000
4	0000	0000	6 8661	7 1030	7 1780	7 2417	0000
5	0000	0000	7 1531	7 1780	7 1836	7 2417	0000
6	0000	0000	7 2190	7 2417	7 2417	7 2417	0000
7	0000	0000	0000	0000	0000	0000	0000

ABRAC EDITS COMPLETE.

APPENDIX E

G Dependency

It appears from recent tests conducted at Bettis that void fraction data exhibits a dependence on the mass flow rate, G . At present these data are correlated only in terms of pressure and steam quality. An attempt has been made to provide for use of G dependent correlations when they eventually become available. Due to lack of data at this time, no attempt has been made to verify the correctness of this portion of the code. If (and when) such data becomes available, such attempts may be made.

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