APR 09 1999
Station 15

21

ENGINEERING DATA TRANSMITTAL

Page 1 of 2

1. EDT 626227

2. To: (Receiving Organization) Spent Nuclear Fuel		3. From: (Originating Organization) NHC/Modeling & Engrg Analysis		4. Related EDT No.: N/A	
5. Proj./Prog./Dept./Div.: SNF		6. Design Authority/Design Agent/Cog. Engr.: F. J. Heard		7. Purchase Order No.: N/A	
8. Originator Remarks: Transmittal of HNF-4109, Rev.0 "Thermal Assessment of Shippingport Pressurized Water Reactor Blanket Fuel Assemblies Within a Multi-Canister Overpack within the Canister Storage Building"				9. Equip./Component No.: N/A	
				10. System/Bldg./Facility: N/A	
				12. Major Assm. Dwg. No.: N/A	
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No				13. Permit/Permit Application No.: N/A	
				14. Required Response Date:	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	HNF-4109	N/A	0	Thermal Assessment of Shippingport Pressurized Water Reactor Blanket Fuel Assemblies within a Multi-Canister Overpack within the Canister Storage Building				

16.

KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority				4	1	ER Cramer	ER Cramer	7/8/99	H0-34
		Design Agent						GD Bouchey	(see attached page 2)		
1		Cog. Eng. FJ Heard			H0-34						
1		Cog. Mgr. JP Sloughter			H0-34						
1		QA MF Nicol	(see attached page 2)								
1		Safety LJ Garvin	(see attached page 2)								
		Env.									

18. <i>FJ Heard</i> FJ Heard Signature of EDT Originator Date 4/8/99	19. RL McCormack (see attached page 2) Authorized Representative for Receiving Organization Date	20. <i>JP Sloughter</i> JP Sloughter Design Authority/ Cognizant Manager Date 4-8-99	21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
---	---	--	---

ENGINEERING DATA TRANSMITTAL

Page 2 of 2

1. EDT

626227

EDT - 626227

2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) System Engineering/Site Integr		4. Related EDT No.:			
5. Proj./Prog./Dept./Div.: Site Wide SNF		6. Design Authority/Design Agent/Cog. Engr.: D.M. Johnson		7. Purchase Order No.:			
8. Originator Remarks: Draft Report For Review and Comments				9. Equip./Component No.:			
				10. System/Bldg./Facility: CSB			
				12. Major Assm. Dwg. No.:			
11. Receiver Remarks:		11A. Design Baseline Document? ☐ Yes ☒ No		13. Permit/Permit Application No.:			
				14. Required Response Date: April 7, 1999			
15. DATA TRANSMITTED				(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition
	HNF-4109		1X 0	Thermal Assessment of Shippingport Pressurized Water Reactor Blanket Fuel Assemblies within a Multi-Canister Overpack within the Canister Storage Building	S,Q	4	i
16. KEY							
Approval Designator (F)		Reason for Transmittal (G)			Disposition (H) & (I)		
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)		1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)			1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged		
17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)							
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
		Design Authority				4	4
		Design Agent					
		Cog. Eng.					
		Cog. Mgr.					
4	1	QA	M.F. Nicol	4/5/99	82-48		
4		Safety	L.J. Garvin	4/8/99	R3-26		
		Env.					
18. D.M. Johnson Signature of EDT Originator		19. R.L. McCormack Authorized Representative for Receiving Organization		20. R.L. McCormack Design Authority/Cognizant Manager		21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	

5

THERMAL ASSESSMENT OF SHIPPINGPORT PRESSURIZED WATER REACTOR BLANKET FUEL ASSEMBLIES WITHIN A MULTI-CANISTER OVERPACK WITHIN THE CANISTER STORAGE BUILDING

F. J. Heard

Numatec Hanford Corporation

Richland, WA 99352

U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 626227

UC: 2020

Org Code: 82600

Charge Code: 105667

B&R Code: EW3120072

Total Pages: ~~70~~ 99

KNJ

Key Words: thermal analysis, peak cladding surface temperature, blanket fuel assembly, shippingport, multi-canister overpack, canister storage building.

Abstract: A series of analyses were performed to assess the thermal performance characteristics of the Shippingport Pressurized Water Reactor Core 2 Blanket Fuel Assemblies as loaded within a Multi-Canister Overpack within the Canister Storage Building. A two-dimensional finite element was developed, with enough detail to model the individual fuel plates: including the fuel wafers, cladding, and flow channels.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Release Approval

Date

Karen A. Holand 4/9/99

Release Stamp

Approved For Public Release

HNF-4109, Rev. 0

**THERMAL ASSESSMENT OF SHIPPINGPORT
PRESSURIZED WATER REACTOR BLANKET FUEL
ASSEMBLIES WITHIN A MULTI-CANISTER OVERPACK
WITHIN THE CANISTER STORAGE BUILDING**

Prepared by:

F. J. Heard

Numatec Hanford Corporation

April 1999

ABSTRACT

A series of analyses were performed to assess the thermal performance characteristics of the Shippingport Pressurized Water Reactor (PWR) Core 2 Blanket Fuel Assemblies (BFA) as loaded within a Multi-Canister Overpack (MCO) within the Canister Storage Building (CSB). A two-dimensional finite element model was developed, with enough detail to model the individual fuel plates: including the fuel wafers, cladding, and flow channels. The goal of these analyses was to determine the peak cladding surface temperature for a range of decay heats and ambient temperatures. The analysis methods and modeling assumptions are discussed and the results of the analyses are presented.

TABLE OF CONTENTS

1.0 INTRODUCTION	1
1.1 Purpose and Objective	1
1.2 Background	1
1.3 Content	1
2.0 SUMMARY	2
3.0 CODE DESCRIPTION	4
4.0 MODEL DEVELOPMENT, ANALYSIS METHODOLOGY, AND ASSUMPTIONS	5
4.1 Description of Multi-canister Overpack, Canister Storage Building, and Blanket Fuel Assembly	5
4.1.1 Multi-Canister Overpack (MCO)	5
4.1.2 Canister Storage Building (CSB)	5
4.1.3 Blanket Fuel Assembly (BFA)	6
4.2 Model Development and Assumptions	6
4.2.1 Geometry	6
4.2.2 Material Properties	7
4.2.3 Heat Transfer	8
4.2.4 Decay Heat	10
4.2.5 Boundary Conditions	10
4.3 Analysis Methodology	10
5.0 RESULTS	23
5.1 Helium Backfill	23
5.2 Air Backfill	24
5.3 Comparison of Hand Calculations with Simulation Results	26
6.0 CONCLUSIONS AND RECOMMENDATIONS	40
7.0 REFERENCES	42
APPENDIX A	A-1

LIST OF TABLES

4-1	Non-Isotropic Thermal Conductivity Multipliers.....	12
4-2	Volumetric Heat Generation Rates for the Thermal Analysis of the Shippingport Blanket fuel Assemblies.....	13
4-3	Heat Transfer Coefficients for a Vertical Cylinder for Various Wall Temperatures Given Two Constant Ambient Conditions....	14
5-1	Peak Cladding Temperatures for the Shippingport Blanket Fuel Assemblies At Steady-State Conditions Within a Multi-Canister Overpack Within the Canister Storage Building.....	27
5-2	Comparison of Hand Calculations With Base Case Simulation Results for Helium and Dry Air Backfill (Decay Heat = 164.7 Watts, P/A = 1.00, T _{amb} = 140°F (333.2°K)).....	28

LIST OF FIGURES

4-1	Plan and Sections Views of a MCO Containing Four Shippingport Blanket Fuel Assemblies.....	15
4-2	Isometric View of Shippingport Blanket Fuel Assembly.....	16
4-3	Blanket Fuel Assembly Cluster Details.....	17
4-4	Blanket Fuel Plate.....	18
4-5	Outline of Major Components within Thermal Model.....	19
4-6	Detailed Outline of Blanket Fuel Assembly.....	20
4-7	Blanket Fuel Sub-Assembly Mesh Without Fuel Wafers.....	21
4-8	Blanket Fuel Sub-Assembly Mesh for Fuel Wafers Only.....	22
5-1	Temperature Contour Plot for Helium Backfill – Maximum Conditions (Decay Heat = 164.7 Watts, $P/A = 1.55$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K)).....	29
5-2	Temperature Contour Plot for Helium Backfill – Minimum Conditions (Decay Heat = 93.39 Watts, $P/A = 1.55$, $T_{amb} = 110^{\circ}\text{F}$ (316.5°K)).....	30
5-3	Temperature Contour Plot for Helium Backfill – Base Case Conditions (Decay Heat = 164.7 Watts, $P/A = 1.00$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K)).....	31
5-4	Temperature Contour Plot for Helium Backfill – Base Case Conditions Near Center of MCO (Decay Heat = 164.7 Watts, $P/A = 1.00$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K)).....	32
5-5	Coordinate Direction for Line Plots.....	33
5-6	Temperature versus Horizontal Distance for Helium Backfill Base Case BFA Thermal Model – Including Peak Temperature (Decay Heat = 164.7 Watts, $P/A = 1.00$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K)).....	34
5-7	Temperature versus Vertical Distance for Helium Backfill Base Case BFA Thermal Model – Including Peak Temperature (Decay Heat = 164.7 Watts, $P/A = 1.00$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K)).....	35

5-8	Temperature Contour Plot for Dry Air Backfill – Maximum Conditions (Decay Heat = 164.7 Watts, P/A = 1.55, T _{amb} = 140°F (333.2°K)).....	36
5-9	Temperature Contour Plot for Dry Air Backfill – Minimum Conditions (Decay Heat = 93.39 Watts, P/A = 1.55, T _{amb} = 110°F (316.5°K)).....	37
5-10	Temperature Contour Plot for Dry Air Backfill – Base Case Conditions (Decay Heat = 164.7 Watts, P/A = 1.00, T _{amb} = 140°F (333.2°K)).....	38
5-11	Temperature Contour Plot for Dry Air Backfill – Base Case Conditions Near Center of MCO (Decay Heat = 164.7 Watts, P/A = 1.00, T _{amb} = 140°F (333.2°K)).....	39

Nomenclature (SI and English Units)

Quantity	SI	English
Length (L)	meter (m)	Inches (in.) or feet (ft)
Time (t)	second (s)	Second (s) or hour (hr)
Mass (m)	Kilogram (Kg)	Pound (lbm)
Temperature (T)	Kelvin ($^{\circ}\text{K}$)	Fahrenheit ($^{\circ}\text{F}$) or Rankin ($^{\circ}\text{R}$)
Force (F)	Newton (N)	Pound (lbf)
Energy	Joule (J) or (N-m)	Btu
Gravitational Acceleration (g)	9.8066 m/s^2	32.1739 ft/s^2
Density (ρ)	Kg/m^3	lbm/ft^3
Velocity (v)	m/s	ft/s
Pressure (P)	Pascal (N/m^2)	lbf/in^2
Dynamic Viscosity (μ)	Pascal-s (Kg/m-s)	lbm/ft-s
Kinematic Viscosity (ν)	m^2/s	ft^2/s
Specific Heat (C_p)	$\text{J/Kg-}^{\circ}\text{K}$	$\text{Btu/lbm-}^{\circ}\text{F}$
Power (Q)	Watt (W) or (J/s)	Btu/hr
Heat Flux	$\text{J/m}^2\text{-s}$	$\text{Btu/ft}^2\text{-hr}$
Volumetric Heat Source	$\text{J/m}^3\text{-s}$	$\text{Btu/ft}^3\text{-hr}$
Heat Transfer Coefficient (h_c)	$\text{J/m}^2\text{-s-}^{\circ}\text{K}$	$\text{Btu/ft}^2\text{-hr-}^{\circ}\text{F}$
Thermal Conductivity (k)	$\text{J/m-s-}^{\circ}\text{K}$	$\text{Btu/ft-hr-}^{\circ}\text{F}$
Thermal Diffusivity (α)	m^2/s	ft^2/s
Mass Diffusivity	m^2/s	ft^2/s
Volume Expansion Coefficient (β)	$1/^{\circ}\text{K}$	$1/^{\circ}\text{R}$
Surface Reaction Rate (mass units)	$\text{Kg/m}^2\text{-s}$	$\text{lbm/ft}^2\text{-s}$
Volumetric Reaction Rate (mass units)	$\text{Kg/m}^3\text{-s}$	$\text{lbm/ft}^3\text{-s}$
Heat of Reaction (mass units)	J/Kg	Btu/lbm
Gravitational Constant (g_c)	1 Kg-m/N-s^2	$32.174 \text{ lbm-ft/lbf-s}^2$
Stefan-Boltzman Constant (σ)	$5.6697\text{E-}8 \text{ J/s-m}^2\text{-}^{\circ}\text{K}^4$	$1.714\text{E-}9 \text{ Btu/hr-ft}^2\text{-}^{\circ}\text{R}^4$
Universal Gas Constant (R_u)	$8314.34 \text{ J/Kgmole-}^{\circ}\text{K}$	$1545 \text{ ft-lbm/lbm-mole-}^{\circ}\text{F}$

1.0 INTRODUCTION

1.1 Purpose and Objective

The purpose of this report is to document the results of a series of analyses that were performed to assess the thermal performance of the Shippingport Pressurized Water Reactor (PWR) Core 2 Blanket Fuel Assemblies (BFA) within Multi-Canister Overpacks (MCOs) within the Canister Storage Building (CSB). Specifically, the goal of these analyses was to determine the peak cladding surface temperature for a range of decay heats and ambient temperatures. The results of these analyses are expected to provide general guidance on the acceptability of using a MCO and the CSB to store the subject blanket fuel assemblies.

The primary objectives of this analysis effort were: 1) develop the necessary thermal models with enough detail to allow the individual fuel plates and, hence, cladding thickness to be modeled, and 2) support the definitive design recommendations for the long term storage of the Shippingport blanket fuel assemblies within the CSB.

1.2 Background

Seventy-two Shippingport PWR Core 2 spent BFAs are currently stored within the T-Plant at the Hanford site. A recommendation (Carlson 1996) has been made to transfer the BFAs from the T Plant to the CSB for vault storage. It is expected that nine CSB storage tubes will be required: given four BFAs per MCO and two MCOs per CSB storage tube.

The Blanket Fuel Assemblies were irradiated at the Shippingport pressurized water reactor located near Pittsburgh, Pennsylvania in the late 1960's through early 1970's. The decay heat of the individual assemblies has decreased significantly during the past 25 to 30 years.

1.3 Content

Section 2.0 provides a brief summary of the analysis results and conclusions. Section 3.0 discusses the computer program that was used to perform the analyses. Section 4.0 discusses the model development and assumptions that were made for the analyses. Section 5.0 presents the result of the analyses. Section 6.0 summarizes the results and conclusions. Section 7.0 provides the references.

2.0 SUMMARY

Given one-fourth symmetry, a two-dimensional finite-element thermal model was developed of a MCO containing four Shippingport Blanket Fuel Assemblies within a storage tube at the CSB. The thermal model contained enough detail to model the individual fuel plates; including each of the individual fuel wafers, cladding, and flow channels. The thermal model also modeled the surrounding blanket fuel sub-assembly cans, MCO, and CSB storage tube.

The goal of the thermal analyses was to determine the peak cladding surface temperature for a range of decay heats and ambient vault conditions during nominal steady-state operations. The results of these analyses are expected to provide general guidance and support for the recommendation to transfer the spent Shippingport BFAs to the CSB.

The total assembly decay heat from a maximum exposure assembly was 164.70 Watts. Peak-to-average (P/A) axial multipliers of 1.00 and 1.55 were used to derive the corresponding volumetric heat generation rate for input to the thermal model. (The peak-to-average multiplier of 1.55 is based on a representative cosine shape for the axial power distribution.) The peak ambient air temperature within the CSB vault ranged from 110°F (316.48°K) to 140°F (333.15°K).

In each case, an energy balance was performed to confirm that the energy produced and removed from the energy model was in agreement with the values summarized in Table 4-2.

Seven conclusions are made and a single recommendation is offered in the last paragraph.

The conclusions are as follows:

- 1.) The maximum peak cladding temperature is 410.5°F (483.4°K), given maximum (X 1.55) decay heat, maximum CSB outlet temperature, and dry air (not helium) filled MCO and CSB storage tube.
- 2.) The corresponding maximum (X 1.55) peak cladding temperature for a helium filled MCO and CSB storage tube is 335.9°F (442.0°K).
- 3.) For minimum decay heat and CSB outlet temperature the peak cladding temperatures range from 197.9°F (365.3 °K) to 247.1°F (392.6°K) for a helium and dry air filled MCO and CSB storage tube, respectively.
- 4.) Most of the temperature rise occurs over the large gaps between the MCO and CSB storage tube and the MCO and blanket fuel assembly.
- 5.) Very little temperature rise occurs within the blanket fuel assembly.

- 6.) Very good agreement was obtained between the results of the numerical simulations and a series of hand calculations. The greatest difference occurred when trying to estimate the temperature rise across the wedge shaped gap between the perimeter of the BFA and the ID of the MCO. Based on the agreement between the results of the hand calculations and the numerical simulation, the BFA thermal model was properly developed. Since each case is identical except for input differences associated with the decay heat, backfill gas, and ambient temperature, the results presented in this report are considered reasonable and representative for the given assumptions and conditions.
- 7.) The two-dimensional Blanket Fuel Assembly thermal model is considered conservative. Some conservatism's are; no external radiation losses, no internal convective heat transport, and the simultaneous application of worst case conditions to a single storage tube. An additional conservatism, which continues to increase, is; the actual decay time after shutdown is greater than the 24 years assumed when deriving the total assembly decay heat.
- 8.) Uncertainties in the decay heat loads, geometry, and ambient storage vault conditions will affect peak cladding temperature. Because most of the temperature rise occurs over the various gaps, it is expected that the geometrical position of the blanket fuel assembly within the MCO will have the greatest affect on peak cladding temperatures.

The following recommendation is offered:

Given the dimension of the MCO, the blanket fuel assemblies can rotate and/or tilt axially during transportation and handling. It is recommended that the spacer basket be modified to add small (two or three inches) projecting brackets just beyond the edge of each blanket assembly. These small brackets will help position the blanket fuel assemblies within the MCO canister consistent with the thermal analyses.

3.0 CODE DESCRIPTION

The Fluid Dynamic Analysis Package (FIDAP)* computer program was used to perform the thermal analyses of the Shippingport Blanket Fuel Assemblies. FIDAP has been validated and verified for use at Hanford (Heard 1994) for the performance of quality affecting analyses.

FIDAP is a commercially available general purpose computer package that uses finite element methods (FEM) to simulate many classes of single or multi-phase compressible or incompressible flows, including heat transfer, and mass transport of chemical species (< 15) in both nonreacting and reacting flows. The simulation can be either steady-state or transient and can model flows in complex arbitrary geometries that are 2-D, axis-symmetric, or 3-D. Mixed coordinate, moving, and rotating systems are supported.

FIDAP can be thought of as a single environment for the simulation of thermal-hydraulic problems and can be viewed as an integrated set of components and program modules designed to perform all aspects of model generation, automatic meshing, or paving, problem setup including view factor calculations, solving the resulting matrix of simultaneous finite element forms of the equations for the conservation of momentum, mass, and energy, and post-processing (i.e., visualizing) the results. Users can complete control over each of the conservation equations. For example, only the energy equation would be activated for a thermal analysis. For a coupled thermal-hydraulic analysis, both the conservation of energy and momentum equations can be activated. For a thermal-hydraulic analysis with reacting flows the conservation of energy, momentum, and mass equations would be activated. The post-processing capabilities of FIDAP are considered one of the industries best.

FIDAP is currently active on a Silicon Graphics Power Indigo-2, with an R-10000 CPU, 256 Mb of main system memory, running under the IRIX 6.2 operating system with FORTRAN 77 Version 7.0. The IRIX 6.2 operating system uses a 64-bit single precision word length for real and integer values.

*FIDAP is a registered trademark of Fluid Dynamics, Inc., Evanston, Illinois.

4.0 MODEL DEVELOPMENT, ANALYSIS METHODOLOGY, AND ASSUMPTIONS

A single thermal model was developed for the analysis of the Shippingport PWR Core 2 Blanket Fuel Assemblies within a MCO within a CSB storage tube. The thermal model was detailed enough to model the individual fuel plates; including the individual fuel wafers, cladding and flow channels within the blanket assemblies.

4.1 Description of Multi-canister Overpack, Canister Storage Building, and Blanket Fuel Assembly

Figure 4-1 presents a plan and section view of a MCO containing four Shippingport blanket fuel assemblies. Figures 4-2 through 4-4 present dimensional details associated with the Blanket Fuel Assembly and its components.

4.1.1 Multi-Canister Overpack (MCO)

The MCO will contain spent nuclear fuel in a variety of forms ranging from the highly corroded K-basin spent fuel elements to nearly pristine but irradiated light water reactor fuel assemblies.

A MCO is essentially a large diameter pipe loaded with spent nuclear fuel and sealed at both ends. For the majority of the K-Basin fuel, the MCO is expected to be vacuum processed at the Cold Vacuum Drying Facility (CVDF) to remove water moisture and back-filled with helium. It is not known if the same vacuum drying process will be used or is even necessary for the Shippingport blanket fuel assemblies. The upper end plug is massive enough to act as a radiation shield for manual operations requiring personnel access. The MCO has an outer diameter of 23.985 inches (0.609219 m), a wall thickness of 0.5 inches (0.0127 m), and an inner diameter of 22.985 inches (0.583819 m). The MCO is fabricated from stainless steel 304. The MCO is described in Lorenz (1997) in much greater detail.

The inner diameter of the MCO is such that four Shippingport blanket fuel assemblies can be loaded. A spacer basket or cruciform insert will be used to subdivide the interior of the MCO into four quadrants; hence, one-fourth symmetry. Each quadrant will contain a blanket fuel assembly.

4.1.2 Canister Storage Building (CSB)

The Canister storage Building provides a dry environment for the storage of spent nuclear fuel away from the Columbia River. The Canister Storage Building contains three underground vaults and above ground operating and miscellaneous support areas.

A CSB storage tube has an outer diameter 28 inches and an inner diameter of 27 inches. A diametrical gap of approximately 1.5 inches will occur between the outer diameter of the MCO and inner diameter of the CSB storage tube. Vault number one contains 220

vertical storage tubes. Each of the CSB storage tubes can contain two MCOs stacked on top of each other for 440 MCOs. The CSB is designed for a decay heat load of approximately 192 kW.

The Canister Storage Building is designed to be cooled by natural circulation driven by the density difference between the vault inlet and outlet air. With a fully loaded CSB vault, the long-term concrete temperature will be maintained below 150°F (339.7°K). The maximum outlet air temperature is estimated to be approximately 140°F (333.2°K) given a maximum inlet temperature of 110°F (316.5°K).

4.1.3 Blanket Fuel Assembly (BFA)

Each blanket fuel assembly, as shown in Figure 4-3, consists of two sub-assemblies (half an assembly) separated by a small gap. Each half consists of 30 fuel plates, as shown in Figure 4-4, arranged within a rectangular can with 31 flow channels. Each fuel plate is 0.140 inches thick. Each fuel plate consists of high density (> 96% TD) natural uranium oxide fuel wafers 0.100 inches thick by approximately 0.250 inches wide clad on both sides with Zircaloy-4 0.020 inches thick. Each fuel plate contains 10 fuel wafers. The overall fueled length is 96.5625 inches (2.4527 m). The fuel plate cladding also contains transverse and longitudinal ribbing between each of the fuel wafers. The center or interior flow channels are 0.091 inches thick and the two end channels are 0.066 inches thick.

4.2 Model Development and Assumptions

Figures 4-5 through 4-8 illustrate the two-dimensional finite element model that was developed to perform the thermal analyses. Figures 4-5 through 4-8 was obtained using a screen print option within the FIDAP computer code.

The goal of these analyses was to determine the peak cladding surface temperature. The thermal model was developed with enough detail to identify each of the individual fuel wafers, cladding, and flow channels within each subassembly. This was necessary to resolve the energy transport within each subassembly, since the thermal resistance is significantly less along each fuel plate than across each flow channel.

4.2.1 Geometry

As discussed in section 4.1, the thermal model represents a single Shippingport blanket fuel assembly within a MCO within a CSB storage tube. The dimensions of the MCO and CSB storage tube are well known and can be modeled exactly. However, the location of the blanket fuel assembly within the MCO is not that precise. The blanket fuel assembly could be positioned tightly against the center insert resulting in maximum separation distance from the MCO. In addition, given the dimensions of the MCO, the blanket fuel assemblies can rotate and/or tilt axially during transportation and handling. It must be noted that the subject analyses did not treat the position of the blanket fuel

assembly within the MCO as a variable. Each different location for a blanket fuel assembly would require a new model with different meshing to accommodate the changes in the separation distances, as well as a recalculation of the radiation view factors between the various surfaces.

Figure 4-5 presents the major components that comprise the Shippingport BFA thermal model. The spacer basket is shown as the “L” shaped right angle item in the center of the model. The blanket fuel assembly is fixed 0.25 inches from the spacer basket. This thermally isolates the blanket fuel assembly from the spacer basket, which acts as a large fin conducting energy away from the interior of the MCO. The two sub-assembly cans surrounding the fuel plates are clearly shown. The small gap (0.0855 inches) between each subassembly is also shown. The outermost corner of the BFA is approximately 0.34 inches from the MCO inner diameter.

Figure 4-6 presents the details associated with the fuel plates within each sub-assembly. The 31 flow channels, 30 fuel plates, and 300 fuel wafers within each sub-assembly are clearly shown. The fuel plates are shown contacting the surrounding sub-assembly can.

Figure 4-7 presents the meshing associated with one BFA sub-assembly. The fuel wafer meshing is not shown in order to allow a better visualization of the meshing associated with the surrounding can, fuel plate cladding, and flow channels. The clad ribbing between each of the fuel wafers is clearly shown. Figure 4-8 presents the fuel wafer meshing. Visually the elements within Figure 4-7 and 4-8 may appear slightly distorted, but they are not. Figures 4-5 through 4-8 were obtained using a screen print option and reflect the resolution of the video monitor.

The interior of the blanket fuel assembly was modeled using 151 elements over 6.971 inches in the X directions and 65 elements over 3.25 inches in the Y direction. The 151 elements can be factored into 60 elements for the fuel wafers, 60 elements for the cladding faces, 2 elements for the end channels, and 29 elements for the internal flow channels. The resulting size of an element in the X direction is 0.046166 inches and does not accurately represent the true thickness of the individual flow channels, cladding and fuel wafers and required the use of non-isotropic thermal conductivity (see Section 4.2.2). The resulting size of an element in the Y direction is 0.050 inches and does allow an accurate representation of each fuel plate, clad ribbing, and the individual fuel wafers

4.2.2 Material Properties

Figures 4-7 and 4-8 show each fuel plate containing (4 X 65) elements, each fuel wafer containing (2 X 5) elements, and each flow channel containing (1 X 65) elements. However, the size (0.046166 inches) associated with each element in the X direction does not accurately represent the true thickness.

Since thermal resistance is proportional to a change in distance divided by the thermal conductivity of the material, a non-isotropic thermal conductivity can be derived for each

material and applied corresponding to the coordinate axes used for the model. For example, in a two-dimensional (XY) model, a different thermal conductivity can be applied in the X direction versus the Y direction.

FIDAP supports both isotropic and non-isotropic thermal conductivity properties. For an isotropic conductivity property set, the conductivity is a scalar value. This value may be a complicated function of temperature or species concentration, but when used in the conservation of energy equation, it is represented by a single number at a given point in the model. Non-isotropic thermal conductivity is input through tensor notation. A fully non-symmetric tensor is supported; if only the diagonal terms are non-zero, an orthotropic conductivity model results.

External to the blanket fuel assembly the thermal model used isotropic thermal conductivities for air, helium, Zircaloy-4 and uranium oxide.

Internal to the blanket fuel sub-assemblies, the thermal model used orthotropic (non-isotropic) thermal conductivities for air, helium, Zircaloy, and uranium oxide. The non-isotropic thermal conductivity's were applied only in the X direction for those materials associated with the flow channels, cladding, and fuel wafers. This was necessary to retain the correct thermal resistance corresponding to the actual dimensions of the component. Isotropic thermal conductivity's were applied in the Y direction.

Two separate non-isotropic thermal conductivity's were derived for air and helium based on the different widths of the end and interior flow channels. For example, for the end channels, the nominal thermal conductivity of helium in the X direction was multiplied by 0.6995 (i.e., 0.046166/0.066). Table 4-1 summarizes the multipliers used to obtain the non-isotropic thermal conductivity for application in the X direction only. The Y direction thermal conductivity's remain unchanged from the nominal values.

4.2.3 Heat Transfer

Heat transfer can take place by one or more modes: conduction, convection, and radiation. The BFA thermal model uses two modes: conduction and radiation internal to the CSB storage tube. Convective heat transfer internal to the CSB storage tube was not explicitly calculated. Convective heat transfer from the external surface of the CSB storage tube was approximated by the application of a heat transfer coefficient. (To explicitly calculate the convective flow fields within the MCO or between the MCO and CSB would have required the development of an axi-symmetric or three-dimensional (3D) thermal-hydraulic model.)

4.2.3.1 Internal

The BFA thermal model assumes the energy gain mechanism is nuclear decay heat. The decay heat is assumed to be deposited 100% within the fuel wafers. Heat is transferred radially (two-dimensionally, X and Y) by conduction or radiation from the interior of the blanket fuel assembly to the exterior surface of the CSB storage tube. For symmetry

reasons, the X- and Y-axes are modeled as adiabatic surfaces. Axial heat transfer is not modeled. However, a unit depth of one meter is assumed for the purposes of calculating the heat transfer surface areas and volumetric dependent terms such as the heat generation rate.

Heat transfer by conduction depends on the thermal conductivity of the material, surface area, and the temperature gradient across the material. Heat transfer by radiation involves a different physical mechanism based on the propagation of electromagnetic energy. Radiation depends on other parameters, such as the emissivity of the various surfaces, the geometrical relationship or view factors between the two surfaces, and the difference between the surface temperatures raised to the fourth power.

FIDAP can compute the radiation view factors between the various surfaces based on user input. However, the calculation can be very time consuming. The resulting radiation network couples every node on a given radiation surface to every other node on adjacent radiation surfaces and so forth. This quickly leads to a significant increase in computational time. Each time the geometry is changed, the view factors have to be recalculated.

Radiation view factors are typically calculated only once and supplied to each case via a separate input file.

4.2.3.2 External

The BFA thermal model assumes the only energy loss mechanism is convective heat transfer from the external surface of the CSB storage tube. Energy is removed from the BFA thermal model by the application of convective heat transfer coefficient to the external surface of the CSB storage tube and the specification of the environmental ambient temperature.

Radiation loss from the external surface of the storage tube was not modeled. The BFA thermal model assumes that the storage tube is positioned within an array of storage tubes, such that the net energy loss from radiation is zero.

The convective heat transfer coefficients applied to the external surface of the storage tube were derived from known correlation's for vertical cylinders, per Table 7-1 and Equations 7-28 and 7-29 on page 343 of HOLMAN 1990. The convective heat transfer coefficients are derived from correlation's dependent on air properties, the calculated wall temperature, known geometrical characteristics, and a fixed ambient temperature.

Table 4-3 presents the natural circulation (free convection) heat transfer coefficients that were derived for vertical cylinders at a constant wall temperature for two ambient temperatures, 110°F (316.5°K) and 140°F (333.2°K). For a vertical cylinder, the characteristic length was assumed equal to the heated fuel length of 96.5626 inches (2.4527 m). As shown in Table 4-3, when the wall temperature is equal to the ambient air temperature no heat transfer occurs and the heat transfer coefficient is zero. Energy

would be added to the MCO if the wall temperature were less than the ambient air temperature. For energy to be removed from the MCO, the wall temperature must be greater than the ambient temperature.

4.2.4 Decay Heat

Table 4-2 summarizes the average volumetric heat generation rates ($\text{J}/\text{m}^3\text{-s}$) that were used for the thermal analyses. The average volumetric heat generation rates ($\text{J}/\text{m}^3\text{-s}$) were derived by dividing the blanket fuel assembly decay heat (Watts or J/s) by the fuel wafer volume (m^3). The fuel volume was derived using the dimensions shown in Figures 4-1 through 4-4. The blanket fuel assembly decay heat was obtained from Wittekind (1997) and Wittekind (1998).

Commercial pressurized light water reactors have a cosine shaped axial power distribution. Typical design values for a peak-to-average (P/A) axial power ratio range from 1.435 to 1.55. The use of volumetric heat generation rates based on an average or flat decay heat distribution would underestimate peak temperatures. Table 4-2 also presents the volumetric heat generation rates for a peak-to-average axial multiplier of 1.55.

It is conservative to assume a peak-to-average axial decay heat multiplier of 1.55 and a two-dimensional model with no axial heat transfer.

4.2.5 Boundary Conditions

The ambient environmental temperatures, 110°F (316.5°K) and 140°F (333.2°K), represent the boundary conditions applied to the external surface of the storage tube via a heat transfer coefficient. The minimum temperature cannot be less than the boundary condition.

Adiabatic boundary conditions were applied to the centerline of the spacer basket along the X- and Y-axes. Energy transfer is allowed parallel to the X- and Y-axes, but not across.

4.3 Analysis Methodology

Initially, two base case inputs were developed and debugged. These two cases were based on the maximum decay heat power, a peak-to-average axial decay heat multiplier of 1.00, ambient environmental temperature of 140 °F, and two different backfill gases; helium and air. The radiation view factors were calculated and supplied to each file through a separate input file. Appendix A presents the input for the maximum decay heat air filled case.

The input for the remaining sixteen cases were developed from the two base cases by simply changing the input values for the title cards, decay heat, peak-to-average axial multiplier, and the ambient environmental temperature.

A computer runscript was developed that automatically ran each of the remaining cases. Each case took approximately four hours to converge. Each individual case was postprocessed to obtain the results presented in Section 5.0.

Table 4-1.

Non-Isotropic Thermal Conductivity Multipliers

<u>Component</u>	<u>Multiplier</u>	<u>Material</u>
Flow Channel – End	0.6995	Air and helium
Flow Channel – Interior	0.5073	Air and helium
Clad	1.3190	Zircaloy-4
Fuel Wafer	0.9233	Uranium Oxide

Table 4-2.

Volumetric Heat Generation Rate ($\text{W}/\text{m}^3\text{-s}$) for Shippingport Blanket Fuel Assembly

Total Assembly Decay Heat (W)	P/A	Volumetric Heat Generation Rate ($\text{J}/\text{m}^3\text{-s}$)	Assembly Decay Heat (W) for a Unit Depth of 1.0m
93.39	1.00	4261.39	38.07
	1.55	6605.16	59.02
99.69	1.00	4548.86	40.65
	1.55	7050.73	63.00
151.70	1.00	6922.08	61.85
	1.55	10729.22	95.87
164.70	1.00	7515.27	67.15
	1.55	11648.67	104.08

Table 4-3

Heat Transfer Coefficients for a Vertical Cylinder for
Various Wall Temperatures Given Two Ambient Conditions

		Heat Transfer Coefficient ($W/m^2 \cdot ^\circ K$)	
$T_{wall}, ^\circ F(^{\circ}K)$		$T_{amb}=110^\circ F(316.5^\circ K)$	$T_{amb}=140^\circ F(333.2^\circ K)$
32.0	(273.15)	4.469	4.869
49.7	(283.0)	4.042	4.513
68.0	(293.15)	3.542	4.145
80.6	(300.15)	3.117	3.862
98.3	(310.0)	2.256	3.393
107.3	(315.0)	1.372	3.113
111.8	(317.5)	1.209	2.955
116.3	(320.0)	1.825	2.781
125.3	(325.0)	2.435	2.359
134.3	(330.0)	2.826	1.709
137.9	(332.0)	2.953	1.219
143.3	(335.0)	3.123	1.424
152.3	(340.0)	3.365	2.191
170.3	(350.0)	3.747	2.926
188.3	(360.0)	4.044	3.379
206.3	(370.0)	4.285	3.712
224.3	(380.0)	4.485	3.974
242.3	(390.0)	4.655	4.188
260.3	(400.0)	4.800	4.367
278.3	(410.0)	4.924	4.535
296.3	(420.0)	5.038	4.683
314.3	(430.0)	5.150	4.813
332.3	(440.0)	5.251	4.929
350.3	(450.0)	5.341	5.031
395.3	(475.0)	5.526	5.240
440.3	(500.0)	5.662	5.393
530.3	(550.0)	5.868	5.654
620.3	(600.0)	6.022	5.821

Figure 4-1.

Plan and Section View of a MCO Containing
Four Shippingport Blanket Fuel Assemblies

Figure 4-2.

Isometric View of Shippingport Blanket Fuel Assembly

PWR CORE II BLANKET FUEL ASSEMBLY

Figure 4-3.

Blanket Fuel Assembly Cluster Details

Figure 4-4.

Blanket Fuel Plate

Figure 4-5.

Outline of Major Components Within Thermal Model

Figure 4-6.

Detailed Outline of Blanket Fuel Assembly

Figure 4-7.

Blanket Fuel Sub-Assembly Mesh Within Fuel Wafers

Figure 4-8.

Blanket Fuel Sub-Assembly Mesh for Fuel Wafers Only

5.0 RESULTS

The results of the steady-state thermal analyses for the Shippingport Blanket Fuel Assemblies are presented in the following sections. The results have been separated into two sections depending on the backfill gas that was used: helium or air. Section 5.1 presents the results for helium. Section 5.2 presents the results for air. The emphasis in the following sections is on peak temperatures. This assumes that the peak fuel temperature resulting from each analysis is representative of the peak cladding surface temperature. This is supported by a close inspection of the results, which shows that the peak fuel temperature is within a few tenths of a degree of the peak cladding surface temperature. This is due to the high thermal conductivity of the Zircaloy-4 cladding and the thin fuel wafers.

The analyses were performed using a quarter-symmetric two-dimensional finite element model of a single Shippingport BFA within a Multi-Canister Overpack (MCO) within a Canister Storage Building (CSB) storage tube.

The total assembly decay heat ranged from 93.39 to 164.70 Watts. Peak-to-average (P/A) axial multipliers of 1.00 and 1.55 were used to derive the corresponding volumetric heat generation rate for input to the thermal model. The peak ambient air temperature within the CSB ranged from 110°F (316.48°K) to 140°F (333.15°K).

In each case, an energy balance was performed to confirm that the energy produced and removed from the energy model was in agreement with the values used to calculate the heat transfer coefficients.

5.1 Helium Backfill

Table 5-1 presents the results of the steady-state thermal analyses that were performed for the Shippingport Blanket Fuel Assemblies (BFA) with helium as the backfill gas. Helium was assumed internal to the MCO and within the gap between the MCO and CSB storage tube.

Figure 5-1 presents a contour plot of the maximum steady-state temperature distribution for the worst case conditions: maximum decay heat of 164.7 watts per assembly, a P/A multiplier of 1.55, and a maximum peak ambient temperature of 140 F. The maximum peak cladding temperature was determined to be 335.9°F (442.0°K). Figure 5-1 was derived based on subdividing the range of the results from the minimum to maximum temperature into twenty divisions. The contours represent the midpoints within each temperature division. Note that the spacer basket acts like a large fin removing energy from the center of the MCO.

Figure 5-2 presents a contour plot of the steady-state temperature distribution for the minimum worst case conditions: decay heat of 93.39 watts per assembly, a P/A multiplier of 1.00, and an ambient temperature of 110°F (316.5°K). The minimum peak cladding temperature was determined to be 197.9°F (365.3°K).

With reference to Figures 4-5 and 4-6, Figures 5-1 and 5-2 indicate that the temperature gradient of across the blanket fuel assembly is relatively flat. The largest temperature gradients occur across the gaps between the MCO and CSB storage tube and between the BFA and MCO.

Figure 5-3 presents a contour plot of the steady-state temperature conditions associated with the base case conditions for helium. Figure 5-3 does not represent the worst case conditions, but indicates that the same type of temperature distribution exists as in Figures 5-1 and 5-2. Only the magnitude of the peak temperature differs. Figure 5-4 presents a contour temperature plot of the area near the center of the BFA thermal model. Figure 5-4 is actually an enlargement of Figure 5-3, but is based on the temperature distribution within the enlarged area. The two halves of the BFA are discernable along with the small gap between them. The affects of the spacer basket are also shown along each axis. The spacer basket acts like a large fin removing energy from the center of the MCO. The temperature distribution across the BFA actually shows a slight decrease for those areas nearest the spacer basket.

Figure 5-5 presents the concept of a line plot running through the point of peak temperature. Figures 5-6 and 5-7 present temperature versus distance for a line running through the peak temperature and parallel to the X- and Y- axis, respectively. Figures 5-6 and 5-7 allow a more detailed inspection of the radial temperature distribution through the blanket fuel assembly to the CSB storage tube.

Figure 5-6 presents the temperature distribution in the X direction running through the point of peak temperature. The peak temperature shown in Figure 5-6 agrees with Table 5-1. The small temperature gradient within the BFA is shown, as well as the steeper gradients associated with the helium gaps. Very little temperature drops occurs across the MCO and canister storage tube, because of the high thermal conductivity of stainless and mild carbon steels. Near the origin, the temperature decreases slightly. This is due to the spacer basket acting as a conduction fin.

Figure 5-7 presents a similar temperature distribution in the Y direction running through the point of peak temperature. Again, the peak temperature shown in Figure 5-7 agrees with Table 5-1. Figure 5-7 shows a small temperature change between the two halves of the blanket fuel assembly. This is due to the small gap between the two halves. Near the origin, the temperature decreases slightly. This is due to the spacer basket acting as a conduction fin.

5.2 Air Backfill

Table 5-1 presents the results of the steady-state thermal analyses that were performed for the Shippingport Blanket Fuel Assemblies (BFA) with dry air as the backfill gas. Dry air was assumed internal to the MCO and within the gap between the MCO and CSB storage tube.

Figure 5-8 presents a contour plot of the steady-state temperature distribution for the maximum worst case conditions: decay heat of 164.7 watts per assembly, a P/A multiplier of 1.55, and an ambient temperature of 333.2°K (140°F). The maximum peak cladding temperature was determined to be 410.5°F (483.4°K). Figure 5-8 was derived based on subdividing the range of the results from the minimum to maximum temperature into twenty divisions. The contours represent the midpoints within each temperature division. Note that the spacer basket acts like a large fin removing energy from the center of the MCO.

Figure 5-9 presents a contour plot of the steady-state temperature distribution for the minimum worst case conditions: decay heat of 93.39 watts per assembly, a P/A multiplier of 1.00, and an ambient temperature of 316.5°K (110°F). The minimum peak cladding temperature was determined to be 247.1°F (392.6°K).

With reference to Figures 4-5 and 4-6, Figures 5-8 and 5-9 indicate that the temperature gradient of across the blanket fuel assembly is relatively flat. The largest temperature gradients occur across the gap between the MCO and CSB storage tube and between the BFA and MCO.

A comparison of Figures 5-8 and 5-9 with Figures 5-1 and 5-2 show the same minimum temperature, but steeper temperature gradients. This is expected given the reduced thermal conductivity of dry air relative to helium. Helium reduces the peak cladding temperature by a maximum of approximately 75°F (41.4°K) for the worst case conditions presented within Table 5-1.

Figure 5-10 presents a contour plot of the steady-state temperature conditions associated with the base case conditions for air. Figure 5-10 does not represent the worst case conditions, but indicates that the same type of temperature distribution exists as in Figures 5-8 and 5-9. Only the magnitude of the peak temperature differs.

Figure 5-11 presents a contour temperature plot of the area near the center of the BFA thermal model. Figure 5-11 is actually an enlargement of Figure 5-10, but is based on the temperature distribution within the enlarged area. The two halves of the BFA are discernable along with the small gap between them. The affects of the spacer basket are also shown along each axis. The temperature distribution across the BFA actually shows a slight decrease for those areas nearest the spacer basket. The spacer basket acts like a large fin removing energy from the center of the MCO.

Figure 5-6 and 5-7 are representative of the temperature distributions expected for the air filled cases. The peak temperature will be higher for an air filled MCO and CSB storage tube and the temperature gradients will be steeper across the air gaps, but the general overall shape will be similar to the helium cases, as discussed in Section 5.1.

5.3 Comparison of Hand Calculations with Simulation Results

A series of iterative hand calculations were performed to check the results presented in Sections 5.1 and 5.2 for the base cases associated with helium and air. Table 5-2 summarizes the comparison between the results of the numerical simulation and hand calculations.

The hand calculations were performed assuming a blanket fuel assembly decay heat of 164.7 watts, a peak-to-average decay heat value of 1.00, and an ambient temperature of 140°F (333.2°K). Different backfill gases were used: helium and dry air. The classical forms of Fourier's Law of Heat Transfer for cylindrical and slab geometry were used to estimate the temperature rise across each component. Some iteration was necessary to determine the surface temperature when accounting for thermal radiation across a helium or dry air filled gap.

Very good agreement is shown. The maximum difference of 17.1°F (9.5°K) was noted for the outer wall of the blanket fuel assembly. This difference is a result of trying to estimate the temperature rise across the wedge shaped gap between the perimeter of the BFA and the ID of the MCO. The hand calculations were performed based on an average gap of 2.74 inches: whereas, the numerical thermal model accounted for the variable width.

Based on the agreement between the results of the hand calculations and the numerical simulation, the BFA thermal model was properly developed. Therefore, since each case is identical except for input differences associated with the decay heat, backfill, and ambient temperature, the results presented in Table 5-1 are considered reasonable and accurate for the given assumptions and conditions.

Table 5-1.

**Peak Cladding Temperatures for the Shippingport Blanket Fuel
Assemblies At Steady-State Conditions Within A
Multi-Canister Overpack Within the Canister Storage Building**

			Peak Cladding Temperature, °F (°K) for Various Back Fill Gases			
Blanket Fuel Assembly Decay Heat (watts)	Axial P/A	Ambient CSB Vault Air Temperature, °F (°K)	Helium		Air	
93.39	1.00	110 (316.5)	197.9	(365.3)*	247.1	(392.6)
	1.55	140 (333.2)	264.1	(402.1)	320.9	(433.7)
99.69	1.00	110 (316.5)	202.9	(368.1)	254.1	(396.5)
	1.55	140 (333.2)	270.9	(405.9)	329.8	(438.6)
151.70	1.00	110 (316.5)	241.7	(389.6)	306.8	(425.8)
	1.55	140 (333.2)	323.6	(435.2)	395.8	(475.3)
164.70	1.00	110 (316.5)	250.8	(394.7)	318.5	(432.3)
	1.00	140 (333.2)	277.9	(409.8)	338.7	(443.6)
	1.55	140 (333.2)	335.9	(442.0)	410.5	(483.4)**

* Maximum Peak Cladding Temperature (Helium)

** Maximum Peak Cladding Temperature (Air)

Table 5-2.

Comparison of Hand Calculations with Base Case Simulation
 Results for Helium and Dry Air Backfill
 (Decay Heat = 164.7 Watts, P/A = 1.00, T_{amb} = 140°F (333.2°K))

Component	Helium		Dry Air	
	Hand Calc., °F(°K)	FIDAP, °F(°K)	Hand Calc., °F(°K)	FIDAP, °F(°K)
OD-Storage Tube	200.0 (366.5)	200.0 (366.5)	200.0 (366.5)	200.0 (366.5)
ID-Storage Tube	200.2 (366.6)	200.4 (366.7)	200.2 (366.6)	200.4 (366.7)
OD-MCO	234.6 (385.7)	235.0 (385.9)	272.0 (406.5)	270.6 (405.7)
ID-MCO	235.1 (386.0)	235.5 (386.2)	272.2 (406.6)	271.0 (405.9)
OD-Blanket Assy.	285.5 (414.0)*	268.4 (404.5)*	326.6 (436.8)	336.7 (442.4)
Peak	290.6 (416.8)	278.0 (409.8)	338.8 (443.6)	341.7 (445.2)

* Maximum Difference of 17.1°F (9.5°K)

Figure 5-1.

Temperature Contour Plot for Helium Backfill - Maximum Conditions
 (Decay Heat = 164.7 Watts, $P/A = 1.55$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

SHIPPINGPORT BFA - TAMB140F HE/HE DKHT 164.7 x 1.55

TEMPERATURE
CONTOUR PLOT

LEGEND

A - 0.3814E+03
 B - 0.3845E+03
 C - 0.3876E+03
 D - 0.3908E+03
 E - 0.3939E+03
 F - 0.3970E+03
 G - 0.4001E+03
 H - 0.4032E+03
 I - 0.4063E+03
 J - 0.4094E+03
 K - 0.4125E+03
 L - 0.4156E+03
 M - 0.4187E+03
 N - 0.4218E+03
 O - 0.4249E+03
 P - 0.4280E+03
 Q - 0.4311E+03
 R - 0.4342E+03
 S - 0.4373E+03
 T - 0.4404E+03

MINIMUM

0.37989E+03

MAXIMUM

0.44197E+03

SCREEN LIMITS

XMIN - .237E-01

XMAX 0.379E+00

YMIN - .893E-03

YMAX 0.356E+00

FIDAP 7.62

17 Feb 99

11:59:35

Figure 5-2.

Temperature Contour Plot for Helium Backfill - Minimum Conditions
 (Decay Heat = 93.39 Watts, P/A = 1.00, $T_{amb} = 110^{\circ}\text{F}$ (316.5°K))

Figure 5-3.

Temperature Contour Plot for Helium Backfill Base Case Conditions
(Decay Heat = 164.7 Watts, $P/A = 1.00$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

Figure 5-4.

Temperature Contour Plot for Helium Backfill
 Base Case Conditions Near Center of MCO
 (Decay Heat = 164.7 Watts, P/A = 1.00, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

Figure 5-5.

Coordinate Directions for Line Plots

Figure 5-6.

Temperature versus Horizontal Distance for Helium Backfill
 Base Case BFA Thermal Model - Including Peak Temperature
 (Decay Heat = 164.7 Watts, P/A = 1.00, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

Figure 5-7.

Temperature versus Vertical Distance for Helium Backfill
 Base Case BFA Thermal Model – Including Peak Temperature
 (Decay Heat = 164.7 Watts, P/A = 1.00, T_{amb} = 140°F (333.2°K))

Figure 5-8.

Temperature Contour Plot for Dry Air Backfill - Maximum Conditions
 (Decay Heat = 164.7 Watts, $P/A = 1.55$, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

Figure 5-9.

Temperature Contour Plot for Dry Air Backfill - Minimum Conditions
 (Decay Heat = 93.39 Watts, $P/A = 1.00$, $T_{amb} = 110^{\circ}\text{F}$ (316.5°K))

Figure 5-10.

Temperature Contour Plot for Dry Air Backfill
 Base Case Conditions
 (Decay Heat = 164.7 Watts, P/A = 1.00, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

Figure 5-11.

Temperature Contour Plot for Dry Air Backfill – Base Case Conditions Near Center of MCO
 (Decay Heat = 164.7 Watts, P/A = 1.00, $T_{amb} = 140^{\circ}\text{F}$ (333.2°K))

6.0 CONCLUSIONS AND RECOMMENDATIONS

Given one-fourth symmetry, a two-dimensional finite-element thermal model was developed of a MCO containing four Shippingport Blanket Fuel Assemblies (BFA) within a storage tube at the CSB. The thermal model contained enough detail to model the individual fuel plates; including each of the individual fuel wafers, cladding, and flow channels. The thermal model also modeled the surrounding blanket fuel sub-assembly cans, MCO, and CSB storage tube.

The goal of the thermal analyses was to determine the peak cladding temperature for a range of decay heats and ambient vault conditions during nominal steady-state operations. The results of these analyses are expected to provide general guidance and support for the recommendation to transfer the spent Shippingport BFAs to the CSB.

The total assembly decay heat from a maximum exposure assembly was 164.70 Watts. Peak-to-average (P/A) axial multipliers of 1.00 and 1.55 were used to derive the corresponding volumetric heat generation rate for input to the thermal model. (The peak-to-average multiplier of 1.55 is based on a representative cosine shape for the axial power distribution.) The peak ambient air temperature within the CSB vault ranged from 110°F (316.48°K) to 140°F (333.15°K).

In each case, an energy balance was performed to confirm that the energy produced and removed from the energy model was in agreement with the values summarized in Table 4-3.

Seven conclusions are made and a single recommendation is offered in the last paragraph.

The conclusions are as follows:

- 1.) The maximum peak cladding temperature is 410.5°F (483.4°K), given maximum (X 1.55) decay heat, maximum CSB outlet temperature, and dry air (not helium) as the backfill gas within the MCO and CSB storage tube.
- 2.) The corresponding maximum (X 1.55) peak cladding temperature for a helium backfill within the MCO and CSB storage tube is 335.9°F (442.0°K).
- 3.) For minimum decay heat and CSB outlet temperature the peak cladding temperatures range from 197.9°F (365.3°K) to 247.1°F (392.6°K) for a helium and dry air filled MCO and CSB storage tube, respectively.
- 4.) Most of the temperature rise occurs over the large gaps between the MCO and CSB storage tube and the MCO and blanket fuel assembly.
- 5.) Very little temperature rise occurs within the blanket fuel assembly.
- 6.) Very good agreement was obtained between the results of the numerical simulations and a series of hand calculations. The greatest difference occurred when trying to estimate the temperature rise across the wedge shaped gap between the perimeter of the BFA and

the ID of the MCO. Based on the agreement between the results of the hand calculations and the numerical simulation, the BFA thermal model was properly developed. Therefore, the results presented in Sections 5.1 and 5.2 are considered reasonable and representative of the expected temperatures for the given assumptions and conditions.

- 7.) The two-dimensional Blanket fuel Assembly thermal model is considered conservative. Some conservatism's are; no external radiation losses, no internal convective heat transport, and the simultaneous application of worst case conditions to a single storage tube. An additional conservatism, which continues to increase, is; the actual decay time after shutdown is greater than the 24 years assumed when deriving the total assembly decay heat.
- 8.) Uncertainties in the decay heat loads, geometry, and ambient storage vault conditions will affect peak cladding temperature. Because most of the temperature rise occurs over the various gaps, it is expected that the geometrical position of the blanket fuel assembly within the MCO will have the greatest affect on cladding temperatures

The following recommendation is offered:

Given the dimension of the MCO, the blanket fuel assemblies can rotate and/or tilt axially during transportation and handling. It is recommended that the spacer basket be modified to add small (two or three inches) projecting brackets just beyond the edge of each blanket assembly. These small brackets will help position the blanket fuel assemblies within the MCO canister consistent with the thermal analyses.

7.0 REFERENCES

- Carlson, A. B., "Evaluation of Other Spent Nuclear Fuel Management at the Canister Storage Building Complex," WHC-SD-SNF-TA-010, Westinghouse Hanford Company, Richland, Washington, dated November 1996.
- Heard, F. J., "FIDAP - Validation and Verification," WHC-SD-WM-ER-302, Rev. 1, Westinghouse Hanford Company, Richland, Washington, dated 1994.
- Holman, J. P., "Heat Transfer," Seventh Edition, McGraw-Hill, Inc., New York, New York, 1990.
- Lorenz, B. D., "Multi-Canister Overpack Topical Report," HNF-SD-SNF-SARR-005, Rev. 0, Duke Engineering and Services Hanford, Richland, Washington, dated March 26, 1997.
- Wittekind, W. D., "Shippingport Pressurized Water Reactor Core 2 Blanket Assemblies Source Term Calculations Using ORIGEN2," HNF-SD-SNF-TI-061, Rev. 0, Fluor Daniel Northwest, Inc., Richland, Washington, dated November 5, 1997.
- Wittekind, W. D. "Shippingport Pressurized Water Reactor Core 2 Blanket Assemblies in Multi-Canister Overpack Shielding Calculations Using MCNP," HNF-SD-SNF-TI-062, Rev. 0, Fluor Daniel Northwest, Inc., Richland, Washington, dated March 23, 1998.

Appendix A

Representative Input for BFA Thermal Model

```

TITLE
SHIPPINGPORT BFA - TAMB140F AIR/AIR DKHT 164.7 x 1.55
$tole=0.001
FI-GEN(ELEM=1,POIN=1,CURV=1,SURF=1,NODE=0,MEDG=1,MLOO=1,MFAC=1,
BEDG=1,SPAV=1,MSHE=1,MSOL=1,COOR=1,TOLE=$tole)
UTILITY(MESH,LIVE)
WINDOW(CHANGE= 1, MATRIX )
    1.000000    0.000000    0.000000    0.000000
    0.000000    1.000000    0.000000    0.000000
    0.000000    0.000000    1.000000    0.000000
    0.000000    0.000000    0.000000    1.000000
    -4.05375    15.54625    -0.35000    14.35000    -14.70000    14.70000
    45.000000    45.000000    45.000000    45.000000
/
/ 2D XY MODEL - QUARTER SYMMETRY
/ ZERO FLUX BOUNDARIES - X AND Y AXES
/ DECAY HEAT = 164.7 W
/ RATIO OF PEAK-TO-AVERAGE DECAY HEAT = 1.55
/ FILL GAS - INTERNAL MCO = AIR
/ FILL GAS - MCO_STUBE GAP = AIR
/ AMBIENT TEMPERATATURE = 140F = 60.00C = 333.15K
/ SEPARATE FLOW CHANNELS
/ SEPARATE CLAD + RIBBING
/ SEPARATE FUEL SEGMENTS
/ NONISOTROPIC THERMAL CONDUCTIVITY TO ACCOUNT FOR DELTA X VARIATIONS
/ "HE2X" - END CHANNELS          KMODEL = KACTUAL X 0.6995
/ "HE3X" - INTERIOR CHANNELS     KMODEL = KACTUAL X 0.5073
/ "AIR2X" - END CHANNELS         KMODEL = KACTUAL X 0.6995
/ "AIR3X" - INTERIOR CHANNELS    KMODEL = KACTUAL X 0.5073
/ "ZIRC2X" - CLADDING AND RIBBING KMODEL = KACTUAL X 1.3191
/ "UO2X" - FUEL                  KMODEL = KACTUAL X 0.9233
/
/ NODAL STRUCTURE
/ EDGE NODES=2
/ QUAD NODES=4
/
/ INPUT FILE = hnf4109.inp
/
/ METRIC UNITS USED - EXCEPT INPUT DIMENSIONS WHICH USE INCHES
/ INCHES CONVERTED TO METERS VIA FIPREP SCALE FACTOR
/
/ METERS, KILOGRAMS, SECONDS, AND KELVIN
/
/ BASIC GEOMETRY - CENTRAL CROSS
/          GAP1, GAP2, AND GAP3
/          BLANKET FUEL ASSEMBLY (FLOW+CLAD+FUEL)
/          INTER-ASSEMBLY GAP
/          BLANKET FUEL ASSEMBLY (FLOW+CLAD+FUEL)
/          INTERNAL MCO FLOW REGIONS
/          MCO WALL
/          GAP BETWEEN MCO AND ST (E=0.01)
/          STORAGE TUBE (ST) WALL
/
$DX=0.25
$DY=0.25
/
/ POINTS 1 - 19
/
POINT(ADD,SHOW,COOR,X=0.0,Y=0.0)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY+0.20)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY+0.20+0.25)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY+0.20+0.25+2.75)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY+0.20+0.25+2.75+0.25)
POINT(ADD,SHOW,COOR,X=0.0,Y=0.25+$DY+0.20+0.25+2.75+0.25+0.20)

```

```

POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855)
POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855+0.20)
POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855+0.20+0.25)
POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75)
POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75+0.25)
POINT(ADD, SHOW, COOR, X=0.0, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75+0.25+0.20)
POINT(ADD, SHOW, COOR, X=0.0, Y=11.3675)
POINT(ADD, SHOW, COOR, X=0.0, Y=11.4925)
POINT(ADD, SHOW, COOR, X=0.0, Y=11.9925)
POINT(ADD, SHOW, COOR, X=0.0, Y=13.5)
POINT(ADD, SHOW, COOR, X=0.0, Y=14.0)
/
/ POINTS 20 - 38
/
POINT(ADD, SHOW, COOR, X=0.25, Y=0.0)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+0.20)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+0.20+0.25)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+0.20+0.25+2.75)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+0.20+0.25+2.75+0.25)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+0.20+0.25+2.75+0.25+0.20)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855+0.20)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855+0.20+0.25)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75+0.25)
POINT(ADD, SHOW, COOR, X=0.25, Y=0.25+$DY+3.65+0.0855+0.20+0.25+2.75+0.25+0.20)
POINT(ADD, SHOW, COOR, X=0.25, Y=11.3675)
POINT(ADD, SHOW, COOR, X=0.25, Y=11.4897818)
POINT(ADD, SHOW, COOR, X=0.25, Y=11.98989505)
POINT(ADD, SHOW, COOR, X=0.25, Y=13.49768578)
POINT(ADD, SHOW, COOR, X=0.25, Y=13.99776839)
/
/ POINTS 39 - 42
/
POINT(ADD, SHOW, COOR, X=8.126424683, Y=8.126424683)
POINT(ADD, SHOW, COOR, X=8.479978073, Y=8.479978073)
POINT(ADD, SHOW, COOR, X=9.545941546, Y=9.545941546)
POINT(ADD, SHOW, COOR, X=9.899494937, Y=9.899494937)
/
/ POINTS 43 - 60
/
POINT(ADD, SHOW, COOR, X=0.25+$DX, Y=0.0)
POINT(ADD, SHOW, COOR, X=0.25+$DX, Y=0.25)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725, Y=0.0)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725, Y=0.25)
POINT(ADD, SHOW, COOR, X=11.3675, Y=0.0)
POINT(ADD, SHOW, COOR, X=11.3675, Y=0.25)
POINT(ADD, SHOW, COOR, X=11.4925, Y=0.0)
POINT(ADD, SHOW, COOR, X=11.4897818, Y=0.25)
POINT(ADD, SHOW, COOR, X=11.9925, Y=0.0)
POINT(ADD, SHOW, COOR, X=11.98989505, Y=0.25)
POINT(ADD, SHOW, COOR, X=13.5, Y=0.0)
POINT(ADD, SHOW, COOR, X=13.49768578, Y=0.25)
POINT(ADD, SHOW, COOR, X=14.0, Y=0.0)
POINT(ADD, SHOW, COOR, X=13.99776839, Y=0.25)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725+6.971, Y=0.0)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725+6.971, Y=0.25)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725+6.971+0.20725, Y=0.0)
POINT(ADD, SHOW, COOR, X=0.25+$DX+0.20725+6.971+0.20725, Y=0.25)
/
/ CONNECT DOT-TO-DOT (I.E. POINTS) TO FORM CURVES
/
/ CURVE #1
/

```

```
POINT (SELE, ID, WIND=1)
1
20
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
20
21
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
21
2
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
2
1
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #5
/
POINT (SELE, ID, WIND=1)
21
22
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
22
23
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
23
24
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
24
25
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
25
26
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #10
/
POINT (SELE, ID, WIND=1)
26
27
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
27
28
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
28
29
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
29
30
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
30
31
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #15
/
POINT (SELE, ID, WIND=1)
```



```

31
32
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
32
33
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
33
34
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
34
15
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
15
14
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #20
/
POINT (SELE, ID, WIND=1)
14
13
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
13
12
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
12
11
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
11
10
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
10
9
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #25
/
POINT (SELE, ID, WIND=1)
9
8
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
8
7
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
7
6
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
6
5
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
5
4
CURVE (ADD, SHOW, ARROW, ORDER=1)
/

```

```
/ CURVE #30
/
POINT (SELE, ID, WIND=1)
4
3
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
3
2
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
34
35
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
35
16
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
16
15
CURVE (ADD, SHOW, ARROW, ORDER=1)
/ .
/ CURVE #35
/
POINT (SELE, ID, WIND=1)
1
35
39
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
1
39
50
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
50
49
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
49
51
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
51
52
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #40
/
POINT (SELE, ID, WIND=1)
1
52
40
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
1
40
36
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
36
17
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
17
```

```

16
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
17
18
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #45
/
POINT (SELE, ID, WIND=1)
18
37
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
1
37
41
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
1
41
54
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
54
53
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
51
53
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #50
/
POINT (SELE, ID, WIND=1)
53
55
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
55
56
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
1
56
42
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
1
42
38
CURVE (ADD, ARC, SHOW, ARROW, CENT)
POINT (SELE, ID, WIND=1)
38
19
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #55
/
POINT (SELE, ID, WIND=1)
19
18
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
50
48

```

```

CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
48
47
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
47
49
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
20
43
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #60
/
POINT (SELE, ID, WIND=1)
21
44
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
59
47
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
60
48
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
43
45
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
44
46
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVE #65
/
POINT (SELE, ID, WIND=1)
45
57
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
46
58
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
57
59
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
58
60
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ SURFACE
/
CURVE (SELECT, ID, WIND=1)
1
59
63
65
67
61
58

```

```

38
49
50
51
52
53
54
55
44
43
34
19
20
21
22
23
24
25
26
27
28
29
30
31
4
SURFACE(ADD,WIRE,SHOW,EDG1=10,EDG2=2,EDG3=2,EDG4=18)
/
MACRO( name = "half")
/
/ argument 6 increments entity names for given fuel assembly numbers
/
$FA = 1
$FA = $ARG06
$ANUM = NTOS($FA)
/
/ The LASTID commands finds the last ID of any geometrical entity
/ All parameters correspond to those created by "id2copy"
/ DO NOT CHANGE THESE OR USE THESE PARAMETER NAMES FOR YOUR DEFINITIONS
/
$POI = LASTID(POINT_ID)
$CUR = LASTID(CURVE_ID)
$MED = LASTID(MEDGE_ID)
$SUR = LASTID(SURFACE_ID)
$MLO = LASTID(MLOOP_ID)
$MFA = LASTID(MFACE_ID)
$MSH = LASTID(MSHELL_ID)
$MSO = LASTID(MSOLID_ID)
$EGR = LASTID(EGROUP_ID)
$COR = LASTID(CORSYS_ID)
$BED = LASTID(BEDGE_ID)
/
/ argumets 1 - 5 enable each copy to have different location and
/ orientation. Argument 7 allows new system ids (2 thru 3) to be specified.
/
COORDINATE (ADD, CARTESIAN, GLOBALORIGIN, OLDSYSTEM = 1, SYSTEM = $ARG07)
$ARG01 $ARG02 $ARG03 $ARG04 $ARG05
COORDINATE ( SELE, ID = $ARG07 )
COORDINATE (ACTIVE)
/
/ insert your basic geometry that has been parameterized via id2copy
/
/ POINTS 61 - 64 and POINTS 85-88
/
POINT(ADD,SHOW,COORD,Y=0.0,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.0,X=0.20725)

```

```

POINT(ADD,SHOW,COORD,Y=0.0,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.0,X=0.20725+6.971+0.20725)
/
/ POINTS 65 - 68 and POINTS 89 - 92
/
POINT(ADD,SHOW,COORD,Y=0.20,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.20,X=0.20725)
POINT(ADD,SHOW,COORD,Y=0.20,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.20,X=0.20725+6.971+0.20725)
/
/ POINTS 69 - 72 and POINTS 93 - 96
/
POINT(ADD,SHOW,COORD,Y=0.20+0.25,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.20+0.25,X=0.20725)
POINT(ADD,SHOW,COORD,Y=0.20+0.25,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.20+0.25,X=0.20725+6.971+0.20725)
/
/ POINTS 73 - 76 and POINTS 97 - 100
/
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75,X=0.20725)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75,X=0.20725+6.971+0.20725)
/
/ POINTS 77 - 80 and POINTS 101 - 104
/
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25,X=0.20725)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25,X=0.20725+6.971+0.20725)
/
/ POINTS 81 - 84 and POINTS 105 - 108
/
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25+0.20,X=0.0)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25+0.20,X=0.20725)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25+0.20,X=0.20725+6.971)
POINT(ADD,SHOW,COORD,Y=0.20+0.25+2.75+0.25+0.20,X=0.20725+6.971+0.20725)
/
/ CURVES
/
POINT(SELECT,ID,WINDOW=1)
($POI + 1)
($POI + 2)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 2)
($POI + 3)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 3)
($POI + 4)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 4)
($POI + 8)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 8)
($POI + 12)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 12)
($POI + 16)
CURVE(ADD,SHOW,ARROW,ORDER=1)
POINT(SELECT,ID,WINDOW=1)
($POI + 16)

```

```

($POI + 20)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 20)
($POI + 24)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 24)
($POI + 23)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 23)
($POI + 22)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 22)
($POI + 21)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 21)
($POI + 17)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 17)
($POI + 13)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 13)
($POI + 9)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 9)
($POI + 5)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 5)
($POI + 1)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 6)
($POI + 7)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 7)
($POI + 11)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 11)
($POI + 15)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 15)
($POI + 19)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 19)
($POI + 18)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 18)
($POI + 14)
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELECT, ID, WINDOW=1)
($POI + 14)
($POI + 10)
CURVE(ADD, SHOW, ARROW, ORDER=1)

```

```

POINT(SELECT, ID, WINDOW=1)
($POI + 10)
($POI + 6)
CURVE(ADD, SHOW, ARROW, ORDER=1)
/
COORDINATE ( SELE, ID = 1 )
COORDINATE ( ACTIVE )
ENDMACRO
/
$xloc= 0.25 + $DX
$yloc= 0.25 + $DY
$zloc= 0
$axis= 3
$angl= 0.0
$sysid = 2
MACRO( EXECUTE = "half", ARG01 = $xloc, ARG02 = $yloc , ARG03 = $zloc ,
      ARG04 = $axis, ARG05 = $angl, ARG06 = 1, ARG07 = $sysid)
/
$xloc= 0.25 + $DX
$yloc= 0.25 + $DY + 3.65 + 0.0855
$zloc= 0
$axis= 3
$angl= 0.0
$sysid = 3
MACRO( EXECUTE = "half", ARG01 = $xloc, ARG02 = $yloc , ARG03 = $zloc ,
      ARG04 = $axis, ARG05 = $angl, ARG06 = 2, ARG07 = $sysid)
/
/
/ Define the remaining geometry and mesh beginning here
/
/
UTILITY(MESH, LIVE)
/
/ Insert global WINDOW command here for first part of construction
/
WINDOW(CHANGE= 1, MATRIX )
      1.000000    0.000000    0.000000    0.000000
      0.000000    1.000000    0.000000    0.000000
      0.000000    0.000000    1.000000    0.000000
      0.000000    0.000000    0.000000    1.000000
      -4.05375    15.54625    -0.35000    14.35000    -14.70000    14.70000
      45.000000    45.000000    45.000000    45.000000
/
/ REMAINING CURVES 117 - 123
/
POINT(SELE, ID, WIND=1)
105
33
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELE, ID, WIND=1)
60
64
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELE, ID, WIND=1)
108
39
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELE, ID, WIND=1)
85
81
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELE, ID, WIND=1)
84
88
CURVE(ADD, SHOW, ARROW, ORDER=1)
POINT(SELE, ID, WIND=1)

```



```

61
22
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
44
61
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ CURVES 124 - 131
/
POINT (SELE, ID, WIND=1)
66
62
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
63
67
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
82
78
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
79
83
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
90
86
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
87
91
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
106
102
CURVE (ADD, SHOW, ARROW, ORDER=1)
POINT (SELE, ID, WIND=1)
103
107
CURVE (ADD, SHOW, ARROW, ORDER=1)
/
/ ADD MESH INTERVALS TO EDGES
/
CURVE (SELECT, ID, WINDOW=1)
4
2
57
37
39
48
51
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
31
5
123
118
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
30
6
84
72
MEDGE (ADD, SHOW, SUCC, INTE=4, RATI=0.0, 2RAT=0.0, PCEN=0.0)

```

```

CURVE (SELECT, ID, WINDOW=1)
29
7
83
92
86
73
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
28
8
82
91
87
74
MEDGE (ADD, SHOW, SUCC, INTE=55, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
27
9
81
90
88
75
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
26
10
80
76
MEDGE (ADD, SHOW, SUCC, INTE=4, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
25
11
120
121
MEDGE (ADD, SHOW, SUCC, INTE=3, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
24
12
108
96
MEDGE (ADD, SHOW, SUCC, INTE=4, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
23
13
107
116
110
97
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
22
14
106
115
111
98
MEDGE (ADD, SHOW, SUCC, INTE=55, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE (SELECT, ID, WINDOW=1)
21
15
105
114
112
99
MEDGE (ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)

```

```

CURVE(SELECT, ID, WINDOW=1)
20
16
104
100
MEDGE(ADD, SHOW, SUCC, INTE=4, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
19
17
62
61
MEDGE(ADD, SHOW, SUCC, INTE=70, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
34
32
56
58
MEDGE(ADD, SHOW, SUCC, INTE=3, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
43
38
MEDGE(ADD, SHOW, SUCC, INTE=10, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
44
49
MEDGE(ADD, SHOW, SUCC, INTE=30, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
55
50
MEDGE(ADD, SHOW, SUCC, INTE=10, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
1
3
18
33
42
45
54
MEDGE(ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
59
60
122
117
MEDGE(ADD, SHOW, SUCC, INTE=5, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
63
64
69
79
93
103
MEDGE(ADD, SHOW, SUCC, INTE=4, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)
65
66
70
85
89
78
94
109
113
102
MEDGE(ADD, SHOW, SUCC, INTE=151, RATI=0.0, 2RAT=0.0, PCEN=0.0)
CURVE(SELECT, ID, WINDOW=1)

```

```

67
68
71
77
95
101
MEDGE(ADD,SHOW,SUCC,INTE=4,RATI=0.0,2RAT=0.0,PCEN=0.0)
CURVE(SELECT,ID,WINDOW=1)
119
MEDGE(ADD,SHOW,SUCC,INTE=7,RATI=0.0,2RAT=0.0,PCEN=0.0)
CURVE(SELECT,ID,WINDOW=1)
35
41
46
53
36
40
47
52
MEDGE(ADD,SHOW,SUCC,INTE=190,RATI=0.0,2RAT=0.0,PCEN=0.0)
CURVE(SELECT,ID,WINDOW=1)
124
125
126
127
128
129
130
131
MEDGE(ADD,SHOW,SUCC,INTE=4,RATI=0.0,2RAT=0.0,PCEN=0.0)
/
/ APPLY ENTITY NAMES FOR 2D EDGE ELEMENTS
/
MEDGE(SELECT,ID,WINDOW=1)
88
119
123
7
ELEMENT(SETD,EDGE,NODE=2)
MEDGE(MESH,MAP,ENTI="STOD_PLOT")
MEDGE(SELECT,ID,WINDOW=1)
88
119
123
7
ELEMENT(SETD,EDGE,NODE=2)
MEDGE(MESH,MAP,ENTI="STOD_RAD")
MEDGE(SELECT,ID,WINDOW=1)
88
119
123
7
ELEMENT(SETD,EDGE,NODE=2)
MEDGE(MESH,MAP,ENTI="STOD_CONV")
MEDGE(SELECT,ID,WINDOW=1)
87
118
122
6
ELEMENT(SETD,EDGE,NODE=2)
MEDGE(MESH,MAP,ENTI="STID_PLOT")
MEDGE(SELECT,ID,WINDOW=1)
87
118
122
6

```

```

ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="STID_RAD")
MEDGE (SELECT, ID, WINDOW=1)
78
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOSTRHS_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
78
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOSTRHS_RAD")
MEDGE (SELECT, ID, WINDOW=1)
79
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOSTLHS_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
79
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOSTLHS_RAD")
MEDGE (SELECT, ID, WINDOW=1)
86
117
121
5
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOOD_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
86
117
121
5
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOOD_RAD")
MEDGE (SELECT, ID, WINDOW=1)
85
116
120
4
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOID_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
116
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOID_RAD1")
MEDGE (SELECT, ID, WINDOW=1)
120
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="MCOID_RAD2")
MEDGE (SELECT, ID, WINDOW=1)
9
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD1")
MEDGE (SELECT, ID, WINDOW=1)
13
17
23
29
35
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD2")
MEDGE (SELECT, ID, WINDOW=1)
39
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD3")
MEDGE (SELECT, ID, WINDOW=1)
43
47

```

```

53
59
65
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD4")
MEDGE (SELECT, ID, WINDOW=1)
69
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD5")
MEDGE (SELECT, ID, WINDOW=1)
73
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="VCROSS_RAD6")
MEDGE (SELECT, ID, WINDOW=1)
90
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="HCROSS_RAD1")
MEDGE (SELECT, ID, WINDOW=1)
94
100
110
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="HCROSS_RAD2")
MEDGE (SELECT, ID, WINDOW=1)
70
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="HCROSS_RAD3")
MEDGE (SELECT, ID, WINDOW=1)
74
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="HCROSS_RAD4")
MEDGE (SELECT, ID, WINDOW=1)
95
101
111
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1OD_RAD1")
MEDGE (SELECT, ID, WINDOW=1)
15
21
27
33
37
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1OD_RAD2")
MEDGE (SELECT, ID, WINDOW=1)
112
104
96
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1OD_RAD3")
MEDGE (SELECT, ID, WINDOW=1)
36
30
24
18
14
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1OD_RAD4")
MEDGE (SELECT, ID, WINDOW=1)
95
101
111
15
21
27

```

```

33
37
112
104
96
36
30
24
18
14
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1OD_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
102
20
26
32
103
31
25
19
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN1ID_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
97
105
113
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2OD_RAD1")
MEDGE (SELECT, ID, WINDOW=1)
45
51
57
63
67
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2OD_RAD2")
MEDGE (SELECT, ID, WINDOW=1)
114
108
98
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2OD_RAD3")
MEDGE (SELECT, ID, WINDOW=1)
66
60
54
48
44
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2OD_RAD4")
MEDGE (SELECT, ID, WINDOW=1)
97
105
113
45
51
57
63
67
114
108
98
66
60
54

```

```

48
44
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2OD_PLOT")
MEDGE (SELECT, ID, WINDOW=1)
106
50
56
62
107
61
55
49
ELEMENT (SETD, EDGE, NODE=2)
MEDGE (MESH, MAP, ENTI="CAN2ID_PLOT")
/
/ MESH LOOPS AND MFAVES
/
/ MESH LOOP #1, MESH FACE #1
/
CURVE (SELECT, ID, WINDOW=1)
1
2
3
4
MLOOP (ADD, MAP, VISI, SHOW, EDG1=1, EDG2=1, EDG3=1, EDG4=1)
SURFACE (SELECT, ID, WINDOW=1)
1
UTILITY (HIGH=9)
MLOOP (SELECT, ID, WINDOW=1)
1
UTILITY (HIGH=3)
MFACE (ADD)
MFACE (SELECT, ID, WINDOW=1)
1
MFACE (MESH, MAP, ENTI="CCROSS")
/
/ MESH LOOP #2, MESH FACE #2
/
CURVE (SELECT, ID, WINDOW=1)
3
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

```



```

30
31
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=13,EDG3=1,EDG4=13)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
2
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
2
MFACE(MESH,MAP,ENTI="VCROSS")
/
/ MESH LOOP #3, MESH FACE #3
/
CURVE(SELECT,ID,WINDOW=1)
18
32
33
34
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=1,EDG3=1,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
3
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
3
MFACE(MESH,MAP,ENTI="MINI_GAP1")
/
/ MESH LOOP #4, MESH FACE #4
/
CURVE(SELECT,ID,WINDOW=1)
33
35
36
37
38
39
40
41
42
43
MLOOP(ADD,MAP,VISI,SHOW,EDG1=4,EDG2=1,EDG3=4,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
4
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
4
MFACE(MESH,MAP,ENTI="MCO")
/
/ MESH LOOP #5, MESH FACE #5
/
CURVE(SELECT,ID,WINDOW=1)
42
41
40
39
49

```

```

48
47
46
45
44
MLOOP(ADD,MAP,VISI,SHOW,EDG1=4,EDG2=1,EDG3=4,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
5
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
5
MFACE(MESH,MAP,ENTI="MCOST_GAP")
/
/ MESH LOOP #6, MESH FACE #6
/
CURVE(SELECT,ID,WINDOW=1)
45
46
47
48
50
51
52
53
54
55
MLOOP(ADD,MAP,VISI,SHOW,EDG1=4,EDG2=1,EDG3=4,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
6
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
6
MFACE(MESH,MAP,ENTI="ST")
/
/ MESH LOOP #7, MESH FACE #7
/
CURVE(SELECT,ID,WINDOW=1)
59
63
65
67
61
57
62
68
66
64
60
2
MLOOP(ADD,MAP,VISI,SHOW,EDG1=5,EDG2=1,EDG3=5,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
7
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)

```

```

7
MFACE(MESH,MAP,ENTI="HCROSS")
/
/ MESH LOOP #8, MESH FACE #8
/
CURVE(SELECT, ID, WINDOW=1)
58
37
56
57
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=1,EDG3=1,EDG4=1)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
8
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
8
MFACE(MESH,MAP,ENTI="MINI_GAP2")
/
/ MESH LOOP #9, MESH FACE #9
/
CURVE(SELECT, ID, WINDOW=1)
122
84
83
82
81
80
120
108
107
106
105
104
117
16
15
14
13
12
11
10
9
8
7
6
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=11,EDG3=1,EDG4=11)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
9
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
9
MFACE(MESH,MAP,ENTI="GAP1")
/
/ MESH LOOP #10, MESH FACE #10
/
CURVE(SELECT, ID, WINDOW=1)
60
123

```

```

122
5
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=1,EDG3=1,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
10
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
10
MFACE(MESH,MAP,ENTI="GAP2")
/
/ MESH LOOP #11, MESH FACE #11
/
CURVE(SELECT,ID,WINDOW=1)
64
66
68
118
71
70
69
123
MLOOP(ADD,MAP,VISI,SHOW,EDG1=3,EDG2=1,EDG3=3,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
11
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
11
MFACE(MESH,MAP,ENTI="GAP3")
/
/ MESH LOOP #12, MESH FACE #12
/
CURVE(SELECT,ID,WINDOW=1)
79
78
77
121
95
94
93
120
MLOOP(ADD,MAP,VISI,SHOW,EDG1=3,EDG2=1,EDG3=3,EDG4=1)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
12
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
12
MFACE(MESH,MAP,ENTI="ASMBLY_GAP")
/
/ MESH LOOP #13, MESH FACE #13
/
CURVE(SELECT,ID,WINDOW=1)
117
103
102

```

```

101
119
35
32
17
MLOOP(ADD,PAVE,VISI,SHOW)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
13
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
13
MFACE(MESH,PAVE,ENTI="FLOW1")
/
/ MESH LOOP #14, MESH FACE #14
/
CURVE(SELECT,ID,WINDOW=1)
62
56
36
119
100
99
98
97
96
121
76
75
74
73
72
118
MLOOP(ADD,PAVE,VISI,SHOW)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
14
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
14
MFACE(MESH,PAVE,ENTI="FLOW2")
/
/ MESH LOOP #15, MESH FACE #15
/
CURVE(SELECT,ID,WINDOW=1)
85
86
87
88
89
90
91
92
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=3,EDG3=1,EDG4=3)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
15
UTILITY(HIGH=3)

```

```

MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
15
MFACE(MESH, MAP, ENTI="FUEL1")
/
/ MESH LOOP #16, MESH FACE #16
/
CURVE(SELECT, ID, WINDOW=1)
109
110
111
112
113
114
115
116
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=3, EDG3=1, EDG4=3)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
16
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
16
MFACE(MESH, MAP, ENTI="FUEL2")
/
/ MESH LOOP #17, MESH FACE #17
/
CURVE(SELECT, ID, WINDOW=1)
70
125
85
124
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=1, EDG3=1, EDG4=1)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
17
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
17
MFACE(MESH, MAP, ENTI="CAN11")
/
/ MESH LOOP #18, MESH FACE #18
/
CURVE(SELECT, ID, WINDOW=1)
71
72
73
74
75
76
77
127
88
87
86
125
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=5, EDG3=1, EDG4=5)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)

```

```

MLOOP(SELECT, ID, WINDOW=1)
18
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
18
MFACE(MESH, MAP, ENTI="CAN12")
/
/ MESH LOOP #19, MESH FACE #19
/
CURVE(SELECT, ID, WINDOW=1)
89
127
78
126
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=1, EDG3=1, EDG4=1)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
19
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
19
MFACE(MESH, MAP, ENTI="CAN13")
/
/ MESH LOOP #20, MESH FACE #20
/
CURVE(SELECT, ID, WINDOW=1)
69
124
92
91
90
126
79
80
81
82
83
84
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=5, EDG3=1, EDG4=5)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)
20
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT, ID, WINDOW=1)
20
MFACE(MESH, MAP, ENTI="CAN14")
/
/ MESH LOOP #21, MESH FACE #21
/
CURVE(SELECT, ID, WINDOW=1)
94
129
109
128
MLOOP(ADD, MAP, VISI, SHOW, EDG1=1, EDG2=1, EDG3=1, EDG4=1)
SURFACE(SELECT, ID, WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT, ID, WINDOW=1)

```

```

21
UTILITY (HIGH=3)
MFACE (ADD)
MFACE (SELECT, ID, WINDOW=1)
21
MFACE (MESH, MAP, ENTI="CAN21")
/
/ MESH LOOP #22, MESH FACE #22
/
CURVE (SELECT, ID, WINDOW=1)
95
96
97
98
99
100
101
131
112
111
110
129
MLOOP (ADD, MAP, VISI, SHOW, EDG1=1, EDG2=5, EDG3=1, EDG4=5)
SURFACE (SELECT, ID, WINDOW=1)
1
UTILITY (HIGH=9)
MLOOP (SELECT, ID, WINDOW=1)
22
UTILITY (HIGH=3)
MFACE (ADD)
MFACE (SELECT, ID, WINDOW=1)
22
MFACE (MESH, MAP, ENTI="CAN22")
/
/ MESH LOOP #23, MESH FACE #23
/
CURVE (SELECT, ID, WINDOW=1)
113
131
102
130
MLOOP (ADD, MAP, VISI, SHOW, EDG1=1, EDG2=1, EDG3=1, EDG4=1)
SURFACE (SELECT, ID, WINDOW=1)
1
UTILITY (HIGH=9)
MLOOP (SELECT, ID, WINDOW=1)
23
UTILITY (HIGH=3)
MFACE (ADD)
MFACE (SELECT, ID, WINDOW=1)
23
MFACE (MESH, MAP, ENTI="CAN23")
/
/ MESH LOOP #24, MESH FACE #24
/
CURVE (SELECT, ID, WINDOW=1)
93
128
116
115
114
130
103
104
105
106

```



```
107
108
MLOOP(ADD,MAP,VISI,SHOW,EDG1=1,EDG2=5,EDG3=1,EDG4=5)
SURFACE(SELECT,ID,WINDOW=1)
1
UTILITY(HIGH=9)
MLOOP(SELECT,ID,WINDOW=1)
24
UTILITY(HIGH=3)
MFACE(ADD)
MFACE(SELECT,ID,WINDOW=1)
24
MFACE(MESH,MAP,ENTI="CAN24")
/
/ REVISE ELEMENTS INTERNAL TO CAN1 AND CAN2
/ FLOW CHANNELS - AIR OR HELIUM; 2 END AND 29 INTERIOR CHANNELS
/ CLAD - 60 CLAD - 1 ON EACH SIDE OF FUEL AND RIBBING BETWEEN FUEL SEGMENTS
/ FUEL - 10 SEGMENTS PER PLATE AND 30 PLATES
/
$E1=51592
$E2=51743
$E3=51894
$E4=52045
$E5=52196
$E6=52347
$E7=52498
$E8=52649
$E9=52800
$E10=52951
$E11=53102
$E12=53253
$E13=53404
$E14=53555
$E15=53706
$E16=53857
$E17=54008
$E18=54159
$E19=54310
$E20=54461
$E21=54612
$E22=54763
$E23=54914
$E24=55065
$E25=55216
$E26=55367
$E27=55518
$E28=55669
$E29=55820
$E30=55971
$E31=56122
$E32=56273
$E33=56424
$E34=56575
$E35=56726
$E36=56877
$E37=57028
$E38=57179
$E39=57330
$E40=57481
$E41=57632
$E42=57783
$E43=57934
$E44=58085
$E45=58236
$E46=58387
$E47=58538
```

```

$E48=58689
$E49=58840
$E50=58991
$E51=59142
$E52=59293
$E53=59444
$E54=59595
$E55=59746
$E56=59897
$E57=60048
$E58=60199
$E59=60350
$E60=60501
$E61=60652
$E62=60803
$E63=60954
$E64=61105
$E65=61256
/
$ANUM=1
$CNUM=NTOS($ANUM)
/
DO ( $A = 1, $A .LT. 32, 1 )
$FCHAN=NTOS($A)
ELEMENT(SELECT, ID, WINDOW=1)
($E1+((($A-1)*5))
($E2+((($A-1)*5))
($E3+((($A-1)*5))
($E4+((($A-1)*5))
($E5+((($A-1)*5))
($E6+((($A-1)*5))
($E7+((($A-1)*5))
($E8+((($A-1)*5))
($E9+((($A-1)*5))
($E10+((($A-1)*5))
($E11+((($A-1)*5))
($E12+((($A-1)*5))
($E13+((($A-1)*5))
($E14+((($A-1)*5))
($E15+((($A-1)*5))
($E16+((($A-1)*5))
($E17+((($A-1)*5))
($E18+((($A-1)*5))
($E19+((($A-1)*5))
($E20+((($A-1)*5))
($E21+((($A-1)*5))
($E22+((($A-1)*5))
($E23+((($A-1)*5))
($E24+((($A-1)*5))
($E25+((($A-1)*5))
($E26+((($A-1)*5))
($E27+((($A-1)*5))
($E28+((($A-1)*5))
($E29+((($A-1)*5))
($E30+((($A-1)*5))
($E31+((($A-1)*5))
($E32+((($A-1)*5))
($E33+((($A-1)*5))
($E34+((($A-1)*5))
($E35+((($A-1)*5))
($E36+((($A-1)*5))
($E37+((($A-1)*5))
($E38+((($A-1)*5))
($E39+((($A-1)*5))
($E40+((($A-1)*5))
($E41+((($A-1)*5))

```

```

($E42+((($A-1)*5))
($E43+((($A-1)*5))
($E44+((($A-1)*5))
($E45+((($A-1)*5))
($E46+((($A-1)*5))
($E47+((($A-1)*5))
($E48+((($A-1)*5))
($E49+((($A-1)*5))
($E50+((($A-1)*5))
($E51+((($A-1)*5))
($E52+((($A-1)*5))
($E53+((($A-1)*5))
($E54+((($A-1)*5))
($E55+((($A-1)*5))
($E56+((($A-1)*5))
($E57+((($A-1)*5))
($E58+((($A-1)*5))
($E59+((($A-1)*5))
($E60+((($A-1)*5))
($E61+((($A-1)*5))
($E62+((($A-1)*5))
($E63+((($A-1)*5))
($E64+((($A-1)*5))
($E65+((($A-1)*5))
ELEMENT(MODIFY, GROUP=60+$A, NODE=4, QUAD)
$GRP = 60+$A
EGROUP(SELECT, ID, WINDOW=1)
$GRP
EGROUP(MODIFY, ENTITY="FLOW"+$CNUM+$FCHAN)
ENDDO
/
$ANUM=2
$CNUM=NTOS($ANUM)
/
DO ( $B = 1, $B .LT. 32, 1 )
$FCHAN=NTOS($B)
ELEMENT(SELECT, ID, WINDOW=1)
($E1+9815+((($B-1)*5))
($E2+9815+((($B-1)*5))
($E3+9815+((($B-1)*5))
($E4+9815+((($B-1)*5))
($E5+9815+((($B-1)*5))
($E6+9815+((($B-1)*5))
($E7+9815+((($B-1)*5))
($E8+9815+((($B-1)*5))
($E9+9815+((($B-1)*5))
($E10+9815+((($B-1)*5))
($E11+9815+((($B-1)*5))
($E12+9815+((($B-1)*5))
($E13+9815+((($B-1)*5))
($E14+9815+((($B-1)*5))
($E15+9815+((($B-1)*5))
($E16+9815+((($B-1)*5))
($E17+9815+((($B-1)*5))
($E18+9815+((($B-1)*5))
($E19+9815+((($B-1)*5))
($E20+9815+((($B-1)*5))
($E21+9815+((($B-1)*5))
($E22+9815+((($B-1)*5))
($E23+9815+((($B-1)*5))
($E24+9815+((($B-1)*5))
($E25+9815+((($B-1)*5))
($E26+9815+((($B-1)*5))
($E27+9815+((($B-1)*5))
($E28+9815+((($B-1)*5))
($E29+9815+((($B-1)*5))

```

```

($E30+9815+((($B-1)*5))
($E31+9815+((($B-1)*5))
($E32+9815+((($B-1)*5))
($E33+9815+((($B-1)*5))
($E34+9815+((($B-1)*5))
($E35+9815+((($B-1)*5))
($E36+9815+((($B-1)*5))
($E37+9815+((($B-1)*5))
($E38+9815+((($B-1)*5))
($E39+9815+((($B-1)*5))
($E40+9815+((($B-1)*5))
($E41+9815+((($B-1)*5))
($E42+9815+((($B-1)*5))
($E43+9815+((($B-1)*5))
($E44+9815+((($B-1)*5))
($E45+9815+((($B-1)*5))
($E46+9815+((($B-1)*5))
($E47+9815+((($B-1)*5))
($E48+9815+((($B-1)*5))
($E49+9815+((($B-1)*5))
($E50+9815+((($B-1)*5))
($E51+9815+((($B-1)*5))
($E52+9815+((($B-1)*5))
($E53+9815+((($B-1)*5))
($E54+9815+((($B-1)*5))
($E55+9815+((($B-1)*5))
($E56+9815+((($B-1)*5))
($E57+9815+((($B-1)*5))
($E58+9815+((($B-1)*5))
($E59+9815+((($B-1)*5))
($E60+9815+((($B-1)*5))
($E61+9815+((($B-1)*5))
($E62+9815+((($B-1)*5))
($E63+9815+((($B-1)*5))
($E64+9815+((($B-1)*5))
($E65+9815+((($B-1)*5))
ELEMENT(MODIFY, GROUP=91+$B, NODE=4, QUAD)
$GRP = 91+$B
EGROUP(SELECT, ID, WINDOW=1)
$GRP
EGROUP(MODIFY, ENTITY="FLOW"+$CNUM+$FCHAN)
ENDDO
/
/ SEPARATE CLADDING + RIBBING GROUPS
/
$ANUM=1
$CNUM=NTOS($ANUM)
/
DO ( $C = 1, $C .LT. 31, 1 )
$FCHAN=NTOS($C)
ELEMENT(SELECT, ID, WINDOW=1)
($E1+1+((($C-1)*5))
($E2+1+((($C-1)*5))
($E3+1+((($C-1)*5))
($E4+1+((($C-1)*5))
($E5+1+((($C-1)*5))
($E6+1+((($C-1)*5))
($E7+1+((($C-1)*5))
($E8+1+((($C-1)*5))
($E9+1+((($C-1)*5))
($E10+1+((($C-1)*5))
($E11+1+((($C-1)*5))
($E12+1+((($C-1)*5))
($E13+1+((($C-1)*5))
($E14+1+((($C-1)*5))
($E15+1+((($C-1)*5))

```

(\$E16+1+(((\$C-1)*5))
(\$E17+1+(((\$C-1)*5))
(\$E18+1+(((\$C-1)*5))
(\$E19+1+(((\$C-1)*5))
(\$E20+1+(((\$C-1)*5))
(\$E21+1+(((\$C-1)*5))
(\$E22+1+(((\$C-1)*5))
(\$E23+1+(((\$C-1)*5))
(\$E24+1+(((\$C-1)*5))
(\$E25+1+(((\$C-1)*5))
(\$E26+1+(((\$C-1)*5))
(\$E27+1+(((\$C-1)*5))
(\$E28+1+(((\$C-1)*5))
(\$E29+1+(((\$C-1)*5))
(\$E30+1+(((\$C-1)*5))
(\$E31+1+(((\$C-1)*5))
(\$E32+1+(((\$C-1)*5))
(\$E33+1+(((\$C-1)*5))
(\$E34+1+(((\$C-1)*5))
(\$E35+1+(((\$C-1)*5))
(\$E36+1+(((\$C-1)*5))
(\$E37+1+(((\$C-1)*5))
(\$E38+1+(((\$C-1)*5))
(\$E39+1+(((\$C-1)*5))
(\$E40+1+(((\$C-1)*5))
(\$E41+1+(((\$C-1)*5))
(\$E42+1+(((\$C-1)*5))
(\$E43+1+(((\$C-1)*5))
(\$E44+1+(((\$C-1)*5))
(\$E45+1+(((\$C-1)*5))
(\$E46+1+(((\$C-1)*5))
(\$E47+1+(((\$C-1)*5))
(\$E48+1+(((\$C-1)*5))
(\$E49+1+(((\$C-1)*5))
(\$E50+1+(((\$C-1)*5))
(\$E51+1+(((\$C-1)*5))
(\$E52+1+(((\$C-1)*5))
(\$E53+1+(((\$C-1)*5))
(\$E54+1+(((\$C-1)*5))
(\$E55+1+(((\$C-1)*5))
(\$E56+1+(((\$C-1)*5))
(\$E57+1+(((\$C-1)*5))
(\$E58+1+(((\$C-1)*5))
(\$E59+1+(((\$C-1)*5))
(\$E60+1+(((\$C-1)*5))
(\$E61+1+(((\$C-1)*5))
(\$E62+1+(((\$C-1)*5))
(\$E63+1+(((\$C-1)*5))
(\$E64+1+(((\$C-1)*5))
(\$E65+1+(((\$C-1)*5))
(\$E1+2+(((\$C-1)*5))
(\$E2+2+(((\$C-1)*5))
(\$E3+2+(((\$C-1)*5))
(\$E9+2+(((\$C-1)*5))
(\$E15+2+(((\$C-1)*5))
(\$E21+2+(((\$C-1)*5))
(\$E27+2+(((\$C-1)*5))
(\$E33+2+(((\$C-1)*5))
(\$E39+2+(((\$C-1)*5))
(\$E45+2+(((\$C-1)*5))
(\$E51+2+(((\$C-1)*5))
(\$E57+2+(((\$C-1)*5))
(\$E63+2+(((\$C-1)*5))
(\$E64+2+(((\$C-1)*5))
(\$E65+2+(((\$C-1)*5))
(\$E1+3+(((\$C-1)*5))

(\$E2+3+(((\$C-1)*5))
 (\$E3+3+(((\$C-1)*5))
 (\$E9+3+(((\$C-1)*5))
 (\$E15+3+(((\$C-1)*5))
 (\$E21+3+(((\$C-1)*5))
 (\$E27+3+(((\$C-1)*5))
 (\$E33+3+(((\$C-1)*5))
 (\$E39+3+(((\$C-1)*5))
 (\$E45+3+(((\$C-1)*5))
 (\$E51+3+(((\$C-1)*5))
 (\$E57+3+(((\$C-1)*5))
 (\$E63+3+(((\$C-1)*5))
 (\$E64+3+(((\$C-1)*5))
 (\$E65+3+(((\$C-1)*5))
 (\$E1+4+(((\$C-1)*5))
 (\$E2+4+(((\$C-1)*5))
 (\$E3+4+(((\$C-1)*5))
 (\$E4+4+(((\$C-1)*5))
 (\$E5+4+(((\$C-1)*5))
 (\$E6+4+(((\$C-1)*5))
 (\$E7+4+(((\$C-1)*5))
 (\$E8+4+(((\$C-1)*5))
 (\$E9+4+(((\$C-1)*5))
 (\$E10+4+(((\$C-1)*5))
 (\$E11+4+(((\$C-1)*5))
 (\$E12+4+(((\$C-1)*5))
 (\$E13+4+(((\$C-1)*5))
 (\$E14+4+(((\$C-1)*5))
 (\$E15+4+(((\$C-1)*5))
 (\$E16+4+(((\$C-1)*5))
 (\$E17+4+(((\$C-1)*5))
 (\$E18+4+(((\$C-1)*5))
 (\$E19+4+(((\$C-1)*5))
 (\$E20+4+(((\$C-1)*5))
 (\$E21+4+(((\$C-1)*5))
 (\$E22+4+(((\$C-1)*5))
 (\$E23+4+(((\$C-1)*5))
 (\$E24+4+(((\$C-1)*5))
 (\$E25+4+(((\$C-1)*5))
 (\$E26+4+(((\$C-1)*5))
 (\$E27+4+(((\$C-1)*5))
 (\$E28+4+(((\$C-1)*5))
 (\$E29+4+(((\$C-1)*5))
 (\$E30+4+(((\$C-1)*5))
 (\$E31+4+(((\$C-1)*5))
 (\$E32+4+(((\$C-1)*5))
 (\$E33+4+(((\$C-1)*5))
 (\$E34+4+(((\$C-1)*5))
 (\$E35+4+(((\$C-1)*5))
 (\$E36+4+(((\$C-1)*5))
 (\$E37+4+(((\$C-1)*5))
 (\$E38+4+(((\$C-1)*5))
 (\$E39+4+(((\$C-1)*5))
 (\$E40+4+(((\$C-1)*5))
 (\$E41+4+(((\$C-1)*5))
 (\$E42+4+(((\$C-1)*5))
 (\$E43+4+(((\$C-1)*5))
 (\$E44+4+(((\$C-1)*5))
 (\$E45+4+(((\$C-1)*5))
 (\$E46+4+(((\$C-1)*5))
 (\$E47+4+(((\$C-1)*5))
 (\$E48+4+(((\$C-1)*5))
 (\$E49+4+(((\$C-1)*5))
 (\$E50+4+(((\$C-1)*5))
 (\$E51+4+(((\$C-1)*5))
 (\$E52+4+(((\$C-1)*5))

```

($E53+4+((($C-1)*5))
($E54+4+((($C-1)*5))
($E55+4+((($C-1)*5))
($E56+4+((($C-1)*5))
($E57+4+((($C-1)*5))
($E58+4+((($C-1)*5))
($E59+4+((($C-1)*5))
($E60+4+((($C-1)*5))
($E61+4+((($C-1)*5))
($E62+4+((($C-1)*5))
($E63+4+((($C-1)*5))
($E64+4+((($C-1)*5))
($E65+4+((($C-1)*5))
ELEMENT(MODIFY, GROUP=122+$C, NODE=4, QUAD)
$GRP = 122+$C
EGROUP(SELECT, ID, WINDOW=1)
$GRP
EGROUP(MODIFY, ENTITY="CLAD"+$CNUM+$FCHAN)
ENDDO
/
$ANUM=2
$CNUM=NTOS($ANUM)
/
DO ( $D = 1, $D .LT. 31, 1 )
$FCHAN=NTOS($D)
ELEMENT(SELECT, ID, WINDOW=1)
($E1+1+9815+((($D-1)*5))
($E2+1+9815+((($D-1)*5))
($E3+1+9815+((($D-1)*5))
($E4+1+9815+((($D-1)*5))
($E5+1+9815+((($D-1)*5))
($E6+1+9815+((($D-1)*5))
($E7+1+9815+((($D-1)*5))
($E8+1+9815+((($D-1)*5))
($E9+1+9815+((($D-1)*5))
($E10+1+9815+((($D-1)*5))
($E11+1+9815+((($D-1)*5))
($E12+1+9815+((($D-1)*5))
($E13+1+9815+((($D-1)*5))
($E14+1+9815+((($D-1)*5))
($E15+1+9815+((($D-1)*5))
($E16+1+9815+((($D-1)*5))
($E17+1+9815+((($D-1)*5))
($E18+1+9815+((($D-1)*5))
($E19+1+9815+((($D-1)*5))
($E20+1+9815+((($D-1)*5))
($E21+1+9815+((($D-1)*5))
($E22+1+9815+((($D-1)*5))
($E23+1+9815+((($D-1)*5))
($E24+1+9815+((($D-1)*5))
($E25+1+9815+((($D-1)*5))
($E26+1+9815+((($D-1)*5))
($E27+1+9815+((($D-1)*5))
($E28+1+9815+((($D-1)*5))
($E29+1+9815+((($D-1)*5))
($E30+1+9815+((($D-1)*5))
($E31+1+9815+((($D-1)*5))
($E32+1+9815+((($D-1)*5))
($E33+1+9815+((($D-1)*5))
($E34+1+9815+((($D-1)*5))
($E35+1+9815+((($D-1)*5))
($E36+1+9815+((($D-1)*5))
($E37+1+9815+((($D-1)*5))
($E38+1+9815+((($D-1)*5))
($E39+1+9815+((($D-1)*5))
($E40+1+9815+((($D-1)*5))

```

(\$E41+1+9815+(((\$D-1)*5))
(\$E42+1+9815+(((\$D-1)*5))
(\$E43+1+9815+(((\$D-1)*5))
(\$E44+1+9815+(((\$D-1)*5))
(\$E45+1+9815+(((\$D-1)*5))
(\$E46+1+9815+(((\$D-1)*5))
(\$E47+1+9815+(((\$D-1)*5))
(\$E48+1+9815+(((\$D-1)*5))
(\$E49+1+9815+(((\$D-1)*5))
(\$E50+1+9815+(((\$D-1)*5))
(\$E51+1+9815+(((\$D-1)*5))
(\$E52+1+9815+(((\$D-1)*5))
(\$E53+1+9815+(((\$D-1)*5))
(\$E54+1+9815+(((\$D-1)*5))
(\$E55+1+9815+(((\$D-1)*5))
(\$E56+1+9815+(((\$D-1)*5))
(\$E57+1+9815+(((\$D-1)*5))
(\$E58+1+9815+(((\$D-1)*5))
(\$E59+1+9815+(((\$D-1)*5))
(\$E60+1+9815+(((\$D-1)*5))
(\$E61+1+9815+(((\$D-1)*5))
(\$E62+1+9815+(((\$D-1)*5))
(\$E63+1+9815+(((\$D-1)*5))
(\$E64+1+9815+(((\$D-1)*5))
(\$E65+1+9815+(((\$D-1)*5))
(\$E1+2+9815+(((\$D-1)*5))
(\$E2+2+9815+(((\$D-1)*5))
(\$E3+2+9815+(((\$D-1)*5))
(\$E9+2+9815+(((\$D-1)*5))
(\$E15+2+9815+(((\$D-1)*5))
(\$E21+2+9815+(((\$D-1)*5))
(\$E27+2+9815+(((\$D-1)*5))
(\$E33+2+9815+(((\$D-1)*5))
(\$E39+2+9815+(((\$D-1)*5))
(\$E45+2+9815+(((\$D-1)*5))
(\$E51+2+9815+(((\$D-1)*5))
(\$E57+2+9815+(((\$D-1)*5))
(\$E63+2+9815+(((\$D-1)*5))
(\$E64+2+9815+(((\$D-1)*5))
(\$E65+2+9815+(((\$D-1)*5))
(\$E1+3+9815+(((\$D-1)*5))
(\$E2+3+9815+(((\$D-1)*5))
(\$E3+3+9815+(((\$D-1)*5))
(\$E9+3+9815+(((\$D-1)*5))
(\$E15+3+9815+(((\$D-1)*5))
(\$E21+3+9815+(((\$D-1)*5))
(\$E27+3+9815+(((\$D-1)*5))
(\$E33+3+9815+(((\$D-1)*5))
(\$E39+3+9815+(((\$D-1)*5))
(\$E45+3+9815+(((\$D-1)*5))
(\$E51+3+9815+(((\$D-1)*5))
(\$E57+3+9815+(((\$D-1)*5))
(\$E63+3+9815+(((\$D-1)*5))
(\$E64+3+9815+(((\$D-1)*5))
(\$E65+3+9815+(((\$D-1)*5))
(\$E1+4+9815+(((\$D-1)*5))
(\$E2+4+9815+(((\$D-1)*5))
(\$E3+4+9815+(((\$D-1)*5))
(\$E4+4+9815+(((\$D-1)*5))
(\$E5+4+9815+(((\$D-1)*5))
(\$E6+4+9815+(((\$D-1)*5))
(\$E7+4+9815+(((\$D-1)*5))
(\$E8+4+9815+(((\$D-1)*5))
(\$E9+4+9815+(((\$D-1)*5))
(\$E10+4+9815+(((\$D-1)*5))
(\$E11+4+9815+(((\$D-1)*5))


```

($E12+4+9815+((($D-1)*5))
($E13+4+9815+((($D-1)*5))
($E14+4+9815+((($D-1)*5))
($E15+4+9815+((($D-1)*5))
($E16+4+9815+((($D-1)*5))
($E17+4+9815+((($D-1)*5))
($E18+4+9815+((($D-1)*5))
($E19+4+9815+((($D-1)*5))
($E20+4+9815+((($D-1)*5))
($E21+4+9815+((($D-1)*5))
($E22+4+9815+((($D-1)*5))
($E23+4+9815+((($D-1)*5))
($E24+4+9815+((($D-1)*5))
($E25+4+9815+((($D-1)*5))
($E26+4+9815+((($D-1)*5))
($E27+4+9815+((($D-1)*5))
($E28+4+9815+((($D-1)*5))
($E29+4+9815+((($D-1)*5))
($E30+4+9815+((($D-1)*5))
($E31+4+9815+((($D-1)*5))
($E32+4+9815+((($D-1)*5))
($E33+4+9815+((($D-1)*5))
($E34+4+9815+((($D-1)*5))
($E35+4+9815+((($D-1)*5))
($E36+4+9815+((($D-1)*5))
($E37+4+9815+((($D-1)*5))
($E38+4+9815+((($D-1)*5))
($E39+4+9815+((($D-1)*5))
($E40+4+9815+((($D-1)*5))
($E41+4+9815+((($D-1)*5))
($E42+4+9815+((($D-1)*5))
($E43+4+9815+((($D-1)*5))
($E44+4+9815+((($D-1)*5))
($E45+4+9815+((($D-1)*5))
($E46+4+9815+((($D-1)*5))
($E47+4+9815+((($D-1)*5))
($E48+4+9815+((($D-1)*5))
($E49+4+9815+((($D-1)*5))
($E50+4+9815+((($D-1)*5))
($E51+4+9815+((($D-1)*5))
($E52+4+9815+((($D-1)*5))
($E53+4+9815+((($D-1)*5))
($E54+4+9815+((($D-1)*5))
($E55+4+9815+((($D-1)*5))
($E56+4+9815+((($D-1)*5))
($E57+4+9815+((($D-1)*5))
($E58+4+9815+((($D-1)*5))
($E59+4+9815+((($D-1)*5))
($E60+4+9815+((($D-1)*5))
($E61+4+9815+((($D-1)*5))
($E62+4+9815+((($D-1)*5))
($E63+4+9815+((($D-1)*5))
($E64+4+9815+((($D-1)*5))
($E65+4+9815+((($D-1)*5))
ELEMENT(MODIFY, GROUP=152+$D, NODE=4, QUAD)
$GRP = 152+$D
EGROUP(SELECT, ID, WINDOW=1)
$GRP
EGROUP(MODIFY, ENTITY="CLAD"+$CNUM+$FCHAN)
ENDDO
/
END
FIPREP
/ CONVERT FROM INCHES TO METERS
SCALE(X=0.0254, Y=0.0254, Z=0.0254)
/SI UNITS USED FROM THIS POINT ON

```

```

DATAPRINT (NONE)
/DATAPRINT (NORMAL, PAGE, NODES, ELEMENTS, CONSTRAINED, FLUX, INITIAL, GENERAL)
EXECUTABLE (NEWJOB)
GRAVITY (MAGNITUDE=9.8066352, THETA=0)
POSTPROCESS (RESIDUAL)
PRESSURE (DISCONTINUOUS, PENALTY=1.0E-8)
/PRINTOUT (ALL)
PRINTOUT (NONE)
PROBLEM (INCOMPRESSIBLE, STEADY, NONLINEAR, NEWTONIAN, 2-D, NOMOMENTUM, LAMINAR,
ENERGY)
/SOLUTION (SEGR=50, VELCONV=0.001, CR=2000, CGS=2000, NCGC=1E-6, SCGC=1E-6,
/ PRECON=21)
SOLUTION (S.S.=100, VELCONV=0.001, RESCONV=0.001, SCHANG=0)
EXTRAPOLATION (OFF)
/EXTRAPOLATION (ON, AFTER=25, EVERY=15, ORDER=2, NOKE, NOFREE)
/EXTRAPOLATION (ON, AFTER=5, EVERY=5, ORDER=2, NOKE, NOFREE)
CLIPPING (MINIMUM)
0,0,0,0,333.15,0,0,0,1E-20,1E-20,1E-20,1E-20,1E-20,1E-20,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
CLIPPING (MAXIMUM)
0,0,0,0,1000.0,0,0,0,0.1403,0.0248,0.3814,0.7552,0.0836,0.2448,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
RELAXATION (RADIATION=0.90)
0.30,0.30,0.30,0.75,0.75,0.0,0.0,0.0,0.0001,0.05,0.05,0.05,0.05,0.05,
0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
/OPTIONS (UPWINDING=7)
/
/ ENTITY NAMES AND ATTRIBUTES
/
/
/ FLUIDS
/
ENTITY (NAME="MCOST_GAP", SOLID, PROPERTY="AIR")
ENTITY (NAME="MINI_GAP1", SOLID, PROPERTY="AIR")
ENTITY (NAME="MINI_GAP2", SOLID, PROPERTY="AIR")
ENTITY (NAME="GAP1", SOLID, PROPERTY="AIR")
ENTITY (NAME="GAP2", SOLID, PROPERTY="AIR")
ENTITY (NAME="GAP3", SOLID, PROPERTY="AIR")
ENTITY (NAME="ASMBLY_GAP", SOLID, PROPERTY="AIR")
ENTITY (NAME="FLOW1", SOLID, PROPERTY="AIR")
ENTITY (NAME="FLOW2", SOLID, PROPERTY="AIR")
/
/ SOLIDS
/
ENTITY (NAME="ST", SOLID, PROPERTY="MCSTEEL")
ENTITY (NAME="MCO", SOLID, PROPERTY="SS304")
ENTITY (NAME="VCROSS", SOLID, PROPERTY="SS304")
ENTITY (NAME="CCROSS", SOLID, PROPERTY="SS304")
ENTITY (NAME="HCROSS", SOLID, PROPERTY="SS304")
ENTITY (NAME="CAN11", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN12", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN13", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN14", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN21", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN22", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN23", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="CAN24", SOLID, PROPERTY="ZIRC4")
ENTITY (NAME="FUEL1", SOLID, PROPERTY="UO2", MCOND="UO2X")
ENTITY (NAME="FUEL2", SOLID, PROPERTY="UO2", MCOND="UO2X")
/
/ FLOW CHANNELS - REVISED ELEMENT GROUPINGS
/
ENTITY (NAME="FLOW11", SOLID, PROPERTY="AIR", MCOND="AIR2X")
ENTITY (NAME="FLOW12", SOLID, PROPERTY="AIR", MCOND="AIR3X")
ENTITY (NAME="FLOW13", SOLID, PROPERTY="AIR", MCOND="AIR3X")
ENTITY (NAME="FLOW14", SOLID, PROPERTY="AIR", MCOND="AIR3X")

```

/ CLAD + RIBBING - REVISED ELEMENT GROUPINGS

A-39

```

ENTITY (NAME="CLAD16", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD17", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD18", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD19", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD110", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD111", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD112", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD113", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD114", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD115", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD116", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD117", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD118", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD119", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD120", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD121", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD122", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD123", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD124", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD125", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD126", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD127", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD128", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD129", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD130", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD21", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD22", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD23", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD24", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD25", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD26", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD27", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD28", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD29", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD210", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD211", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD212", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD213", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD214", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD215", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD216", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD217", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD218", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD219", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD220", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD221", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD222", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD223", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD224", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD225", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD226", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD227", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD228", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD229", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
ENTITY (NAME="CLAD230", SOLID, PROPERTY="ZIRC4", MCOND="ZIRC2X")
/
/ REMAINING ENTITIES - CONVECTION, RADIATION, PLOT, AND WALL (IF NECESSARY)
/
/ ST - MCO GAP
/
ENTITY (NAME="MCOSTRHS_PLOT", PLOT, ATTACH="MCOST_GAP")
ENTITY (NAME="MCOSTRHS_RAD", RADIATION, GREY, MEMSV=2, ATTACH="MCOST_GAP")
ENTITY (NAME="MCOSTLHS_PLOT", PLOT, ATTACH="MCOST_GAP")
ENTITY (NAME="MCOSTLHS_RAD", RADIATION, GREY, MEMSV=2, ATTACH="MCOST_GAP")
/

```

```

/ STORAGE TUBE - ST
/
ENTITY (NAME="STOD_RAD", PLOT, ATTACH="ST")
ENTITY (NAME="STOD_PLOT", PLOT, ATTACH="ST")
ENTITY (NAME="STOD_CONV", CONV, MCNV="AIR140", ATTACH="ST")
ENTITY (NAME="STID_PLOT", PLOT, ATTACH="ST")
ENTITY (NAME="STID_RAD", RADIATION, GREY, MEMSV=1, ATTACH="MCOST_GAP", NATTACH="ST")
/
/ MULTICANISTER OVERPACK - MCO
/
ENTITY (NAME="MCOOD_PLOT", PLOT, ATTACH="MCO")
ENTITY (NAME="MCOOD_RAD", RADIATION, GREY, MEMSV=3, ATTACH="MCOST_GAP", NATTACH="MCO")
ENTITY (NAME="MCOID_PLOT", PLOT, ATTACH="MCO")
ENTITY (NAME="MCOID_RAD1", RADIATION, GREY, MEMSV=3, ATTACH="FLOW1", NATTACH="MCO")
ENTITY (NAME="MCOID_RAD2", RADIATION, GREY, MEMSV=3, ATTACH="FLOW2", NATTACH="MCO")
/
/ MINIGAPS AND CENTRAL CROSS
/
ENTITY (NAME="VCROSS_RAD1", RADIATION, GREY, MEMSV=3, ATTACH="GAP2", NATTACH="VCROSS")
ENTITY (NAME="VCROSS_RAD2", RADIATION, GREY, MEMSV=3, ATTACH="GAP1", NATTACH="VCROSS")
ENTITY (NAME="VCROSS_RAD3", RADIATION, GREY, MEMSV=3, ATTACH="GAP1", NATTACH="VCROSS")
ENTITY (NAME="VCROSS_RAD4", RADIATION, GREY, MEMSV=3, ATTACH="GAP1", NATTACH="VCROSS")
ENTITY (NAME="VCROSS_RAD5", RADIATION, GREY, MEMSV=3, ATTACH="FLOW1", NATTACH="VCROSS")
ENTITY (NAME="VCROSS_RAD6", RADIATION, GREY, MEMSV=3, ATTACH="FLOW1", NATTACH="MINI_GA")
ENTITY (NAME="HCROSS_RAD1", RADIATION, GREY, MEMSV=3, ATTACH="GAP2", NATTACH="HCROSS")
ENTITY (NAME="HCROSS_RAD2", RADIATION, GREY, MEMSV=3, ATTACH="GAP3", NATTACH="HCROSS")
ENTITY (NAME="HCROSS_RAD3", RADIATION, GREY, MEMSV=3, ATTACH="FLOW2", NATTACH="HCROSS")
ENTITY (NAME="HCROSS_RAD4", RADIATION, GREY, MEMSV=3, ATTACH="FLOW2", NATTACH="MINI_GA")
/
/ BLANKET ASSEMBLIES - CAN1 AND CAN2
/
ENTITY (NAME="CAN1OD_RAD1", RADIATION, GREY, MEMSV=4, ATTACH="GAP3", NATTACH="CAN11",
NATTACH="CAN12", NATTACH="CAN14")
ENTITY (NAME="CAN1OD_RAD2", RADIATION, GREY, MEMSV=4, ATTACH="FLOW2", NATTACH="CAN12")
ENTITY (NAME="CAN1OD_RAD3", RADIATION, GREY, MEMSV=4, ATTACH="ASMBLY_GAP", NATTACH="CA
NATTACH="CAN13", NATTACH="CAN14")
ENTITY (NAME="CAN1OD_RAD4", RADIATION, GREY, MEMSV=4, ATTACH="GAP1", NATTACH="CAN14")
ENTITY (NAME="CAN1OD_PLOT", PLOT, ATTACH="GAP3", ATTACH="FLOW2", ATTACH="ASMBLY_GAP",
ATTACH="GAP1", NATTACH="CAN11", NATTACH="CAN12", NATTACH="CAN13", NATTACH="CA
ENTITY (NAME="CAN1ID_PLOT", PLOT, ATTACH="FUEL1", NATTACH="CAN11", NATTACH="CAN12",
NATTACH="CAN13", NATTACH="CAN14")
ENTITY (NAME="CAN2OD_RAD1", RADIATION, GREY, MEMSV=4, ATTACH="ASMBLY_GAP", NATTACH="CA
NATTACH="CAN22", NATTACH="CAN24")
ENTITY (NAME="CAN2OD_RAD2", RADIATION, GREY, MEMSV=4, ATTACH="FLOW2", NATTACH="CAN22")
ENTITY (NAME="CAN2OD_RAD3", RADIATION, GREY, MEMSV=4, ATTACH="FLOW1", NATTACH="CAN22",
NATTACH="CAN23", NATTACH="CAN24")
ENTITY (NAME="CAN2OD_RAD4", RADIATION, GREY, MEMSV=4, ATTACH="GAP1", NATTACH="CAN24")
ENTITY (NAME="CAN2OD_PLOT", PLOT, ATTACH="GAP1", ATTACH="FLOW2", ATTACH="ASMBLY_GAP",
ATTACH="FLOW1", NATTACH="CAN21", NATTACH="CAN22", NATTACH="CAN23", NATTACH="C
ENTITY (NAME="CAN2ID_PLOT", PLOT, ATTACH="FUEL2", NATTACH="CAN21", NATTACH="CAN22",
NATTACH="CAN23", NATTACH="CAN24")
/
/ UNIFORM HEAT GENERATION THROUGHOUT ENTIRE VOLUME
/ PEAK-TO-AVERAGE AXIAL HEAT GENERATION RATIO = 1.55
/
$ASSYHT=7515.269412
$PAHEAT=1.55
/
/ VOLUMETRIC HEAT GENERATION RATE - BASED ON ACTUAL VOLUME IN CAN1 AND CAN2
/ EQUIVALENT TO 82.35 WATTS PER CAN OR 164.7 WATTS TOTAL FOR TWO CANS
/ HOWEVER FOR THIS 2D PROBLEM GIVEN THE ASSUMPTION OF A UNIT DEPTH OF ONE METER
/ THE TOTAL POWER = 2 X 82.35 X (1.0/2.4527) X PAHEAT = 104.0838 WATTS
/
SOURCE (HEAT, ENTITY="FUEL1", CONSTANT=$ASSYHT*$PAHEAT)
SOURCE (HEAT, ENTITY="FUEL2", CONSTANT=$ASSYHT*$PAHEAT)
/

```

/ MATERIAL PROPERTIES

/

/ WATER

SPECIFICHEAT (SET="WATER", CURVE=15, TEMPERATURE, SPATIAL)

273.16, 288.72, 299.83, 310.94, 338.72, 366.49, 367.05,
367.60, 394.27, 422.05, 477.60, 533.16, 588.72, 810.94, 1088.72,
4228.4, 4186.6, 4182.4, 4182.4, 4186.6, 4228.4, 4228.4,
4228.4, 4270.3, 4312.2, 4521.5, 4982.0, 6321.7, 6321.7, 6321.7

DENSITY (SET="WATER", CONSTANT=994.7466)

CONDUCTIVITY (SET="WATER", CURVE=15, TEMPERATURE, ISOTROPIC)

273.16, 288.72, 299.83, 310.94, 338.72, 366.49, 367.05,
367.60, 394.27, 422.05, 477.60, 533.16, 588.72, 810.94, 1088.72,
0.5521, 0.5884, 0.6109, 0.6299, 0.6628, 0.6784, 0.6784,
0.6784, 0.6836, 0.6836, 0.6611, 0.6040, 0.5071, 0.5071, 0.5071

/ AIR

SPECIFICHEAT (SET="AIR", CURVE=22, TEMPERATURE, SPATIAL)

1.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0,
10000.0,

1026.6, 1009.9, 1006.1, 1005.3, 1005.7, 1009.0, 1014.0, 1020.7, 1029.5,
1039.2, 1055.1, 1063.5, 1075.2, 1085.6, 1097.8, 1109.5, 1121.2, 1132.1,
1141.7, 1160.0, 1179.0, 1179.0

DENSITY (SET="AIR", CONSTANT=1.059779, TYP1, TEMPERATURE)

/ CONDUCTIVITY (SET="AIR", CONSTANT=0.0347)

CONDUCTIVITY (SET="AIR", CURVE=22, TEMPERATURE, ISOTROPIC)

1.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0,
10000.0,

0.009246, 0.013735, 0.01809, 0.02227, 0.02624, 0.03003, 0.03365, 0.03707,
0.04038, 0.04360, 0.04659, 0.04953, 0.05230, 0.05509, 0.05779, 0.06028,
0.06279, 0.06525, 0.06752, 0.07320, 0.07820, 0.07820

CONDUCTIVITY (SET="AIR2X", CURVE=22, TEMPERATURE, NONISOTROPIC)

0.6995, 1.0E-20, 1.0E-20, 1.0E-20, 1.0, 1.0E-20, 1.0E-20, 1.0E-20, 1.0
1.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0,
10000.0,

0.009246, 0.013735, 0.01809, 0.02227, 0.02624, 0.03003, 0.03365, 0.03707,
0.04038, 0.04360, 0.04659, 0.04953, 0.05230, 0.05509, 0.05779, 0.06028,
0.06279, 0.06525, 0.06752, 0.07320, 0.07820, 0.07820

CONDUCTIVITY (SET="AIR3X", CURVE=22, TEMPERATURE, NONISOTROPIC)

0.5073, 1.0E-20, 1.0E-20, 1.0E-20, 1.0, 1.0E-20, 1.0E-20, 1.0E-20, 1.0
1.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0,
10000.0,

0.009246, 0.013735, 0.01809, 0.02227, 0.02624, 0.03003, 0.03365, 0.03707,
0.04038, 0.04360, 0.04659, 0.04953, 0.05230, 0.05509, 0.05779, 0.06028,
0.06279, 0.06525, 0.06752, 0.07320, 0.07820, 0.07820

VISCOSITY (SET="AIR", CURVE=22, TEMPERATURE, TWO-EQUATION)

1.0, 150.0, 200.0, 250.0, 300.0, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0,
10000.0,

0.6924E-5, 1.0283E-5, 1.3289E-5, 1.5990E-5, 1.8462E-5, 2.0750E-5, 2.2860E-5,
2.4840E-5, 2.6710E-5, 2.8480E-5, 3.0180E-5, 3.1770E-5, 3.3320E-5, 3.4810E-5,
3.6250E-5, 3.7650E-5, 3.8990E-5, 4.0230E-5, 4.1520E-5, 4.4400E-5, 4.6900E-5,
4.6900E-5

VOLUME EXPANSION (SET="AIR", CURVE=22, TEMPERATURE, GRAVITY=9.8066352,

THETA=0, PHI=0, REFTEMP=333.15)

1.0, 150.0, 200.0, 250.0, 298.15, 350.0, 400.0, 450.0, 500.0, 550.0, 600.0,
650.0, 700.0, 750.0, 800.0, 850.0, 900.0, 950.0, 1000.0, 1100.0, 1200.0, 10000.0,
1E-2, 6.6667E-3, 5E-3, 4E-3, 3.3333E-3, 2.8571E-3, 2.5E-3, 2.2222E-3, 2E-3,
1.8182E-3, 1.6667E-3, 1.5385E-3, 1.4286E-3, 1.3333E-3, 1.25E-3, 1.1765E-3,
1.1111E-3, 1.0526E-3, 1E-3, 9.0909E-4, 8.3333E-4, 1.0E-4

DIFFUSIVITY (SET="AIR", CURVE=21, TEMPERATURE, ISOTROPIC)

-1.0E+6, 255.2, 271.9, 288.6, 299.7, 310.8, 338.6, 366.3, 394.1, 421.9, 477.4, 533.0,
588.6, 699.7, 810.8, 1088.6, 2000, 3000, 5000, 10000, 1.0E+6,
1.5850E-5, 1.5850E-5, 1.7430E-5, 1.9062E-5, 2.0172E-5, 2.1302E-5, 2.4224E-5,

2.7256E-5,3.0416E-5,3.3692E-5,4.0554E-5,4.7840E-5,5.5519E-5,7.1959E-5,
8.9759E-5,1.3964E-4,3.4774E-4,6.3883E-4,1.3746E-3,3.8878E-3,7.7756E-3
/ HELIUM
SPECIFICHEAT (SET="HE", CONSTANT=5200.0)
DENSITY (SET="HE", CONSTANT=0.146438, TYP1, TEMPERATURE)
/ CONDUCTIVITY (SET="HE", CONSTANT=0.18675)
CONDUCTIVITY (SET="HE", CURVE=24, TEMPERATURE, ISOTROPIC)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,1200.0,
1400.0,1500.0,1600.0,1700.0,1800.0,1900.0,2000.0,2500.0,3000.0,
3500.0,4000.0,4500.0,5000.0,
0.073,0.1151,0.1499,0.1795,0.2114,0.2470,0.278,0.307,0.335,0.363,0.416,0.469,
0.494,0.521,0.545,0.570,0.596,0.620,0.739,0.851,0.958,1.064,1.169,1.271
CONDUCTIVITY (SET="HE2X", CURVE=24, TEMPERATURE, NONISOTROPIC)
0.6995,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,1200.0,
1400.0,1500.0,1600.0,1700.0,1800.0,1900.0,2000.0,2500.0,3000.0,
3500.0,4000.0,4500.0,5000.0,
0.073,0.1151,0.1499,0.1795,0.2114,0.2470,0.278,0.307,0.335,0.363,0.416,0.469,
0.494,0.521,0.545,0.570,0.596,0.620,0.739,0.851,0.958,1.064,1.169,1.271
CONDUCTIVITY (SET="HE3X", CURVE=24, TEMPERATURE, NONISOTROPIC)
0.5073,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,1.0E-20,
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,1200.0,
1400.0,1500.0,1600.0,1700.0,1800.0,1900.0,2000.0,2500.0,3000.0,
3500.0,4000.0,4500.0,5000.0,
0.073,0.1151,0.1499,0.1795,0.2114,0.2470,0.278,0.307,0.335,0.363,0.416,0.469,
0.494,0.521,0.545,0.570,0.596,0.620,0.739,0.851,0.958,1.064,1.169,1.271
VISCOSITY (SET="HE", CURVE=22, TEMPERATURE, TWO-EQUATION)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,2000.0,
2200.0,2400.0,5000.0,
9.63E-6,14.97E-6,19.89E-6,24.28E-6,28.27E-6,31.99E-6,35.49E-6,38.84E-6,
42.01E-6,45.04E-6,48.0E-6,50.8E-6,53.5E-6,56.1E-6,58.6E-6,61.0E-6,
63.4E-6,65.7E-6,70.0E-6,74.2E-6,78.3E-6,78.3E-6
VISCOSITY (SET="HEPOROUS", CURVE=22, TEMPERATURE, TWO-EQUATION)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,2000.0,
2200.0,2400.0,5000.0,
9.63E-8,14.97E-8,19.89E-8,24.28E-8,28.27E-8,31.99E-8,35.49E-8,38.84E-8,
42.01E-8,45.04E-8,48.0E-8,50.8E-8,53.5E-8,56.1E-8,58.6E-8,61.0E-8,
63.4E-8,65.7E-8,70.0E-8,74.2E-8,78.3E-8,78.3E-8
VOLUMEEXPANSION (SET="HE", CURVE=22, TEMPERATURE, GRAVITY=9.8066352,
THETA=0, PHI=0, REFTEMP=333.15)
-1.0E+6,150.0,200.0,250.0,298.15,350.0,400.0,450.0,500.0,550.0,600.0,
650.0,700.0,750.0,800.0,850.0,900.0,950.0,1000.0,1100.0,1200.0,10000.0,
1E-2,6.6667E-3,5E-3,4E-3,3.3333E-3,2.8571E-3,2.5E-3,2.2222E-3,2E-3,
1.8182E-3,1.6667E-3,1.5385E-3,1.4286E-3,1.3333E-3,1.25E-3,1.1765E-3,
1.1111E-3,1.0526E-3,1E-3,9.0909E-4,8.3333E-4,1.0E-4
DIFFUSIVITY (SET="HE", CURVE=21, TEMPERATURE, ISOTROPIC)
-1.0E+6,255.2,271.9,288.6,299.7,310.8,338.6,366.3,394.1,421.9,477.4,533.0,
588.6,699.7,810.8,1088.6,2000,3000,5000,10000,1.0E+6,
1.5850E-5,1.5850E-5,1.7430E-5,1.9062E-5,2.0172E-5,2.1302E-5,2.4224E-5,
2.7256E-5,3.0416E-5,3.3692E-5,4.0554E-5,4.7840E-5,5.5519E-5,7.1959E-5,
8.9759E-5,1.3964E-4,3.4774E-4,6.3883E-4,1.3746E-3,3.8878E-3,7.7756E-3
/ ARGON
SPECIFICHEAT (SET="AR", CONSTANT=520.4)
DENSITY (SET="AR", CONSTANT=1.46138)
/ CONDUCTIVITY (SET="AR", CONSTANT=0.023385)
CONDUCTIVITY (SET="AR", CURVE=20, TEMPERATURE, ISOTROPIC)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,
0.00652,0.01244,0.01772,0.02233,0.02638,0.0301,0.0336,0.0369,0.0398,
0.0427,0.0454,0.0481,0.0508,0.0535,0.0561,0.0588,0.0615,0.0641,0.0667,
0.0692
VISCOSITY (SET="AR", CURVE=22, TEMPERATURE, TWO-EQUATION)
-10000.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,

```
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,2200.0,10000.0,
8.34E-6,16.01E-6,22.72E-6,28.52E-6,33.6E-6,38.3E-6,42.5E-6,46.4E-6,
50.1E-6,53.5E-6,56.8E-6,59.9E-6,62.8E-6,65.6E-6,68.4E-6,71.0E-6,
73.5E-6,76.0E-6,78.4E-6,80.7E-6,85.1E-6,85.1E-6
VISCOSITY (SET="ARPOUS", CURVE=22, TEMPERATURE, TWO-EQUATION)
-10000.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,2200.0,10000.0,
8.34E-8,16.01E-8,22.72E-8,28.52E-8,33.6E-8,38.3E-8,42.5E-8,46.4E-8,
50.1E-8,53.5E-8,56.8E-8,59.9E-8,62.8E-8,65.6E-8,68.4E-8,71.0E-8,
73.5E-8,76.0E-8,78.4E-8,80.7E-8,85.1E-8,85.1E-8
VOLUMEEXPANSION (SET="AR", CURVE=22, TEMPERATURE, GRAVITY=9.8066352,
THETA=0, PHI=0, REFTEMP=333.15)
-1.0E+6,150.0,200.0,250.0,298.15,350.0,400.0,450.0,500.0,550.0,600.0,
650.0,700.0,750.0,800.0,850.0,900.0,950.0,1000.0,1100.0,1200.0,10000.0,
1E-2,6.6667E-3,5E-3,4E-3,3.3333E-3,2.8571E-3,2.5E-3,2.2222E-3,2E-3,
1.8182E-3,1.6667E-3,1.5385E-3,1.4286E-3,1.3333E-3,1.25E-3,1.1765E-3,
1.1111E-3,1.0526E-3,1E-3,9.0909E-4,8.3333E-4,1.0E-4
DIFFUSIVITY (SET="AR", CURVE=21, TEMPERATURE, ISOTROPIC)
-1.0E+6,255.2,271.9,288.6,299.7,310.8,338.6,366.3,394.1,421.9,477.4,533.0,
588.6,699.7,810.8,1088.6,2000,3000,5000,10000,1.0E+6,
1.5850E-5,1.5850E-5,1.7430E-5,1.9062E-5,2.0172E-5,2.1302E-5,2.4224E-5,
2.7256E-5,3.0416E-5,3.3692E-5,4.0554E-5,4.7840E-5,5.5519E-5,7.1959E-5,
8.9759E-5,1.3964E-4,3.4774E-4,6.3883E-4,1.3746E-3,3.8878E-3,7.7756E-3
/ NITROGEN
SPECIFICHEAT (SET="N2", CURVE=14, TEMPERATURE, SPATIAL)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,
1000.0,1100.0,1200.0,1298.15,1366.0,
1040.0,1040.0,1040.0,1045.0,1057.0,1075.0,1098.0,1122.0,1146.0,
1168.0,1187.0,1205.0,1220.0,1229.0
DENSITY (SET="N2", CONSTANT=1.04653)
/CONDUCTIVITY (SET="N2", CONSTANT=0.0340725)
CONDUCTIVITY (SET="N2", CURVE=22, TEMPERATURE, ISOTROPIC)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,2500.0,3000.0,
0.00941,0.01826,0.02589,0.03252,0.03864,0.0441,0.0493,0.0541,0.0587,
0.0631,0.0672,0.0713,0.0754,0.0797,0.0842,0.0893,0.0950,0.1013,
0.1080,0.1146,0.1406,0.1640
VISCOSITY (SET="N2", CURVE=21, TEMPERATURE, TWO-EQUATION)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,2200.0,
6.87E-6,12.86E-6,17.86E-6,22.14E-6,25.9E-6,29.27E-6,32.35E-6,
35.2E-6,37.86E-6,40.36E-6,42.7E-6,45.0E-6,47.1E-6,49.2E-6,
51.2E-6,53.1E-6,54.9E-6,56.7E-6,58.5E-6,60.1E-6,63.4E-6
VISCOSITY (SET="N2POROUS", CURVE=21, TEMPERATURE, TWO-EQUATION)
100.0,200.0,298.15,400.0,500.0,600.0,700.0,800.0,900.0,1000.0,
1100.0,1200.0,1298.15,1400.0,1500.0,1600.0,1700.0,1800.0,
1900.0,2000.0,2200.0,
6.87E-8,12.86E-8,17.86E-8,22.14E-8,25.9E-8,29.27E-8,32.35E-8,
35.2E-8,37.86E-8,40.36E-8,42.7E-8,45.0E-8,47.1E-8,49.2E-8,
51.2E-8,53.1E-8,54.9E-8,56.7E-8,58.5E-8,60.1E-8,63.4E-8
VOLUMEEXPANSION (SET="N2", CURVE=22, TEMPERATURE, GRAVITY=9.8066352,
THETA=0, PHI=0, REFTEMP=333.15)
-1.0E+6,150.0,200.0,250.0,298.15,350.0,400.0,450.0,500.0,550.0,600.0,
650.0,700.0,750.0,800.0,850.0,900.0,950.0,1000.0,1100.0,1200.0,10000.0,
1E-2,6.6667E-3,5E-3,4E-3,3.3333E-3,2.8571E-3,2.5E-3,2.2222E-3,2E-3,
1.8182E-3,1.6667E-3,1.5385E-3,1.4286E-3,1.3333E-3,1.25E-3,1.1765E-3,
1.1111E-3,1.0526E-3,1E-3,9.0909E-4,8.3333E-4,1.0E-4
DIFFUSIVITY (SET="N2", CURVE=21, TEMPERATURE, ISOTROPIC)
-1.0E+6,255.2,271.9,288.6,299.7,310.8,338.6,366.3,394.1,421.9,477.4,533.0,
588.6,699.7,810.8,1088.6,2000,3000,5000,10000,1.0E+6,
1.5850E-5,1.5850E-5,1.7430E-5,1.9062E-5,2.0172E-5,2.1302E-5,2.4224E-5,
2.7256E-5,3.0416E-5,3.3692E-5,4.0554E-5,4.7840E-5,5.5519E-5,7.1959E-5,
```



```

8.9759E-5,1.3964E-4,3.4774E-4,6.3883E-4,1.3746E-3,3.8878E-3,7.7756E-3
/ OXYGEN
SPECIFICHEAT (SET="O2", CURVE=9, TEMPERATURE, SPATIAL)
150.0,200.0,250.0,298.15,350.0,400.0,450.0,500.0,550.0,
917.8,913.1,915.7,920.3,929.1,942.0,956.7,972.2,988.1
DENSITY (SET="O2", CONSTANT=1.17645, TYP1, TEMPERATURE)
CONDUCTIVITY (SET="O2", CURVE=9, TEMPERATURE, ISOTROPIC)
150.0,200.0,250.0,298.15,350.0,400.0,450.0,500.0,550.0,
0.01367,0.01824,0.02259,0.02676,0.03070,0.03461,
0.03828,0.04173,0.04517
VISCOSITY (SET="O2", CURVE=9, TEMPERATURE)
150,200,250,300,350,400,450,500,550,
11.49E-6,14.85E-6,17.87E-6,20.63E-6,23.16E-6,25.54E-6,27.27E-6,
29.91E-6,31.97E-6
VOLUMEEXPANSION (SET="O2", CURVE=21, TEMPERATURE, GRAVITY=9.8066352,
THETA=0, PHI=0, REFTEMP=333.15)
100.0,150.0,200.0,250.0,300.0,350.0,400.0,450.0,500.0,550.0,600.0,
650.0,700.0,750.0,800.0,850.0,900.0,950.0,1000.0,1100.0,1200.0,
1E-2,6.6667E-3,5E-3,4E-3,3.3333E-3,2.8571E-3,2.5E-3,2.2222E-3,2E-3,
1.8182E-3,1.6667E-3,1.5385E-3,1.4286E-3,1.3333E-3,1.25E-3,1.1765E-3,
1.1111E-3,1.0526E-3,1E-3,9.0909E-4,8.3333E-4
DIFFUSIVITY (SET="O2", CURVE=21, TEMPERATURE, ISOTROPIC)
-1.0E+6,255.2,271.9,288.6,299.7,310.8,338.6,366.3,394.1,421.9,477.4,533.0,
588.6,699.7,810.8,1088.6,2000,3000,5000,10000,1.0E+6,
1.5850E-5,1.5850E-5,1.7430E-5,1.9062E-5,2.0172E-5,2.1302E-5,2.4224E-5,
2.7256E-5,3.0416E-5,3.3692E-5,4.0554E-5,4.7840E-5,5.5519E-5,7.1959E-5,
8.9759E-5,1.3964E-4,3.4774E-4,6.3883E-4,1.3746E-3,3.8878E-3,7.7756E-3
/ HYDROGEN
SPECIFICHEAT (SET="H2", CURVE=13, TEMPERATURE, SPATIAL)
150.0,200.0,250.0,300.0,350.0,400.0,450.0,500.0,550.0,600.0,700.0,
800.0,900.0,
12602.0,13450.0,14059.0,14314.0,14436.0,14491.0,14499.0,14507.0,
14532.0,14537.0,14574.0,14675.0,14821.0
DENSITY (SET="H2", CONSTANT=0.07409953)
CONDUCTIVITY (SET="H2", CURVE=13, TEMPERATURE, ISOTROPIC)
150.0,200.0,250.0,300.0,350.0,400.0,450.0,500.0,550.0,600.0,700.0,
800.0,900.0,
0.0981,0.1282,0.1561,0.181,0.206,0.228,0.251,0.272,0.292,0.315,
0.351,0.384,0.412
/ UMETAL
SPECIFICHEAT (SET="UMETAL", CURVE=15, TEMPERATURE, SPATIAL)
100.00,273.16,373.16,473.16,573.16,673.16,773.16,
873.16,939.16,940.16,1049.16,1050.16,1403.16,1773.16,10000.0,
114.0843,115.1309,122.4574,131.8772,142.3437,153.6474,168.5098,
188.3960,206.8170,178.7669,178.7669,160.7646,160.7646,160.7646,160.7646
DENSITY (SET="UMETAL", CONSTANT=19037.5, GASCONSTANT=19037.5)
/CONDUCTIVITY (SET="UMETAL", CONSTANT=27.9587)
CONDUCTIVITY (SET="UMETAL", CURVE=15, TEMPERATURE, ISOTROPIC)
100.00,273.16,373.16,473.16,573.16,673.16,773.16,
873.16,939.16,940.16,1049.16,1050.16,1403.16,1773.16,10000.0,
26.7968,26.9015,26.9015,29.0159,30.9838,32.9726,35.0033,
37.8924,39.1485,39.1485,41.4513,41.4513,50.2440,50.2440,50.2440
/ ZIRC4
SPECIFICHEAT (SET="ZIRC4", CURVE=15, TEMPERATURE, SPATIAL)
100.00,273.16,310.94,366.49,422.05,477.60,533.16,
588.72,644.27,699.83,755.38,810.94,922.05,1088.72,2000.0,
284.6873,284.6873,288.8739,293.0605,301.4336,305.2022,309.8068,
318.1800,322.3665,330.7397,334.9263,341.2061,360.0457,376.7921,
376.7921
DENSITY (SET="ZIRC4", CONSTANT=6550.0)
CONDUCTIVITY (SET="ZIRC4", CURVE=9, TEMPERATURE, ISOTROPIC)
273.16,373.16,473.16,573.16,673.16,773.16,873.16,973.16,1073.16,
12.3517,13.3984,14.4452,15.6175,17.0411,18.4228,19.8883,21.5212,
23.0285
CONDUCTIVITY (SET="ZIRC2X", CURVE=9, TEMPERATURE, NONISOTROPIC)
1.3191,1.0E-20,1.0E-20,1.0E-20,1.0,1.0E-20,1.0E-20,1.0E-20,1.0

```

273.16,373.16,473.16,573.16,673.16,773.16,873.16,973.16,1073.16,
12.3517,13.3984,14.4452,15.6175,17.0411,18.4228,19.8883,21.5212,
23.0285
/ UO2
SPECIFICHEAT (SET="UO2", CURVE=14, TEMPERATURE, SPATIAL)
-1.0E+6,298.0,366.33,505.22,644.11,783.0,921.89,
1060.8,1199.7,1338.6,1477.4,1616.3,1755.2,1894.1,
235.62,235.62,256.80,280.36,293.26,301.99,308.78,
314.56,319.77,324.72,329.73,335.42,342.85,353.69
DENSITY (SET="UO2", CONSTANT=10970.0)
CONDUCTIVITY (SET="UO2", CURVE=14, TEMPERATURE, ISOTROPIC)
-1.0E+6,298.0,333.33,444.44,555.56,666.67,777.78,888.89,1000.0,
1222.2,1444.44,1666.7,1888.9,2000.0,
8.2704,8.2704,7.3417,6.7192,5.8508,5.1601,4.5985,4.1337,3.7434,3.1276,
2.6761,2.3638,2.2030,2.1908
CONDUCTIVITY (SET="UO2X", CURVE=14, TEMPERATURE, NONISOTROPIC)
0.9233,1.0E-20,1.0E-20,1.0E-20,1.0,1.0E-20,1.0E-20,1.0E-20,1.0
-1.0E+6,298.0,333.33,444.44,555.56,666.67,777.78,888.89,1000.0,
1222.2,1444.44,1666.7,1888.9,2000.0,
8.2704,8.2704,7.3417,6.7192,5.8508,5.1601,4.5985,4.1337,3.7434,3.1276,
2.6761,2.3638,2.2030,2.1908
/ PUO2 POWDER AT 2.5 GM/CM3
SPECIFICHEAT (SET="PUO2", CURVE=20, TEMPERATURE, SPATIAL)
100.0,200.0,300.0,325.0,350.0,375.0,400.0,450.0,500.0,550.0,
600.0,650.0,700.0,750.0,800.0,900.0,1000.0,1200.0,1400.0,2000.0,
258.64,258.64,258.64,271.23,281.25,289.34,295.98,306.13,313.44,
318.88,323.07,324.27,329.00,331.16,332.96,335.78,337.89,340.86,
342.90,342.90
DENSITY (SET="PUO2", CONSTANT=2500.0)
CONDUCTIVITY (SET="PUO2", CONSTANT=0.282362193)
/ AL
SPECIFICHEAT (SET="AL", CONSTANT=937.7936)
DENSITY (SET="AL", CONSTANT=2700.7129)
CONDUCTIVITY (SET="AL", CURVE=6, TEMPERATURE, ISOTROPIC)
273.16,293.16,373.16,573.16,699.83,1088.72,228.4449,228.4449,228.4449,
230.1755,230.1755,230.1755
/ SS304
SPECIFICHEAT (SET="SS304", CURVE=18, TEMPERATURE, SPATIAL)
-1.0E+6,294.16,311.16,366.16,422.16,477.16,533.16,589.16,644.16,
700.16,755.16,811.16,866.16,922.16,977.16,1033.16,1144.16,10000.0,
477.6,477.6,483.9,503.1,519.1,533.5,545.2,555.2,563.8,571.3,
578.0,584.3,590.5,597.0,604.1,612.2,632.7,632.7
DENSITY (SET="SS304", CONSTANT=8045.0)
/ CONDUCTIVITY (SET="SS304", CONSTANT=17.00)
CONDUCTIVITY (SET="SS304", CURVE=18, TEMPERATURE, ISOTROPIC)
-1.0E+6,294.16,311.16,366.16,422.16,477.16,533.16,589.16,644.16,
700.16,755.16,811.16,866.16,922.16,977.16,1033.16,1144.16,10000.0,
14.83,14.83,15.12,16.08,17.00,17.90,18.76,19.60,20.42,21.22,
22.00,22.77,23.53,24.27,25.01,25.74,27.20,27.20
/ SS 316
SPECIFICHEAT (SET="SS316", CURVE=14, TEMPERATURE, SPATIAL)
1.0,294.27,310.94,366.49,422.05,477.60,533.16,
588.72,644.27,699.83,810.94,922.05,1033.16,1144.27,
465.6,465.6,472.3,492.4,509.7,524.3,536.6,
547.1,556.1,563.9,577.6,590.9,606.9,628.4
DENSITY (SET="SS316", CONSTANT=7962.0)
CONDUCTIVITY (SET="SS316", CURVE=14, TEMPERATURE, ISOTROPIC)
1.0,294.27,310.94,366.49,422.05,477.60,533.16,
588.72,644.27,699.83,810.94,922.05,1033.16,1144.27,
13.36,13.36,13.64,14.58,15.51,16.41,17.31,
18.18,19.04,19.88,21.51,23.06,24.55,25.96
/ MILD CARBON STEEL
SPECIFICHEAT (SET="MCSTEEL", CURVE=14, TEMPERATURE, SPATIAL)
-1.0E+6,294.27,310.94,366.49,422.05,477.60,533.16,
588.72,644.27,699.83,810.94,922.05,1033.16,1144.27,
437.53,437.53,450.22,486.46,515.21,538.84,559.73,

```

580.25,602.79,629.70,706.20,828.74,1758.5,705.89
DENSITY (SET="MCSTEEL", CONSTANT=7852.2506)
CONDUCTIVITY (SET="MCSTEEL", CURVE=14, TEMPERATURE, ISOTROPIC)
-1.0E+6,294.27,310.94,366.49,422.05,477.60,533.16,
588.72,644.27,699.83,810.94,922.05,1033.16,1144.27,
51.733,51.733,51.510,50.574,49.368,47.930,46.298,
44.508,42.599,40.607,36.525,32.562,29.016,26.187
/ CONCRETE
SPECIFICHEAT (SET="CONCRETE", CURVE=5, TEMPERATURE, SPATIAL)
1.0,273.16,473.16,773.16,1273.16,
627.04,607.04,919.66,1045.07,1254.09
DENSITY (SET="CONCRETE", CONSTANT=2300.08)
CONDUCTIVITY (SET="CONCRETE", CONSTANT=0.753634473)
/ DRY HANFORD SOIL - EARTH
SPECIFICHEAT (SET="DRYEARTH", CONSTANT=795.45)
DENSITY (SET="DRYEARTH", CONSTANT=1799.37)
CONDUCTIVITY (SET="DRYEARTH", CONSTANT=0.334942)
/ LEAD
SPECIFICHEAT (SET="LEAD", CURVE=13, TEMPERATURE, SPATIAL)
100.00,293.16,373.16,389.16,472.16,533.16,573.16,578.16,600.66,
600.76,605.16,654.16,964.16,
127.7,125.6,125.6,125.6,125.6,138.6,125.6,140.7,141.5,142.3,
142.3,141.8,139.8
DENSITY (SET="LEAD", CONSTANT=11350.0)
CONDUCTIVITY (SET="LEAD", CURVE=13, TEMPERATURE, ISOTROPIC)
100.00,293.16,373.16,389.16,472.16,533.16,573.16,578.16,600.66,
600.76,605.16,654.16,964.16,
35.58,35.14,33.42,34.02,31.03,29.30,29.76,25.11,21.65,21.64,20.93,
16.74,14.98
/ POLYETHYLENE - MEDIUM DENSITY
SPECIFICHEAT (SET="PE", CONSTANT=2302.619)
DENSITY (SET="PE", CONSTANT=935.0)
CONDUCTIVITY (SET="PE", CONSTANT=0.41449)
/ SMEAR_AIR = AIR + ZIRC4 + UO2 FOR SHIPPINGPORT BFA
CONDUCTIVITY (SET="SMEAR_AIR", CURVE=18, TEMPERATURE, ISOTROPIC)
100.0,200.0,300.0,350.0,400.0,450.0,500.0,550.0,600.0,650.0,700.0,
750.0,800.0,850.0,900.0,950.0,1000.0,10000.0,
6.11923,6.11923,6.11923,5.92803,5.97138,6.01048,6.02489,6.04687,
6.11063,6.19266,6.28486,6.38110,6.48980,6.61174,6.74800,6.90329,
7.04965,7.04965
/ SMEAR_HE = HE + ZIRC4 + UO2 FOR SHIPPINGPORT BFA
CONDUCTIVITY (SET="SMEAR_HE", CURVE=18, TEMPERATURE, ISOTROPIC)
100.0,200.0,300.0,350.0,400.0,450.0,500.0,550.0,600.0,650.0,700.0,
750.0,800.0,850.0,900.0,950.0,1000.0,10000.0,
6.16860,6.16860,6.16860,5.98167,6.02936,6.07343,6.09287,6.12065,
6.19029,6.27732,6.37457,6.47547,6.58886,6.71538,6.85621,7.01608,
7.16711,7.16711
/
/ EMISSIVITIES - 1 = STORAGE TUBE - MILD CARBON STEEL
/ 2 = RADIATION SYMMETRY (X AND Y AXIS) FOR GAP BETWEEN MCO AND
/ 3 = MCO AND CROSS - BRIGHT SS316
/ 4 = OXIDIZED ZIRCALOY-4
/
EMISSION (SET=1, CONSTANT=0.50, STEFB=5.6697E-8)
EMISSION (SET=2, CONSTANT=0.01, STEFB=5.6697E-8)
EMISSION (SET=3, CONSTANT=0.25, STEFB=5.6697E-8)
EMISSION (SET=4, CONSTANT=0.70, STEFB=5.6697E-8)
/
/ INITIAL CONDITIONS - TEMPERATURES
/
ICNODE (TEMPERATURE, READ, ALL)
/ ICNODE (TEMPERATURE, CONSTANT=333.15, ALL)
/
/ BOUNDARY CONDITIONS
/ TAMB = REFTEMP =140F = 60C =333.15K
/

```

```

/
/ RADIATION VIEWFACTOR CALCULATION
/
RADIATION(NOPARTICIPATION,GREY)
RADSURFACE(ENTITY="STID_RAD",INDIVIDUAL)
RADSURFACE(ENTITY="MCOSTRHS_RAD",INDIVIDUAL)
RADSURFACE(ENTITY="MCOSTLHS_RAD",INDIVIDUAL)
RADSURFACE(ENTITY="MCOOD_RAD",INDIVIDUAL)
RADSURFACE(ENTITY="MCOID_RAD1",INDIVIDUAL)
RADSURFACE(ENTITY="MCOID_RAD2",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD1",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD2",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD3",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD4",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD5",INDIVIDUAL)
RADSURFACE(ENTITY="VCROSS_RAD6",INDIVIDUAL)
RADSURFACE(ENTITY="HCROSS_RAD1",INDIVIDUAL)
RADSURFACE(ENTITY="HCROSS_RAD2",INDIVIDUAL)
RADSURFACE(ENTITY="HCROSS_RAD3",INDIVIDUAL)
RADSURFACE(ENTITY="HCROSS_RAD4",INDIVIDUAL)
RADSURFACE(ENTITY="CAN1OD_RAD1",INDIVIDUAL)
RADSURFACE(ENTITY="CAN1OD_RAD2",INDIVIDUAL)
RADSURFACE(ENTITY="CAN1OD_RAD3",INDIVIDUAL)
RADSURFACE(ENTITY="CAN1OD_RAD4",INDIVIDUAL)
RADSURFACE(ENTITY="CAN2OD_RAD1",INDIVIDUAL)
RADSURFACE(ENTITY="CAN2OD_RAD2",INDIVIDUAL)
RADSURFACE(ENTITY="CAN2OD_RAD3",INDIVIDUAL)
RADSURFACE(ENTITY="CAN2OD_RAD4",INDIVIDUAL)
OBSTRUCTION(ALL)
VIEWFACTOR(NOCOMPUTE,FACET,OUTPUTFILE,BINARY,SMOOTH,XZONE=12,YZONE=12)
/
/ HEAT TRANSFER COEFFICIENTS (J/M2-S-K)
/
HTRANSFER(SET="AIR110",CURVE=34,TEMPERATURE,REFTEMP=316.48)
273.0,283.0,293.0,300.0,310.0,315.0,317.5,320.0,325.0,330.0,
332.0,335.0,340.0,350.0,360.0,370.0,380.0,390.0,400.0,410.0,
420.0,430.0,440.0,450.0,475.0,500.0,550.0,600.0,650.0,700.0,
800.0,900.0,1000.0,100000.0,
4.469,4.042,3.542,3.117,2.256,1.372,1.209,1.823,2.435,2.826,
2.953,3.123,3.365,3.747,4.044,4.285,4.485,4.655,4.800,4.924,
5.038,5.150,5.251,5.341,5.526,5.662,5.868,6.022,6.110,6.194,
6.286,6.327,6.328,6.400
HTRANSFER(SET="AIR140",CURVE=34,TEMPERATURE,REFTEMP=333.15)
273.0,283.0,293.0,300.0,310.0,315.0,317.5,320.0,325.0,330.0,
332.0,335.0,340.0,350.0,360.0,370.0,380.0,390.0,400.0,410.0,
420.0,430.0,440.0,450.0,475.0,500.0,550.0,600.0,650.0,700.0,
800.0,900.0,1000.0,100000.0,
4.869,4.513,4.145,3.862,3.393,3.113,2.955,2.781,2.359,1.709,
1.219,1.424,2.191,2.926,3.379,3.712,3.974,4.188,4.367,4.535,
4.683,4.813,4.929,5.031,5.240,5.393,5.654,5.821,5.943,6.032,
6.154,6.211,6.228,6.300
/
RENUMBER
END
CREATE(FISOLV)
END( )

```

REVIEW CHECKLIST

Document Reviewed:

HNF-4109, Rev. 0 "Thermal Assessment of Shippingport Pressurized Water Reactor Blanket Fuel Assemblies within a Multi-Canister Overpack within the Canister Storage Building"

Scope of Review:

Yes No NA

☐	☐	☒	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☐	☐	☒	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivation checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☒	☐	☐	Software input correct and consistent with document reviewed.
☒	☐	☐	Software output consistent with input and with results reported in document reviewed.
☐	☐	☒	Limits/criteria/guidelines applied to analysis results are appropriate and referenced.
			Limits/criteria/guidelines checked against references.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☒	☐	☐	Format consistent with appropriate NRC Regulatory Guide or other standards.
☐	☐	☒	* Review calculations, comments, and/or notes are attached.
☒	☐	☐	Document approved.

Eldon R Cramer
Reviewer (Printed Name and Signature)

E R Cramer

April 8, 1999
Date

*Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

[illegible]