THERMAL-HYDRAULIC ANALYSIS OF A SPECTRAL SHIFT REACTOR CORE

by

Brian Damiano

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE
in
Nuclear Science and Engineering

APPROVED:

Milton C. Edlund, Chairman

Ronald J. Onega

James R. Thomas

December 1982

Blacksburg, Virginia

ACKNOWLEDGEMENTS

I would like to thank the Mechanical Engineering Department of VPI&SU for providing me with an assistantship during my graduate studies. I would also like to thank Dr. Milton C. Edlund for serving as my major professor and Professors Ronald J. Onega and James R. Thomas for being on my advisory committee.

I am deeply indebted to the Nu Prime Chapter of the Kappa Sigma Fraternity for the fellowship and brotherhood I have shared during the past four years. Finally, I want to acknowledge my family for their love and support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Improved utilization of our uranium resources is needed due to the limited supply of economically recoverable uranium. The demand for uranium ore could be greatly reduced by using the uranium-plutonium fuel cycle more efficiently. One alternative to present pressurized water reactors (PWR's) which offers improved fuel cycle utilization is the spectral shift reactor. Spectral shift reactors are fission reactors in which long term reactivity is controlled by changing (shifting) the average energy of the neutron spectrum.

In close-packed fuel rod lattices using low-enriched uranium fuel, the reactivity is inversely proportional to the average energy of the neutron spectrum [1]. Shifting the neutron spectrum to higher energies increases the neutron flux in the resonance energy region. Consequently, the resonance absorption in fertile material is also increased. The reactivity decreases because the absorption cross-section of fertile material is higher than the absorption cross-section of fuel at resonance energies.

The neutron energy spectrum may be shifted by changing the fuel to water ratio (FTWR) of the fuel rod lattice. Increasing the FTWR reduces the amount of moderator in the fuel rod lattice, shifts the neutron spectrum to higher energies, and reduces the reactivity. Conversely, lowering the FTWR increases the amount of moderator in the fuel rod lattice, shifts the neutron spectrum to lower energies, and increases the reactivity. The FTWR may be adjusted by placing blank zirconium rods in the fuel lattice. Removing the blank rods increases the water volume in the lattice, lowering the FTWR. This method of changing the FTWR to shift the neutron spectrum over the core lifetime is called mechanical spectral shift control.

The major advantages of spectral shift reactors over PWR's are a greater conversion ratio and a longer core lifetime. Previous work has shown that the conversion ratio and core lifetime are increased if the neutron energy spectrum is epithermal at the beginning of the core life and is thermalized as the core ages [1]. It has been estimated that conversion ratios of approximately 0.9 and fuel burnups of 42,000 MWD/MT can be obtained using plutonium recycle fuel in a close-packed lattice [2]. A computer code, RFD-1, has been developed recently to calculate criticality and fuel depletion for reactor cores using mechanical spectral shift. Preliminary results using RFD-1 indicate that higher fuel burnups and greater conversion ratios (compared to PWR's) are characteristics of spectral shift reactors [3].

This thesis presents a thermal-hydraulic analysis of a conceptual mechanical spectral shift reactor core. The conceptual reactor core used in the analysis has a tighter fuel lattice than a standard PWR core. The FTWR can be changed from 1.25 to 0.75 during the core lifetime by removing blank rods from the core. Each fuel assembly is enclosed by a hexagonal can and the coolant flowrate through each fuel assembly can be independently selected. The thermal-hydraulics of tight fuel rod lattices have been studied previously and it has been concluded that these lattices meet Nuclear Regulatory Commission thermal-hydraulic guidelines [2, 4]. The ability to handle the varying FTWR's of reactor cores that use mechanical spectral shift is the unique feature of this thermal-hydraulic analysis.

The work described in this thesis had three objectives. The first objective was to create a computer code which performs a thermal-hydraulic analysis of reactors that use mechanical spectral shift. This code should be useful during future designs of such reactors. The second objective was to find if the enthalpy increase through each fuel assembly could be made equal by varying the coolant flowrate through each fuel assembly. The third objective was to determine the effect of different FTWR's on the coolant properties at the reactor coolant outlet. The work performed to accomplish these objectives has four main elements. The conceptual reactor core design was developed first. Once the reactor core and fuel assembly design were known, the thermal-hydraulic analysis computer program was written. Sample cases were analyzed by the computer program and conclusions and recommendations were formed based on the sample case results.

CHAPTER 2

REACTOR CORE DESCRIPTION

2.1 Design Considerations

The conceptual design of the reactor core used in the thermal-hydraulic analysis is based on the following design considerations:

1) The reactor core should be cylindrical, with approximately the same dimensions as a PWR core.
2) The FTWR should range from at least 1.25 to no more than 0.75.
3) Each fuel assembly is to be enclosed in a hex can. The coolant flowrate through each fuel assembly is to be determined by an orifice at the coolant inlet.
4) Conventional fuel rods should be used. The outside and inside diameters were given to be 0.38 in (0.0097 m) and 0.33 in (0.0084 m) respectively.
5) The minimum fuel rod spacing is set at 0.07 in (0.0018 m).
6) The fuel rods should be in a hexagonal lattice and should be separated by helical wire wraps.

The selection of sizes for each component was based solely on geometrical considerations. Thermal expansion, stress, and vibration were not considered. Since this is a conceptual design intended only for thermal-hydraulic analysis, no provisions have been made for control rods or instrumentation. Local variations of neutron flux, such as thermal flux peaking, have also been neglected.

2.2 Fuel Assembly Description

The fuel assembly design used in this analysis is shown in Figs. 2.1 and 2.2. Geometric details of the fuel assembly are listed in Table 2.1.

The fuel assembly consists of a lattice of fuel rods which surround seven blank, or void, rods. The void rods are separated from the reactor coolant by a stainless steel void wall. The entire fueled region of each fuel assembly is surrounded by a similar void wall. Six blank, or void, plates are located between the outer void wall and the stainless steel hex can.

The fuel rods use uranium dioxide fuel pellets encased in zircalloy cladding. The fuel rods are arranged in a hexagonal lattice with a 0.08 in (0.0020 m) spacing between fuel rods. A 0.08 in (0.0020 m) wire wrap spacer with an axial lead of 9 in (0.220 m) is wound around each fuel rod.

The void rods and void plates are used to vary the FTWR of the fuel assembly. By removing void rods or void plates, more core volume is occupied by moderator, reducing the FTWR. Void rods are used for fine adjustment of the FTWR. Void plates, being larger, are used to obtain medium and low FTWR's.

Seven void rods are placed symmetrically within each fuel assembly. The void rod shape was chosen so the void rod would fit easily into the fuel rod lattice.

Short and long void plates occupy opposite corners of the fuel assembly. The dimensions of the two different void plates were selected

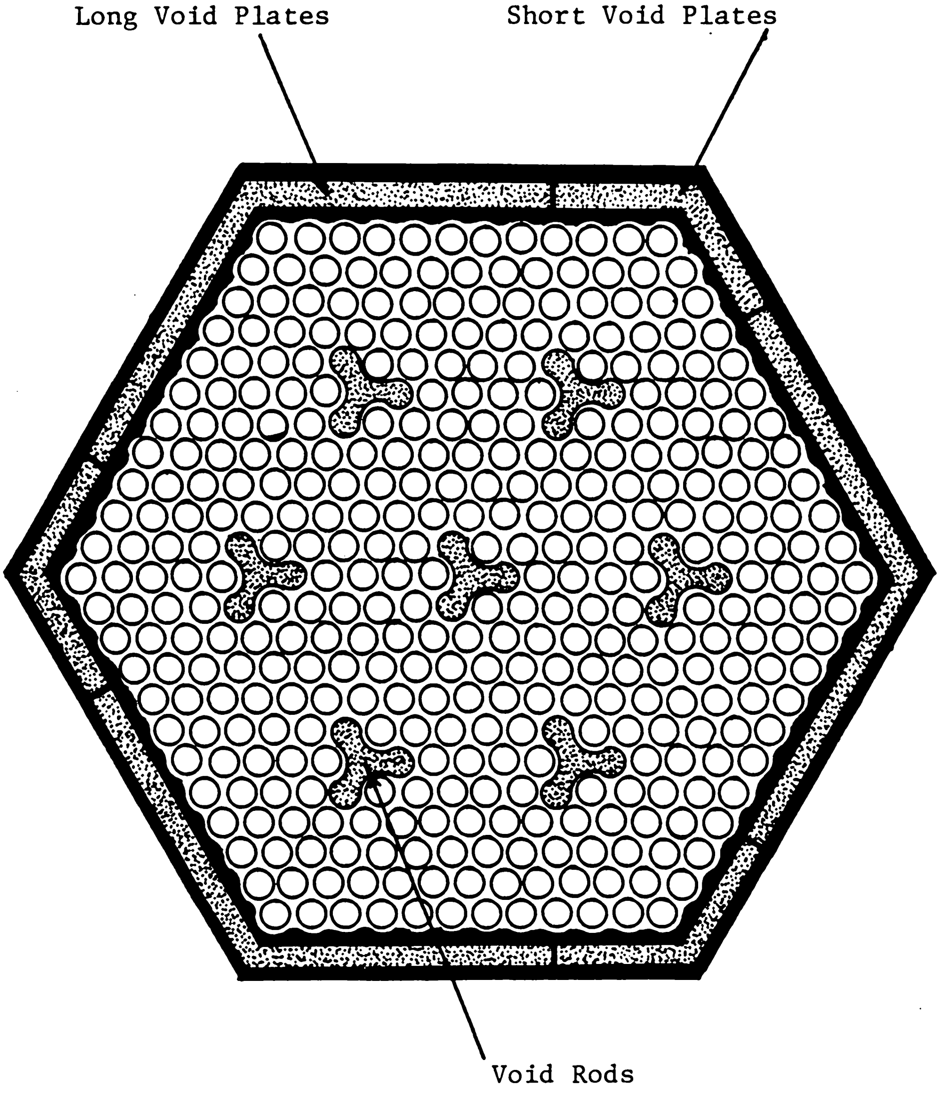


Figure 2.1 Fuel Assembly Cross Section

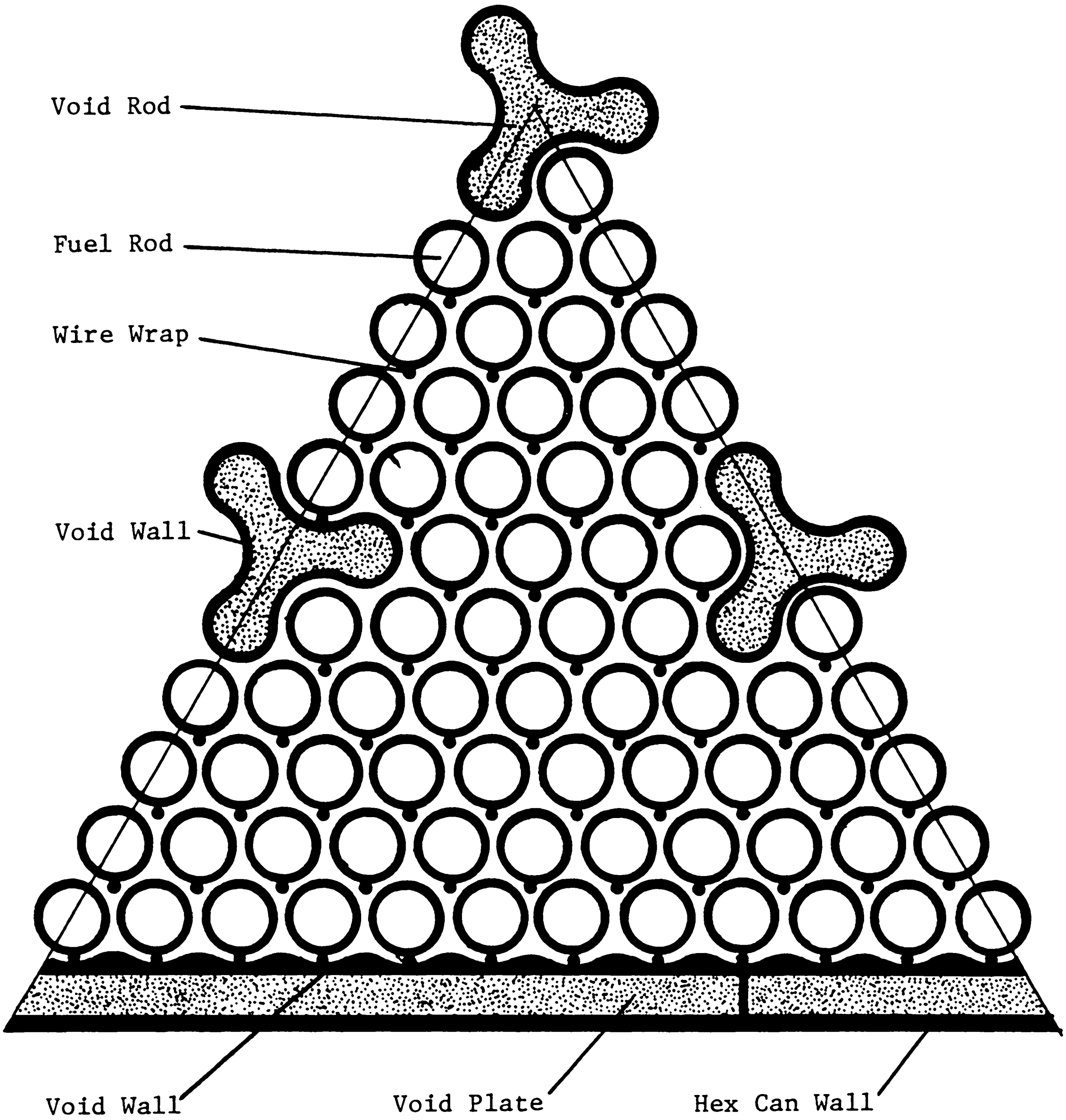


Figure 2.2 Detailed Cross Section of Fuel Assembly

Table 2.1 Geometric Details of Fuel Assemblies

Number of Fuel Rods	369
Number of Void Rods	7
Number of Shord Void Plates	3
Number of Long Void Plates	3
Fuel Assembly Height	120. in (3.05 m)
Dimension of One Side of the Fuel Assembly	6.07 in (0.154 m)
Fuel Rod Outside Diameter	0.38 in (0.0097 m)
Fuel Rod Inside Diameter	0.33 in (0.0084 m)
Fuel Rod Lattice Pitch	0.46 in (0.0117 m)
Wire Wrap Axial Lead	9.0 in (0.227 m)
Reactor Coolant Flow Area	25.02 in^2 (0.0161 m^2)
Short Void Plate Length (Including Corner)	3.75 in (0.0953 m)
Long Void Plate Length (Including Corner)	7.14 in (0.181 m)
Void Plate Thickness	0.4 in (0.0102 m)
Void Rod Cross Sectional Area	0.45 in^2 (0.00029 m^2)
Short Void Plate Cross Sectional Area	1.61 in^2 (0.00104 m^2)
Long Void Plate Cross Sectional Area	2.96 in^2 (0.00191 m^2)
Void Wall Thickness	0.025 in (0.00064 m)
Hex Can Thickness	0.1 in (0.0025 m)
Range of Fuel to Water Ratio	1.25 - 0.75

so the short void plates would provide moderate changes in the FTWR while the long void plates would provide large FTWR changes.

The void walls perform three functions. The void walls are guide tubes during the removal or insertion of void rods or void plates. After a void rod or void plate has been removed, the moderator which replaces the void rod or void plate is separated from the reactor coolant by the void walls. This allows the flowrate through the spaces enclosed by void walls, the void regions, to be independently selected. Finally, the void walls prevent the fuel rod lattice from being disturbed by the insertion or removal of void rods or void plates. The void walls are shaped to be geometrically identical to the fuel rods that would occupy the void wall positions if the fuel rod lattice was undisturbed.

The FTWR of the fuel assembly can be varied from 1.25 to 0.75. Table 2.2 shows recommended combinations of void rods and void plates which, when removed, give the indicated FTWR. The recommended combinations have three important features:

1) The recommended combinations of void rods and void plates give relatively uniform FTWR decrements.
2) Each combination of void rods and void plates, when removed, leaves the fuel assembly in a symmetric geometric configuration.
3) The void rods and void plates are always removed in sets. This allows five control mechanisms to move all of the fuel assembly's void rods and void plates.

Table 2.2 Fuel Assembly Fuel to Water Ratios

Void Rods and Void Plates Removed From Fuel Assembly	FTWR
None	1.25
3 void rods	1.19
7 void rods	1.11
3 short void plates	1.05
3 short void plates and 3 void rods	1.00
3 short void plates and 7 void rods	0.95
3 long void plates and 3 void rods	0.89
3 long void plates and 7 void rods	0.85
All void plates and one void rod	0.80
All void plates and void rods	0.75

A hex can encloses the fuel rods, void rods, and void plates. The hex can prevents the mixing of coolant from adjacent fuel assemblies. Separate coolant flowrates through each fuel assembly allow reactor cores with non-uniform power densities to have a uniform coolant enthalpy increase through each fuel assembly. The coolant enters the fuel assembly at the bottom and exits at the top.

2.3 Core Description

The fuel assemblies can be combined to form a reactor core approximately the same size as a PWR core. The reactor core is hexagonal and is composed of 91 fuel assemblies. There are five different fuel enrichment zones. A cross-section of the reactor core, which shows the five fuel enrichment zones, is shown in Fig. 2.3. Important core parameters are listed in Table 2.3

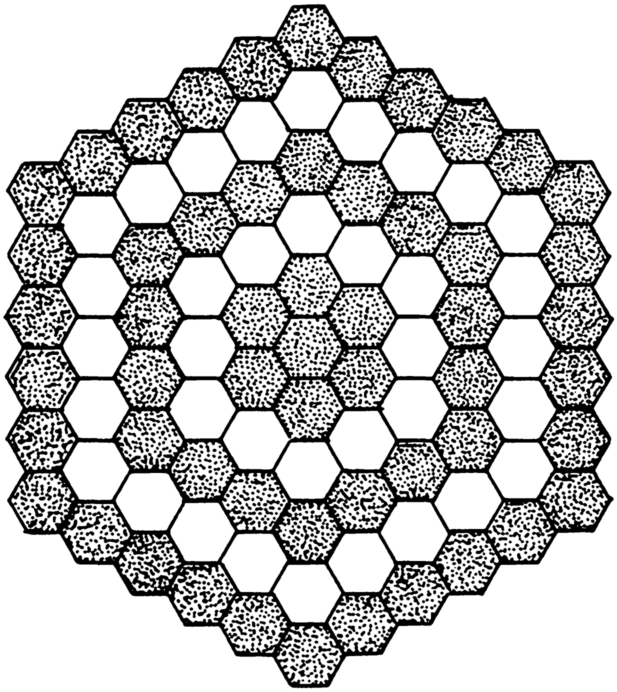


Figure 2.3 Conceptual Reactor Core Cross-Section

Table 2.3 Core Parameters

Core Diameter	116 in (2.95 m)
Core Height	120 in (3.05 m)
Core Volume	593 ft^3 (16.81 m^3)
Number of Fuel Assemblies	91
Number of Fuel Rods	33,579
Number of Void Rods	637
Number of Short Void Plates	273
Number of Long Void Plates	273

CHAPTER 3

THERMAL-HYDRAULIC ANALYSIS

3.1 General Description of the Thermal-Hydraulic Analysis

A steady-state thermal-hydraulic analysis of the fuel assembly described in Chapter 2 is presented in this chapter. Each fuel assembly is analyzed separately since the coolant flowrate through each fuel assembly differs. The heat transfer between adjacent fuel assemblies is assumed to be negligible. The entering coolant pressure and bulk temperature and the power density as a function of position must be known to begin the analysis. The coolant properties are calculated for each fuel assembly height increment, Δz, beginning at the coolant inlet and ending at the coolant exit. The properties calculated for coolant leaving one height increment are used as the coolant input properties of the next height increment. The coolant bulk temperature, the coolant pressure, and the cladding temperature are calculated at each Δz for every coolant channel. Heat transfer coefficients on both sides of each void wall and the temperature of the moderator in the void regions are also calculated.

The thermal-hydraulic analysis for each fuel assembly height increment can be divided into two parts. In the first part of the analysis, a heat balance is performed on each coolant channel to estimate the channel pressures and temperatures. In the second part of the analysis, a finite difference equation which recalculates the incremental coolant exit temperature is written for each coolant channel. The resulting set of equations is solved and a new set of incremental coolant channel exit temperatures is obtained. The heat balance is repeated using the new channel exit temperature estimates. The analysis of this fuel assembly height increment continues until the difference between successive incremental coolant channel exit temperature estimates is acceptable.

3.2 General Heat Balance Description

For each fuel assembly height increment, a heat balance is performed on each coolant channel. The heat balance estimates the coolant bulk temperature, the cladding temperature, and the coolant pressure. Additional parameters calculated are the rate heat is absorbed by each coolant channel, the burnout heat flux, the departure from nucleate boiling ratio (DNBR), and the cladding film heat transfer coefficient. Coolant channels next to void regions, edge channels, require additional analysis if the void regions do not contain void rods or void plates. The void wall temperature, the heat transfer coefficient on each side of the void wall, and the pressure and temperature of the moderator in the void region must be calculated. The calculation of these coolant channel and void region parameters is described below.

Since this is a steady-state thermal-hydraulic analysis, the rate heat is transferred into each coolant channel equals the sum of the heat generation rates in the fuel rods bordering the coolant channel. The heat absorbed by each coolant channel depends on the coolant channel type. Interior coolant channels, i.e. type one, are adjacent to three fuel rods. Since six coolant channels surround each fuel rod, a type one coolant channel removes the heat generated in 3/6, or 1/2, of a fuel rod. Coolant channels next to the convex surface of a void wall, type two, are adjacent to two fuel rods and remove the heat generated in 1/3 of a fuel rod. Coolant channels next to the concave surface of a void wall, type three, are adjacent to one fuel rod and remove the heat generated in 1/6 of a fuel rod. Figure 3.1 shows the three coolant channel types.

The power density is the power generated per unit volume in the fuel assembly. The heat generation rate of a coolant channel is calculated by multiplying the power density by the fuel assembly volume associated with the coolant channel. The fuel assembly volume associated with a coolant channel is the sum of the coolant channel volume and the fuel rod volume that transfers heat into the coolant channel. The rate heat is transferred into a coolant channel is given by:

$$\Delta Q_{gen} = P_d(A_c + A_{rod}N/6)\Delta z \tag{3.1}$$

where ΔQ_{gen} is the rate heat is transferred into the coolant channel,

P_d is the power density,

A_c is the coolant channel cross-sectional area,

A_{rod} is the fuel rod cross sectional area, and

N is the number of fuel rods adjacent to the coolant channel.

The pressure drop through Δz is calculated using a pressure drop model developed by Novendstern [5]. Novendstern's model predicts the pressure drop through a hexagonal fuel rod lattice that uses wire wrap spacers. The coolant velocity through each coolant channel type is calculated using an empirical flow distribution factor. The coolant

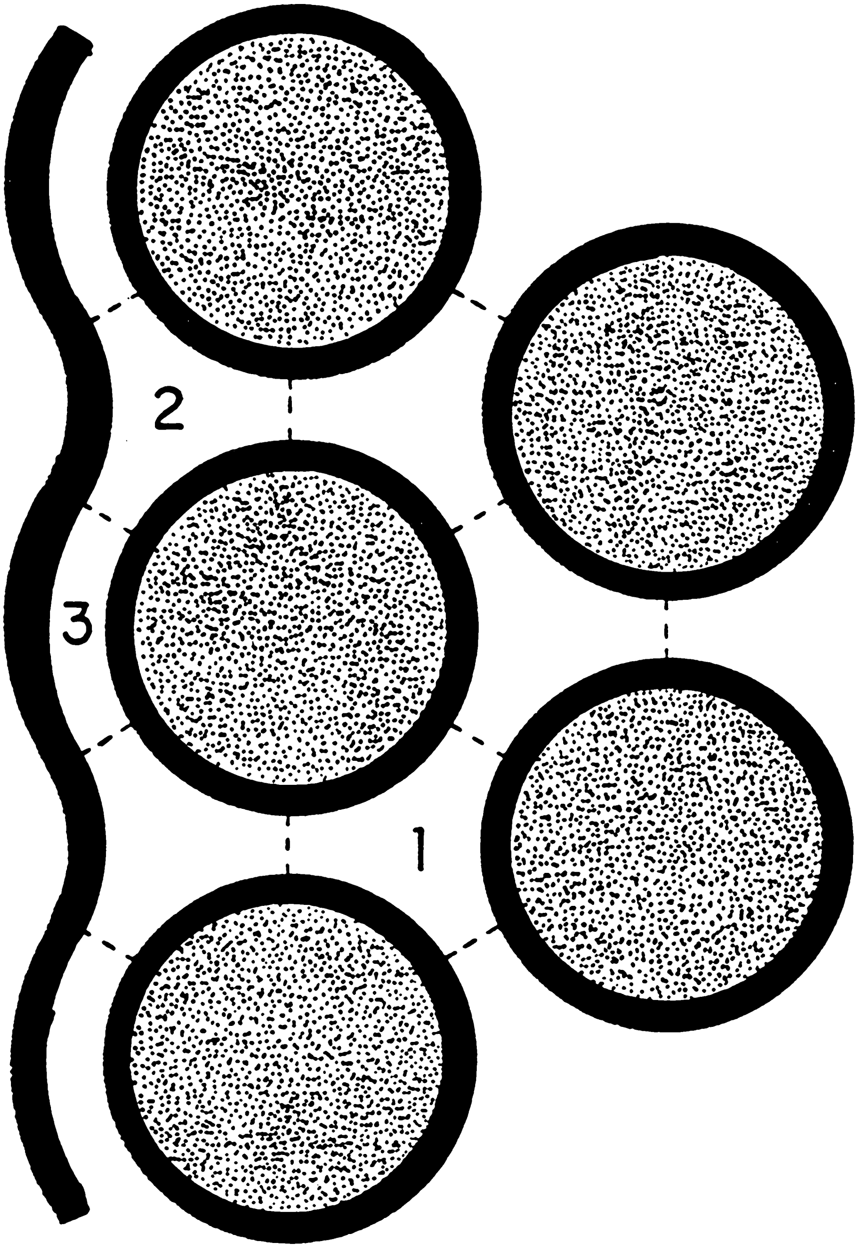


Figure 3.1 Coolant Channel Types

velocities calculated using this flow distribution factor give equal pressure drops through each coolant channel type. The pressure drop is estimated by increasing the pressure drop calculated for a straight smooth tube with a hydraulic diameter equal to that of the coolant channel by an empirical correction factor.

If the average coolant velocity through the fuel assembly, V_{bar}, is known, the coolant velocity through coolant channel type i is calculated using:

$$V_i = X_i V_{bar} \tag{3.2}$$

where V_i is the coolant velocity of coolant channel type i, and

X_i is Novendstern's flow distribution factor for coolant channel type i.

The flow distribution factor depends on the number of channels, the cross sectional area, and the hydraulic diameter of each coolant channel type. The flow distribution factor is given by:

$$X_i = \frac{A_t}{\sum\limits_j N_j A_j \left[\frac{D_{ej}}{D_{ei}}\right]^{0.714}} \qquad (1 \le i \le j) \tag{3.3}$$

where A_t is the total coolant flow area in the fuel assembly,

A_j is the cross sectional area of coolant channel type j,

N_j is the number of type j coolant channels in the fuel assembly, and,

D_{ej} is the hydraulic diameter of coolant channel type j.

The coolant pressure drop through Δz is given by:

$$\Delta P = \frac{M f_{sm} \Delta z \rho V_i^2}{2 D_{ei} g} \qquad (3.4)$$

where ΔP is the estimated pressure drop,

f_{sm} is the friction factor for a smooth pipe,

ρ is the coolant density,

g is the gravitational acceleration, and

M is Novendstern's pressure drop correction factor.

The pressure drop through Δz is greater than the pressure drop through a smooth tube of equal hydraulic diameter primarily because of the wire wrap spacer. The pressure drop correction factor depends on the coolant channel Reynolds number, Re, the pitch to fuel rod diameter ratio, and the ratio of the wire wrap axial lead, H, to the fuel rod diameter. The pressure drop correction factor is calculated using:

$$M = \frac{1.034}{(P_t/D)^{0.124}} + \frac{29.7(P_t/D)^{6.94} Re^{0.086}}{(H/D)^{2.239}} \qquad (3.5)$$

where P_t is the pitch of the fuel rod lattice and

D is the fuel rod outside diameter [5].

If the rate heat enters the coolant channel and the coolant flowrate are known, the temperature of the coolant leaving Δz can be estimated. The incremental coolant exit temperature is estimated by assuming all of the heat entering the coolant channel is used to increase the coolant enthalpy. Assuming the specific heat remains constant through Δz, the incremental exit coolant temperature is estimated using:

$$T_{ei} = \frac{\Delta Q_{gen}}{C_p \; M_{dot}} + T_{ii} \tag{3.6}$$

where T_{ei} is the coolant temperature leaving Δz,

T_{ii} is the coolant temperature entering Δz,

M_{dot} is the coolant channel flowrate, and

C_p is the coolant specific heat at constant pressure.

Since Δz is assumed to be small, a simple average of entering and exiting incremental coolant bulk temperature and pressure is used to calculate the average bulk temperature, T_B, and pressure, P, in Δz. The average pressure and bulk temperature are used to recalculate the coolant thermodynamic and transport properties in Δz.

The pressure drop through Δz is recalculated using the new coolant properties. If the recalculated pressure drop differs greatly from the previous pressure drop estimate, the coolant properties are recalculated and the pressure drop check is repeated. The estimate of the bulk coolant temperature is not checked or refined until the finite difference equations are solved.

The film heat transfer coefficient from the clad is calculated to estimate the cladding temperature. The Dittus-Boelter equation is used to calculate the film heat transfer coefficient [6]. This equation assumes the coolant flow is turbulent and is valid for the conceptual fuel assembly used in this study if the coolant flowrate is greater than 30,000 lbm/hr-ft^2 (408 kg/s-m^2).

$$h_c = C(\frac{K}{De}) Re^m Pr^n \tag{3.7}$$

where h_c is the cladding heat transfer coefficient in BTU/ft^2-s-°R,

K is the coolant thermal conductivity in BTU/ft-s-°R,

Pr is the Prandtl number, and

C, m, and n are empirical constants.

Recommended values for m and n are 0.8 and 0.333 respectively [6]. The value of C depends on the volume fraction of coolant in the fuel rod lattice. The value of C is calculated using:

$$C = 0.0333 \left(\frac{V_w}{V_w + V_F}\right) + 0.0127 \qquad (3.8)$$

where Vw is the coolant volume of the fuel lattice and

VF is the fuel volume of the fuel lattice.

The cladding temperature, T_c, can be calculated since the average bulk coolant temperature, the rate heat enters the coolant channel, and the cladding heat transfer coefficient are known. The cladding temperature is estimated using:

$$T_c = \frac{\Delta Q_{gen}}{Nh_c A} + T_B \qquad (3.9)$$

where A is the fuel rod surface area adjacent to the coolant channel.

The cladding temperature calculated by Eq. 3.9 assumes the coolant is not undergoing nucleate boiling. If nucleate boiling occurs, the cladding temperature is given by the Jens and Lottes correlation [7].

$$T_c = \frac{60(q''/10^6)^{0.25}}{e^{P/900}} + T_{sat} \qquad (3.10)$$

where q" is the cladding heat flux in BTU/hr-ft^2, and

T_{sat} is the coolant saturation temperature in °F based on coolant pressure.

The cladding temperature is calculated using both Eq. 3.9 and Eq. 3.10. The lower of the two calculated cladding temperatures is assumed to be the actual cladding temperature. If the cladding temperature calculated by Eq. 3.10 is the lower of the two cladding temperatures, it is assumed that nucleate boiling occurs.

The burnout heat flux, the heat flux at which departure from nucleate boiling occurs, is required to calculate the DNBR. The DNBR is defined as,

$$\text{DNBR} = \frac{Q_{BO}}{q''} \tag{3.11}$$

where Q_{BO} is the burnout heat flux.

To prevent departure from nucleate boiling, the minimum allowed DNBR for a PWR is 1.3 [6]. The burnout heat flux is calculated using a burnout heat flux correlation developed for low coolant fraction fuel rod lattices [2].

$$\frac{Q_{BO}}{10^6} = A1\left(\frac{D_eG}{h_z-h_i}\right)^{A2} + A3\left(\frac{D_eG}{h_z-h_i}\frac{\partial h}{\partial z}\right)^{A4}\left(A5(\Delta H_s) + \frac{\partial h_f}{\partial P}(2000-P)\right) \tag{3.12}$$

where G is the mass flux in lbm/hr-ft^2,

h_z is the coolant enthalpy in dz in BTU/lbm,

h_i is the coolant enthalpy at the fuel assembly inlet in BTU/lbm,

$\frac{\partial h}{\partial z}$ is the enthalpy gradient in dz in BTU/lbm-in,

ΔH_s is the subcooling at the fuel assembly inlet in BTU/lbm,

$\frac{\partial h_f}{\partial P}$ is the slope of the saturated liquid enthalpy curve in BTU/lbm-psi (a constant value of 0.123 is used), and

A1-A5 are empirical constants [2].

The recommended constants for Eq. 3.12 are listed in Table 3.1 [2] Once the burnout heat flux for a coolant channel is known, the DNBR is calculated using Eq. 3.11.

3.3 Edge Channel Heat Balance

If a void rod or void plate is removed, the edge channels bordering the void wall will transfer heat to the moderator in the void region. The void wall temperature, the water temperature in the void region, and the heat transfer coefficient on each side of the void wall are calculated when a heat balance is performed across the void wall.

The void wall temperature is initially estimated to be the average of the coolant temperature entering Δz and the average coolant bulk temperature in Δz. The film temperature is calculated by averaging the void wall temperature and the average coolant bulk temperature.

The heat transfer coefficient at the void wall is calculated assuming the flow through the coolant channel is turbulent. Equation 3.13 is used to calculate the heat transfer coefficient at the void wall [8].

$$h_{wi} = \frac{f_{sm} \rho C_p V_i}{8 \, Pr} \tag{3.13}$$

where h_{wi} is the heat transfer coefficient on the fuel rod side of the void wall.

Table 3.1 Recommended Constants for the Burnout Heat Flux Correlation

Constant	Value
A1	2.8591
A2	0.51796
A3	0.023018
A4	0.63960
A5	1.2614

This equation is based on the Reynolds analogy which relates the friction loss in tube flow to the heat transfer rate. In Eq. 3.13, the coolant density and specific heat are evaluated at the average coolant bulk temperature, while the Prandtl number is evaluated at the film temperature.

Knowing the average coolant bulk temperature, the void wall temperature, and the void wall heat transfer coefficient, the rate heat is transferred to the void wall can be calculated. For steady-state heat transfer, this will equal the heat absorbed by the moderator in the void region. The temperature across the void wall is assumed to be constant.

The temperature of the moderator in the void region is found by equating the enthalpy rise of the water in the void region to the heat transferred to the void wall surrounding the void region. The void water temperature leaving Δz is found using:

$$T_{vwe} = \frac{Q_i}{M_{doti} C_p} + T_{vwi} \tag{3.14}$$

where Q_i is the heat transferred to the void wall surrounding the void region,

M_{doti} is the mass flowrate of water through the void region,

T_{vwe} is the water temperature leaving Δz, and

T_{vwi} is the water temperature entering Δz.

The average temperature of the water in the void region, T_{vwb}, is calculated by averaging the water temperature entering and leaving the void region. The film temperature is again found by averaging the void wall temperature and the average water temperature in the void region.

The pressure drop through the void region can be calculated knowing the average water temperature and the void region flowrate. The Reynolds number, based on the hydraulic diameter of the void space, is used to determine whether the flow through the void space is laminar or turbulent. If the Reynolds number is greater than 2400, turbulent flow is assumed and the pressure drop is calculated using [9]:

$$\Delta P_{vi} = \frac{f_{sm}\ \rho\ \Delta z\ V_{vi}^{2}}{2\ D_{evi}\ g} \tag{3.15}$$

where ΔP_{vi} is the pressure drop of the void region,

V_{vi} is the fluid velocity in the void region, and

D_{evi} is the equivalent diameter of the void region.

Equation 3.15 assumes the void walls are smooth. If the Reynolds number is less than 2400, indicating laminar flow, the pressure drop is calculated using [9]:

$$\Delta P_{vi} = \frac{128u\ \Delta z\ M_{doti}}{\rho\ \pi\ D_{evi}} \tag{3.16}$$

where u is the dynamic viscosity.

The heat transfer coefficient on the void region side of the void wall is found using Eq. 3.13 if the flow through the void region is turbulent. If laminar flow exists in the void region, the heat transfer coefficient is calculated using [8]:

$$h_{wo} = 4.364K/D_{evi} \tag{3.17}$$

where h_{wo} is the heat transfer coefficient on the void region side of the void wall.

This equation can be derived using the definition of the convection heat transfer coefficient, the definition of the bulk temperature, and the parabolic velocity distribution for laminar tube flow.

A heat balance across the void wall is used to check the void wall temperature assumption. The heat transferred from the void wall into the void region is calculated using the void wall temperature, the average temperature of the water in the void region, and the void wall heat transfer coefficient, h_{wo}. If the amount of heat being transferred into the void region does not equal the heat being transferred to the void wall, the void wall temperature assumption is changed. All of the quantities used to perform the heat balance across the void wall are recalculated and the heat balance is repeated. This procedure continues until the energy transferred from the coolant channels, the energy transferred into the void region, and the energy used to increase the enthalpy of the water flowing through the void region are equal.

3.4 Description of the Finite Difference Equations

After the heat balance is completed for each coolant channel in Δz, the estimated exit temperatures from Δz for each coolant channel are substituted into a set of finite difference equations. Coolant cross-flow between adjacent coolant channels and heat transfer to the void walls are used by the finite difference equations to refine the coolant channel exit temperature estimates.

Coolant cross-flow, coolant flow between adjacent coolant channels, makes the temperature of each coolant channel dependent on the temperatures of the adjacent coolant. With a wire wrap spacer is used to separate adjacent fuel rods, the majority of the coolant cross-flow is caused by flow sweeping, which occurs when the wire wrap spacer winds from one coolant channel into another [10]. Coolant follows the wire wrap, leaving one channel and entering another.

The equation used to predict the cross-flow caused by flow sweeping is [10]:

$$W_{ij} = \frac{M_{dot} \pi t P_t a_f}{H A_c} \tag{3.18}$$

where W_{ij} is the mass flowrate from channel i to channel j,

t is the wire wrap diameter, and

a_f is the fraction of the total channel area that is free flow area.

The factor a_f is set equal to one by neglecting the coolant boundary layer thickness next to the fuel rod. The accuracy of Eq. 3.18 is questionable because it assumes that the cross-flow follows the wire wrap exactly and that only the coolant impinging on the wire wrap is swept out of the coolant channel. However, cross-flow due to flow sweeping is so large that relatively accurate bulk temperature estimates can be made even if the cross-flow is not predicted extremely accurately [10].

An energy balance can be performed on each coolant channel in Δz to form a set of finite difference equations. Figure 3.2 shows a general coolant channel and illustrates the physical meaning of the terms used in the finite difference equations.

Energy enters channel i from the adjacent coolant channels by coolant cross-flow and from the adjacent fuel rods by convective heat transfer. Energy leaves channel i by convective heat transfer to the void wall and by coolant cross-flow to adjacent coolant channels. Some of the energy entering the coolant channel is used to increase the coolant enthalpy as it passes through Δz. Equating the energy flow into the coolant channel to the sum of the energy used to increase the coolant enthalpy and the energy flow out of the coolant channel gives:

$$\Delta Q_{gen} + \sum_j W_{ji} C_{pj} T_{Bj} = \sum_j W_{ij} C_{pi} T_{Bi} + h_{wi} A_i \, (T_{Bi} - T_w) \\ + M_{dot} C_{pi} \, [T_{ei} - T_{ii}]. \qquad (3.19)$$

Replacing each average coolant bulk temperature with its definition and rearranging so the known and unknown variables appear on different sides of the equation results in the general finite difference equation:

$$A = B \, T_{ei} + \sum_j C_j T_{je}, \qquad (3.20)$$

where

$$A = \Delta Q_{gen} + \sum_j \frac{W_{ji} C_{pj} T_{ji}}{2} + [M_{dot} C_{pi} - \frac{h_{wi} A_i}{2} - \sum_j \frac{W_{ij} C_{pi}}{2}] \, T_{ii} \\ + h_{wi} A_i T_w, \qquad (3.20a)$$

$$B = M_{dot} C_{pi} + \frac{h_{wi} A_i}{2} + \sum_j \frac{W_{ij} C_{pi}}{2}, \qquad (3.20b)$$

and $C = - W_{ji} C_{pi} / 2.$ (3.20c)

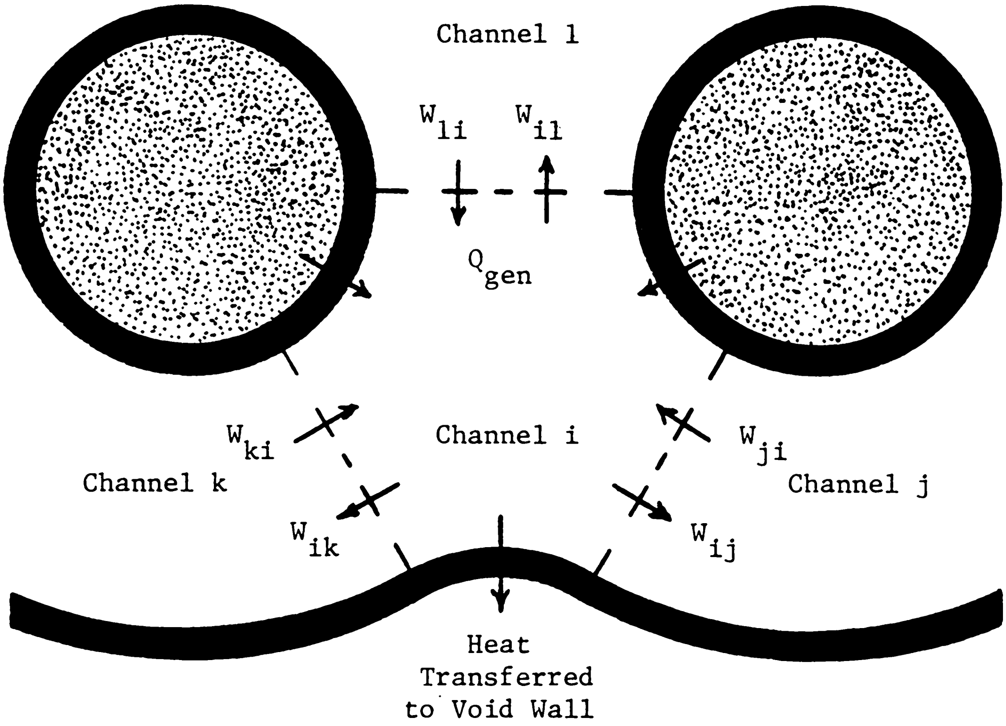


Figure 3.2 Finite Difference Equation Parameters

The set of equations generated from Eq. 3.20 is solved for a new set of coolant channel exit temperatures. If the new coolant channel incremental exit temperature estimates differ greatly from the old estimates, the fuel assembly heat balance is repeated using the new coolant channel incremental exit temperature estimates. This procedure is repeated until the temperature estimates of successive iterations do not differ appreciably.

When the temperature estimates from two successive iterations through the heat balance-finite difference equation procedure are nearly identical, the thermal-hydraulic calculations for Δz are finished. The coolant bulk temperature and pressure, the cladding temperature, and the cladding film heat transfer coefficient are known for each coolant channel in Δz. For edge channels, the void wall temperature and the heat transfer coefficient on each side of the void wall are known. Finally, the temperature and pressure of the moderator in the void regions are known.

The thermal-hydraulic analysis is continued by incrementing the fuel assembly axial position and repeating the thermal-hydraulic analysis on a new Δz. The outlet coolant pressures and temperatures of the previous Δz are used as the inlet pressures and temperatures for the new Δz. The thermal-hydraulic analysis is repeated for fuel assembly height increments of Δz until the top of the fuel assembly is reached.

CHAPTER 4

THE THERMAL-HYDRAULIC COMPUTER PROGRAM

4.1 General Program Description

A digital computer was used to perform the thermal-hydraulic calculations presented in Chapter 3. The computer program can be divided into three parts:

1) The dimensional parameters of the coolant channels must be defined before the thermal-hydraulic analysis can be performed. For each coolant channel, the position, the dimensions, and the adjacent coolant channels are determined. Additional parameters defined for edge channels are the type of void region the channel borders and if heat is transferred through the void wall.
2) The thermodynamic and transport properties of water were calculated using the WASP steam table subprogram. This subprogram was chosen because it is accurate and easy to use.
3) The thermal-hydraulic calculations are the smallest of the three program sections. These calculations have already been described in Chapter 3.

The program segments are performed in the following order: After reading the input data, the dimensional parameters of each coolant channel are assigned. The FTWR is used to determine which void rods and void plates are removed and which edge channels transfer heat into the void regions. The thermal-hydraulic calculations follow. Beginning at the coolant inlet, the various pressures and temperatures throughout the fuel assembly are calculated for height increments of Δz. WASP is called during these calculations to provide coolant thermodynamic properties. When the thermal-hydraulic calculations are finished, the average exit enthalpy is calculated and the program results are printed. A program flow chart is presented in Appendix A and Appendix B and contains the program listing.

4.2 Assignment of Coolant Channel Parameters

Before coolant channel dimensional parameters can be assigned, each coolant channel must be identified. A set of three integers is used to identify each coolant channel. These coolant channel identification numbers (CIDN) are assigned based on the position of the coolant channel.

Each coolant channel can be associated with a fuel rod. A coolant channel's fuel rod determines the first two integers of its CIDN. The first integer is the row number of the fuel rod. The fuel rods are numbered consecutively in each row to obtain the second integer. Figure 4.1 shows how the fuel rods are numbered. The position of the coolant channel relative to its associated fuel rod determines the third integer of the CIDN. Figure 4.2 shows how the six coolant channels surrounding each fuel rod are numbered.

In addition to identifying the coolant channel, the CIDN is used to find the position of the coolant channel relative to the center of the fuel assembly. Using the row number, the position in the row, and the fuel rod lattice pitch, the distance a fuel rod is from the fuel

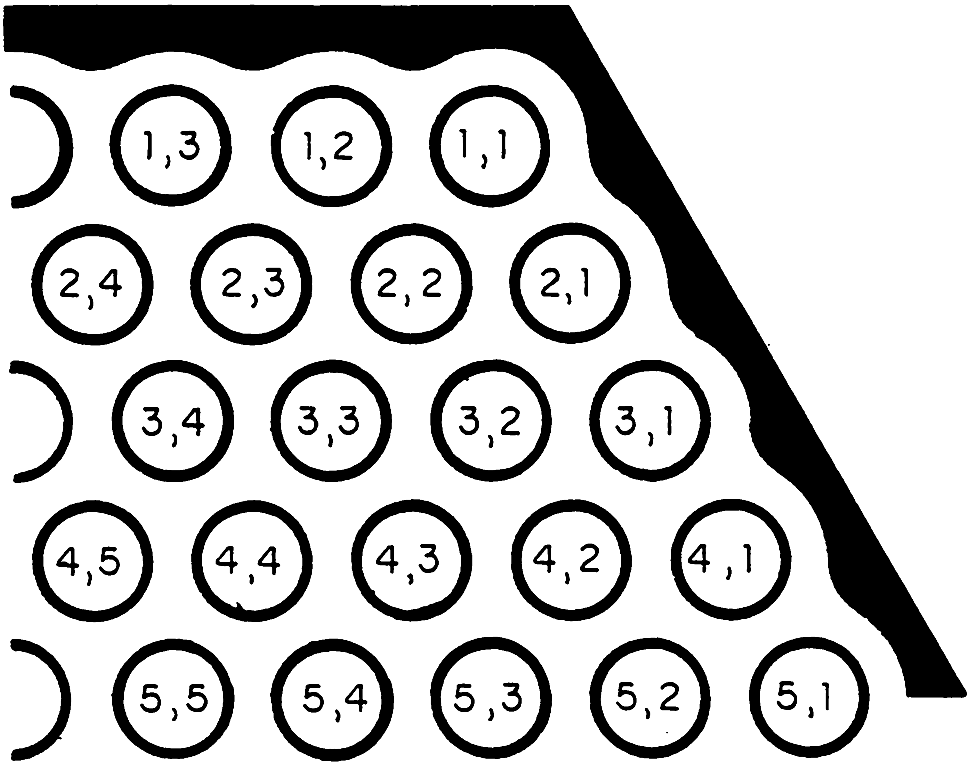


Figure 4.1 Fuel Rod Number Assignment

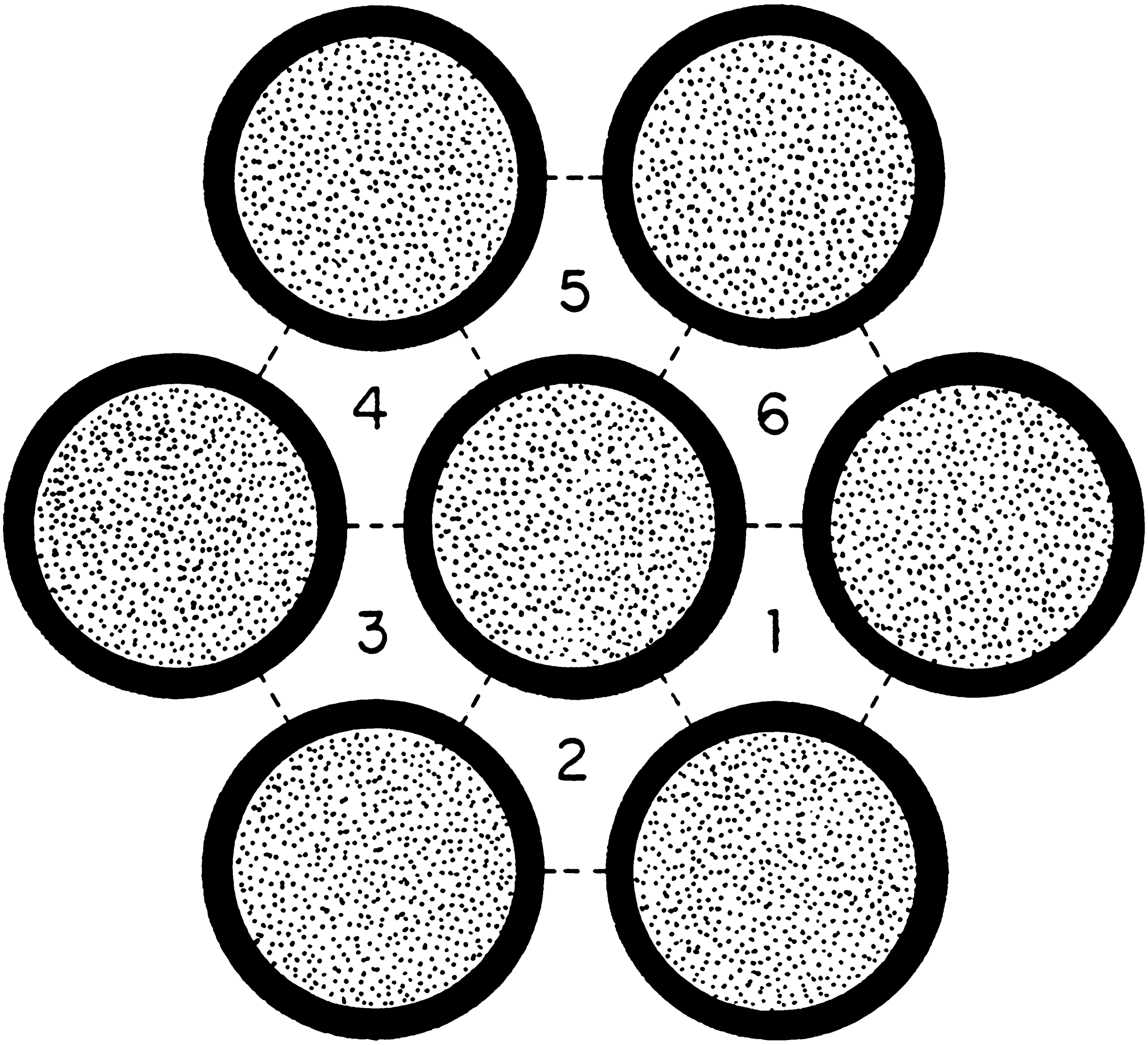


Figure 4.2 Coolant Channel Numbers

assembly center can be calculated. If the distance from the fuel assembly center to the reactor core centerline is known, the position of each fuel rod relative to the core centerline can be calculated. This distance must be known if any quantity used in the thermal-hydraulic analysis is radially space-dependent.

The coolant channel dimension, hydraulic diameter, cross sectional area, and the number of adjacent cooling channels depend on the coolant channel type. The coolant channel type also specifies whether a channel is an interior or an edge channel. The three types of coolant channels are shown in Fig. 3.1.

The coolant channel type is specified by the channel type number. The channel type number is a subscripted integer variable that is assigned a value of one, two, or three depending on whether a coolant channel is a type one, a type two, or a type three coolant channel. The channel type number also prevents a coolant channel from using more than one CIDN. Any of the fuel rods that border a coolant channel can be selected as the fuel rod associated with that coolant channel. After a coolant channel has been associated with a fuel rod and its CIDN assigned, any other CIDN that identifies the same channel is assigned a channel type number of four. Coolant channel identification numbers that have channel type numbers of four are ignored during the thermal-hydraulic analysis.

One set of three subscripted integer variables is used to specify each adjacent coolant channel. Each integer variable in a set equals one of the integers comprising the CIDN of an adjacent coolant channel.

The CIDN of the adjacent coolant channels are reconstructed from these sets of subscripted integer variables.

The parameters described above are defined for every coolant channel in the fuel assembly. Edge channels have two additional parameters. These parameters define the void region bordering the coolant channel and determine if heat is being transferred into that void region.

The type of void region adjacent to an edge channel, either a void rod, a short void plate, or a long void plate, is specified by another subscripted integer variable. This variable has a value of one if the adjacent void region is a short void plate, two if the adjacent void region is a long void plate, and three if the adjacent void region is a void rod.

The FTWR determines which edge channels border void regions containing water. The void wall heat transfer coefficient of these coolant channels is set equal to negative one. The void wall heat transfer coefficient of the remaining edge channels is set equal to zero. Negative void wall heat transfer coefficients are replaced during the thermal-hydraulic analysis.

4.3 Calculation of Coolant Properties

The WASP steam table subprogram is used to calculate the cooling water thermodynamic and transport properties. To calculate these properties, WASP uses an equation developed by Keyes, Keenan, Hill, and Moore which is valid from the triple point to a pressure of 14,500 psi (100 MPa) and to a temperature of 3150 F (1750 K) [11]. WASP calculates any combination of temperature, pressure, density, entropy, enthalpy, specific heat at constant pressure, specific heat at constant volume, viscosity, sonic velocity, thermal conductivity, surface tension, and the Laplace constant, given any two of the variables temperature, pressure, and density. A complete explanation of WASP and its use may be found in reference 11.

The input parameters to WASP were assigned so the properties of saturated water were calculated using the water temperature and pressure as input properties. The properties calculated were the density, the viscosity, the thermal conductivity, and the specific heat at constant pressure.

The number of times WASP is called to calculate coolant properties is considerably fewer than the flow chart in Appendix A indicates. The program is written so WASP is not called unless the temperature difference between the present and the previous input temperatures is greater than 20°F (11°C). This reduces the program execution time considerably. The results of the thermal-hydraulic calculations are not significantly affected by this change because the properties calculated by WASP do not change greatly over a temperature range of 20°F (11°C).

CHAPTER 5

TEST CASE RESULTS

5.1 Test Case Procedure

The results from three test cases are used to determine the thermal-hydraulic characteristics of the reactor core presented in Chapter 2. The test case results are used to draw conclusions about the particular core used in the analysis and about mechanical spectral shift reactor cores in general. Each test case consisted of analyzing one fuel assembly from each of the five fuel enrichment zones. For each fuel assembly, the coolant flowrate, the inlet pressure, the outlet pressure, and the enthalpy gain through the fuel assembly were determined.

For each test case, equal coolant enthalpy gains through the fuel assemblies were obtained by adjusting the coolant flowrates. The inlet pressure of the fuel assemblies was selected so the fuel assembly outlet pressures were equal. Each test case was analyzed using FTWR's of 1.25, 0.95, and 0.75 to find how changing the FTWR affects the coolant outlet conditions. The flowrates through the void regions were selected to be 18 lbm/hr (0.002 Kg/s).

The following procedure was used to analyze each test case:

1) The average power density in each of the five fuel enrichment zones was determined using the computer code, RFD-1.
2) The coolant flowrate through each fuel assembly was adjusted until the desired enthalpy gain was achieved. By selecting

the coolant flowrates, the pressure drop through each fuel assembly is specified.

3) The core pressure drop equals the pressure drop through the fuel assembly with the greatest power density and flowrate. The inlet pressures of the remaining fuel assemblies were selected so the calculated outlet pressures of all the fuel assemblies are equal.

5.2 Test Case 1

The first test case uses U-235 fuel enrichments of 2.7%, 2.2%, 2.0%, 1.8%, and 1.6%. The fuel distribution selected has the greatest enrichment in the central fuel enrichment zone with each subsequent enrichment zone being less highly enriched. This fuel distribution produces a high power density in the core center and a low power density at the core edge. The power density ranges from 16,030 BTU/s-ft^3 (597 W/cm^3) to 258 BTU/s-ft^3 (9.6 W/cm^3). The reactor power is 1800 MW$_{th}$. The input data and the thermal-hydraulic results are shown in Table 5.1. The program printout for a FTWR of 0.95 and a fuel enrichment of 2.7% is presented in Appendix D.

5.3 Test Case 2

The second test case uses a U-235 enrichment of 2.1% in each fuel enrichment zone. The power densities range from 4,530 BTU/s-ft^3 (169 W/cm^3) in the central enrichment zone to 1,320 BTU/s-ft^3 (49.2 W/cm^3) in the outer enrichment zone. The reactor power is 1800 MW$_{th}$. Table

5.2 contains the input data and the results of the thermal-hydraulic analysis.

5.4 Test Case 3

The third test case uses low fuel enrichments at the core center and higher fuel enrichments at the core edge. The fuel enrichments used are 1.6%, 1.8%, 2.0%, 2.2%, and 2.7% U-235. The power density ranges from 3330 BTU/s-ft^3 (124 W/cm^3) in the outer enrichment zone to 497 BTU/s-ft^3 (18.5 W/cm^3) in the central enrichment zone. Again, the reactor power is 1800 MW_{th}. The results of the thermal-hydraulic analysis and the input data are presented in Table 5.3.

5.5 Summary and Discussion of Results

The test case results show that the fuel assembly enthalpy gains can be equalized by adjusting the coolant flowrate through each fuel assembly. The results also show that changing the FTWR does affect the coolant outlet conditions. Some thermal-hydraulic characteristics of the fuel assembly used for the test cases can be determined from the results.

To achieve a given enthalpy increase through a reactor core, a wider variety of fuel distributions may be used if the coolant flowrates can be varied through each fuel assembly. The flowrate through each fuel assembly may be chosen so the average enthalpy gain through the core equals the enthalpy gain through each fuel assembly. The results show that this can be done even for fuel distributions producing a wide range of power densities. This results in a large average

Table 5.1a Results From Test Case One (English Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	2.7	2.2	2.0	1.8	1.6
Power Density (BTU/s-ft^3)	16,030.	7,870.	3.030.	960.	260.
Coolant Flowrate (lbm/hr-ft^2-10^6)	13.8	6.79	2,62	0.83	0.22
Inlet Pressure (psia)	2,400.	2,143.7	2,066.3	2,051.7	2,049.9
Outlet Pressure (psia)	2,049.7	2,049.7	2,049.7	2,049.7	2,049.7
Pressure Drop (psi)	350.3	94.2	16.6	2.08	0.18
Enthalpy Gain for a FTWR of 1.25 (BTU/lbm)	120.5	120.4	119.8	119.9	127.0
Enthalpy Gain for a FTWR of 0.95 (BTU/lbm)	120.5	120.3	119.7	119.8	119.6
Enthalpy Gain for a FTWR of 0.75 (BTU/lbm)	120.4	120.2	118.5	119.7	120.1

Table 5.1b Results From Test Case One (Metric Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	2.7	2.2	2.0	1.8	1.6
Power Density (W/m^3-10^6)	597.	293.	113.	35.8	9.7
Coolant Flowrate (kg/s-m^2)	18,750.	9,228.	3,561.	1,128.	299.
Inlet Pressure (kPa)	16,540.	14,770.	14,240.	14,140.	14,125.
Outlet Pressure (kPa)	14,120.	14,120.	14,120.	14,120.	14,120.
Pressure Drop (kPa)	2,420.	650.	120.	20.	5.
Enthalpy Gain for a FTWR of 1.25 (KJ/Kg)	280.3	280.0	278.6	278.9	295.4
Enthalpy Gain for a FTWR of 0.95 (KJ/Kg)	280.3	279.8	278.4	278.6	278.2
Enthalpy Gain for a FTWR of 0.75 (KJ/Kg)	280.0	279.6	275.6	278.4	279.4

Table 5.2a Results From Test Cast Two (English Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	2.1	2.1	2.1	2.1	2.1
Power Density (BTU/s-ft^3)	4530.	4130.	3380.	2390.	1321.
Coolant Flowrate (lbm/hr-ft^2-10^6)	3.93	3.58	2.93	2.07	1.15
Inlet Pressure (psia)	2200.	2194.6	2185.7	2176.2	2169.0
Outlet Pressure (psia)	2165.3	2165.3	2165.3	2165.3	2165.3
Pressure Drop (psi)	34.7	29.3	20.4	10.9	3.7
Enthalpy Gain for a FTWR of 1.25 (BTU/lbm)	118.8	118.8	118.7	118.6	119.6
Enthalpy Gain for a FTWR of 0.95 (BTU/lbm)	118.8	118.7	118.6	118.5	119.4
Enthalpy Gain for a FTWR of 0.75 (BTU/lbm)	116.6	116.6	116.5	116.3	116.0

Table 5.2b Results From Test Case Two (Metric Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	2.1	2.1	2.1	2.1	2.1
Power Density (W/m^3-10^6)	168.7	153.8	125.9	89.0	49.2
Coolant Flowrate ($Kg/s-m^2$)	5,340.	4,865.	3,982.	2,810.	1,563.
Inlet Pressure (kPa)	15,160.	15,120.	15,060.	14,990.	14,940.
Outlet Pressure (kPa)	14,920.	14,920.	14,920.	14,920.	14,920.
Pressure Drop (kPa)	240.	200.	140.	70.	20.
Enthalpy Gain for a FTWR of 1.25 (KJ/Kg)	276.3	276.3	276.1	275.9	278.2
Enthalpy Gain for a FTWR of 0.95 (KJ/Kg)	276.3	276.1	275.9	275.6	277.7
Enthalpy Gain for a FTWR of 0.75 (KJ/Kg)	271.2	271.2	271.0	270.3	269.8

Table 5.3a Results From Test Case Three (English Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	1.6	1.8	2.0	2.2	2.7
Power Density (BTU/s-ft^3)	500.	880.	1710.	2820.	3330.
Coolant Flowrate (lbm/hr-ft^2-10^6)	0.43	0.77	1.48	2.44	2.89
Inlet Pressure (psia)	2181.0	2182.1	2186.2	2194.9	2200.
Outlet Pressure (psia)	2180.3	2180.3	2180.3	2180.3	2180.3
Pressure Drop (psi)	0.7	1.8	5.9	14.6	19.7
Enthalpy Gain for a FTWR of 1.25 (BTU/lbm)	119.4	119.5	118.6	118.7	118.8
Enthalpy Gain for a FTWR of 0.95 (BTU/lbm)	118.1	119.1	118.4	118.6	118.7
Enthalpy Gain for a FTWR of 0.75 (BTU/lbm)	118.4	115.7	116.2	116.4	116.5

Table 5.3b Results From Test Case Three (Metric Units)

Fuel Enrichment Zone	1	2	3	4	5
Fuel Enrichment (% U-235)	1.6	1.8	2.0	2.2	2.7
Power Density (W/m^3-10^6)	18.6	32.7	63.7	105.0	124.0
Coolant Flowrate ($Kg/s-m^2$)	584.	1,046.	2,010.	3,316.	3,928.
Inlet Pressure (kPa)	15,030.	15,035.	15,060.	15,120.	15,160.
Outlet Pressure (kPa)	15,020.	15,020.	15,020.	15,020.	15,020.
Pressure Drop (kPa)	10.	15.	40.	100.	140.
Enthalpy Gain for a FTWR of 1.25 (KJ/Kg)	277.7	278.0	275.9	276.1	276.3
Enthalpy Gain for a FTWR of 0.95 (KJ/Kg)	274.7	277.0	275.4	275.9	276.1
Enthalpy Gain for a FTWR of 0.75 (KJ/Kg)	275.4	269.1	270.3	270.7	271.0

enthalpy gain through the core. To achieve a similar enthalpy gain, a reactor core in which the coolant mixes freely between fuel assemblies must use a fuel distribution with a relatively even power density.

Changing the FTWR does affect the outlet conditions of the coolant. The outlet enthalpy decreases by approximately 2.0 BTU/lbm (4.7 KJ/Kg) as the FTWR decrease from 1.25 to 0.75. This decrease is not surprising since the outlet temperature of the water in the void regions is considerably less than the reactor coolant outlet temperature. The change in the enthalpy gain as the FTWR varies increases as the coolant flowrate decreases. The change in the outlet enthalpy caused by varying the FTWR may be reduced if the flowrates through the void regions are reduced. The low exit temperature of the water in the void regions indicates that little heat is transferred into these regions.

The maximum fuel assembly power density increases as the variation between the fuel assembly power densities increases. To achieve an equal enthalpy increase through each fuel assembly, the coolant flowrate through each fuel assembly must be proportional to the fuel assembly power density. Since the maximum fuel assembly coolant flowrate determines the core pressure drop, the pressure drop increases as the variation between the fuel assembly power densities increases.

Some thermal-hydraulic characteristics of the fuel assembly used in the test cases are shown in Figs. 5.1 and 5.2. Figure 5.1 shows how the fuel assembly pressure drop varies with the coolant flowrate. Since the pressure drop depends on the square of the coolant velocity, the rapid increase of pressure drop with coolant flowrate is expected.

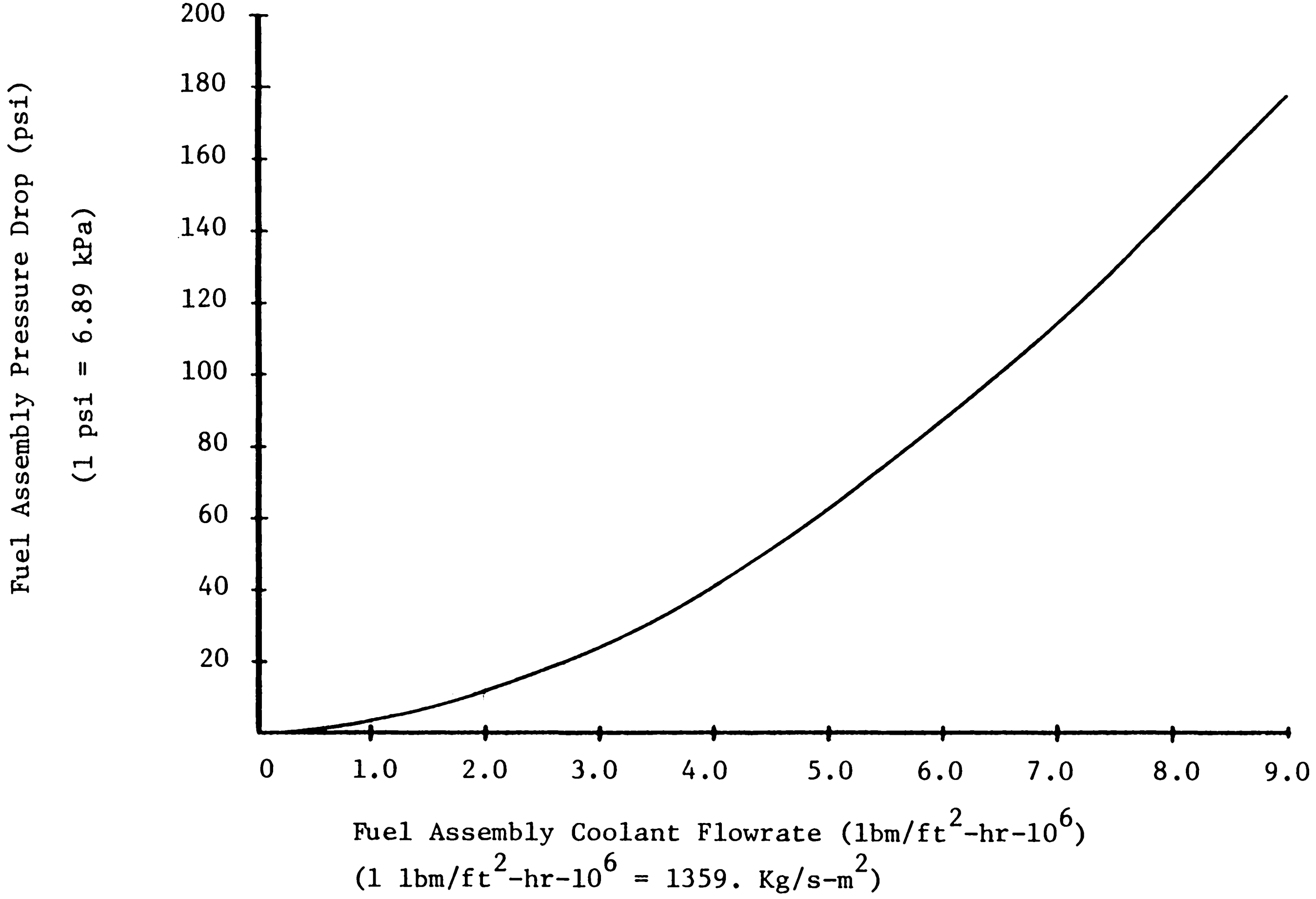


Figure 5.1 Fuel Assembly Pressure Drop

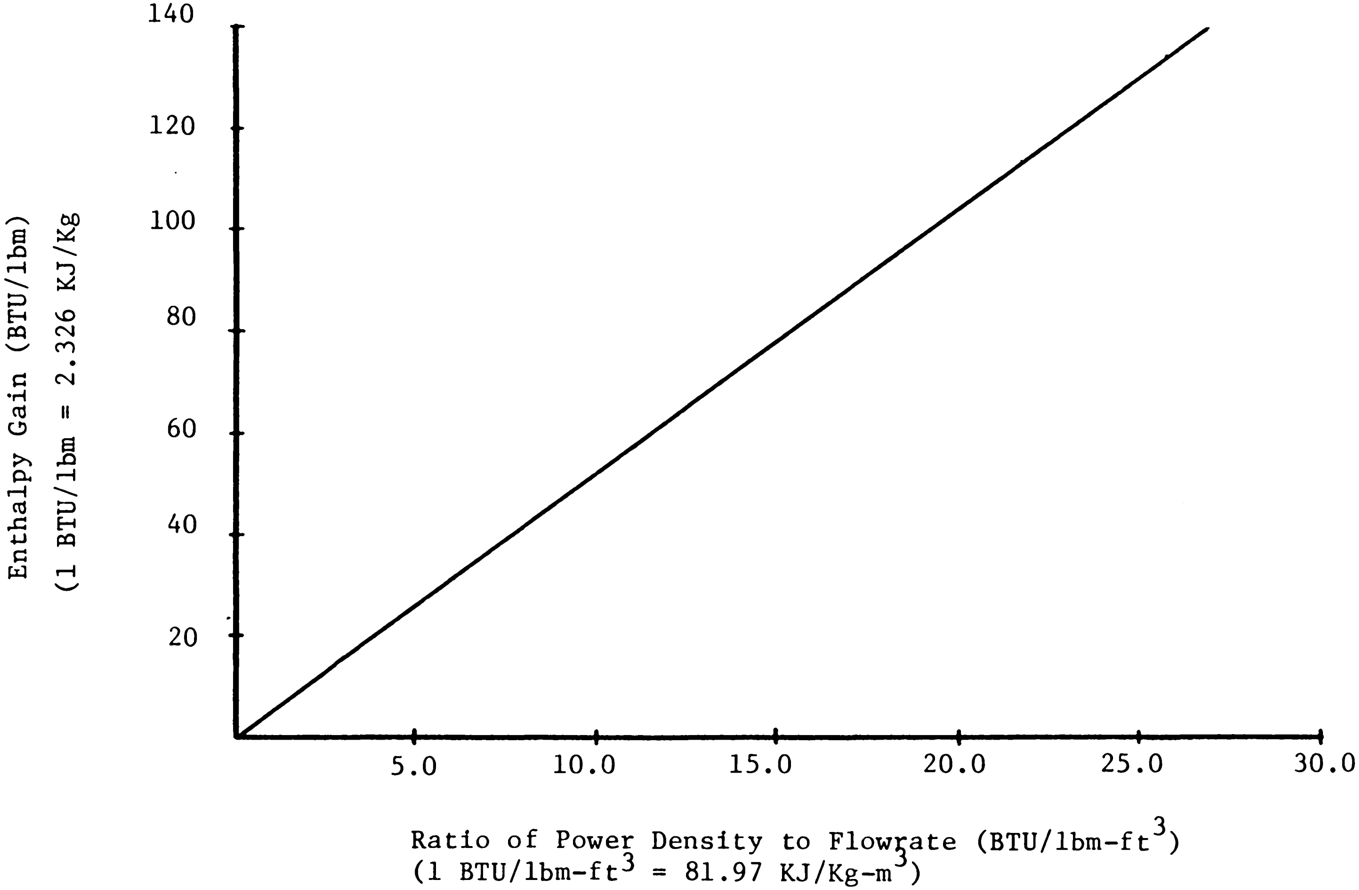


Figure 5.2 Fuel Assembly Enthalpy Increase

If an upper limit is placed on the allowed pressure drop, the maximum coolant flowrate can be found using Fig. 5.1. A reasonable value to select for the maximum pressure drop is 60 psi (414 kPa). The flowrate corresponding to this pressure drop is 5.9 x 10^6 lbm/hr-ft^2 (69.1 Kg/s-m^2).

If the fuel assembly is at steady-state conditions and if the heat transferred to the void regions is negligible, the ratio of the power density to the coolant flowrate is proportional to the fuel assembly enthalpy gain. This linear relationship is shown in Fig. 5.2. Figure 5.2 can be used to determine the coolant flowrate required to give a desired fuel assembly enthalpy gain if the power density is known. For the given coolant inlet conditions, the maximum fuel assembly enthalpy gain is approximately 130 BTU/lbm (302 KJ/Kg). Using this value and the maximum coolant flowrate determined from Fig. 5.1, the greatest power density that can be used in this fuel assembly is 7410 BTU/hr-ft^3 (276 W/m^2).

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

A computer program that performs a steady-state thermal hydraulic analysis of a mechanical spectral shift reactor core has been written. The program input contains the coolant flowrates, the coolant inlet conditions, the FTWR, and the fuel assembly power density. The program calculates the coolant pressures and temperatures, the cladding temperatures, and the void region pressures and temperatures throughout one fuel assembly.

A conceptual mechanical spectral shift core design was analyzed for three different fuel distributions. Two general conclusions based on the test case results are:

1) Equal coolant enthalpy increases through the fuel assemblies can be obtained by selecting the proper coolant flowrate through each fuel assembly. The test case results show that this can be done even if large variations exist between the fuel assembly power densities. The maximum allowable pressure drop through the core limits the range of power densities that can be used.
2) The coolant outlet conditions are affected by changing the FTWR, even though the flowrates through the void regions is very low. This indicates that very little heat is transferred into the void regions.

The program presented in this thesis is the first step toward obtaining a general thermal-hydraulic computer program for analyzing mechanical spectral shift reactor cores, however many changes are needed if the program is to be made more general and useful. Some recommended improvements are:

1) The program input needs to be changed so the coolant channel parameters can be defined easily and quickly for a large variety of fuel assemblies. This would allow the effects of changing the fuel rod lattice or the fuel assembly dimensions to be examined.
2) The accuracy of the calculated coolant cross-flow rates is questionable. If a fuel rod lattice for which experimental cross-flow data was available was being analyzed, a more accurate cross-flow prediction could be made.
3) The program results are only valid if the coolant remains subcooled or undergoes nucleate boiling. The program would be more versatile if it could calculate the coolant conditions and the cladding temperature during bulk coolant boiling and annular flow.

The suggested changes are needed if the present computer program is to be made more useful. Certainly many more improvements than the three listed above could be made. The advantages of mechanical spectral shift reactor cores make this reactor type an interesting alternative to the present PWR. A thermal-hydraulic computer code that would easily analyze any proposed mechanical spectral shift core design would be useful in the development of this reactor type.

REFERENCES

1. Edlund, M. C., "Physics of Spectral Shift Reactors," Ph.D. Dissertation, Ann Arbor, Mi., 1966.

2. V. O. Uotinen, et al., "Technical Feasibility of a Pressurized Water Reactor Design with a Low Water Volume Fraction Lattice," Final Report, EPRl NP-1833, 1981.

3. Sherman, R. L., "RFD-1: A 1-D, 4-Group Code to Calculate Burnup Cycles Using Mechanical Spectral Shift," Master's Thesis, Blacksburg, Va., 1982.

4. Edlund, M. C., "High Conversion Ratio Plutonium Recycle in Pressurized Water Reactors," Annals of Nuclear Energy, 2, 801-807 (1975).

5. Novendstern, E. H., "Turbulent Flow Pressure Drop Model for Fuel Rod Assemblies Using a Helical Wire-Wrap Spacer System," Nuclear Engineering and Design, 22, 19-27, (1972).

6. Lamarsh, J. R., Introduction to Nuclear Engineering, Addison-Wesley Publishing Company, Reading, Mass., 1975.

7. Jens, W. H., and D. A. Lottes, "Analysis of Heat Transfer, Burnout, Pressure Drop, and Density Data for High Pressure Water," ANL-4627, Argonne Natl. Laboratory, Chicago, Ill., 1951.

8. Holman, J. P., Heat Transfer, Fourth Edition, McGraw-Hill Book Company, New York, 1972.

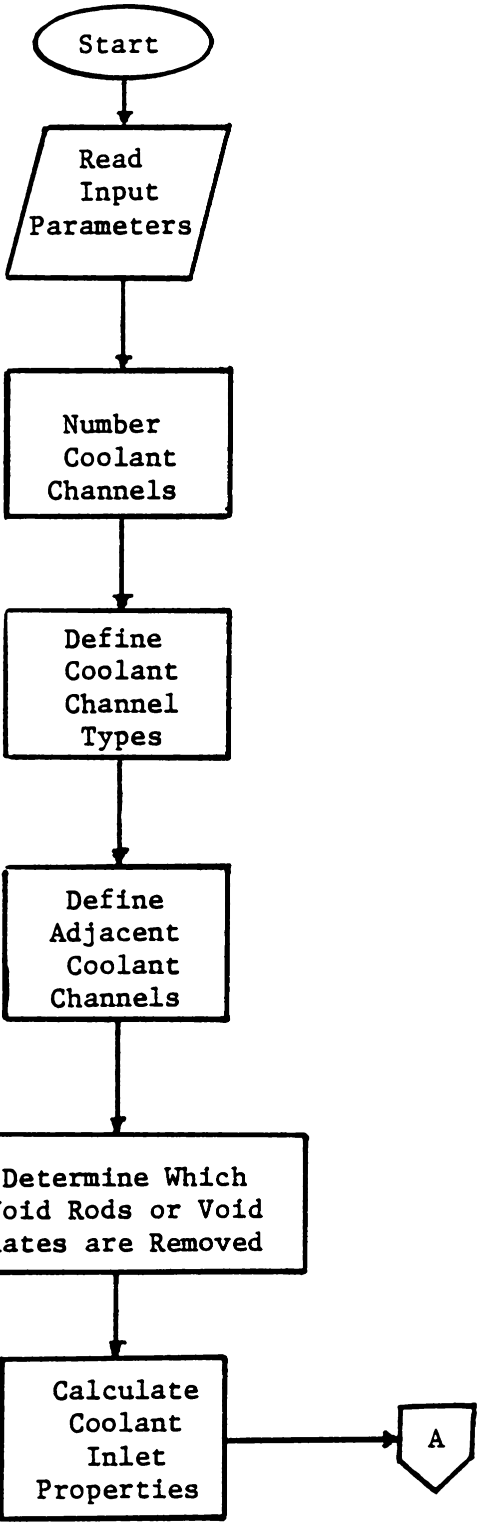
9. Fox, R. W., and A. T. McDonald, Introduction to Fluid Mechanics, Second Edition, John Wiley and Sons, New York, 1973.

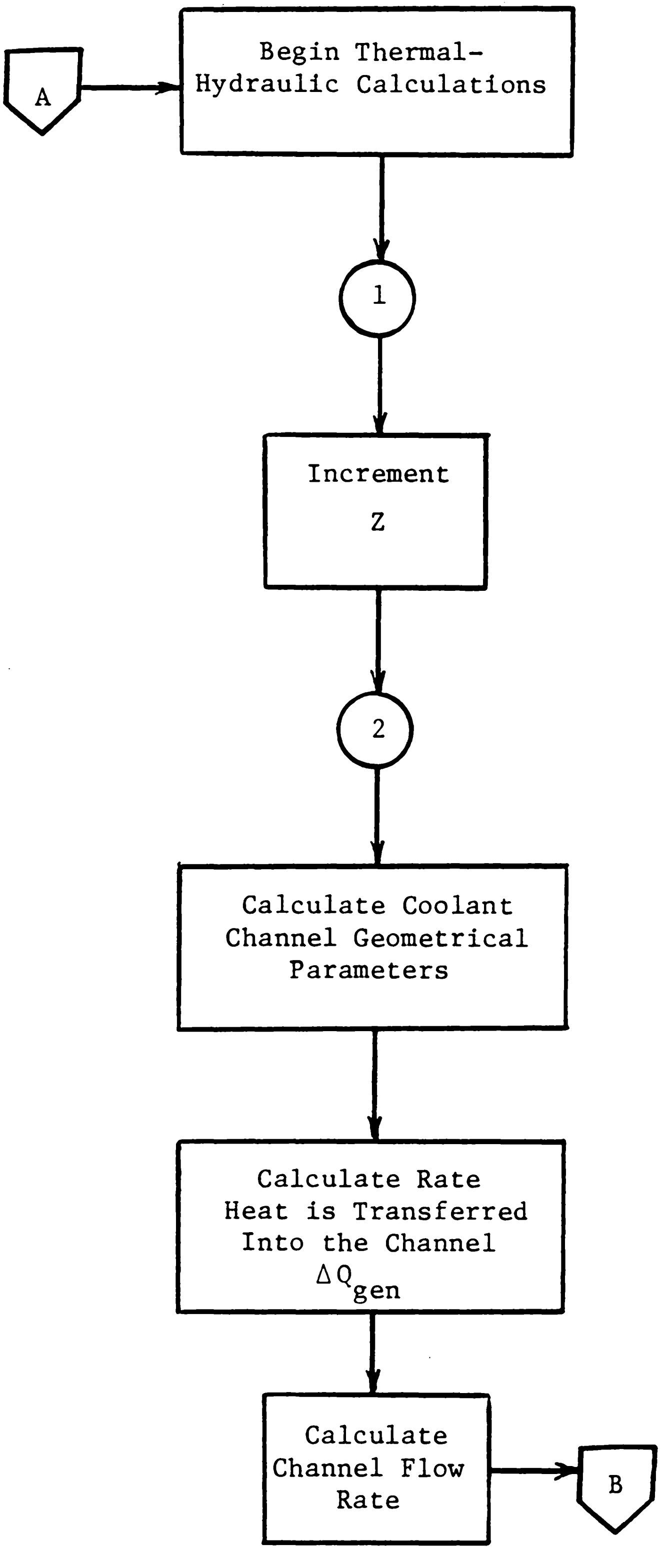
10. Rogers, J. T., and N. E. Todreas, "Coolant Interchannel Mixing in Reactor Fuel Rod Bundles Single-Phase Coolants," Heat Transfer in Rod Bundles, ASME, New York, 1968, 1-57.

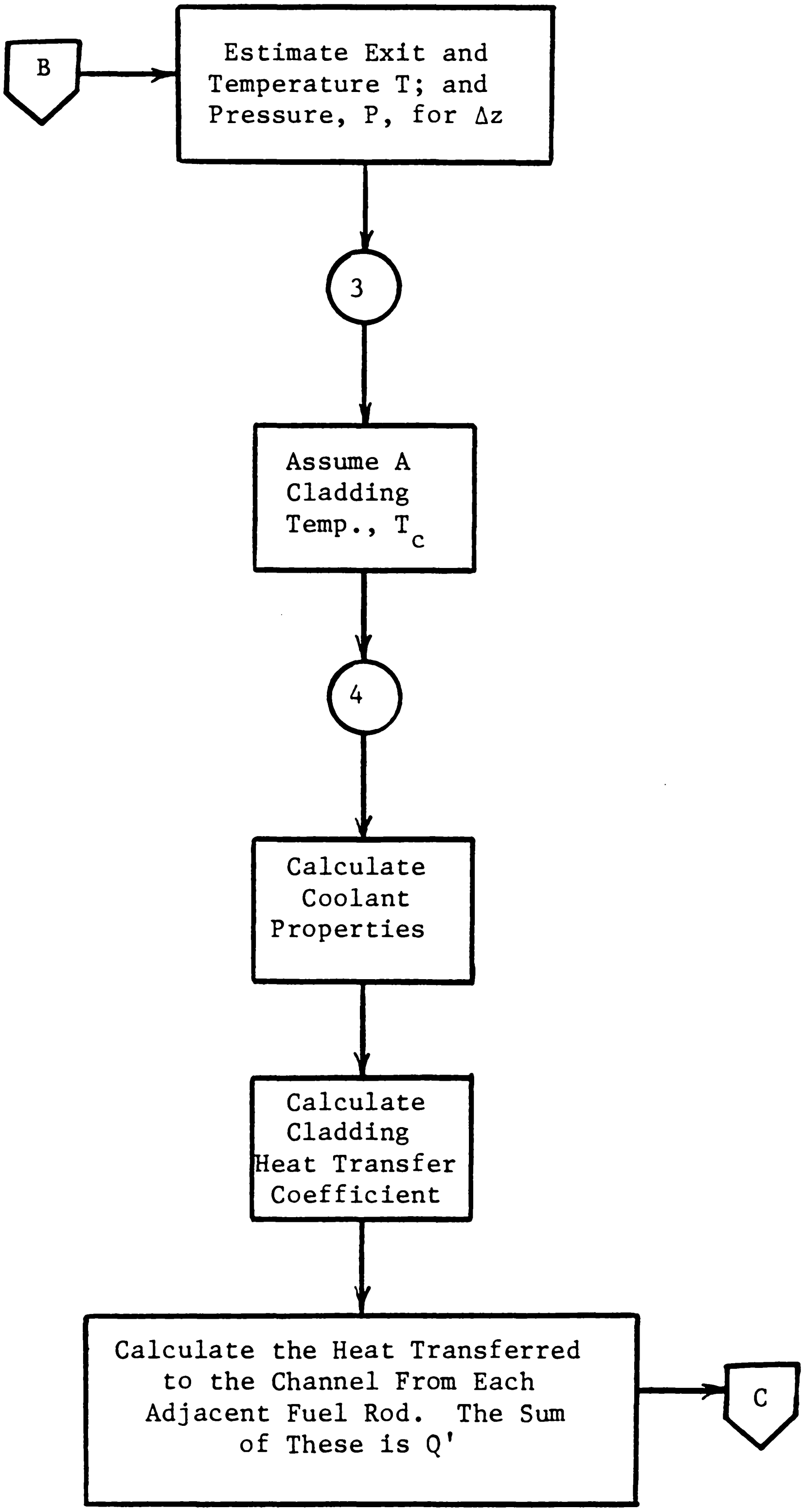
11. Hendricks, R. C., I. C. Peller, and A. K. Baron, "WASP - A Flexible Fortran IV Computer Code for Calculating Water and Steam Properties," NASA TN D-7391, Lewis Research Center, Cleveland, O., 1973.

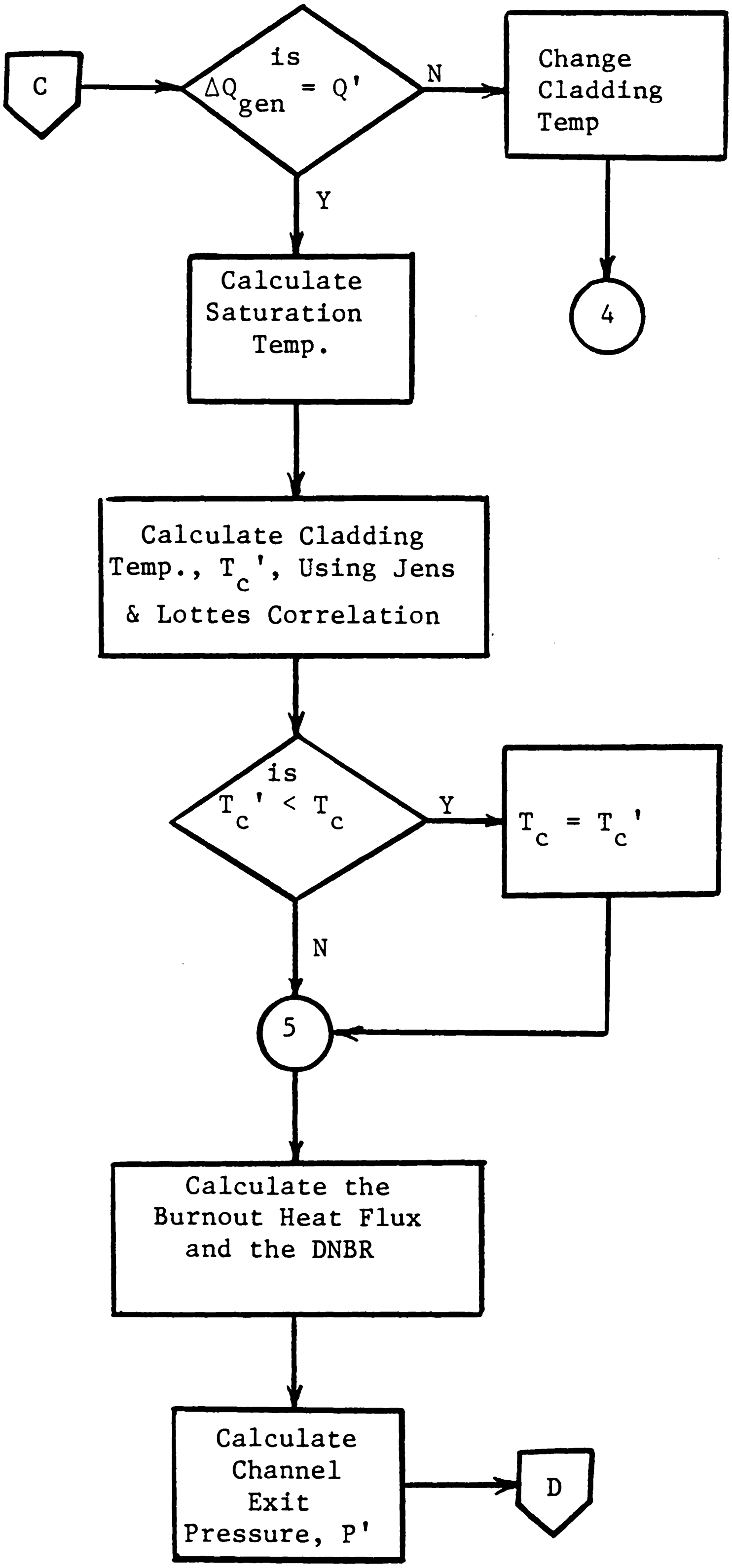
APPENDIX A

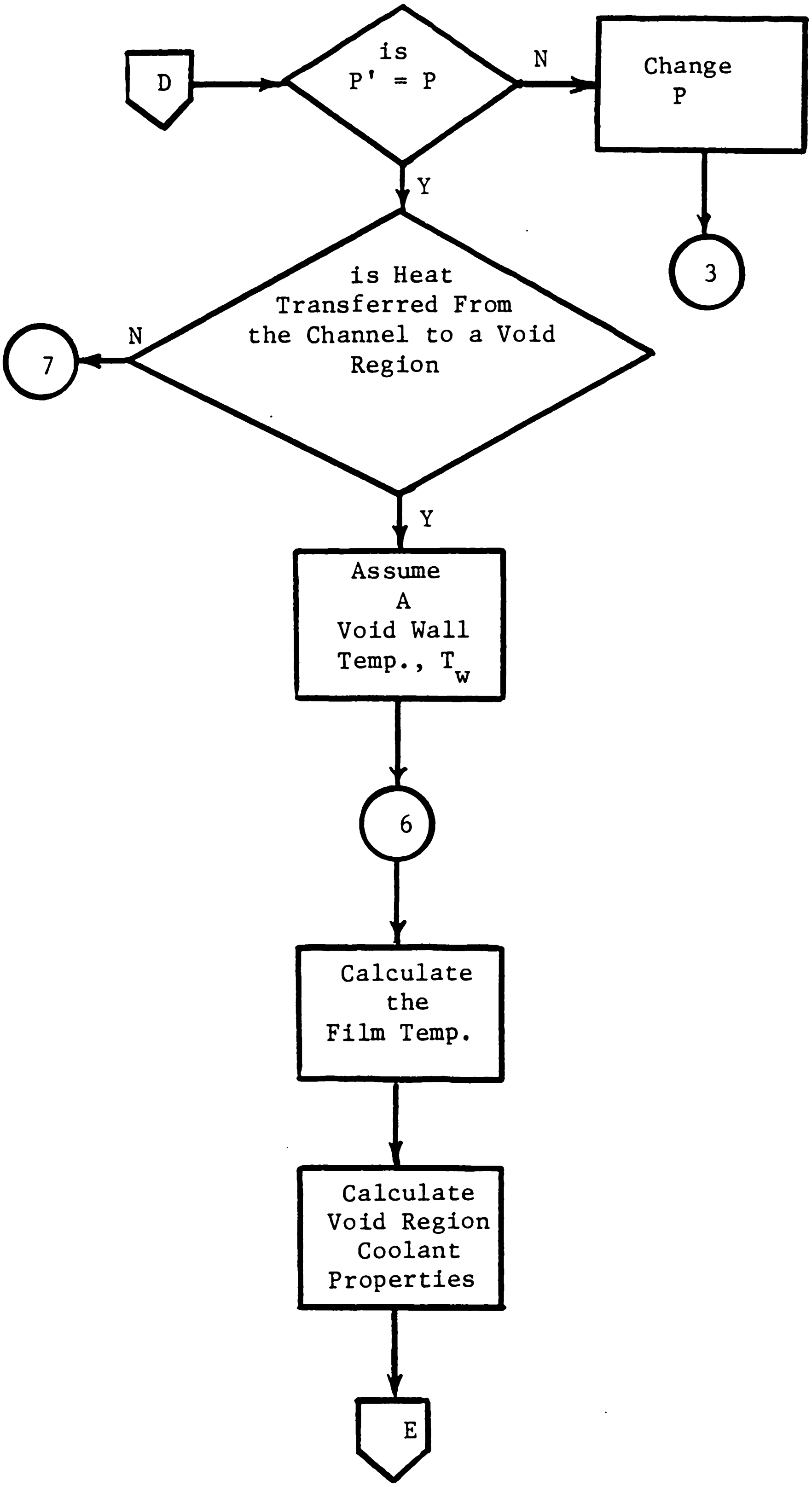
Program Flow Chart

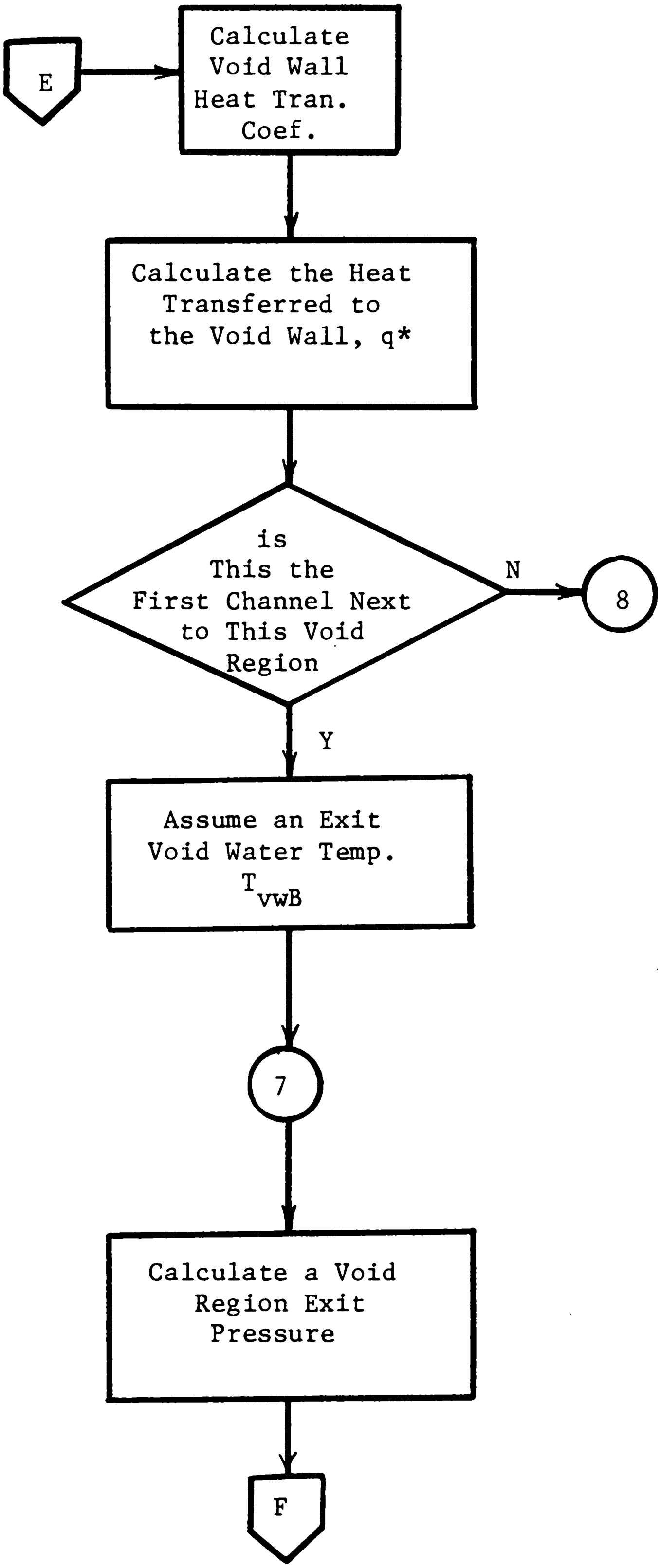

Start
Read Input Parameters
Number Coolant Channels
Define Coolant Channel Types
Define Adjacent Coolant Channels
Determine Which Void Rods or Void Plates are Removed
Calculate Coolant Inlet Properties
A

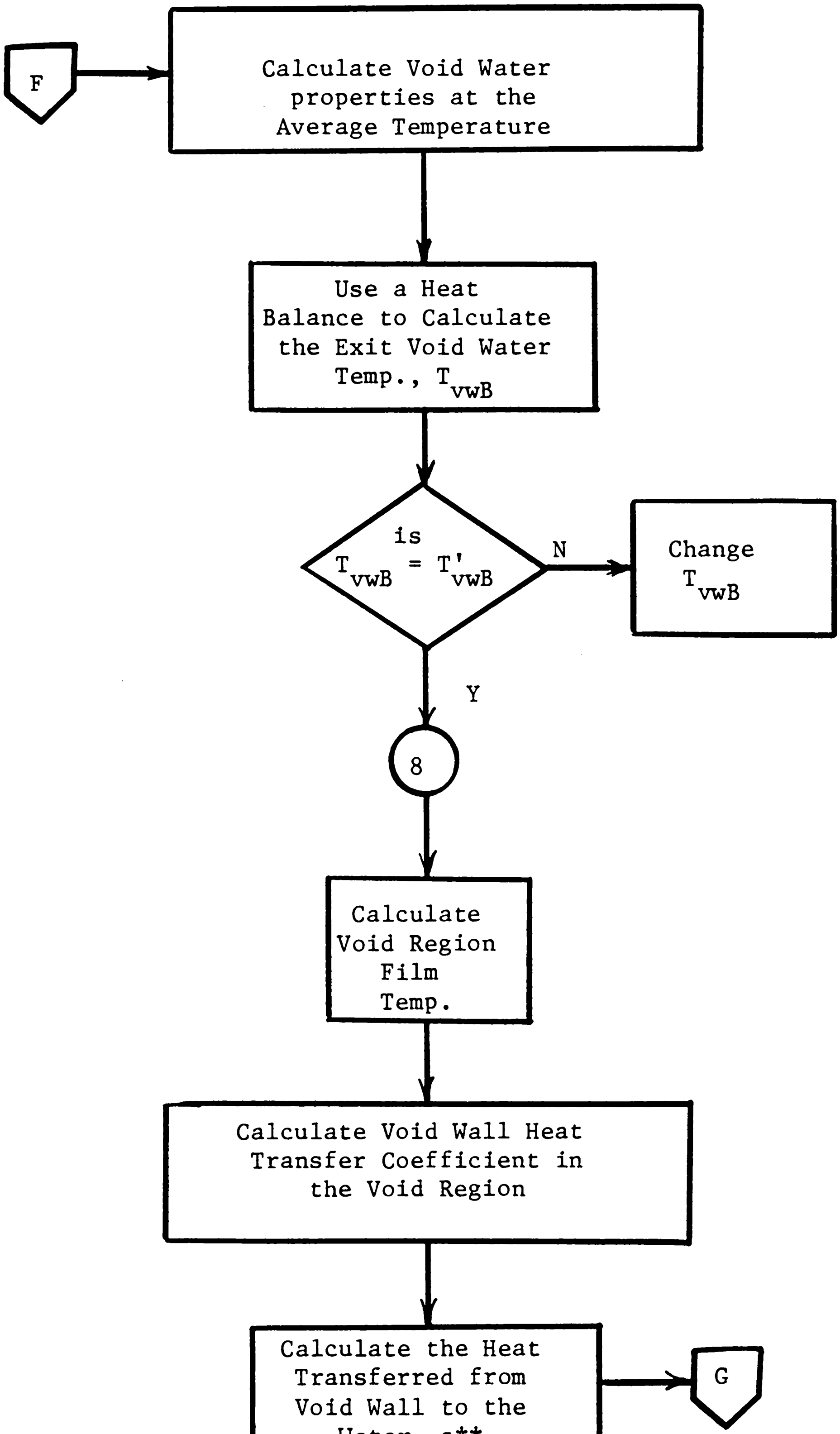

A
Begin Thermal-Hydraulic Calculations
1
Increment Z
2
Calculate Coolant Channel Geometrical Parameters
Calculate Rate Heat is Transferred Into the Channel ΔQ_{gen}
Calculate Channel Flow Rate
B

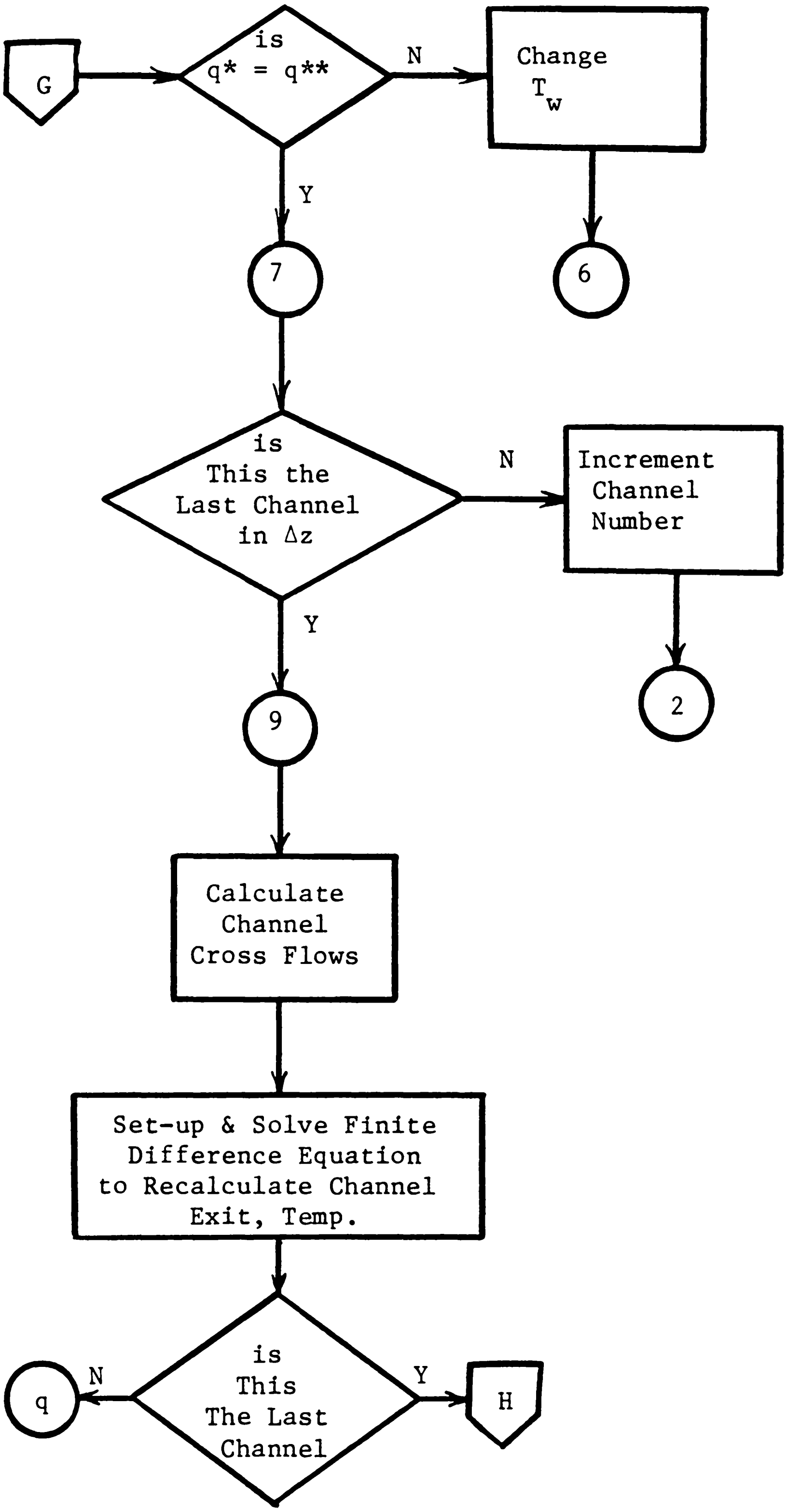

B
Estimate Exit and Temperature T; and Pressure, P, for Δz
3
Assume A Cladding Temp., T_c
4
Calculate Coolant Properties
Calculate Cladding Heat Transfer Coefficient
Calculate the Heat Transferred to the Channel From Each Adjacent Fuel Rod. The Sum of These is Q'
C

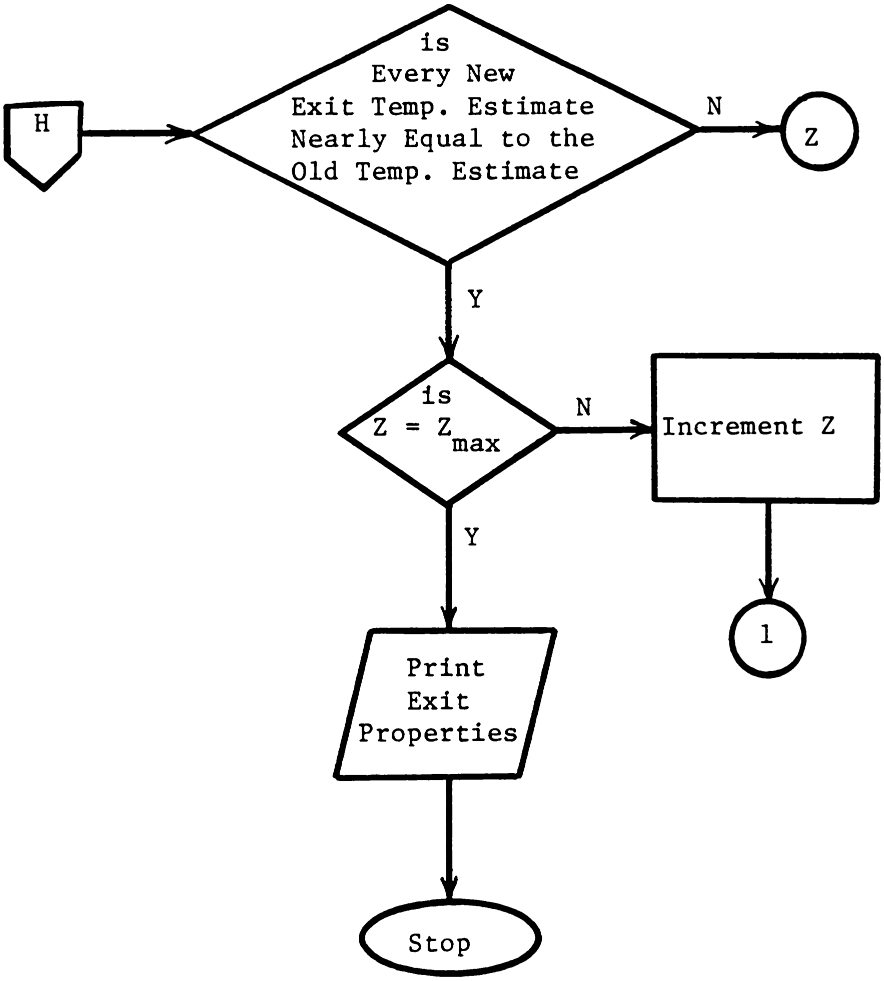

C
is
$\Delta Q_{gen} = Q'$
N
Change Cladding Temp
Y
4
Calculate Saturation Temp.
Calculate Cladding Temp., T_c', Using Jens & Lottes Correlation
is
$T_c' < T_c$
Y
$T_c = T_c'$
N
5
Calculate the Burnout Heat Flux and the DNBR
Calculate Channel Exit Pressure, P'
D


D
is
P' = P
N
Change
P
3
Y
is Heat
Transferred From
the Channel to a Void
Region
N
7
Y
Assume
A
Void Wall
Temp., T_w
6
Calculate
the
Film Temp.
Calculate
Void Region
Coolant
Properties
E


E
Calculate Void Wall Heat Tran. Coef.
Calculate the Heat Transferred to the Void Wall, q*
is This the First Channel Next to This Void Region
N
8
Y
Assume an Exit Void Water Temp. T_{vwB}
7
Calculate a Void Region Exit Pressure
F


F
Calculate Void Water properties at the Average Temperature
Use a Heat Balance to Calculate the Exit Void Water Temp., T_{vwB}
is $T_{vwB} = T'_{vwB}$
N
Change T_{vwB}
Y
8
Calculate Void Region Film Temp.
Calculate Void Wall Heat Transfer Coefficient in the Void Region
Calculate the Heat Transferred from Void Wall to the Water, q**
G


G
is
q* = q**
N
Change
T w
Y
7
6
is
This the
Last Channel
in Δz
N
Increment
Channel
Number
Y
9
2
Calculate
Channel
Cross Flows
Set-up & Solve Finite
Difference Equation
to Recalculate Channel
Exit, Temp.
is
This
The Last
Channel
N
q
Y
H


H
is
Every New
Exit Temp. Estimate
Nearly Equal to the
Old Temp. Estimate
N
Z
Y
is
Z = Zmax
N
Increment Z
Y
1
Print
Exit
Properties
Stop

APPENDIX B

Program Listing

```
C
C
C   THIS PROGRAM CALCULATES THE TEMPERATURES AND PRESSURES THROUGHOUT
C   A SPECTRAL SHIFT REACTOR CORE.  THIS IS NOT A GENERAL THERMAL-
C   HYDRAULICS PROGRAM SINCE THE POSITIONS OF THE FUEL RODS,SPACERS,
C   ETC,ARE DEFINED IN THE PROGRAM.  FOR EACH DZ INCREMENT,THE
C   FOLLOWING PARAMETERS ARE CALCULATED:
C
C     1) THE EXIT AND AVERAGE BULK TEMPERATURES AND PRESSURES
C     2) THE CLADDING TEMPERATURE AND THE CLADDING HEAT TRANSFER
C        COEFFICIENT
C     3) THE VOID WALL TEMPERATURES AND THE VOID WALL HEAT TRANSFER
C        COEFFICIENTS
C     4) THE TEMPERATURES AND PRESSURES OF THE UNFUELED WATER REGIONS
C
C   ALL TEMPERATURES ARE IN DEGREES F AND ALL PRESSURES ARE IN PSIA.
C   THE HEAT TRANSFER COEFFICIENTS ARE IN BTU/FT**2-S-F AND THE ENTHALPY
C   IS IN BTU/LBM.
C
C
C   THE PROGRAM INPUT DATA IS:
C
C     CARD 1-INLET TEMP(F),INLET PRESS.(PSIA),CORE HEIGHT(IN.),DZ THE
C            AXIAL DISTANCE INCREMENT(IN),FUEL TO WATER RATIO PARAMETER
C            NNN, THE U-235 ENRICHMENT IN %,AND THE POWER DENSITY IN
C            W/CM**3.
C     CARD 2-FUEL PIN PITCH(IN),FUEL ROD DIAMETER(IN),LEAD OF THE WIRE
C            WRAP SPACER(IN).
C     CARD 3-INLET PRESSURES(PSIA) OF EACH OF THE THREE VOID REGIONS,
C            (SHORT VOID PLATES,LONG VOID PLATES,AND VOID RODS)
C     CARD 4-MASS FLOW RATES(LBM/S)THROUGH THE FUELED AREA,A SINGLE
C            SHORT VOID PLATE,A SINGLE LONG VOID PLATE, AND A SINGLE
C            VOID ROD.
C
C   THE FUEL TO WATER RATIO PARAMETER NNN CORRESPONDS TO THE FOLLOWING
C   FUEL TO WATER RATIOS
C
C       NNN                F/W
C
C        1                 1.25
C        2                 1.19
C        3                 1.11
C        4                 1.05
C        5                 1.00
C        6                 0.95
C        7                 0.89
C        8                 0.85
C        9                 0.80
C       10                 0.75
C
```

```
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      DIMENSION X(23,23),Y(23,23),R(23,23),TBAR(23,23,6),PBAR(23,23,6)
      DIMENSION N(23,23,6),H(23,23,6),NITPIC(23,23,6),T(23,23,6)
      DIMENSION V(23,23,6),QGEN(23,23,6),P(23,23,6),TE(23,23,6)
      DIMENSION DE(23,23,6),AC(23,23,6),PE(23,23,6),HW(23,23,6)
      DIMENSION HCLAD(23,23,6),TC(23,23,6),TVWB(23,23,6),TW(23,23,6)
      DIMENSION TVWBI(23,23,6),TVWBE(23,23,6),PWRIN(23,23,6)
      DIMENSION PWROUT(23,23,6),K1(23,23,6),K2(23,23,6),K3(23,23,6)
      DIMENSION L1(23,23,6),L2(23,23,6),L3(23,23,6),M1(23,23,6)
      DIMENSION M2(23,23,6),M3(23,23,6),W1(23,23,6),W2(23,23,6)
      DIMENSION W3(23,23,6),CPP(23,23,6)
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      COMMON/JING/T,P
      COMMON/HICK/TE,PE,TC,TVWB,PWROUT
      READ(5,*)TIN,PIN,ZMAX,DZ,NNN,ENR,PDENS
      READ(5,*) PITCH,CLADOD,XLEAD
      READ(5,*)PWRIN1,PWRIN2,PWRIN3
      READ(5,*)MDOT,XMDOT1,XMDOT2,XMDOT3
      DZ=DZ/12.
      PITCH=PITCH/12.
      CLADOD=CLADOD/12.
      XLEAD=XLEAD/12.
      I=1
      J=1
      IF(NNN.EQ.1)FW=1.25
      IF(NNN.EQ.2)FW=1.19
      IF(NNN.EQ.3)FW=1.11
      IF(NNN.EQ.4)FW=1.05
      IF(NNN.EQ.5)FW=1.00
      IF(NNN.EQ.6)FW=0.95
      IF(NNN.EQ.7)FW=0.89
      IF(NNN.EQ.8)FW=0.85
      IF(NNN.EQ.9)FW=0.80
      IF(NNN.EQ.10)FW=0.75
C
C *** DEFINE FLOW CHANNEL TYPES ***
C
      ZMAX=ZMAX/12.
      DNBR1=1.0D+10
      Z=0.0
      PIN1=PWRIN1
      PIN2=PWRIN2
      PIN3=PWRIN3
      TFRIG=0.0
      CALL TYPEC(NNN,I,J,TIN,PIN)
C
C *** DEFINE ADJACIENT FLOW CHANNELS ***
C
      CALL ADJC(I,J)
C
```

```
C *** DEFINE WHICH VOID REGIONS ARE REMOVED ***
C
      CALL VRGN(NNN)
C
C *** DEFINE WHICH TYPE OF VOID REGION A FLOW CHANNEL IS NEXT TO ***
C
      CALL VOIT(I,J)
C
C *** BEGIN THERMAL-HYDRAULIC CALCULATIONS ***
C
      NUMNIT=0
C
C *** FIND INLET ENTHALPY ***
C
      CALL FRIG(TIN,PIN,D,HIN,TFRIG)
C
C *** FIND INLET SATURATION PROPERTIES ***
C
      CALL SATP(PIN,TSATIN)
      TFRIG=0.0
      PX=PIN+100.
      CALL FRIG(TSATIN,PX,D,HF,TFRIG)
 2017 CONTINUE
      NX=0
      NUMNUT=0
 2018 CONTINUE
      NX=NX+1
      NFLAG1=0.0
      NFLAG2=0.0
      NFLAG3=0.0
      DO 262 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 262 L=1,LMAX
      DO 262 M=1,6
      NN=N(KK,L,M)
      IF(NN.EQ.4)GO TO 262
      NITPIK=NITPIC(KK,L,M)
      TT=T(KK,L,M)
      PP=P(KK,L,M)
      HH=H(KK,L,M)
C
C *** CALCULATE THE CHANNEL POSITION,THE CHANNEL FLOW AREA,THE ***
C *** EQUIVALENT DIAMETER,AND THE CHANNEL HEAT GENERATION RATE ***
C
      CALL SPINK(I,J,KK,L,M,MDOT,NN,TT,PP,VV,Z,DZ,QQGEN,DDE,AAC,TFRIG,
     1D,PDENS,ZMAX,HZ)
C
C *** ESTIMATE THE EXIT TEMP. AND PRESSURE FOR DELTZ ***
C
      CALL ZICK(TT,PP,AAC,DDE,VV,DZ,QQGEN,PITCH,CLADOD,XLEAD,PPE,TTE,
     1TFRIG,D,HZ)
      IF((KK.NE.1).AND.(L.NE.1).AND.(M.NE.1))PPE=PFOUND
      IF(NX.NE.1)TTE=TE(KK,L,M)
C
```

```
C *** CALCULATE THE AVERAGE TEMPERATURES AND PRESSURES ***
C
  277 CONTINUE
      TTBAR=(TT+TTE)/2.
      PPBAR=(PP+PPE)/2.
      PC=CP
C
C *** ESTIMATE THE CLADDING TEMPERATURES ***
C
      CALL CLADT(PPBAR,TTBAR,FW,DDE,VV,HHCLAD,HZ,D,QQGEN,TTC,NN,TFRIG,
     1DZ)
  263 CONTINUE
C
C *** CALCULATE THE CLADDING HEAT TRANSFER COEFFICIENT ***
C
      CALL CLADH(PPBAR,TTBAR,FW,DDE,VV,HZ,HHCLAD,D,TFRIG)
C
C *** CHECK THE ESTIMATED VALUE OF THE CLADDING TEMPERATURE ***
C
      IF(NN.EQ.1)DEE=0.38*3.1416*DZ/(12.*2.)
      IF(NN.EQ.2)DEE=0.38*3.1416*DZ/(12.*3.)
      IF(NN.EQ.3)DEE=0.38*3.1416*DZ/(12.*6.)
      QGENP=HHCLAD*(TTC-TTBAR)*DEE
      DELTQ1=DABS(QGENP-QQGEN)
      IF(DELTQ1.LE.0.05)GO TO 264
      DELTQ=QGENP-QQGEN
      IF(DELTQ.GT.0.0)GO TO 265
      TTC=DELTQ1/(2.*HHCLAD)+TTC
      GO TO 263
  265 TTC=TTC-DELTQ1/(2.*HHCLAD)
      GO TO 263
  264 CONTINUE
C
C *** CHECK FOR BOILING HEAT TRANSFER ***
C
C *** FIND THE SATURATION TEMPERATURE FOR THE AVERAGE PRESSURE ***
C
      CALL SATP(PPBAR,TSAT)
      QDP=QQGEN*3600./DEE
      DTSUB=TSAT-TTBAR
C
C *** CALCULATE THE CLADDING TEMPERATURE AT WHICH LOCAL BOILING ***
C *** WOULD OCCUR ***
C
      TCLB=60.*(QDP/1.0D+06)**0.25/DEXP(PPBAR/900.)+TSAT
      IF(TCLB.GT.TTC)GO TO 272
      TTC=TCLB
  272 CONTINUE
C
C *** CALCULATE BURN-OUT HEAT FLUX ***
C
      G=VV*D*3600.
      A1=2.8591
      A2=0.51796
      A3=0.023018
```

```
      A4=0.6396
      A5=1.2614
      CALL FRIG(TTBAR,PPBAR,D,HZ,TFRIG)
      SPURT=TTE-TT
      IF(SPURT.LE.0.0)SPURT=1.0
      DHDZ=CP*SPURT/(DZ*12.)
      IF(NUMNIT.EQ.0)HZ=HIN+1.
      BOB=HZ-HIN
      IF(BOB.LE.0.0)HZ=HIN+1.
      Q1=A1*(DDE*G*DHDZ*12./BOB)**A2
      Q2=A3*(DDE*G*DHDZ*12./BOB)**A4
      Q3=A5*(HF-HIN)+0.123*(2000.-PIN)
      QBO=(Q1+Q2*Q3)*1.0D+06
C     IF(DTSUB.LT.0.0)WRITE(6,*)KK,L,M,TTBAR,PPBAR,TSAT,Z
C
C *** CALCULATE THE DNBR ***
C
      DNBR=QBO/QDP
C
C *** CHECK THE ESTIMATED PRESSURE DROP ***
C
      IF((KK.EQ.1).AND.(L.EQ.1).AND.(M.EQ.1))GO TO 275
      GO TO 276
  275 CALL ZICK1(TT,PP,PPBAR,TTBAR,AAC,DDE,VV,DZ,QQGEN,PITCH,CLADOD,
     1XLEAD,PENEW,TX,TFRIG,D)
      DELP=PENEW-PPE
      DELPP=DABS(DELP)
      IF(DELPP.LE.0.2)GO TO 278
      IF(DELP.GT.0.1)PPE=PPE+0.5*DELPP
      IF(DELP.LT.-0.1)PPE=PPE-0.5*DELPP
      GO TO 277
  276 CONTINUE
      PFOUND=PPE
  278 CONTINUE
C
C *** CHECK IF THE CHANNEL IS NEXT TO A WATER REGION ***
C
      IF(NN.EQ.1)GO TO 2000
      IF(HH.GT.-.01)GO TO 2000
C
C *** ASSUME A WALL TEMPERATURE ***
C
      TTW=(TTBAR+TT)/2.
 1400 CONTINUE
C
C *** CALCULATE THE INNER VOID-WALL FILM TEMPERATURE ***
C
      TFP=(TTBAR+TTW)/2.0
C
C *** CALCULATE THE INNER VOID-WALL HEAT TRANSFER COEFFICIENT ***
C
      CALL WALLH(PPBAR,TTBAR,TFP,DDE,VV,HH,TFRIG,D)
C
C *** CALCULATE THE HEAT TRANSFERRED TO THE WALL ***
C
```

```
      IF(NN.EQ.2)A=3.1416*(0.38/12.)/6.0*DZ
      IF(NN.EQ.3)A=3.1416*(0.46/12.)/6.*DZ
      QPRIM=HH*A*(TTBAR-TTW)
C
C *** CHECK IF THIS IS THE FIRST CHANNEL NEXT TO THE VOID SPACE ***
C
      IF(NUMNIT.EQ.0)T1I=TIN
      IF(NUMNIT.EQ.0)T2I=TIN
      IF(NUMNIT.EQ.0)T3I=TIN
      GO TO (1507,1508,1509),NITPIK
 1507 NFLAG1=NFLAG1+1
      IF(NFLAG1.EQ.1)GO TO 1510
      GO TO 1520
 1508 NFLAG2=NFLAG2+1
      IF(NFLAG2.EQ.1)GO TO 1510
      GO TO 1520
 1509 NFLAG3=NFLAG3+1
      IF(NFLAG3.EQ.1)GO TO 1510
      GO TO 1520
 1510 CONTINUE
C
C *** ASSUME AN EXIT WATER ROD WATER TEMPERATURE ***
C
      TTVWBE=TTW-(TTBAR-TT)
      GO TO (1516,1517,1518),NITPIK
 1516 TTVWBI=T1I
      PPWRIN=PWRIN1
      AX=1.605/144.
      TTVWB=(TTVWBE+TTVWBI)/2.0
      CALL KICK(XMDOT1,XMDOT2,XMDOT3,PPWRIN,PPWROU,
     1TTVWB,NITPIK,DZ,DEW,VR,TFRIG,D)
      PW=(PPWRIN+PPWROU)/2.0
      CALL FRIG(TTVWB,PW,D,HY,TFRIG)
      VX=XMDOT1/(D*AX)
      XXV=14.
      GO TO 1519
 1517 TTVWBI=T2I
      PPWRIN=PWRIN2
      AX=2.96/144.
      TTVWB=(TTVWBE+TTVWBI)/2.0
      CALL KICK(XMDOT1,XMDOT2,XMDOT3,PPWRIN,PPWROU,
     1TTVWB,NITPIK,DZ,DEW,VR,TFRIG,D)
      PW=(PPWRIN+PPWROU)/2.0
      CALL FRIG(TTVWB,PW,D,HY,TFRIG)
      VX=XMDOT2/(D*AX)
      XXV=34.
      GO TO 1519
 1518 TTVWBI=T3I
      PPWRIN=PWRIN3
      AX=.4474/144.
      TTVWB=(TTVWBE+TTVWBI)/2.0
      CALL KICK(XMDOT1,XMDOT2,XMDOT3,PPWRIN,PPWROU,
     1TTVWB,NITPIK,DZ,DEW,VR,TFRIG,D)
      PW=(PPWRIN+PPWROU)/2.0
      CALL FRIG(TTVWB,PW,D,HY,TFRIG)
```

```
      VX=XMDOT3/(D*AX)
      XXV=18.
 1519 CONTINUE
 1511 CONTINUE
C
C *** CHECK THE WATER ROD TEMPERATURE ASSUMPTION
C
      TEP=XXV*QPRIM/(VX*D*AX*CP)+TTVWBI
      DELTVD=TEP-TTVWBE
      ADELT=DABS(DELTVD)
      IF(ADELT.LT.0.1)GO TO 1609
      IF(DELTVD.LT.0.0)TTVWBE=TTVWBE-0.5*ADELT
      IF(DELTVD.GT.0.0)TTVWBE=TTVWBE+0.5*ADELT
      GO TO 1511
 1609 CONTINUE
      GO TO(1610,1611,1612),NITPIK
 1610 TVWBE1=TTVWBE
      POUT1=PPWROU
      GO TO 1520
 1611 TVWBE2=TTVWBE
      POUT2=PPWROU
      GO TO 1520
 1612 TVWBE3=TTVWBE
      POUT3=PPWROU
 1520 CONTINUE
      GO TO (1512,1513,1514),NITPIK
 1512 TTVWBE=TVWBE1
      PPWROU=POUT1
      PPWRIN=PWRIN1
      TTVWBI=T1I
      AX=1.605/144.
      VR=XMDOT1/(D*AX)
      DEW=0.0645
      GO TO 1515
 1513 TTVWBE=TVWBE2
      PPWROU=POUT2
      PPWRIN=PWRIN2
      TTVWBI=T2I
      AX=2.96/144.
      VR=XMDOT2/(D*AX)
      DEW=0.0655
      GO TO 1515
 1514 TTVWBE=TVWBE3
      PPWROU=POUT3
      PPWRIN=PWRIN3
      TTVWBI=T3I
      AX=0.4474/144.
      VR=XMDOT3/(D*AX)
      DEW=0.03
 1515 CONTINUE
      TTVWB=(TTVWBE+TTVWBI)/2.0
C
C *** CALCULATE THE WATER ROD FILM TEMPERATURE ***
C
      TFDP=(TTVWB+TTW)/2.0
```

```
      PW=(PPWRIN+PPWROU)/2.0
C
C *** CALCULATE THE HEAT TRANSFER COEFFICIENT OF WATER REGION ***
C
      CALL WALLH(PW,TTVWB,TFDP,DEW,VR,HHW,TFRIG,D)
C
C *** CHECK THE WALL TEMPERATURE ASSUMPTION ***
C
      IF(NITPIK.LE.2)ATRIP=DZ*0.23/12.
      IF((NITPIK.EQ.3).AND.(NN.EQ.2))ATRIP=DZ*0.01440
      IF((NITPIK.EQ.3).AND.(NN.EQ.3))ATRIP=DZ*0.02356
      QTRIP=ATRIP*HHW*(TTW-TTVWB)
      DELWQ=QTRIP-QPRIM
      DELG=DABS(DELWQ)
      IF(DELG.LT.0.01)GO TO 1999
      GX=A*HH*TTBAR+ATRIP*HHW*TTVWB
      GXX=ATRIP*HHW+A*HH
      TTTW=GX/GXX
      TTW=(TTW+TTTW)/2.
      IF((NFLAG1.EQ.1).AND.(NITPIK.EQ.1))NFLAG1=NFLAG1-1
      IF((NFLAG2.EQ.1).AND.(NITPIK.EQ.2))NFLAG2=NFLAG2-1
      IF((NFLAG3.EQ.1).AND.(NITPIK.EQ.3))NFLAG3=NFLAG3-1
      GO TO 1400
 1999 TW(KK,L,M)=TTW
      H(KK,L,M)=HH
      PWRIN(KK,L,M)=PPWRIN
      TVWBI(KK,L,M)=TTVWBI
      TVWB(KK,L,M)=TTVWB
      TVWBE(KK,L,M)=TTVWBE
      PWROUT(KK,L,M)=PPWROU
      HW(KK,L,M)=HHW
 2000 CONTINUE
      IF(DNBR.LT.DNBR1)DNBR1=DNBR
      V(KK,L,M)=VV
      QGEN(KK,L,M)=QQGEN
      PE(KK,L,M)=PPE
      TE(KK,L,M)=TTE
      TC(KK,L,M)=TTC
      HCLAD(KK,L,M)=HHCLAD
      CPP(KK,L,M)=PC
      TBAR(KK,L,M)=TTBAR
      PBAR(KK,L,M)=PPBAR
      AC(KK,L,M)=AAC
  262 CONTINUE
C
C *** CALCULATE THE CHANNEL CROSS-FLOW RATES ***
C
      DO 2151 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 2151 L=1,LMAX
      DO 2151 M=1,6
      IF(N(KK,L,M).EQ.4)GO TO 2151
      CALL SPUD(TBAR(KK,L,M),PBAR(KK,L,M),TFRIG,PITCH,XLEAD,CLADOD,
     1W1(KK,L,M),W2(KK,L,M),W3(KK,L,M),V(KK,L,M),N(KK,L,M),D)
```

```
      IF(N(KK,L,M).NE.2)GO TO 2151
      IF(N(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M)).EQ.3)GO TO 2110
 2100 CONTINUE
      IF(N(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M)).EQ.3)GO TO 2115
 2105 CONTINUE
      IF(N(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M)).EQ.3)GO TO 2120
      GO TO 2151
 2110 CALL SPID(TBAR(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M)),PBAR(K1(KK,L,M),
     1L1(KK,L,M),M1(KK,L,M)),TFRIG,PITCH,XLEAD,CLADOD,W1(KK,L,M),
     2V(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M)),D)
      GO TO 2100
 2115 CALL SPID(TBAR(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M)),PBAR(K2(KK,L,M),
     1L2(KK,L,M),M2(KK,L,M)),TFRIG,PITCH,XLEAD,CLADOD,W2(KK,L,M),
     2V(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M)),D)
      GO TO 2105
 2120 CALL SPID(TBAR(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M)),PBAR(K3(KK,L,M),
     1L3(KK,L,M),M3(KK,L,M)),TFRIG,PITCH,XLEAD,CLADOD,W3(KK,L,M),
     2V(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M)),D)
 2151 CONTINUE
C
C *** PERFORM GAUSS-SEIDEL ITERATION ON THE CHANNEL EXIT TEMPERATURES **
C
      NNT=0
      CPV=CP
      DO 4060 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 4060 L=1,LMAX
      DO 4060 M=1,6
      IF(N(KK,L,M).EQ.4) GO TO 4060
      CP=CPP(KK,L,M)
      IF(N(KK,L,M).EQ.1)GO TO 4010
      IF(N(KK,L,M).EQ.2)GO TO 4015
      IF(H(KK,L,M).LT.0.0000001)GO TO 4016
C
C *** CALCULATE CONSTANTS FOR CHANNEL TYPE 3 ***
C
      A=3.14159*0.46*DZ/72.
      ATRIP=0.23*DZ/12.
      IF(NITPIC(KK,L,M).EQ.3)ATRIP=DZ*0.02356
      XMDOT=V(KK,L,M)*D*AC(KK,L,M)
      G=H(KK,L,M)*A+HW(KK,L,M)*ATRIP
      G2=((W1(KK,L,M)+W2(KK,L,M))*DZ*CP+H(KK,L,M)*A)/2.0
      G3=G2+XMDOT*CP-((H(KK,L,M)*A)**2)/(2.*G)
      G4=H(KK,L,M)*A*HW(KK,L,M)*ATRIP*TVWB(KK,L,M)/G
      G5=W1(KK,L,M)*DZ*CP*T(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))/2.0
      G6=W2(KK,L,M)*DZ*CP*T(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M))/2.0
      G7=(((H(KK,L,M)*A)**2)/(2.*G)+XMDOT*CP-G2)*T(KK,L,M)
      B=QGEN(KK,L,M)+G5+G6+G7+G4
      AA=G3
      A1=-W1(KK,L,M)*DZ*CP/2.0
      A2=-W2(KK,L,M)*DZ*CP/2.0
      GO TO 4030
C
C *** CALCULATE CONSTANTS FOR CHANNEL TYPE 1 ***
```

```
C
 4010 A=3.14159*0.38*DZ/72.
      XMDOT=V(KK,L,M)*D*AC(KK,L,M)
      G=(XMDOT-3.*W1(KK,L,M)*DZ/2.0)*CP*T(KK,L,M)
      G2=(T(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))+T(K2(KK,L,M),L2(KK,L,M),
     1M2(KK,L,M))+T(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M)))*CP*DZ*
     2W1(KK,L,M)/2.0
      B=QGEN(KK,L,M)+G2+G
      AA=(XMDOT+3.0*W1(KK,L,M)*DZ/2.0)*CP
      A1=-W1(KK,L,M)*DZ*CP/2.0
      A2=A1
      A3=A1
      GO TO 4020
C
C *** CALCULATE CONSTANTS FOR CHANNEL TYPE 2 ***
C
 4015 IF(H(KK,L,M).LT.0.0000001)GO TO 4017
      A=3.14159*0.38*DZ/72.
      ATRIP=0.23*DZ/12.
      IF(NITPIC(KK,L,M).EQ.3)ATRIP=0.0144*DZ
      XMDOT=V(KK,L,M)*D*AC(KK,L,M)
      G=H(KK,L,M)*A+HW(KK,L,M)*ATRIP
      G2=(W1(KK,L,M)+W2(KK,L,M)+W3(KK,L,M))*DZ*CP+H(KK,L,M)*A
      G3=XMDOT*CP-((H(KK,L,M)*A)**2)/(G*2.)+G2/2.0
      G4=H(KK,L,M)*A*HW(KK,L,M)*ATRIP*TVWB(KK,L,M)/G
      G5=W1(KK,L,M)*DZ*CP*T(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))/2.
      G6=W2(KK,L,M)*DZ*CP*T(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M))/2.
      G7=W3(KK,L,M)*DZ*CP*T(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M))/2.
      G8=((H(KK,L,M)*A)**2)/(2.*G)+XMDOT*CP
      G9=((W1(KK,L,M)+W2(KK,L,M)+W3(KK,L,M))*DZ*CP+H(KK,L,M)*A)/2.0
      G10=(G8-G9)*T(KK,L,M)
      B=QGEN(KK,L,M)+G5+G6+G7+G10+G4
      AA=G3
      A1=-W1(KK,L,M)*DZ*CP/2.
      A2=-W2(KK,L,M)*DZ*CP/2.
      A3=-W3(KK,L,M)*DZ*CP/2.
      GO TO 4020
C
C *** CALCULATE CONSTANTS FOR CHANNEL TYPE 3 W/INSULATED WALLS ***
C
 4016 XMDOT=V(KK,L,M)*D*AC(KK,L,M)
      G=(XMDOT-(W1(KK,L,M)+W2(KK,L,M))*DZ/2.)*CP*T(KK,L,M)
      G2=(W1(KK,L,M)*T(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))+W2(KK,L,M)*
     1T(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M)))*DZ*CP/2.
      B=QGEN(KK,L,M)+G2+G
      AA=(XMDOT+(W1(KK,L,M)+W2(KK,L,M))*DZ/2.0)*CP
      A1=-W1(KK,L,M)*DZ*CP/2.0
      A2=-W2(KK,L,M)*DZ*CP/2.0
      GO TO 4030
C
C *** CALCULATE CONSTANTS FOR CHANNEL TYPE 2 W/INSULATED WALLS ***
C
 4017 XMDOT=V(KK,L,M)*D*AC(KK,L,M)
      G=(XMDOT-(W1(KK,L,M)+W2(KK,L,M)+W3(KK,L,M))*DZ/2.)*CP*T(KK,L,M)
      G2=(W1(KK,L,M)*T(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))+W2(KK,L,M)*
```

```
     1T(K2(KK,L,M),L2(KK,L,M),M2(KK,L,M))+W3(KK,L,M)*T(K3(KK,L,M),
     2L3(KK,L,M),M3(KK,L,M)))*DZ*CP/2.0
      B=QGEN(KK,L,M)+G2+G
      AA=(XMDOT+(W1(KK,L,M)+W2(KK,L,M)+W3(KK,L,M))*DZ/2.0)*CP
      A1=-W1(KK,L,M)*CP*DZ/2.0
      A2=-W2(KK,L,M)*CP*DZ/2.0
      A3=-W3(KK,L,M)*CP*DZ/2.0
 4020 CONTINUE
C
C *** CALCULATE NEW EXIT TEMP. FOR CHANNEL TYPES 1 AND 2 ***
C
      TENEW=(B-A1*TE(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))-A2*TE(K2(KK,L,M),
     1L2(KK,L,M),M2(KK,L,M))-A3*TE(K3(KK,L,M),L3(KK,L,M),M3(KK,L,M)))/AA
      GO TO 4040
C
C *** CALCULATE NEW EXIT TEMP. FOR CHANNEL TYPE 3 ***
C
 4030 TENEW=(B-A1*TE(K1(KK,L,M),L1(KK,L,M),M1(KK,L,M))-A2*TE(K2(KK,L,M),
     1L2(KK,L,M),M2(KK,L,M)))/AA
C
C *** CHECK DIFFERENCE BETWEEN NEW AND OLD EXIT TEMPERATURES ***
C
 4040 DELT=DABS(TENEW-TE(KK,L,M))
      IF(DELT.GT.5.)NNT=NNT+1
      TE(KK,L,M)=1.87*TENEW-.87*TE(KK,L,M)
 4060 CONTINUE
      CP=CPV
      NUMNUT=NUMNUT+1
      IF(NNT.GT.0)GO TO 2018
C
C *** CHECK IF Z EQUALS ZMAX ***
C
      DELZ=DABS(ZMAX-Z-DZ)
C
C *** RESET INITIAL VALUES ***
C
      Z=Z+DZ
      NUMNIT=NUMNIT+1
      NFLAG1=0
      NFLAG2=0
      NFLAG3=0
      DO 2040 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 2040 L=1,LMAX
      DO 2040 M=1,6
      IF(N(KK,L,M).EQ.4)GO TO 2040
      P(KK,L,M)=PE(KK,L,M)
      T(KK,L,M)=TE(KK,L,M)
      IF(H(KK,L,M).LE..000001)GO TO 2040
      IF(NITPIC(KK,L,M).EQ.1)GO TO 2027
      IF(NITPIC(KK,L,M).EQ.2)GO TO 2028
      IF(NITPIC(KK,L,M).EQ.3)GO TO 2029
 2027 NFLAG1=NFLAG1+1
      IF(NFLAG1.EQ.1)GO TO 2030
```

```
      GO TO 2040
 2028 NFLAG2=NFLAG2+1
      IF(NFLAG2.EQ.1)GO TO 2030
      GO TO 2040
 2029 NFLAG3=NFLAG3+1
      IF(NFLAG3.EQ.1)GO TO 2030
      GO TO 2040
 2030 CONTINUE
      IF(NITPIC(KK,L,M).EQ.1)T1I=TVWBE(KK,L,M)
      IF(NITPIC(KK,L,M).EQ.2)T2I=TVWBE(KK,L,M)
      IF(NITPIC(KK,L,M).EQ.3)T3I=TVWBE(KK,L,M)
      IF(NITPIC(KK,L,M).EQ.1)PWRIN1=PWROUT(KK,L,M)
      IF(NITPIC(KK,L,M).EQ.2)PWRIN2=PWROUT(KK,L,M)
      IF(NITPIC(KK,L,M).EQ.3)PWRIN3=PWROUT(KK,L,M)
 2040 CONTINUE
      IF(DELZ.LE.0.001)GO TO 2050
      GO TO 2017
C
C *** AVERAGE THE CORE ENTHALPY AT THE CORE EXIT CONDITIONS ***
C
 2050 XMTOT=0.0
      TFRIG=0.0
      HTOT=0.0
      DO 2051 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 2051 L=1,LMAX
      DO 2051 M=1,6
      IF(N(KK,L,M).EQ.4)GO TO 2051
      CALL FRIG(TE(KK,L,M),PE(KK,L,M),D,HP,TFRIG)
      XMDOT=V(KK,L,M)*AC(KK,L,M)*D
      HTOT=HTOT+XMDOT*HP
      XMTOT=XMTOT+XMDOT
 2051 CONTINUE
      TFRIG=0.0
      CALL FRIG(T1I,PWRIN1,D1,HO1,TFRIG)
      TFRIG=0.0
      CALL FRIG(T2I,PWRIN2,D2,HO2,TFRIG)
      TFRIG=0.0
      CALL FRIG(T3I,PWRIN3,D3,HO3,TFRIG)
      XN1=0.0
      XN2=0.0
      XN3=0.0
      IF(NNN.EQ.1)GO TO 2058
      IF(NNN.EQ.2)XN3=3.
      IF(NNN.EQ.3)XN3=7.
      IF(NNN.EQ.4)XN1=3.
      IF(NNN.EQ.5)GO TO 2052
      IF(NNN.EQ.6)GO TO 2053
      IF(NNN.EQ.7)GO TO 2054
      IF(NNN.EQ.8)GO TO 2055
      IF(NNN.EQ.9)GO TO 2056
      IF(NNN.EQ.10)GO TO 2057
      GO TO 2058
 2052 XN3=3.
```

```
      XN1=3.
      GO TO 2058
 2053 XN3=7.
      XN1=3.
      GO TO 2058
 2054 XN2=3.
      XN3=3.
      GO TO 2058
 2055 XN2=3.
      XN3=7.
      GO TO 2058
 2056 XN2=3.
      XN1=3.
      XN3=1.
      GO TO 2058
 2057 XN1=3.
      XN2=3.
      XN3=7.
 2058 HTOT=HTOT+XMDOT1*XN1*HO1+XMDOT2*XN2*HO2+XMDOT3*XN3*HO3
      XMTOT=XMTOT+XMDOT1*XN1+XMDOT2*XN2+XMDOT3*XN3
      HEXIT=HTOT/XMTOT
      DELH=HEXIT-HIN
      DELP=PIN-PE(2,5,2)
C
C *** WRITE EXIT TEMPERATURES AND PRESSURES ***
C
      ZMAX=ZMAX*12.
      WRITE(6,9050)
 9050 FORMAT(1H1,////,50X,'***** FUEL ASSEMBLY DATA *****',//)
      WRITE(6,9051)ZMAX,ENR,MDOT
 9051 FORMAT(5X,'THE HEIGHT IS ',F5.1,' INCHES. THE ENRICHMENT IS ',
     1F5.2,'% URANIUM-235. THE FLOWRATE THROUGH THE FUEL RODS IS ',
     2F7.2,' LBM/S',/)
      WRITE(6,9052)XMDOT3,XMDOT1
 9052 FORMAT(5X,'THE FLOWRATE THROUGH THE VOID RODS IS ',F6.2,' LBM/S.
     1THE FLOWRATE THROUGH THE SHORT VOID PLATES IS ',F6.2,' LBM/S',/)
      WRITE(6,9053)XMDOT2
 9053 FORMAT(5X,'THE FLOWRATE THROUGH THE LONG VOID PLATES IS ',F6.2,
     1' LBM/S',/)
      WRITE(6,9054)FW
 9054 FORMAT(5X,'THE FUEL TO WATER RATIO IS ',F4.2,/)
      WRITE(6,9068)DNBR1
 9068 FORMAT(5X,'THE MINIMUM DNBR IS ',F10.2,/)
      WRITE(6,9069)PDENS
 9069 FORMAT(5X,'THE POWER DENSITY IS ',F10.3,' W/CM**3',///)
      WRITE(6,9055)
 9055 FORMAT(51X,'***** INLET CONDITIONS *****',//)
      WRITE(6,9056)TIN
 9056 FORMAT(5X,'THE INLET TEMPERATURE IS ',F6.2,' DEGREES F',/)
      WRITE(6,9057)PIN
 9057 FORMAT(5X,'THE PRESSURE AT THE INLET TO THE FUEL RODS IS ',F7.2,
     1' PSIA',/)
      WRITE(6,9058)PIN3,PIN1
 9058 FORMAT(5X,'THE PRESSURE AT THE INLET TO THE VOID RODS IS ',F7.2,
     1' PSIA.  THE PRESSURE AT THE INLET TO THE SHORT VOID PLATES IS ',
```

```
     2F7.2,' PSIA',/)
      WRITE(6,9059)PIN2
 9059 FORMAT(5X,'THE PRESSURE AT THE INLET TO THE LONG VOID PLATES IS ',
     1F7.2,' PSIA',/)
      WRITE(6,9060)HIN
 9060 FORMAT(5X,'THE INLET ENTHALPY IS ',F7.2,' BTU/LBM',///)
      WRITE(6,9061)
 9061 FORMAT(49X,'***** OUTLET CONDITIONS *****',//)
      WRITE(6,9062)PE(2,5,2)
 9062 FORMAT(5X,'THE PRESSURE AT THE FUEL ROD EXIT IS ',F7.2,' PSIA',/
     1)
      WRITE(6,9063)PWRIN3,PWRIN1
 9063 FORMAT(5X,'THE PRESSURE AT THE EXIT OF THE VOID RODS IS ',F7.2,
     1' PSIA  THE PRESSURE AT THE EXIT OF THE SHORT VOID PLATES IS ',
     2F7.2,' PSIA',/)
      WRITE(6,9064)PWRIN2
 9064 FORMAT(5X,'THE PRESSURE AT THE EXIT OF THE LONG VOID PLATES IS ',
     1F7.2,' PSIA',/)
      WRITE(6,9065)HEXIT
 9065 FORMAT(5X,'THE EXIT ENTHALPY IS ',F7.2,' BTU/LBM',/)
      WRITE(6,9066)DELH
 9066 FORMAT(5X,'THE ENTHALPY INCREASE THROUGH THE ASSEMBLY IS ',F7.2,
     1' BTU/LBM',/)
      WRITE(6,9067)DELP
 9067 FORMAT(5X,'THE PRESSURE DROP THROUGH THE ASSEMBLY IS ',F7.2,' PSI'
     1)
C
C *** PRINT EXIT VALUES FOR THE INDIVIDUAL CHANNELS ***
C
      CALL PPRINT(TIN,PIN,Z)
      STOP
      END
C
C
C
C
C
C
C
      SUBROUTINE FRIG(T,P,D,H,TFRIG)
C
C *** THIS SUBROUTINE USES WASP4 TO CALCULATE THE THERMODYNAMIC ***
C *** PROPERTIES OF SATURATED WATER AT THE GIVEN PRESSURE AND   ***
C *** TEMPERATURE. THE TEMPERATURE IS INPUT IN DEGREES F AND THE ***
C *** PRESSURE IS INPUT IN PSIA.  THE RETURNED OUTPUT IS;        ***
C *** ENTHALPY IN BTU/LBM
C *** DENSITY IN LBM/FT**3
C *** ENTROPY IN BTU/LBM-R
C *** CV IN BTU/LBM-R
C *** CP IN BTU/LBM-R
C *** GAMMA (NO UNITS)
C *** C IN FT/S
C *** VISCOSITY IN LBM/FT-S
C *** THERMAL CONDUCTIVITY IN BTU/FT-S-R
C
```

```
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      PT=DABS(T-TFRIG)
      IF(PT.LT.20.)GO TO 1
C     WRITE(6,*)T,P
      KU=2
      TEMPK=273.16D00
      T=5./9.*(T-32.)+TEMPK
      PP=P*0.068046
      KR=2
      CALL WASP(1,31,T,PP,D,H,KR)
      D=D/0.016018
      H=H/2.32544
      S=S*0.2373
      CV=CV*0.2373
      CP=CP*0.2373
      C=C*0.03281
      MU=MU*0.0672
      K=K*0.01607
      T=(T-TEMPK)*9./5.+32.0
      P=PP/0.068046
      TFRIG=T
    1 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE WASP (KS,KP,TT,P,D,H,KR)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
C KEYES   KENNAN   HILL   MOORE   EQUATION  OF STATE FOR WATER
C      --------------------------MARCH 1, 1974 VERSION---------------------
C         CHANGE       10 MAY 1975      RCH
C         CHANGE       30 JUNE 1982     RCL
C                  DELETED SUBROUTINES:  TEMP
C                                        TEMPPS
C                                        TEMPPH
C                                        TSF
C                                        TSHF
C                  THIS PRECLUDES THE USE OF OPTIONS KS = 3, 4, AND 5
C
C      FOR MORE INFO ON WASP, SEE:  NASA TN D-7391  (LEW-12206)
C                                   NOVEMBER 1973
C                                   LIBRARY OF CONGRESS CALL NUMBER
C                                       TL  521  A3525
C
```

```
C
C        COMPUTE THE STATE RELATIONS AND THERMODYNAMIC AND TRANSPORT
C        PROPERTIES OF WATER  GIVEN TEMPERATURE TT, PRESSURE P,
C        DENSITY D, OR ENTHALPY H, OR ENTROPY S.  STATE RELATIONS ARE
C        SPECIFIED BY KS.  THERMODYNAMIC AND TRANSPORT PROPERTIES
C        ARE SPECIFIED BY KP.  IF KR IS RETURNED OR SPECIFIED AS 1,
C        PROPERTIES ARE COMPUTED AT SATURATION.
C   TAU IS THE TEMPERATURE PARAMETER USED IN THE EQUATION OF STATE
C          TAU IS EQUIVALENT TO T IN THIS SUBROUTINE
C
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      COMMON/PARTLS/  PTV1,PDT1
      COMMON/DERIV/PDT,PTV,PDTL,PDTV,PTVL,PTVV
      COMMON /CONV1/DCONV(5)
      COMMON /CONV3/PCONV(5)
      COMMON/TDEG  /TDEGF,TDEGC
      DIMENSION TCON(5)
C
C      DATA IN ALL 'DATA' STATEMENTS CHANGED TO DOUBLE PRECISION
C      FORMAT (6/30/82, RCL)
C
      DATA TCON/1.0D00,1.0D00,1.8D00,1.0D00,1.0D00/
      KTR=0
      TCONS=0.0
C
C      THESE TWO STATEMENTS LOCK WASP INTO UNITS OF DEGREES KELVIN
C
      TDEGF=-1.0D00
      TDEGC=-1.0D00
C
      IF (TDEGF.GT..9) TCONS=459.67
      IF(TDEGC.GT..9) TCONS=273.15
      T=TT
       IF (TT.GT.0.)  T=1000./TT
      IF ( TCONS.GT.0.0 .AND. TT.NE.0.0 )  T=1000./(TT+TCONS)
      GO TO (10,20,30,40,45),KS
C
C         COMPUTE DENSITY
   10 CALL DENS(KU,T,P,D,DL,DV,KR)
      IF ( TT .EQ. 0.0) TT=1000./T - TCONS
      GO TO 50
C
C         COMPUTE PRESSURE
   20 CALL PRESS(KU,T,D,P,KR)
      GO TO 50
C
C      THESE THREE CONTINUE STATEMENTS REPLACE CALLING STATEMENTS TO
C      THE DELETED SUBROUTINES TEMP, TEMPPH, AND TEMPPS, RESPECTIVELY.
C
   30 CONTINUE
   40 CONTINUE
   45 CONTINUE
C
   50 IF (KR.NE.1.OR.(KS.EQ.1.OR.KS.GT.3)) GO TO 55
```

```
C
C  OBTAIN SATURATION DENSITIES DL AND DV FOR KS=2 AND KS=3 CALLS WHEN
C     KR=1
      CALL DENS(KU,T,P,D,DL,DV,1)
C
 55   CONTINUE
      KTRA=KP/2**KTR
      IF(KTRA.EQ.0) RETURN
      KTR=KTR+1
      IF(MOD(KTRA,2).EQ.0) GOTO 55
      GOTO (60,100,130,160,180,240),KTR
C
C
C          COMPUTE ENTHALPY
   60 IF (KR.EQ.1) GO TO 65
      CALL ENTH(KU,T,D,H,KR)
      GO TO 70
   65 CALL ENTH(KU,T,DL,HL,KR)
      CALL ENTH (KU,T,DV,HV,KR)
 70   GOTO 55
C
C          COMPUTE ENTROPY
  100 IF (KR.EQ.1) GO TO 105
      CALL ENT(KU,T,D,S,KR)
      GO TO 110
  105 CALL ENT (KU,T,DL,SL,KR)
      CALL ENT(KU,T,DV,SV,KR)
 110  GOTO 55
C
C          COMPUTE SPECIFIC HEATS AND GAMMA AND SONIC VELOCITY
  130 IF (KR.NE.1) GO TO 135
C
C      THE PARAMETER 'KR' WAS ADDED TO THE PARAMETER LIST IN ALL
C      CALLS TO SUBROUTINE CPPRL.
C
      CALL CPPRL(KU,KR,T,DL,CPL,CVL,GAMMAL,CL)
      PTVL=PTV1*PCONV(KU)/TCON (KU)
      PDTL=PDT1*PCONV(KU)/DCONV(KU)
      CALL CPPRL(KU,KR,T,DV,CPV,CVV,GAMMAV,CVP)
      PDTV=PDT1*PCONV(KU)/DCONV(KU)
      PTVV=PTV1*PCONV(KU)/TCON (KU)
      GO TO 140
  135 CALL CPPRL(KU,KR,T,D,CP,CV,GAMMA,C)
      PTV =PTV1*PCONV(KU)/TCON (KU)
      PDT =PDT1*PCONV(KU)/DCONV(KU)
 140  GOTO 55
C
C          COMPUTE VISCOSITY
  160 IF (KR.NE.1) GO TO 165
      CALL VISC(KU,KR,T,P,DL,MUL)
      CALL VISC(KU,KR,T,P,DV,MUV)
      GO TO 170
  165 CALL VISC(KU,KR,T,P,D,MU)
 170  GOTO 55
C
```

```
C        COMPUTE THERMAL CONDUCTIVITY
  180 IF (KR.NE.1) GO TO 220
      CALL THERM (KU,KR,P,T,DL,EXCL,KL)
      CALL THERM (KU,KR,P,T,DV,EXCV,KV)
       GO TO 190
  220 CALL THERM (KU,KR,P,T,D,EXCESK,K)
 190  GOTO 55
C          COMPUTE SURFACE TENSION
  240 CALL SURF (KU,KR,T,SIGMA)
      RETURN
      END
C     -------------------------AUGUST 1, 1973 VERSION-------------------
C
      BLOCK DATA
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A1(10),A2(10),A3(10),A4(10),A5(10),A6(10),A7(10)
      COMMON /CODE/ MESSAG(24)
      COMMON /COF/ A(10,7)
      COMMON /CRIT/ RHOCRT,PCRT,TCRT
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      EQUIVALENCE (A1(1),A(1,1)),(A2(1),A(1,2)),(A3(1),A(1,3)),(A4(1),A(
     11,4)),(A5(1),A(1,5)),(A6(1),A(1,6)),(A7(1),A(1,7))
C
      COMMON/COSAT/CPS1, CPS2,CPS3,CPS4,CPS5,CPS6,CPS7
      COMMON /SICOF/ SIC1,SIC2,SIC3,SIC4,SIC5
      COMMON /CONV1/DCONV(5)
      COMMON /CONV2/TCONV(5)
      COMMON /CONV3/PCONV(5)
      COMMON/CONV4/SCONV(5)
      COMMON/CONV5/CCONV(5)
      COMMON/CONV6/HCONV(5)
      COMMON/CONV7/MCONV(5)
      COMMON/CONV8/KCONV(5)
      COMMON/CONV9/STCONV(5)
      COMMON/CONV10/ALCONV(5)
      REAL*8 MCONV,KCONV
      DATA A1/29.492937,-132.13917,274.64632,-360.93828,342.18431,
     1 -244.50042, 155.18535, 5.9728487, -410.30848, -416.05860 /
      DATA A2/ -5.1985860, 7.7779182, -33.301902, -16.254622,-177.31074,
     1 127.48742,137.416153,155.97836,337.31180,-209.88866/
      DATA A3/ 6.8335354, -26.149751, 65.326396, -26.181978, 4*0.0D00,
     1-137.46618, -733.96848  /
      DATA A4/ -0.1564104, -0.72546108, -9.2734289, 4.3125840, 4*0.0D00,
     1 6.7874983, 10.401717   /
      DATA A5/ -6.3972405, 26.409282, -47.740374, 56.323130, 4*0.0D00,
     1 136.87317, 645.81880   /
      DATA A6/ -3.9661401, 15.453061, -29.142470, 29.568796, 4*0.0D00,
     1 79.847970, 399.17570    /
      DATA A7/ -.69048554, 2.7407416, -5.1028070, 3.9636085, 4*0.0D00,
     1 13.041253, 71.531353  /
      DATA CPS1,CPS2,CPS3,CPS4,CPS5,CPS6,CPS7/
     1     0.29304370D+01,     -0.23095789D+04,     0.34522497D-01,
     2       -.13621289D-03,     0.25878044D-06,     -.24709162D-09,
```

```
     3     0.95937646D-13    /
      DATA DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2/0.0D00,1.04539D00,0.000611D00,22.089D00,100.01D00,0.55
     2555556,1.5449120,3.6609D00,0.8D00,400.0D00,0.0D00,6052.2D00 /
      DATA MESSAG / 4H THE,4HRMOD,4HYNAM,4HIC A,4HND T,4HRANS,4HPORT,4H
     1PRO,4HPERT,4HIES ,4HFOR ,4HWATE,4HRPC=,4H218.,4H07AT,4HM,TC,4H= 64
     2,4H7.29,4H K,R,4HOC=.,4H317 ,4HG/CC,4H    ,4H    /
      DATA RHOCRT,PCRT,TCRT/0.317D00, 22.089D00, 647.286D00 /
      DATA SIC1,SIC2,SIC3,SIC4,SIC5/1855.3865, 3.2786420,
     1-0.00037903, 46.174D00, -1.02117D00 /
      DATA TAUC,RHOA,RHOB,TAUA,E,R/ 1.5449120,0.634D00,1.0D00,2.5D00,4.8
     1D00,0.46151D00 /
      DATA TCONV/1.0D00,1.00D00,.55555555D00,1.0D00,1.0D00/
      DATA PCONV/1.0D00,9.8692327,145.038243,1.D06,1.0D00/
      DATA DCONV/2*1.0D00,62.4283D00,1000.0D00,1.0D00/
      DATA SCONV/2*1.0D00,.238849D00,1000.0D00,1.0D00/
      DATA CCONV/2*1.0D00,.0328084D00,0.01D00,1.0D00/
      DATA HCONV/2*1.0D00,.429929D00,1000.0D00,1.0D00/
      DATA MCONV/2*1.0D00,.67196899D-01,0.1D00 ,1.0D00/
      DATA KCONV/2*1.0D-02,1.60644D-04,1.0D00,0.1D00/
      DATA STCONV/2*1.0D00,6.8521766D-5,.001D00,1.0D00/
      DATA ALCONV/2*0.1D00,.328084D-02,0.001D00,1.0D00/
      COMMON/XMINUS/XM1(7)
      DATA XM1/1.0D00,2.0D00,3.0D00,4.0D00,5.0D00,6.0D00,7.0D00/
      END
C       ------------------------VERSION MARCH 1,1972-------------------
C
      FUNCTION   CHECK(KU,KR,T)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CONV1/DCONV(5)
      COMMON/CONV2/TCONV(5)
      COMMON/CONV3/PCONV(5)
      COMMON/IERROR/ IROUT
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      DIMENSION   FM1(13), FM2(13), FM3(13), FMT(13), ROUT(11)
C
C     THE OLD DATA STATEMENTS FOR FM1, FM2, AND FM3 WERE NOT COMPATIBLE
C     WITH THE VPISU SYSTEM, SO THEY WERE MADE INTO COMMENTS AND
C     REPLACED WITH THE THREE 'DUMMY' DATA STATEMENTS WHICH WILL STILL
C     INDICATE THAT AN ERROR HAS OCCURRED BUT NOT QUITE AS ELEGANTLY.
C
C     DATA  FM1  /52H(1H ,G12.4 ,31HIS OUT OF RANGE FOR T  IN SUB.-,A6 )
C    1 /
      DATA  FM1  /13*4HTOUT/
      DATA  FM2  /13*4HPOUT/
      DATA  FM3  /13*4HDOUT/
C     DATA  FM2  /52H(1H ,G12.4 ,31HIS OUT OF RANGE FOR P  IN SUB.-,A6 )
C    1 /
C     DATA  FM3  /52H(1H ,G12.4 ,31HIS OUT OF RANGE FOR D  IN SUB.-,A6 )
C    1 /
C
      DATA  ROUT /4HDENS,5HPRESS,4HTEMP ,4HENTH,3HENT ,6HTEMPPH,6HTEMPPS
     1,5HCPPRL,4HVISC,5HTHERM,4HSURF/
C
```

```
C        CONVERT TEMPERATURE T TO DEGREES KELVIN AND CHECK
C        FOR OUT OF RANGE.  UNITS ARE SPECIFIED BY KU.  IF KR
C        IS SPECIFIED AS 1, T IS CHECKED FOR OUT OF SATURATION
C        RANGE.
C
      ENTRY   TCHECK (KU,KR,T)
      CHECK=1000.*TCONV(KU)/T
      CH1=1000./TCH3
      CH2=1000./TCH2
      CH3=1000./TCH1
      KODE=1
      DO 1 J=1,13
    1 FMT(J)=FM1(J)
      GO TO 10
C
C         CONVERT PRESSURE TO MN/M**2 AND CHECK
C        FOR OUT OF RANGE.  UNITS ARE SPECIFIED BY KU. IF KR IS
C        SPECIFIED AS 1, P IS CHECKED FOR OUT OF SATURATION
      ENTRY  PCHECK(KU,KR,P)
      CHECK=P/PCONV(KU)
      CH1= PCH1
      CH2= PCH2
      CH3= PCH3
      KODE=0
      DO 2 J=1,13
    2 FMT(J)=FM2(J)
      GO TO 10
C
C         CONVERT DENSITY TO G/CC AND CHECK
C        FOR OUT OF RANGE.  UNITS ARE SPECIFIED BY KU.
C
      ENTRY DCHECK(KU,D)
      CHECK =D/DCONV(KU)
      CH1=DCH1
      CH3=DCH2
      KODE=0
      DO 3 J=1,13
    3 FMT(J)=FM3(J)
      GO TO 20
   10 IF(KR.EQ.1) GO TO 30
   20 IF(CHECK.LT.CH1) GO TO 40
      IF(CHECK.GT.CH3) GO TO 40
   25 IF (KODE.EQ.1) CHECK=T/TCONV(KU)
      RETURN
   30 IF(CHECK.LT.CH1) GO TO 40
      IF(CHECK.LE.CH2) GO TO 25
   40 WRITE(6,FMT) CHECK,ROUT(IROUT)
      GO TO 25
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C     THIS SUBROUTINE RETURNS THE FOLLOWING TO WASP IN USERS UNITS.
C         SPECIFIC HEAT AT CONSTANT PRESSURE  =CP
C         SPECIFIC HEAT AT CONSTANT VOLUME    =CV
C         SPECIFIC HEAT RATIO                 =GAMMA
C         SONIC VELOCITY                      = C
```

```
C       THE PARTIALS PTV AND PDT EXPLAINED BELOW ARE RETURNED IN COMMON.
C
C       THE PARAMETER 'KR' WAS ADDED TO THE INPUT LIST (6/30/82, RCL)
C
      SUBROUTINE CPPRL(KU,KR,T,D,CP,CV,GAMMA,C)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/COCPO/     COC1,COC2,COC3
      COMMON/SICOF/  C1,C2,C3,C4,C5
      COMMON /PARTLS/ PTV,PDT
      COMMON/CONSTS/ TAUC,RHOA,RHOB,TAUA,E,R
      COMMON/CONV4/SCONV(5)
      COMMON/CONV5/CCONV(5)
      COMMON/IERROR/IROUT
      IROUT=8
      TS=TCHECK(KU,KR,T)
      TT=1000./TS
      DS= DCHECK(KU,D)
      CALL QMUST(DS)
      CALL QMUST2(TS)
      CQ2T2D=Q2T2D(TS)
      CQCALC=QCALC(TS)
      CQDT=QDT(DS,TS)
      CQTD=QTD(TS)
      CQ2DT=Q2DT(DS,TS)
      CQ2D2T=Q2D2T(DS,TS)
      CV    = -2.*C3*TT+C4/TT-C5-     R*DS*TS*TS*CQ2T2D
C--- PTV IS PARTIAL OF P BY T (NOT TAU)
C--- PDT IS PARTIAL OF P BY RHO
      PTV=R*DS*(1.+DS*(CQCALC+DS*CQDT-TS*(CQTD+DS*CQ2DT)))
      PDT=R*TT*(1.+DS*(2.*CQCALC+DS*(4.*CQDT+DS*CQ2D2T)))
      DHDT=-2.*C3*TT+C4/TT-C5+R*(1.+DS*(CQCALC+DS*CQDT-TS*(DS*CQ2DT+
     1CQTD+TS*CQ2T2D)))
      DHDD=R*(TT*CQCALC+1000.*CQTD+DS*(TT*(3.*CQDT+DS*CQ2D2T)+1000.*
     1CQ2DT))
      CP    = DHDT-DHDD*(PTV/PDT)
      GAMMA=CP/CV
      CP=CP*SCONV(KU)
      CV=CV*SCONV(KU)
      GAMMAP=GAMMA * 10.* PDT
      CS=0.0
      IF ( GAMMAP.GT. 0.0) CS=1000.*DSQRT(GAMMAP)
      C= CS*CCONV(KU)
      RETURN
      END
C       -------------------------VERSION MARCH 1,1972------------------
C     CHANGE   28 APRIL 1975         RCH
C        COMPUTE DENSITY D GIVEN TEMPERATURE T AND PRESSURE P.
C        UNITS ARE SPECIFIED BY KU.  IF KR IS RETURNED OR
C        SPECIFIED AS 1, THE SATURATED LIQUID AND VAPOR DENSITIES,
C        DL AND DV RESPECTIVELY, ARE COMPUTED AS A FUNCTION
C        OF T OR P.  THE OTHER VALUE MUST BE INPUT AS 0.0 .
C
      SUBROUTINE DENS(KU,T,P,D,DL,DV,KR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CHECK1/NI
```

```
      COMMON /CONV1/DCONV(5)
      COMMON/CONV2/TCONV(5)
      COMMON/CONV3 /PCONV(5)
      COMMON/IERROR/IROUT
      COMMON /CRIT/ RHOCRT,PCRT,TCRT
      COMMON/ PSICON/ SIC1,SIC2,SIC3,SIC4,SIC5
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      COMMON/TPARAM/TS
      COMMON /PRHOT/PS,DS,TT
      EXTERNAL DSF,DDSF
      IROUT=1
      IF (KR.EQ.1) GO TO 70
      TS=TCHECK(KU,KR,T)
      TT = TS
      CALL QMUST2(TS)
      GO TO 5
   70 IF (T.GT.0.0) GO TO 75
      PS=PCHECK(KU,KR,P)
      TS=TSS(PS)
       TT = TS
      IF (T.LE.0.) T=TS *TCONV(KU)
      CALL QMUST2(TS)
      GO TO  5
   75 TS = TCHECK (KU,KR,T)
      TT = TS
      CALL QMUST2(TS)
      CALL PSSS(PS)
      IF (P.LE.0.) P=PS *PCONV(KU)
C
C         DETERMINE REGION
C
    5 IF (KR-1) 10,80,10
   10 PS=PCHECK(KU,KR,P)
      IF (PS-PCH2)110,110,100
  100 IF (TS-TCH2)130,130,120
  120 KR=2
      EST1 = 1.0455
      EST2 = RHOCRT
      TEST = 1000./TS - 273.15
      IF ( TEST .GT. 100.) EST1 = 1.0107054
      IF ( TEST .GT. 180.0) GO TO 121
      IF (TEST.LT.40.) TEST=40.
      EST2=(TEST*(TEST*(TEST*(TEST*.12476711D-09-.52277795D-07)
     1 +.54790571D-05)-.69617325D-03)+1.0220277 )
  121 CALL ROOT (EST1,EST2,0.D0,DSF,DS)
      GO TO 150
  130 KR=3
      EST=RHOCRT*3.
      CALL ROOT(EST,DCH1,0.D0,DSF,DS)
      GO TO 150
  110 IF (TS-TCH2) 50,50,20
   20 CALL PSSS(PSS)
      IF (DABS((PSS-PS)/PSS)-1.D-4) 60,30,30
```

```
   30 IF (PS-PSS) 50,60,40
   40 KR=2
   41 DS=.71854566
      IF ( TS .GT. 1.7447439) DS = .822368
      IF(TS .GT. 1.9487479) DS = .8474576
      IF ( TS .GT. 2.0277805) DS = .907441
      IF ( TS .GT. 2.3086690) DS=.961538
      IF ( TS .GT. 2.6798874) DS = 1.001001
      IF ( KR .EQ. 1) GO TO 81
      GO TO 90
   50 KR=3
      DS = PS*TS/(1000.*R)
      GO TO 90
C
C         REGION 1
C
   60 KR=1
   80 CONTINUE
      GO TO 41
   81 CONTINUE
      IF(TCH2/TS.GT..9995)  DS=1.151*RHOCRT
      DSL=SOLVE(DS,DSF,DDSF)
      IF(DSL.LT.RHOCRT.OR.1000./TS.GE.647.08)DSL=.118*DSQRT(DABS((647.36
     1-1000./TS)**2-0.0041))+.317+2.64D-4
      DS = PS*TS/(1000.*R)
      IF (TCH2/TS.GT..985)DS=.65*RHOCRT
      IF (TCH2/TS.GT..995) DS=.75*RHOCRT
      IF (TCH2/TS.GT..999) DS=.85*RHOCRT
      IF (TCH2/TS.GT..9995) DS=.90*RHOCRT
      DSV=SOLVE(DS,DSF,DDSF)
C   THE CORRECTION ADDED TO DSL CAN BE ADDED TO DSV; HOWEVER
C   THE VAPOR LOCUS DISPLAYS A SMALL CUSP WHICH MATCHES CURRENT
C   THEORY  AND SO THE CHANGE WILL NOT BE ADDED AT THIS TIME
C     PREVIOUS COEFFICIENTS FOR DL  AND DV  WERE -.0036 INSTEAD OF
C     .0041  AND  -.098 AND .0225 INSTEAD OF -.098 AND .0269
C     THE FORMER WERE BASED ON 647.3=TC AND NOW ON 647.286=TC
C     THE ADDITIONS TO DSL AND DSV  (2.64E-4AND1.2E-3) TO MATCH WASP
C ADDITIONS OF DSL AND DSV (2.64E-4&1.2E-3) TO MATCH WASP;.098 TO .11 AL
      IF((1000./TS).GT.647.15)DSV=-.11*DSQRT(DABS((647.45-1000./TS)
     1**2-.0269))+.317   +1.2D-3
C
      DL=DSL*DCONV(KU)
      DV=DSV*DCONV(KU)
      RRR=.9*RHOCRT
      IF(DSV .LT. 0.) CALL ROOT(RRR,.01D0,0.D0,DSF,DSV)
      RETURN
C
C         REGIONS 2 AND 3
C
   90 DS=SOLVE(DS,DSF,DDSF)
  150 D=DS*DCONV(KU)
      RETURN
      END
C     -------------------------VERSION MARCH 1,1972------------------
C--- PARTIAL DER OF Q --- PQ/PRHO
```

```
C
      FUNCTION QDTA(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /QAUX/ RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF/ A(10,7)
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E,R
      COMMON/XMINUS/XM1(7)
      COMMON/QS2/SUMI(7)
      EQUIVALENCE (SUMI(1),SUM)
    1 TSUM=0.0
      DO 2 J=2,7
    2 TSUM=TSUM+TADIF(J)*SUMI(J)
      QDTA=SUM+(TAU-TAUC)*TSUM
      RETURN
      ENTRY QDT(D,TAU)
      SUM=0.0
      DO 10 I=2,8
   10 SUM=SUM+XM1(I-1)*A(I,1)*RADIF(I-1)
      SUM=SUM+ER*(A(10,1)-E*(A(9,1)+A(10,1)*D))
      DO 15 J=2,7
      SUMI(J)=0.0
      DO 12 I=2,8
   12 SUMI(J)=SUMI(J)+XM1(I-1)*A(I,J)*RBDIF(I-1)
      SUMI(J)=SUMI(J)+ER*(A(10,J)-E*(A(9,J)+A(10,J)*D))
   15 CONTINUE
      GO TO 1
      END
C      -------------------------AUGUST 1, 1973 VERSION-------------------
C         FUNCTION USED TO SOLVE FOR DENSITY D  GIVEN TEMPERATURE
C         AND PRESSURE
C
      FUNCTION DSF(D )
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON /PRHOT/ PS,DS,TS
      CALL QMUST(D )
      PSTATE=1000.*R*D /TS*(1.+D *(QCALC(TS)+D *QDT(D ,TS)))
      DSF=PSTATE-PS
      RETURN
C
      ENTRY DDSF(D  )
      CALL QMUST(D)
       DSF=1000.*R/TS*(1.+D*(2.0*QCALC(TS)+4.0*D*QDT(D,TS)+D*D*Q2D2T(D,
     1TS)))
      RETURN
      END
C      -------------------------AUGUST 1, 1973 VERSION--------------------
C      MODIFIED     RCH     30 MAY 1975
C        CALCULATE THE VISCOSITY GIVEN TAU,P,AND D IN USER-S UNITS KU.
C                  ANSWER RETURNED IN USER-UNITS IN SVISC.
C
      SUBROUTINE VISC(KU,KR,TIN,PIN,DIN,SVISC)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION AVO(4),DT(6),DD(5),BV(6,5)
      DIMENSION BV1(6),BV2(6),BV3(6),BV4(6),BV5(6)
```

```
      EQUIVALENCE (BV1(1),BV(1,1)),(BV2(1),BV(1,2)),(BV3(1),BV(1,3))
     1,(BV4(1),BV(1,4)),(BV5(1),BV(1,5))
      COMMON/IERROR/IROUT
      COMMON/CRIT/ RHOCRT,PCRT,TCRT
      COMMON /TPARAM/ TIN1
      COMMON/CONV7/MCONV(5)
      COMMON/TESTMU/UNITMU
      REAL*8 MCONV
      DATA AVO/1.81583D-2,1.77624D-2,1.05287D-2,-3.6744D-3/
      DATA RHOS,TSTR/.317763D00,647.27D00/
      DATABV1/0.5019380,0.1628880,-0.1303560,0.9079190,-0.5511190,0.1465
     143D00/
      DATABV2/0.235622D00,0.789393D00, 0.673665D00,1.207552D00, 0.067066
     15D00,-0.084337D00/
      DATABV3/-0.274637D00,-0.743539D00,-0.959456D00,-0.687343D00,-0.497
     1089D00,0.195286D00/
      DATABV4/0.145831D00,0.263129D00,0.347247D00,0.213486D00,0.100754D0
     10,-0.032932D00/
      DATABV5/-0.0270448,-0.0253093,-0.0267758,-0.0822904,0.0602253,-0.0
     1202595/
      IROUT=9
      TIN1=TIN
C---
C---TK IS DEG K, T IS DEG C, TR IS REDUCED TEMP
      TK=1000./TCHECK(KU,KR,TIN)
      T = TK- 273.15
      TR=TK/TCRT
C---P IS BARS,  PMN IS MEGA NEWTONS/M*M ,PR IS REDUCED PRESSURE
      PMN=PCHECK(KU,KR ,PIN)
      P = 10.0*PMN
      PR=PMN/PCRT
C---  DS IS G/CC, SPVR IS REDUCED SPECIFIC VOLUME.
      DS=DCHECK(KU,DIN)
      SPVR= RHOCRT/DS
C
C   CHECK FOR OUT OF RANGE ON P AND T
C
      IF ( P .LT. .99 .OR. P .GT. 1000.01)  WRITE(6,100) T,P
      IF ( T .GT. 900.0 .OR. T .LT. 0.0 )   WRITE(6,100)   T,P
  100 FORMAT(1H ,48H OUT OF RANGE. VISCOSITY EXTRAPOLATED  FOR T=
     1,F12.4, 4H P= ,F12.4)
C
C     CALCULATE VISCOSITY FOR ALL REGIONS TO 900 CENT AND 1000 BAR
C
      TST=TSTR/TK-1.
      DT(1)=1.
      DT(2)=TST
      DT(3)=TST*DT(2)
      DT(4)=TST*DT(3)
      DT(5)=TST*DT(4)
      DT(6)=TST*DT(5)
      DR=DS/RHOS
      DELD=DR-1.
      DD(1)=1.
      DD(2)=DELD
```

```
      DD(3)=DELD*DD(2)
      DD(4)=DELD*DD(3)
      DD(5)=DELD*DD(4)
      SUM=0.
  101 DO 103 I=1,6
      DO 103 J=1,5
  103 SUM=SUM+BV(I,J)*DT(I)*DD(J)
      DELMU=DEXP(DR*SUM)
  102 TSR=TSTR/TK
      AMUO=DSQRT(TK/TSTR)/(((TSR*AVO(4)+AVO(3))*TSR+AVO(2))*TSR+AVO(1))
      SVISC=DELMU*AMUO*1.D-5 *MCONV(KU)
      RETURN
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C       THIS ROUTINE COMPUTES ENTROPY  GIVEN THE TEMPERATURE PARAMETER
TT
C       AND THE DENSITY D.   I/O UNITS ARE SPECIFIED BY KU.
C    IF SATURATION VALUES ARE NEEDED,THIS ROUTINE MUST BE CALLED TWICE
C       WITH DL AND DV INPUT AS D.
C               ENTROPY IS RETURNED IN S.
C
      SUBROUTINE ENT(KU,TT,D,S,KR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SICOF / PSI1,PSI2,PSI3,PSI4,PSI5
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON/IERROR/IROUT
      COMMON/CONV4/SCONV(5)
      IROUT=5
      TS=TCHECK(KU,KR,TT)
      DS=DCHECK(KU,D)
      CALL QMUST(DS)
      CALL QMUST2(TS)
      T=1000./TS
      PSIT=2.*PSI3*T +PSI2+PSI4/T +PSI5*(1.+DLOG(T ))
      SSS=-R*(DLOG(DS)+DS*(QCALC(TS)-TS*QTD(TS)))-PSIT
      S=SSS*SCONV(KU)
      RETURN
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C       THIS ROUTINE COMPUTES ENTHALPY GIVEN THE TEMPERATURE PARAMETER
TT
C       AND THE DENSITY D.   I/O UNITS ARE SPECIFIED BY KU.
C    IF SATURATION VALUES ARE NEEDED,THIS ROUTINE MUST BE CALLED TWICE
C       WITH DL AND DV INPUT AS D.
C               ENTHALPY IS RETURNED IN H.
C
      SUBROUTINE ENTH(KU,TT,D,H,KR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IERROR/IROUT
      COMMON/CONV6/HCONV(5)
      COMMON/SICOF / PSI1,PSI2,PSI3,PSI4,PSI5
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      IROUT=4
      TS=TCHECK(KU,KR,TT)
      DS=DCHECK(KU,D)
      CALL QMUST(DS)
      CALL QMUST2(TS)
```

```
      T=1000./TS
       PSIO= (PSI3*T+PSI2)*T+PSI1+(PSI4+PSI5*T)*DLOG(T)
      PSIT=2.*PSI3*T +PSI2+PSI4/T +PSI5*(1.+DLOG(T ))
      H1= PSIO-T*PSIT
      H2=1000.*R/TS*(1.+DS*(QCALC(TS)+TS*QTD(TS)+DS*QDT(DS,TS)))
      H=(H1+H2)*HCONV(KU)
      RETURN
      END
C       -------------------------VERSION MARCH 1,1972-------------------
C          COMPUTE PRESSURE P GIVEN TEMPERATURE T AND DENSITY D.
C          UNITS ARE SPECIFIED BY KU.  IF KR IS RETURNED OR
C          SPECIFIED AS 1, P IS COMPUTED AT SATURATION AS A
C          FUNCTION OF T ONLY.
C
      SUBROUTINE PRESS(KU,T,D,P,KR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CONV3/PCONV(5)
      COMMON/TPARAM/TS
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      COMMON/IERROR/IROUT
      IROUT=2
      TS=TCHECK(KU,KR,T)
C
C          DETERMINE REGION
C
      IF (KR-1) 10,70,10
   10 DS=DCHECK(KU,D)
      IF ( KR .GT. 1) GO TO 80
      IF (TS-TCH2) 50,50,20
   20 CALL DENS(1,TS,ZE,ZE,DSL,DSV,1)
      IF (DS-DSL) 30,60,40
   30 IF (DS-DSV) 50,60,60
   40 KR=2
      GO TO 80
   50 KR=3
      GO TO 80
C
C          REGION 1
C
   60 KR=1
   70 CALL PSSS(PS)
      GO TO 90
C
C          REGIONS 2 AND 3
C
   80 CALL QMUST(DS)
      CALL QMUST2(TS)
      PS=1000.*R*DS/TS*(1.+DS*(QCALC(TS)+DS*QDT(DS,TS)))
   90 P=PS*PCONV(KU)
      RETURN
      END
C       -------------------------VERSION MARCH 1,1972-------------------
C COMPUTE SATURATION PRESSURE PSSS IN BARS AS A FUNCTION OF T IN DEGREES
```

```
C          C AND RETURN ANSWER IN PSS IN MN/M**2
C
      SUBROUTINE PSSS(PSS)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/COSAT/ CPS1   ,CPS2,CPS3,CPS4,CPS5,CPS6,CPS7
C--- THE T IN THE COMMON TPARAM IS REALLY TAU
      COMMON/TPARAM/T
      DIMENSION   CTIPS(6)
      DATA  CTIPS / .31602383D-03 , 1.00044775, -0.46487771D-05,
     1  0.69431852D-08, 0.15621197D-12 , 1.00043357  /
      TSC = 1000./T -273.15
C---CONVERT  TSC(THERMODYNAMIC CELSIUS  TO INT.PRACTICAL SCALE (C) WHICH
C-----IS USED IN SATURATION  EQUATION
      IF (TSC .GE. 9.996) GO TO 9
      TS = CTIPS(6) * TSC
      GO TO 10
    9 TS =    (((CTIPS(5)*TSC+CTIPS(4))*TSC + CTIPS(3))*TSC +CTIPS(2))
     1      *TSC + CTIPS(1)
   10 TS=TS+273.15
      PSS=10.**(((((CPS7*TS+CPS6)*TS+CPS5)*TS+CPS4)*TS+CPS3)*TS+CPS2/TS+
     1CPS1)
      PSS=PSS/10.0
      RETURN
      END
C     ---------------------------VERSION 2/1/72------------------------
C        SAME AS ROOTX - NEEDED  TO  PREVENT  RECURSION
C        SOLVE FOR X1 SUCH THAT FUNC(X1) = FOFX, WHERE X1 LIES
C        BETWEEN X0 AND X2
C
      SUBROUTINE ROOT (X0,X2,FOFX,FUNC,X1)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CHECK1/KOUNT
      TOL=1.D-5
      XX0 = X0
      XX2 = X2
      F0 = FUNC(XX0)
      F2 = FUNC(XX2)
      A=(FOFX-F0)/(F2-F0)
      IF (A) 1007,120,120
  120 IF (A-1.) 130,130,1008
  130 IF (FOFX-0.) 80,70,80
   70 ASSIGN 100 TO JUMP
      GO TO 90
   80 ASSIGN 110 TO JUMP
   90 X = (XX0+XX2)/2.
      KOUNT = 0
  150 X1 = X
      KOUNT = KOUNT + 1
      A = FOFX - F2
      FX = FUNC(X)
      FXL=F0+(X-XX0)*(F2-F0)/(XX2-XX0)
      B=DABS((FX-FXL)/(F2-F0))
      IF (A*(FX-FOFX) .LT. 0.) GO TO 1001
      XX0 = X
      F0=FX
```

```
      IF (B-.3) 10,20,20
   20 X = (X+XX2)/2.
      GO TO 40
 1001 XX2 = X
      F2 = FX
      IF (B-.3) 10,30,30
   30 X = (XX0+X)/2.
      GO TO 40
   10 X=XX0+(FOFX-F0)*(XX2-XX0)/(F2-F0)
   40 IF (DABS((X-X1)/X)-TOL  ) 50,1000,1000
   50 GO TO JUMP,(100,110)
  100 IF (DABS(FUNC(X))-TOL*10. )60,1000,1000
  110 IF (DABS((FOFX-FUNC(X))/FOFX)-TOL  ) 60,1000,1000
 1000 IF (KOUNT.GT.40) TOL=TOL*10.
      IF (KOUNT.GT.60) TOL=TOL*10.
      IF (KOUNT.GT.80) TOL=TOL*10.
      IF (KOUNT.LT.100) GO TO 150
  160 WRITE (6,170) X1,X
  170 FORMAT (1HL,79HAN ITERATION HAS BEEN TERMINATED AT 100 ITERATIONS.
     1  THE LAST TWO VALUES WERE  ,3G15.5)
   60 X1=X
      RETURN
 1007 X1 = X0
      GO TO 140
 1008 X1 = X2
  140 WRITE(6,141)
  141 FORMAT(1H0,24H SOLUTION OUT OF RANGE         )
      RETURN
      END
C     ---------------------------VERSION 2/1/72------------------------
C         SOLVE FOR X1 SUCH THAT FUNC(X1) = FOFX, WHERE X1 LIES
C         BETWEEN X0 AND X2
C
      SUBROUTINE ROOTX(X0,X2,FOFX,FUNC,X1)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CHECK2/KOUNT
      TOL=1.D-5
      XX0 = X0
      XX2 = X2
      F0 = FUNC(XX0)
      F2 = FUNC(XX2)
      A=(FOFX-F0)/(F2-F0)
      IF (A) 1007,120,120
  120 IF (A-1.) 130,130,1008
  130 IF (FOFX-0.) 80,70,80
   70 ASSIGN 100 TO JUMP
      GO TO 90
   80 ASSIGN 110 TO JUMP
   90 X = (XX0+XX2)/2.
      KOUNT = 0
  150 X1 = X
      KOUNT = KOUNT + 1
      A = FOFX - F2
      FX = FUNC(X)
      FXL=F0+(X-XX0)*(F2-F0)/(XX2-XX0)
```

```
      B=DABS((FX-FXL)/(F2-F0))
      IF (A*(FX-FOFX) .LT. 0.) GO TO 1001
      XX0 = X
      F0=FX
      IF (B-.3) 10,20,20
   20 X = (X+XX2)/2.
      GO TO 40
 1001 XX2 = X
      F2 = FX
      IF (B-.3) 10,30,30
   30 X = (XX0+X)/2.
      GO TO 40
   10 X=XX0+(FOFX-F0)*(XX2-XX0)/(F2-F0)
   40 IF (DABS((X-X1)/X)-TOL  ) 50,1000,1000
   50 GO TO JUMP,(100,110)
  100 IF (DABS(FUNC(X))-TOL*10. )60,1000,1000
  110 IF (DABS((FOFX-FUNC(X))/FOFX)-TOL  ) 60,1000,1000
 1000 IF (KOUNT.GT.40) TOL=TOL*10.
      IF (KOUNT.GT.60) TOL=TOL*10.
      IF (KOUNT.GT.80) TOL=TOL*10.
      IF (KOUNT.LT.100) GO TO 150
  160 WRITE (6,170) X1,X
  170 FORMAT (1HL,79HAN ITERATION HAS BEEN TERMINATED AT 100 ITERATIONS.
     1  THE LAST TWO VALUES WERE  ,3G15.5)
   60 X1=X
      RETURN
 1007 X1 = X0
      GO TO 140
 1008 X1 = X2
  140 WRITE(6,141)
  141 FORMAT(1H0,24H SOLUTION OUT OF RANGE         )
      RETURN
      END
C     ---------------------------VERSION 2/1/72------------------------
C     MODIFIED FOR 1106    30 MAY 1975
C        NEWTON-RAPHSON ITERATION GIVEN AN INITIAL ESTIMATE XI
C        AND THE FUNCTIONS F AND DF
C
      FUNCTION SOLVE(XI,F,DF)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CHECK1/NI
      TOL=1.D-5
      NI=0
      XO=XI
      XN=XI
   10 XOO=XO
      XO=XN
C      XN=XO-F(XO)/DF(XO)
      A=F(XO)
      B=DF(XO)
      XN=XO-A/B
      NI=NI+1
      IF (DABS((XN-XO)/XN)-TOL  ) 70,20,20
   20 IF (NI.GT.40) TOL=TOL*10.
      IF (NI.GT.60) TOL=TOL*10.
```

```
      IF (NI.GT.80) TOL=TOL*10.
      IF (NI-100) 30,50,50
   30 IF (DABS((XN-XOO)/XN)-TOL  ) 40,10,10
   40 XN=(XO+XN)/2.
      GO TO 10
   50 WRITE (6,60) XOO,XO,XN
   60 FORMAT (1HL,81HAN ITERATION HAS BEEN TERMINATED AT 100 ITERATIONS.
     1  THE LAST THREE VALUES WERE   ,3G15.5)
   70 SOLVE=XN
      RETURN
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C--- THE FUNCTION Q(RHO,TAU)
C
      FUNCTION QCALC(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CHECKS/DCH1,DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,
     1HSCH1,HSCH2
      COMMON /QAUX/ RBDIF(8), RADIF(8),ER,ED, TADIF(7)
      COMMON  /COF / A(10,7)
      COMMON/QS1/SUMI(7)
      TSUM = 0.0
      DO 4 J=2,7
    4 TSUM=TSUM+TADIF(J)*SUMI(J)
      QCALC=SUMI(1)+(TAU-TCH2)*TSUM
      RETURN
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C
      SUBROUTINE QMUST(D)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON /QAUX /  RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF/ A(10,7)
      COMMON/QS1/SUMI(7)
      RADIF (1)= 1.0
      RADIF (2) = D- RHOA
      RBDIF (1) = 1.0
      RBDIF (2) = D- RHOB
      DO   1   I= 3,8
      RBDIF (I) =  RBDIF (I-1)* RBDIF(2)
    1  RADIF (I)=  RADIF (I-1) *RADIF(2)
      ED =  E*D
      ER=  1.0/ DEXP(ED)
      SUMI(1)=0.0
      DO 4 I=1,8
    4 SUMI(1)=SUMI(1)+A(I,1)*RADIF(I)
      SUMI(1)=SUMI(1)+ER*(A(9,1)+A(10,1)*D)
      DO 6 J=2,7
      SUMI(J)=0.0
      DO 5 I=1,8
    5 SUMI(J)=SUMI(J)+A(I,J)*RBDIF(I)
      SUMI(J)=SUMI(J)+ER*(A(9,J)+A(10,J)*D)
    6 CONTINUE
      RETURN
```

```
      ENTRY QMUST2(TAU)
      TADIF (1) = 0.0
      TADIF  (2) = 1.0
      TADIF  (3) = TAU-TAUA
      DO   2  I= 4,7
    2  TADIF  (I)= TADIF(I-1)* TADIF(3)
      RETURN
      END
C       -------------------------VERSION MARCH 1,1972-------------------
C--- PARTIAL DER OF Q --- PQ/PTAU
C
      DOUBLE PRECISION FUNCTION QTD(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /QAUX/RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF/ A(10,7)
      COMMON /CONSTS/TAUC,RHOA,RHOB,TAUA,E,R
      COMMON/QS1/SUMI(7)
      COMMON/XMINUS/XM1(7)
      TSUM1 = 0.0
      TSUM2 = 0.0
      DO 18 J=3,7
      TSUM1=TSUM1+XM1(J-2)*TADIF(J-1)*SUMI(J)
   18 TSUM2=TSUM2+TADIF(J)*SUMI(J)
      TSUM2=TSUM2+SUMI(2)
      QTD=TSUM2+(TAU-TAUC)*TSUM1
      RETURN
      END
C       -------------------------VERSION MARCH 1,1972-------------------
C--- PARTIAL DER OF Q --- P2Q/PRHO-PTAU
C
      DOUBLE PRECISION FUNCTION Q2DTA(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /QAUX/  RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF/ A(10,7)
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E ,R
      COMMON/QS3/SUM(6)
      COMMON/XMINUS/XM1(7)
    1 TSUM1=0.0
      TSUM2=0.0
      DO 10 J=3,7
      TSUM1=TSUM1+XM1(J-2)*TADIF(J-1)*SUM(J-1)
   10 TSUM2=TSUM2+TADIF(J)*SUM(J-1)
      TSUM2=TSUM2+SUM(1)
      TSUM1=TSUM1*(TAU-TAUC)
      Q2DTA=TSUM1+TSUM2
      RETURN
      ENTRY Q2DT(D,TAU)
      DO 20 J=2,7
      SUM(J-1)=0.
      DO 15 I=2,8
   15 SUM(J-1)=SUM(J-1)+XM1(I-1)*A(I,J)*RBDIF(I-1)
      SUM(J-1)=SUM(J-1)+ER*(A(10,J)-E*(A(9,J)+A(10,J)*D))
   20 CONTINUE
      GO TO 1
      END
```

```
C      -------------------------VERSION MARCH 1,1972-------------------
C---PARTIAL DER OF Q --- P2Q/PTAU2
C
      DOUBLE PRECISION FUNCTION Q2T2D(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /QAUX/ RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF / A(10,7)
      COMMON /CONSTS/ TAUC,RHOA,RHOB,TAUA,E,R
      COMMON/QS1/SUMI(7)
      COMMON/XMINUS/XM1(7)
      TSUM1 = 0.0
      TSUM2 = 0.0
      DO 2 J=3,7
      TSUM1=TSUM1+XM1(J-2)*TADIF(J-1)*SUMI(J)
      IF (J.EQ.3) GO TO 2
      TSUM2=TSUM2+XM1(J-2)* XM1(J-3)*TADIF(J-2)*SUMI(J)
    2 CONTINUE
      Q2T2D=2.0*TSUM1+(TAU-TAUC)*TSUM2
      RETURN
      END
C      -------------------------VERSION MARCH 1,1972-------------------
C--- PARTIAL DER OF Q --- P2Q/PRHO2
C
      DOUBLE PRECISION FUNCTION Q2D2TA(TAU)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /QAUX/ RBDIF(8),RADIF(8),ER,ED,TADIF(7)
      COMMON /COF/ A(10,7)
      COMMON /CONSTS/ TAUC, RHOA, RHOB, TAUA, E, R
      COMMON/QS4/SUMI(7)
      COMMON/XMINUS/XM1(7)
    1 TSUM=0.0
      DO 5 J=2,7
    5 TSUM=TSUM+TADIF(J)*SUMI(J)
      Q2D2TA=SUMI(1)+(TAU-TAUC)*TSUM
      RETURN
      ENTRY Q2D2T(D,TAU)
      SUMI(1)=0.0
      DO 3 I=3,8
    3 SUMI(1)=SUMI(1)+XM1(I-1)*XM1(I-2)*A(I,1)*RADIF(I-2)
      SUMI(1)=SUMI(1)+ER*(-E*A(10,1)*(2.0-ED)+E*E*A(9,1))
      DO 10 J=2,7
      SUMI(J)=0.0
      DO 8 I=3,8
    8 SUMI(J)=SUMI(J)+XM1(I-1)*XM1(I-2)*A(I,J)*RBDIF(I-2)
      SUMI(J)=SUMI(J)+ER*(-E* A(10,J)*(2.0-ED)+E*E*A(9,J))
   10 CONTINUE
      GO TO 1
      END
C      -------------------------AUGUST 1, 1973 VERSION-----------------
C     REVISED  OCT  75  ,  MAY  76  RCH
C     THIS ROUTINE CALCULATES THE SURFACE TENSION OF LIQUID WATER AND
C        THE LAPLACE CONSTANT
C
      SUBROUTINE SURF(KU,KR,TIN,SURFT)
      IMPLICIT REAL*8 (A-H,O-Z)
```

```
      COMMON/IERROR/IROUT
      COMMON /CONV1/DCONV(5)
      COMMON/CONV9/STCONV(5)
      COMMON/CONV10/ALCONV(5)
      COMMON /LAPLAC/ ALC
C---UNITS OF  G - M/S**2
       DATA G ,TK/9.80665D00,647.15D00/
      IROUT=11
C---T IS DEG K
      TAU=TCHECK(KU,KR,TIN)
      T = 1000./TAU
      SURFT=0.0
      ALC=0.0
      IF (T.GT.TK) RETURN
C--- UNITS OF SURFT MUST BE DYNE/CM
C--- UNITS OF ALC IS MM.
      TR=T/TK
      R=DABS(1.-TR)
      SURFT=235.8   *R**1.256*(1.-.625*R)
      IF (TR.GT. .998) GO TO 2
      CALL DENS(KU,TIN,ZE,ZE,DL,DV,1)
      ALC  =  DSQRT  (SURFT/  (G* DABS(DL-DV) ))
C---CONVERSION FACTOR FOR RESULTS TO BE IN MM AS IN THE TABLES
    2 ALC=ALC*ALCONV(KU)*DSQRT(DCONV(KU))
      SURFT=SURFT*STCONV(KU)
      RETURN
      END
C        -------------------------VERSION MARCH 1,1972-------------------
C          CHANGE     10 MAY 1975         RCH
C     THE YATA  MINAMIYAMA  FORM FOR THERM  COND  IS  NOT NECESSARILY
C     THE FORM  ACCEPTABLE TO IAPS   BUT  ADDED HERE BECAUSE OF ITS
C      SIMPLICITY  AND ACCURACY   RCH    5  JULY   1977
C           SUBROUTINE CALCULATES THE THERMAL CONDUCTIVITY  IN INTERNAL
C           UNITS OF W/CM-K AND CONVERTS TO USERS UNITS
C          EQUATIONS ARE THE INTERNATIONALLY AGREED UPON ONES IN REGIONS
C          WHERE SAME ARE AVAILABLE AND ARE PROPOSED EQUATIONS IN OTHER
C          REGIONS.
C         THE NEAR SUBCRITICAL REGION IS THE AUTHORS FIT
C
      SUBROUTINE THERM(KU,KR,PIN,TIN,DIN,EXCESK,TCOND)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CONV8/KCONV(5)
      COMMON/IERROR/IROUT
      COMMON/ITERAT/TR,T0,T1,T2,T3,T4,T5,T6,T7,T8
      REAL*8 KCONV
      COMMON /CRIT/ RHOCRT,PCRT,TCRT
      COMMON/TPARAM/TAU
      IROUT=10
      PMN=PCHECK(KU,KR,PIN)
      TAU=TCHECK(KU,KR,TIN)
      DS=DCHECK(KU,DIN)
C        CONVERT TAU AND PMN TO VARIOUS UNITS
      TK=1000./TAU
      TR = TK/TCRT
      T = TK-273.15
```

```
      PBAR = PMN*10.
      PR=PMN/PCRT
C---OUT OF RANGE CHECK ON PRESS AND TEMP.
      IF (PBAR.LT. .01 .OR. PBAR.GT.1000.) WRITE(6,151) TIN,PIN
      IF (T.LT.0.0.OR.T.GT.800.) WRITE(6,151) TIN,PIN
  151 FORMAT (1H0, 5H  T =,F12.4,8H OR   P =,F12.4, 64HIS OUT OF RANGE,
     1RETURNED THERMAL CONDUCTIVITY IS EXTRAPOLATED      )
      DATA A0,A1,A2,A3/1.02811D-2,2.99621D-2,1.56146D-2,-4.22464D-3/
      DATA TC,DC/647.3D00,.3177D00/
      DATA C1,C2,C3,C4,C5,C6/.642857D00,-4.11717D00,-6.17937D00,3.08976D
     1-03,8.22994D-02,10.0932D00/
       DATA Q1,Q2,Q3,Q4/7.01309D-2,1.1852D-2,1.69937D-3,-1.02D00/
      T=TK
       TR=T/TC
      D=DS
       R=D/DC
      SUM1=DSQRT(TR)*(((A3*TR+A2)*TR+A1)*TR+A0)
      SUM2=-.39707+.400302*R+1.06*DEXP(-.171587*(R+2.39219)**2)
      DELT2=DABS(TR-1.)+C4
      A=2.+C5/DELT2**.6
      B=1.+A
      D2=1./DELT2
      IF(TR.LT.1.) D2=C6/DELT2**.6
      ZZ=C2*TR**1.5+C3/R**5
      IF(ZZ.LE.-60.)GO TO 301
      ZZZ=DEXP(ZZ)
      GO TO 302
  301 ZZZ=0.0
  302 CONTINUE
      SUM4=(Q1/TR**10+Q2)*R**1.8*DEXP(C1*(1.-R**2.8))
     1+Q3*D2*R**A*DEXP(A*(1.-R**B)/B) + Q4*ZZZ
      ANS=SUM1+SUM2+SUM4
      TCOND=ANS*KCONV(KU)
      RETURN
      END
      FUNCTION TSS(PS)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CHECKS/DCH1(1),DCH2,PCH1,PCH2,PCH3,TCH1,TCH2,TCH3,DST,TST,H
     1SCH1,HSCH2
      COMMON/COSAT/ CPS1   ,CPS2,CPS3,CPS4,CPS5,CPS6,CPS7
      COMMON/BEND9/A1,A2,A3,A4,A5
      DIMENSION  CTT(6)
      DATA CTT /-.30733645D-03, 0.99955209,0.46490458D-05,-.69336443D-08
     1,-0.18086305D-12 , .99956709    /
      EXTERNAL TSSF,DTSSF
      PS1=PS*10.0
      A1=CPS1-DLOG10(PS1)
      A2=5.*CPS7
      A3=4.*CPS6
      A4=3.*CPS5
      A5=2.*CPS4
      TESTM =(1000./TCH2 -20.0 )
      TSS=SOLVE(TESTM,TSSF,DTSSF)
      IF (PS1.LT..085) CALL ROOT(273.15D0,316.D0,0.D0,TSSF,TSS)
      TSS=TSS-273.15
```

```
C---CONVERT THE CALCULATED SATURATION TEMP. FROM INT. PRACTCAL SCALE
C------(C) TO THERMODYNAMIC CELSIUS SCALE
      TSIP=TSS
      IF (TSS .GT. 10.) GO TO 9
      TSS = CTT(6)* TSS
      GO TO 10
    9 TSS =  (((CTT(5)*TSS + CTT(4))*TSS + CTT(3))*TSS + CTT(2))*TSS +
     1         CTT(1)
   10 TSS = 1000./(TSS+273.15)
      RETURN
      END
      FUNCTION TSSF(TSS)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/COSAT/ CPS1   ,CPS2,CPS3,CPS4,CPS5,CPS6,CPS7
      COMMON/BEND9/A1,A2,A3,A4,A5
      TSSF=((((CPS7*TSS+CPS6)*TSS+CPS5)*TSS+CPS4)*TSS+CPS3)*TSS+CPS2/
     1TSS+A1
      RETURN
      ENTRY    DTSSF(TSS)
C
C         DERIVATIVE OF FUNCTION USED TO SOLVE FOR SATURATION
C         TEMPERATURE TSS GIVEN PRESSURE
C
       TSSF=(((A2*TSS+A3)*TSS+A4)*TSS+A5)*TSS+CPS3-CPS2/(TSS*TSS)
      RETURN
      END
C
C
C
      SUBROUTINE CLADH(P,TB,FW,DE,V,HY,H,D,TFRIG)
C
C *** THIS SUBROUTINE CALCULATES THE CLADDING HEAT TRANSFER COEFFICIENT
C     THE UNITS USED ARE; P IN PSIA,TBULK IN F,DE IN FT, V IN FT/S
C     H IS RETURNED IN BTU/FT**2-S-R.
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
       AF=0.3277
       CC=0.0333*(AF/(AF*FW+AF))+0.0127
       XM=0.8
       XN=0.33333
       CALL FRIG(TB,P,D,HY,TFRIG)
       RE=DE*V*D/MU
       PR=CP*MU/K
       H=CC*K/DE*(RE**XM)*(PR**XN)
       RETURN
       END
C
C
C
      SUBROUTINE WALLH(P,TB,TF,DE,V,H,TFRIG,D)
C
```

```
C *** THIS SUBROUTINE CALCULATES THE WALL HEAT TRANSFER COEFFICIENT ***
C     THE UNITS USED ARE;P IN PSIA,TB IN F,TF IN F,DE IN FT,
C     V IN FT/S,H IS RETURNED IN BTU/FT**2-S-R
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(TB,P,D,HY,TFRIG)
      REB=D*V*DE/MU
      IF(REB.GT.2400.)GO TO 1
      H=4.364*K/DE
      GO TO 2
    1 CALL FRIG(TF,P,D,HY,TFRIG)
      REF=D*V*DE/MU
      PRF=CP*MU/K
      G=DLOG10(16.76/REF)
      GG=2.*DLOG10(-5.08/REF*G)
      F=GG*GG
      FS=1./F
      CALL FRIG(TB,P,D,HY,TFRIG)
      H=D*CP*V*FS/(8.*PRF**1.3)
    2 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE SPONGE(ID,J,KK,L,M,X,Y,R)
C
C     THIS SUBROUNTINE CALCULATES THE POSITION OF EACH FUEL ROD
C     GIVEN THE COORDINATES KK,&L. THE RETURNED POSITION IS GIVEN
C     IN X-Y COORDINATES AND THE RADIUS FROM THE CORE CENTER IS ALSO
C     RETURNED.  ALL DIMENSIONS ARE IN
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV
      YCAP=9.49275
      XCAP=5.4806
      I=ID-1
      XIV=FLOAT(I)
      IB=I/2*2
      IF(I.EQ.IB)GO TO 1005
      J1=(I+1)/2
      XJV=FLOAT(J)
      RCX=2.*(XJV-1.)*XCAP+XCAP
      RCY=YCAP*XIV
      IF(J.GT.J1)RCX=0.0
      IF(J.GT.J1)RCY=0.0
      GO TO 1010
 1005 J1=(I+2)/2
      XJV=FLOAT(J)
      RCX=2.*XCAP*(XJV-1.)
      RCY=YCAP*XIV
```

```
      IF(J.GT.J1)RCX=0.0
      IF(J.GT.J1)RCY=0.0
 1010 CONTINUE
      XK=FLOAT(KK)
      YP=0.398372*(12.-XK)
      XL=FLOAT(L)
      IF(KK.LE.12)XLMAX=XK+11.
      IF(KK.GT.12)XLMAX=(24.-XK)+11.
      IF(KK.LE.12)XPMAX=YP*0.57735 +(XK-1.)*0.46
      IF(KK.GT.12)XPMAX=DABS(YP)*0.57735+(23.-XK)*0.46
      XP=XPMAX-(XL-1.)*0.46
      XPP=-YP*0.5+XP*0.866
      YPP=XP*0.5+YP*0.866
      AXP=DABS(XP)
      IF(AXP.GT.XPMAX)XPP=0.0
      IF(AXP.GT.XPMAX)YPP=0.0
      X=(RCX+XPP)/12.
      Y=(RCY+YPP)/12.
      R=DSQRT(X**2+Y**2)
      RETURN
      END
C
C
C
      SUBROUTINE SPINK(I,J,KK,L,M,MDOT,N,T,P,V,Z,DZ,QGEN,DE,AC,TFRIG,D,
     1PDENS,ZMAX,HT)
C
C *** THIS SUBROUTINE IDENTIFIES THE CHANNEL TYPE GIVEN KK,L,&M.
C     GIVEN MDOT IN LBM/S,T IN F,P IN PSIA,Z IN FT, AND DZ IN FT IT
C     CALCULATES THE CHANNEL AREA AND RETURNS THE EQUIVALENT DIAMETER
C     THE CHANNEL VELOCITY IN FT/S AND THE RATE OF HEAT GENERATION
C     IN BTU/S.
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      AF=3.14159*((0.38/12.)**2)/4.+5.4512D-04
      IF((N.EQ.1).OR.(N.EQ.2))GO TO 2
      IF(N.EQ.3)GO TO 3
      IF(N.EQ.4)WRITE(6,1)
    1 FORMAT(1H1,20X,'N EQUALS 4, THIS IS N.G.')
      GO TO 4
    2 AC=0.0324/144.
      DEE=0.723/12.
      DE=4.*AC/DEE
      X1=1.017
      XGD=2.
      IF(N.EQ.2)XGD=3.
      AG=AC+AF/XGD
      GO TO 4
    3 AC=0.00628/144.
      DEE=0.480/12.
```

```
      DE=4.*AC/DEE
      X1=0.45
      XGD=6.
      AG=AC+AF/XGD
    4 CONTINUE
      AT=(125.*0.0324/144.+19.*0.00628/144.)*6.
      CALL FRIG(T,P,D,HT,TFRIG)
      VBAR=MDOT/(AT*D)
      V=VBAR*X1
C
C *** FIND LOCATION OF CHANNEL ***
C
      CALL SPONGE(I,J,KK,L,M,XX,YY,R)
      ABZ=DABS((0.51873*ZMAX-Z)*3.14159/(1.19385*ZMAX))
      QGEN=PDENS*AG*DZ*26.84*DCOS(ABZ)
      RETURN
      END
C
C
C
      SUBROUTINE ZICK(T,P,AC,DE,V,DZ,Q,PITCH,CLADOD,XLEAD,PE,TE,TFRIG,D,
     1H)
C
C      THIS SUBROUTINE ESTIMATES VALUES OF EXIT TEMPERATURE IN DEGREES
C      F AND EXIT PRESSURE IN PSIA GIVEN INLET TEMPERATURE IN DEGREES F
C      GIVEN
C      INLET PRESSURE IN PSIA,CHANNEL AREA IN FT**2,EQUIVALENT DIAMETER
C      IN FT,COOLANT VELOCITY IN FT/S,CHANNEL HEAT GENERATION RATE IN
C      BTU/S,FUEL PIN PITCH IN FT,CLADDING DIAMETER IN FT,AND THE WIRE
C      WRAP LEAD IN FT.
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(T,P,D,H,TFRIG)
      MDOT=V*AC*D
      TE=Q/(CP*MDOT)+T
      RE=DE*V*D/MU
      PR=CP*MU/K
      G=DLOG10(16.76/RE)
      GG=2.*DLOG10(-5.08/RE*G)
      F=GG*GG
      FS=1./F
      E=PITCH/CLADOD
      EE=E**6.94
      EEE=E**0.124
      E4=(XLEAD/CLADOD)**2.239
      E5=(29.7*EE*RE**0.086)/E4
      XM=1.034/EEE+E5
      PE=-(XM*FS*DZ*D*V**2)/(DE*2.*32.2*144.)+P
      RETURN
      END
```

```
C
C
C
      SUBROUTINE CLADT(P,T,FW,DE,V,HY,H,D,Q,TC,N,TFRIG,DZ)
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      IF(N.EQ.1)A=DZ*3.1416*0.38/(12.*2.)
      IF(N.EQ.2)A=DZ*3.1416*0.38/(12.*3.)
      IF(N.EQ.3)A=DZ*3.1416*0.38/(12.*6.)
      CALL CLADH(P,T,FW,DE,V,H,HY,D,TFRIG)
      TC=Q/(HY*A)+T
      RETURN
      END
      SUBROUTINE SATP(P,TSAT)
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      DIMENSION PT(30),TT(30)
      DATA PT /750.D+00,800.D+00,850.D+00,900.D+00,
     1950.D+00,1000.D+00,1050.D+00,1100.D+00,1150.D+00,1200.D+00,
     21250.D+00,1300.D+00,1350.D+00,1400.D+00,1450.D+00,1500.D+00,
     31550.D+00,1600.D+00,1650.D+00,1700.D+00,1750.D+00,1800.D+00,
     41850.D+00,1900.D+00,1950.D+00,2000.D+00,2100.D+00,2200.D+00,
     52300.D+00,2400.D+00/
      DATA TT /510.84D+00,518.21D+00,525.24D+00,531.95D+00,
     1538.39D+00,544.58D+00,550.53D+00,556.28D+00,561.82D+00,
     2567.19D+00,572.38D+00,577.42D+00,582.32D+00,587.07D+00,
     3591.70D+00,596.20D+00,600.59D+00,604.87D+00,609.05D+00,613.13D+00,
     4617.12D+00,621.02D+00,624.83D+00,628.56D+00,632.22D+00,635.80D+00,
     5642.76D+00,649.45D+00,655.89D+00,662.11D+00/
      NN=0
      DO 1I=1,30
      G=P-PT(I)
      NN=NN+1
      IF(G.LE.0.0)GO TO 2
    1 CONTINUE
    2 TSAT=TT(NN)-((PT(NN)-P)*(TT(NN)-TT(NN-1)))/(PT(NN)-PT(NN-1))
      RETURN
      END
C
C
C
C
C
      SUBROUTINE KICK(XMDOT1,XMDOT2,XMDOT3,PWRIN,PWROUT,T,NITPIC,DZ,
     1DE,V,TFRIG,D)
C
C *** THIS SUBROUTINE CALCULATES THE PRESSURE DROP OF THE WATER ***
C *** REGIONS IN PSIA GIVEN THE CHANNEL FLOWRATE IN LBM/SEC THE ***
C *** THE CHANNEL PRESSURE IN PSIA,AND THE CHANNEL TEMPERATURE  ***
C *** IN DEGREES F.
C
```

```
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(T,PWRIN,D,HY,TFRIG)
      IF(NITPIC.EQ.1)GO TO 1
      IF(NITPIC.EQ.2)GO TO 2
      IF(NITPIC.EQ.3)GO TO 3
    1 A=1.605/144.
      MDOT=XMDOT1
      DE=0.0645
      GO TO 4
    2 A=2.96/144.
      MDOT=XMDOT2
      DE=0.0655
      GO TO 4
    3 A=0.4474/144.
      MDOT=XMDOT3
      DE=0.03
    4 CONTINUE
      V=MDOT/(D*A)
      RE=D*V*DE/MU
      IF(RE.LT.2400.)GO TO 5
      PR=CP*MU/K
      G=DLOG10(16.76/RE)
      GG=2.*DLOG10(-5.08/RE*G)
      F=GG*GG
      FS=1./F
      PWROUT=PWRIN-((FS*DZ*D*V**2)/(DE*64.4))
      GO TO 6
    5 PWROUT=PWRIN-MU*DZ*MDOT/(113.804*DE**4)
    6 CONTINUE
      RETURN
      END
C
C
C
C
      SUBROUTINE ZICK1(T,P,PBAR,TBAR,AC,DE,V,DZ,Q,PITCH,CLADOD,XLEAD,PE,
     1TE,TFRIG,D)
C
C      THIS SUBROUTINE ESTIMATES VALUES OF EXIT TEMPERATURE IN DEGREES
C      F AND EXIT PRESSURE IN PSIA GIVEN INLET TEMPERATURE IN DEGREES F
C      GIVEN AVERAGE TEMPERATURE IN DEGREES F,AVERAGE PRESSURE IN PSIA,
C      INLET PRESSURE IN PSIA,CHANNEL AREA IN FT**2,EQUIVALENT DIAMETER
C      IN FT,COOLANT VELOCITY IN FT/S,CHANNEL HEAT GENERATION RATE IN
C      BTU/S,FUEL PIN PITCH IN FT,CLADDING DIAMETER IN FT,AND THE WIRE
C      WRAP LEAD IN FT.
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
```

```
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(TBAR,PBAR,D,H,TFRIG)
      MDOT=V*AC*D
      TE=Q/(CP*MDOT)+T
      RE=DE*V*D/MU
      PR=CP*MU/K
      G=DLOG10(16.76/RE)
      GG=2.*DLOG10(-5.08/RE*G)
      F=GG*GG
      FS=1./F
      E=PITCH/CLADOD
      EE=E**6.94
      EEE=E**0.124
      E4=(XLEAD/CLADOD)**2.239
      E5=(29.7*EE*RE**0.086)/E4
      XM=1.034/EEE+E5
      PE=-(XM*FS*DZ*D*V**2)/(DE*2.*32.2*144.)+P
      RETURN
      END
C
C
C
      SUBROUTINE SPUD(T,P,TFRIG,PITCH,XLEAD,CLADOD,W1,W2,W3,V,NN,D)
C
C     THIS SUBROUTINE CALCULATES THE CROSS-FLOW RATES IN LBM/S-FT
C     GIVEN THE AVERAGE CHANNEL TEMP. IN DEGREES F, THE AVERAGE
C     CHANNEL PRESSURE IN PSIA, THE FUEL ROD PITCH IN FT,THE
C     FUEL ROD DIAMETER IN FT,THE AXIAL PITCH OF THE WIRE WRAP IN
C     FT,THE CHANNEL COOLANT VELOCITY IN FT/S, AND THE CHANNEL TYPE.
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(T,P,D,H,TFRIG)
      G=V*D
      XM=3.14159*PITCH/XLEAD
      W1=XM*G*(PITCH-CLADOD)
      W2=W1
      IF(NN.EQ.3)GO TO 1
      W3=W1
    1 CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE SPID(T,P,TFRIG,PITCH,XLEAD,CLADOD,W,V,D)
C
C     THIS SUBROUTINE CALCULATES THE CROSS-FLOW RATES FOR TYPE 3
C     CHANNELS. VARIABLE DEFINITIONS AND UNITS ARE THE SAME AS
C     THOSE OF SUBROUTINE SPUD
```

```
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      COMMON/PROPTY/DL,DV,HL,HV,S,SL,SV,CV,CVL,CVV,CP,CPL,CPV,GAMMA,
     1GAMMAL,GAMMAV,C,CL,CVP,MU,MUL,MUV,K,KL,KV,SIGMA,EXCESK,EXCL,EXCV,
     2KU
      CALL FRIG(T,P,D,H,TFRIG)
      G=V*D
      XM=3.14159*PITCH/XLEAD
      W=XM*G*(PITCH-CLADOD)
      RETURN
      END
C
C
C
      SUBROUTINE TYPEC(NN,I,J,TIN,PIN)
C
C     THIS SUBROUTINE DEFINES THE CHANNEL TYPE OF EACH CHANNEL
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION NITPIC(23,23,6),N(23,23,6),K1(23,23,6),K2(23,23,6)
      DIMENSION K3(23,23,6),L1(23,23,6),L2(23,23,6),L3(23,23,6)
      DIMENSION M1(23,23,6),M2(23,23,6),M3(23,23,6),H(23,23,6)
      DIMENSION T(23,23,6),P(23,23,6)
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      COMMON/JING/T,P
      DO 900 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 900 L=1,LMAX
      DO 900 M=1,6
      T(KK,L,M)=TIN
      P(KK,L,M)=PIN
      NITPIC(KK,L,M)=0
      IF(KK.GT.12)GO TO 102
      IF(KK.NE. 1)GO TO 101
      IF(L.NE.12)GO TO 104
      IF((M.LE.3).OR.(M.EQ.6))N(KK,L,M)=2
      IF(M.LE.2)N(KK,L,M)=1
      N(KK,L,4)=3
      N(KK,L,5)=3
      GO TO 900
C
  104 IF(M.LE.5)N(KK,L,M)=3
      IF(M.LE.2)N(KK,L,M)=1
      N(KK,L,3)=4
      N(KK,L,4)=4
      N(KK,L,6)=2
      N(1,1,6)=3
      N(1,1,1)=2
      GO TO 900
C
  101 CONTINUE
      IF(L.EQ.1)GO TO 106
```

```
      IF(L.LT.LMAX)GO TO 105
      IF(M.LE.2)N(KK,L,M)=1
      N(KK,L,4)=3
      IF(M.GE.5)N(KK,L,M)=4
      N(KK,L,3)=2
      N(12,L,3)=3
      N(12,L,2)=2
      GO TO 900
C
  105 IF(M.GE.3)N(KK,L,M)=4
      IF(M.LE.2)N(KK,L,M)=1
      GO TO 900
C
  106 IF(M.LE.5)N(KK,L,M)=4
      IF(M.LE.2)N(KK,L,M)=1
      N(KK,L,1)=2
      N(12,L,1)=3
      IF(M.EQ.6)N(KK,L,M)=3
      N(12,L,2)=2
      GO TO 900
C
  102 CONTINUE
      IF(L.LT.LMAX)GO TO 107
      IF(M.LE.6)N(KK,L,M)=4
      N(KK,L,1)=1
      N(KK,L,2)=2
      N(KK,L,3)=3
      N(23,L,2)=3
      N(23,L,1)=2
      GO TO 900
C
  107 IF(M.LE.6)N(KK,L,M)=4
      IF(L.EQ.1)GO TO 108
      IF(M.LE.2)N(KK,L,M)=1
      N(23,L,1)=2
      N(23,L,2)=3
      GO TO 900
C
  108 IF(M.LE.6)N(KK,L,M)=4
      N(KK,L,1)=3
      N(KK,L,2)=2
      N(23,L,2)=3
  900 CONTINUE
C
      DO 901 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 901 L=1,LMAX
      DO 901 M=1,6
      KK1=KK-3
      KK2=KK-9
      KK3=KK-15
      GO TO(119,120,121,122),KK1
      GO TO(118,123,124,125,117),KK2
      GO TO(116,126,127,128,129),KK3
```

```
      GO TO 901
C
  116 N(KK,7,2)=2
      N(KK,8,1)=2
      N(KK,8,2)=2
      N(KK,13,2)=2
      N(KK,14,1)=2
      N(KK,14,2)=2
      GO TO 901
C
  117 N(KK,5,5)=2
      N(KK,5,4)=2
      N(KK,11,5)=2
      N(KK,11,4)=2
      N(KK,17,5)=2
      N(KK,17,4)=2
      GO TO 901
C
  118 N(KK,5,2)=2
      N(KK,6,1)=2
      N(KK,6,2)=2
      N(KK,11,2)=2
      N(KK,12,1)=2
      N(KK,12,2)=2
      N(KK,17,2)=2
      N(KK,18,1)=2
      N(KK,18,2)=2
      GO TO 901
C
  119 N(KK,5,2)=2
      N(KK,6,1)=2
      N(KK,6,2)=2
      N(KK,11,2)=2
      N(KK,12,1)=2
      N(KK,12,2)=2
      GO TO 901
C
  120 N(KK,5,1)=2
      N(KK,4,2)=2
      N(KK,5,2)=3
      N(KK,5,3)=3
      N(KK,6,2)=4
      N(KK,6,1)=4
      N(KK,7,1)=2
      N(KK,10,2)=2
      N(KK,11,1)=2
      N(KK,11,2)=3
      N(KK,11,3)=3
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=2
      GO TO 901
C
  121 N(KK,5,1)=4
      N(KK,5,2)=4
```

```
      N(KK,4,3)=2
      N(KK,6,1)=4
      N(KK,6,2)=4
      N(KK,7,1)=3
      N(KK,7,6)=3
      N(KK,7,2)=2
      N(KK,10,3)=2
      N(KK,11,1)=4
      N(KK,11,2)=4
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=3
      N(KK,13,2)=2
      N(KK,13,6)=3
      GO TO 901
C
  122 N(KK,5,4)=2
      N(KK,6,4)=3
      N(KK,6,5)=3
      N(KK,6,3)=2
      N(KK,7,1)=4
      N(KK,7,2)=4
      N(KK,8,1)=2
      N(KK,11,4)=2
      N(KK,12,4)=3
      N(KK,12,5)=3
      N(KK,12,3)=2
      N(KK,13,1)=4
      N(KK,13,2)=4
      N(KK,14,1)=2
      N(8,8,6)=2
      N(8,14,6)=2
      GO TO 901
C
  123 N(KK,4,2)=2
      N(KK,5,2)=3
      N(KK,5,3)=3
      N(KK,5,1)=2
      N(KK,6,1)=4
      N(KK,6,2)=4
      N(KK,7,1)=2
      N(KK,10,2)=2
      N(KK,11,2)=3
      N(KK,11,3)=3
      N(KK,11,1)=2
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=2
      N(KK,13,6)=4
      N(KK,16,2)=2
      N(KK,17,2)=3
      N(KK,17,3)=3
      N(KK,17,1)=2
      N(KK,18,1)=4
      N(KK,18,2)=4
```

```
      N(KK,19,1)=2
      GO TO 901
C
  124 N(KK,6,1)=4
      N(KK,4,3)=2
      N(KK,5,1)=4
      N(KK,5,2)=4
      N(KK,6,2)=4
      N(KK,7,1)=3
      N(KK,7,6)=3
      N(KK,7,2)=2
      N(KK,10,3)=2
      N(KK,11,1)=4
      N(KK,11,2)=4
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=3
      N(KK,13,6)=3
      N(KK,13,2)=2
      N(KK,16,3)=2
      N(KK,17,1)=4
      N(KK,17,2)=4
      N(KK,18,1)=4
      N(KK,18,2)=4
      N(KK,19,1)=3
      N(KK,19,2)=2
      N(KK,19,6)=3
      GO TO 901
C
  125 N(KK,4,4)=2
      N(KK,5,4)=3
      N(KK,5,5)=3
      N(KK,6,1)=4
      N(KK,6,2)=4
      N(KK,7,1)=2
      N(KK,10,4)=2
      N(KK,11,4)=3
      N(KK,11,5)=3
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=2
      N(KK,16,4)=2
      N(KK,17,4)=3
      N(KK,17,5)=3
      N(KK,18,1)=4
      N(KK,18,2)=4
      N(KK,19,1)=2
      GO TO 901
C
  126 N(KK,5,2)=2
      N(KK,6,1)=2
      N(KK,6,2)=3
      N(KK,6,3)=3
      N(KK,7,1)=4
      N(KK,7,2)=4
```

```
      N(KK,8,1)=2
      N(KK,11,2)=2
      N(KK,12,1)=2
      N(KK,12,2)=3
      N(KK,12,3)=3
      N(KK,13,1)=4
      N(KK,13,2)=4
      N(KK,14,1)=2
      GO TO 901
C
  127 N(KK,4,3)=2
      N(KK,5,1)=4
      N(KK,5,2)=4
      N(KK,6,1)=4
      N(KK,6,2)=4
      N(KK,7,1)=3
      N(KK,7,6)=3
      N(KK,10,3)=2
      N(KK,11,1)=4
      N(KK,11,2)=4
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=3
      N(KK,13,2)=2
      N(KK,13,6)=3
      GO TO 901
C
  128 N(KK,4,4)=2
      N(KK,5,3)=2
      N(KK,5,4)=3
      N(KK,5,5)=3
      N(KK,6,1)=4
      N(KK,6,2)=4
      N(KK,7,1)=2
      N(KK,7,6)=4
      N(KK,10,5)=4
      N(KK,10,4)=2
      N(KK,11,3)=2
      N(KK,11,4)=3
      N(KK,11,5)=3
      N(KK,12,1)=4
      N(KK,12,2)=4
      N(KK,13,1)=2
      N(KK,13,6)=4
      GO TO 901
  129 N(KK,5,4)=2
      N(KK,11,4)=2
  901 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ADJC(I,J)
C
C      THIS SUBROUTINE DEFINES WHICH CHANNELS ARE ADJACIENT TO THE
```

```
C     GIVEN CHANNEL
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION NITPIC(23,23,6),N(23,23,6),K1(23,23,6),K2(23,23,6)
      DIMENSION K3(23,23,6),L1(23,23,6),L2(23,23,6),L3(23,23,6)
      DIMENSION M3(23,23,6),M1(23,23,6),M2(23,23,6),H(23,23,6)
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      DO 3040 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 3040 L=1,LMAX
      DO 3040 M=1,6
      IF(N(KK,L,M).EQ.4)GO TO 3040
      IF(N(KK,L,M).EQ.1)GO TO 3000
      IF((KK.EQ.1).AND.(M.GE.5))GO TO 3010
      IF((KK.LE.12).AND.(L.EQ.1))GO TO 3020
      IF((KK.LE.12).AND.(L.EQ.LMAX))GO TO 3025
      IF(KK.GE.12)GO TO 3030
      IF(N(KK,L,M).EQ.2)GO TO 3000
      GO TO 3040
 3000 IF(KK.LE.12)GO TO 3002
      IF(M.GT.2)GO TO 3040
      IF(M.EQ.1)GO TO 3001
      IF(L.EQ.LMAX)GO TO 3007
      K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK+1
      L1(KK,L,M)=L
      L2(KK,L,M)=L+1
      L3(KK,L,M)=L
      M1(KK,L,M)=1
      M2(KK,L,M)=1
      M3(KK,L,M)=1
      GO TO 3040
 3001 K1(KK,L,M)=KK-1
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK
      L1(KK,L,M)=L
      L2(KK,L,M)=L-1
      L3(KK,L,M)=L
      M1(KK,L,M)=2
      M2(KK,L,M)=2
      M3(KK,L,M)=2
      GO TO 3040
 3002 IF(M.GT.2)GO TO 3040
      IF(M.EQ.1)GO TO 3003
      IF(L.EQ.LMAX)GO TO 3006
      IF(L.EQ.LMAX)GO TO 3006
      K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK+1
      L1(KK,L,M)=L
      L2(KK,L,M)=L+1
      L3(KK,L,M)=L+1
      M1(KK,L,M)=1
```

```
      M2(KK,L,M)=1
      M3(KK,L,M)=1
      GO TO 3040
3003  IF(KK.EQ.1)GO TO 3004
      K1(KK,L,M)=KK-1
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK
      L1(KK,L,M)=L-1
      L2(KK,L,M)=L-1
      L3(KK,L,M)=L
      M1(KK,L,M)=2
      M2(KK,L,M)=2
      M3(KK,L,M)=2
      GO TO 3040
3004  K1(KK,L,M)=1
      K2(KK,L,M)=1
      K3(KK,L,M)=1
      L1(KK,L,M)=L
      L2(KK,L,M)=L
      L3(KK,L,M)=L-1
      M1(KK,L,M)=6
      M2(KK,L,M)=2
      M3(KK,L,M)=2
      GO TO 3040
3006  K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK+1
      L1(KK,L,M)=L
      L2(KK,L,M)=L
      L3(KK,L,M)=L+1
      M1(KK,L,M)=3
      M2(KK,L,M)=1
      M3(KK,L,M)=1
      IF(KK.EQ.12)GO TO 3008
      GO TO 3040
3007  K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK+1
      L1(KK,L,M)=L
      L2(KK,L,M)=L
      L3(KK,L,M)=L-1
      M1(KK,L,M)=3
      M2(KK,L,M)=1
      M3(KK,L,M)=3
      GO TO 3040
3008  L3(KK,L,M)=L-1
      M3(KK,L,M)=3
      GO TO 3040
3010  IF(M.EQ.6)GO TO 3015
      K1(KK,L,M)=1
      K2(KK,L,M)=1
      L1(KK,L,M)=L
      L2(KK,L,M)=L+1
      M1(KK,L,M)=6
      M2(KK,L,M)=6
```

```
     GO TO 3040
3015 IF(L.EQ.1)GO TO 3016
     K1(KK,L,M)=1
     K2(KK,L,M)=1
     K3(KK,L,M)=1
     L1(KK,L,M)=L-1
     L2(KK,L,M)=L
     L3(KK,L,M)=L
     M1(KK,L,M)=5
     M2(KK,L,M)=5
     M3(KK,L,M)=1
     GO TO 3040
3016 K1(KK,L,M)=1
     K2(KK,L,M)=1
     L1(KK,L,M)=L
     L2(KK,L,M)=1
     M1(KK,L,M)=5
     M2(KK,L,M)=1
     GO TO 3040
3020 IF(M.EQ.1)GO TO 3021
     IF(M.NE.6)GO TO 3040
     K1(KK,L,M)=KK
     K2(KK,L,M)=KK-1
     L1(KK,L,M)=1
     L2(KK,L,M)=1
     M1(KK,L,M)=1
     M2(KK,L,M)=1
     GO TO 3040
3021 IF(KK.EQ.12)GO TO 3040
     K1(KK,L,M)=KK
     K2(KK,L,M)=KK
     K3(KK,L,M)=KK+1
     L1(KK,L,M)=1
     L2(KK,L,M)=1
     L3(KK,L,M)=1
     M1(KK,L,M)=2
     M2(KK,L,M)=6
     M3(KK,L,M)=6
     GO TO 3040
3025 IF(M.EQ.4)GO TO 3026
     IF(M.EQ.2)GO TO 3006
     IF(M.NE.3)GO TO 3040
     IF(KK.EQ.12)GO TO 3027
     K1(KK,L,M)=KK
     K2(KK,L,M)=KK
     K3(KK,L,M)=KK+1
     L1(KK,L,M)=L
     L2(KK,L,M)=L
     L3(KK,L,M)=L+1
     M1(KK,L,M)=2
     M2(KK,L,M)=4
     M3(KK,L,M)=4
     GO TO 3040
3026 IF(KK.EQ.12)GO TO 3040
     K1(KK,L,M)=KK
```

```
      K2(KK,L,M)=KK-1
      L1(KK,L,M)=L
      L2(KK,L,M)=L-1
      M1(KK,L,M)=3
      M2(KK,L,M)=3
      GO TO 3040
 3027 K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      L1(KK,L,M)=L
      L2(KK,L,M)=L
      M1(KK,L,M)=2
      M2(KK,L,M)=4
      GO TO 3040
 3030 IF((L.EQ.1).AND.(M.EQ.1))GO TO 3033
      IF(L.EQ.LMAX)GO TO 3031
      IF((KK.EQ.12).AND.(N(KK,L,M).EQ.2))GO TO 3000
      IF((KK.NE.23).AND.(N(KK,L,M).EQ.2))GO TO 3000
      IF(KK.NE.23)GO TO 3040
      IF((L.EQ.1).AND.(M.EQ.1))GO TO 3040
      IF((KK.EQ.23).AND.(M.EQ.1))GO TO 3000
      IF(M.NE.2)GO TO 3040
      K1(KK,L,M)=23
      K2(KK,L,M)=23
      L1(KK,L,M)=L
      L2(KK,L,M)=L+1
      M1(KK,L,M)=1
      M2(KK,L,M)=1
      GO TO 3040
 3031 IF(KK.EQ.12)GO TO 3040
      IF(M.GT.3)GO TO 3040
      IF(M.EQ.1)GO TO 3000
      IF(M.EQ.2)GO TO 3032
      K1(KK,L,M)=KK
      K2(KK,L,M)=KK-1
      L1(KK,L,M)=L
      L2(KK,L,M)=L+1
      M1(KK,L,M)=2
      M2(KK,L,M)=2
      GO TO 3040
 3032 K1(KK,L,M)=KK
      K2(KK,L,M)=KK
      K3(KK,L,M)=KK+1
      L1(KK,L,M)=L
      L2(KK,L,M)=L
      L3(KK,L,M)=L-1
      M1(KK,L,M)=1
      M2(KK,L,M)=3
      M3(KK,L,M)=3
      GO TO 3040
 3033 K1(KK,L,M)=KK
      K2(KK,L,M)=KK-1
      L1(KK,L,M)=1
      L2(KK,L,M)=1
      M1(KK,L,M)=2
      M2(KK,L,M)=2
```

```
3040 CONTINUE
     K1(1,12,5)=1
     K2(1,12,5)=1
     L1(1,12,5)=12
     L2(1,12,5)=12
     M1(1,12,5)=6
     M2(1,12,5)=4
     K1(1,12,4)=1
     K2(1,12,4)=1
     L1(1,12,4)=12
     L2(1,12,4)=12
     M1(1,12,4)=5
     M2(1,12,4)=3
     K1(1,12,3)=1
     K2(1,12,3)=1
     K3(1,12,3)=2
     L1(1,12,3)=12
     L2(1,12,3)=12
     L3(1,12,3)=13
     M1(1,12,3)=4
     M2(1,12,3)=2
     M3(1,12,3)=4
     K1(4,5,2)=4
     K2(4,5,2)=4
     K3(4,5,2)=5
     L1(4,5,2)=5
     L2(4,5,2)=6
     L3(4,5,2)=5
     M1(4,5,2)=1
     M2(4,5,2)=1
     M3(4,5,2)=3
     K1(4,11,2)=4
     K2(4,11,2)=4
     K3(4,11,2)=5
     L1(4,11,2)=11
     L2(4,11,2)=12
     L3(4,11,2)=11
     M1(4,11,2)=1
     M2(4,11,2)=1
     M3(4,11,2)=3
     K1(5,5,2)=5
     K2(5,5,2)=5
     L1(5,5,2)=5
     L2(5,5,2)=5
     M1(5,5,2)=1
     M2(5,5,2)=3
     K1(5,5,3)=5
     K2(5,5,3)=4
     L1(5,5,3)=5
     L2(5,5,3)=5
     M1(5,5,3)=2
     M2(5,5,3)=2
     K1(5,4,2)=5
     K2(5,4,2)=5
     K3(5,4,2)=6
```

```
L1(5,4,2)=4
L2(5,4,2)=5
L3(5,4,2)=4
M1(5,4,2)=1
M2(5,4,2)=1
M3(5,4,2)=3
K1(5,7,1)=4
K2(5,7,1)=5
K3(5,7,1)=6
L1(5,7,1)=6
L2(5,7,1)=7
L3(5,7,1)=7
M1(5,7,1)=2
M2(5,7,1)=2
M3(5,7,1)=6
K1(5,10,2)=5
K2(5,10,2)=5
K3(5,10,2)=6
L1(5,10,2)=10
L2(5,10,2)=11
L3(5,10,2)=10
M1(5,10,2)=1
M2(5,10,2)=1
M3(5,10,2)=3
K1(5,11,2)=5
K2(5,11,2)=5
L1(5,11,2)=11
L2(5,11,2)=11
M1(5,11,2)=1
M2(5,11,2)=3
K1(5,11,3)=5
K2(5,11,3)=4
L1(5,11,3)=11
L2(5,11,3)=11
M1(5,11,3)=2
M2(5,11,3)=2
K1(5,13,1)=5
K2(5,13,1)=4
K3(5,13,1)=6
L1(5,13,1)=13
L2(5,13,1)=12
L3(5,13,1)=13
M1(5,13,1)=2
M2(5,13,1)=2
M3(5,13,1)=6
K1(6,4,3)=6
K2(6,4,3)=5
K3(6,4,3)=7
L1(6,4,3)=4
L2(6,4,3)=4
L3(6,4,3)=5
M1(6,4,3)=2
M2(6,4,3)=2
M3(6,4,3)=4
K1(6,7,1)=6
```

```
K2(6,7,1)=6
L1(6,7,1)=7
L2(6,7,1)=7
M1(6,7,1)=2
M2(6,7,1)=6
K1(6,7,6)=6
K2(6,7,6)=5
L1(6,7,6)=7
L2(6,7,6)=7
M1(6,7,6)=1
M2(6,7,6)=1
K1(6,4,2)=6
K2(6,4,2)=6
K3(6,4,2)=7
L1(6,4,2)=4
L2(6,4,2)=4
L3(6,4,2)=5
M1(6,4,2)=1
M2(6,4,2)=3
M3(6,4,2)=1
K1(6,10,2)=6
K2(6,10,2)=6
K3(6,10,2)=7
L1(6,10,2)=10
L2(6,10,2)=10
L3(6,10,2)=11
M1(6,10,2)=1
M2(6,10,2)=3
M3(6,10,2)=1
K1(6,10,3)=6
K2(6,10,3)=5
K3(6,10,3)=7
L1(6,10,3)=10
L2(6,10,3)=10
L3(6,10,3)=11
M1(6,10,3)=2
M2(6,10,3)=2
M3(6,10,3)=4
K1(6,13,1)=6
K2(6,13,1)=6
L1(6,13,1)=13
L2(6,13,1)=13
M1(6,13,1)=2
M2(6,13,1)=6
K1(6,13,6)=6
K2(6,13,6)=5
L1(6,13,6)=13
L2(6,13,6)=13
M1(6,13,6)=1
M2(6,13,6)=1
K1(7,5,4)=6
K2(7,5,4)=7
K3(7,5,4)=7
L1(7,5,4)=4
L2(7,5,4)=6
```

```
L3(7,5,4)=6
M1(7,5,4)=3
M2(7,5,4)=1
M3(7,5,4)=5
K1(7,6,3)=7
K2(7,6,3)=7
K3(7,6,3)=8
L1(7,6,3)=6
L2(7,6,3)=6
L3(7,6,3)=8
M1(7,6,3)=4
M2(7,6,3)=2
M3(7,6,3)=6
K1(7,6,4)=7
K2(7,6,4)=7
L1(7,6,4)=6
L2(7,6,4)=6
M1(7,6,4)=3
M2(7,6,4)=5
K1(7,6,5)=7
K2(7,6,5)=7
L1(7,6,5)=6
L2(7,6,5)=5
M1(7,6,5)=4
M2(7,6,5)=4
K1(7,6,1)=7
K2(7,6,1)=7
K3(7,6,1)=7
L1(7,6,1)=5
L2(7,6,1)=5
L3(7,6,1)=6
M1(7,6,1)=4
M2(7,6,1)=2
M3(7,6,1)=2
K1(7,6,2)=7
K2(7,6,2)=7
K3(7,6,2)=8
L1(7,6,2)=6
L2(7,6,2)=6
L3(7,6,2)=7
M1(7,6,2)=1
M2(7,6,2)=3
M3(7,6,2)=1
K1(7,8,1)=6
K2(7,8,1)=8
K3(7,8,1)=7
L1(7,8,1)=7
L2(7,8,1)=8
L3(7,8,1)=8
M1(7,8,1)=2
M2(7,8,1)=6
M3(7,8,1)=2
K1(7,11,4)=6
K2(7,11,4)=7
K3(7,11,4)=7
```

```
L1(7,11,4)=10
L2(7,11,4)=12
L3(7,11,4)=12
M1(7,11,4)=3
M2(7,11,4)=1
M3(7,11,4)=5
K1(7,12,1)=7
K2(7,12,1)=7
K3(7,12,1)=7
L1(7,12,1)=11
L2(7,12,1)=11
L3(7,12,1)=12
M1(7,12,1)=4
M2(7,12,1)=2
M3(7,12,1)=2
K1(7,12,2)=7
K2(7,12,2)=7
K3(7,12,2)=8
L1(7,12,2)=12
L2(7,12,2)=12
L3(7,12,2)=13
M1(7,12,2)=1
M2(7,12,2)=3
M3(7,12,2)=1
K1(7,12,3)=7
K2(7,12,3)=7
K3(7,12,3)=8
L1(7,12,3)=12
L2(7,12,3)=12
L3(7,12,3)=14
M1(7,12,3)=2
M2(7,12,3)=4
M3(7,12,3)=6
K1(7,12,4)=7
K2(7,12,4)=7
L1(7,12,4)=12
L2(7,12,4)=12
M1(7,12,4)=5
M2(7,12,4)=3
K1(7,12,5)=7
K2(7,12,5)=7
L1(7,12,5)=12
L2(7,12,5)=11
M1(7,12,5)=4
M2(7,12,5)=4
K1(7,14,1)=7
K2(7,14,1)=8
K3(7,14,1)=6
L1(7,14,1)=14
L2(7,14,1)=14
L3(7,14,1)=13
M1(7,14,1)=2
M2(7,14,1)=6
M3(7,14,1)=2
K1(8,8,6)=7
```

```
K2(8,8,6)=7
K3(8,8,6)=8
L1(8,8,6)=6
L2(8,8,6)=8
L3(8,8,6)=8
M1(8,8,6)=3
M2(8,8,6)=1
M3(8,8,6)=1
K1(8,14,6)=7
K2(8,14,6)=7
K3(8,14,6)=8
L1(8,14,6)=12
L2(8,14,6)=14
L3(8,14,6)=14
M1(8,14,6)=3
M2(8,14,6)=1
M3(8,14,6)=1
K1(8,8,1)=8
K2(8,8,1)=8
K3(8,8,1)=8
L1(8,8,1)=8
L2(8,8,1)=8
L3(8,8,1)=7
M1(8,8,1)=6
M2(8,8,1)=2
M3(8,8,1)=2
K1(8,14,1)=8
K2(8,14,1)=8
K3(8,14,1)=8
L1(8,14,1)=14
L2(8,14,1)=14
L3(8,14,1)=13
M1(8,14,1)=6
M2(8,14,1)=2
M3(8,14,1)=2
K1(10,5,2)=10
K2(10,5,2)=10
K3(10,5,2)=11
L1(10,5,2)=5
L2(10,5,2)=6
L3(10,5,2)=5
M1(10,5,2)=1
M2(10,5,2)=1
M3(10,5,2)=3
K1(10,11,2)=10
K2(10,11,2)=10
K3(10,11,2)=11
L1(10,11,2)=11
L2(10,11,2)=12
L3(10,11,2)=11
M1(10,11,2)=1
M2(10,11,2)=1
M3(10,11,2)=3
K1(10,17,2)=10
K2(10,17,2)=10
```

```
K3(10,17,2)=11
L1(10,17,2)=17
L2(10,17,2)=18
L3(10,17,2)=17
M1(10,17,2)=1
M2(10,17,2)=1
M3(10,17,2)=3
K1(11,4,2)=11
K2(11,4,2)=11
K3(11,4,2)=12
L1(11,4,2)=4
L2(11,4,2)=5
L3(11,4,2)=4
M1(11,4,2)=1
M2(11,4,2)=1
M3(11,4,2)=3
K1(11,10,2)=11
K2(11,10,2)=11
K3(11,10,2)=12
L1(11,10,2)=10
L2(11,10,2)=11
L3(11,10,2)=10
M1(11,10,2)=1
M2(11,10,2)=1
M3(11,10,2)=3
K1(11,16,2)=11
K2(11,16,2)=11
K3(11,16,2)=12
L1(11,16,2)=16
L2(11,16,2)=17
L3(11,16,2)=16
M1(11,16,2)=1
M2(11,16,2)=1
M3(11,16,2)=3
K1(11,5,2)=11
K2(11,5,2)=11
L1(11,5,2)=5
L2(11,5,2)=5
M1(11,5,2)=1
M2(11,5,2)=3
K1(11,11,2)=11
K2(11,11,2)=11
L1(11,11,2)=11
L2(11,11,2)=11
M1(11,11,2)=1
M2(11,11,2)=3
K1(11,17,2)=11
K2(11,17,2)=11
L1(11,17,2)=17
L2(11,17,2)=17
M1(11,17,2)=1
M2(11,17,2)=3
K1(11,5,3)=11
K2(11,5,3)=10
L1(11,5,3)=5
```

```
L2(11,5,3)=5
M1(11,5,3)=2
M2(11,5,3)=2
K1(11,11,3)=11
K2(11,11,3)=10
L1(11,11,3)=11
L2(11,11,3)=11
M1(11,11,3)=2
M2(11,11,3)=2
K1(11,17,3)=11
K2(11,17,3)=10
L1(11,17,3)=17
L2(11,17,3)=17
M1(11,17,3)=2
M2(11,17,3)=2
K1(11,7,1)=10
K2(11,7,1)=11
K3(11,7,1)=12
L1(11,7,1)=6
L2(11,7,1)=7
L3(11,7,1)=7
M1(11,7,1)=2
M2(11,7,1)=2
M3(11,7,1)=6
K1(11,13,1)=10
K2(11,13,1)=11
K3(11,13,1)=12
L1(11,13,1)=12
L2(11,13,1)=13
L3(11,13,1)=13
M1(11,13,1)=2
M2(11,13,1)=2
M3(11,13,1)=6
K1(11,19,1)=10
K2(11,19,1)=11
K3(11,19,1)=12
L1(11,19,1)=18
L2(11,19,1)=19
L3(11,19,1)=19
M1(11,19,1)=2
M2(11,19,1)=2
M3(11,19,1)=6
K1(12,1,1)=12
K2(12,1,1)=12
L1(12,1,1)=1
L2(12,1,1)=1
M1(12,1,1)=2
M2(12,1,1)=6
K1(12,1,2)=12
K2(12,1,2)=12
K3(12,1,2)=13
L1(12,1,2)=1
L2(12,1,2)=2
L3(12,1,2)=1
M1(12,1,2)=1
```

```
M2(12,1,2)=1
M3(12,1,2)=1
K1(12,4,2)=12
K2(12,4,2)=12
K3(12,4,2)=13
L1(12,4,2)=4
L2(12,4,2)=4
L3(12,4,2)=4
M1(12,4,2)=1
M2(12,4,2)=3
M3(12,4,2)=1
K1(12,10,2)=12
K2(12,10,2)=12
K3(12,10,2)=13
L1(12,10,2)=10
L2(12,10,2)=10
L3(12,10,2)=10
M1(12,10,2)=1
M2(12,10,2)=3
M3(12,10,2)=1
K1(12,16,2)=12
K2(12,16,2)=12
K3(12,16,2)=13
L1(12,16,2)=16
L2(12,16,2)=16
L3(12,16,2)=16
M1(12,16,2)=1
M2(12,16,2)=3
M3(12,16,2)=1
K1(12,4,3)=12
K2(12,4,3)=11
K3(12,4,3)=13
L1(12,4,3)=4
L2(12,4,3)=4
L3(12,4,3)=4
M1(12,4,3)=2
M2(12,4,3)=2
M3(12,4,3)=4
K1(12,10,3)=12
K2(12,10,3)=11
K3(12,10,3)=13
L1(12,10,3)=10
L2(12,10,3)=10
L3(12,10,3)=10
M1(12,10,3)=2
M2(12,10,3)=2
M3(12,10,3)=4
K1(12,16,3)=12
K2(12,16,3)=11
K3(12,16,3)=13
L1(12,16,3)=16
L2(12,16,3)=16
L3(12,16,3)=16
M1(12,16,3)=2
M2(12,16,3)=2
```

```
M3(12,16,3)=4
K1(12,7,1)=12
K2(12,7,1)=12
L1(12,7,1)=7
L2(12,7,1)=7
M1(12,7,1)=6
M2(12,7,1)=2
K1(12,13,1)=12
K2(12,13,1)=12
L1(12,13,1)=13
L2(12,13,1)=13
M1(12,13,1)=6
M2(12,13,1)=2
K1(12,19,1)=12
K2(12,19,1)=12
L1(12,19,1)=19
L2(12,19,1)=19
M1(12,19,1)=6
M2(12,19,1)=2
K1(12,7,6)=12
K2(12,7,6)=11
L1(12,7,6)=7
L2(12,7,6)=7
M1(12,7,6)=1
M2(12,7,6)=1
K1(12,13,6)=12
K2(12,13,6)=11
L1(12,13,6)=13
L2(12,13,6)=13
M1(12,13,6)=1
M2(12,13,6)=1
K1(12,19,6)=12
K2(12,19,6)=11
L1(12,19,6)=19
L2(12,19,6)=19
M1(12,19,6)=1
M2(12,19,6)=1
K1(12,23,4)=12
K2(12,23,4)=11
L1(12,23,4)=23
L2(12,23,4)=22
M1(12,23,4)=3
M2(12,23,4)=3
L3(12,22,2)=22
K1(13,5,1)=13
K2(13,5,1)=13
K3(13,5,1)=13
L1(13,5,1)=4
L2(13,5,1)=4
L3(13,5,1)=5
M1(13,5,1)=2
M2(13,5,1)=4
M3(13,5,1)=2
K1(13,11,1)=13
K2(13,11,1)=13
```

```
K3(13,11,1)=13
L1(13,11,1)=10
L2(13,11,1)=10
L3(13,11,1)=11
M1(13,11,1)=2
M2(13,11,1)=4
M3(13,11,1)=2
K1(13,17,1)=13
K2(13,17,1)=13
K3(13,17,1)=13
L1(13,17,1)=16
L2(13,17,1)=16
L3(13,17,1)=17
M1(13,17,1)=2
M2(13,17,1)=4
M3(13,17,1)=2
K1(13,4,4)=13
K2(13,4,4)=13
K3(13,4,4)=12
L1(13,4,4)=5
L2(13,4,4)=5
L3(13,4,4)=4
M1(13,4,4)=1
M2(13,4,4)=5
M3(13,4,4)=3
K1(13,10,4)=13
K2(13,10,4)=13
K3(13,10,4)=12
L1(13,10,4)=11
L2(13,10,4)=11
L3(13,10,4)=10
M1(13,10,4)=1
M2(13,10,4)=5
M3(13,10,4)=3
K1(13,16,4)=13
K2(13,16,4)=13
K3(13,16,4)=12
L1(13,16,4)=17
L2(13,16,4)=17
L3(13,16,4)=16
M1(13,16,4)=1
M2(13,16,4)=5
M3(13,16,4)=3
K1(13,5,2)=13
K2(13,5,2)=14
K3(13,5,2)=14
L1(13,5,2)=5
L2(13,5,2)=5
L3(13,5,2)=5
M1(13,5,2)=1
M2(13,5,2)=5
M3(13,5,2)=1
K1(13,11,2)=13
K2(13,11,2)=14
K3(13,11,2)=14
```

```
L1(13,11,2)=11
L2(13,11,2)=11
L3(13,11,2)=11
M1(13,11,2)=1
M2(13,11,2)=5
M3(13,11,2)=1
K1(13,17,2)=13
K2(13,17,2)=14
K3(13,17,2)=14
L1(13,17,2)=17
L2(13,17,2)=17
L3(13,17,2)=17
M1(13,17,2)=1
M2(13,17,2)=5
M3(13,17,2)=1
K1(14,5,5)=13
K2(14,5,5)=13
K3(14,5,5)=14
L1(14,5,5)=5
L2(14,5,5)=5
L3(14,5,5)=5
M1(14,5,5)=2
M2(14,5,5)=4
M3(14,5,5)=4
K1(14,11,5)=13
K2(14,11,5)=13
K3(14,11,5)=14
L1(14,11,5)=11
L2(14,11,5)=11
L3(14,11,5)=11
M1(14,11,5)=2
M2(14,11,5)=4
M3(14,11,5)=4
K1(14,17,5)=13
K2(14,17,5)=13
K3(14,17,5)=14
L1(14,17,5)=17
L2(14,17,5)=17
L3(14,17,5)=17
M1(14,17,5)=2
M2(14,17,5)=4
M3(14,17,5)=4
K1(14,17,4)=14
K2(14,17,4)=14
K3(14,17,4)=13
L1(14,17,4)=18
L2(14,17,4)=17
L3(14,17,4)=19
M1(14,17,4)=1
M2(14,17,4)=5
M3(14,17,4)=1
K1(13,5,4)=14
K2(13,5,4)=13
L1(13,5,4)=5
L2(13,5,4)=5
```

```
M1(13,5,4)=5
M2(13,5,4)=5
K1(13,11,4)=14
K2(13,11,4)=13
L1(13,11,4)=11
L2(13,11,4)=11
M1(13,11,4)=5
M2(13,11,4)=5
K1(13,17,4)=14
K2(13,17,4)=13
L1(13,17,4)=17
L2(13,17,4)=17
M1(13,17,4)=5
M2(13,17,4)=5
K1(13,5,5)=13
K2(13,5,5)=13
L1(13,5,5)=5
L2(13,5,5)=4
M1(13,5,5)=4
M2(13,5,5)=4
K1(13,11,5)=13
K2(13,11,5)=13
L1(13,11,5)=11
L2(13,11,5)=10
M1(13,11,5)=4
M2(13,11,5)=4
K1(13,17,5)=13
K2(13,17,5)=13
L1(13,17,5)=17
L2(13,17,5)=16
M1(13,17,5)=4
M2(13,17,5)=4
K1(13,7,1)=13
K2(13,7,1)=12
K3(13,7,1)=14
L1(13,7,1)=7
L2(13,7,1)=7
L3(13,7,1)=5
M1(13,7,1)=2
M2(13,7,1)=2
M3(13,7,1)=4
K1(13,13,1)=13
K2(13,13,1)=12
K3(13,13,1)=14
L1(13,13,1)=13
L2(13,13,1)=13
L3(13,13,1)=11
M1(13,13,1)=2
M2(13,13,1)=2
M3(13,13,1)=4
K1(13,19,1)=13
K2(13,19,1)=12
K3(13,19,1)=14
L1(13,19,1)=19
L2(13,19,1)=19
```

```
L3(13,19,1)=17
M1(13,19,1)=2
M2(13,19,1)=2
M3(13,19,1)=4
K1(14,5,4)=14
K2(14,5,4)=13
K3(14,5,4)=14
L1(14,5,4)=5
L2(14,5,4)=7
L3(14,5,4)=6
M1(14,5,4)=5
M2(14,5,4)=1
M3(14,5,4)=1
K1(14,11,4)=14
K2(14,11,4)=13
K3(14,11,4)=14
L1(14,11,4)=11
L2(14,11,4)=13
L3(14,11,4)=12
M1(14,11,4)=5
M2(14,11,4)=1
M3(14,11,4)=1
K1(14,7,4)=13
K2(14,7,4)=13
K3(14,7,4)=14
L1(14,7,4)=17
L2(14,7,4)=19
L3(14,7,4)=18
M1(14,7,4)=3
M2(14,7,4)=1
M3(14,7,4)=1
K1(14,6,1)=14
K2(14,6,1)=14
K3(14,6,1)=14
L1(14,6,1)=5
L2(14,6,1)=6
L3(14,6,1)=5
M1(14,6,1)=4
M2(14,6,1)=2
M3(14,6,1)=2
K1(14,12,1)=14
K2(14,12,1)=14
K3(14,12,1)=14
L1(14,12,1)=11
L2(14,12,1)=12
L3(14,12,1)=11
M1(14,12,1)=4
M2(14,12,1)=2
M3(14,12,1)=2
K1(14,18,1)=14
K2(14,18,1)=14
K3(14,18,1)=14
L1(14,18,1)=17
L2(14,18,1)=18
L3(14,18,1)=17
```

```
M1(14,18,1)=4
M2(14,18,1)=2
M3(14,18,1)=2
K1(16,7,2)=16
K2(16.7,2)=16
K3(16,7,2)=17
L1(16,7,2)=7
L2(16,7,2)=8
L3(16,7,2)=6
M1(16,7,2)=1
M2(16,7,2)=1
M3(16,7,2)=3
K1(16,13,2)=16
K2(16,13,2)=16
K3(16,13,2)=17
L1(16,13,2)=13
L2(16,13,2)=14
L3(16,13,2)=12
M1(16,13,2)=1
M2(16,13,2)=1
M3(16,13,2)=3
K1(17,5,2)=17
K2(17,5,2)=17
K3(17,5,2)=18
L1(17,5,2)=5
L2(17,5,2)=6
L3(17,5,2)=4
M1(17,5,2)=1
M2(17,5,2)=1
M3(17,5,2)=3
K1(17,11,2)=17
K2(17,11,2)=17
K3(17,11,2)=18
L1(17,11,2)=12
L2(17,11,2)=11
L3(17,11,2)=10
M1(17,11,2)=1
M2(17,11,2)=1
M3(17,11,2)=3
K1(17,6,2)=17
K2(17,6,2)=17
L1(17,6,2)=6
L2(17,6,2)=6
M1(17,6,2)=3
M2(17,6,2)=1
K1(17,12,2)=17
K2(17,12,2)=17
L1(17,12,2)=12
L2(17,12,2)=12
M1(17,12,2)=3
M2(17,12,2)=1
K1(17,6,3)=17
K2(17,6,3)=16
L1(17,6,3)=6
L2(17,6,3)=7
```

```
M1(17,6,3)=2
M2(17,6,3)=2
K1(17,12,3)=17
K2(17,12,3)=16
L1(17,12,3)=12
L2(17,12,3)=13
M1(17,12,3)=2
M2(17,12,3)=2
K1(17,8,1)=17
K2(17,8,1)=16
K3(17,8,1)=18
L1(17,8,1)=8
L2(17,8,1)=8
L3(17,8,1)=7
M1(17,8,1)=2
M2(17,8,1)=2
M3(17,8,1)=6
K1(17,14,1)=17
K2(17,14,1)=16
K3(17,14,1)=18
L1(17,14,1)=14
L2(17,14,1)=14
L3(17,14,1)=13
M1(17,14,1)=2
M2(17,14,1)=2
M3(17,14,1)=6
K1(18,4,2)=18
K2(18,4,2)=18
K3(18,4,2)=19
L1(18,4,2)=4
L2(18,4,2)=4
L3(18,4,2)=4
M1(18,4,2)=1
M2(18,4,2)=3
M3(18,4,2)=1
K1(18,10,2)=18
K2(18,10,2)=18
K3(18,10,2)=19
L1(18,10,2)=10
L2(18,10,2)=10
L3(18,10,2)=5
M1(18,10,2)=1
M2(18,10,2)=3
M3(18,10,2)=3
K1(18,4,3)=18
K2(18,4,3)=17
K3(18,4,3)=19
L1(18,4,3)=4
L2(18,4,3)=5
L3(18,4,3)=4
M1(18,4,3)=2
M2(18,4,3)=2
M3(18,4,3)=4
K1(18,10,3)=18
K2(18,10,3)=17
```

```
K3(18,10,3)=19
L1(18,10,3)=10
L2(18,10,3)=11
L3(18,10,3)=10
M1(18,10,3)=2
M2(18,10,3)=2
M3(18,10,3)=4
K1(18,7,1)=18
K2(18,7,1)=18
L1(18,7,1)=7
L2(18,7,1)=7
M1(18,7,1)=2
M2(18,7,1)=6
K1(18,13,1)=18
K2(18,13,1)=18
L1(18,13,1)=13
L2(18,13,1)=13
M1(18,13,1)=2
M2(18,13,1)=6
K1(18,7,6)=18
K2(18,7,6)=17
L1(18,7,6)=7
L2(18,7,6)=8
M1(18,7,6)=1
M2(18,7,6)=1
K1(18,13,6)=18
K2(18,13,6)=17
L1(18,13,6)=13
L2(18,13,6)=14
M1(18,13,6)=1
M2(18,13,6)=1
K1(19,5,1)=19
K2(19,5,1)=19
K3(19,5,1)=19
L1(19,5,1)=4
L2(19,5,1)=4
L3(19,5,1)=5
M1(19,5,1)=4
M2(19,5,1)=2
M3(19,5,1)=2
K1(19,11,1)=19
K2(19,11,1)=19
K3(19,11,1)=19
L1(19,11,1)=10
L2(19,11,1)=10
L3(19,11,1)=11
M1(19,11,1)=4
M2(19,11,1)=2
M3(19,11,1)=2
K1(19,4,4)=19
K2(19,4,4)=18
K3(19,4,4)=19
L1(19,4,4)=5
L2(19,4,4)=4
L3(19,4,4)=5
```

```
M1(19,4,4)=1
M2(19,4,4)=3
M3(19,4,4)=5
K1(19,10,4)=19
K2(19,10,4)=18
K3(19,10,4)=19
L1(19,10,4)=11
L2(19,10,4)=10
L3(19,10,4)=11
M1(19,10,4)=1
M2(19,10,4)=3
M3(19,10,4)=5
K1(19,5,3)=19
K2(19,5,3)=19
K3(19,5,3)=20
L1(19,5,3)=5
L2(19,5,3)=5
L3(19,5,3)=5
M1(19,5,3)=2
M2(19,5,3)=4
M3(19,5,3)=4
K1(19,11,3)=19
K2(19,11,3)=19
K3(19,11,3)=20
L1(19,11,3)=11
L2(19,11,3)=11
L3(19,11,3)=11
M1(19,11,3)=2
M2(19,11,3)=4
M3(19,11,3)=4
K1(19,5,4)=19
K2(19,5,4)=19
K3(19,5,4)=19
L1(19,5,4)=5
L2(19,5,4)=5
L3(19,5,4)=4
M1(19,5,4)=5
M2(19,5,4)=3
M3(19,5,4)=4
K1(19,11,4)=19
K2(19,11,4)=19
L1(19,11,4)=11
L2(19,11,4)=11
M1(19,11,4)=5
M2(19,11,4)=3
K1(19,5,5)=19
K2(19,5,5)=19
L1(19,5,5)=5
L2(19,5,5)=4
M1(19,5,5)=4
M2(19,5,5)=4
K1(19,11,5)=19
K2(19,11,5)=19
L1(19,11,5)=11
L2(19,11,5)=10
```

```
M1(19,11,5)=4
M2(19,11,5)=4
K1(19,5,2)=19
K2(19,5,2)=19
K3(19,5,2)=20
L1(19,5,2)=5
L2(19,5,2)=5
L3(19,5,2)=5
M1(19,5,2)=1
M2(19,5,2)=3
M3(19,5,2)=1
K1(19,11,2)=19
K2(19,11,2)=19
K3(19,11,2)=20
L1(19,11,2)=11
L2(19,11,2)=11
L3(19,11,2)=11
M1(19,11,2)=1
M2(19,11,2)=3
M3(19,11,2)=1
K1(19,7,1)=19
K2(19,7,1)=18
K3(19,7,1)=20
L1(19,7,1)=7
L2(19,7,1)=7
L3(19,7,1)=5
M1(19,7,1)=2
M2(19,7,1)=2
M3(19,7,1)=4
K1(19,13,1)=19
K2(19,13,1)=18
K3(19,13,1)=20
L1(19,13,1)=13
L2(19,13,1)=13
L3(19,13,1)=11
M1(19,13,1)=2
M2(19,13,1)=2
M3(19,13,1)=4
K1(20,5,4)=19
K2(20,5,4)=19
K3(20,5,4)=20
L1(20,5,4)=5
L2(20,5,4)=7
L3(20,5,4)=6
M1(20,5,4)=3
M2(20,5,4)=1
M3(20,5,4)=1
K1(20,11,4)=19
K2(20,11,4)=19
K3(20,11,4)=20
L1(20,11,4)=11
L2(20,11,4)=13
L3(20,11,4)=12
M1(20,11,4)=3
M2(20,11,4)=1
```

```
      M3(20,11,4)=1
      K1(20,6,1)=20
      K2(20,6,1)=20
      K3(20,6,1)=20
      L1(20,6,1)=6
      L2(20,6,1)=5
      L3(20,6,1)=5
      M1(20,6,1)=2
      M2(20,6,1)=2
      M3(20,6,1)=4
      K1(20,12,1)=20
      K2(20,12,1)=20
      K3(20,12,1)=20
      L1(20,12,1)=12
      L2(20,12,1)=11
      L3(20,12,1)=11
      M1(20,12,1)=2
      M2(20,12,1)=2
      M3(20,12,1)=4
       K1(23,12,2)=23
       K2(23,12,2)=23
       L1(23,12,2)=12
       L2(23,12,2)=12
       M1(23,12,2)=1
       M2(23,12,2)=3
       K1(23,12,3)=23
       K2(23,12,3)=22
       L1(23,12,3)=12
       L2(23,12,3)=13
       M1(23,12,3)=2
       M2(23,12,3)=2
       RETURN
       END
C
C
      SUBROUTINE VRGN(NN)
C
C     THIS SUBROUTINE DETERMINES WHICH VOID REGIONS ARE REMOVED FROM
C     THE CORE GIVEN THE PARAMETER NN
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION NITPIC(23,23,6),N(23,23,6),K1(23,23,6),K2(23,23,6)
      DIMENSION K3(23,23,6),L1(23,23,6),L2(23,23,6),L3(23,23,6)
      DIMENSION M1(23,23,6),M2(23,23,6),M3(23,23,6),H(23,23,6)
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      DO 710 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 710 L=1,LMAX
      DO 710 M=1,6
      H(KK,L,M)=-1.0
  710 CONTINUE
      IF(NN.EQ.1)GO TO 700
      N1=NN-1
      IF(NN.EQ.4)GO TO 700
```

```
      N2=NN-4
      IF(NN.LE.4)N2=5
      GO TO(702,706),N1
      GO TO(702,706,702,708),N2
      IF(NN.EQ.10)GO TO 709
C
  700 CONTINUE
      H(4,5,2)=0.0
      H(4,6,1)=0.0
      H(4,6,2)=0.0
      H(5,4,2)=0.0
      H(5,5,1)=0.0
      H(5,5,2)=0.0
      H(5,5,3)=0.0
      H(5,7,1)=0.0
      H(6,4,3)=0.0
      H(6,7,1)=0.0
      H(6,7,2)=0.0
      H(7,5,4)=0.0
      H(7,6,3)=0.0
      H(6,7,6)=0.0
      H(7,6,4)=0.0
      H(7,6,5)=0.0
      H(7,8,1)=0.0
      H(8,8,6)=0.0
      H(10,17,2)=0.0
      H(10,18,1)=0.0
      H(10,18,2)=0.0
      H(11,16,2)=0.0
      H(11,17,1)=0.0
      H(11,17,2)=0.0
      H(11,17,3)=0.0
      H(11,19,1)=0.0
      H(12,16,3)=0.0
      H(12,19,1)=0.0
      H(12,19,2)=0.0
      H(12,19,6)=0.0
      H(13,16,4)=0.0
      H(13,17,4)=0.0
      H(13,17,5)=0.0
      H(13,19,1)=0.0
      H(14,17,4)=0.0
      H(14,17,5)=0.0
      H(16,7,2)=0.0
      H(16,8,1)=0.0
      H(16,8,2)=0.0
      H(17,5,2)=0.0
      H(17,6,1)=0.0
      H(17,6,2)=0.0
      H(17,6,3)=0.0
      H(17,8,1)=0.0
      H(18,4,3)=0.0
      H(18,7,1)=0.0
      H(18,7,6)=0.0
      H(19,4,4)=0.0
```

```
      H(19,5,4)=0.0
      H(19,5,5)=0.0
      H(19,5,3)=0.0
      H(19,7,1)=0.0
      H(19,7,6)=0.0
      H(20,5,4)=0.0
C
  701 CONTINUE
      IF(NN.EQ.9)GO TO 704
C
  702 CONTINUE
      H(10,11,2)=0.0
      H(10,12,1)=0.0
      H(10,12,2)=0.0
      H(11,10,2)=0.0
      H(11,11,1)=0.0
      H(11,11,2)=0.0
      H(11,11,3)=0.0
      H(11,13,1)=0.0
      H(12,10,3)=0.0
      H(12,13,1)=0.0
      H(12,13,2)=0.0
      H(12,13,6)=0.0
      H(13,10,4)=0.0
      H(13,11,4)=0.0
      H(13,11,5)=0.0
      H(13,13,1)=0.0
      H(14,11,4)=0.0
      H(14,11,5)=0.0
C
  703 CONTINUE
      IF(NN.EQ.9)GO TO 706
C
  704 CONTINUE
      H(4,11,2)=0.0
      H(4,12,1)=0.0
      H(4,12,2)=0.0
      H(5,10,2)=0.0
      H(5,11,1)=0.0
      H(5,11,2)=0.0
      H(5,11,3)=0.0
      H(5,13,1)=0.0
      H(6,10,3)=0.0
      H(6,13,1)=0.0
      H(6,13,2)=0.0
      H(6,13,6)=0.0
      H(7,11,4)=0.0
      H(7,12,3)=0.0
      H(7,12,4)=0.0
      H(7,12,5)=0.0
      H(7,14,1)=0.0
      H(8,14,6)=0.0
      H(10,5,2)=0.0
      H(10,6,1)=0.0
      H(10,6,2)=0.0
```

```
      H(11,4,2)=0.0
      H(11,5,1)=0.0
      H(11,5,2)=0.0
      H(11,5,3)=0.0
      H(11,7,1)=0.0
      H(12,4,3)=0.0
      H(12,7,1)=0.0
      H(12,7,2)=0.0
      H(12,7,6)=0.0
      H(13,4,4)=0.0
      H(13,5,4)=0.0
      H(13,5,5)=0.0
      H(13,7,1)=0.0
      H(14,5,4)=0.0
      H(14,5,5)=0.0
      H(16,13,2)=0.0
      H(16,14,1)=0.0
      H(16,14,2)=0.0
      H(17,11,2)=0.0
      H(17,12,1)=0.0
      H(17,12,2)=0.0
      H(17,12,3)=0.0
      H(17,14,1)=0.0
      H(18,10,3)=0.0
      H(18,13,1)=0.0
      H(18,13,2)=0.0
      H(18,13,6)=0.0
      H(19,10,4)=0.0
      H(19,11,3)=0.0
      H(19,11,4)=0.0
      H(19,11,5)=0.0
      H(19,13,1)=0.0
      H(20,11,4)=0.0
C
  705 CONTINUE
      IF(NN.EQ.7)GO TO 708
      IF(NN.EQ.9)GO TO 709
C
  706 DO 707 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 707 L=1,LMAX
      DO 707 M=1,6
      IF((N(KK,L,M).EQ.1).OR.(N(KK,L,M).EQ.4))GO TO 800
      IF((KK.EQ.1).AND.(L.GT.4))H(KK,L,M)=0.0
      IF((KK.GT.1).AND.(KK.LT.4).AND.(L.EQ.LMAX))H(KK,L,M)=0.0
      IF((KK.GT.3).AND.(KK.LT.9).AND.(L.EQ.LMAX))H(KK,L,M)=0.0
      IF((KK.GT.3).AND.(KK.LT.9).AND.(L.EQ.1))H(KK,L,M)=0.0
      IF((KK.GT.8).AND.(KK.LT.15).AND.(L.EQ.1))H(KK,L,M)=0.0
      IF((KK.GT.14).AND.(KK.LT.20).AND.(L.EQ.1))H(KK,L,M)=0.0
      IF((KK.GT.14).AND.(KK.LT.21).AND.(L.EQ.LMAX))H(KK,L,M)=0.0
      IF((KK.GT.20).AND.(KK.LT.23).AND.(L.EQ.LMAX))H(KK,L,M)=0.0
      IF((KK.EQ.23).AND.(L.GT.4))H(KK,L,M)=0.0
      GO TO 707
  800 IF(N(KK,L,M).EQ.1)H(KK,L,M)=0.0
```

```
  707 CONTINUE
      H(4,1,6)=-1.0
      H(15,20,3)=-1.0
      IF(NN.GE.4)GO TO 709
C
  708 DO 711 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 711 L=1,LMAX
      DO 711 M=1,6
      IF((N(KK,L,M).EQ.1).OR.(N(KK,L,M).EQ.4))GO TO 810
      IF((KK.EQ.1).AND.(L.LT.5))H(KK,L,M)=0.0
      IF((KK.LT.5).AND.(L.EQ.1))H(KK,L,M)=0.0
      IF((KK.GT.8).AND.(KK.LT.16).AND.(L.EQ.LMAX))H(KK,L,M)=0.0
      IF((KK.GT.19).AND.(KK.LT.23).AND.(L.EQ.1))H(KK,L,M)=0.0
      IF((KK.EQ.23).AND.(L.LT.5))H(KK,L,M)=0.0
      H(15,20,2)=-1.0
      H(4,1,1)=-1.0
      GO TO 711
  810 IF(N(KK,L,M).EQ.1)H(KK,L,M)=0.0
  711 CONTINUE
      IF(NN.EQ.1)H(15,20,2)=0.0
      IF(NN.EQ.1)H(4,1,1)=0.0
      IF(NN.EQ.1)H(4,1,6)=0.0
      IF(NN.EQ.1)H(15,20,3)=0.0
  709 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE VOIT(I,J)
C
C      THIS SUBROUTINE DETERMINES THE TYPE OF VOID REGION A CHANNEL
C      IS NEXT TO
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION NITPIC(23,23,6),N(23,23,6),K1(23,23,6),K2(23,23,6)
      DIMENSION K3(23,23,6),L1(23,23,6),L2(23,23,6),L3(23,23,6)
      DIMENSION M1(23,23,6),M2(23,23,6),M3(23,23,6),H(23,23,6)
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      NITPIC(1,1,1)=1
      NITPIC(1,1,5)=1
      NITPIC(1,1,6)=1
      NITPIC(1,2,5)=1
      NITPIC(1,2,6)=1
      NITPIC(1,3,5)=1
      NITPIC(1,3,6)=1
      NITPIC(1,4,5)=1
      NITPIC(1,4,6)=1
      NITPIC(1,5,5)=2
      NITPIC(1,5,6)=2
      NITPIC(1,6,5)=2
      NITPIC(1,6,6)=2
      NITPIC(1,7,5)=2
      NITPIC(1,7,6)=2
```

```
NITPIC(1,8,5)=2
NITPIC(1,8,6)=2
NITPIC(1,9,5)=2
NITPIC(1,9,6)=2
NITPIC(1,10,5)=2
NITPIC(1,10,6)=2
NITPIC(1,11,5)=2
NITPIC(1,11,6)=2
NITPIC(1,12,3)=2
NITPIC(1,12,4)=2
NITPIC(1,12,5)=2
NITPIC(1,12,6)=2
NITPIC(2,1,1)=1
NITPIC(2,1,6)=1
NITPIC(2,13,3)=2
NITPIC(2,13,4)=2
NITPIC(3,1,1)=1
NITPIC(3,1,6)=1
NITPIC(3,14,3)=2
NITPIC(3,14,4)=2
NITPIC(4,1,1)=2
NITPIC(4,1,6)=1
NITPIC(4,5,2)=3
NITPIC(4,6,1)=3
NITPIC(4,6,2)=3
NITPIC(4,11,2)=3
NITPIC(4,12,1)=3
NITPIC(4,12,2)=3
NITPIC(4,15,3)=2
NITPIC(4,15,4)=2
NITPIC(5,1,1)=2
NITPIC(5,1,6)=2
NITPIC(5,4,2)=3
NITPIC(5,5,1)=3
NITPIC(5,5,2)=3
NITPIC(5,5,3)=3
NITPIC(5,7,1)=3
NITPIC(5,10,2)=3
NITPIC(5,11,1)=3
NITPIC(5,11,2)=3
NITPIC(5,11,3)=3
NITPIC(5,13,1)=3
NITPIC(5,16,3)=2
NITPIC(5,16,4)=2
NITPIC(6,1,1)=2
NITPIC(6,1,6)=2
NITPIC(6,4,3)=3
NITPIC(6,7,1)=3
NITPIC(6,7,2)=3
NITPIC(6,7,6)=3
NITPIC(6,10,3)=3
NITPIC(6,13,1)=3
NITPIC(6,13,2)=3
NITPIC(6,13,6)=3
NITPIC(6,17,3)=2
```

```
NITPIC(6,17,4)=2
NITPIC(7,1,1)=2
NITPIC(7,1,6)=2
NITPIC(7,5,4)=3
NITPIC(7,6,3)=3
NITPIC(7,6,4)=3
NITPIC(7,6,5)=3
NITPIC(7,8,1)=3
NITPIC(7,11,4)=3
NITPIC(7,12,3)=3
NITPIC(7,12,4)=3
NITPIC(7,12,5)=3
NITPIC(7,14,1)=3
NITPIC(7,18,3)=2
NITPIC(7,18,4)=2
NITPIC(8,1,1)=2
NITPIC(8,1,6)=2
NITPIC(8,8,6)=3
NITPIC(8,14,6)=3
NITPIC(8,19,3)=2
NITPIC(8,19,4)=2
NITPIC(9,1,1)=2
NITPIC(9,1,6)=2
NITPIC(9,20,3)=1
NITPIC(9,20,4)=1
NITPIC(10,1,1)=2
NITPIC(10,1,6)=2
NITPIC(10,5,2)=3
NITPIC(10,6,1)=3
NITPIC(10,6,2)=3
NITPIC(10,11,2)=3
NITPIC(10,12,1)=3
NITPIC(10,12,2)=3
NITPIC(10,17,2)=3
NITPIC(10,18,1)=3
NITPIC(10,18,2)=3
NITPIC(10,21,3)=1
NITPIC(10,21,4)=1
NITPIC(11,1,1)=2
NITPIC(11,1,6)=2
NITPIC(11,4,2)=3
NITPIC(11,5,1)=3
NITPIC(11,5,2)=3
NITPIC(11,5,3)=3
NITPIC(11,7,1)=3
NITPIC(11,10,2)=3
NITPIC(11,11,1)=3
NITPIC(11,11,2)=3
NITPIC(11,11,3)=3
NITPIC(11,13,1)=3
NITPIC(11,16,2)=3
NITPIC(11,17,1)=3
NITPIC(11,17,2)=3
NITPIC(11,17,3)=3
NITPIC(11,19,1)=3
```

```
NITPIC(11,22,3)=1
NITPIC(11,22,4)=1
NITPIC(12,1,1)=2
NITPIC(12,1,2)=2
NITPIC(12,1,6)=2
NITPIC(12,4,3)=3
NITPIC(12,7,1)=3
NITPIC(12,7,2)=3
NITPIC(12,7,6)=3
NITPIC(12,10,3)=3
NITPIC(12,13,1)=3
NITPIC(12,13,2)=3
NITPIC(12,13,6)=3
NITPIC(12,16,3)=3
NITPIC(12,19,1)=3
NITPIC(12,19,2)=3
NITPIC(12,23,2)=1
NITPIC(12,23,3)=1
NITPIC(12,23,4)=1
NITPIC(13,1,1)=2
NITPIC(13,1,2)=2
NITPIC(13,4,4)=3
NITPIC(13,5,4)=3
NITPIC(13,5,5)=3
NITPIC(13,7,1)=3
NITPIC(13,10,4)=3
NITPIC(13,11,4)=3
NITPIC(13,11,5)=3
NITPIC(13,13,1)=3
NITPIC(13,16,4)=3
NITPIC(13,17,4)=3
NITPIC(13,17,5)=3
NITPIC(13,19,1)=3
NITPIC(13,22,2)=1
NITPIC(13,22,3)=1
NITPIC(14,1,1)=2
NITPIC(14,1,2)=2
NITPIC(14,5,4)=3
NITPIC(14,5,5)=3
NITPIC(14,11,4)=3
NITPIC(14,11,5)=3
NITPIC(14,17,4)=3
NITPIC(14,17,5)=3
NITPIC(14,21,2)=1
NITPIC(14,21,3)=1
NITPIC(15,1,1)=2
NITPIC(15,1,2)=2
NITPIC(15,20,2)=2
NITPIC(15,20,3)=1
NITPIC(16,1,1)=2
NITPIC(16,1,2)=2
NITPIC(16,7,2)=3
NITPIC(16,8,1)=3
NITPIC(16,8,2)=3
NITPIC(16,13,2)=3
```

```
NITPIC(16,14,1)=3
NITPIC(16,14,2)=3
NITPIC(16,19,2)=2
NITPIC(16,19,3)=2
NITPIC(17,1,1)=2
NITPIC(17,1,2)=2
NITPIC(17,5,2)=3
NITPIC(17,6,1)=3
NITPIC(17,6,2)=3
NITPIC(17,6,3)=3
NITPIC(17,8,1)=3
NITPIC(17,11,2)=3
NITPIC(17,12,1)=3
NITPIC(17,12,2)=3
NITPIC(17,12,3)=3
NITPIC(17,14,1)=3
NITPIC(17,18,2)=2
NITPIC(17,18,3)=2
NITPIC(18,1,1)=2
NITPIC(18,1,2)=2
NITPIC(18,4,3)=3
NITPIC(18,7,1)=3
NITPIC(18,7,6)=3
NITPIC(18,10,3)=3
NITPIC(18,13,1)=3
NITPIC(18,13,2)=3
NITPIC(18,13,6)=3
NITPIC(18,17,2)=2
NITPIC(18,17,3)=2
NITPIC(19,1,1)=2
NITPIC(19,1,2)=2
NITPIC(19,4,4)=3
NITPIC(19,5,3)=3
NITPIC(19,5,4)=3
NITPIC(19,5,5)=3
NITPIC(19,7,1)=3
NITPIC(19,7,6)=3
NITPIC(19,10,4)=3
NITPIC(19,11,3)=3
NITPIC(19,11,4)=3
NITPIC(19,11,5)=3
NITPIC(19,13,1)=3
NITPIC(19,16,2)=2
NITPIC(19,16,3)=2
NITPIC(20,1,1)=1
NITPIC(20,1,2)=1
NITPIC(20,5,4)=3
NITPIC(20,11,4)=3
NITPIC(20,15,2)=2
NITPIC(20,15,3)=2
NITPIC(21,1,1)=1
NITPIC(21,1,2)=1
NITPIC(21,14,2)=2
NITPIC(21,14,3)=2
NITPIC(22,1,1)=1
```

```
      NITPIC(22,1,2)=1
      NITPIC(22,13,2)=2
      NITPIC(22,13,3)=2
      NITPIC(23,1,1)=1
      NITPIC(23,1,2)=1
      NITPIC(23,2,1)=1
      NITPIC(23,2,2)=1
      NITPIC(23,3,1)=1
      NITPIC(23,3,2)=1
      NITPIC(23,4,1)=1
      NITPIC(23,4,2)=1
      NITPIC(23,5,1)=2
      NITPIC(23,5,2)=2
      NITPIC(23,6,1)=2
      NITPIC(23,6,2)=2
      NITPIC(23,7,1)=2
      NITPIC(23,7,2)=2
      NITPIC(23,8,1)=2
      NITPIC(23,8,2)=2
      NITPIC(23,9,1)=2
      NITPIC(23,9,2)=2
      NITPIC(23,10,1)=2
      NITPIC(23,10,2)=2
      NITPIC(23,11,1)=2
      NITPIC(23,11,2)=2
      NITPIC(23,12,1)=2
      NITPIC(23,12,2)=2
      NITPIC(23,12,3)=2
      RETURN
      END
C
C
      SUBROUTINE PPRINT(TIN,PIN,Z)
C
C    THIS SUBROUTINE CONTAINS WRITE STATEMENTS AND FORMAT STATEMENTS
C    USED TO PRINT INDIVIDUAL CHANNEL PARAMETERS
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 MU,MUL,MUV,K,KL,KV,MDOT
      DIMENSION NITPIC(23,23,6),N(23,23,6),K1(23,23,6),K2(23,23,6)
      DIMENSION K3(23,23,6),L1(23,23,6),L2(23,23,6),L3(23,23,6)
      DIMENSION M3(23,23,6),M1(23,23,6),M2(23,23,6),H(23,23,6)
      DIMENSION TE(23,23,6),PE(23,23,6),TC(23,23,6),TVWB(23,23,6)
      DIMENSION PWROUT(23,23,6),T(23,23,6),P(23,23,6)
      COMMON/HICK/TE,PE,TC,TVWB,PWROUT
      COMMON/FRUIT/NITPIC,N,K1,K2,K3,L1,L2,L3,M1,M2,M3,H
      COMMON/JING/T,P
      Z=Z*12.
      NTYPE=0
      DO 9000 KK=1,23
      IF(KK.LE.12)LMAX=KK+11
      IF(KK.GT.12)LMAX=(24-KK)+11
      DO 9000 L=1,LMAX
      DO 9000 M=1,6
```

APPENDIX C

Program Input and Output

The input data for the program is contained in four cards. The input data includes the coolant inlet conditions, the fuel assembly height, the axial height increment, the coolant flowrates, the fuel lattice parameters, and the power density. The required input is:

TIN - The inlet coolant temperature in degrees Fahrenheit.

PIN - The inlet coolant pressure in PSIA.

ZMAX - The fuel assembly height in inches.

DZ - The height increment in inches.

NNN - An integer that defines the FTWR. Values for NNN and the corresponding FTWR are listed in Table C-1.

ENR - The fuel enrichment in percent U-235.

PDENS - The power density in W/cm^3.

PITCH - The fuel rod lattice pitch in inches.

LEAD - The axial lead of the wire wrap in inches.

CLADOD - The outside diameter of the fuel rods.

PWRIN1 - The inlet pressure of the short void plates in PSIA.

PWRIN2 - The inlet pressure of the long void plates in PSIA.

PWRIN3 - The inlet pressure of the void rods in PSIA.

MDOT - The coolant mass flowrate in lbm/s.

XMDOT1 - The coolant mass flowrate through each short void plate in lbm/s.

XMDOT2 - The coolant mass flowrate through each long void plate in lbm/s.

XMDOT3 - The coolant mass flowrate through the void rods in lbm/s.

The order these input parameters are read into the program is shown in Table C-2.

The program prints a summary of the input data, the coolant properties at the fuel assembly exit, the coolant enthalpy increase through the fuel assembly, and the fuel assembly pressure drop. The inlet and outlet pressures and temperatures of each coolant channel are also printed.

Table C-1 Fuel to Water Ratio Input Parameters

Parameter Value	Fuel to Water Ratio
1	1.25
2	1.19
3	1.11
4	1.05
5	1.00
6	0.95
7	0.89
8	0.85
9	0.80
10	0.75

Table C-2 Program Input Parameters

Card Number	Input Parameters
1	TIN, PIN, ZMAX, DZ, NNN, ENR, PDENS
2	PITCH, CLADOD, XLEAD
3	PWRIN1, PWRIN2, PWRIN3
4	MDOT, XMDOT1, XMDOT2, XMDOT3

APPENDIX D

Program Output for Test Case 1

```
                              ***** FUEL ASSEMBLY DATA *****

THE HEIGHT IS 120.0 INCHES. THE ENRICHMENT IS  2.70% URANIUM-235. THE FLOWRATE THROUGH THE FUEL RODS IS  670.00 LBM/S
THE FLOWRATE THROUGH THE VOID RODS IS   0.01 LBM/S.  THE FLOWRATE THROUGH THE SHORT VOID PLATES IS   0.01 LBM/S
THE FLOWRATE THROUGH THE LONG VOID PLATES IS   0.01 LBM/S
THE FUEL TO WATER RATIO IS 0.95
THE MINIMUM DNBR IS      10.12
THE POWER DENSITY IS    597.000 W/CM**3

                              ***** INLET CONDITIONS *****

THE INLET TEMPERATURE IS 550.00 DEGREES F
THE PRESSURE AT THE INLET TO THE FUEL RODS IS 2400.00 PSIA
THE PRESSURE AT THE INLET TO THE VOID RODS IS 2049.70 PSIA.  THE PRESSURE AT THE INLET TO THE SHORT VOID PLATES IS 2049.70 PSIA
THE PRESSURE AT THE INLET TO THE LONG VOID PLATES IS 2049.70 PSIA
THE INLET ENTHALPY IS  546.71 BTU/LBM

                              ***** OUTLET CONDITIONS *****

THE PRESSURE AT THE FUEL ROD EXIT IS 2049.66 PSIA
THE PRESSURE AT THE EXIT OF THE VOID RODS IS 2049.70 PSIA  THE PRESSURE AT THE EXIT OF THE SHORT VOID PLATES IS 2049.70 PSIA
THE PRESSURE AT THE EXIT OF THE LONG VOID PLATES IS 2049.70 PSIA
THE EXIT ENTHALPY IS  667.21 BTU/LBM
THE ENTHALPY INCREASE THROUGH THE ASSEMBLY IS  120.50 BTU/LBM
THE PRESSURE DROP THROUGH THE ASSEMBLY IS  350.34 PSI
```

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(1, 1,1)	550.000	633.653	2400.000	2049.659	643.525	557.186	2049.700
120.00	(1, 1,2)	550.000	633.410	2400.000	2049.659	642.092	N/A	N/A
120.00	(1, 1,5)	550.000	634.744	2400.000	2064.307	644.995	557.186	2049.700
120.00	(1, 1,6)	550.000	636.127	2400.000	2064.307	645.418	557.186	2049.700
120.00	(1, 2,1)	550.000	633.535	2400.000	2049.659	641.761	N/A	N/A
120.00	(1, 2,2)	550.000	632.259	2400.000	2049.659	641.678	N/A	N/A
120.00	(1, 2,5)	550.000	632.831	2400.000	2064.307	645.489	557.186	2049.700
120.00	(1, 2,6)	550.000	633.875	2400.000	2049.659	643.285	557.186	2049.700
120.00	(1, 3,1)	550.000	633.289	2400.000	2049.659	641.128	N/A	N/A
120.00	(1, 3,2)	550.000	632.020	2400.000	2049.659	640.870	N/A	N/A
120.00	(1, 3,5)	550.000	632.628	2400.000	2064.307	645.489	557.186	2049.700
120.00	(1, 3,6)	550.000	631.073	2400.000	2049.659	643.626	557.186	2049.700
120.00	(1, 4,1)	550.000	632.615	2400.000	2049.659	640.202	N/A	N/A
120.00	(1, 4,2)	550.000	631.707	2400.000	2049.659	639.929	N/A	N/A
120.00	(1, 4,5)	550.000	632.888	2400.000	2064.307	645.082	557.186	2049.700
120.00	(1, 4,6)	550.000	630.453	2400.000	2049.659	642.860	557.186	2049.700
120.00	(1, 5,1)	550.000	632.883	2400.000	2049.659	639.706	N/A	N/A
120.00	(1, 5,2)	550.000	631.131	2400.000	2049.659	639.956	N/A	N/A
120.00	(1, 5,5)	550.000	631.866	2400.000	2064.307	644.961	N/A	N/A
120.00	(1, 5,6)	550.000	630.628	2400.000	2049.659	642.629	N/A	N/A
120.00	(1, 6,1)	550.000	632.206	2400.000	2049.659	639.216	N/A	N/A
120.00	(1, 6,2)	550.000	631.414	2400.000	2049.659	639.542	N/A	N/A
120.00	(1, 6,5)	550.000	631.781	2400.000	2064.307	644.554	N/A	N/A
120.00	(1, 6,6)	550.000	629.978	2400.000	2049.659	642.068	N/A	N/A
120.00	(1, 7,1)	550.000	632.100	2400.000	2049.659	639.558	N/A	N/A
120.00	(1, 7,2)	550.000	630.902	2400.000	2049.659	639.783	N/A	N/A
120.00	(1, 7,5)	550.000	632.948	2400.000	2064.307	643.812	N/A	N/A
120.00	(1, 7,6)	550.000	630.401	2400.000	2049.659	641.934	N/A	N/A
120.00	(1, 8,1)	550.000	632.188	2400.000	2049.659	639.133	N/A	N/A
120.00	(1, 8,2)	550.000	631.057	2400.000	2049.659	639.965	N/A	N/A
120.00	(1, 8,5)	550.000	631.139	2400.000	2064.307	645.008	N/A	N/A
120.00	(1, 8,6)	550.000	630.389	2400.000	2049.659	641.695	N/A	N/A
120.00	(1, 9,1)	550.000	632.804	2400.000	2049.659	639.699	N/A	N/A
120.00	(1, 9,2)	550.000	631.840	2400.000	2049.659	640.422	N/A	N/A
120.00	(1, 9,5)	550.000	631.585	2400.000	2064.307	645.475	N/A	N/A
120.00	(1, 9,6)	550.000	629.998	2400.000	2049.659	642.497	N/A	N/A
120.00	(1,10,1)	550.000	632.728	2400.000	2049.659	640.256	N/A	N/A
120.00	(1,10,2)	550.000	632.862	2400.000	2049.659	640.819	N/A	N/A
120.00	(1,10,5)	550.000	634.666	2400.000	2064.307	644.963	N/A	N/A
120.00	(1,10,6)	550.000	631.018	2400.000	2049.659	642.610	N/A	N/A
120.00	(1,11,1)	550.000	633.349	2400.000	2049.659	641.506	N/A	N/A
120.00	(1,11,2)	550.000	633.415	2400.000	2049.659	641.578	N/A	N/A
120.00	(1,11,5)	550.000	632.835	2400.000	2064.307	645.489	N/A	N/A
120.00	(1,11,6)	550.000	631.606	2400.000	2049.659	643.658	N/A	N/A
120.00	(1,12,1)	550.000	633.661	2400.000	2049.659	641.960	N/A	N/A
120.00	(1,12,2)	550.000	633.231	2400.000	2049.659	642.816	N/A	N/A
120.00	(1,12,3)	550.000	632.528	2400.000	2049.659	644.813	N/A	N/A
120.00	(1,12,4)	550.000	637.163	2400.000	2064.307	644.070	N/A	N/A
120.00	(1,12,5)	550.000	637.351	2400.000	2064.307	645.112	N/A	N/A
120.00	(1,12,6)	550.000	633.799	2400.000	2049.659	643.381	N/A	N/A
120.00	(2, 1,1)	550.000	633.327	2400.000	2049.659	643.427	557.186	2049.700
120.00	(2, 1,2)	550.000	633.166	2400.000	2049.659	641.685	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(2, 1,6)	550.000	635.098	2400.000	2064.307	645.489	557.186	2049.700
120.00	(2, 2,1)	550.000	633.664	2400.000	2049.659	641.727	N/A	N/A
120.00	(2, 2,2)	550.000	632.602	2400.000	2049.659	641.463	N/A	N/A
120.00	(2, 3,1)	550.000	632.773	2400.000	2049.659	640.994	N/A	N/A
120.00	(2, 3,2)	550.000	631.928	2400.000	2049.659	640.930	N/A	N/A
120.00	(2, 4,1)	550.000	631.859	2400.000	2049.659	640.794	N/A	N/A
120.00	(2, 4,2)	550.000	631.410	2400.000	2049.659	640.492	N/A	N/A
120.00	(2, 5,1)	550.000	631.601	2400.000	2049.659	640.183	N/A	N/A
120.00	(2, 5,2)	550.000	631.244	2400.000	2049.659	640.163	N/A	N/A
120.00	(2, 6,1)	550.000	631.070	2400.000	2049.659	639.954	N/A	N/A
120.00	(2, 6,2)	550.000	631.162	2400.000	2049.659	640.034	N/A	N/A
120.00	(2, 7,1)	550.000	631.313	2400.000	2049.659	639.913	N/A	N/A
120.00	(2, 7,2)	550.000	631.311	2400.000	2049.659	639.966	N/A	N/A
120.00	(2, 8,1)	550.000	631.073	2400.000	2049.659	640.071	N/A	N/A
120.00	(2, 8,2)	550.000	631.002	2400.000	2049.659	640.327	N/A	N/A
120.00	(2, 9,1)	550.000	631.882	2400.000	2049.659	640.091	N/A	N/A
120.00	(2, 9,2)	550.000	631.371	2400.000	2049.659	640.962	N/A	N/A
120.00	(2,10,1)	550.000	631.930	2400.000	2049.659	640.739	N/A	N/A
120.00	(2,10,2)	550.000	631.740	2400.000	2049.659	641.189	N/A	N/A
120.00	(2,11,1)	550.000	632.553	2400.000	2049.659	641.236	N/A	N/A
120.00	(2,11,2)	550.000	632.997	2400.000	2049.659	641.644	N/A	N/A
120.00	(2,12,1)	550.000	633.421	2400.000	2049.659	641.880	N/A	N/A
120.00	(2,12,2)	550.000	632.875	2400.000	2049.659	642.360	N/A	N/A
120.00	(2,13,1)	550.000	634.162	2400.000	2049.659	642.175	N/A	N/A
120.00	(2,13,2)	550.000	632.377	2400.000	2049.659	643.712	N/A	N/A
120.00	(2,13,3)	550.000	635.025	2400.000	2049.659	643.797	N/A	N/A
120.00	(2,13,4)	550.000	633.490	2400.000	2049.659	644.570	N/A	N/A
120.00	(3, 1,1)	550.000	633.223	2400.000	2049.659	643.224	557.186	2049.700
120.00	(3, 1,2)	550.000	633.011	2400.000	2049.659	641.551	N/A	N/A
120.00	(3, 1,6)	550.000	634.581	2400.000	2064.307	645.489	557.186	2049.700
120.00	(3, 2,1)	550.000	633.582	2400.000	2049.659	641.269	N/A	N/A
120.00	(3, 2,2)	550.000	632.871	2400.000	2049.659	641.182	N/A	N/A
120.00	(3, 3,1)	550.000	632.370	2400.000	2049.659	641.153	N/A	N/A
120.00	(3, 3,2)	550.000	631.780	2400.000	2049.659	640.603	N/A	N/A
120.00	(3, 4,1)	550.000	631.848	2400.000	2049.659	640.636	N/A	N/A
120.00	(3, 4,2)	550.000	631.491	2400.000	2049.659	640.481	N/A	N/A
120.00	(3, 5,1)	550.000	631.340	2400.000	2049.659	640.466	N/A	N/A
120.00	(3, 5,2)	550.000	630.626	2400.000	2049.659	640.333	N/A	N/A
120.00	(3, 6,1)	550.000	630.607	2400.000	2049.659	640.344	N/A	N/A
120.00	(3, 6,2)	550.000	631.461	2400.000	2049.659	640.260	N/A	N/A
120.00	(3, 7,1)	550.000	631.105	2400.000	2049.659	640.522	N/A	N/A
120.00	(3, 7,2)	550.000	631.193	2400.000	2049.659	640.357	N/A	N/A
120.00	(3, 8,1)	550.000	631.454	2400.000	2049.659	640.242	N/A	N/A
120.00	(3, 8,2)	550.000	631.456	2400.000	2049.659	640.556	N/A	N/A
120.00	(3, 9,1)	550.000	631.338	2400.000	2049.659	640.553	N/A	N/A
120.00	(3, 9,2)	550.000	631.284	2400.000	2049.659	640.688	N/A	N/A
120.00	(3,10,1)	550.000	631.791	2400.000	2049.659	640.754	N/A	N/A
120.00	(3,10,2)	550.000	631.578	2400.000	2049.659	641.146	N/A	N/A
120.00	(3,11,1)	550.000	631.777	2400.000	2049.659	641.161	N/A	N/A
120.00	(3,11,2)	550.000	631.645	2400.000	2049.659	641.479	N/A	N/A
120.00	(3,12,1)	550.000	632.068	2400.000	2049.659	642.020	N/A	N/A
120.00	(3,12,2)	550.000	633.104	2400.000	2049.659	641.934	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(3,13,1)	550.000	632.946	2400.000	2049.659	642.387	N/A	N/A
120.00	(3,13,2)	550.000	633.735	2400.000	2049.659	642.764	N/A	N/A
120.00	(3,14,1)	550.000	633.816	2400.000	2049.659	643.249	N/A	N/A
120.00	(3,14,2)	550.000	632.710	2400.000	2049.659	644.187	N/A	N/A
120.00	(3,14,3)	550.000	634.821	2400.000	2049.659	644.045	N/A	N/A
120.00	(3,14,4)	550.000	637.452	2400.000	2049.659	644.570	N/A	N/A
120.00	(4, 1,1)	550.000	632.834	2400.000	2049.659	643.240	N/A	N/A
120.00	(4, 1,2)	550.000	632.977	2400.000	2049.659	641.635	N/A	N/A
120.00	(4, 1,6)	550.000	634.027	2400.000	2064.307	645.489	557.186	2049.700
120.00	(4, 2,1)	550.000	633.659	2400.000	2049.659	641.529	N/A	N/A
120.00	(4, 2,2)	550.000	632.700	2400.000	2049.659	641.699	N/A	N/A
120.00	(4, 3,1)	550.000	632.813	2400.000	2049.659	641.000	N/A	N/A
120.00	(4, 3,2)	550.000	632.031	2400.000	2049.659	640.620	N/A	N/A
120.00	(4, 4,1)	550.000	631.975	2400.000	2049.659	640.372	N/A	N/A
120.00	(4, 4,2)	550.000	631.024	2400.000	2049.659	640.440	N/A	N/A
120.00	(4, 5,1)	550.000	630.751	2400.000	2049.659	640.314	N/A	N/A
120.00	(4, 5,2)	550.000	631.062	2400.000	2049.659	641.093	558.642	2049.699
120.00	(4, 6,1)	550.000	631.425	2400.000	2049.659	640.967	558.642	2049.699
120.00	(4, 6,2)	550.000	630.608	2400.000	2049.659	641.662	558.642	2049.699
120.00	(4, 7,1)	550.000	630.980	2400.000	2049.659	640.668	N/A	N/A
120.00	(4, 7,2)	550.000	631.236	2400.000	2049.659	640.503	N/A	N/A
120.00	(4, 8,1)	550.000	631.304	2400.000	2049.659	640.465	N/A	N/A
120.00	(4, 8,2)	550.000	631.430	2400.000	2049.659	640.651	N/A	N/A
120.00	(4, 9,1)	550.000	631.447	2400.000	2049.659	640.569	N/A	N/A
120.00	(4, 9,2)	550.000	631.415	2400.000	2049.659	640.434	N/A	N/A
120.00	(4,10,1)	550.000	631.600	2400.000	2049.659	640.485	N/A	N/A
120.00	(4,10,2)	550.000	631.309	2400.000	2049.659	640.836	N/A	N/A
120.00	(4,11,1)	550.000	630.825	2400.000	2049.659	640.987	N/A	N/A
120.00	(4,11,2)	550.000	631.337	2400.000	2049.659	641.859	558.642	2049.699
120.00	(4,12,1)	550.000	632.563	2400.000	2049.659	642.009	558.642	2049.699
120.00	(4,12,2)	550.000	631.721	2400.000	2049.659	643.160	558.642	2049.699
120.00	(4,13,1)	550.000	632.029	2400.000	2049.659	642.324	N/A	N/A
120.00	(4,13,2)	550.000	633.320	2400.000	2049.659	642.078	N/A	N/A
120.00	(4,14,1)	550.000	633.305	2400.000	2049.659	643.006	N/A	N/A
120.00	(4,14,2)	550.000	634.112	2400.000	2049.659	643.105	N/A	N/A
120.00	(4,15,1)	550.000	633.724	2400.000	2049.659	644.005	N/A	N/A
120.00	(4,15,2)	550.000	632.324	2400.000	2049.659	644.694	N/A	N/A
120.00	(4,15,3)	550.000	635.057	2400.000	2049.659	644.204	N/A	N/A
120.00	(4,15,4)	550.000	636.690	2400.000	2049.659	644.570	N/A	N/A
120.00	(5, 1,1)	550.000	633.442	2400.000	2049.659	642.580	N/A	N/A
120.00	(5, 1,2)	550.000	633.083	2400.000	2049.659	641.725	N/A	N/A
120.00	(5, 1,6)	550.000	635.550	2400.000	2064.307	645.060	N/A	N/A
120.00	(5, 2,1)	550.000	633.452	2400.000	2049.659	641.548	N/A	N/A
120.00	(5, 2,2)	550.000	633.232	2400.000	2049.659	641.341	N/A	N/A
120.00	(5, 3,1)	550.000	632.818	2400.000	2049.659	641.462	N/A	N/A
120.00	(5, 3,2)	550.000	632.282	2400.000	2049.659	640.959	N/A	N/A
120.00	(5, 4,1)	550.000	631.927	2400.000	2049.659	640.746	N/A	N/A
120.00	(5, 4,2)	550.000	630.838	2400.000	2049.659	641.843	558.642	2049.699
120.00	(5, 5,1)	550.000	630.897	2400.000	2049.659	641.322	558.642	2049.699
120.00	(5, 5,2)	550.000	633.534	2400.000	2049.659	643.183	558.642	2049.699
120.00	(5, 5,3)	550.000	633.693	2400.000	2049.659	644.291	558.642	2049.699
120.00	(5, 7,1)	550.000	631.732	2400.000	2049.659	640.998	558.642	2049.699

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(5, 7,2)	550.000	631.823	2400.000	2049.659	640.255	N/A	N/A
120.00	(5, 8,1)	550.000	631.453	2400.000	2049.659	640.521	N/A	N/A
120.00	(5, 8,2)	550.000	631.781	2400.000	2049.659	640.413	N/A	N/A
120.00	(5, 9,1)	550.000	631.683	2400.000	2049.659	640.690	N/A	N/A
120.00	(5, 9,2)	550.000	631.589	2400.000	2049.659	640.722	N/A	N/A
120.00	(5,10,1)	550.000	631.435	2400.000	2049.659	640.532	N/A	N/A
120.00	(5,10,2)	550.000	631.161	2400.000	2049.659	641.907	558.642	2049.699
120.00	(5,11,1)	550.000	630.782	2400.000	2049.659	641.842	558.642	2049.699
120.00	(5,11,2)	550.000	633.902	2400.000	2049.659	643.378	558.642	2049.699
120.00	(5,11,3)	550.000	633.591	2400.000	2049.659	644.570	558.642	2049.699
120.00	(5,13,1)	550.000	633.442	2400.000	2049.659	642.164	558.642	2049.699
120.00	(5,13,2)	550.000	633.276	2400.000	2049.659	641.827	N/A	N/A
120.00	(5,14,1)	550.000	633.324	2400.000	2049.659	642.166	N/A	N/A
120.00	(5,14,2)	550.000	633.744	2400.000	2049.659	642.217	N/A	N/A
120.00	(5,15,1)	550.000	634.173	2400.000	2049.659	642.784	N/A	N/A
120.00	(5,15,2)	550.000	634.813	2400.000	2049.659	643.324	N/A	N/A
120.00	(5,16,1)	550.000	634.342	2400.000	2049.659	644.062	N/A	N/A
120.00	(5,16,2)	550.000	632.656	2400.000	2049.659	644.704	N/A	N/A
120.00	(5,16,3)	550.000	634.950	2400.000	2049.659	644.399	N/A	N/A
120.00	(5,16,4)	550.000	635.893	2400.000	2049.659	644.570	N/A	N/A
120.00	(6, 1,1)	550.000	633.940	2400.000	2049.659	642.101	N/A	N/A
120.00	(6, 1,2)	550.000	633.138	2400.000	2049.659	641.607	N/A	N/A
120.00	(6, 1,6)	550.000	635.629	2400.000	2064.307	644.937	N/A	N/A
120.00	(6, 2,1)	550.000	634.139	2400.000	2049.659	641.399	N/A	N/A
120.00	(6, 2,2)	550.000	633.120	2400.000	2049.659	641.599	N/A	N/A
120.00	(6, 3,1)	550.000	633.578	2400.000	2049.659	641.364	N/A	N/A
120.00	(6, 3,2)	550.000	632.610	2400.000	2049.659	641.398	N/A	N/A
120.00	(6, 4,1)	550.000	632.403	2400.000	2049.659	640.977	N/A	N/A
120.00	(6, 4,2)	550.000	632.023	2400.000	2049.659	640.900	N/A	N/A
120.00	(6, 4,3)	550.000	630.845	2400.000	2049.659	641.884	558.642	2049.699
120.00	(6, 7,1)	550.000	633.907	2400.000	2064.307	642.554	558.642	2049.699
120.00	(6, 7,2)	550.000	631.356	2400.000	2064.307	641.715	558.642	2049.699
120.00	(6, 7,6)	550.000	634.637	2400.000	2064.307	643.390	558.642	2049.699
120.00	(6, 8,1)	550.000	632.382	2400.000	2049.659	640.179	N/A	N/A
120.00	(6, 8,2)	550.000	631.700	2400.000	2049.659	640.673	N/A	N/A
120.00	(6, 9,1)	550.000	632.204	2400.000	2049.659	640.622	N/A	N/A
120.00	(6, 9,2)	550.000	632.107	2400.000	2049.659	641.086	N/A	N/A
120.00	(6,10,1)	550.000	631.935	2400.000	2049.659	640.855	N/A	N/A
120.00	(6,10,2)	550.000	632.142	2400.000	2049.659	641.003	N/A	N/A
120.00	(6,10,3)	550.000	631.074	2400.000	2049.659	642.213	558.642	2049.699
120.00	(6,13,1)	550.000	634.631	2400.000	2064.307	644.255	558.642	2049.699
120.00	(6,13,2)	550.000	632.426	2400.000	2064.307	642.814	558.642	2049.699
120.00	(6,13,6)	550.000	635.529	2400.000	2064.307	645.021	558.642	2049.699
120.00	(6,14,1)	550.000	633.487	2400.000	2049.659	641.640	N/A	N/A
120.00	(6,14,2)	550.000	633.162	2400.000	2049.659	642.101	N/A	N/A
120.00	(6,15,1)	550.000	633.582	2400.000	2049.659	642.488	N/A	N/A
120.00	(6,15,2)	550.000	634.196	2400.000	2049.659	642.923	N/A	N/A
120.00	(6,16,1)	550.000	634.281	2400.000	2049.659	643.543	N/A	N/A
120.00	(6,16,2)	550.000	635.332	2400.000	2049.659	643.589	N/A	N/A
120.00	(6,17,1)	550.000	634.891	2400.000	2049.659	644.498	N/A	N/A
120.00	(6,17,2)	550.000	633.602	2400.000	2049.659	644.704	N/A	N/A
120.00	(6,17,3)	550.000	635.089	2400.000	2049.659	644.852	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(6,17,4)	550.000	637.261	2400.000	2049.659	644.570	N/A	N/A
120.00	(7, 1,1)	550.000	633.065	2400.000	2049.659	642.608	N/A	N/A
120.00	(7, 1,2)	550.000	633.145	2400.000	2049.659	641.399	N/A	N/A
120.00	(7, 1,6)	550.000	635.481	2400.000	2064.307	644.870	N/A	N/A
120.00	(7, 2,1)	550.000	634.310	2400.000	2049.659	641.132	N/A	N/A
120.00	(7, 2,2)	550.000	633.174	2400.000	2049.659	641.455	N/A	N/A
120.00	(7, 3,1)	550.000	633.561	2400.000	2049.659	641.382	N/A	N/A
120.00	(7, 3,2)	550.000	632.869	2400.000	2049.659	641.397	N/A	N/A
120.00	(7, 4,1)	550.000	632.427	2400.000	2049.659	641.323	N/A	N/A
120.00	(7, 4,2)	550.000	632.336	2400.000	2049.659	640.969	N/A	N/A
120.00	(7, 5,1)	550.000	631.946	2400.000	2049.659	641.243	N/A	N/A
120.00	(7, 5,2)	550.000	631.682	2400.000	2049.659	641.167	N/A	N/A
120.00	(7, 5,4)	550.000	631.770	2400.000	2049.659	641.669	558.642	2049.699
120.00	(7, 6,1)	550.000	632.476	2400.000	2049.659	640.781	N/A	N/A
120.00	(7, 6,2)	550.000	632.190	2400.000	2049.659	641.228	N/A	N/A
120.00	(7, 6,3)	550.000	631.277	2400.000	2049.659	642.306	558.642	2049.699
120.00	(7, 6,4)	550.000	633.594	2400.000	2049.659	643.781	558.642	2049.699
120.00	(7, 6,5)	550.000	634.178	2400.000	2049.659	644.390	558.642	2049.699
120.00	(7, 8,1)	550.000	631.800	2400.000	2049.659	641.571	558.642	2049.699
120.00	(7, 8,2)	550.000	631.421	2400.000	2049.659	640.866	N/A	N/A
120.00	(7, 9,1)	550.000	632.240	2400.000	2049.659	640.631	N/A	N/A
120.00	(7, 9,2)	550.000	632.630	2400.000	2049.659	641.196	N/A	N/A
120.00	(7,10,1)	550.000	632.144	2400.000	2049.659	641.352	N/A	N/A
120.00	(7,10,2)	550.000	632.408	2400.000	2049.659	641.099	N/A	N/A
120.00	(7,11,1)	550.000	632.039	2400.000	2049.659	641.501	N/A	N/A
120.00	(7,11,2)	550.000	631.880	2400.000	2049.659	641.445	N/A	N/A
120.00	(7,11,4)	550.000	631.908	2400.000	2049.659	642.017	558.642	2049.699
120.00	(7,12,1)	550.000	632.729	2400.000	2049.659	641.048	N/A	N/A
120.00	(7,12,2)	550.000	632.597	2400.000	2049.659	641.589	N/A	N/A
120.00	(7,12,3)	550.000	631.395	2400.000	2049.659	642.844	558.642	2049.699
120.00	(7,12,4)	550.000	634.009	2400.000	2049.659	643.868	558.642	2049.699
120.00	(7,12,5)	550.000	634.308	2400.000	2049.659	644.522	558.642	2049.699
120.00	(7,14,1)	550.000	632.648	2400.000	2049.659	642.433	558.642	2049.699
120.00	(7,14,2)	550.000	632.299	2400.000	2049.659	641.929	N/A	N/A
120.00	(7,15,1)	550.000	633.467	2400.000	2049.659	641.908	N/A	N/A
120.00	(7,15,2)	550.000	633.476	2400.000	2049.659	642.685	N/A	N/A
120.00	(7,16,1)	550.000	633.973	2400.000	2049.659	643.032	N/A	N/A
120.00	(7,16,2)	550.000	634.499	2400.000	2049.659	643.298	N/A	N/A
120.00	(7,17,1)	550.000	634.996	2400.000	2049.659	643.909	N/A	N/A
120.00	(7,17,2)	550.000	635.165	2400.000	2049.659	644.127	N/A	N/A
120.00	(7,18,1)	550.000	635.108	2400.000	2049.659	644.675	N/A	N/A
120.00	(7,18,2)	550.000	633.511	2400.000	2049.659	644.704	N/A	N/A
120.00	(7,18,3)	550.000	635.968	2400.000	2049.659	644.852	N/A	N/A
120.00	(7,18,4)	550.000	636.288	2400.000	2049.659	644.570	N/A	N/A
120.00	(8, 1,1)	550.000	633.002	2400.000	2049.659	643.133	N/A	N/A
120.00	(8, 1,2)	550.000	633.200	2400.000	2049.659	641.443	N/A	N/A
120.00	(8, 1,6)	550.000	634.728	2400.000	2064.307	645.324	N/A	N/A
120.00	(8, 2,1)	550.000	633.515	2400.000	2049.659	641.605	N/A	N/A
120.00	(8, 2,2)	550.000	632.891	2400.000	2049.659	641.395	N/A	N/A
120.00	(8, 3,1)	550.000	633.492	2400.000	2049.659	641.184	N/A	N/A
120.00	(8, 3,2)	550.000	632.517	2400.000	2049.659	641.373	N/A	N/A
120.00	(8, 4,1)	550.000	632.380	2400.000	2049.659	641.332	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(8, 4,2)	550.000	632.242	2400.000	2049.659	640.946	N/A	N/A
120.00	(8, 5,1)	550.000	632.492	2400.000	2049.659	640.953	N/A	N/A
120.00	(8, 5,2)	550.000	632.103	2400.000	2049.659	641.149	N/A	N/A
120.00	(8, 6,1)	550.000	631.597	2400.000	2049.659	641.157	N/A	N/A
120.00	(8, 6,2)	550.000	632.504	2400.000	2049.659	640.917	N/A	N/A
120.00	(8, 7,1)	550.000	631.878	2400.000	2049.659	641.274	N/A	N/A
120.00	(8, 7,2)	550.000	632.388	2400.000	2049.659	640.813	N/A	N/A
120.00	(8, 8,1)	550.000	631.459	2400.000	2049.659	641.201	N/A	N/A
120.00	(8, 8,2)	550.000	631.845	2400.000	2049.659	641.108	N/A	N/A
120.00	(8, 8,6)	550.000	631.826	2400.000	2049.659	641.863	558.642	2049.699
120.00	(8, 9,1)	550.000	632.386	2400.000	2049.659	640.922	N/A	N/A
120.00	(8, 9,2)	550.000	632.172	2400.000	2049.659	641.571	N/A	N/A
120.00	(8,10,1)	550.000	632.106	2400.000	2049.659	641.622	N/A	N/A
120.00	(8,10,2)	550.000	632.264	2400.000	2049.659	641.222	N/A	N/A
120.00	(8,11,1)	550.000	632.663	2400.000	2049.659	641.139	N/A	N/A
120.00	(8,11,2)	550.000	632.368	2400.000	2049.659	641.482	N/A	N/A
120.00	(8,12,1)	550.000	631.819	2400.000	2049.659	641.462	N/A	N/A
120.00	(8,12,2)	550.000	632.713	2400.000	2049.659	641.197	N/A	N/A
120.00	(8,13,1)	550.000	632.331	2400.000	2049.659	641.587	N/A	N/A
120.00	(8,13,2)	550.000	632.490	2400.000	2049.659	641.266	N/A	N/A
120.00	(8,14,1)	550.000	631.989	2400.000	2049.659	641.602	N/A	N/A
120.00	(8,14,2)	550.000	632.506	2400.000	2049.659	641.777	N/A	N/A
120.00	(8,14,6)	550.000	632.241	2400.000	2049.659	642.399	558.642	2049.699
120.00	(8,15,1)	550.000	633.210	2400.000	2049.659	641.753	N/A	N/A
120.00	(8,15,2)	550.000	632.817	2400.000	2049.659	642.474	N/A	N/A
120.00	(8,16,1)	550.000	633.432	2400.000	2049.659	642.549	N/A	N/A
120.00	(8,16,2)	550.000	633.721	2400.000	2049.659	642.795	N/A	N/A
120.00	(8,17,1)	550.000	634.058	2400.000	2049.659	643.243	N/A	N/A
120.00	(8,17,2)	550.000	634.348	2400.000	2049.659	643.232	N/A	N/A
120.00	(8,18,1)	550.000	634.462	2400.000	2049.659	643.849	N/A	N/A
120.00	(8,18,2)	550.000	635.664	2400.000	2049.659	643.873	N/A	N/A
120.00	(8,19,1)	550.000	635.011	2400.000	2049.659	644.704	N/A	N/A
120.00	(8,19,2)	550.000	633.461	2400.000	2049.659	644.704	N/A	N/A
120.00	(8,19,3)	550.000	635.514	2400.000	2049.659	644.852	N/A	N/A
120.00	(8,19,4)	550.000	637.163	2400.000	2049.659	644.570	N/A	N/A
120.00	(9, 1,1)	550.000	632.751	2400.000	2049.659	643.435	N/A	N/A
120.00	(9, 1,2)	550.000	632.891	2400.000	2049.659	641.403	N/A	N/A
120.00	(9, 1,6)	550.000	633.475	2400.000	2064.307	645.489	N/A	N/A
120.00	(9, 2,1)	550.000	633.722	2400.000	2049.659	641.293	N/A	N/A
120.00	(9, 2,2)	550.000	632.514	2400.000	2049.659	641.552	N/A	N/A
120.00	(9, 3,1)	550.000	632.984	2400.000	2049.659	641.232	N/A	N/A
120.00	(9, 3,2)	550.000	631.882	2400.000	2049.659	641.324	N/A	N/A
120.00	(9, 4,1)	550.000	632.646	2400.000	2049.659	640.987	N/A	N/A
120.00	(9, 4,2)	550.000	631.895	2400.000	2049.659	641.236	N/A	N/A
120.00	(9, 5,1)	550.000	631.978	2400.000	2049.659	641.118	N/A	N/A
120.00	(9, 5,2)	550.000	631.203	2400.000	2049.659	641.027	N/A	N/A
120.00	(9, 6,1)	550.000	631.732	2400.000	2049.659	640.998	N/A	N/A
120.00	(9, 6,2)	550.000	631.895	2400.000	2049.659	641.257	N/A	N/A
120.00	(9, 7,1)	550.000	631.851	2400.000	2049.659	641.496	N/A	N/A
120.00	(9, 7,2)	550.000	631.940	2400.000	2049.659	641.151	N/A	N/A
120.00	(9, 8,1)	550.000	632.197	2400.000	2049.659	641.149	N/A	N/A
120.00	(9, 8,2)	550.000	631.994	2400.000	2049.659	641.366	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(9, 9,1)	550.000	632.153	2400.000	2049.659	641.393	N/A	N/A
120.00	(9, 9,2)	550.000	631.581	2400.000	2049.659	641.569	N/A	N/A
120.00	(9,10,1)	550.000	632.346	2400.000	2049.659	641.212	N/A	N/A
120.00	(9,10,2)	550.000	632.085	2400.000	2049.659	641.491	N/A	N/A
120.00	(9,11,1)	550.000	632.086	2400.000	2049.659	641.495	N/A	N/A
120.00	(9,11,2)	550.000	631.454	2400.000	2049.659	641.421	N/A	N/A
120.00	(9,12,1)	550.000	631.931	2400.000	2049.659	641.358	N/A	N/A
120.00	(9,12,2)	550.000	631.988	2400.000	2049.659	641.478	N/A	N/A
120.00	(9,13,1)	550.000	632.055	2400.000	2049.659	641.684	N/A	N/A
120.00	(9,13,2)	550.000	631.972	2400.000	2049.659	641.373	N/A	N/A
120.00	(9,14,1)	550.000	632.292	2400.000	2049.659	641.336	N/A	N/A
120.00	(9,14,2)	550.000	632.381	2400.000	2049.659	641.618	N/A	N/A
120.00	(9,15,1)	550.000	632.498	2400.000	2049.659	642.044	N/A	N/A
120.00	(9,15,2)	550.000	632.065	2400.000	2049.659	642.058	N/A	N/A
120.00	(9,16,1)	550.000	632.881	2400.000	2049.659	642.017	N/A	N/A
120.00	(9,16,2)	550.000	632.895	2400.000	2049.659	642.430	N/A	N/A
120.00	(9,17,1)	550.000	633.422	2400.000	2049.659	642.713	N/A	N/A
120.00	(9,17,2)	550.000	632.793	2400.000	2049.659	642.946	N/A	N/A
120.00	(9,18,1)	550.000	633.778	2400.000	2049.659	643.108	N/A	N/A
120.00	(9,18,2)	550.000	634.350	2400.000	2049.659	643.525	N/A	N/A
120.00	(9,19,1)	550.000	634.616	2400.000	2049.659	644.221	N/A	N/A
120.00	(9,19,2)	550.000	635.228	2400.000	2049.659	643.978	N/A	N/A
120.00	(9,20,1)	550.000	635.400	2400.000	2049.659	644.490	N/A	N/A
120.00	(9,20,2)	550.000	633.244	2400.000	2049.659	644.704	N/A	N/A
120.00	(9,20,3)	550.000	635.473	2400.000	2049.659	644.852	557.186	2049.700
120.00	(9,20,4)	550.000	637.034	2400.000	2049.659	644.570	557.186	2049.700
120.00	(10, 1,1)	550.000	632.938	2400.000	2049.659	643.343	N/A	N/A
120.00	(10, 1,2)	550.000	632.969	2400.000	2049.659	641.809	N/A	N/A
120.00	(10, 1,6)	550.000	634.109	2400.000	2064.307	645.489	N/A	N/A
120.00	(10, 2,1)	550.000	633.084	2400.000	2049.659	641.498	N/A	N/A
120.00	(10, 2,2)	550.000	632.697	2400.000	2049.659	641.321	N/A	N/A
120.00	(10, 3,1)	550.000	632.683	2400.000	2049.659	640.932	N/A	N/A
120.00	(10, 3,2)	550.000	632.389	2400.000	2049.659	640.685	N/A	N/A
120.00	(10, 4,1)	550.000	632.439	2400.000	2049.659	640.838	N/A	N/A
120.00	(10, 4,2)	550.000	631.288	2400.000	2049.659	641.097	N/A	N/A
120.00	(10, 5,1)	550.000	631.351	2400.000	2049.659	640.884	N/A	N/A
120.00	(10, 5,2)	550.000	631.577	2400.000	2049.659	641.827	558.642	2049.699
120.00	(10, 6,1)	550.000	631.723	2400.000	2049.659	641.651	558.642	2049.699
120.00	(10, 6,2)	550.000	631.561	2400.000	2049.659	642.078	558.642	2049.699
120.00	(10, 7,1)	550.000	632.092	2400.000	2049.659	641.011	N/A	N/A
120.00	(10, 7,2)	550.000	631.959	2400.000	2049.659	641.117	N/A	N/A
120.00	(10, 8,1)	550.000	631.925	2400.000	2049.659	641.074	N/A	N/A
120.00	(10, 8,2)	550.000	632.067	2400.000	2049.659	641.071	N/A	N/A
120.00	(10, 9,1)	550.000	632.324	2400.000	2049.659	640.967	N/A	N/A
120.00	(10, 9,2)	550.000	632.140	2400.000	2049.659	640.997	N/A	N/A
120.00	(10,10,1)	550.000	632.401	2400.000	2049.659	641.048	N/A	N/A
120.00	(10,10,2)	550.000	631.620	2400.000	2049.659	641.547	N/A	N/A
120.00	(10,11,1)	550.000	631.498	2400.000	2049.659	641.320	N/A	N/A
120.00	(10,11,2)	550.000	631.671	2400.000	2049.659	642.144	558.642	2049.699
120.00	(10,12,1)	550.000	631.789	2400.000	2049.659	641.976	558.642	2049.699
120.00	(10,12,2)	550.000	631.435	2400.000	2049.659	642.177	558.642	2049.699
120.00	(10,13,1)	550.000	632.018	2400.000	2049.659	641.109	N/A	N/A

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(10,13,2)	550.000	631.939	2400.000	2049.659	641.163	N/A	N/A
120.00	(10,14,1)	550.000	631.988	2400.000	2049.659	641.160	N/A	N/A
120.00	(10,14,2)	550.000	631.966	2400.000	2049.659	641.224	N/A	N/A
120.00	(10,15,1)	550.000	632.513	2400.000	2049.659	641.148	N/A	N/A
120.00	(10,15,2)	550.000	632.214	2400.000	2049.659	641.230	N/A	N/A
120.00	(10,16,1)	550.000	632.839	2400.000	2049.659	641.314	N/A	N/A
120.00	(10,16,2)	550.000	632.214	2400.000	2049.659	642.004	N/A	N/A
120.00	(10,17,1)	550.000	632.003	2400.000	2049.659	642.153	N/A	N/A
120.00	(10,17,2)	550.000	632.501	2400.000	2049.659	642.978	558.642	2049.699
120.00	(10,18,1)	550.000	633.645	2400.000	2049.659	643.323	558.642	2049.699
120.00	(10,18,2)	550.000	632.424	2400.000	2049.659	644.423	558.642	2049.699
120.00	(10,19,1)	550.000	633.412	2400.000	2049.659	643.221	N/A	N/A
120.00	(10,19,2)	550.000	634.270	2400.000	2049.659	643.145	N/A	N/A
120.00	(10,20,1)	550.000	634.208	2400.000	2049.659	644.039	N/A	N/A
120.00	(10,20,2)	550.000	634.630	2400.000	2049.659	643.866	N/A	N/A
120.00	(10,21,1)	550.000	634.563	2400.000	2049.659	644.595	N/A	N/A
120.00	(10,21,2)	550.000	633.506	2400.000	2049.659	644.704	N/A	N/A
120.00	(10,21,3)	550.000	636.396	2400.000	2049.659	644.852	557.186	2049.700
120.00	(10,21,4)	550.000	637.379	2400.000	2049.659	644.570	557.186	2049.700
120.00	(11, 1,1)	550.000	633.752	2400.000	2049.659	643.357	N/A	N/A
120.00	(11, 1,2)	550.000	633.192	2400.000	2049.659	642.159	N/A	N/A
120.00	(11, 1,6)	550.000	635.663	2400.000	2064.307	645.489	N/A	N/A
120.00	(11, 2,1)	550.000	633.208	2400.000	2049.659	641.911	N/A	N/A
120.00	(11, 2,2)	550.000	633.434	2400.000	2049.659	641.510	N/A	N/A
120.00	(11, 3,1)	550.000	632.729	2400.000	2049.659	641.494	N/A	N/A
120.00	(11, 3,2)	550.000	632.337	2400.000	2049.659	640.942	N/A	N/A
120.00	(11, 4,1)	550.000	631.804	2400.000	2049.659	640.922	N/A	N/A
120.00	(11, 4,2)	550.000	631.258	2400.000	2049.659	641.790	558.642	2049.699
120.00	(11, 5,1)	550.000	631.197	2400.000	2049.659	641.736	558.642	2049.699
120.00	(11, 5,2)	550.000	634.225	2400.000	2049.659	643.663	558.642	2049.699
120.00	(11, 5,3)	550.000	634.204	2400.000	2049.659	644.570	558.642	2049.699
120.00	(11, 7,1)	550.000	632.157	2400.000	2049.659	642.136	558.642	2049.699
120.00	(11, 7,2)	550.000	632.345	2400.000	2049.659	640.806	N/A	N/A
120.00	(11, 8,1)	550.000	631.921	2400.000	2049.659	641.094	N/A	N/A
120.00	(11, 8,2)	550.000	632.506	2400.000	2049.659	640.833	N/A	N/A
120.00	(11, 9,1)	550.000	632.078	2400.000	2049.659	641.274	N/A	N/A
120.00	(11, 9,2)	550.000	631.867	2400.000	2049.659	640.976	N/A	N/A
120.00	(11,10,1)	550.000	631.616	2400.000	2049.659	641.026	N/A	N/A
120.00	(11,10,2)	550.000	631.390	2400.000	2049.659	642.042	558.642	2049.699
120.00	(11,11,1)	550.000	630.686	2400.000	2049.659	642.364	558.642	2049.699
120.00	(11,11,2)	550.000	634.250	2400.000	2049.659	643.509	558.642	2049.699
120.00	(11,11,3)	550.000	633.842	2400.000	2049.659	644.570	558.642	2049.699
120.00	(11,13,1)	550.000	632.212	2400.000	2049.659	641.945	558.642	2049.699
120.00	(11,13,2)	550.000	632.443	2400.000	2049.659	640.680	N/A	N/A
120.00	(11,14,1)	550.000	631.877	2400.000	2049.659	641.065	N/A	N/A
120.00	(11,14,2)	550.000	632.497	2400.000	2049.659	640.713	N/A	N/A
120.00	(11,15,1)	550.000	631.999	2400.000	2049.659	641.205	N/A	N/A
120.00	(11,15,2)	550.000	631.960	2400.000	2049.659	640.899	N/A	N/A
120.00	(11,16,1)	550.000	631.800	2400.000	2049.659	641.121	N/A	N/A
120.00	(11,16,2)	550.000	631.491	2400.000	2049.659	642.219	558.642	2049.699
120.00	(11,17,1)	550.000	631.131	2400.000	2049.659	642.677	558.642	2049.699
120.00	(11,17,2)	550.000	634.351	2400.000	2049.659	644.176	558.642	2049.699

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(11,17,3)	550.000	634.198	2400.000	2049.659	644.570	558.642	2049.699
120.00	(11,19,1)	550.000	634.132	2400.000	2049.659	643.292	558.642	2049.699
120.00	(11,19,2)	550.000	633.294	2400.000	2049.659	642.920	N/A	N/A
120.00	(11,20,1)	550.000	633.726	2400.000	2049.659	643.129	N/A	N/A
120.00	(11,20,2)	550.000	634.539	2400.000	2049.659	643.103	N/A	N/A
120.00	(11,21,1)	550.000	635.568	2400.000	2049.659	643.476	N/A	N/A
120.00	(11,21,2)	550.000	635.298	2400.000	2049.659	644.508	N/A	N/A
120.00	(11,22,1)	550.000	634.849	2400.000	2049.659	644.704	N/A	N/A
120.00	(11,22,2)	550.000	633.315	2400.000	2049.659	644.704	N/A	N/A
120.00	(11,22,3)	550.000	635.387	2400.000	2049.659	644.852	557.186	2049.700
120.00	(11,22,4)	550.000	636.569	2400.000	2049.659	644.570	557.186	2049.700
120.00	(12, 1,1)	550.000	634.571	2400.000	2064.307	645.489	N/A	N/A
120.00	(12, 1,2)	550.000	633.452	2400.000	2049.659	643.282	N/A	N/A
120.00	(12, 1,6)	550.000	634.953	2400.000	2064.307	645.489	N/A	N/A
120.00	(12, 2,1)	550.000	634.672	2400.000	2049.659	641.627	N/A	N/A
120.00	(12, 2,2)	550.000	632.882	2400.000	2049.659	642.091	N/A	N/A
120.00	(12, 3,1)	550.000	632.908	2400.000	2049.659	641.852	N/A	N/A
120.00	(12, 3,2)	550.000	632.179	2400.000	2049.659	641.345	N/A	N/A
120.00	(12, 4,1)	550.000	632.394	2400.000	2049.659	640.897	N/A	N/A
120.00	(12, 4,2)	550.000	631.817	2400.000	2049.659	641.155	N/A	N/A
120.00	(12, 4,3)	550.000	631.112	2400.000	2049.659	642.015	558.642	2049.699
120.00	(12, 7,1)	550.000	634.740	2400.000	2064.307	643.978	558.642	2049.699
120.00	(12, 7,2)	550.000	632.037	2400.000	2064.307	642.322	558.642	2049.699
120.00	(12, 7,6)	550.000	634.491	2400.000	2064.307	645.088	558.642	2049.699
120.00	(12, 8,1)	550.000	633.032	2400.000	2049.659	640.707	N/A	N/A
120.00	(12, 8,2)	550.000	632.095	2400.000	2049.659	641.308	N/A	N/A
120.00	(12, 9,1)	550.000	632.294	2400.000	2049.659	641.060	N/A	N/A
120.00	(12, 9,2)	550.000	631.972	2400.000	2049.659	640.970	N/A	N/A
120.00	(12,10,1)	550.000	631.996	2400.000	2049.659	640.677	N/A	N/A
120.00	(12,10,2)	550.000	631.874	2400.000	2049.659	640.859	N/A	N/A
120.00	(12,10,3)	550.000	631.093	2400.000	2049.659	642.026	558.642	2049.699
120.00	(12,13,1)	550.000	634.928	2400.000	2064.307	643.811	558.642	2049.699
120.00	(12,13,2)	550.000	631.508	2400.000	2064.307	642.376	558.642	2049.699
120.00	(12,13,6)	550.000	634.861	2400.000	2064.307	645.067	558.642	2049.699
120.00	(12,14,1)	550.000	632.629	2400.000	2049.659	640.652	N/A	N/A
120.00	(12,14,2)	550.000	632.118	2400.000	2049.659	641.131	N/A	N/A
120.00	(12,15,1)	550.000	632.213	2400.000	2049.659	641.001	N/A	N/A
120.00	(12,15,2)	550.000	631.799	2400.000	2049.659	640.836	N/A	N/A
120.00	(12,16,1)	550.000	631.796	2400.000	2049.659	640.646	N/A	N/A
120.00	(12,16,2)	550.000	631.643	2400.000	2049.659	640.661	N/A	N/A
120.00	(12,16,3)	550.000	630.965	2400.000	2049.659	641.959	558.642	2049.699
120.00	(12,19,1)	550.000	635.697	2400.000	2064.307	644.829	558.642	2049.699
120.00	(12,19,2)	550.000	633.959	2400.000	2064.307	643.318	558.642	2049.699
120.00	(12,19,6)	550.000	635.463	2400.000	2064.307	645.489	557.186	2049.700
120.00	(12,20,1)	550.000	635.520	2400.000	2049.659	641.929	N/A	N/A
120.00	(12,20,2)	550.000	634.983	2400.000	2049.659	643.330	N/A	N/A
120.00	(12,21,1)	550.000	635.055	2400.000	2049.659	643.594	N/A	N/A
120.00	(12,21,2)	550.000	634.797	2400.000	2049.659	643.708	N/A	N/A
120.00	(12,22,1)	550.000	634.873	2400.000	2049.659	643.781	N/A	N/A
120.00	(12,22,2)	550.000	634.980	2400.000	2049.659	643.609	N/A	N/A
120.00	(12,23,1)	550.000	633.751	2400.000	2049.659	644.529	N/A	N/A
120.00	(12,23,2)	550.000	634.238	2400.000	2049.659	644.852	557.186	2049.700

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(12,23,3)	550.000	635.784	2400.000	2049.659	644.570	557.186	2049.700
120.00	(12,23,4)	550.000	637.882	2400.000	2049.659	644.570	557.186	2049.700
120.00	(13, 1,1)	550.000	633.640	2400.000	2064.307	645.489	N/A	N/A
120.00	(13, 1,2)	550.000	632.970	2400.000	2049.659	642.964	N/A	N/A
120.00	(13, 2,1)	550.000	634.158	2400.000	2049.659	641.079	N/A	N/A
120.00	(13, 2,2)	550.000	632.484	2400.000	2049.659	641.775	N/A	N/A
120.00	(13, 3,1)	550.000	632.681	2400.000	2049.659	640.950	N/A	N/A
120.00	(13, 3,2)	550.000	632.417	2400.000	2049.659	641.221	N/A	N/A
120.00	(13, 4,1)	550.000	632.357	2400.000	2049.659	641.322	N/A	N/A
120.00	(13, 4,2)	550.000	632.005	2400.000	2049.659	641.690	N/A	N/A
120.00	(13, 4,4)	550.000	632.257	2400.000	2049.659	642.030	558.642	2049.699
120.00	(13, 5,1)	550.000	632.845	2400.000	2049.659	641.290	N/A	N/A
120.00	(13, 5,2)	550.000	632.189	2400.000	2049.659	641.634	N/A	N/A
120.00	(13, 5,4)	550.000	633.482	2400.000	2049.659	644.234	558.642	2049.699
120.00	(13, 5,5)	550.000	633.633	2400.000	2049.659	644.570	558.642	2049.699
120.00	(13, 7,1)	550.000	632.192	2400.000	2049.659	642.110	558.642	2049.699
120.00	(13, 7,2)	550.000	631.658	2400.000	2049.659	641.393	N/A	N/A
120.00	(13, 8,1)	550.000	632.546	2400.000	2049.659	641.096	N/A	N/A
120.00	(13, 8,2)	550.000	632.103	2400.000	2049.659	641.600	N/A	N/A
120.00	(13, 9,1)	550.000	632.086	2400.000	2049.659	641.016	N/A	N/A
120.00	(13, 9,2)	550.000	632.185	2400.000	2049.659	641.035	N/A	N/A
120.00	(13,10,1)	550.000	632.156	2400.000	2049.659	641.247	N/A	N/A
120.00	(13,10,2)	550.000	631.879	2400.000	2049.659	641.518	N/A	N/A
120.00	(13,10,4)	550.000	632.190	2400.000	2049.659	641.889	558.642	2049.699
120.00	(13,11,1)	550.000	632.807	2400.000	2049.659	641.064	N/A	N/A
120.00	(13,11,2)	550.000	632.190	2400.000	2049.659	641.435	N/A	N/A
120.00	(13,11,4)	550.000	633.521	2400.000	2049.659	644.055	558.642	2049.699
120.00	(13,11,5)	550.000	633.595	2400.000	2049.659	644.570	558.642	2049.699
120.00	(13,13,1)	550.000	631.834	2400.000	2049.659	642.160	558.642	2049.699
120.00	(13,13,2)	550.000	630.697	2400.000	2049.659	641.466	N/A	N/A
120.00	(13,14,1)	550.000	632.357	2400.000	2049.659	640.657	N/A	N/A
120.00	(13,14,2)	550.000	632.259	2400.000	2049.659	641.425	N/A	N/A
120.00	(13,15,1)	550.000	631.813	2400.000	2049.659	641.074	N/A	N/A
120.00	(13,15,2)	550.000	631.662	2400.000	2049.659	640.764	N/A	N/A
120.00	(13,16,1)	550.000	632.058	2400.000	2049.659	640.866	N/A	N/A
120.00	(13,16,2)	550.000	631.703	2400.000	2049.659	641.422	N/A	N/A
120.00	(13,16,4)	550.000	632.295	2400.000	2049.659	641.749	558.642	2049.699
120.00	(13,17,1)	550.000	632.745	2400.000	2049.659	640.885	N/A	N/A
120.00	(13,17,2)	550.000	632.292	2400.000	2049.659	641.332	N/A	N/A
120.00	(13,17,4)	550.000	633.800	2400.000	2049.659	644.228	558.642	2049.699
120.00	(13,17,5)	550.000	633.531	2400.000	2049.659	644.570	558.642	2049.699
120.00	(13,19,1)	550.000	633.022	2400.000	2049.659	643.490	558.642	2049.699
120.00	(13,19,2)	550.000	632.799	2400.000	2049.659	642.469	N/A	N/A
120.00	(13,20,1)	550.000	635.015	2400.000	2049.659	642.869	N/A	N/A
120.00	(13,20,2)	550.000	633.950	2400.000	2049.659	643.927	N/A	N/A
120.00	(13,21,1)	550.000	634.191	2400.000	2049.659	643.265	N/A	N/A
120.00	(13,21,2)	550.000	634.326	2400.000	2049.659	642.925	N/A	N/A
120.00	(13,22,1)	550.000	633.542	2400.000	2049.659	643.631	N/A	N/A
120.00	(13,22,2)	550.000	634.668	2400.000	2049.659	644.285	557.186	2049.700
120.00	(13,22,3)	550.000	635.462	2400.000	2049.659	644.570	557.186	2049.700
120.00	(14, 1,1)	550.000	631.244	2400.000	2064.307	645.489	N/A	N/A
120.00	(14, 1,2)	550.000	633.180	2400.000	2049.659	643.357	N/A	N/A

```
   Z     CHANNEL NUMBER    INLET TEMP    OUTLET TEMP   INLET PRES   OUTLET PRES    CLAD TEMP     VOID TEMP    VOID PRES
 (IN.)     (KK, L,M)     (DEGREES F)   (DEGREES F)     (PSIA)       (PSIA)     (DEGREES F)  (DEGREES F)    (PSIA)

120.00    (14, 2,1)        550.000       632.781      2400.000     2049.659      641.896        N/A          N/A
120.00    (14, 2,2)        550.000       632.358      2400.000     2049.659      641.739        N/A          N/A
120.00    (14, 3,1)        550.000       632.459      2400.000     2049.659      641.492        N/A          N/A
120.00    (14, 3,2)        550.000       632.670      2400.000     2049.659      641.650        N/A          N/A
120.00    (14, 4,1)        550.000       632.269      2400.000     2049.659      641.658        N/A          N/A
120.00    (14, 4,2)        550.000       633.224      2400.000     2049.659      641.566        N/A          N/A
120.00    (14, 5,1)        550.000       632.319      2400.000     2049.659      641.905        N/A          N/A
120.00    (14, 5,2)        550.000       632.600      2400.000     2049.659      641.395        N/A          N/A
120.00    (14, 5,4)        550.000       631.814      2400.000     2049.659      642.131      558.642     2049.699
120.00    (14, 5,5)        550.000       632.919      2400.000     2049.659      641.935      558.642     2049.699
120.00    (14, 6,1)        550.000       632.035      2400.000     2049.659      641.269        N/A          N/A
120.00    (14, 6,2)        550.000       632.185      2400.000     2049.659      641.174        N/A          N/A
120.00    (14, 7,1)        550.000       632.481      2400.000     2049.659      641.164        N/A          N/A
120.00    (14, 7,2)        550.000       632.299      2400.000     2049.659      641.651        N/A          N/A
120.00    (14, 8,1)        550.000       631.700      2400.000     2049.659      641.856        N/A          N/A
120.00    (14, 8,2)        550.000       632.176      2400.000     2049.659      641.323        N/A          N/A
120.00    (14, 9,1)        550.000       632.258      2400.000     2049.659      641.233        N/A          N/A
120.00    (14, 9,2)        550.000       632.487      2400.000     2049.659      641.330        N/A          N/A
120.00    (14,10,1)        550.000       631.897      2400.000     2049.659      641.495        N/A          N/A
120.00    (14,10,2)        550.000       633.132      2400.000     2049.659      641.217        N/A          N/A
120.00    (14,11,1)        550.000       631.984      2400.000     2049.659      641.735        N/A          N/A
120.00    (14,11,2)        550.000       632.223      2400.000     2049.659      640.998        N/A          N/A
120.00    (14,11,4)        550.000       631.405      2400.000     2049.659      642.066      558.642     2049.699
120.00    (14,11,5)        550.000       632.759      2400.000     2049.659      641.822      558.642     2049.699
120.00    (14,12,1)        550.000       631.891      2400.000     2049.659      640.999        N/A          N/A
120.00    (14,12,2)        550.000       631.881      2400.000     2049.659      641.174        N/A          N/A
120.00    (14,13,1)        550.000       631.750      2400.000     2049.659      640.936        N/A          N/A
120.00    (14,13,2)        550.000       632.179      2400.000     2049.659      641.405        N/A          N/A
120.00    (14,14,1)        550.000       631.444      2400.000     2049.659      641.865        N/A          N/A
120.00    (14,14,2)        550.000       631.698      2400.000     2049.659      640.913        N/A          N/A
120.00    (14,15,1)        550.000       632.240      2400.000     2049.659      640.720        N/A          N/A
120.00    (14,15,2)        550.000       632.409      2400.000     2049.659      641.287        N/A          N/A
120.00    (14,16,1)        550.000       631.279      2400.000     2049.659      641.451        N/A          N/A
120.00    (14,16,2)        550.000       633.059      2400.000     2049.659      640.837        N/A          N/A
120.00    (14,17,1)        550.000       632.204      2400.000     2049.659      641.748        N/A          N/A
120.00    (14,17,2)        550.000       631.924      2400.000     2049.659      641.302        N/A          N/A
120.00    (14,17,4)        550.000       631.608      2400.000     2049.659      642.786      558.642     2049.699
120.00    (14,17,5)        550.000       633.111      2400.000     2049.659      642.001      558.642     2049.699
120.00    (14,18,1)        550.000       633.323      2400.000     2049.659      641.067        N/A          N/A
120.00    (14,18,2)        550.000       631.763      2400.000     2049.659      642.814        N/A          N/A
120.00    (14,19,1)        550.000       633.343      2400.000     2049.659      641.816        N/A          N/A
120.00    (14,19,2)        550.000       633.809      2400.000     2049.659      642.810        N/A          N/A
120.00    (14,20,1)        550.000       633.814      2400.000     2049.659      643.462        N/A          N/A
120.00    (14,20,2)        550.000       633.901      2400.000     2049.659      643.026        N/A          N/A
120.00    (14,21,1)        550.000       632.840      2400.000     2049.659      643.096        N/A          N/A
120.00    (14,21,2)        550.000       633.193      2400.000     2049.659      643.433      557.186     2049.700
120.00    (14,21,3)        550.000       636.152      2400.000     2049.659      644.570      557.186     2049.700
120.00    (15, 1,1)        550.000       631.174      2400.000     2064.307      645.489        N/A          N/A
120.00    (15, 1,2)        550.000       633.060      2400.000     2049.659      643.313        N/A          N/A
120.00    (15, 2,1)        550.000       632.988      2400.000     2049.659      641.769        N/A          N/A
120.00    (15, 2,2)        550.000       632.810      2400.000     2049.659      641.946        N/A          N/A
120.00    (15, 3,1)        550.000       632.696      2400.000     2049.659      641.986        N/A          N/A
```

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(15, 3,2)	550.000	633.026	2400.000	2049.659	642.073	N/A	N/A
120.00	(15, 4,1)	550.000	632.759	2400.000	2049.659	642.164	N/A	N/A
120.00	(15, 4,2)	550.000	632.740	2400.000	2049.659	641.724	N/A	N/A
120.00	(15, 5,1)	550.000	632.159	2400.000	2049.659	641.738	N/A	N/A
120.00	(15, 5,2)	550.000	632.591	2400.000	2049.659	641.435	N/A	N/A
120.00	(15, 6,1)	550.000	632.416	2400.000	2049.659	641.361	N/A	N/A
120.00	(15, 6,2)	550.000	632.427	2400.000	2049.659	641.405	N/A	N/A
120.00	(15, 7,1)	550.000	632.735	2400.000	2049.659	641.234	N/A	N/A
120.00	(15, 7,2)	550.000	632.597	2400.000	2049.659	641.473	N/A	N/A
120.00	(15, 8,1)	550.000	632.255	2400.000	2049.659	641.648	N/A	N/A
120.00	(15, 8,2)	550.000	631.448	2400.000	2049.659	641.557	N/A	N/A
120.00	(15, 9,1)	550.000	631.835	2400.000	2049.659	641.524	N/A	N/A
120.00	(15, 9,2)	550.000	632.459	2400.000	2049.659	641.644	N/A	N/A
120.00	(15,10,1)	550.000	632.225	2400.000	2049.659	641.908	N/A	N/A
120.00	(15,10,2)	550.000	632.428	2400.000	2049.659	641.297	N/A	N/A
120.00	(15,11,1)	550.000	632.300	2400.000	2049.659	641.229	N/A	N/A
120.00	(15,11,2)	550.000	632.324	2400.000	2049.659	641.377	N/A	N/A
120.00	(15,12,1)	550.000	632.014	2400.000	2049.659	641.328	N/A	N/A
120.00	(15,12,2)	550.000	632.248	2400.000	2049.659	641.206	N/A	N/A
120.00	(15,13,1)	550.000	632.465	2400.000	2049.659	641.199	N/A	N/A
120.00	(15,13,2)	550.000	631.980	2400.000	2049.659	641.199	N/A	N/A
120.00	(15,14,1)	550.000	632.032	2400.000	2049.659	641.126	N/A	N/A
120.00	(15,14,2)	550.000	631.437	2400.000	2049.659	641.358	N/A	N/A
120.00	(15,15,1)	550.000	630.924	2400.000	2049.659	641.420	N/A	N/A
120.00	(15,15,2)	550.000	632.589	2400.000	2049.659	640.740	N/A	N/A
120.00	(15,16,1)	550.000	632.326	2400.000	2049.659	641.739	N/A	N/A
120.00	(15,16,2)	550.000	632.510	2400.000	2049.659	641.261	N/A	N/A
120.00	(15,17,1)	550.000	632.619	2400.000	2049.659	641.167	N/A	N/A
120.00	(15,17,2)	550.000	632.536	2400.000	2049.659	641.852	N/A	N/A
120.00	(15,18,1)	550.000	632.555	2400.000	2049.659	642.114	N/A	N/A
120.00	(15,18,2)	550.000	632.974	2400.000	2049.659	642.521	N/A	N/A
120.00	(15,19,1)	550.000	633.419	2400.000	2049.659	642.806	N/A	N/A
120.00	(15,19,2)	550.000	634.069	2400.000	2049.659	642.473	N/A	N/A
120.00	(15,20,1)	550.000	632.281	2400.000	2049.659	643.143	N/A	N/A
120.00	(15,20,2)	550.000	633.026	2400.000	2049.659	643.141	N/A	N/A
120.00	(15,20,3)	550.000	635.430	2400.000	2049.659	644.570	557.186	2049.700
120.00	(16, 1,1)	550.000	631.531	2400.000	2064.307	645.489	N/A	N/A
120.00	(16, 1,2)	550.000	633.134	2400.000	2049.659	643.926	N/A	N/A
120.00	(16, 2,1)	550.000	633.102	2400.000	2049.659	641.962	N/A	N/A
120.00	(16, 2,2)	550.000	633.109	2400.000	2049.659	642.067	N/A	N/A
120.00	(16, 3,1)	550.000	633.241	2400.000	2049.659	642.119	N/A	N/A
120.00	(16, 3,2)	550.000	632.631	2400.000	2049.659	642.203	N/A	N/A
120.00	(16, 4,1)	550.000	633.172	2400.000	2049.659	641.742	N/A	N/A
120.00	(16, 4,2)	550.000	632.666	2400.000	2049.659	642.316	N/A	N/A
120.00	(16, 5,1)	550.000	632.797	2400.000	2049.659	641.855	N/A	N/A
120.00	(16, 5,2)	550.000	632.499	2400.000	2049.659	641.804	N/A	N/A
120.00	(16, 6,1)	550.000	632.233	2400.000	2049.659	641.651	N/A	N/A
120.00	(16, 6,2)	550.000	632.049	2400.000	2049.659	641.521	N/A	N/A
120.00	(16, 7,1)	550.000	631.715	2400.000	2049.659	641.455	N/A	N/A
120.00	(16, 7,2)	550.000	631.995	2400.000	2049.659	642.156	558.642	2049.699
120.00	(16, 8,1)	550.000	632.243	2400.000	2049.659	641.931	558.642	2049.699
120.00	(16, 8,2)	550.000	631.911	2400.000	2049.659	642.560	558.642	2049.699

```
   Z      CHANNEL NUMBER     INLET TEMP    OUTLET TEMP    INLET PRES    OUTLET PRES     CLAD TEMP      VOID TEMP     VOID PRES
 (IN.)      (KK, L,M)      (DEGREES F)   (DEGREES F)      (PSIA)        (PSIA)      (DEGREES F)   (DEGREES F)     (PSIA)

120.00    (16, 9,1)          550.000       632.466      2400.000      2049.659       641.640         N/A           N/A
120.00    (16, 9,2)          550.000       632.145      2400.000      2049.659       641.723         N/A           N/A
120.00    (16,10,1)          550.000       632.306      2400.000      2049.659       641.529         N/A           N/A
120.00    (16,10,2)          550.000       632.432      2400.000      2049.659       641.618         N/A           N/A
120.00    (16,11,1)          550.000       632.587      2400.000      2049.659       641.344         N/A           N/A
120.00    (16,11,2)          550.000       631.893      2400.000      2049.659       641.272         N/A           N/A
120.00    (16,12,1)          550.000       631.828      2400.000      2049.659       641.373         N/A           N/A
120.00    (16,12,2)          550.000       631.535      2400.000      2049.659       641.163         N/A           N/A
120.00    (16,13,1)          550.000       631.034      2400.000      2049.659       640.950         N/A           N/A
120.00    (16,13,2)          550.000       631.670      2400.000      2049.659       641.555       558.642      2049.699
120.00    (16,14,1)          550.000       631.340      2400.000      2049.659       641.796       558.642      2049.699
120.00    (16,14,2)          550.000       631.273      2400.000      2049.659       641.720       558.642      2049.699
120.00    (16,15,1)          550.000       631.745      2400.000      2049.659       641.327         N/A           N/A
120.00    (16,15,2)          550.000       632.081      2400.000      2049.659       641.099         N/A           N/A
120.00    (16,16,1)          550.000       632.474      2400.000      2049.659       641.300         N/A           N/A
120.00    (16,16,2)          550.000       632.166      2400.000      2049.659       641.691         N/A           N/A
120.00    (16,17,1)          550.000       632.616      2400.000      2049.659       641.676         N/A           N/A
120.00    (16,17,2)          550.000       633.047      2400.000      2049.659       642.112         N/A           N/A
120.00    (16,18,1)          550.000       633.019      2400.000      2049.659       642.436         N/A           N/A
120.00    (16,18,2)          550.000       633.684      2400.000      2049.659       642.237         N/A           N/A
120.00    (16,19,1)          550.000       632.007      2400.000      2049.659       642.707         N/A           N/A
120.00    (16,19,2)          550.000       633.423      2400.000      2049.659       642.526         N/A           N/A
120.00    (16,19,3)          550.000       634.435      2400.000      2049.659       644.570         N/A           N/A
120.00    (17, 1,1)          550.000       630.233      2400.000      2064.307       645.489         N/A           N/A
120.00    (17, 1,2)          550.000       633.386      2400.000      2049.659       643.704         N/A           N/A
120.00    (17, 2,1)          550.000       633.396      2400.000      2049.659       642.365         N/A           N/A
120.00    (17, 2,2)          550.000       633.821      2400.000      2049.659       642.327         N/A           N/A
120.00    (17, 3,1)          550.000       633.173      2400.000      2049.659       642.139         N/A           N/A
120.00    (17, 3,2)          550.000       633.443      2400.000      2049.659       642.127         N/A           N/A
120.00    (17, 4,1)          550.000       633.368      2400.000      2049.659       642.130         N/A           N/A
120.00    (17, 4,2)          550.000       632.643      2400.000      2049.659       642.182         N/A           N/A
120.00    (17, 5,1)          550.000       632.974      2400.000      2049.659       641.639         N/A           N/A
120.00    (17, 5,2)          550.000       632.057      2400.000      2049.659       643.333       558.642      2049.699
120.00    (17, 6,1)          550.000       631.394      2400.000      2049.659       642.810       558.642      2049.699
120.00    (17, 6,2)          550.000       634.783      2400.000      2049.659       643.858       558.642      2049.699
120.00    (17, 6,3)          550.000       634.425      2400.000      2049.659       644.570       558.642      2049.699
120.00    (17, 8,1)          550.000       633.127      2400.000      2049.659       642.440       558.642      2049.699
120.00    (17, 8,2)          550.000       633.537      2400.000      2049.659       641.454         N/A           N/A
120.00    (17, 9,1)          550.000       632.914      2400.000      2049.659       641.451         N/A           N/A
120.00    (17, 9,2)          550.000       633.299      2400.000      2049.659       641.348         N/A           N/A
120.00    (17,10,1)          550.000       632.573      2400.000      2049.659       641.728         N/A           N/A
120.00    (17,10,2)          550.000       632.340      2400.000      2049.659       641.236         N/A           N/A
120.00    (17,11,1)          550.000       632.674      2400.000      2049.659       640.640         N/A           N/A
120.00    (17,11,2)          550.000       631.730      2400.000      2049.659       642.517       558.642      2049.699
120.00    (17,12,1)          550.000       630.665      2400.000      2049.659       642.361       558.642      2049.699
120.00    (17,12,2)          550.000       633.991      2400.000      2049.659       643.157       558.642      2049.699
120.00    (17,12,3)          550.000       634.027      2400.000      2049.659       644.374       558.642      2049.699
120.00    (17,14,1)          550.000       632.938      2400.000      2049.659       641.265       558.642      2049.699
120.00    (17,14,2)          550.000       632.446      2400.000      2049.659       640.357         N/A           N/A
120.00    (17,15,1)          550.000       632.991      2400.000      2049.659       640.767         N/A           N/A
120.00    (17,15,2)          550.000       632.263      2400.000      2049.659       641.489         N/A           N/A
120.00    (17,16,1)          550.000       632.730      2400.000      2049.659       641.460         N/A           N/A
```

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(17,16,2)	550.000	633.028	2400.000	2049.659	642.161	N/A	N/A
120.00	(17,17,1)	550.000	633.335	2400.000	2049.659	642.236	N/A	N/A
120.00	(17,17,2)	550.000	633.699	2400.000	2049.659	642.315	N/A	N/A
120.00	(17,18,1)	550.000	632.108	2400.000	2049.659	642.621	N/A	N/A
120.00	(17,18,2)	550.000	632.898	2400.000	2049.659	642.696	N/A	N/A
120.00	(17,18,3)	550.000	635.097	2400.000	2049.659	644.570	N/A	N/A
120.00	(18, 1,1)	550.000	631.928	2400.000	2064.307	645.489	N/A	N/A
120.00	(18, 1,2)	550.000	633.580	2400.000	2049.659	644.636	N/A	N/A
120.00	(18, 2,1)	550.000	633.383	2400.000	2049.659	643.080	N/A	N/A
120.00	(18, 2,2)	550.000	633.214	2400.000	2049.659	642.888	N/A	N/A
120.00	(18, 3,1)	550.000	633.160	2400.000	2049.659	642.600	N/A	N/A
120.00	(18, 3,2)	550.000	633.194	2400.000	2049.659	642.405	N/A	N/A
120.00	(18, 4,1)	550.000	632.873	2400.000	2049.659	642.140	N/A	N/A
120.00	(18, 4,2)	550.000	633.318	2400.000	2049.659	642.196	N/A	N/A
120.00	(18, 4,3)	550.000	631.898	2400.000	2049.659	643.470	558.642	2049.699
120.00	(18, 7,1)	550.000	634.830	2400.000	2064.307	645.172	558.642	2049.699
120.00	(18, 7,2)	550.000	634.497	2400.000	2064.307	642.170	N/A	N/A
120.00	(18, 7,6)	550.000	635.123	2400.000	2064.307	645.489	558.642	2049.699
120.00	(18, 8,1)	550.000	634.105	2400.000	2049.659	642.099	N/A	N/A
120.00	(18, 8,2)	550.000	633.308	2400.000	2049.659	641.863	N/A	N/A
120.00	(18, 9,1)	550.000	633.447	2400.000	2049.659	641.728	N/A	N/A
120.00	(18, 9,2)	550.000	632.840	2400.000	2049.659	641.787	N/A	N/A
120.00	(18,10,1)	550.000	632.483	2400.000	2049.659	641.801	N/A	N/A
120.00	(18,10,2)	550.000	632.453	2400.000	2049.659	642.139	N/A	N/A
120.00	(18,10,3)	550.000	631.769	2400.000	2049.659	642.682	558.642	2049.699
120.00	(18,13,1)	550.000	634.153	2400.000	2064.307	643.774	558.642	2049.699
120.00	(18,13,2)	550.000	632.290	2400.000	2064.307	641.601	558.642	2049.699
120.00	(18,13,6)	550.000	633.949	2400.000	2064.307	645.489	558.642	2049.699
120.00	(18,14,1)	550.000	634.101	2400.000	2049.659	640.036	N/A	N/A
120.00	(18,14,2)	550.000	632.112	2400.000	2049.659	641.678	N/A	N/A
120.00	(18,15,1)	550.000	633.155	2400.000	2049.659	641.263	N/A	N/A
120.00	(18,15,2)	550.000	633.058	2400.000	2049.659	642.253	N/A	N/A
120.00	(18,16,1)	550.000	633.159	2400.000	2049.659	642.392	N/A	N/A
120.00	(18,16,2)	550.000	633.598	2400.000	2049.659	642.280	N/A	N/A
120.00	(18,17,1)	550.000	632.237	2400.000	2049.659	642.645	N/A	N/A
120.00	(18,17,2)	550.000	633.078	2400.000	2049.659	642.880	N/A	N/A
120.00	(18,17,3)	550.000	635.203	2400.000	2049.659	644.570	N/A	N/A
120.00	(19, 1,1)	550.000	632.546	2400.000	2064.307	645.489	N/A	N/A
120.00	(19, 1,2)	550.000	634.134	2400.000	2049.659	643.846	N/A	N/A
120.00	(19, 2,1)	550.000	634.123	2400.000	2049.659	642.755	N/A	N/A
120.00	(19, 2,2)	550.000	634.130	2400.000	2049.659	643.046	N/A	N/A
120.00	(19, 3,1)	550.000	633.698	2400.000	2049.659	642.651	N/A	N/A
120.00	(19, 3,2)	550.000	633.709	2400.000	2049.659	642.607	N/A	N/A
120.00	(19, 4,1)	550.000	633.206	2400.000	2049.659	642.771	N/A	N/A
120.00	(19, 4,2)	550.000	633.048	2400.000	2049.659	642.688	N/A	N/A
120.00	(19, 4,4)	550.000	633.181	2400.000	2049.659	643.037	558.642	2049.699
120.00	(19, 5,1)	550.000	633.459	2400.000	2049.659	642.424	N/A	N/A
120.00	(19, 5,2)	550.000	633.624	2400.000	2049.659	642.542	N/A	N/A
120.00	(19, 5,3)	550.000	632.460	2400.000	2049.659	644.112	558.642	2049.699
120.00	(19, 5,4)	550.000	635.199	2400.000	2049.659	644.570	558.642	2049.699
120.00	(19, 5,5)	550.000	635.655	2400.000	2049.659	644.570	558.642	2049.699
120.00	(19, 7,1)	550.000	633.946	2400.000	2049.659	643.403	558.642	2049.699

```
   Z      CHANNEL NUMBER      INLET TEMP    OUTLET TEMP    INLET PRES    OUTLET PRES      CLAD TEMP      VOID TEMP     VOID PRES
 (IN.)      (KK, L,M)       (DEGREES F)   (DEGREES F)      (PSIA)         (PSIA)       (DEGREES F)   (DEGREES F)     (PSIA)

 120.00    (19, 7,2)          550.000       633.068       2400.000       2049.659        642.112         N/A           N/A
 120.00    (19, 8,1)          550.000       633.838       2400.000       2049.659        641.719         N/A           N/A
 120.00    (19, 8,2)          550.000       633.101       2400.000       2049.659        642.307         N/A           N/A
 120.00    (19, 9,1)          550.000       633.523       2400.000       2049.659        641.505         N/A           N/A
 120.00    (19, 9,2)          550.000       632.590       2400.000       2049.659        641.979         N/A           N/A
 120.00    (19,10,1)          550.000       633.235       2400.000       2049.659        641.732         N/A           N/A
 120.00    (19,10,2)          550.000       632.020       2400.000       2049.659        642.455         N/A           N/A
 120.00    (19,10,4)          550.000       632.393       2400.000       2049.659        642.673       558.642      2049.699
 120.00    (19,11,1)          550.000       633.058       2400.000       2049.659        641.515         N/A           N/A
 120.00    (19,11,2)          550.000       632.970       2400.000       2049.659        641.801         N/A           N/A
 120.00    (19,11,3)          550.000       631.456       2400.000       2049.659        642.923       558.642      2049.699
 120.00    (19,11,4)          550.000       634.743       2400.000       2049.659        644.037       558.642      2049.699
 120.00    (19,11,5)          550.000       634.834       2400.000       2049.659        644.570       558.642      2049.699
 120.00    (19,13,1)          550.000       631.975       2400.000       2049.659        642.273       558.642      2049.699
 120.00    (19,13,2)          550.000       631.250       2400.000       2049.659        641.550         N/A           N/A
 120.00    (19,14,1)          550.000       632.960       2400.000       2049.659        641.043         N/A           N/A
 120.00    (19,14,2)          550.000       632.631       2400.000       2049.659        642.339         N/A           N/A
 120.00    (19,15,1)          550.000       633.066       2400.000       2049.659        642.266         N/A           N/A
 120.00    (19,15,2)          550.000       633.459       2400.000       2049.659        642.172         N/A           N/A
 120.00    (19,16,1)          550.000       632.108       2400.000       2049.659        642.602         N/A           N/A
 120.00    (19,16,2)          550.000       633.113       2400.000       2049.659        642.890         N/A           N/A
 120.00    (19,16,3)          550.000       634.580       2400.000       2049.659        644.570         N/A           N/A
 120.00    (20, 1,1)          550.000       631.411       2400.000       2064.307        645.489       557.186      2049.700
 120.00    (20, 1,2)          550.000       635.025       2400.000       2049.659        644.152       557.186      2049.700
 120.00    (20, 2,1)          550.000       634.556       2400.000       2049.659        643.390         N/A           N/A
 120.00    (20, 2,2)          550.000       634.132       2400.000       2049.659        643.187         N/A           N/A
 120.00    (20, 3,1)          550.000       634.000       2400.000       2049.659        642.677         N/A           N/A
 120.00    (20, 3,2)          550.000       634.288       2400.000       2049.659        642.831         N/A           N/A
 120.00    (20, 4,1)          550.000       633.761       2400.000       2049.659        642.583         N/A           N/A
 120.00    (20, 4,2)          550.000       633.845       2400.000       2049.659        642.639         N/A           N/A
 120.00    (20, 5,1)          550.000       633.812       2400.000       2049.659        642.435         N/A           N/A
 120.00    (20, 5,2)          550.000       633.710       2400.000       2049.659        642.516         N/A           N/A
 120.00    (20, 5,4)          550.000       633.285       2400.000       2049.659        643.710       558.642      2049.699
 120.00    (20, 6,1)          550.000       633.760       2400.000       2049.659        642.419         N/A           N/A
 120.00    (20, 6,2)          550.000       633.388       2400.000       2049.659        642.463         N/A           N/A
 120.00    (20, 7,1)          550.000       633.345       2400.000       2049.659        642.087         N/A           N/A
 120.00    (20, 7,2)          550.000       633.852       2400.000       2049.659        642.169         N/A           N/A
 120.00    (20, 8,1)          550.000       632.814       2400.000       2049.659        642.650         N/A           N/A
 120.00    (20, 8,2)          550.000       632.946       2400.000       2049.659        641.998         N/A           N/A
 120.00    (20, 9,1)          550.000       633.319       2400.000       2049.659        641.910         N/A           N/A
 120.00    (20, 9,2)          550.000       633.068       2400.000       2049.659        642.484         N/A           N/A
 120.00    (20,10,1)          550.000       632.614       2400.000       2049.659        642.132         N/A           N/A
 120.00    (20,10,2)          550.000       633.052       2400.000       2049.659        642.034         N/A           N/A
 120.00    (20,11,1)          550.000       632.198       2400.000       2049.659        642.161         N/A           N/A
 120.00    (20,11,2)          550.000       632.633       2400.000       2049.659        641.243         N/A           N/A
 120.00    (20,11,4)          550.000       632.343       2400.000       2049.659        642.192       558.642      2049.699
 120.00    (20,12,1)          550.000       632.500       2400.000       2049.659        641.439         N/A           N/A
 120.00    (20,12,2)          550.000       632.350       2400.000       2049.659        641.640         N/A           N/A
 120.00    (20,13,1)          550.000       632.814       2400.000       2049.659        641.239         N/A           N/A
 120.00    (20,13,2)          550.000       632.552       2400.000       2049.659        642.390         N/A           N/A
 120.00    (20,14,1)          550.000       633.151       2400.000       2049.659        642.219         N/A           N/A
 120.00    (20,14,2)          550.000       633.258       2400.000       2049.659        642.430         N/A           N/A
```

Z (IN.)	CHANNEL NUMBER (KK, L,M)	INLET TEMP (DEGREES F)	OUTLET TEMP (DEGREES F)	INLET PRES (PSIA)	OUTLET PRES (PSIA)	CLAD TEMP (DEGREES F)	VOID TEMP (DEGREES F)	VOID PRES (PSIA)
120.00	(20,15,1)	550.000	631.965	2400.000	2049.659	642.528	N/A	N/A
120.00	(20,15,2)	550.000	632.798	2400.000	2049.659	642.784	N/A	N/A
120.00	(20,15,3)	550.000	634.876	2400.000	2049.659	644.570	N/A	N/A
120.00	(21, 1,1)	550.000	631.923	2400.000	2064.307	645.489	557.186	2049.700
120.00	(21, 1,2)	550.000	634.570	2400.000	2049.659	644.108	557.186	2049.700
120.00	(21, 2,1)	550.000	634.319	2400.000	2049.659	643.388	N/A	N/A
120.00	(21, 2,2)	550.000	634.451	2400.000	2049.659	643.586	N/A	N/A
120.00	(21, 3,1)	550.000	634.185	2400.000	2049.659	643.733	N/A	N/A
120.00	(21, 3,2)	550.000	634.421	2400.000	2049.659	643.617	N/A	N/A
120.00	(21, 4,1)	550.000	634.110	2400.000	2049.659	643.225	N/A	N/A
120.00	(21, 4,2)	550.000	633.918	2400.000	2049.659	643.186	N/A	N/A
120.00	(21, 5,1)	550.000	633.874	2400.000	2049.659	642.818	N/A	N/A
120.00	(21, 5,2)	550.000	633.744	2400.000	2049.659	642.820	N/A	N/A
120.00	(21, 6,1)	550.000	633.477	2400.000	2049.659	642.694	N/A	N/A
120.00	(21, 6,2)	550.000	633.433	2400.000	2049.659	642.656	N/A	N/A
120.00	(21, 7,1)	550.000	633.652	2400.000	2049.659	642.436	N/A	N/A
120.00	(21, 7,2)	550.000	633.214	2400.000	2049.659	642.374	N/A	N/A
120.00	(21, 8,1)	550.000	633.079	2400.000	2049.659	642.222	N/A	N/A
120.00	(21, 8,2)	550.000	633.289	2400.000	2049.659	642.343	N/A	N/A
120.00	(21, 9,1)	550.000	632.779	2400.000	2049.659	642.549	N/A	N/A
120.00	(21, 9,2)	550.000	633.188	2400.000	2049.659	642.206	N/A	N/A
120.00	(21,10,1)	550.000	633.236	2400.000	2049.659	642.296	N/A	N/A
120.00	(21,10,2)	550.000	632.594	2400.000	2049.659	642.238	N/A	N/A
120.00	(21,11,1)	550.000	632.435	2400.000	2049.659	641.612	N/A	N/A
120.00	(21,11,2)	550.000	632.846	2400.000	2049.659	641.623	N/A	N/A
120.00	(21,12,1)	550.000	632.881	2400.000	2049.659	641.858	N/A	N/A
120.00	(21,12,2)	550.000	633.003	2400.000	2049.659	642.264	N/A	N/A
120.00	(21,13,1)	550.000	633.349	2400.000	2049.659	642.196	N/A	N/A
120.00	(21,13,2)	550.000	633.555	2400.000	2049.659	642.543	N/A	N/A
120.00	(21,14,1)	550.000	632.208	2400.000	2049.659	642.713	N/A	N/A
120.00	(21,14,2)	550.000	633.009	2400.000	2049.659	643.121	N/A	N/A
120.00	(21,14,3)	550.000	634.704	2400.000	2049.659	644.570	N/A	N/A
120.00	(22, 1,1)	550.000	633.911	2400.000	2064.307	645.489	557.186	2049.700
120.00	(22, 1,2)	550.000	633.246	2400.000	2049.659	644.852	557.186	2049.700
120.00	(22, 2,1)	550.000	634.659	2400.000	2049.659	643.454	N/A	N/A
120.00	(22, 2,2)	550.000	634.401	2400.000	2049.659	643.912	N/A	N/A
120.00	(22, 3,1)	550.000	634.496	2400.000	2049.659	643.840	N/A	N/A
120.00	(22, 3,2)	550.000	633.964	2400.000	2049.659	643.744	N/A	N/A
120.00	(22, 4,1)	550.000	634.189	2400.000	2049.659	643.307	N/A	N/A
120.00	(22, 4,2)	550.000	633.703	2400.000	2049.659	643.526	N/A	N/A
120.00	(22, 5,1)	550.000	633.792	2400.000	2049.659	642.931	N/A	N/A
120.00	(22, 5,2)	550.000	633.326	2400.000	2049.659	642.954	N/A	N/A
120.00	(22, 6,1)	550.000	633.415	2400.000	2049.659	642.788	N/A	N/A
120.00	(22, 6,2)	550.000	633.379	2400.000	2049.659	642.823	N/A	N/A
120.00	(22, 7,1)	550.000	633.691	2400.000	2049.659	642.317	N/A	N/A
120.00	(22, 7,2)	550.000	633.151	2400.000	2049.659	642.678	N/A	N/A
120.00	(22, 8,1)	550.000	633.097	2400.000	2049.659	642.301	N/A	N/A
120.00	(22, 8,2)	550.000	633.055	2400.000	2049.659	642.160	N/A	N/A
120.00	(22, 9,1)	550.000	632.955	2400.000	2049.659	642.363	N/A	N/A
120.00	(22, 9,2)	550.000	632.990	2400.000	2049.659	642.165	N/A	N/A
120.00	(22,10,1)	550.000	632.583	2400.000	2049.659	642.068	N/A	N/A
120.00	(22,10,2)	550.000	632.696	2400.000	2049.659	641.936	N/A	N/A

```
   Z      CHANNEL NUMBER      INLET TEMP     OUTLET TEMP     INLET PRES     OUTLET PRES      CLAD TEMP      VOID TEMP      VOID PRES
 (IN.)     (KK, L,M)         (DEGREES F)    (DEGREES F)       (PSIA)         (PSIA)        (DEGREES F)    (DEGREES F)     (PSIA)

120.00     (22,11,1)           550.000        632.497        2400.000       2049.659        641.931          N/A            N/A
120.00     (22,11,2)           550.000        632.732        2400.000       2049.659        641.778          N/A            N/A
120.00     (22,12,1)           550.000        632.775        2400.000       2049.659        642.260          N/A            N/A
120.00     (22,12,2)           550.000        633.662        2400.000       2049.659        642.248          N/A            N/A
120.00     (22,13,1)           550.000        632.063        2400.000       2049.659        642.883          N/A            N/A
120.00     (22,13,2)           550.000        633.652        2400.000       2049.659        643.089          N/A            N/A
120.00     (22,13,3)           550.000        635.197        2400.000       2049.659        644.570          N/A            N/A
120.00     (23, 1,1)           550.000        637.847        2400.000       2064.307        645.489        557.186       2049.700
120.00     (23, 1,2)           550.000        635.500        2400.000       2064.307        645.489        557.186       2049.700
120.00     (23, 2,1)           550.000        635.818        2400.000       2049.659        644.852        557.186       2049.700
120.00     (23, 2,2)           550.000        633.416        2400.000       2049.659        644.570        557.186       2049.700
120.00     (23, 3,1)           550.000        634.304        2400.000       2049.659        644.722        557.186       2049.700
120.00     (23, 3,2)           550.000        632.874        2400.000       2049.659        644.570        557.186       2049.700
120.00     (23, 4,1)           550.000        634.114        2400.000       2049.659        644.731        557.186       2049.700
120.00     (23, 4,2)           550.000        631.512        2400.000       2049.659        644.570        557.186       2049.700
120.00     (23, 5,1)           550.000        633.907        2400.000       2049.659        644.019          N/A            N/A
120.00     (23, 5,2)           550.000        631.968        2400.000       2049.659        644.570          N/A            N/A
120.00     (23, 6,1)           550.000        633.395        2400.000       2049.659        644.409          N/A            N/A
120.00     (23, 6,2)           550.000        631.976        2400.000       2049.659        644.570          N/A            N/A
120.00     (23, 7,1)           550.000        633.722        2400.000       2049.659        643.925          N/A            N/A
120.00     (23, 7,2)           550.000        630.726        2400.000       2049.659        644.570          N/A            N/A
120.00     (23, 8,1)           550.000        633.499        2400.000       2049.659        643.396          N/A            N/A
120.00     (23, 8,2)           550.000        631.198        2400.000       2049.659        644.570          N/A            N/A
120.00     (23, 9,1)           550.000        633.215        2400.000       2049.659        643.433          N/A            N/A
120.00     (23, 9,2)           550.000        631.352        2400.000       2049.659        644.570          N/A            N/A
120.00     (23,10,1)           550.000        632.932        2400.000       2049.659        643.332          N/A            N/A
120.00     (23,10,2)           550.000        630.490        2400.000       2049.659        644.570          N/A            N/A
120.00     (23,11,1)           550.000        633.538        2400.000       2049.659        642.846          N/A            N/A
120.00     (23,11,2)           550.000        631.798        2400.000       2049.659        644.570          N/A            N/A
120.00     (23,12,1)           550.000        631.941        2400.000       2049.659        643.910          N/A            N/A
120.00     (23,12,2)           550.000        633.909        2400.000       2049.659        644.570          N/A            N/A
120.00     (23,12,3)           550.000        634.793        2400.000       2049.659        644.570          N/A            N/A
```

THERMAL-HYDRAULIC ANALYSIS OF A SPECTRAL SHIFT REACTOR

by

Brian Damiano

(ABSTRACT)

A computer program has been developed which performs a thermal-hydraulic analysis of a mechanical spectral shift reactor fuel assembly. In this reactor type, the fuel to water volume ratio is changed to shift the neutron energy spectrum and control reactivity. The ability to handle different fuel to water ratios is the unique feature of this program.

The required input parameters are the coolant inlet pressure and temperature, the mass flow rates, and the power density. The cladding temperature and the coolant pressure and temperature are calculated throughout the fuel assembly.

Three test cases were performed using a conceptual reactor core design. The fuel to water ratio of this design can be varied from 1.25 to 0.75 by removing blank rods from the core. Each fuel assembly is enclosed in a hex can. The fuel assembly flowrates can be independently selected.

The test case results indicate that proper flowrate selection can produce equal fuel assembly enthalpy gains. The maximum allowable pressure drop determines the maximum coolant flowrate and the maximum

power density variation between fuel assemblies. The coolant exit properties are relatively unaffected by changing the fuel to water ratio. This indicates that little heat is transferred into the moderator regions that are formed when void rods are removed.

The most useful program modification would be the addition of a routine that defines the coolant channel parameters for any fuel assembly.